ASSESSMENT OF THE WATER BALANCE OF LAKE BOSUMTWI

Water Resources and Environmental Sanitation Program

Department of Civil Engineering

MSc. Thesis

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ASSESSMENT OF THE WATER BALANCE OF LAKE BOSUMWTI

by

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Certification

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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Dedication

I dedicate this work to my father Francis Amo, my mothers Elizabeth Amo and Lydia Quaicoo and my sisters Akosua Buabeng Boateng and Akua Fobi Oti Boateng for being a source of inspiration to the attainment of higher excellence.

Abstract

The goal of this research was to establish the hydrological processes that affect the water balance of Lake Bosumtwi, contributing to the marked lake level rise (+6.8m) and fall (-3.2m) within the past centenary (1938 – 2000). Thus, this work focuses on the development of a distributed model for Lake Bosumtwi using satellite altimetry and GIS. The distributed model approach would allow the easy modification of land use and land cover to present the true picture at any given time. The GIS based distributed model was developed using regional (Kumasi) climatic conditions as inputs to the model on a monthly time-step (Mar, 1977 – Dec, 1998). Landsat images were used to determine land cover changes. Investigations were made into the components of the surface hydrological processes occurring at the lake. Also, the possible contributions of subsurface runoff and regional aquifer were investigated.The water balance of Lake Bosumtwi was determined to be $\Delta V = P + R - E$. Rainfall, ***P*** values of Kumasi was used. Runoff, ***R*** was determined using the SCS-CN method and was successfully modified to incorporate the average slope of Lake Bosumtwi's catchment area.The Simplified Penman Evaporation model (Valiantzas, 2006) was determined the best evaporation, ***E***, model for the Lake. The model was calibrated and validated using the *level pool reservoir routing equation*(using precipitation and runoff as inputs, and evaporation as the only output) and the Klemes split-sample test method (1986). In general, the water balance model developed had a total error of -0.005% (systematic error = -0.692% and random error = +0.687%). The model has a $R^2 = 0.998$, D = 0.99 and PRMSE = 9.29%. The Nash-Sutcliffe model efficiency was found to be 100%.The study revealed that satellite altimetry and GIS can be successfully used to model hydrological processes of ungagged catchments. Also, land cover changes at lake can be assumed to be linear with the resultant rate of change in curve numbers being -0.000021651 per month. Again, direct precipitation onto the surface of the lake is the major input into the water balance model. And in addition, the gradual decrease in rainfall and increase in evaporation accounts for the consistent lake level fall. In conclusion, the study shows that Lake level rise and fall reflects regional climatic conditions.

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List of Abbreviations and Symbols

Abbreviation / Symbol		Meaning
E_{ET}^{forest}	-	Evapotranspiration of forest catchments
$\bar{X}$	-	Mean of observed data
$\bar{Y}$	-	Mean of simulated data
$\frac{dV}{dt}$	-	Rate of change of Lake volume
s_1^1	-	Sample standard deviation of dataset 1
s_1^2	-	Sample standard deviation of dataset 2
σ_1^1	-	Population standard deviation of dataset 1
σ_1^2	-	Population standard deviation of dataset 2
^{16}O, ^{18}O	-	Oxygen-16, Oxygen-18 isotopes
A	-	Area of catchment (land or lake)
a	-	Parameter for estimation of cloud cover
Abs	-	Abstraction from Lake Bosumtwi
AESC	-	Architectural and Engineering Services Corporation
A_i	-	Area of a time series i
AMC	-	Antecedent Soil Moisture Condition
ArcGIS	-	GIS software by ERSI
a_s	-	Regression constant = 0.2006
ASI	-	Italian Space Agency
b_s	-	Regression constant = 0.5313
C	-	Fraction of sky obscured by clouds
C_{air}	-	Heat capacity of air
C_D	-	Surface drag coefficient
CN	-	Curve Number
CN_w	-	Weighted Curve Number
CN(I)	-	Curve number at dry soil moisture conditions, AMC(I)
CN(II)	-	Curve number at average soil moisture conditions, AMC(II)
CN(III)	-	Curve number at wet soil moisture conditions, AMC (III)
CN_2 or *CN(II)*	-	Curve number at average soil moisture conditions, AMC(II)
D	-	Index of Agreement
d	-	Solar decimation
DEM	-	Digital Elevation Model
DLR	-	German Aerospace Centre
d_r	-	Inverse relative distance between the Earth and Sun
E	-	Evaporation
E	-	Evapotranspiration
E	-	Nash-Sutcliffe Efficiency
e	-	Random error
e_a	-	Actual vapour pressure
E_a	-	Drying power of air
ENVISAT	-	

$e^o(T)$	-	Saturated vapour pressure at temperature (T)
Erdas	-	Image analysis and processing software by Leica Geosystems
e_s	-	Saturation vapour pressure
F	-	Integral factor for the estimation of C (fraction of sky obscured by clouds)
F_t		F-test / Fisher – test
F-test	-	Fisher test or F_t
GeoTiff	-	Geo-referenced Tiff (tagged image format file) image
G_i	-	Groundwater inflow
GIS	-	Geographic Information System
GLCF	-	Global Land Cover Facility
GMA	-	Ghana Meteorological Agency
GPS	-	Global Positioning System
G_{sc}	-	Solar constant
G_w	-	Groundwater flow or subsurface flow
G_{yr}	-	Giga year (x 10^9 years)
H	-	Outgoing sensible heat flux
H_0	-	Null hypothesis
H_1	-	Alternate hypothesis
HSG	-	Hydrologic Soil Group
I	-	Annual Heat Index
i	-	Monthly Heat Index
IAEA	-	International Atomic Energy Agency
I_i	-	Inputs of the reservoir routing equation at data point i
I_{i+1}	-	Inputs of the reservoir routing equation at data point i+1
ITCZ	-	Inter Tropical Convergence Zone
J	-	Julian day
j	-	Latitude (radians)
K	-	Correction factor for double mass analysis
k^2	-	Empirical constant for determination of surface drag coefficient (k = 0.40)
Kx_i	-	Rank of variable x in chronological order of its time series
Ky_i	-	Transformed rank equivalent of series observations of variable x_i
Landsat	-	Land Satellite Imagery
L_{obs}	-	Lake level (observed)
L_{sim}	-	Lake level (simulated)
L_{sim} - *RB*	-	Simulated lake level – systematic depth error
masl	-	metres above sea level
n	-	Actual sunshine hours
N	-	Maximum number of sunshine hours
n	-	Number of data in a dataset
NASA	-	National Aeronautics and Space Agency
N_d	-	Number of days in a month
NGA	-	National Geospatial-Intelligence Agency
N_s	-	Number of rainfall storms in a month

O_i	-	Outflows of the reservoir routing equation at data point i in the time series
O_{i+1}	-	Outflows of the reservoir routing equation at data point i+1 in the time series
P	-	Precipitation (rain, snow, hail, etc.)
P_{atm}	-	Atmospheric pressure
$P_{catchment}$	-	Precipitation onto catchments
P_e	-	Effective precipitation (rainfall)
P_i	-	Direct precipitation onto Lake Bosumtwi at a time step i of a time series
P_{i+1}	-	Direct precipitation onto Lake Bosumtwi at a time step i+1 of a time series
P_o	-	Observed precipitation (rainfall)
PRB	-	Per cent Relative Bias
PRMSE	-	Per cent Root Mean Square Error
Q	-	Surface runoff from catchment
Q_E	-	Average evaporation / evapotranspiration rate
Q_I	-	Average groundwater inflow rate
Q_O	-	Average groundwater outflow rate
Q_P	-	Precipitation rate
Q_S	-	Average surface runoff rate
r	-	Number of data in a dataset
R	-	Runoff from Lake Bosumtwi's catchment
R^2 or *R2*	-	Coefficient of determination
R_a	-	Extra-terrestrial radiation
RB	-	Relative Bias
R_{forest}	-	Runoff from forest catchments
RH_{max}	-	Relative Humidity (maximum)
RH_{mean}	-	Relative Humidity (mean)
RH_{min}	-	Relative Humidity (minimum)
R_i	-	Runoff from Lake Bosumtwi's catchment at data point i of a time series
R_{i+1}	-	Runoff from Lake Bosumtwi's catchment at data point i+1 of a time series
R_{ldown}	-	Long wave radiation (receiving)
R_{lup}	-	Long wave radiation (outgoing)
rms	-	root mean square
RMSE	-	Root Mean Square Error
R_n	-	Net solar radiation
R_r	-	Shortwave radiation (reflected)
R_s	-	Shortwave radiation (incoming)
R_{sp}	-	Spearman's correlation coefficient
S	-	Potential maximum soil retention capacity (storage capacity of the soil)
S	-	Storage capacity of broad leaf cover

S	-	Surface runoff
SCS-CN	-	Soil Conservation Services – Curve Number
STRM	-	Shuttle Radar Topography Mission
T_a	-	Air temperature
t_d	-	Number of seconds in a day
T_{max}	-	Temperature (maximum)
T_{mean}	-	Temperature (mean)
T_{min}	-	Temperature (minimum)
t_s	-	Duration of storm
t_t	-	Students' t-distribution
T-test	-	Student's T-distribution test or T_t
T_w	-	Water surface temperature
U	-	Baseflow / underground discharge
U	-	Critical region of a hypothesis
U	-	Wind speed
U_2	-	Wind speed at standard height of 2 m asl
USA	-	United States of America
USGS	-	United States Geological Survey
U_z	-	Wind speed at height of z m asl
V	-	Volume
V_{obs}	-	Lake volume (observed)
V_{sim}	-	Lake volume (simulated)
V_{sim} - *RB*	-	Simulated lake volume – systematic volume error
w_s	-	Half day length
X	-	Parameter for computing w_s
X_i	-	Cumulative observed values (x_i)
x_i	-	Observed data in a time series at point i
Y_i	-	Cumulative simulated values (y_i)
y_i	-	Simulated data in a time series at a point i
Z_o	-	Height above water surface at which wind speed is zero
Z_r	-	Reference height for measurement of wind speed = 2.0 m
α	-	Priestly-Taylor coefficient = 1.26
α_i	-	Fractional interception loss
α_w	-	Albedo or reflection coefficient of a water surface
β	-	Average annual potential evapotranspiration of River Pra Basin runoff model
γ	-	Psychometric constant
Δ	-	Slope of saturation vapour pressure
δ	-	Solar decimation
δ_E	-	Isotopic composition of evaporation
δ_{Gi}	-	Isotopic composition of groundwater inflow
δ_L	-	Isotopic composition of lake water level
δ_P	-	Isotopic composition of precipitation
ΔS	-	Change in energy stored of a lake or body
δV	-	Change in lake volume

ΔV	-	Change in lake volume
ΔV_{obs}	-	Change in lake volume (observed)
ΔV_{sim}	-	Change in lake volume (simulated)
ε	-	Total error
ε_a	-	Emissivity of Air
ε_w	-	Emissivity of water
θ	-	Latitude in degrees
θ	-	Slope of catchment (degrees)
λ	-	Initial abstraction ratio
λ	-	Latent heat of evaporation
λE	-	Heat lost to evaporation of a water body
μ	-	Empirical mass coefficient
μ	-	Rainfall correction coefficient ($P_c = \mu P_o$)
ν	-	Degrees of freedom in a dataset
ρ	-	Density of water
σ	-	Stefan-Boltzmann constant
τ	-	Systematic error

Acknowledgement

Sir Isaac Newton (1643-1727) once remarked:*"If I had seen further, it is by standing on the shoulders of giants..."* and today I can also say that *"if this work would ever be of great value, then it was because of of the great assistance and guidance offered to me by these men..."* Many people deserve the thanks and appreciation for making this work a reality. My thanks goes to the Almighty God for breath and sustenance.

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1 Introduction

1.1 Background

Lake Bosumtwi, situated within an ancient meteorite impact crater,is the only natural lake in Ghana(Lake Bosumtwi, 2009). It has been argued that Lake Bosumtwi lies in the best-preserved complex young impact structure known on Earth(*ibid.*). It is the source crater of the Ivory Coast tektites. The structure was excavated in 2.1-2.2 Gyr old metasediments and metavolcanics of the Birimian Supergroup(Koeberl *et al.*, 2007).

Figure -: Aerial Photograph of Lake Bosumtwi

(Source: Dutch A.,2004)

Observation of the spatial and temporal variability of water resources is crucial for societal and scientific issues.In the African tropics, the hydrologic cycle is known to have been characterized by substantial decadal variability over the last 50–100 years, with profound societal and economic impacts. Thus, the volume of water stored within lakes and reservoirs acts as a sensitive proxy for the components of the hydrologic cycle and may be used to study the combined impact of climate change and water resources management.

studies of the paleoflora of the basin reveals that the climatic factors has not changed drastically. There is, thus, the potential of the lake overflowing crater rim, inundating all surrounding communities and ecology. Therefore, factors that go into the lake level rise and fall thus becomes eminent for research.

Also, lake level records may serve as a proxy for understanding and reconstructing paleoclimatic data, providing insight of the climatic history of the sub-region and the consequence of climate change. Understanding of the lake's hydrological components (water balance) may also be used as the basis for climate change studies.

1.3 Justification

It has been documented that climatologically factors greatly and directly affect the lake level records (Turner *et al*., 1996). Since paleoclimatic conditions have not changed drastically during the time the lake overflowed the crater rim and the present (Koeberl *et al*., 2007), a proper assessment of the components of the hydrological cycle which directly influences the level of the lake is extremely essential for any future water resources development.

1.4 Study Objective

The primary objective of this study is: "To establish the water balance of Lake Bosumtwi".

1.5 Specific Objectives

Specific objectives which would facilitate the realization of this study include:

- To determine the total catchment area of Lake Bosumtwi;
- To establish all inflows and outflows of Lake Bosumtwi; and
- To establish the water balance of Lake Bosumtwi.

1.6 Research Questions

The main question of this study is: "What is the water budget of Lake Bosumtwi?" To answer this crucial question, a study would be conducted to answer these specific questions:

- What is the surface area of Lake Bosumtwi's catchment?
- What are the monthly precipitations in the catchment area of Lake Bosumtwi?
- What are the monthly evaporations from the lake surface?
- What are the monthly outflows from Lake Bosumtwi (if any)?

2 Overview of Study Area

Lake Bosumtwi fills a million year old meteorite impact crater (Koeberl and Reimold, 2005) that was formed in dense crystalline rock. The crater diameter is 10.5 km at the rim where there is a well-defined spillway believed to have been overflown during the Holocene. The crater is internally drained with no surface outlet.

2.1 Location and Accessibility

Figure -: Lake Bosumtwi and surrounding communities

The lake is centered at 06°30"N and 01°25"W (Koeberl and Reimold, 2005; Russel *et al.*, 2003; Karp *et al.*, 2002; Peck *et al.*, 2004). The lake lies 35 km southwest of Kumasi (310 masl). Nearby towns such as Bobiri (278 masl) and Konongo (233 masl) lies about 30 km to the northeast with Bekwai (230 masl) 20 km to the southwest of the lake (Turner *et al.*, 1996). The lake level ranges between 80 and 100 m below the terrain outside the lake's catchment. The Lake water level edges at 99 masl and rises steeply to 460 masl within a span of 1.5 km. The lowest point on the rim is 210 masl. The highest point on the crater rim is 460 masl.

The lake is situated within the Obuom mountain range (710 masl peak) which is located at the southern part of the lake. The west, east and north of the lake have typical elevation of 240 masl. The lake also falls within the Pra River Basin (catchment area of 22,500 km^2) and has similar climate, vegetation and bedrock as the lake. There are thirty small villages with an aggregate population of about seven thousand.

2.2 Physiography and Drainage

Lake Bosumtwi has a 10.5 km rim-rim wide basin diameter. The current lake level occupies ~8.5 km of the lake diameter. The lake is surrounded by a shallow, near-circular but slight depression of 7 to 8.5 km; and a shallow outer topographic ring feature 18-20 km diameter (Koeberl and Reimold, 2005). The total catchment area is reported to be 106 km^2 and the lake covers approximately 80% (50 km^2) of the catchment area(Turner *et al*., 1996; Peck *et al*., 2004; Russel *et al*., 2003).

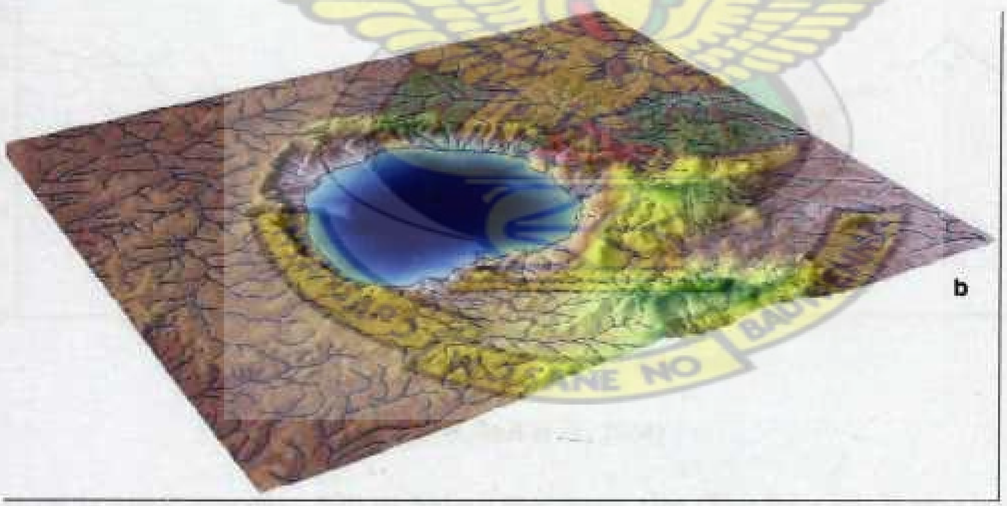


Figure -: Drainage pattern at Lake Bosumtwi

(Source: Wagner et al., 2002 and cited by Koeberl and Reimold, 2005)

The lake is hydrologically closed and is maintained by direct precipitation, groundwater and numerous small streams (Russel *et al*., 2003; Peck *et al*., 2004). The lake is asymmetrical in nature though not completely circular (Koeberl and Reimold, 2005).

2.3 Lake Ecosystem

The lake is a relatively freshwater lake, with salinity of 1‰, as reported by Turner *et al.*, 1996. The lake is barely potable, as little is ever drawn for domestic use. It is not used for irrigation or industrial activities. There are eleven species of fish, with four being cichlids and one endemic. Wooden floats are used for fishing and are made from Corkwood or *Musanga Smithii*(as reported by Whyte, 1965 and cited by Koeberl and Reimold, 2005).

The lake is highly stratified and meromitic. There is a well-mixed surface epilimnion (10-15m) and anoxic hypolimnion below 15-18 m depth. In the anoxic zone bioturbation is absent (Peck *et al.*, 2004). Infrequent, localized overturning events resulting in mass fish kills have been reported though only two accounts have been reported (Shananhan *et al.*, 2007).

2.4 Lake Morphology

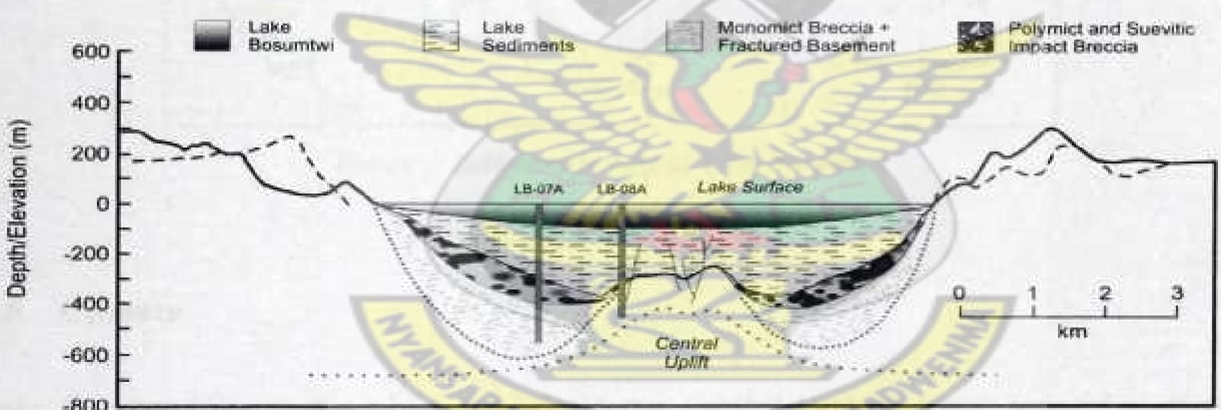


Figure -: Morphology of Lake Bosumtwi

(Source: Koberl *et al.*, 2004)

The lake level is approximately 120 m below the crater rim. The lake has a maximum depth reported to be in the range of 75-80m(Karp *et al.*, 2002; Shananhan *et al.*, 2007; Peck *et al.*, 2004; Koeberl and Reimold, 2005). According to Turner*et al.*, 1996, Lake Bosumtwi has its lowest point at 21.2 masl. Investigations into the bathymetry of the lake show that the lake follows its roughly circular shape at the surface and tapers into a near oval shape at the bottom. Morphology, bathymetric map and data of Lake Bosumtwi areshown in figure 2-3, figure 2-4 and Appendix 1.

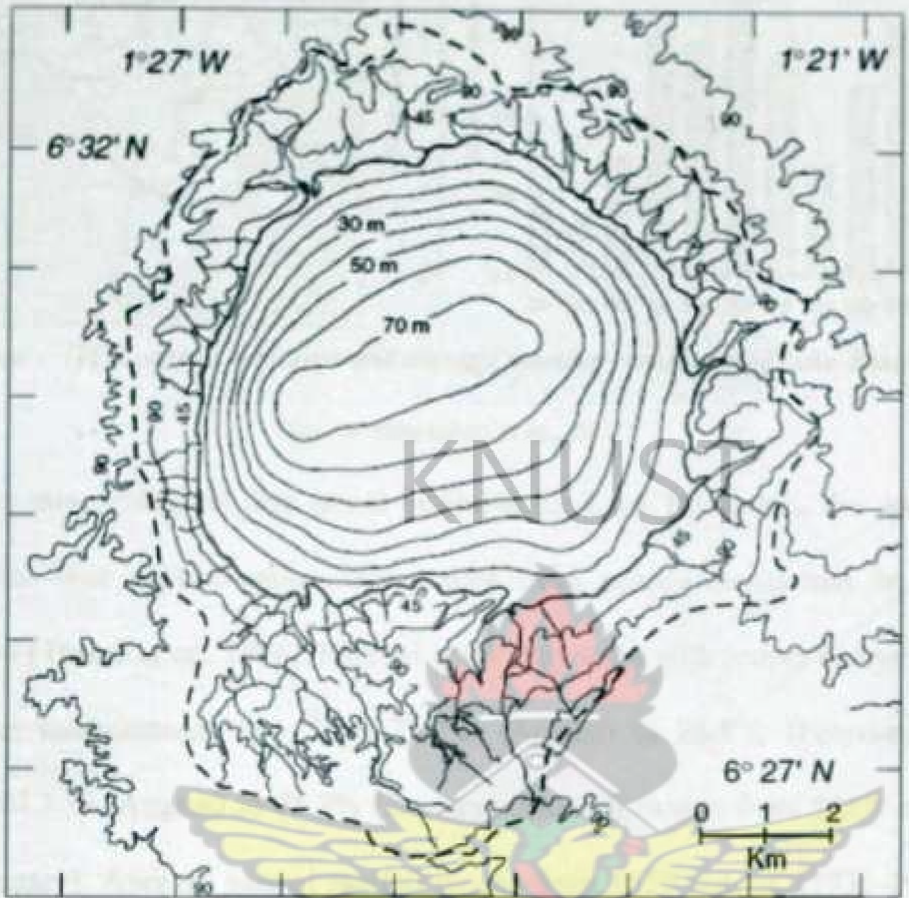


Figure -: Bathymetric map of Lake Bosumtwi

(Source: Shananhan *et al*., 2007)

2.5 Climate

Lake Bosumtwi lies in the moist, semi-deciduous tropical lowland forest zone of southern Ghana (Shananhan *et al*., 2007). The climate is strongly affected by the seasonal migration of the ITCZ (the atmospheric boundary between the NE continental trade winds – Harmattan trades – and the SW onshore – Monsoon – winds) and sea surface temperatures on moisture sources traveling from the Gulf of Guinea and the eastern tropical Atlantic. During the rainy season, ITCZ migrates to the north of Lake Bosumtwi, and the SW Monsoon winds bring heavy precipitation over the lake. In the dry season, the ITCZ is displaced southward of the lake, and dry aerosol-rich NE trade winds (Harmattan) dominates over the lake(Peck *et al*., 2004).

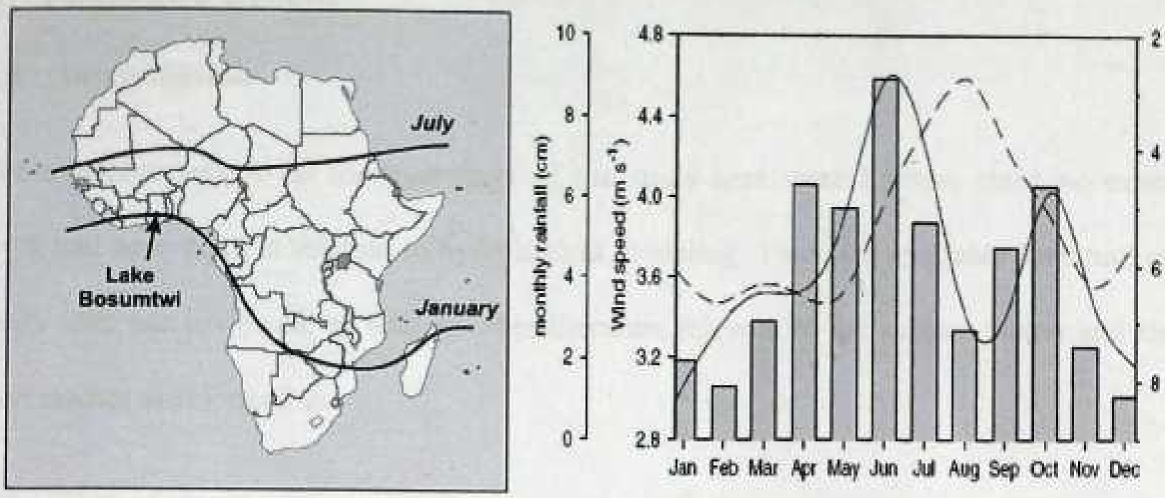


Figure -: ITCZ annual variation and average weather conditions of Lake Bosumtwi

(Source:Shananhan *et al*., 2007)

Though direct meteorological data is not available for Lake Bosumtwi, the use of regional data offers the best approximation. Thus, data from nearby towns can be used as an approximation (Turner *et al*., 1996). Kumasi is the only town with proper meteorological data records. Mean temperatures vary from 23.2°C (August) to 26.8°C (February). Humidity ranges from 84.7 % (August) to 75.3% (January). Rainfall ranges from 233.9 mm (June) to 17.0 mm (January). Average annual rainfall ranges from 1550 mm/yr. (1935-1969) to 1380 mm/yr. (1969-1992), with an average of 1450 mm/yr. (1935-1992). Details of other climatological parameters are described in figure 2.5 above; with precipitation as bars, wind speed as solid line and sunshine hours as dashed lines (Koeberl *et al*., 2007; Shananhan *et al*., 2007).

2.6 Geology

Lake Bosumtwi's crater lies in Precambrian rocks of the Birimian Supergoup, which consists of mainly metasediments: graywackes, phyllites and quartizites. The southeast corner of the structure has metavolcanic rocks of the upper Birimian group. The Birimian formations strike northeast-southwest and dip sub-vertical(Jones *et al*., 1981; Koeberl and Reimold, 2005; Karp *et al*., 2002). Geological map of Lake Bosumtwi is given in Appendix 2.

3 Literature Review

3.1 Introduction

The available reports on the hydrology of the study area were limited, since no extensive work had been done in relation to hydrological modeling. Thus, the available literature on the study area was reviewed, as well as other literature relevant to the subject matter and similar case studies also looked at.

3.2 Previous Work on the Study Area

Insights into the mechanisms controlling the annual water balance of Lake Bosumtwi were first published in 1996 (Turner *et al*., 1996). The model was based on lake level rises between 1938 and 1980. In 2007 Shanahan *et al* however described this model as one that overestimates as they do not appropriately address all controlling factors of historical lake level changes(Shananhan *et al*., 2007).

They thus improved upon the work by (a) examining the influence of seasonal and monthly changes in the water budget on lake level, (b) providing a more detailed and flexible physical parameterization of hydrological processes that is more easily applied to prehistoric periods, (c) evaluating the effectiveness of different evaporation models in lake level simulations, (d) providing more detailed insights into the controls on lake level fluctuations, and (e) expanding the model simulation to the present day (1938–2004) (Shananhan *et al*., 2007).

Though the work of Shananhan *et al.* (2007) provides satisfactory conclusions, the model lumps land cover into static percentages, creating inflexibility in changing land use patterns. The model is calibrated by comparing it with other basins that differ in characteristics to that of Lake Bosumtwi, and thus, does not provide satisfactory grounds for evaluation of the model. Though it has been argued that the lake is hydrologically separated from the surrounding groundwater aquifer, efforts has not been made to quantify the subsurface flow of infiltrated water into the lake within the basin.

3.3 Lake Studies Using GIS and Satellite Altimetry

3.3.1 Satellite Altimetry

The observations of spatial and temporal variability of water resources are crucial for societal and scientific issues. In particular, the volume of water stored within lakes and reservoirs whose location makes them a sensitive proxy for both effective water resources management and climate change studies could be vital for the socio-economic development of the inhabitants. However, in many regions, the expense of data collection is restricted due to economic reasons, or is being considered as sensitive national information, and there is also the physical removal of lake gauges from many lakes (Cretaux and Birkett, 2006). In the wake of these, satellite altimetry provides the best option in providing information for lake studies.

Satellite altimetry has successfully been used for monitoring the variation of continental surface water, such as inland seas, lakes, rivers and more recently wetland zones (*ibid.*). Satellite altimetry has one prominent advantage: data acquisition is not affected by weather conditions. Another prominent advantage is the repeatability of the recording, which range from 10 days to 35 days. However, rapidly varying topography or complex terrain may inhibit the retrieval of good elevation data. Again, the instruments operate in a profiling mode and do not have a true global view. Stage accuracies are also dependent on target size and surface roughness, which limit worldwide surveying and limnological applications. Satellite altimetry, however, provides the scope for continental scale monitoring and the provision of new stage information where gauge data is absent. Typical accuracies of altimetry measurement range from few centimeters (e.g. Great Lakes, USA) to tens of centimeters (e.g. Lake Chad, Africa), depending on the size and wind conditions. A summary of the general characteristics of some satellite altimetry is given below:

Table -: Radar satellites and orbital cycle

Satellites	Operation period	Orbital cycle	Accuracy	Target area	Target width
ERS2	1995 - 2002	35 days	>9 cm rms	>100 km^2	>500 m
ENVISAT	>2002	35 days	>9 cm rms	>100 km^2	>500 m
T/P	1992 -2005	10 days	>3 cm rms	>100 km^2	>500 m
Jason-1	>2002	10 days	>3 cm rms	>100 km^2	>500 m

(Source: Cretaux and Birkett, 2006)

Some products of satellite altimetry include: Landsat, SRTM DEM, ASTER, MODIS, AVHRR, and QuickBird.

3.3.2 Landsat GeoCover Images

The Landsat GeoCover dataset is a collection of high resolution satellite imagery provided in a standardized, orthorectified format, covering the entire land surface of the world (except Antarctica). This is an invaluable record of land cover and land cover change, provided in a consistent manner that allows for use in a wide range of activities including environmental assessment, planning, land management, resource stewardship and many Earth science research activities. The following table describes Landsat GeoCover satellite characteristics.

Table -: Landsat GeoCover satellites characteristics

Satellite	Sensor	Pixel size (in meters for visible, thermal, and pan bands)	RMSe
C. 1970	MSS	57, N/A, N/A	100m
C. 1990	TM	28.5, 114, N/A	50m
C. 2000	ETM+	28.5, 57, 14.25	50m

3.3.3 SRTM DEM

The Shuttle Radar Topography Mission (SRTM) obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000. SRTM is an international project spearheaded by the National Geospatial-Intelligence Agency (NGA), NASA, the Italian Space Agency (ASI) and the German Aerospace Center (DLR). There are three resolution outputs available, including 1 kilometer and 90 meter resolutions for the world and a 30 meter resolution for the US. GLCF serves the main USGS editions, plus has 'enhanced' editions as well as provides editions in WRS-2 tiles to approximate Landsat scenes. The table below summarizes the editions of STRM DEM data available at the GLCF.

Table -: STRM data characteristics

Resolution	Projection	Coverage
1 arc-second / 30 meters	Geographic	Native USGS Tiles
	UTM	WRS-2 Path/Row
3 arc-second / 90 meters	Geographic	Native USGS Tiles
	UTM	WRS-2 Path / Row
1 kilometre	Geographic	Native USGS Tiles
	Geographic	Global

3.4 Water Balance Components of Closed Lakes

The water balance components of lakes and river basins have primarily been known to include: *Precipitation, Runoff, Evaporation / Evapotranspiration, and Groundwater contribution.* The contribution of groundwater over the long term has generally been nullified, thus, making the principal components being precipitation, runoff and evaporation (evapotranspiration)(Sinyukovich, 2008). Thus, the general water balance equation, although there are several variations, is normally expressed in the form (Zamanov, n.d.):

$$P = S + U + E \tag{3-1}$$

Where P is the precipitation (rain, snow, hail, etc.), S is the surface runoff, flood runoff or river runoff, U is the underground discharge or base flow, and E is the evaporation or evapotranspiration.

3.5 Approaches in Estimating Water Balance Components

Several methods have been proposed for the estimation of water balance components in hydrologic systems. A summary of these approaches have been classified below:

3.5.1 Income and Expenditure Approach:

The income and expenditure method offers the simplest method of approximation of the water balance components. The general equation is of the form, as described by Zamnov (n.d.), is:

$$P = S + U + E \tag{3-2}$$

Where P is the precipitation (rain, snow, hail, etc.), S is surface runoff, flood runoff or river runoff, U is underground discharge or base flow, and E is evaporation or evapotranspiration. In this model, where there exists no groundwater contribution, surface runoff maybe taken as the remainder term of precipitation and evaporation, as shown below:

$$S = P - E \tag{3-3}$$

However, if groundwater exists and both inflow and outflow occurred, then over the long term, a steady state maybe assumed for the hydrologic system. Thus, groundwater may be estimated by the remainder term of precipitation and evaporation.

$$P - E = U \tag{3-4}$$

3.5.2 Mass Balance / Volumetric Balance Approach:

The mass balance / volumetric balance approach offers increased control in the estimation of the water balance components. This approach works on the assumption that both confined and unconfined aquifers are in a steady state. Thus, the general equation, (after Jones *et al.*, 2001) is given by:

$$\delta V = (P - E)A_l + G_w \tag{3-5}$$

Where G_w is groundwater into the lake, and δV is the change in volume of the lake.

3.5.3 (Volumetric) Rate Approach:

The rate approach (Sanchez-Moral *et al.*, 2002) is as generalized by:

$$\frac{dV}{dt} = Q_P + Q_S + Q_I - Q_O - Q_E \qquad (3\text{-}6)$$

Where dV / dt is the rate of change in the volume of the lake, Q_P is the precipitation rate, Q_S is average surface runoff, Q_I is the groundwater inflow (influent seepage), Q_O is the groundwater outflow (effluent seepage), and Q_E is the evaporation rate.

3.5.4 Isotopic Water Balance Approach:

This approach uses isotopic dating to estimate the age and origins of water within the hydrologic cycle, and is also known as **isotope hydrology** (IAEA, 2006). This approach is based on the fact that water molecules carry different and unique fingerprints, based on differing portions of oxygen and hydrogen isotopes that constitute all water.

The two primary isotopes of oxygen are oxygen-16 and oxygen-18. Air, soil and water contain mostly oxygen-16 (^{16}O). Oxygen-18 (^{18}O) occurs in approximately one oxygen atom in every five hundred and is a bit heavier than oxygen-16. Thus, ^{16}O evaporates more easily than ^{18}O, leaving lakes and seas rich in ^{18}O, whilst rain and snow being rich in ^{16}O (Wikipedia, 2009).The isotopic water balance equation, for both hydrogen and oxygen species, is given by:

$$\frac{\Delta V \delta_L}{\Delta t} = P\delta_P + G_i\delta_{Gi} - G_O\delta_L - E\delta_E \qquad (3\text{-}7)$$

Where $\delta_P$is the isotopic composition of precipitation, δ_{Gi} is the isotopic composition of water inflows, δ_L is the isotopic composition of lake water, and δ_E is the isotopic composition of evaporated moisture, measured according to the Craig and Gordon model (1965).

Based on the availability of data, the mass balance approach was selected for this study.

3.6 Estimation of Water Balance Components

Various approaches exist for the determination of water balance components. However, this section focuses on methods that have been applied to ungagged catchments and hydrologically closed lakes.

3.6.1 Runoff

Several conceptual models exist for estimation of runoff from ungagged catchments. Based on the availability of data and prior application to similar catchments, the following were reviewed:

3.6.1.1 Shuttleworth model(1992)

The Shuttleworth model for estimating runoff from forest catchments is given by:

$$R_{forest} = P_{catchement} - (0.8E_{ET}^{forest} + \alpha_i P) \quad (3\text{-}8)$$

Where R is the runoff from the forest catchment, $P_{catchment}$ the precipitation on the catchment, E_{ET}^{forest} the evapotranspiration from the catchment and α_i the fractional interception loss, given by:

$$\alpha_i P = \frac{0.95 N_s (S + 0.2 t_s)}{N_d} \quad (3\text{-}9)$$

Where N_s and $N_d$are the number of storms and number of days in the month and t_s- the duration of the storm. S is the storage capacity of the canopy (0.8mm for a broadleaf canopy in full leaf).

3.6.1.2 SCS-CN Runoff Model

The SCS-CN rainfall-runoff model, developed by United States Department of Agriculture (USDA–SCS, 1972), transforms rainfall directly into volume of flow and also incorporates evapotranspiration and infiltration into to the model, and is given by:

$$Q = \frac{(P - \lambda S)^2}{P + (1 - \lambda)S} \qquad (3\text{-}10)$$

Where, *Q (mm)* is the direct runoff depth, *P (mm)* the average precipitation (rainfall), *S (mm)*- the potential maximum soil water retention and λ - the initial abstraction ratio. The above equation is valid for $P \geq \lambda S$.

The initial abstraction consists mainly of interception, infiltration and surface storage, all of which occur before runoff begins. The standard CN method assigns a value of 0.2 to the initial abstraction ratio ($\lambda = 0.2$). This simplifies the model as:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}, P > 0.2S \qquad (3\text{-}11)$$

The value of S is defined as:

$$S(mm) = \frac{25400}{CN} - 254 \qquad (3\text{-}12)$$

CN - the curve number of the soil and is mainly a function of **soil type** and **land cover**. As different soil types and land covers may be found in the same catchment, a weighted *CN* for each catchment has to be computed using the formula:

$$CN_w = \frac{\sum_{i=1}^{n} CN_i A_i}{\sum_{i=1}^{n} A_i} \qquad (3\text{-}13)$$

Where, CN_w is the weighted curve number, CN_i- the curve number for land cover type, A_i - area with curve number CN_i and $\sum_{i=1}^{n} A_i$ is the total area of the catchment. The values of CN range from 0 to 100 and are found in the table below.

Table -: SCS Curve Number Values for AMC (II)

Land Cover	HSG A	HSG B	HSG C	HSG D
Settlement	77	85	90	92
Open area	49	69	79	84
Shrubs/Trees	39	61	74	80
Open Forest	44	65	76	82
Closed Forest	32	58	72	79
Water body	100	100	100	100
Unclassified	50	50	50	50

Selection of the appropriate curve number depends on knowledge of the Hydrologic Soil Group (HSG), Antecedent Moisture Condition (AMC) and land cover within the catchment. Soils are classified into four Hydrologic Soil Group based on the soil's runoff potential. The four Hydrologic Soils Groups are A, B, C and D where group A soils generally have the smallest runoff potential and group D soils the greatest (Hydrological Soil Group).

The antecedent moisture condition (AMC) is an index of basin wetness (Silveira *et al.* 2000). AMC I, AMC II and AMC III represent respectively dry, average and wet conditions of the soil in the concerned catchment. Adjustment for AMC I and AMC III are given in the equations below:

$$CN(I) = \frac{4.2\, CN(II)}{10 - 0.05\, CN(II)} \tag{3-14a}$$

$$CN(III) = \frac{23\, CN(II)}{10 + 0.13\, CN(II)} \tag{3-14b}$$

3.6.1.3 Adapted Pra River Basin Model

The adapted Pra river basin annual rainfall-runoff model for Lake Bosumtwi (Turner *et al.*, 1996) is given as:

$$R = P - \beta \tanh\left(\frac{P}{\beta}\right) \tag{3-15}$$

Where P is the rainfall, β is the average annual potential evapotranspiration and *P/β*- the fraction of potential evapotranspiration that becomes actual evapotranspiration. Turner *et al.* (1996) determined β as:

$$\beta = 2012.2 \pm 53.5\ mm \tag{3-16}$$

3.6.2 Evaporation

Direct measurement of evaporation is difficult and unreliable (Shuttleworth, 1992). This has led to the development of several empirical models for the estimation of evaporation. Several evaporation models rely on a combination of input variables, thus making the evaporation estimates more or less accurate depending on the characteristics of the lake (Shananhan *et al.*, 2007). Based on availability of data, models that have been proven reliably accurate when applied to small mountainous and closed lakes have been reviewed.

3.6.2.1 Energy Budget Evaporation Model

The energy budget evaporation model is simplified by the energy balance model at the surface of the lake as:

$$R_n = H + \lambda E + \Delta S \tag{3-17}$$

Where R_n is the net solar radiation (MJ m^{-2} day^{-1}), *H*- the outgoing sensible heat flux (MJ m^{-2} day^{-1}), λE- heat lost to evaporation and ΔS- the change in energy stored in the lake (MJ m^{-2} day^{-1}). Rearranging the energy balance equation gives:

$$E = \frac{R_n - H - \Delta S}{\lambda} \tag{3-18}$$

Where λ is the latent heat of evaporation of water, approximately equal to 2.45 MJ kg^{-1}, and can be determined by:

$$\lambda = 597.3 - 0.564T_w \qquad (3\text{-}19)$$

The outgoing sensible heat flux, H, can be determined from the relation:

$$H = \frac{P_{atm}\, C_D U C_{air}}{RT_a}(T_w - T_a) \qquad (3\text{-}20)$$

Where C_D is the surface drag coefficient, k - an empirical constant ($k \approx 0.40$), U - wind speed, C_{air}- heat capacity of air ($C_{air} \approx 0.24\ cal\ g^{-1o}C$), R- gas constant, T_a- temperature of air and T_w- the temperature of water; and can be estimated by:

$$P_{atm} = 101.3\left(\frac{293 - 0.006z}{293}\right)^{5.62} \qquad (3\text{-}21)$$

$$C_D = k^2 \ln\left(\frac{z_r}{z_0}\right)^{-2} \qquad (3\text{-}22)$$

$$U_2 = U_z\left[\frac{4.87}{\ln(67.8z - 5.42)}\right] \qquad (3\text{-}23)$$

Where Z_r is the reference height at which wind speed is measured ($Z_r = 2.0$m), and Z_o is the height above water surface at which wind speed is zero ($Z_o = 0.000006$m (Shuttleworth, 1992)). U_z is wind speed at Z m above sea level and U_2 is wind speed at 2m above sea level.

Since seasonal and inter-annual lake heat storage changes is negligible(Shananhan *et al.*, 2007), ΔS is neglected in this model. Thus evaporation by the energy budget model used in this study is simplified as:

$$E = \frac{R_n - H}{\lambda} \qquad (3\text{-}24)$$

Net solar radiation, R_n, is given by:

$$R_n = \textit{Net incoming solar radiation} - \textit{net outgoing longwave radiation} \qquad (3\text{-}25a)$$

$$R_n = (R_s \downarrow - R_r \uparrow) - (R_{lup} \uparrow - R_{ldown} \downarrow) \qquad (3\text{-}25b)$$

Where R_s is the incoming shortwave radiation (MJ m^{-2}), R_r- the reflected shortwave radiation (MJ m^{-2}), R_{lup}- the emitting longwave radiation (MJ m^{-2}) and R_{ldown}- the receiving long wave radiation (MJ m^{-2}). The reflected shortwave radiation is given by:

$$R_r = \alpha_w R_s \tag{3-26}$$

Where α_w is the albedo or reflection coefficient of the water surface (dimensionless), also a time dependent function of solar position and mean cloudiness, and can be estimated by:

$$\alpha_w = \left(\frac{a\, t_d}{2\pi\, w_s}\right)^F \tag{3-27}$$

Where a is a parameter that depends on the cloud cover and Julian day, t_d the number of seconds in a day, w_s half day length and F the integral factor; which are given by:

$$a = 0.02 + 0.01(0.5 - C)\left\{1.0 - sin\left(\frac{\pi(J - 81)}{183}\right)\right\} \tag{3-28}$$

Where C is the fraction of sky obscured by the cloud and J- the Julian day. C is given below, and where n is the actual duration of sunshine:

$$C = 1 - \frac{24\, w_s\, n}{\pi} \tag{3-29}$$

The integration factor, with θis the latitude in degree and δ the solar declination in degrees,

is given by:

$$F = \begin{cases} 2(b^2 - c^2)^{-\frac{1}{2}} tan^{-1}\left(B^{\frac{1}{2}}\right), & b^2 - c^2 > 0 \\ (b^2 - c^2)^{-\frac{1}{2}}\, ln\left[\dfrac{1 + (-B)^{\frac{1}{2}}}{1 - (-B)^{\frac{1}{2}}}\right], & b^2 - c^2 < 0 \end{cases} \tag{3-30a}$$

$$b = a + sin\,\theta\, sin\,\delta \tag{3-30b}$$

$$c = cos\,\theta\, cos\,\delta \tag{3-30c}$$

$$B = \left(\frac{b-c}{b+c}\right)tan^2\left(\frac{\pi\, w_s}{2t_d}\right) \quad (3\text{-}30d)$$

R_s is proposed and validated by Angstrom (1956) and Ali *et al.* (1998) respectively is given by:

$$R_s = \left(a_s + b_s\frac{n}{N}\right)R_a \quad (3\text{-}31)$$

R_a is the extra-terrestrial radiation (MJ m^{-2} day^{-1}), N the maximum number of sunshine hours, n/N relative sunshine duration, a_s and b_s are regression constants given by Srivastava *et al.* (1993) as $a_s = 0.2006$ and $b_s = 0.5313$.

$R_a$for a day in a year for a specific location can be computed using Allen *et al.*'s (1998) equation, which is given by:

$$R_a = \frac{24(60)}{\pi}G_{sc}d_r[w_s\,sin(\varphi)\,sin(\delta) + cos(\varphi)\,cos(\delta)\,sin(w_s)] \quad (3\text{-}32a)$$

$$d_r = 1 + 0.033\ cos\left(\frac{2\pi}{365}J\right) \quad (3\text{-}32b)$$

$$\delta = 0.409\ sin\left(\frac{2\pi}{365}J - 1.39\right) \quad (3\text{-}32c)$$

$$w_s = \frac{\pi}{2} - tan^{-1}\left[\frac{-tan(\varphi)\,tan(\delta)}{X^{0.5}}\right] \quad (3\text{-}33a)$$

$$X = 1 - [tan(j)]^2[tan(d)]^2, X = 0.00001\ for\ X \leq 0 \quad (3\text{-}33b)$$

$$[Radians] = \frac{\pi}{180}[decimal\ degrees] \quad (3\text{-}34)$$

Where R_a is extra-terrestrial radiation [MJm^{-2}day^{-1}], G_{sc} is solar constant = 0.0820 [MJm^{-2}min^{-1}], d_r is inverse relative distance Earth-Sun, j is the latitude [rad] and d is the solar decimation.

Thus, after Hosteller and Barlein (1990) and Dingman (1994), the analytical equation for estimating net radiation is given as:

$$R_n = (1-\alpha_w)R_s - [\varepsilon_w\varepsilon_a\sigma(T_a + 273.15)^4 + \varepsilon_w\sigma(T_a + 273.15)^4] \quad (3\text{-}35)$$

Where ε_w is the emissivity of the water surface (dimensionless), ε_a is the emissivity of the atmosphere (dimensionless), σ is the Stefan-Boltzmann constant = 4.903 x 10^{-9} MJ m^{-2} K^{-4}, and T_a the air temperature (Kelvin). The emissivity of water was determined as ε_w = 0.97 (Hostetler and Bartlein, 1990). The clear sky emissivity, ε_a, after Henderson-Seller (1986), is given by:

$$\varepsilon_a = \begin{cases} 0.84 - (0.1 - 9.973 \times 10^{-6} e_a)(1 - C) + 3.491 \times 10^{-5} e_a; for\ 1 - C > 0.4 \\ 0.87 - (0.175 - 29.92 \times 10^{-6} e_a)(1 - C) + 2.693 \times 10^{-5} e_a; for\ 1 - C < 0.4 \end{cases} \quad (3\text{-}36)$$

Where e_a is the actual vapour pressure (kPa), and is given by Burman and Pochop (1994):

$$e_a = \frac{e^o(T_{min})\frac{RH_{max}}{100} + e^o(T_{max})\frac{RH_{min}}{100}}{2} \quad (3\text{-}37)$$

Where $e^o\ (T_{max})$ is the saturated vapour pressure at maximum temperature (kPa), $e^o(T_{min})$ is the saturated vapour pressure at minimum temperature (kPa) and RH is the relative humidity (%).

The saturated vapour pressure, e_s is given by (Asmar and Ergenzinger, 1999):

$$e_s = 0.6108\, exp\left[\frac{17.269\, T_w}{T_w + 273.3}\right] \quad (3\text{-}38)$$

Where T_w is the temperature of water.

3.6.2.2 *Priestly-Taylor Evaporation Model*

The Priestly-Taylor evaporation model (Priestly and Taylor, 1972) is based on the combination of radiation and aerodynamic components, but with the aerodynamics component replaced by a coefficient, α, greater than 1.0. The model is given by Stewart and Rouse (1976) as:

$$E = \alpha \frac{\Delta}{\Delta + \gamma} \frac{R_n - \Delta S}{\lambda \rho} \times 86.4 \quad (3\text{-}39)$$

Where α is the Priestly-Taylor constant ($\alpha = 1.26$), ρ is the density of water (998 kg m^{-3}), R_n the net radiation (W m^{-2}), γ is the psychometric constant, and ΔS is the changed in heat storage in the water body. Since inter-annual variation of heat stored in the lake is negligible (Shananhan *et al.*, 2007), ΔS is neglected in the equation. Thus the model becomes:

$$E = \alpha \frac{\Delta}{\Delta + \gamma} R_n \times \left(\frac{86.4}{\lambda \rho}\right) \tag{3-40}$$

Where Δ is the slope of the saturated vapour pressure – temperature curve at mean air temperature (Pa $^{o}C^{-1}$), and is given by:

$$\Delta = \frac{4098\left[0.6108\, exp\left(\frac{17.27\, T_w}{T_w + 237.3}\right)\right]}{(T_w + 237.30)^2} \tag{3-41}$$

3.6.2.3 Penman and Simplified Penman Evaporation Model

The standard Penman evaporation model (Penman, 1948) is based on description of energy required for evaporation and the removal of energy from the water surface by advection (Shuttleworth, 1992). The Penman evaporation model is written as:

$$E = \frac{R_n}{\lambda} \frac{\Delta}{\Delta + \gamma} + E_a \frac{\gamma}{\Delta + \gamma} \tag{3-42}$$

Where R_n / λ (mm day^{-1}) is the component of evaporation due to solar radiation and E_a (mm day^{-1}) is the component of evaporation due to wind. Ea is known as the drying power of air and its estimation is given by Brutsaert (1982) as:

$$E_a = 0.26(1 + 0.54U_2)(e_s - e_a) \tag{3-43}$$

Where $e_s - e_a$ is the saturation vapour deficit and U_2 is the wind speed at 2m above the water surface. The standard Penman evaporation model has been simplified by Valiantzas (2006) to eliminate wind data. The simplified Penman evaporation model, as given by Valiantzas is written as:

$$E \approx 0.047R_s\sqrt{T_a + 9.5} - 2.4\left(\frac{R_s}{R_a}\right)^2 + 0.09(T_a + 20)\left(1 - \frac{RH}{100}\right) \quad (3\text{-}44)$$

3.6.2.4 Thornwaite-Matter Evaporation Model

The Thornwaite evaporation model (Matter, 1978) is an empirical model based only on temperature, and is written as:

$$E = \left(1.6\left(\frac{10T_a}{I}\right)^x\right)\left(\frac{10}{d}\right); \quad (3\text{-}45)$$

$$x = 6.75 \times 10^{-7}I^3 - 7.71 \times 10^{-5}I^2 + 1.79 \times 10^{-2}I + 0.49$$

Where I is the annual heat index, and i is the monthly heat index which is given as:

$$I = \sum i, \quad i = \left(\frac{T_a}{5}\right)^{1.1514} \quad (3\text{-}46)$$

3.6.2.5 Mass Transfer Model

The mass transfer model assumes evaporation rates are a linear function of wind speed and the difference between saturated vapour pressure and actual vapour pressure. The mass transfer model of evaporation is given by:

$$E = \mu U_2(e_s - e_a); \ \mu = 2.909\,A^{-0.05} \quad (3\text{-}47)$$

Evaporation is related to wind speed and the saturation vapour deficit $(e_s - e_a)$ by an empirical mass coefficient, μ (mm s m^{-1} kPa^{-1}), with A as the water surface area of the water body in km^2.

Selection of the best evaporation model of Lake Bosumtwi was done by assessing the performance (section 3.8) of each of the above evaporation models when compared to measured pan evaporation values of Kumasi.

3.7 Model Selection, Calibration and Evaluation

3.7.1 Model Selection

Several models were reviewed for this project. However, models that were selected were based on data availability and its popularity (application to similar projects). The selected models were then evaluated and calibrated.

3.7.2 Model Performance

The performance of the water balance model was evaluated by using two indices of agreement (coefficient of determination – R^2 and index of agreement – D) and two indices of error (root mean square – RMSE and relative bias – RB) as described by (Ali *et al.*, 2008). The model that possesses the highest indices of agreement values (R^2 and D) and least indices of error values (RMSE and RB) was chosen. The performance models are:

3.7.2.1 Indices of Agreement

3.7.2.1.1 Coefficient of determination, R^2

R^2describes the proportion of total variance between the actual and simulated data sets. R^2 is given by equation 3—48, where X_i and $\bar{X}$ denotes the observed and mean of the observed data values; Yi and $\bar{Y}$ denotes the simulated and the mean of the simulated values.

$$R^2 = \frac{\sum_{i=1}^{T}(X_i - \bar{X})(Y_i - \bar{Y})}{\left[\sum_{i=1}^{T}(X_i - \bar{X})\right]^{0.5}\left[\sum_{i=1}^{T}(Y_i - \bar{Y})\right]^{0.5}} \qquad \textit{(3-48a)}$$

The value of R^2 can be interpreted, after Coulibali *et al.* (2005), as given below:

$$0 < R^2 < 1 \rightarrow \begin{cases} R^2 > 0.9, & \textit{very good model} \\ 0.8 > R^2 > 0.9, & \textit{fairly good model} \\ R^2 < 0.8, & \textit{unsatisfactory model} \end{cases} \qquad \textit{(3-48b)}$$

3.7.2.1.2 Index of agreement, D

The index of agreement, after Legates and McCabe (1999), measures the between the observed and simulated data sets and is given by:

$$D = 1.0 - \frac{\sum_{i=1}^{r}(X_i - Y_i)^2}{\sum_{i=1}^{r}(|Y_i - \bar{X}| + |X_i - \bar{X}|)^2} \quad (3\text{-}49)$$

D ranges between 0 and 1, with 0 signifying no agreement and 1 means perfect agreement.

3.7.2.2 Indices of Error

The indices of error indicate the average difference between measured and simulated data sets (Ali *et al*., 2008). Larger value of RMSE and also larger absolute value of RB indicate a less accurate model.

3.7.2.2.1 Root mean square error, RMSE

This gives the measure of non-systematic variation between two datasets and is given by:

$$RMSE = \sqrt{\frac{1}{r}\sum_{i=1}^{r}(Y_i - X_i)^2} \quad (3\text{-}50)$$

3.7.2.2.2 Relative Bias, RB

RB gives the amount of systematic error by indicating how much the model underestimates (RB < 0) or overestimates (RB > 0), and is given by:

$$RB = \frac{1}{r}\sum_{i=1}^{r}(Y_i - X_i) \quad (3\text{-}51)$$

3.7.3 Model Calibration and Validation

Several methods of calibrating models exist, however, since enough data was available Klemes split-sample test method (1986) was chosen. In this method, the whole dataset is split into two independent datasets; the first set of data is used in calibration, whiles the other is used in validation of the calibrated dataset. Thus one set of the data was used in calibrating the model by soundly fine-tuning its physical and numerical parameters by trial-and-error to minimize difference between model results and field observations. Afterwards, the second independent data set is used to validate the model, without adjusting the models parameters physical and numerical parameters (cited by Dahmen and Hall, 1990).

3.7.4 Model Evaluation

The Nash-Sutcliffe efficiency (Nash *et al.* 1970), *E*, provides a method of determining how the lower dynamics of a model compares with the higher dynamics of observed values. The range of values of E lies between -1 (no fit) and 1 (perfect fit). *E* also shows how well a model can predict observed values. *E* values less than zero implies that the mean of the observed values be a better predictor than the model. *E* is given in the equation below; with $x_i$and $y_i$are observed and simulated data.

$$E = 1 - \frac{\sum_{i=1}^{T}(x_i - y_i)^2}{\sum_{i=1}^{T}(x_i - \bar{y})^2}; where \begin{cases} -1 \le E \le 0 \rightarrow Poor\ model \\ 0 < E < 1 \rightarrow Good\ model \\ E = 1 \rightarrow Perfect\ model \end{cases} \quad (3\text{-}52)$$

3.8 Statistical Methods for Data Validation

Hydrological data is subject to obtrusive alterations which may introduce non-homogeneity and inconsistency into the data series. Non-homogeneity may span periods of change and inconsistency may arise out of extraneous influences on equipment. Since hydrological data used for hydrologic modeling must be sound (stationary, consistent and homogenous), it is necessary to screen the data prior to its use for modeling. Literature on screening and correcting hydrologic data prior hydrologic modeling is discussed below.

3.8.1 Level of Significance

It has been demonstrated that 5% change in data during hydrologic modeling does not significantly affect the results (Dahmen and Hall, 1990). Though other levels of significance maybe computed, it has become customary to adopt a 5% level of significance during data screening and validation (*.ibid*). Thus, a 5% level of significance is adopted for this research.

3.8.2 Rough Screening, Plotting of Data and Time Series Analysis

Rough screening of data allows for the visual detection of whether the observations have been consistently or accidently credited to the wrong day or whether they show gross errors (*ibid*). Plotting of the time series data follows rough screening and allows for confirmation of visual inspection carried out earlier. Rough screening and time series analysis forms the preliminary step in data validation.

3.8.3 Test for Absence of Trend

Test for absence of trend often follows rough screening and ensures that no correlation exists between the orders in which the data has been collected. The test is based on the Spearman's rank-correlation method, where the Spearman's rank-correlation coefficient, R_{sp}, is defined as:

$$R_{sp} = 1 - \frac{6\sum_{i=1}^{n}(Kx_i - Ky_i)^2}{n\,(n^2-1)} \tag{3-53}$$

Where n is the total number of data, Kx_i is the rank of the variable x in the chronological order of observations and $Ky_i$is the transformed rank equivalent of the series observations y_i.

The tests is done with the null hypothesis, H_0: Rsp = 0 (there is no trend), against the alternate hypothesis, H_1: Rsp<> 0 (there is a trend) with the test statistic:

$$t_t = R_{sp}\left[\frac{n-2}{1-R_{sp}^2}\right]^{0.5} \tag{3-54}$$

Where t_t has Student's t-distribution with $v = n\text{-}2$ degrees of freedom. At a significance level of 5%, the two-sided critical region, U, of t_t is bounded by:

$$\{-\infty, t\{v, 2.5\%\}\} U \{t\{v, 97.5\%\}, +\infty\} \tag{3-55a}$$

Thus, the null hypothesis is accepted if $t_t$is not contained in the critical region if:

$$t\{v, 2.5\%\} < t_t < t\{v, 97.5\%\} \tag{3-55b}$$

3.8.4 Tests for Stability of Variance

Test for stability of variance is carried out using the Fisher distribution test, F-test. The test statistic is the ratio of two split, non-overlapping subsets of the time series; and is given by:

$$F_t = \frac{\sigma_1^2}{\sigma_2^2} = \frac{s_1^2}{s_2^2} \tag{3-56}$$

Where σ^2 and s^2 are the population and sample standard deviations respectively. The null hypothesis for the test, $H_0: s_1^2 = s_2^2$, is the equality of variances; the alternate hypothesis is $H_0: s_1^2 <> s_2^2$. The rejection region, for a 5% level of significance, is bounded by:

$$\{0, F\{v_1, v_2, 2.5\%\}\} \, U \, \{F\{v_1, v_2, 97.5\%\}, +\infty\} \tag{3-57a}$$

Where $v_1 = n_1 - 1$ is the number of degrees of freedom of the numerator, $v_2 = n_2 - 1$ is the number of degrees of freedom of the denominator, and n_1 and n_2 the number of data in each subset. The variance of the time series is stable if:

$$F\{v_1, v_2, 2.5\%\} < F_t < F\{v_1, v_2, 97.5\%\} \tag{3-57b}$$

3.8.5 Tests for Stability of Mean

The test for stability of mean is confirmed with the t-test by comparing the means of two or three non-overlapping sub-sets of the time series, using the statistic for the null hypothesis $H_0: \bar{x}_1 = \bar{x}_2$, against the alternate hypothesis, $H_1: \bar{x}_1 <> \bar{x}_2$. The test statistic is given by:

$$t_t = \frac{\bar{x}_1 - \bar{x}_2}{\left[\frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2} \times \left(\frac{1}{n_1} + \frac{1}{n_2}\right)\right]^{0.5}} \tag{3-58}$$

In samples from a normal distribution, t_t has a Student t-distribution. For a 5% level of significance, the two-sided critical region is bounded by:

$$\{-\infty, t\{v, 2.5\%\}\} \cup \{t\{v, 97.5\%\}, +\infty\} \quad (3\text{-}59a)$$

Where $v = n_1 - 1 + n_2 - 1$ gives the degrees of freedom. Thus the mean of the time series is considered stable if:

$$t\{v, 2.5\%\} < t_t < t\{v, 97.5\%\} \quad (3\text{-}59b)$$

3.8.6 Test for Independence of Time Series (Absence of Persistence)

Independence of a time series (complete randomness) can be verified using the serial-correlation coefficient. After Box and Jenkins (1970), (Dahmen and Hall, 1990) the serial-correlation coefficient between adjacent observations (lag 1) is given by:

$$r_1 = \frac{\sum_{i=1}^{n-1}(x_i - \bar{x})(x_{i+1} - \bar{x})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \quad (3\text{-}60a)$$

The test statistic for the null hypothesis $H_0: r_1 = 0$ (there is no correlation between adjacent observations) against the alternate hypothesis $H_0: r_1 <> 0$. At a 5% level of significance, the critical region, as defined by Anderson (1942) is:

$$\left\{-1, \frac{-1 - 1.96(n-2)^{0.5}}{(n-1)}\right\} \cup \left\{\frac{-1 + 1.96(n-2)^{0.5}}{(n-1)}, +1\right\} \quad (3\text{-}60b)$$

3.8.7 Location Break-points and Correction of Time Series Data

Detection of break-points (points in a time series where statistical properties of the time series changes) have been accomplished in history by comparing the cumulativedepartures from the mean and double-mass analysis of the time series.

3.8.7.1 Cumulative Departures from the Mean

Cumulative departures from the mean works on the assumption that all previous observations results in a zero cumulative departure from the mean. Thus the mean of the time series is subtracted from each data point. The results are cumulated, plotted and compared to the plot of the double mass analysis.

3.8.7.2 Double Mass Analysis

Double mass analysis assumes a linear relationship between a stationary, consistent and homogenous time series data (x_i) with the time series of the data to be tested (y_i), given by:

$$y = bx \qquad (3\text{-}61)$$

A plot of the cumulative of the stationary time series $X_i = \sum x_i$ with the cumulative of the time series to be tested $Y_i = \sum y_i$ is made, with the average slope $b_{av} = Y_n/X_n$ passing through the origin. Location of the break point is aided visually with the plot of the cumulative departures from the mean. Slopes of the time series being tested before (b_1) and after (b_2) the breakpoint is found and the correction factor (K) of $K = b_2/b_1$ can then be applied to the time series.

3.8.8 Estimation of Missing Data

Estimation of missing data is made by regressing a consistent, stationary and homogenous time series with the corrected time series used of the double mass analysis. The correlation coefficient and equation of the slope is then used to estimate the missing data.

4 Research Methodology

4.1 Introduction

This section focuses on the research methodology that was adopted in this study. The section also provides in-depth explanation of the tools and methods employed during the research process. The general approach to the assessment of the water balance of Lake Bosumtwi is illustrated below:

- ☐ Desk Studies and Reconnaissance Surveys
- ☐ Data Collection, Verification and Validation
- ☐ Catchment Area Determination
- ☐ Water Balance Model Development
- ☐ Estimation of Water Balance Components
- ☐ Model Evaluation and Calibration

4.2 Desk Studies and Reconnaissance Surveys

The project begun with desk studies which included a review of literature on the study area and the determination of water balance methods on similar catchments. This was coupled with a reconnaissance survey of the study area to provide an insight to the physiological features that might have a bearing on this study.

4.3 Data Collection

The data for the study was acquired from various sources. Meteorological data was taken from the regional office of the Ghana Meteorological Services Department, Kumasi. Since climatological data was not available for Lake Bosumtwi, Kumasi, a nearby town (within 100 km radius from the lake) was used as an approximation of the climatological conditions of the lake. Kumasi has a complete set of all metrological parameters from 1945 to date, as compared with other nearby towns such as Bobiri or Bekwai with punctuated data.

Satellite images were downloaded from the Global Land Cover Facility (GCLF) at the University of Maryland, USA. Satellite images were used for catchment delineation (STRM) and for land cover reclassification (Landsat).

Lake level records were taken from the Kumasi regional office of the Hydrological Services Department of Architectural and Engineering Services Corporation (AESC), under the Ministry of Water Resources, Works and Housing, Ghana. Additional data were taken from literature of previous published studies on the Lake Bosumtwi.

4.4 Data Screening, Correction and Validation

Data screening was carried out on the climatological and lake level records. This was done statistically to ensure that the data were independent, consistent, homogenous and stationary. Data screening was done in the manner illustrated below.

The climatological data were validated by comparing them with data measured in-situ on the lake's catchment. In addition, satellite data were validated by comparing them with GPS way points on the catchment.

Rough screening of the meteorological data was carried to remove any outliers from the data. The hydrological data were verified using statistical tools such as the F-Test, T-Test and the Spearman's Rank Correlation Coefficient. Meteorological data were corrected using the double mass curve between the sample data set and the data sets of known accuracy. Missing lake level and meteorological data were filled using the coefficient of correlation and the double mass curve. This was done after data correction as described in the preceding section.

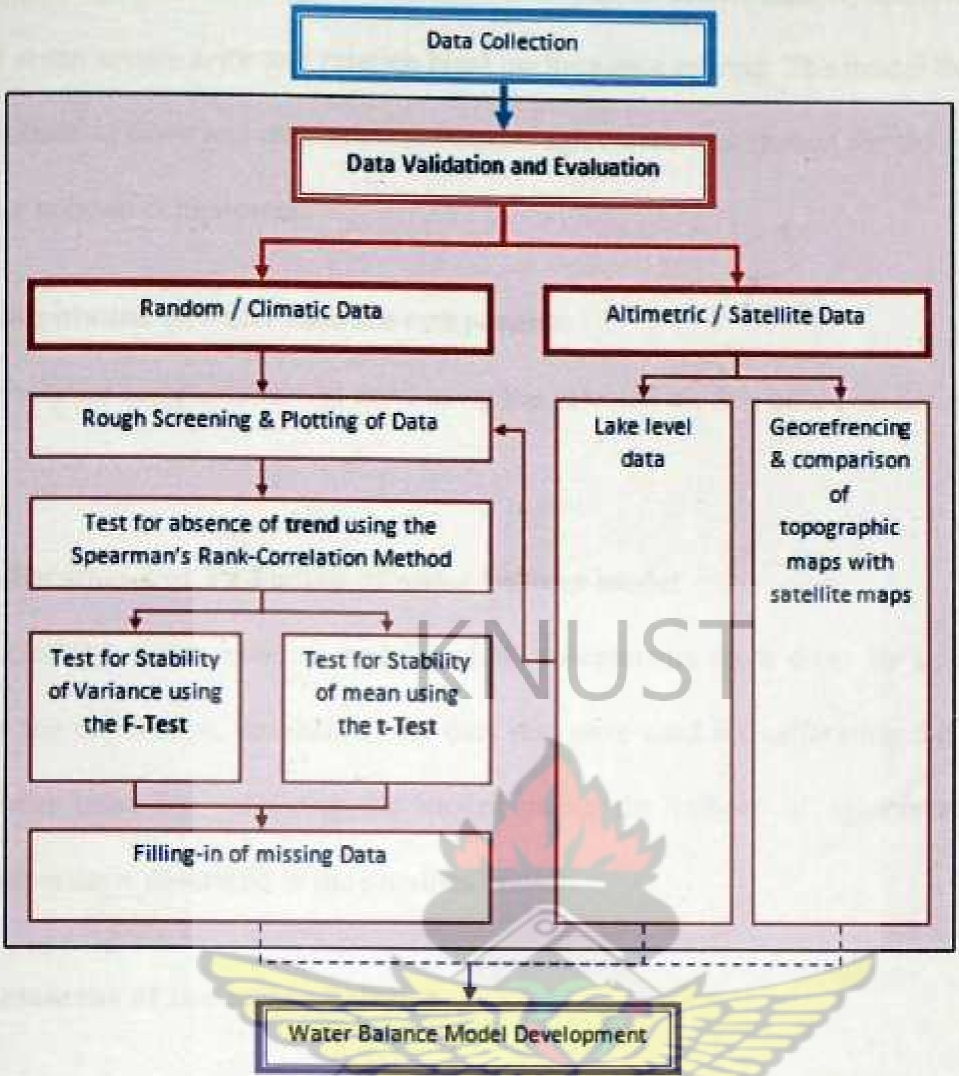


Figure -: Flowchart of data validation and verification process

4.5 Modeling of Lake Bosumtwi Water Balances

Modeling of the water balance of Lake Bosumtwi took place in the following sequence:

4.5.1 Schematization of the water balance model

Lake Bosumtwi hydrological cycle was first schematized to abstract the components of the water balance. This was then used in the design of the water balance model.

4.5.2 Model selections and evaluation

After model design, several conceptual models were selected to estimate the components of the water balance. The selection was primarily from models that have been applied to estimation of similar water balance components. The models were then evaluated using two indices of agreement (index of agreement and coefficient of determination) and two indices of error (root mean square error and relative bias) performance criteria. The model that provided the least indices of error and maximum indices of agreement was chosen for the computation of the water balance components.

4.5.3 Computation of water balance components

The water balance computation was done using the selected models based on the performance criteria.

4.5.4 Calibration and Validation of water balance model

Calibration of the water balance model and its components were done by trial and error method. In the calibration, one-half of the data sets were used for calibrating the model, and the remainder used for validating the model, using the indices of agreement and error performance criteria described in the previous section.

4.6 Assessment of the water balance

The water balance model, after calibration, was used in interpret the available data to provide more insight into the occurrences of the lake.

4.7 Software tools

ArcGIS version 9.2 and Erdas Imagine version 9.1 were used for GIS and satellite image processing respectively. MS Excel, Spell-Stat and Trend were used for statistical data analysis. MS Excel was also used for the development of the spreadsheet water balance model, whiles MS Access was used for the development of the CN lookup database for processing of CN values in ArcGIS.

5 Results and Discussions

5.1 Data Collection

Data used in this project, its format and units, and its dates of acquisition are summarized in the table below.

Table -: Summary \of data sources

Data Collected	Purpose	Format / Units	Acquired Date	Freq.	Source
Landsat	Land classification for Runoff estimation	GeoTiff / UTM	1975, 1990, 2000		USGS, Global Land Cover Facility
STRM	Catchment delineation	USGS DEM / UTM	Feb., 2000		
Lake level records	Change in lake storage	m	1978 - 2000	Monthly	Hydrological Services, Kumasi
Climatological Data (Kumasi, Agogo, Bekwai, Barekese)	Inputs into hydrological models 1. Rainfall	mm	1945 -2007	Monthly	Meteorological Services Department, Kumasi
		mm	1980 -2009	Daily	
	2. Other (RH, Wind speed, ET_o, Tmax, Tmin, Sunshine Hours)		1961 - 2002	Monthly	
			1980 2009	Daily	

5.2 Data Validation

The data used for the project were validated by the following methods discussed below:

5.2.1 Satellite Data

Satellite data were validated by the use of physical land marks on the project site. With the aid of a potable GPS device (Garmin 76), it was realized that visible landmarks on the project site were consistent with satellite data acquired from GLCF. Garmin 76 was used to mark waypoints and also pick tracks on the project site. Garmin 76 has the capability of producing the longitude, latitude and elevation of any location by accessing three or more satellites. The accuracy of Garmin 76 range from few centimeters to several meters, depending on the available satellites at the time of acquisition of the information. The data acquire by Garmin 76 was then overlaid on satellite images of the project site using Google Earth and ArcView GIS. Screen shot of the overlaid map of Garmin 76 data and satellite imagery in Google Earth is shown below.

Figure -: Plot of GPS waypoints on Google Earth version 5.0

5.2.2 Meteorological data validation

Meteorological data were validated statistically and on the field. Statistical validation was done by the use of methods (Time Series analysis, Spearman's rank correlation coefficient, F-Test and T-Tests) as discussed in the literature review section.

5.3 Catchment Delineation

5.3.1 Results

Catchment delineation was carried out using ArcGIS 9.2 software. This was done using STRM DEM downloaded from GLCF at the University of Maryland, USA. Since no automated approach currently exists for the determination of catchment areas of tropically closed lakes, such as Lake Bosumtwi, the following procedure was ensured for the catchment delineation.

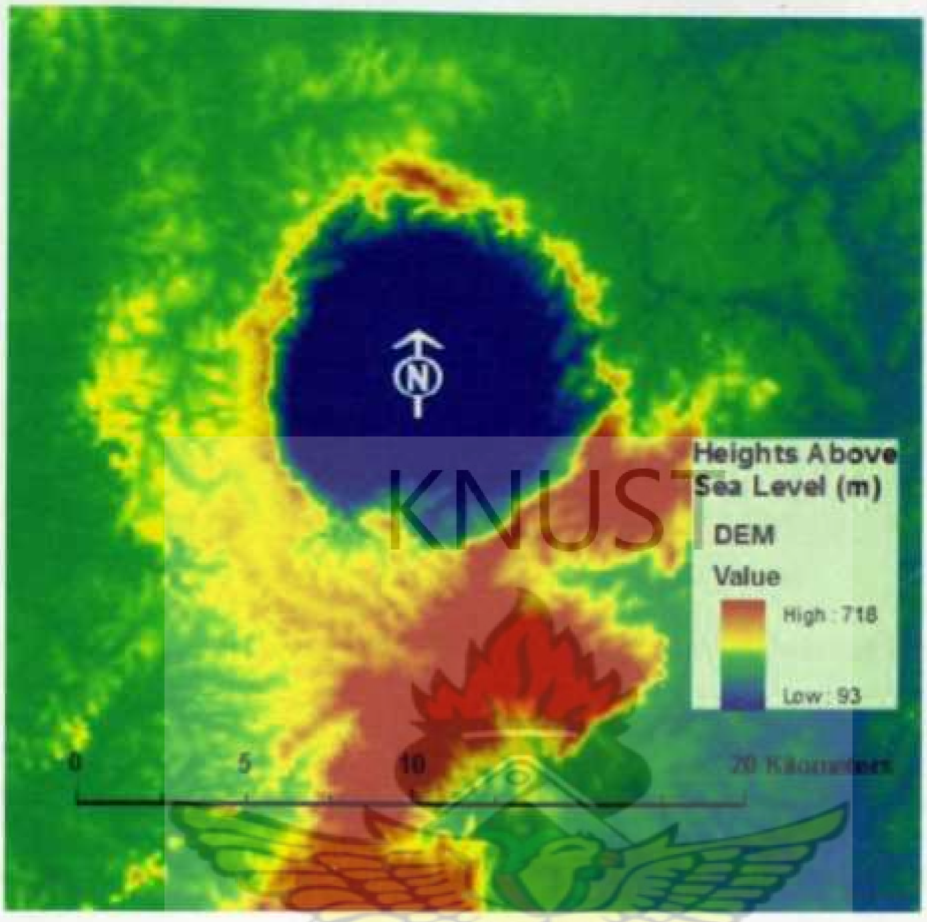


Figure -: Digital elevation model of Lake Bosumtwi

The hill shade of the DEM was first created to give a true picture of the terrain of the area. This was done using the Hillshade tool under the Spatial Analyst extension. Next was the creation of contours at 5m, 10m, 20m and 50m intervals study area, using the Surface/Contour tool under the Spatial Analyst extension. Next, the Aspect of the study area was created and reclassified to provide a proper view of the flow directions on the study area. The contour map generated was then superimposed on the Aspect map, and with the contours as a guide, the boundary of the catchment area was carefully digitized into a new shape file.

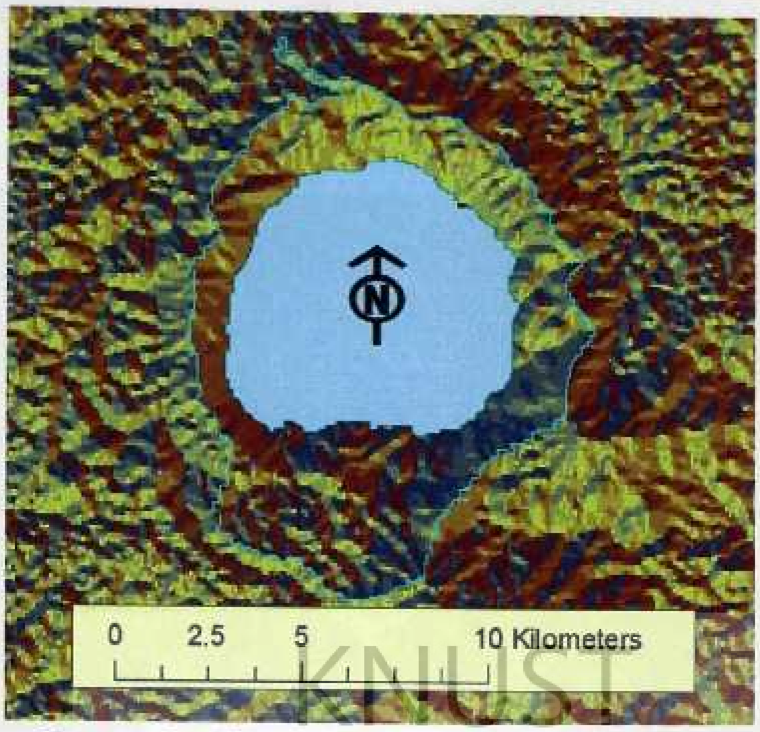


Figure -: Initial catchment delineated of Lake Bosumtwi

The lake area was delineated by converting the raster image of the converting the reclassified aspect map into polygons, and then extracting the lake area into a separate shapefile. Three dimensional models of Lake Bosumtwi were generated (using 3D analyst extension)and the delineated catchment superimposed on it using ArcScene (see figure below and Appendix 3).

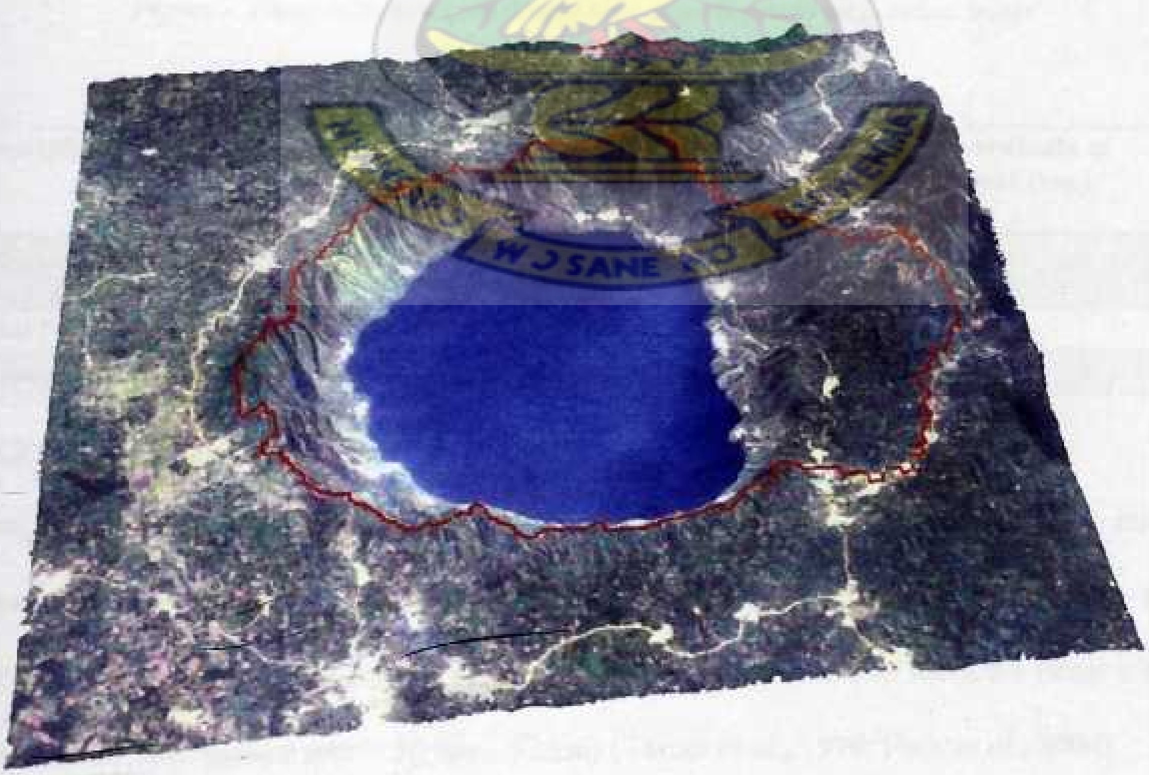


Figure -: Delineated catchment superimposed on 3D model of Lake Bosumtwi

The delineated catchment was then modified to reflect the actual catchment area of the lake. The results of the catchment delineation are given below.

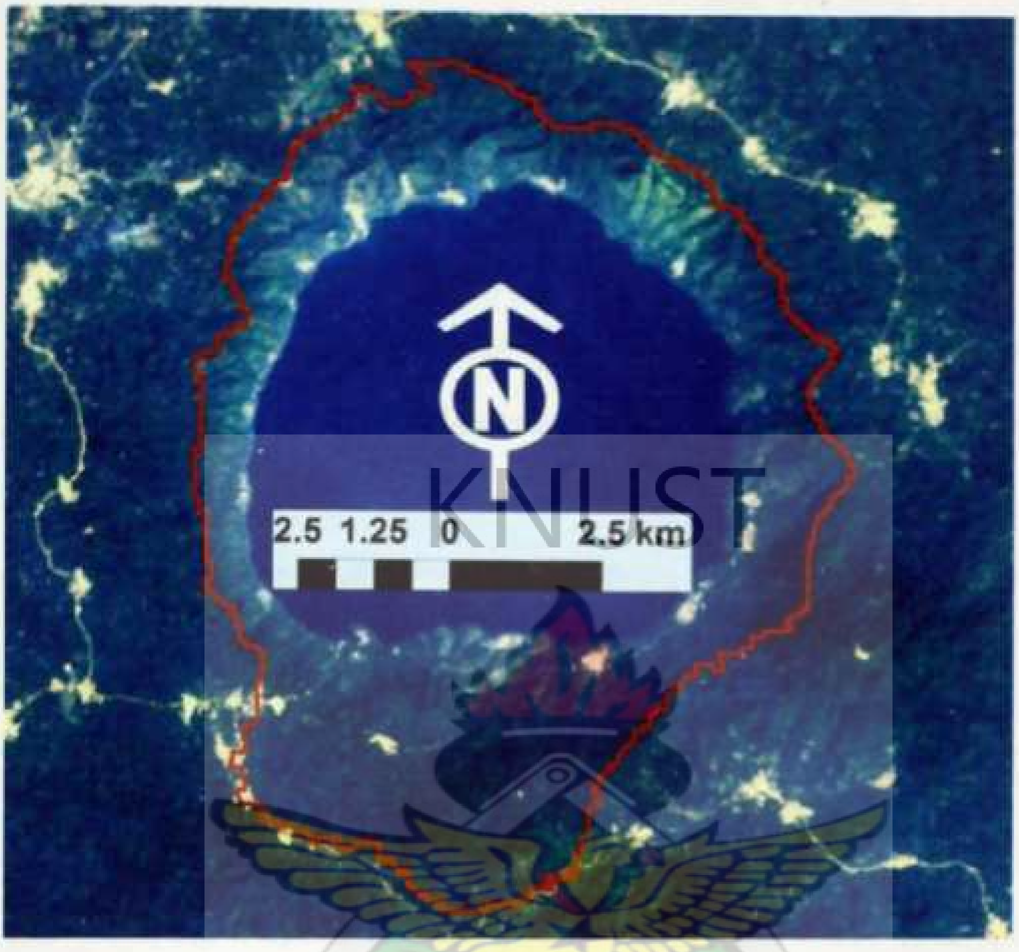


Figure -: Final delineated catchment area superimposed on Landsat image

Table -: Catchment area of Lake Bosumtwi

Description	Area (km2)	Perimeter (km)	X Coordinate of Centroid (km)	Y Coordinate of Centroid (km)
Total Catchment Area (including Lake)	103.79019	59.71579	675.85214	718.48013
Total Lake Surface Area	45.84288	29.57527	675.76488	719.1469
Actual Catchment Area	57.94731	89.29106		

5.3.2 Deductions

Thus it can be deduced from the catchment areas that the total lake area surface covers approximately 44% of the total catchment area as detailed in the table below. The total catchment area and the lake surface area is thus less than that cited in literature (total area = 106 km^2 and lake surface area = 50 km – 52 km) (Turner *et al.*, 1996; Peck *et al.*, 2004).

Table -: Comparison of catchment area and lake surface area of Lake Bosumtwi

Description	Area	Perimeter
Total Catchment Area (including Lake)	100%	100%
Total Lake Surface Area	44.169%	49.527%
Actual Catchment Area	55.831%	149.527%

Using the Pythagoras theorem, it can be said that the centroid of Lake Bosumtwi lays 1.44 radians to the North West of the centroid of the total catchment area, and is at a distance of 0.672 km. Since the distance between the centroids of the total catchment area and the lake surface is less than 1 km, then direct runoff response due to precipitation over the entire catchment is uniform and enters the lake with the same approximately lag time. This can be justified on the assumption that the total catchment area and the lake surface area are circular in nature, and the same soil and land cover conditions exists over the entire catchment area.

5.4 Modeling of Lake Bosumtwi Water Balances

5.4.1 Modeling Approach

A semi-distributed modeling approach was adopted in this study. This was to allow for accounting of all spatio-temporal variables without increasing the complexity of neither model nor over-generalization of the water balance model of the Lake. In this semi-distributed model, rainfall is assumed to be of the same intensity over the entire catchment. All meteorological variables, such as air temperature, relative humidity and the radiation fluxes (R_a, R_s, and R_n), are also assumed to be even over the entire catchment. Land use and soil characteristics are however considered as distributed in this project.

5.4.2 Model formulation

In this study, the mass balance/volumetric approach was chosen for formulation of the water balance of Lake Bosumtwi. The water balance computations were made using Microsoft Excel spreadsheet models.

a) The minimum elevation in water table in the plain surrounding the lake is 200 masl (Gill, 1969) which is several hundred meters above the current lake levels, suggesting that the regional aquifer and the lake are hydrologically disconnected (a long term connection would have the lake levels the same as the regional water table levels) and also makes it impossible for water to seep out of the lake;

b) Groundwater seepage from the regional aquifer is also inhibited by the raised crater rim of the lake which induces a groundwater divide that inhibits subsurface flow from beyond the topographic divide (Turner *et al.*, 1996);

c) The lake lies in animpact consolidated bedrock which would require outflow to occur within a sluggish fracture flow, however, 20m – 1000m thick of mud underlies the bottom of the lake (Turner *et al.*, 1996), hydraulically isolating the lake from any fractures in the bedrock.

Since no data exists currently for the quantification of the subsurface runoff contributions to the lake, it is assumed the G_c component is negligible because the steepness of the catchment reduces infiltration and storage on the catchment. The time of concentration of subsurface runoff is reduced due to the steepness of the catchment and very short runoff length, thus G_c has a negligible long term effect on the lake.

5.4.4 Simplified water balance model of Lake Bosumtwi

Thus, the simplified water balance model becomes:

$$\Delta V = P + R - E \qquad (5\text{-}2)$$

5.5 Estimation of Water Balance Components

5.5.1 Rainfall

5.5.1.1 Location of synoptic weather stations

Since no metrological data exists for Lake Bosumtwi, data for nearby towns (Kumasi, Agogo, Bekwai, and Barekese) was used as approximate for this study. Locations of the towns are shown in the figure below.

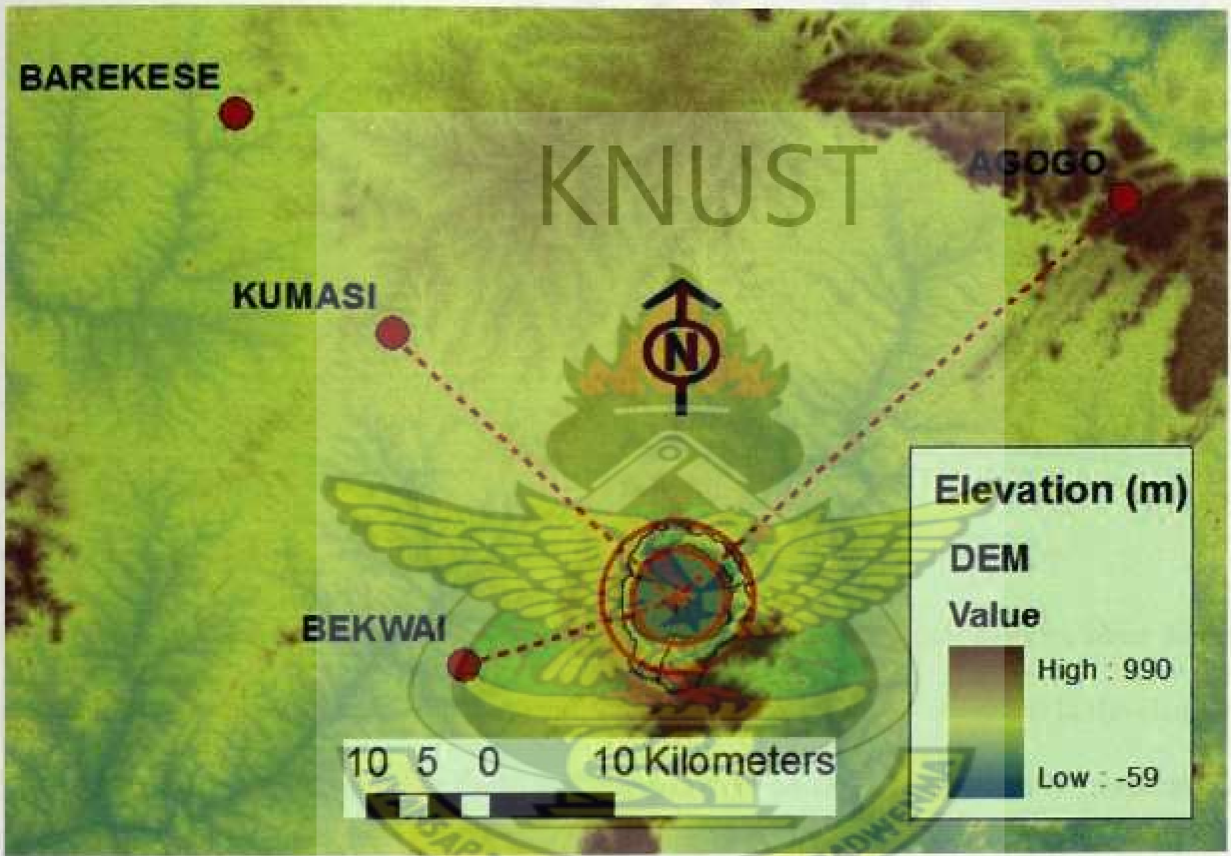


Figure -: Location of synoptic weather stations

5.5.1.2 Estimation of Lake Bosumtwi's Areal Rainfall

Since punctuated rainfall records existed for Bekwai, Agogo and Barekese, and it has been also documented that Lake Bosumtwi's Lake level records correlated with regional rainfall pattern - rainfall records of Kumasi (Turner *et al.*, 1996), rainfall records of Kumasi were used for this study. Rainfall data for Bekwai, Agogo, and Barekese was only used for comparison. Data also collected at Abono during the study period (September, 2009 –

November, 2009) was also used for comparison purposes only. The figure below shows average monthly variation of the rainfall for Kumasi.

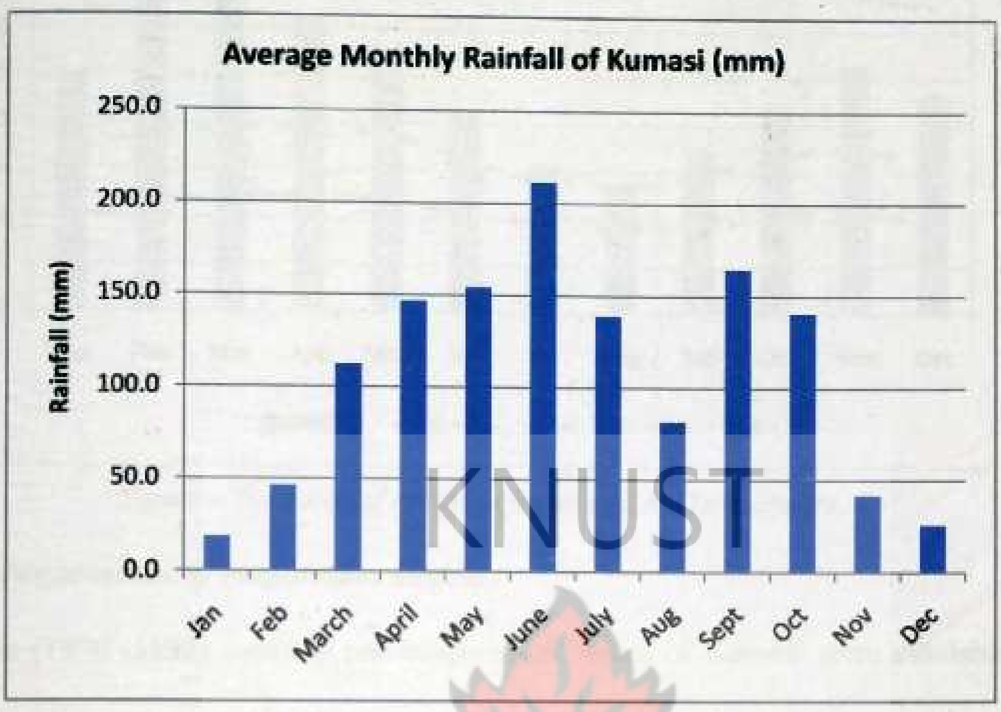


Figure -: Average monthly rainfall of Kumasi in mm (1977 -2002)

5.5.2 Evaporation

5.5.2.1 Model selection

Estimation of evaporation was done by the use of conceptual evaporation models, since direct evaporation measurements were not available. All evaporation models reviewed in the chapter 3.6 were evaluated on a monthly basis and compared to an eight year monthly evaporation values of Kumasi. Since most of the evaporation models depend on radiation fluxes, radiation fluxes were estimated as discussed in the following section.

5.5.2.2 Radiation calculations

Most of the evaporation models reviewed in this project require the knowledge of the shortwave or solar radiation, extraterrestrial radiation and net radiation fluxes. Since these were not available, the radiation fluxes were estimated by methods discussed in the literature review (section 3.7.1.1 - 3.7.1.3). Summary of average monthly variation of the radiation fluxes estimates are shown in figure 5-9.

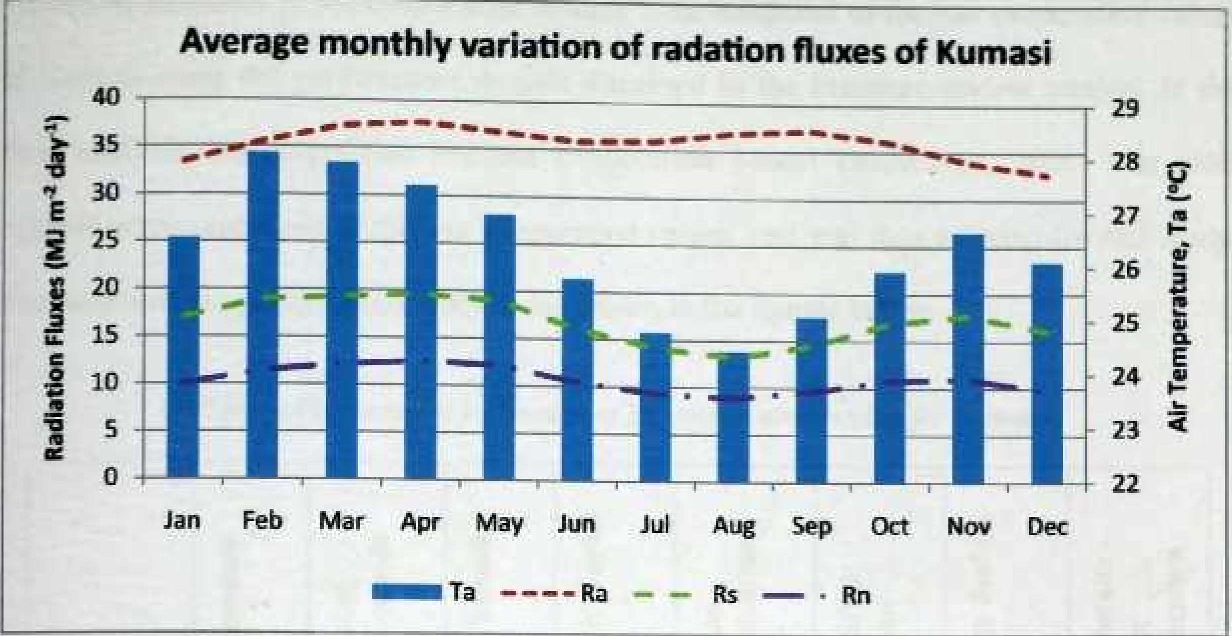


Figure -: Variation of radiation fluxes and Air Temperature, Ta

5.5.2.3 Performance of evaporation models

Eight year (1990 -1998) monthly pan evaporation values of Kumasi were available for this study. The evaporation models that were evaluated in this project include: a) Energy budget evaporation model (equation 3-18); b) Priestly-Taylor evaporation model (equation 3-40); c) Penman Combination evaporation model (equation 3-42); d) Simplified penman combination evaporation model (equation 3-44); e) Thornwaite-Matter evaporation model (equation 3-45); and f) Mass Transfer evaporation model (equation 3-47).

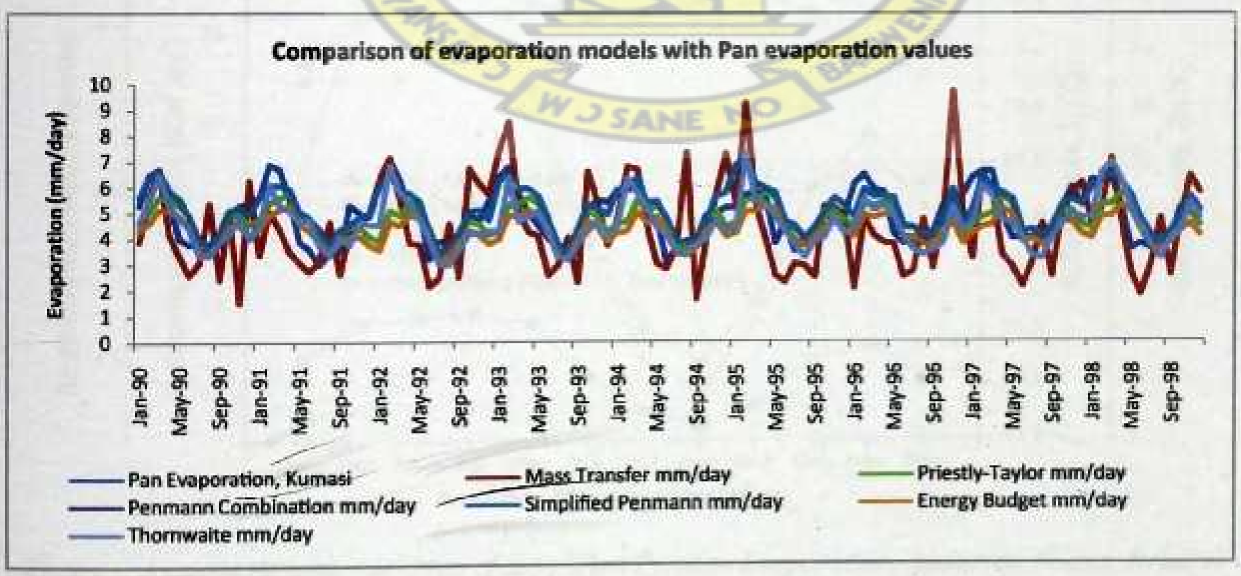


Figure -: Comparison of evaporation models with Pan Evaporation

Results of estimates of the evaporation models were compared to the pan evaporation values of Kumasi using the performance models discussed in the literature review section. In the final analysis, the Simplified Penman Evaporation Model (Valiantzas, 2006) was most suitable when compared to the pan evaporation values, and was thus selected for this study. The results of the performance analysis are shown in the figures below.

Table -: Performance evaluation of six evaporation models for Kumasi

	Performance	Expected Performance Value	Mass Transfer	Priestly-Taylor	Penman Combination	Simplified Penman	Energy Budget	Thornwaite - Matter Evaporation
Error Indices	*RMSE*	*0.000*	*5.054*	*1.942*	*6.023*	*2.662*	*6.023*	*3.567*
	RB	*0.000*	*0.486*	*0.187*	*0.580*	*-0.256*	*0.580*	*0.343*
Agreement Indices	*D*	*1.000*	*0.707*	*0.651*	*0.602*	*0.847*	*0.602*	*0.818*
	R^2	*1.000*	*0.368*	*0.243*	*0.243*	*0.579*	*0.243*	*0.513*

Average monthly evaporation estimates for Lake Bosumtwi, using the Simplified Penman Evaporation is shown in the figure given below. Detailed results are shown in Appendix4 and Appendix 5.

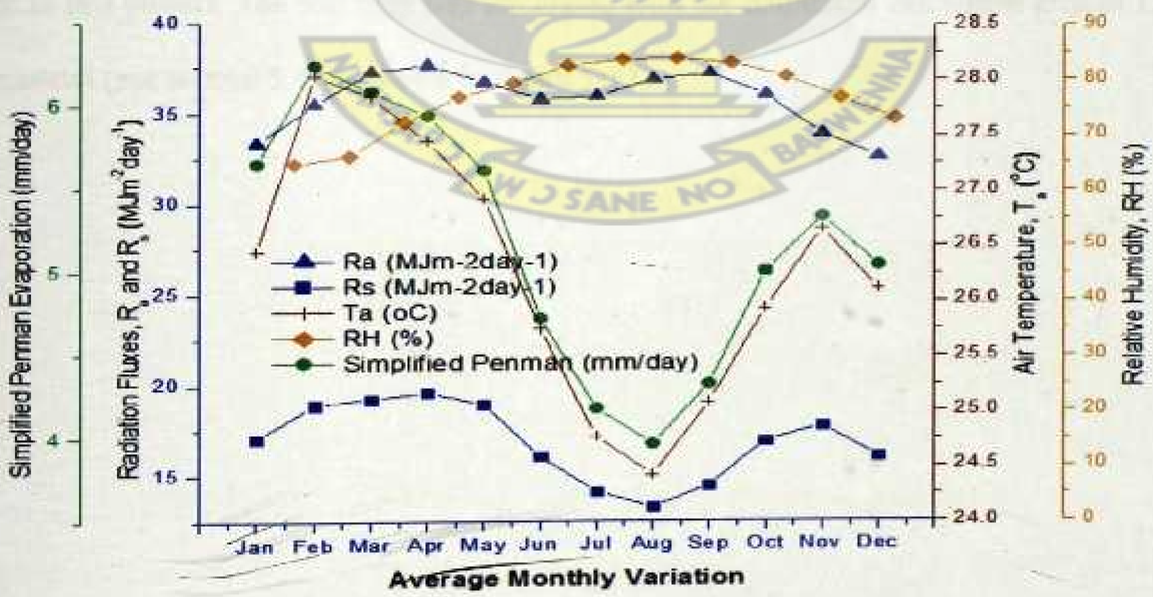


Figure -: Average monthly variation of Simplified Penman Evaporation, Radiation Fluxes, Relative Humidity (RH) and Air Temperature (Ta)

5.5.3 Surface Runoff

5.5.3.1 Modeling of Lake Bosumtwi's Catchment Runoff

No available gauged measurements exist for Lake Bosumtwi as the time of this study. Thus Lake Bosumtwi's catchment was considered as an ungagged catchment. Runoff from the catchment was estimated using conceptual rainfall runoff models discussed in the literature review section.

5.5.3.2 Selection of Rainfall-Runoff Model

The SCS-CN method (equation 3-10) was chosen as the most suitable method for runoff estimation given data availability. A particular advantage is that land cover changes as a result of anthropogenic activities and climate change are accounted for in this method. The SCS-CN method for runoff estimation is discussed in-depth in the literature review section.SCS-CN method of computing runoff depends on soil the soil characteristics and land cover classification.

5.5.3.3 Soil Reclassification

Digitized soil map (shapefile) of Ghana, produced by the Soil Research Institute of CSIR was used in this project. The soil map was integrated with the delineated catchment area of Lake Bosumtwi (see section 5.4) as shown in figure 5-12.

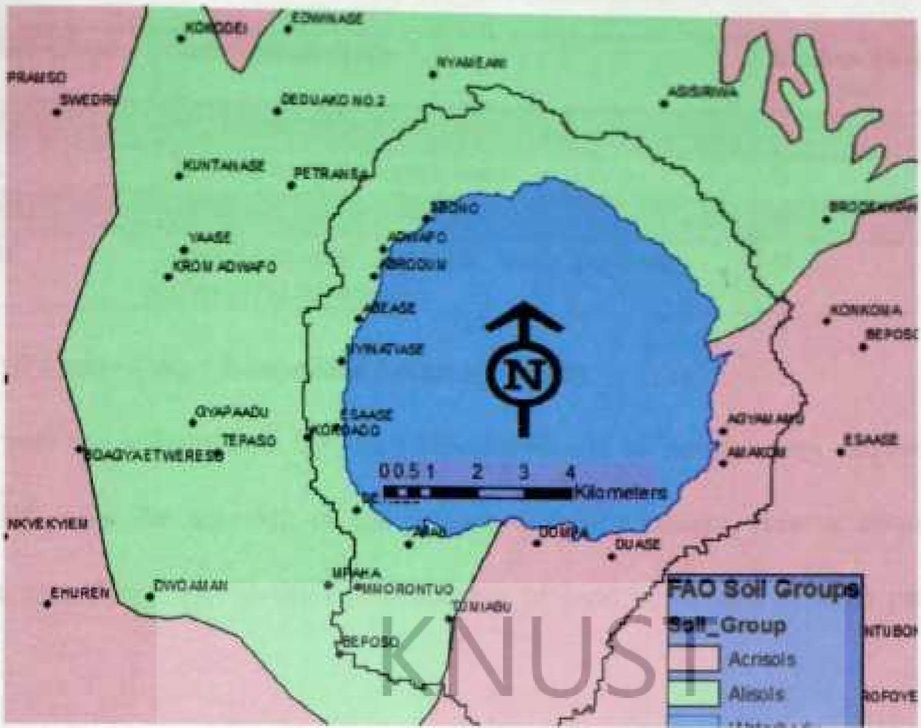


Figure -: Integrated soil map showing soil groups, towns and Lake Bosumtwi's catchment

The map was then reclassified based on its composition as given by the FAO soil group classification and the soil classification triangle. The conversion of the soil classification triangle into HSG based on the four major soils found in Ghana is shown in the figure below:

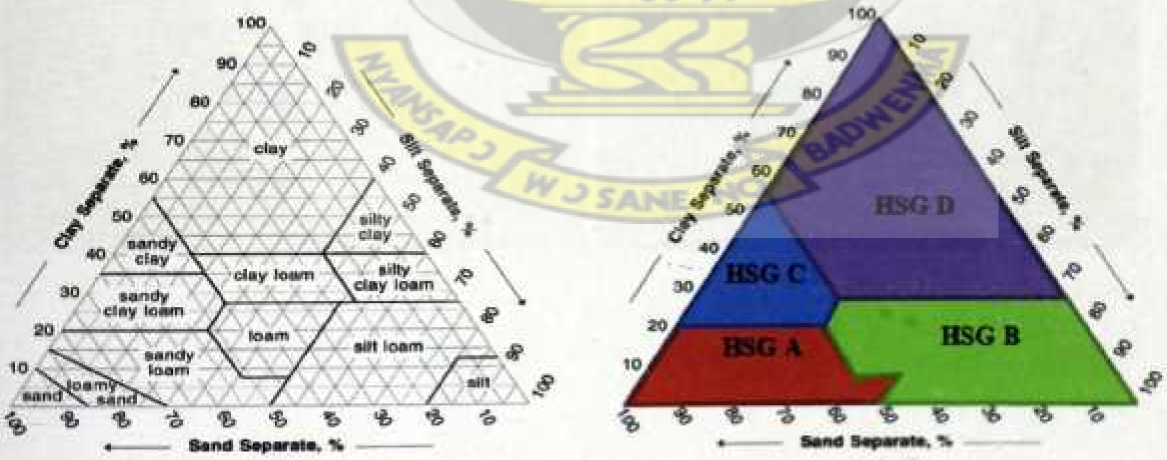


Figure -: Soil classification triangle and HSG reclassification diagram

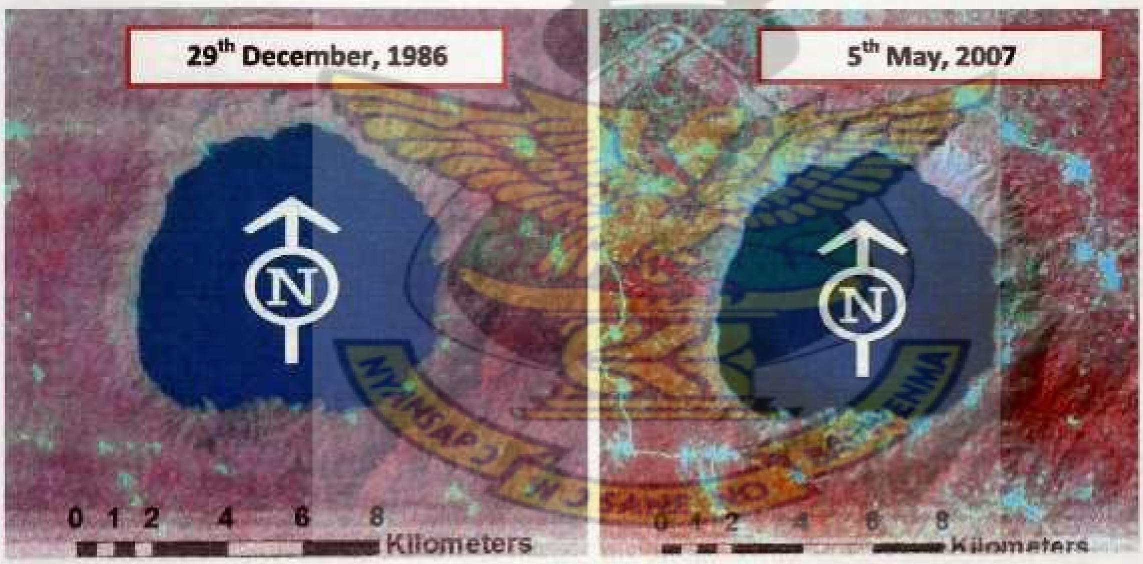
The soil reclassification of the major soils in Ghana into the SCS-CN Hydrologic Soil Group (HSG) is given in the table below.

Table -: Soil reclassification table

FAO Soil Class	Soil Composition	Reclassified SCS-CN HSG
Acrisols	sand, loamy sand and sandy loam types of soils	A
Alisols	silt, silt loam and loam soils	B
Leptosols	sandy clay loam soils	C
Lixisols	clay loam, silty clay loam, sandy clay, silty clay and clay soils	D

5.5.3.4 Land Cover Use, Change and Reclassification

Land cover and use information for Lake Bosumtwi and its surrounding catchment was not readily available for the duration of the project. Satellite images, remote sensing and GIS technologies was thus used in the determination of land cover and change pattern for the catchment.



The Landsat images were converted from Tiff (*.tiff) and GeoTiff format (*.tiff) to Imagine (*.img) format using Import/Export panel in Erdas Imagine 9.1. This was to allow for file compatibility in Erdas Imagine software. The images were stacked in Imagine and the AOI (area of interest) was selected using select tools under AOI. Using the Subset tool (*Interpreter → Utilities → Subset*) a subset image of the catchment area was created and used for further image processing.

Using the Unsupervised Classification tool under the Classifier panel, the subsetted images were classified into thirty classes using Landsat band combinations (5, 4, 2 – approximate true colour composite) and thirty iterations (see figure 5-15). The thirty classes for each subsetted image were then recoded into seven land cover classes using the Raster Attribute Editor tool by visually comparing the classified images to the original subsetted images with different band combinations. The seven land cover classes are given in table 5-6.

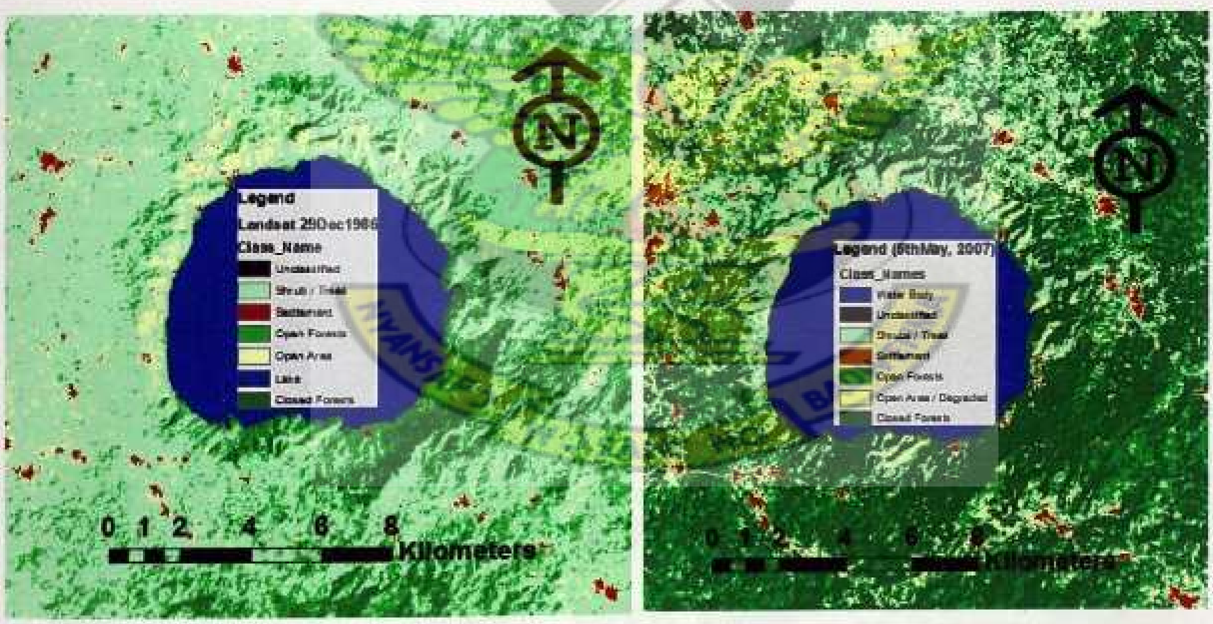


Figure -: Unsupervised classification of Landsat image 29th December, 1986 and 5th May, 2007 (p194r055)

Table -: Recoded classification class names

ID	Recoded Class	Recoded Class Name	Description
0	Class 1	No Data / Cloud Cover / Unclassified	Unclassified land cover either due to no information or cloud / shadow cover
1	Class 2	Settlements/Urban Area	Dense Settlements / Urban area
2	Class 3	Open Area	Light Settlement / Grassland / Farmlands / Roads / Pathways
3	Class 4	Shrubs/Trees/Farmland	Land cover is basically grassland with shrubs and few trees or farmlands
4	Class 5	Open Forests	Forests with widely spaced trees and grass land (50%-75% tree cover)
5	Class 6	Closed Forests	Forests with moderate to closely spaced trees (>75% tree cover)
6	Class 7	Water body / Lake	Lake Bosumtwi

5.5.3.5 SCS-CN Values of Lake Bosumtwi's Catchment

A procedure for the determination of CN values of the catchment area was developed using ArcGIS and MS Access. The database,with three lookup tables (Soil_Group, LandCover and CN_Lookup) was in MSAccess ® 2000 file format (*.mdb), was used to extend the land cover and soil classification shapefiles to incorporate HSG and CN values into their attribute tables. Details of this procedure are given in Appendix 6.The final CN values for Lake Bosumtwi's catchment are shown in figure 5-16 below.

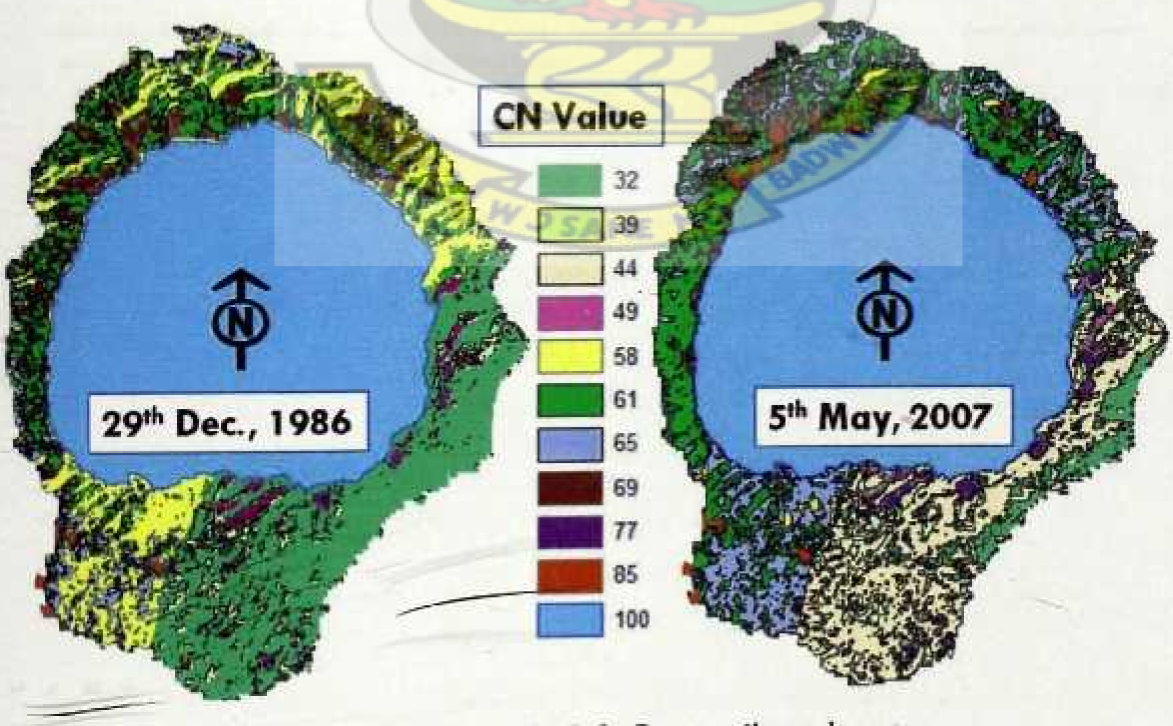
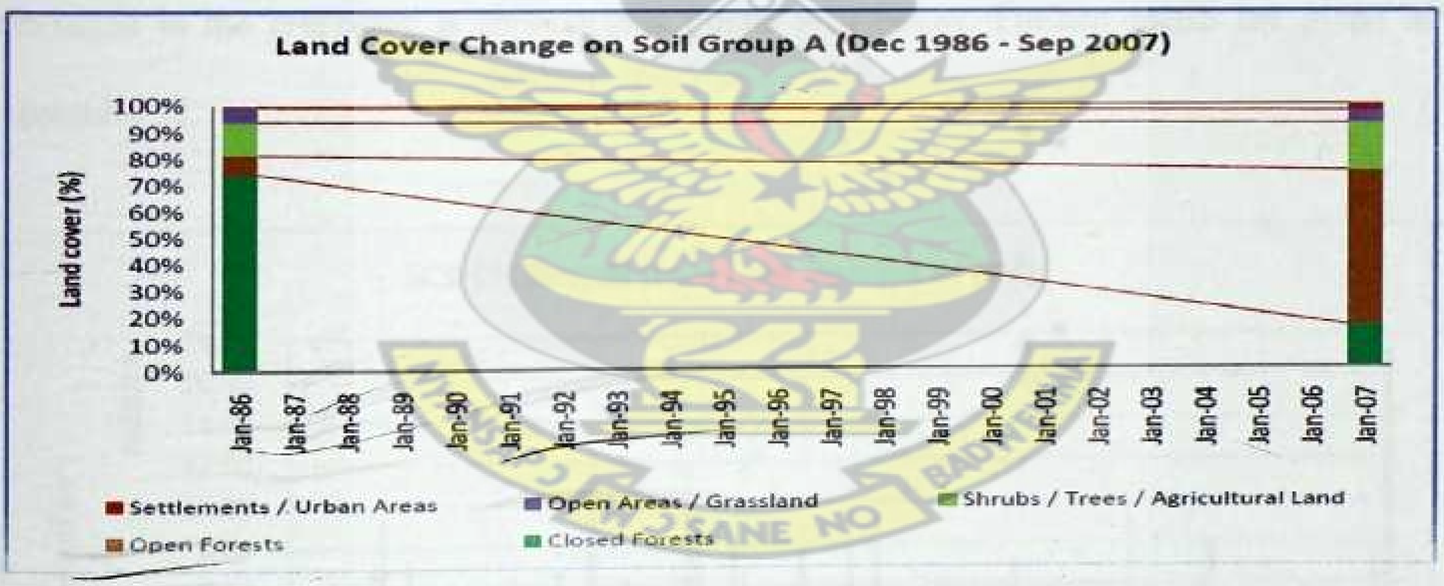


Figure -: CN Values for Lake Bosumtwi's catchment

Since only few satellite images were available for this project, land use change was assumed to be linear. Land use was thus linearly interpolated and used for the estimation of CN values for the unknown periods. The resultant interpolation show a gradual increase in settlement, a sharp decrease in closed forests and an increase in open forests for the catchment of Lake Bosumtwi. It was realized that interpolating land use and CN values gave similar results. CN values were weighted for Soils Group A (*acrisols*) and B (*alisols*) respectively (using the weighted CN formula discussed in the literature review section). The interpolation of land cover changes is shown in figure 5-17 below.It was realized that interpolating land cover gave the same results as interpolating CN values. Details of the interpolation of land cover and CN values are also given in Appendix 7 and 8.



5.5.3.6 Antecedent Soil Moisture Condition of Lake Bosumtwi

The CN value (CN_2) is based on average soil moisture condition (AMC II) and was adjusted based on a 5-day prior rainfall depth. The 5-day prior rainfall depth was determined from monthly rainfall records on the assumption that equal rainfall events occurred on each day in the prior month. Dormant season was assumed for the whole catchment since detailed farming information was not available and most of the catchment was made up of forests. The CN values were adjusted accordingly for dry conditions (AMC I), and wet conditions (AMC III) using equations 3-14a and 3-14b.

5.5.3.7 Surface Runoff into Lake Bosumtwi

Runoff computed by the SCS-CN method (equation 3-11), with estimated CN values discussed in the preceding is summarized figure 5-18 below. Further details are given in Appendix 11.

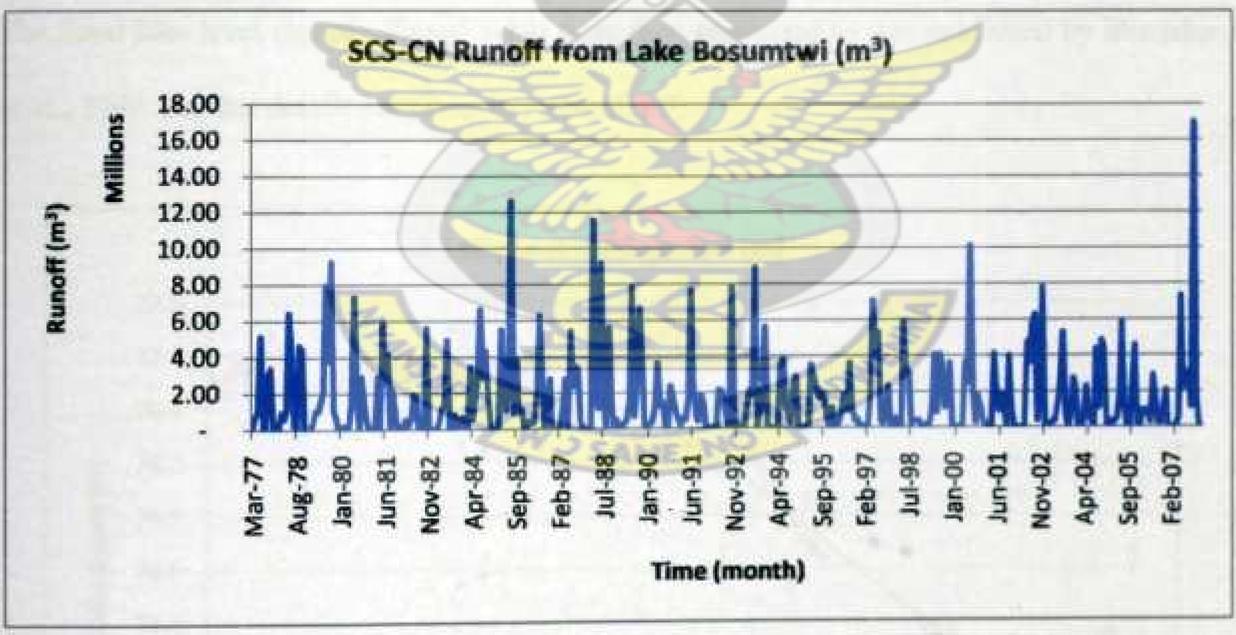


Figure -: Monthly runoff estimates for Lake Bosumtwi (Mar-77 to Dec-2007) using SCS-CN method

5.6 Fixing of Datum of Lake Level Records

Lake level records taken from AESC, Kumasi were punctuated (incomplete) and without datum. Missing lake level records were estimated by correlating adjacent monthly lake level records. Datum for the lake level records was fixed by comparing it with published lake level records of Shanahan *et al*., 2007.Changes in the lake level (reported by Shanahan *et al*., 2007) were cumulated and compared to lake level records of Lake Bosumtwi taken from AESC (as shown in table 5-7 below). Datum of the lake levelswasfound by taking the difference between *L* and *L'* of August, 1984 as shown in table 5-7.

Table -: Fixing of datum for Lake Bosumtwi lake level records

Year	*ΔL* (Shanahan et. Al, 2007)	*L* (m)	*L'* (Lake Level by AESC)
1938	-	72.25 m	-
Jul, 1952	+2.56 m	74.81 m	-
May, 1961	+1.07 m	75.88 m	-
Jul, 1977	+0.96 m	76.84 m	-
Aug, 1984	-0.59 m	76.25 m	1.062 m
Datum (with respect to bottom of Lake)			75.188 m
Datum (with respect to m asl, Lake bottom =21.2m, Turner *et al*., 1996)			96.388 m

The fixed lake level records (figure 5-19) were then compared to that published by Shanahan *et al*., 2007. Further details are given in Appendix 9.

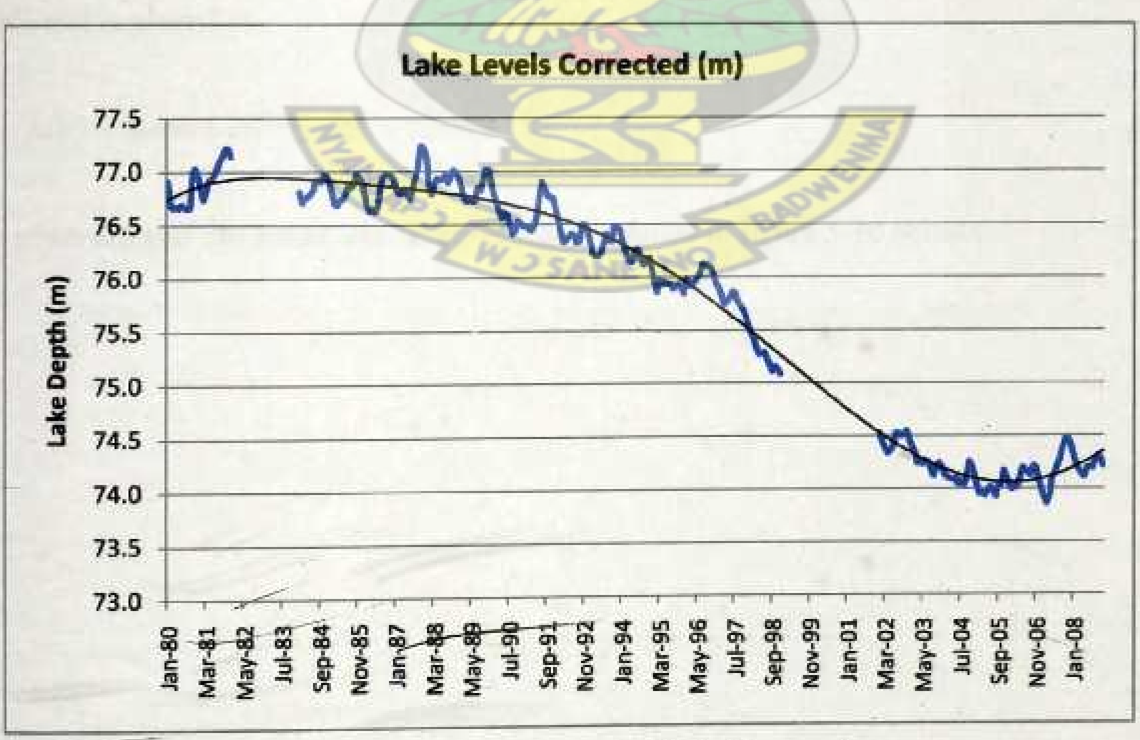


Figure -: Lake level records of Lake Bosumtwi

5.7 Water Balance Model of Lake Bosumtwi

With the water balance components (P, E, and R) estimated, the water balance model of Lake Bosumtwi (ΔV) can also be determined as $\Delta V = P + R - E$. Determination of simulated cumulative lake storage was done by the use of the *Level Pool Routing equation*. The *Level Pool Reservoir Routing equation* is given by:

$$\frac{1}{2}(I_i + I_{i+1})\Delta t + \left(S_i - \frac{1}{2}O_i\Delta t\right) = \left(S_{i+1} + \frac{1}{2}O_{i+1}\Delta t\right) \tag{5-3}$$

Where $I=P+R$is the input to the model $O = E$ is the output of the model and $S = V$is the lake storage. The modified level pool routing equation for Lake Bosumtwi is given by:

$$\left(\frac{1}{2}(P_i + R_i) + \frac{1}{2}(P_{i+1} + R_{i+1})\right)\Delta t + \left(V_i - \frac{1}{2}E_i\Delta t\right) = \left(V_{i+1} + \frac{1}{2}E_{i+1}\Delta t\right) \tag{5-4}$$

Thus, for a monthly time-step ($\Delta t = 1$) the routing equation becomes:

$$\left(\frac{1}{2}(P_i + P_{i+1}) + \frac{1}{2}(R_i + R_{i+1})\right) + \left(V_i - \frac{1}{2}E_i\right) = \left(V_{i+1} + \frac{1}{2}E_{i+1}\right) \tag{5-5}$$

Lake Storage-Lake Level relationship was developed from bathymetric data (Turner *et al.*, 1996) and is given by:

$$h(V) = 0.0005\,V^{0.561}, \quad R^2 = 0.9998 \tag{5-6}$$

The observed and simulated lake level records areshown in figure 5-20 below:

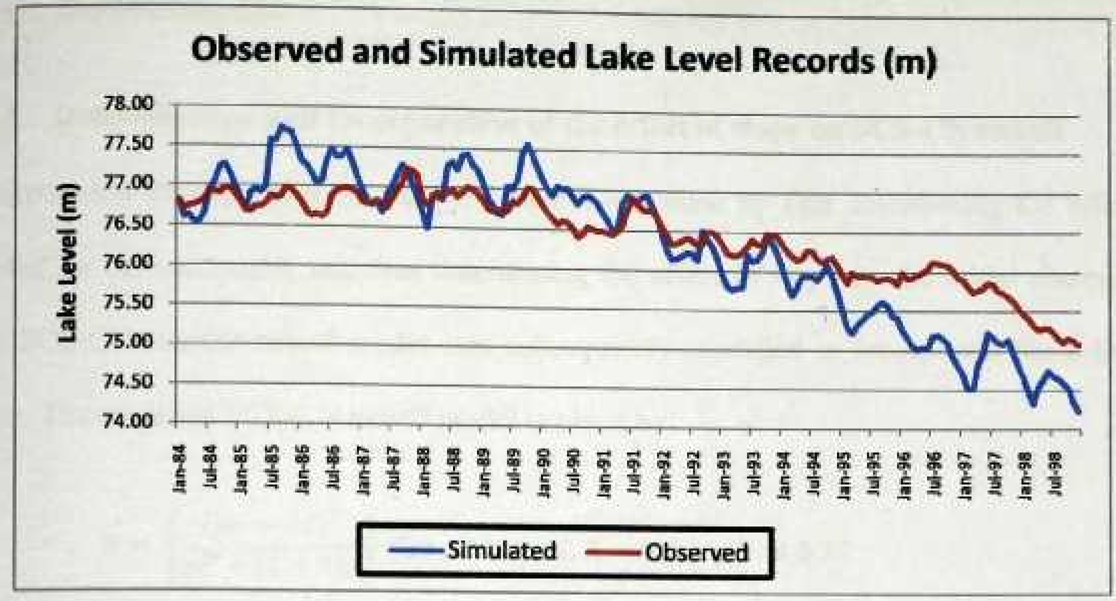


Figure -: Simulated and observed lake level records

Details of performance of the water balance of Lake Bosumtwi without calibration are given below in table 5-8:

Table -: Performance of Water Balance Model of Lake Bosumtwi

Performance Indices		Expected Values	Volume (m^3)	Levels (m)
Error Indices	*RMSE*	*0.00*	*57,142,820.65*	*2.097*
	PRMSE	*0.00%*	*2.70%*	*2.74%*
	RB(τ)	*0.00*	*4,259,174.38*	*0.12*
	PRB	*0.00%*	0.20%	0.16%
Agreement Indices	*D*	*1.000*	*0.90*	*0.878*
	R^2	*1.000*	*0.90*	*0.896*

5.8 Water Balance Model Calibration, Validation and Evaluation

Calibration and validation of the water balance model was done by splitting the available and continuous lake level records (Jan, 1984 – Dec, 1998) into two datasets for calibration (Jan, 1984 – Dec, 1989) and validation (Jan, 1990 – Dec, 1998). In general, the following steps were ensued for successful model improvement:

a. Incorporation of the effect of slope on SCS-CN runoff, R,

b. Error minimization (removal of systematic errors), and

c. Model evaluation.

5.8.1 Determination and Incorporation of the effect of slope on SCS-CN runoff

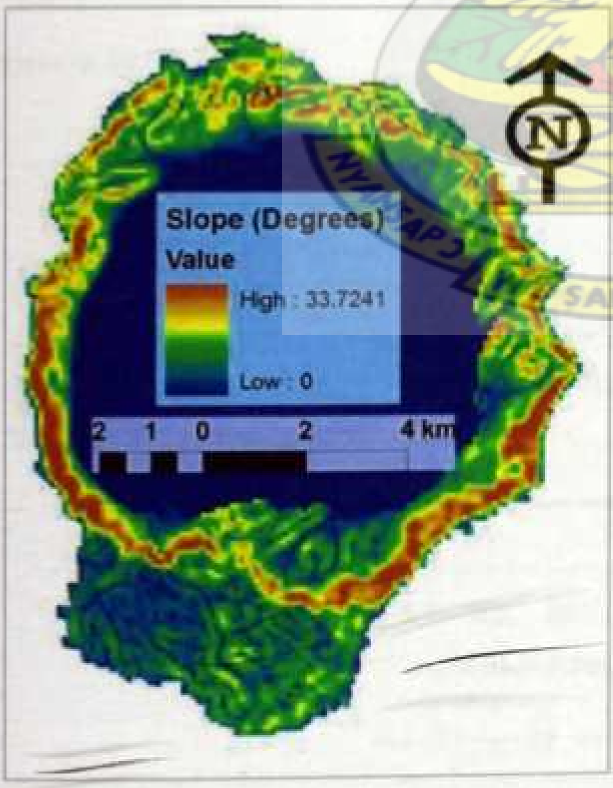
Incorporation of slope into the SCS-CN runoff was done by first determining the effective rainfall on the catchment, and then determining the effect of slope on the initial abstraction. The SCS-CN rainfall-runoff model was subsequently modified to incorporate the effect of slope. The modified SCS-CN runoff model is given by:

$$R = \left\{\frac{(\mu P - \lambda S)^2}{\mu P + (1-\lambda)S}\right\} for\ \mu P > 0.2S, R = 0\ for\ \mu P \le 0.2S \quad (5\text{-}7)$$

Where μ is the rainfall correction coefficient, λ is the initial abstraction ratio.

5.8.1.1 Determination of slope and rainfall correction coefficient (μ)

Determination of the slope of Lake Bosumtwi was done using the Slope Tool in ArcGIS spatial analyst extension. The average slope was determined using the statistics tool. Details of the slopes of Lake Bosumtwi are given in figure 5-21below:



Slope Raster Statistics:

Minimum = 0.0°

Maximum = 33.72°

Mean = 11.806°

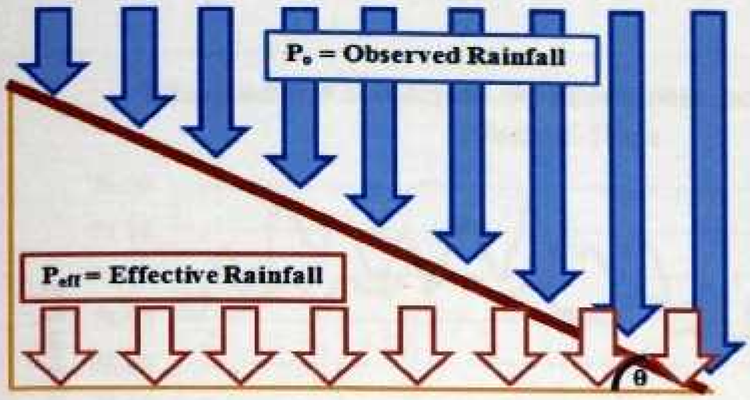
Standard deviation = 6.6942°

Columns and Rows = 117, 151

Cos (11.806°) = 0.9788459686

Figure -: Slope of Lake Bosumtwi

The rainfall correction coefficient was determined using the following relation between observed rainfall (P_o) and effective rainfall (P_e) (see figure 5-22 below):



$$\cos\theta = \frac{P_e}{P_o}$$

$$\Rightarrow P_e = \cos\theta \times P_o$$

$$\therefore P_e = \mu P_o$$

Where $\mu = \cos\theta = 0.979$

Figure -: Determination of rainfall correction coefficient

5.8.1.2 Determination of initial abstraction ratio, λ

The initial abstraction ratio, λ, for the lake was varied from 0.0 to 1.1 and the resultant runoff and its effect on the overall performance of the water balance of the lake were determined. It was observed that optimal values for λ ranged from 0.09 to 0.14. The value of 0.12 was chosen for λ since it gave the minimum RMSE whiles maintaining high values for D and R^2. Summary of the results for λ is given in the figure below. Detailed results are given in Appendix 10.

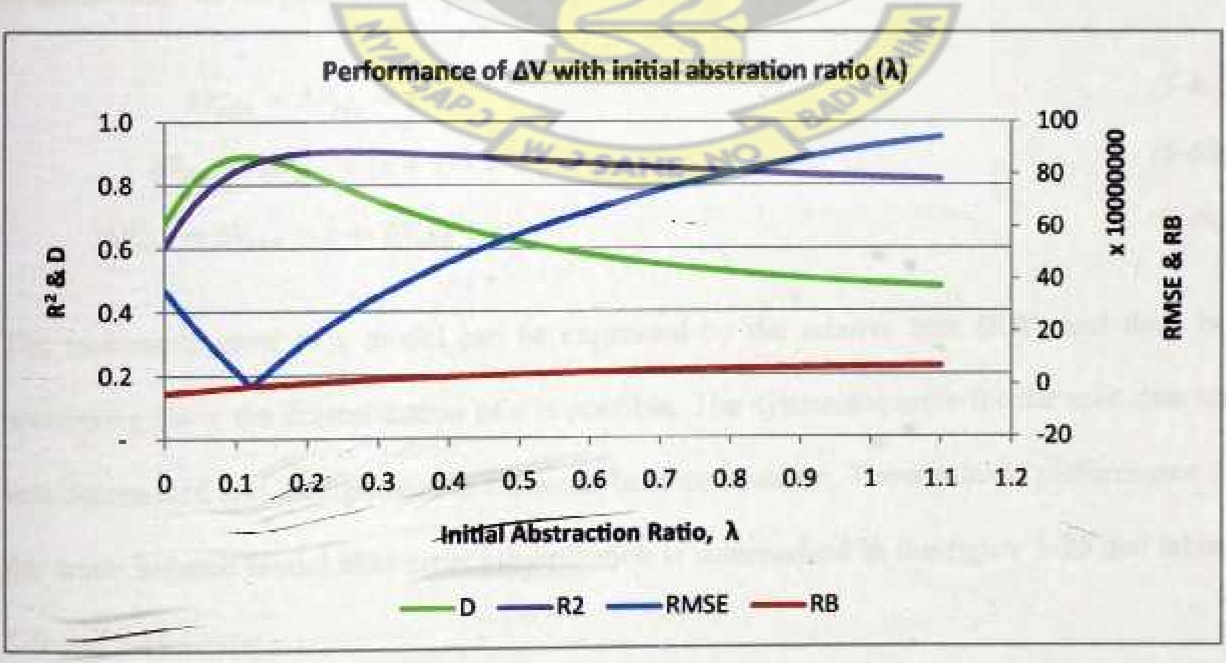


Figure -: Performance of initial abstraction ratio

The incorporation of slope in the SCS-CN runoff slightly improved the water balance model. The performance of the water balance model after incorporation of slope is summarized in the figure 5-24below.

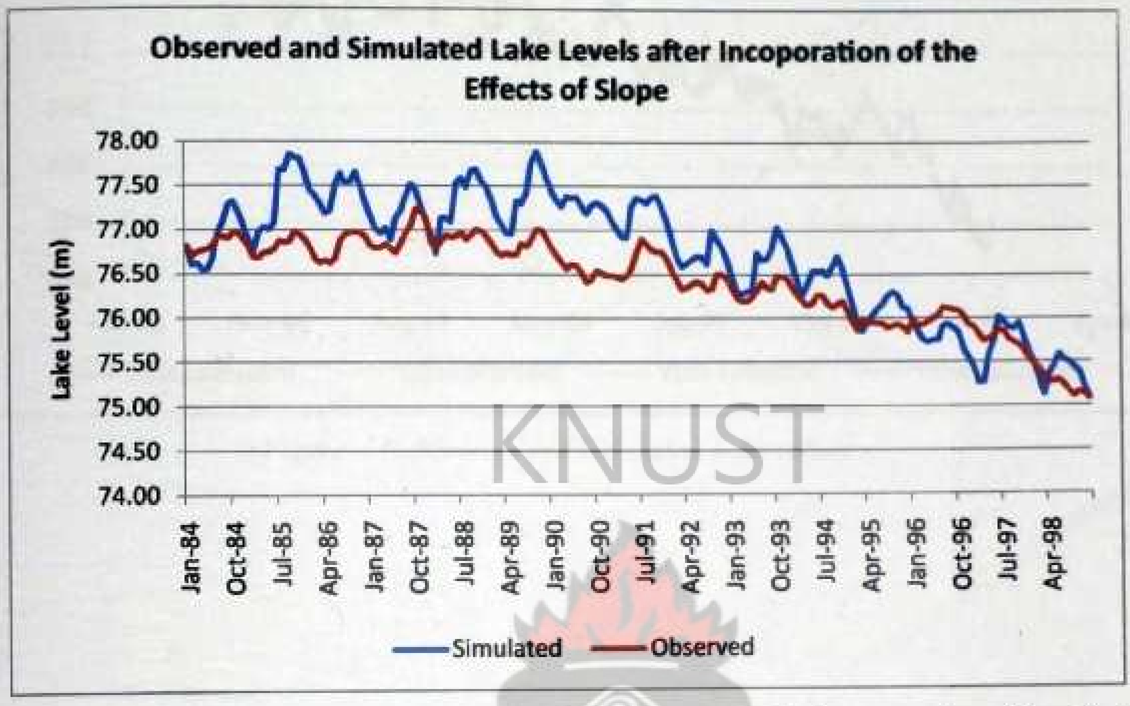


Figure -: Observed and simulated lake levels of Lake Bosumtwi after incorporation of the effect of slope

5.8.2 Error Minimization (removal of systematic errors)

The relation between observed and simulated records is given below; where ε is the total error of the model, τ is the pure systematic error and e the pure random error of the model.

$$\Delta V_{sim} = \Delta V_{obs} + \varepsilon \quad (5\text{-}8a)$$

$$\Delta V_{sim} = \Delta V_{obs} + (e + \tau) \quad (5\text{-}8b)$$

$$\Delta V_{sim}^{*} = \Delta V_{sim} - \tau = \Delta V_{obs} + e \quad (5\text{-}8c)$$

The systematic error of a model can be expressed by the relative bias (RB), and thus, by accounting for τ, the determination of e is possible. The systematic error for the split data set was determined and incorporated in the water balance equation. The results of performance of the water balance model after error minimization is summarized in the figure 5-25 and tables 5-9 and 5-10 below.

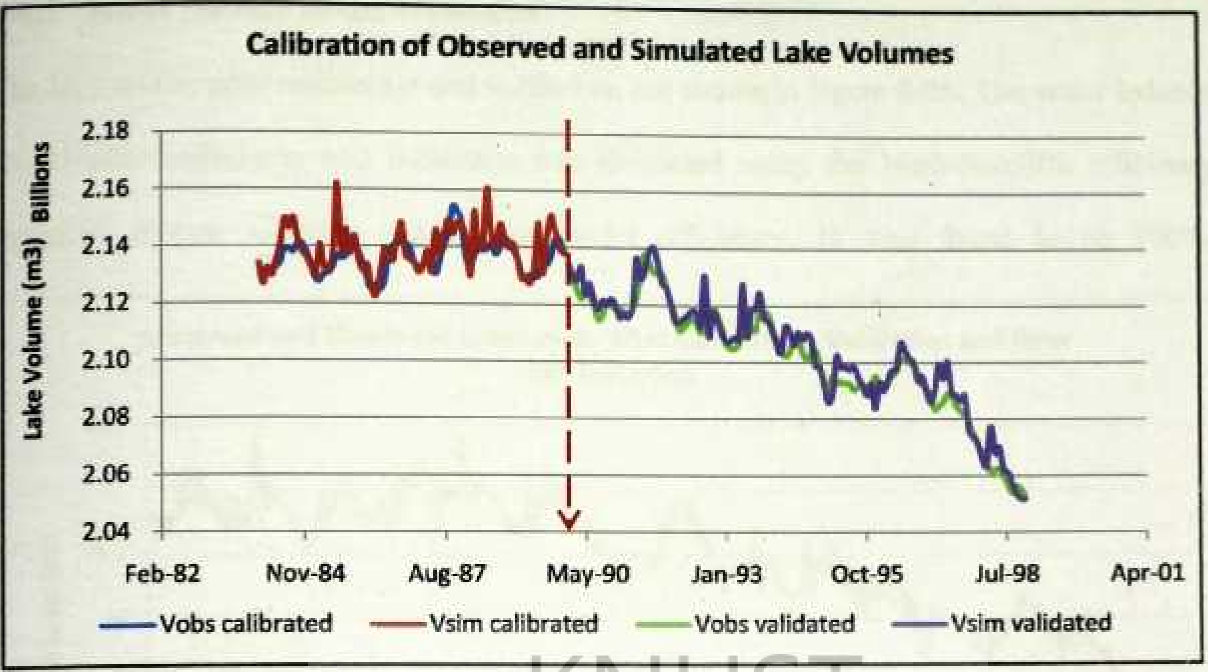


Figure -: Calibration and Validation Lake volumes

Table -: Performance of calibration dataset (1984 -1989)

	Tests	Expected	V_{sim} (m^3)	V_{sim}–τ (m^3)	L_{sim} - τ	L_{sim}(m)
Error Indices	*RMSE*	*0.000*	*148,938,540.02*	*118,926,700.60*	*0.358*	*3.391*
	PRMSE	*0%*	*6.97*	*5.52*	*0.463*	*4.411*
	RB(τ)	*0.00*	*-17,552,575.27*	*14,015,646.08*	*-0.04*	*-0.40*
Agreement Indices	*D*	*1.000*	*0.36*	*0.44*	*0.714*	*0.339*
	R^2	*1.000*	*0.23*	*0.32*	*0.343*	*0.233*

Table -: Performance of Validation dataset (1990 - 1998)

	Tests	Expected	V_{sim} (m^3)	V_{sim} – τ (m^3)	L_{sim} - τ	L_{sim} (m)
Error Indices	*RMSE*	*0.000*	*139,297,741.73*	*163,174,702.43*	*0.223*	*2.553*
	PRMSE	*0%*	*6.63*	*7.72*	*0.291*	*3.354*
	RB	*0.00*	*-12,702,996.76*	*14,880,411.49*	*0.02*	*-0.25*
Agreement Indices	*D*	*1.000*	*0.87*	*0.87*	*0.981*	*0.868*
	R^2	*1.000*	*0.84*	*0.93*	*0.935*	*0.842*

5.8.3 Water balance model evaluation

The lake levels, after calibration and validation, are shown in figure 5-26. The water balance model after calibration and validation was evaluated using the Nash-Sutcliffe efficiency equation, ***E*** (see equation 3-52). The model efficiency, ***E***, was found to be 100%.

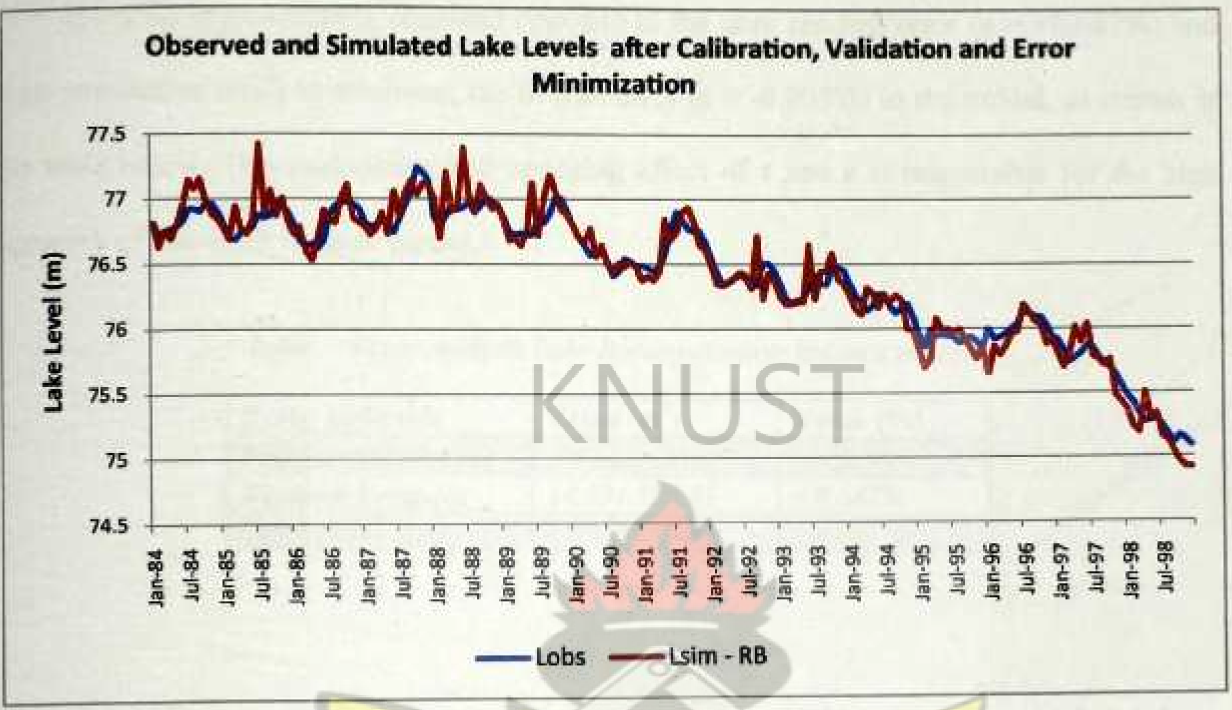


Figure -: Observed and simulated Lake levels after calibration, validation and evaluation

Results of the water balance model after calibration, validation and evaluation is given table 5-11 below. Further details are given in Appendix 11.

Table -: Performance of Lake Bosumtwi water balance model

Performance Indices		Expected	Lake Volume (m^3)		Lake Levels (m)	
			V_{sim}	V_{sim} - τ	L_{sim} - τ	L_{sim}
Error Indices	*RMSE*	*0.00*	*196,454,154.98*	*195,000,851.56*	*0.070*	*5.322*
	PRMSE	*0.00%*	*9.29%*	*9.15%*	*0.091%*	*6.96%*
	RB(τ)	*0.00*	*-14,642,828.17*	*14,534,505.33*	*0.00*	*-0.31*
	PRB	*0.00%*	-0.69%	0.69%	-0.01%	-0.40%
Agreement Indices	*D*	*1.000*	*0.87*	*0.90*	*0.983*	*0.870*
	R^2	*1.000*	*0.84*	*0.94*	*0.942*	*0.843*
Efficiency	*E*	*100%*	100%	100%	100%	100%

5.8.4 Discussion on model calibration, validation and evaluation

The performance of the overall water balance model provides further information on the water balance processes. Using an average lake volume of 2,115,386,153.95 m^3 (January, 1984 – December, 1998), it can be deduced that the water balance model has a pure systematic error (τ = -0.692%) approximately equaland opposite of the pure random error (e = +0.687%) and their cumulative tends to minimum the overall error (ε = -0.005%) in the model, as shown in the table below. This cumulative and opposing effect of τ and e is responsible for the high accuracy of the water balance model.

Table -: Error analysis Lake Bosumtwi water balance model

Error Indicator	Value (m^3)	Value (%)
Systematic Error (τ)	*-14,642,828.17*	*-0.692%*
Random Error (e)	*14,534,505.33*	*+0.687%*
Total Error (ε)	*- 103,322.84*	*- 0.005 %*

Thus from the preceding results, the final water balance calibration is simplified by the following expression:

Water Balance Model (5-10a)

$$\Delta V = P + R - E \quad (5\text{-}10b)$$

Reservoir Routing Equivalent (5-10c)

$$\left(\frac{1}{2}(P_i + P_{i+1}) + \frac{1}{2}(R_i + R_{i+1})\right) + \left(V_i - \frac{1}{2}E_i\right) = \left(V_{i+1} + \frac{1}{2}E_{i+1}\right) \quad (5\text{-}10d)$$

Incorporation of Systematic Error

$$\Delta V = P + R - E + (\varepsilon) \quad (5\text{-}10e)$$

$$\Rightarrow \Delta V = P + R - E + (\tau + e) \quad (5\text{-}10f)$$

$$\Rightarrow \Delta V_{sim} = \Delta V_{obs} + \varepsilon \quad (5\text{-}10g)$$

$$\Rightarrow \Delta V_{sim} = \Delta V_{obs} + (\tau + e) \quad (5\text{-}10h)$$

Application of Systematic Error in Water Balance Model

$$\left(\frac{1}{2}(P_i + P_{i+1}) + \frac{1}{2}(R_i + R_{i+1})\right) + \left(V_i - \frac{1}{2}E_i\right) = \left(V_{i+1} + \frac{1}{2}E_{i+1}\right) + (\tau + e)_i \tag{5-10i}$$

Since random cannot be easily quantified

$$\left(\frac{1}{2}(P_i + P_{i+1}) + \frac{1}{2}(R_i + R_{i+1})\right) + \left(V_i - \frac{1}{2}E_i\right) = \left(V_{i+1} + \frac{1}{2}E_{i+1}\right) + (\tau)_i \tag{5-10j}$$

Final Application of the Water Balance Model

$$\left(\frac{1}{2}(P_i + P_{i+1}) + \frac{1}{2}(R_i + R_{i+1})\right) + \left(V_i - \frac{1}{2}E_i + \tau_i\right) = \left(V_{i+1} + \frac{1}{2}E_{i+1}\right) \tag{5-10k}$$

6 Conclusions and Recommendations

6.1 Introduction

The main goal of this research was to establish the hydrological processes that affect the water balance of Lake Bosumtwi, contributing to the marked lake level rise and fall within the past centenary. Since limited data was available for this study, several assumptions were made during the course of this study, and they include:

a) Regional climatic conditions (Kumasi) exist over Lake Bosumtwi's catchment.

b) The Lake is hydrologically isolated from the regional aquifer.

c) Abstraction from the Lake for domestic, agriculture and industrial purposes is negligible.

d) Runoff from the catchment can be modeled using the SCS-CN rainfall-runoff model.

e) Sub-surface runoff within the catchment is negligible.

f) Land cover changes assumed a linear model, and soil characteristics, however,remains unchanged.

6.2 Conclusions

The assessment of the water balance of Lake Bosumtwi was done by the development of a distributed hydrological model. Since data was not available for the study area, satellite altimetry provided a useful tool for the assessment of the hydrology of the Lake. Software tools such as ArcGIS, ERDAS Imagine, MS Access, MS Excel, Trend and Spell-Stat were used for satellite image processing and hydrological data analysis. In the end, the following conclusions were drawn from the study:

a) Regional climatic conditions can be successfully used to model hydrological conditions of Lake Bosumtwi.

b) Inputs to the Lake can be simplified by only surface runoff and precipitation.

c) Outputs from the Lake are simplified by only evaporation.

d) The Simplified Penman Evaporation model (Valantias, 2006) provides the best evaporation estimates for the Lake

e) SCS-CN rainfall-runoff model successfully models surface runoff, although it was modified by incorporating the effect of steep slope into the equation ($\mu = 0.98$ and $\lambda = 0.12$) to improve the performance of the model.

f) Land cover changes for the lake can be assumed to be linear in nature.

g) The use of satellite altimetry and software tools such as ArcGIS and ERDAS Imagine allows for the development of distributed hydrological models which greatly improves model performance.

h) The overall water balance model has a total error of 0.005% (systematic error = -0.692 % and random error = + 0.687%) which may be due to the effect of parameter transfer of meteorological data.

i) The model shows that Lake level rise and fall reflects regional climatic conditions.

6.3 Recommendations

The following are recommended to improve upon the study:

a) Further research on the effects of slope on the SCS-CN method is should be carried out to allow for easy application to steep sloped catchments.

b) Further research on the transfer of meteorological parameters from Kumasi to Lake Bosumtwi must be carried out to improve upon the model.

c) Further research should be carried out to establish the link between the water balance of the Lake and climate change.

d) Further research should be carried out to scale up the water balance of Lake Bosumtwi for the West-African sub-region.

e) A meteorological station should be set up at the Lake site to use actual meteorological data of the site as inputs to the model.

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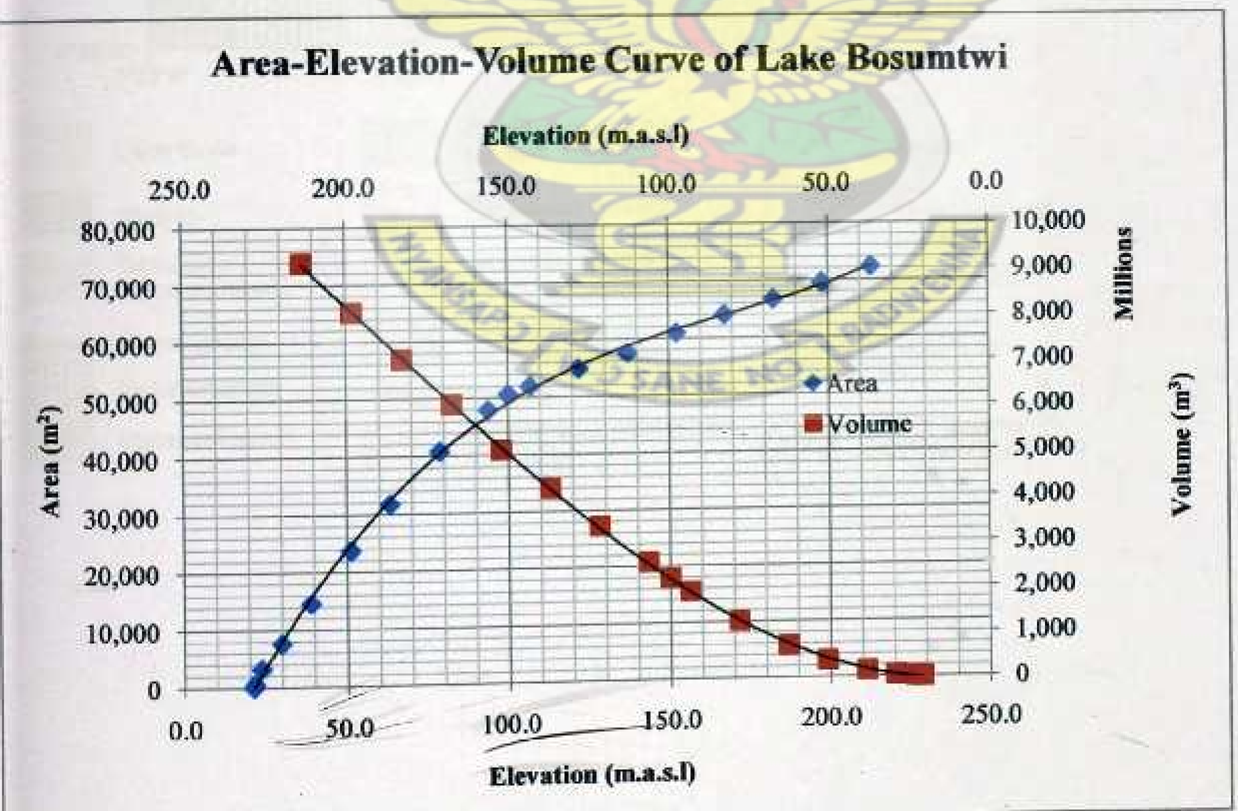
Appendices

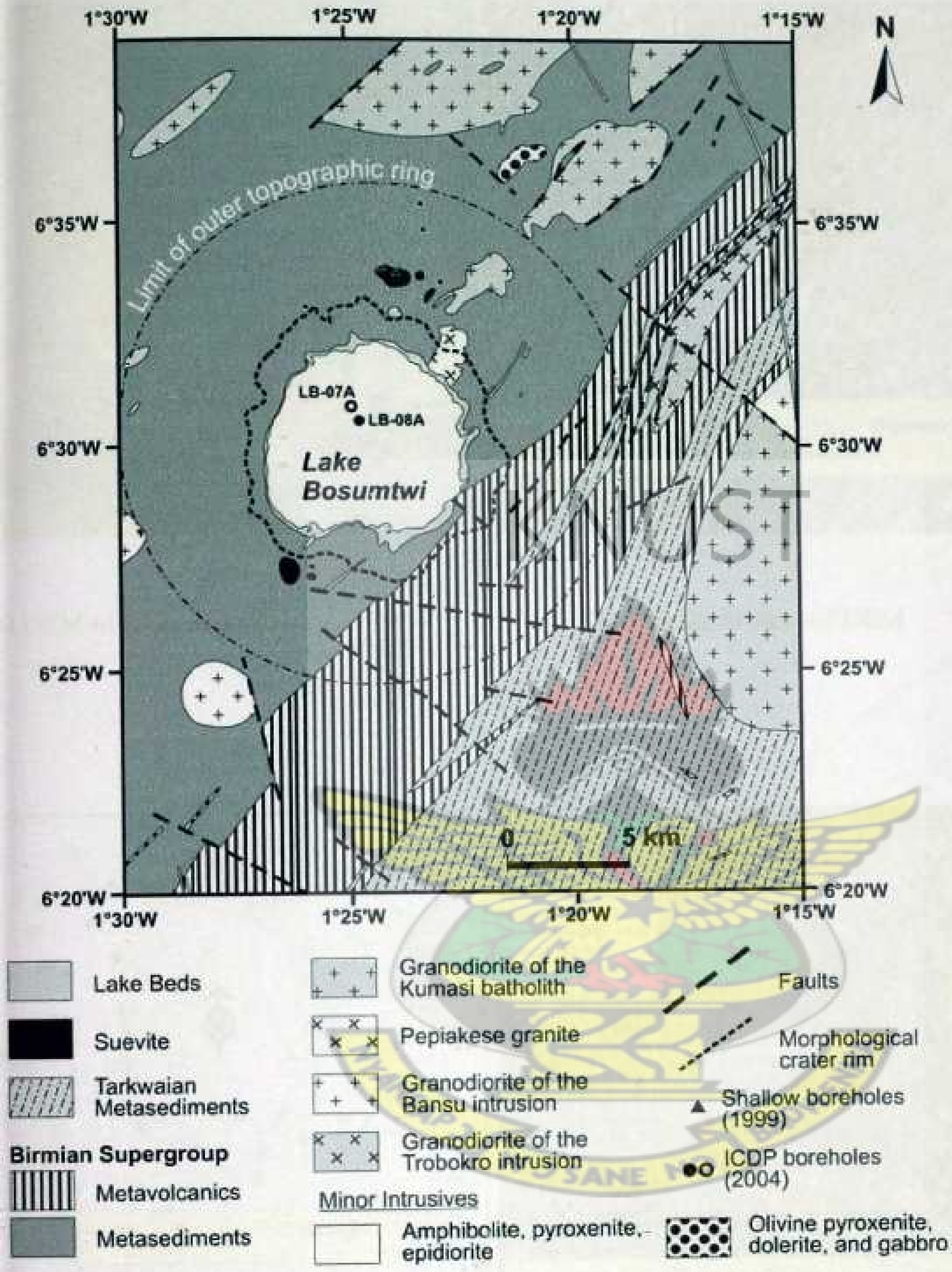
ppendix 1. Bathymetric Data of Lake Bosumtwi

Elevation	Depth	Area		Lake Volume	
masl	*m*	*km²*	*m²*	*km³*	*m³*
213.4	192.2	72.3	72,300	9.23	9,234,200,000
198.1	176.9	69.5	69,500	8.15	8,153,600,000
182.9	161.7	66.7	66,700	7.12	7,115,500,000
167.6	146.4	64.1	64,100	6.12	6,119,300,000
152.4	131.2	61.0	61,000	5.12	5,116,000,000
137.2	116.0	57.5	57,500	4.26	4,262,700,000
121.9	100.7	54.9	54,900	3.41	3,406,600,000
106.7	85.5	52.0	52,000	2.59	2,592,100,000
99.8	78.6	50.6	50,600	2.24	2,237,400,000
93.7	72.5	47.9	47,900	1.94	1,939,300,000
78.5	57.3	40.8	40,800	1.26	1,263,100,000
63.2	42.0	31.7	31,700	0.71	710,700,000
51.0	29.8	23.7	23,700	0.37	373,000,000
38.8	17.6	14.6	14,600	0.14	139,300,000
29.7	8.5	7.7	7,700	0.04	37,500,000
23.6	2.4	3.3	3,300	0.00	4,200,000
21.5	0.3	0.6	600	0.00	100,000
21.2	0.0	0.0	0	0	0

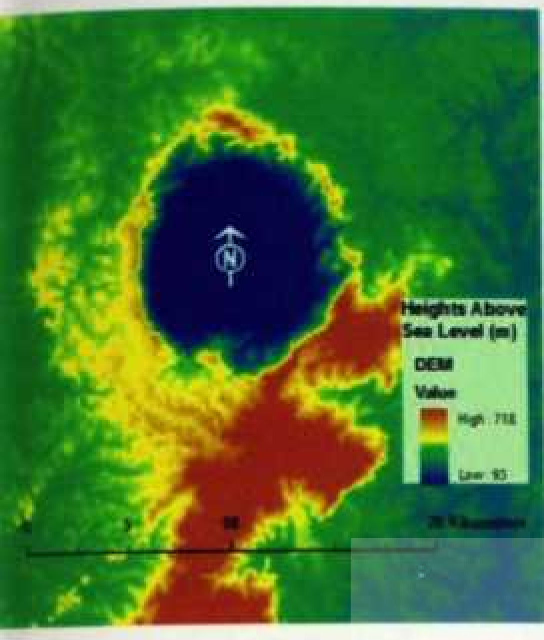
Source: (Turner *et al.*, 1996)



ppendix 2. Geology of Lake Bosumtwi

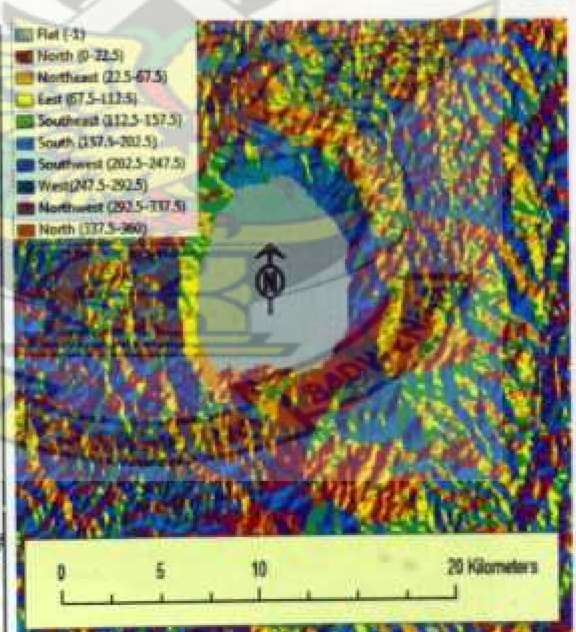


ppendix 3. Catchment Delineation of Lake Bosumtwi



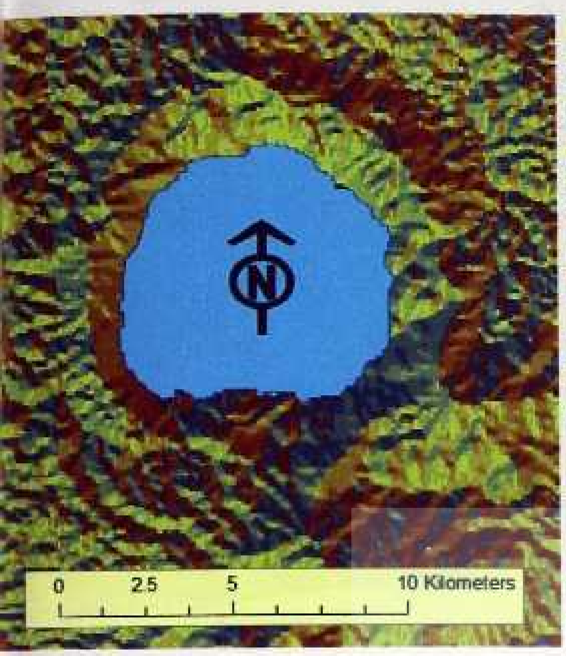
) DEM of Lake Bosumtwi

(b) Hill shade view of DEM

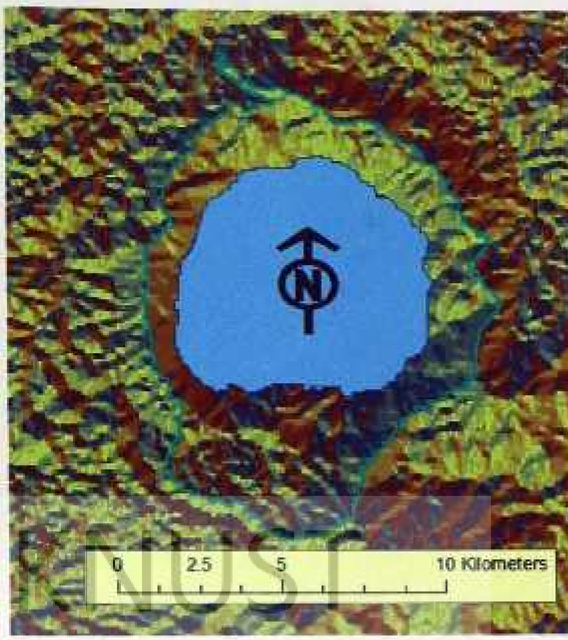


c) 50-m contour map generated from DEM

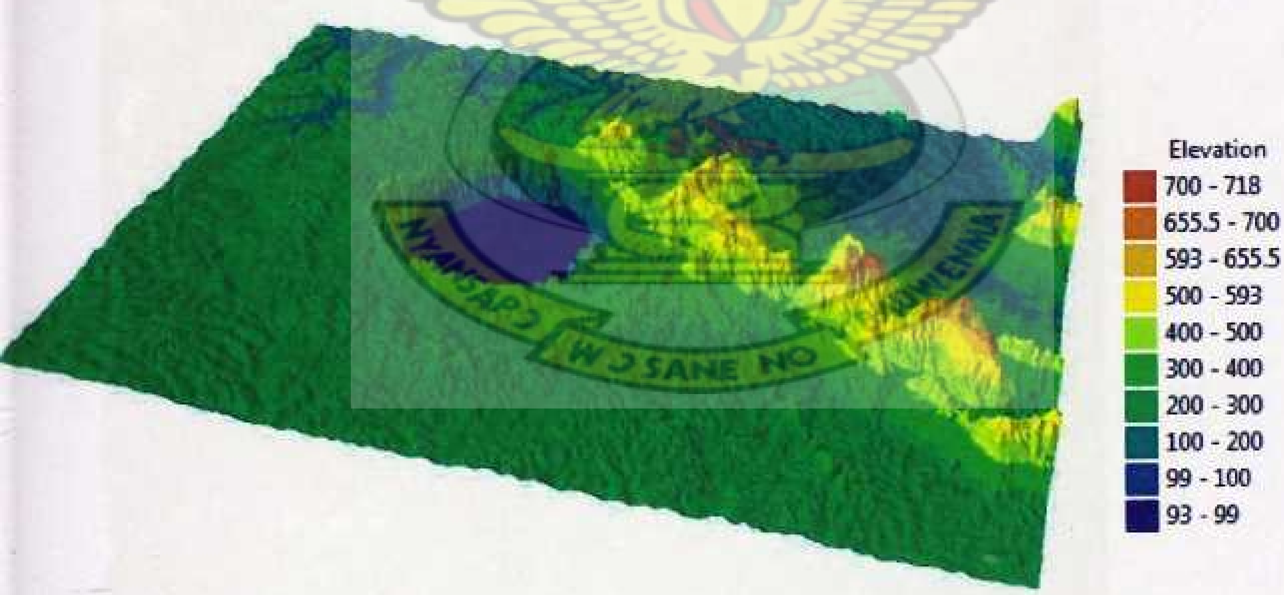
(d) Aspect map (showing flow irections)



e) Reclassified Aspect map

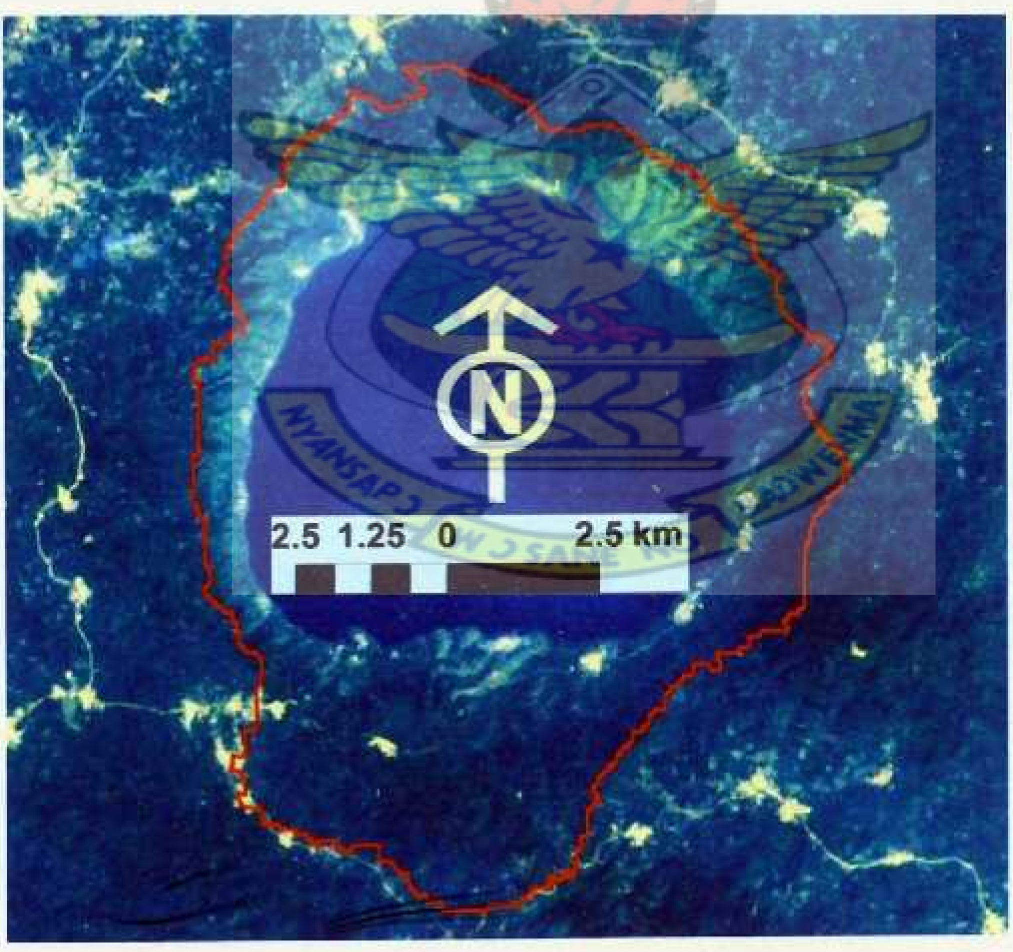


(f) Initial digitized catchment boundary



(g) 3D Model of Lake Bosumtwi

(h) Overlay and correction of digitized catchment on 3D model of Lake Bosumtwi (with Landsat 5th May, 2007 draped on the 3D model)



(i) Final delineated catchment of Lake Bosumtwi

Appendix 4. Comparison of Pan Evaporation to Evaporation models

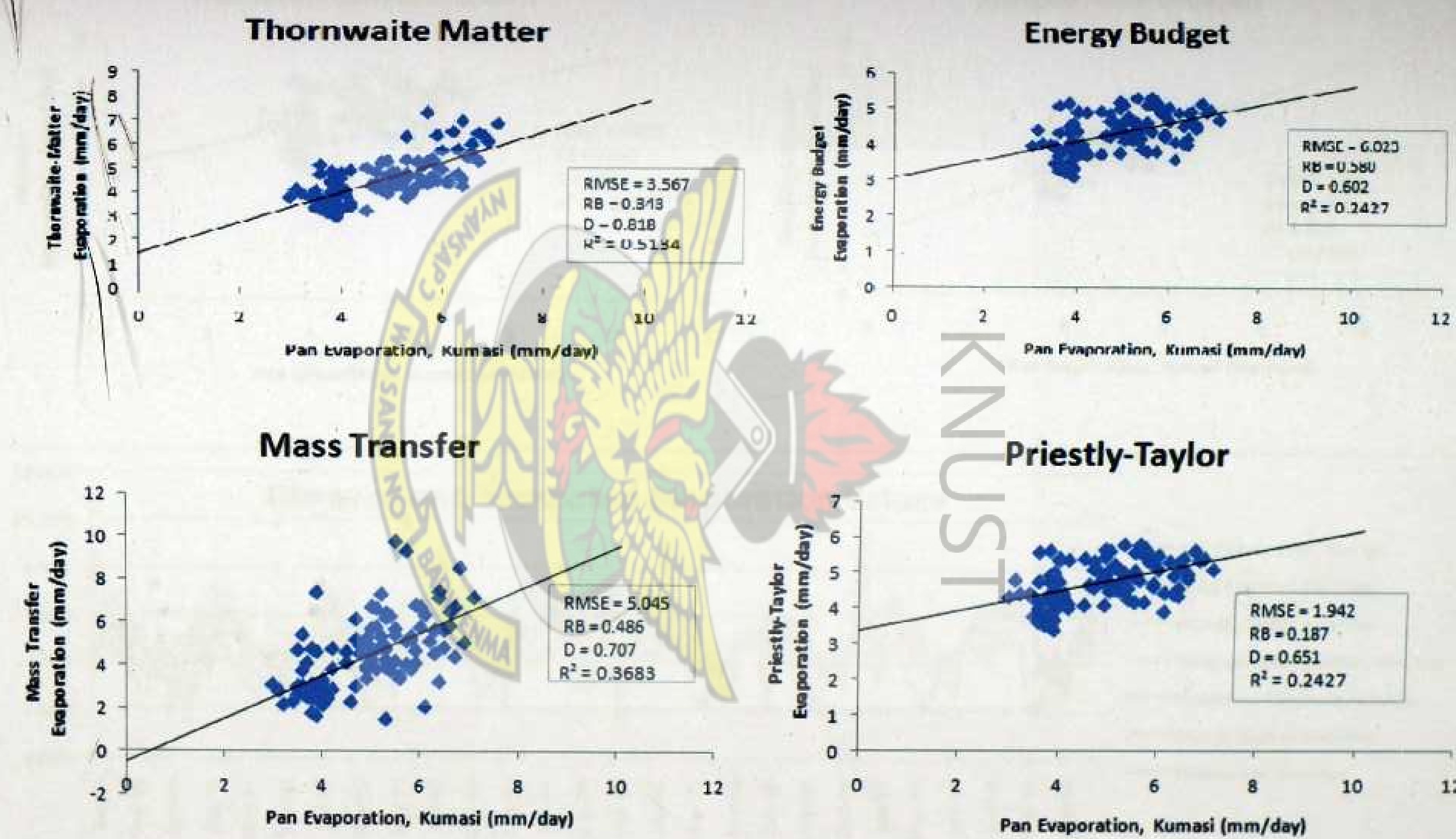
(a) Table showing evaporation from conceptual models and pan evaporation

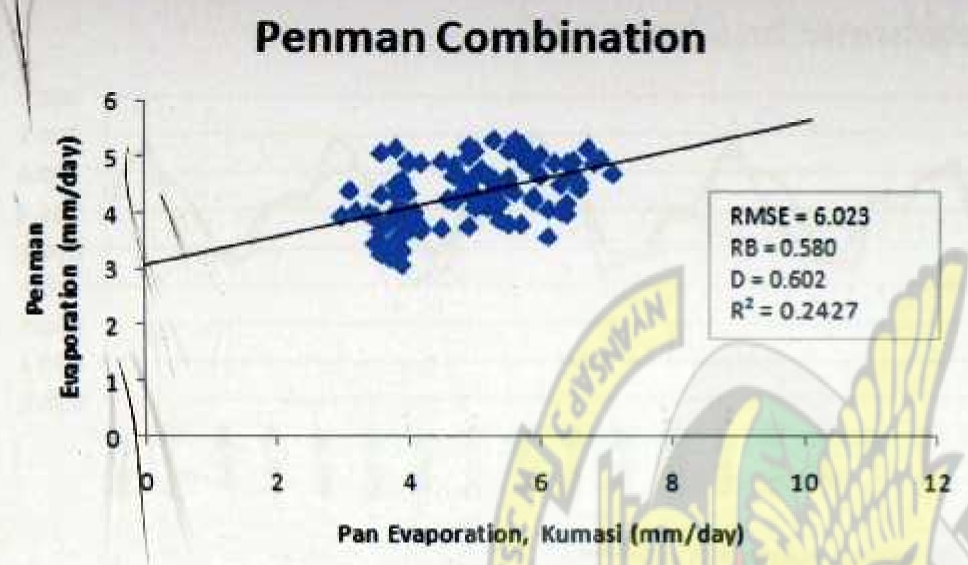
Date	Pan Evaporation, Kumasi	Mass Transfer	Priestly-Taylor	Penman Combination	Simplified Penman	Energy Budget	Thornwaite-Matter
Month	mm/day	mm/day	mm/day	mm/day	mm/day	mm/day	mm/day
Jan-90	5.300	3.892	4.707	4.315	5.624	4.315	4.549
Feb-90	6.500	5.621	5.081	4.658	6.395	4.658	5.513
Mar-90	6.700	6.720	5.605	5.138	6.610	5.138	6.470
Apr-90	5.500	4.177	5.559	5.096	5.896	5.096	5.325
May-90	4.000	3.340	5.337	4.893	5.569	4.893	4.816
Jun-90	3.800	2.589	4.916	4.507	4.891	4.507	4.454
Jul-90	3.800	3.108	3.804	3.488	3.923	3.488	3.341
Aug-90	3.600	5.395	3.752	3.440	3.812	3.440	3.366
Sep-90	3.800	2.430	4.207	3.857	4.263	3.857	3.887
Oct-90	4.900	5.024	4.929	4.519	5.119	4.519	4.190
Nov-90	5.300	1.519	4.955	4.542	5.219	4.542	4.808
Dec-90	5.400	6.286	4.547	4.169	4.967	4.169	3.986
Jan-91	5.600	3.380	4.763	4.367	5.601	4.367	4.485
Feb-91	6.900	5.065	5.403	4.953	6.056	4.953	6.145
Mar-91	6.700	4.373	5.613	5.146	6.077	5.146	5.292
Apr-91	5.600	3.530	5.777	5.296	5.953	5.296	5.114
May-91	3.900	3.081	5.000	4.583	5.097	4.583	4.719
Jun-91	3.600	2.734	4.732	4.338	4.804	4.338	4.711
Jul-91	3.000	3.126	4.297	3.939	4.387	3.939	3.766
Aug-91	3.500	4.675	3.768	3.454	3.708	3.454	3.346
Sep-91	3.500	2.625	4.249	3.895	4.365	3.895	4.093
Oct-91	5.300	4.248	4.477	4.104	4.574	4.104	3.766
Nov-91	5.000	4.575	4.464	4.093	4.861	4.093	4.679
Dec-91	4.900	4.990	4.093	3.752	4.984	3.752	4.559
Jan-92	6.100	6.329	3.893	3.569	6.050	3.569	4.526
Feb-92	7.100	7.176	5.105	4.680	6.536	4.680	6.873
Mar-92	6.300	5.620	4.923	4.513	5.848	4.513	5.809
Apr-92	4.900	3.844	5.447	4.994	5.768	4.994	5.325
May-92	5.100	3.781	5.214	4.780	5.460	4.780	4.780
Jun-92	3.200	2.153	4.391	4.026	4.297	4.026	3.964
Jul-92	3.900	2.465	3.376	3.095	3.462	3.095	3.012
Aug-92	3.900	4.594	3.629	3.326	3.662	3.326	2.989
Sep-92	3.700	2.516	4.188	3.839	4.219	3.839	3.546
Oct-92	5.000	6.734	4.704	4.312	5.058	4.312	4.243
Nov-92	4.700	6.149	4.571	4.190	5.123	4.190	4.200
Dec-92	5.500	5.716	4.152	3.806	4.718	3.806	4.304
Jan-93	6.400	7.417	4.338	3.977	6.241	3.977	4.282
Feb-93	6.800	8.536	5.339	4.894	6.483	4.894	6.362
Mar-93	5.800	5.175	5.310	4.868	5.967	4.868	4.674

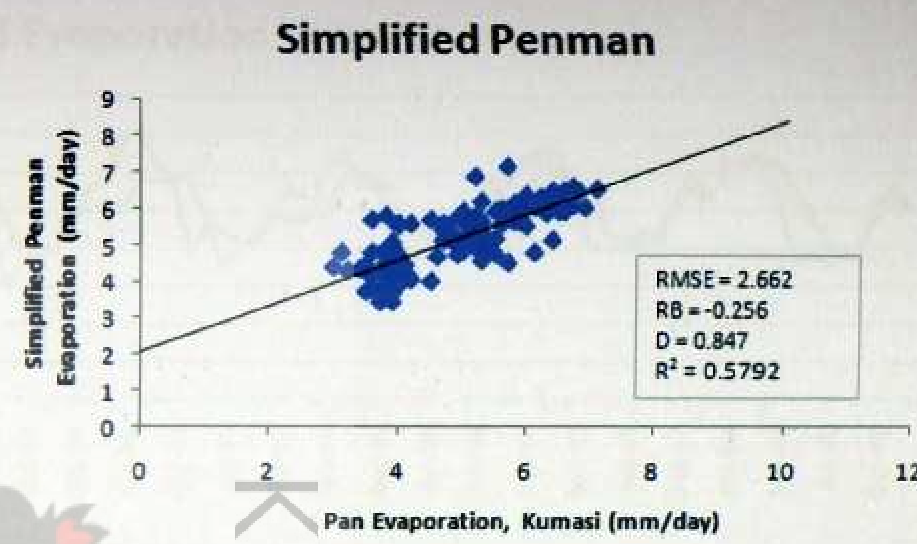
Date	Pan Evaporation, Kumasi	Mass Transfer	Priestly-Taylor	Penman Combination	Simplified Penman	Energy Budget	Thornwaite-Matter
Month	mm/day	mm/day	mm/day	mm/day	mm/day	mm/day	mm/day
Apr-93	5.000	4.253	5.589	5.123	5.945	5.123	4.864
May-93	4.500	4.106	5.378	4.930	5.677	4.930	5.047
Jun-93	4.000	2.562	4.751	4.356	4.736	4.356	4.214
Jul-93	3.600	2.955	3.588	3.289	3.762	3.289	3.304
Aug-93	3.700	4.073	3.497	3.206	3.467	3.206	3.178
Sep-93	3.400	2.300	4.365	4.001	4.373	4.001	3.770
Oct-93	5.100	6.606	5.122	4.695	5.322	4.695	4.290
Nov-93	5.500	5.436	4.852	4.448	5.204	4.448	4.662
Dec-93	5.400	3.726	4.233	3.881	4.936	3.881	4.078
Jan-94	5.900	4.716	4.597	4.214	5.846	4.214	4.490
Feb-94	5.900	6.807	4.675	4.286	6.046	4.286	6.389
Mar-94	6.000	6.683	5.494	5.037	6.347	5.037	5.770
Apr-94	4.800	4.519	5.050	4.629	5.407	4.629	5.218
May-94	4.700	3.019	5.286	4.846	5.440	4.846	4.428
Jun-94	3.100	2.823	4.776	4.378	4.776	4.378	4.141
Jul-94	3.600	3.755	3.698	3.390	3.876	3.390	3.433
Aug-94	3.900	7.341	3.666	3.360	3.853	3.360	3.433
Sep-94	3.900	1.617	3.945	3.617	3.941	3.617	3.793
Oct-94	4.900	3.942	4.702	4.311	4.711	4.311	3.978
Nov-94	5.000	5.723	5.083	4.660	5.650	4.660	4.706
Dec-94	5.200	7.298	4.450	4.080	5.782	4.080	4.274
Jan-95	5.200	5.349	4.596	4.213	6.850	4.213	4.447
Feb-95	5.700	9.290	5.482	5.026	7.168	5.026	7.299
Mar-95	5.800	5.345	5.537	5.076	6.171	5.076	5.440
Apr-95	5.700	4.007	5.709	5.234	5.935	5.234	5.325
May-95	3.800	2.571	5.614	5.146	5.780	5.146	4.844
Jun-95	4.600	2.282	4.640	4.254	4.668	4.254	4.284
Jul-95	3.500	3.008	4.317	3.957	4.481	3.957	3.742
Aug-95	4.000	2.926	4.033	3.698	3.921	3.698	3.241
Sep-95	4.100	2.472	4.405	4.038	4.443	4.038	3.895
Oct-95	4.900	5.252	4.846	4.442	5.031	4.442	4.027
Nov-95	4.700	5.192	5.089	4.665	5.581	4.665	4.868
Dec-95	4.800	4.892	4.706	4.314	5.295	4.314	4.175
Jan-96	6.100	2.055	4.434	4.065	4.808	4.065	4.397
Feb-96	6.500	4.815	5.367	4.921	5.931	4.921	5.546
Mar-96	5.900	4.096	5.256	4.818	5.626	4.818	5.109
Apr-96	5.800	3.829	5.385	4.937	5.651	4.937	5.279
May-96	4.200	3.787	5.337	4.893	5.576	4.893	4.892
Jun-96	3.800	2.500	4.394	4.028	4.492	4.028	4.037
Jul-96	3.900	2.720	4.415	4.047	4.432	4.047	3.557
Aug-96	4.200	4.734	4.118	3.776	4.040	3.776	3.365
Sep-96	4.200	2.838	4.001	3.668	4.053	3.668	3.533
Oct-96	5.300	4.840	4.692	4.301	4.829	4.301	3.817

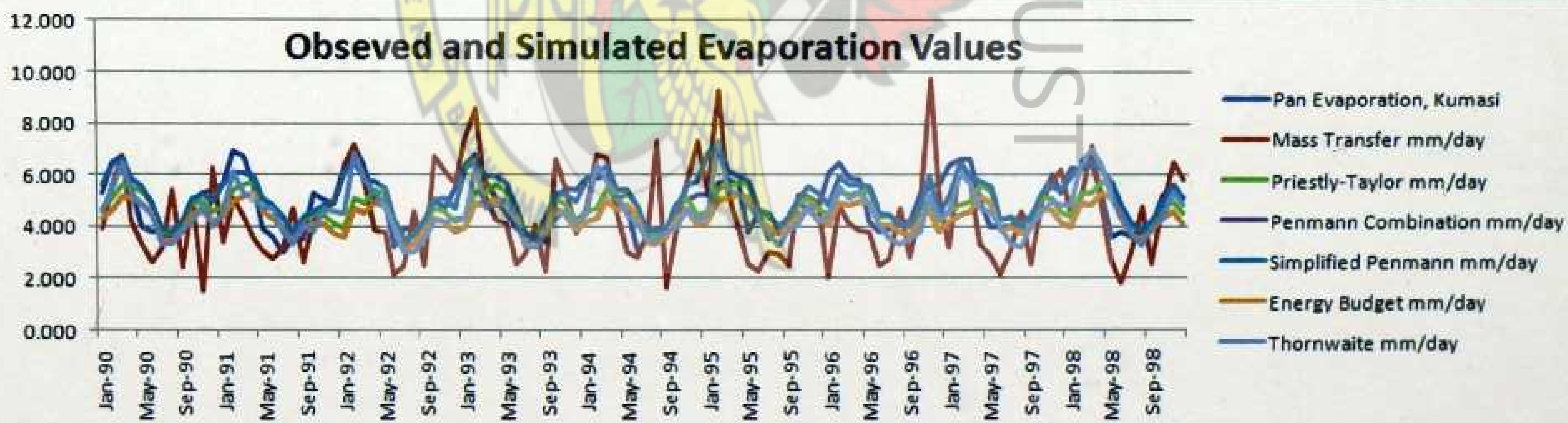
Date	Pan Evaporation, Kumasi	Mass Transfer	Priestly-Taylor	Penman Combination	Simplified Penman	Energy Budget	Thornwaite-Matter
Month	mm/day	mm/day	mm/day	mm/day	mm/day	mm/day	mm/day
Nov-96	5.500	9.733	5.051	4.631	5.919	4.631	5.241
Dec-96	5.700	5.092	4.152	3.807	4.501	3.807	4.346
Jan-97	6.400	3.212	4.564	4.184	5.134	4.184	4.581
Feb-97	6.600	6.530	4.842	4.439	6.474	4.439	6.053
Mar-97	6.600	5.845	4.974	4.560	5.918	4.560	5.661
Apr-97	4.900	3.349	5.638	5.169	5.773	5.169	4.703
May-97	4.000	2.891	5.369	4.922	5.549	4.922	4.583
Jun-97	4.000	2.130	4.224	3.873	4.254	3.873	3.987
Jul-97	4.000	3.074	4.355	3.992	4.352	3.992	3.322
Aug-97	4.500	4.587	4.060	3.722	3.992	3.722	3.222
Sep-97	4.100	2.525	4.364	4.000	4.467	4.000	4.046
Oct-97	5.200	4.938	5.076	4.653	5.270	4.653	4.551
Nov-97	6.000	5.752	5.090	4.666	5.522	4.666	4.972
Dec-97	5.300	6.197	4.553	4.174	5.346	4.174	4.812
Jan-98	6.300	4.541	4.379	4.015	5.964	4.015	4.821
Feb-98	6.200	5.143	5.316	4.874	6.337	4.874	6.518
Mar-98	6.400	7.122	5.308	4.866	6.454	4.866	6.976
Apr-98	5.300	4.742	5.770	5.290	6.225	5.290	6.315
May-98	3.600	2.655	5.548	5.086	5.677	5.086	5.118
Jun-98	3.800	1.806	4.722	4.328	4.748	4.328	4.422
Jul-98	3.600	3.028	4.004	3.671	4.137	3.671	3.706
Aug-98	3.800	4.781	3.869	3.547	3.840	3.547	3.240
Sep-98	3.900	2.568	4.215	3.864	4.277	3.864	4.000
Oct-98	5.200	4.823	4.685	4.295	4.880	4.295	4.309
Nov-98	5.300	6.449	4.993	4.577	5.640	4.577	5.360
Dec-98	5.100	5.798	4.511	4.135	5.108	4.135	4.815

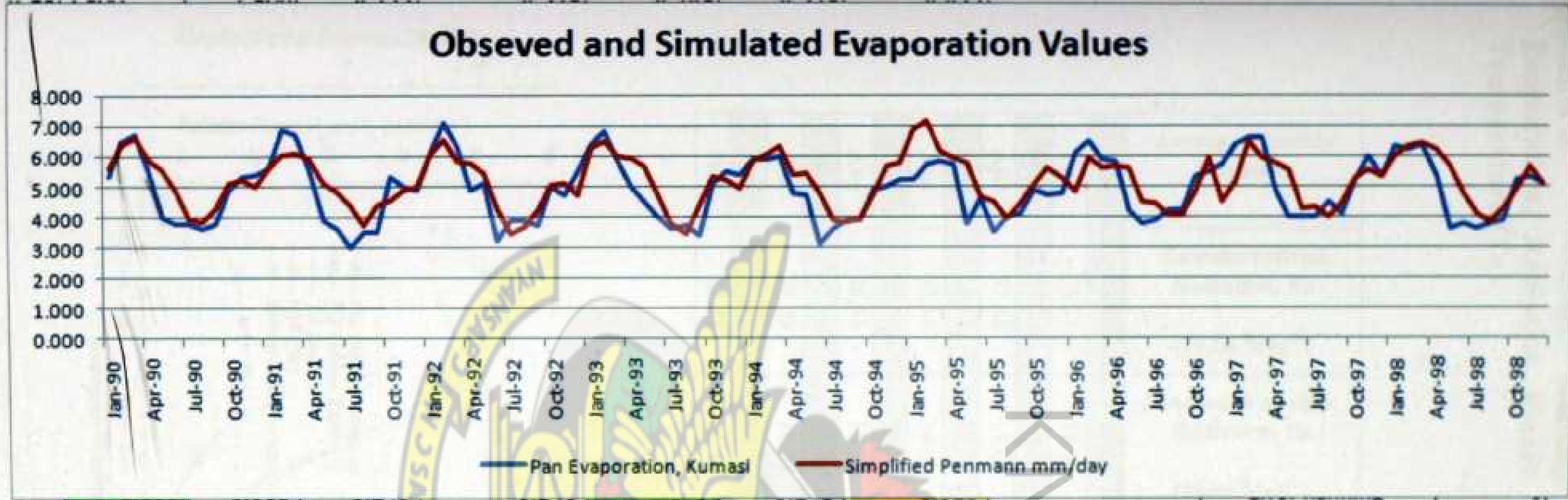
(b) Regression analysis of conceptual evaporation models and pan evaporation




Penman Combination
Penman Evaporation (mm/day)
Pan Evaporation, Kumasi (mm/day)
RMSE = 6.023
RB = 0.580
D = 0.602
R² = 0.2427


Simplified Penman
Simplified Penman Evaporation (mm/day)
Pan Evaporation, Kumasi (mm/day)
RMSE = 2.662
RB = -0.256
D = 0.847
R² = 0.5792


Obseved and Simulated Evaporation Values
Pan Evaporation, Kumasi
Mass Transfer mm/day
Priestly-Taylor mm/day
Penmann Combination mm/day
Simplified Penmann mm/day
Energy Budget mm/day
Thornwaite mm/day


Obseved and Simulated Evaporation Values
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
Jan-90
Apr-90
Jul-90
Oct-90
Jan-91
Apr-91
Jul-91
Oct-91
Jan-92
Apr-92
Jul-92
Oct-92
Jan-93
Apr-93
Jul-93
Oct-93
Jan-94
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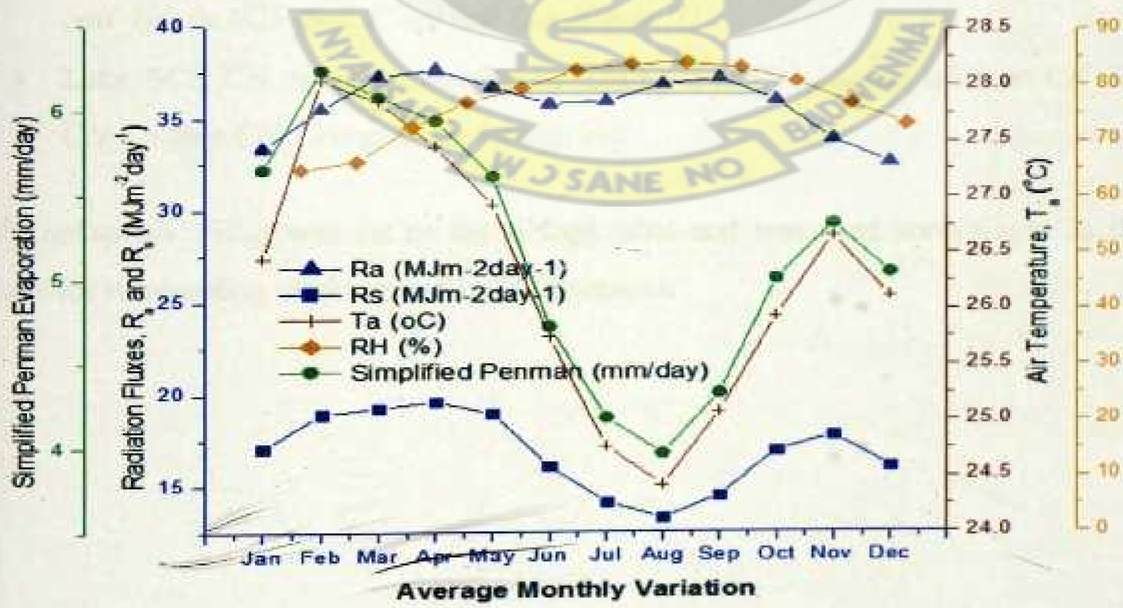
Jan-95
Apr-95
Jul-95
Oct-95
Jan-96
Apr-96
Jul-96
Oct-96
Jan-97
Apr-97
Jul-97
Oct-97
Jan-98
Apr-98
Jul-98
Oct-98
Pan Evaporation, Kumasi
Simplified Penmann mm/day

Appendix 5. Average monthly variation of Simplified Penman Evaporation, Radiation Fluxes, Relative Humidity (RH) and Air Temperature (Ta)

Average Monthly Estimates	Extraterrestrial Radiation, Ra ($MJm^{-2}day^{-1}$)	Shortwave or solar Radiation, Rs ($MJm^{-2}day^{-1}$)	Air Temperature, Ta (°C)	Relative Humidity, RH (%)	Simplified Penman Evaporation (mm/day)
Jan	33.36	17.05	26.44	64.56	5.65
Feb	35.51	18.94	28.02	65.99	6.24
Mar	37.28	19.25	27.83	72.19	6.08
Apr	37.68	19.61	27.44	76.70	5.94
May	36.75	18.96	26.92	79.21	5.62
Jun	35.84	16.07	25.74	82.43	4.72
Jul	36.00	14.13	24.77	83.50	4.18
Aug	36.93	13.25	24.42	83.77	3.97
Sep	37.26	14.47	25.07	82.96	4.33
Oct	36.09	16.94	25.93	80.62	5.01
Nov	33.98	17.76	26.65	76.71	5.34
Dec	32.72	16.10	26.10	73.08	5.05



Appendix 6. Procedure for the generation of CN values of Lake Bosumtwi's catchment

The following procedure outlined the steps used in generating the CN values of Lake Bosumtwi.

- A new ArcMap project (*Lake_Bosumtwi_CN.mxd*) was created using ArcGIS and was georeferenced to UTM Zone 30 N.
- Shapefiles (the soil map shapefile of Ghana – *Soil_map.shp*, catchment area shapefile of Lake Bosumtwi – *Cathment_boundary.shp*), the reclassified land cover raster images (*Landsat_p154r055_861229.img* and *Landsat_p154r055_2007055.img*) and the CN lookup database (*CN_Lookup_db.mdf*) were added to the ArcMap project. The reclassified land cover raster images were converted to shapefiles and added to the ArcMap project (using the *From Raster* tool found under the *Conversion Tools*).
- The soil map and land cover shape file were extended by joining it to the soil group and land cover lookup tables using the *Joins and Relate* tab found under the properties of each shapefile (using *FAO_Soil_Group* and *LANDCOVER* columns as the foreign keys respectively).
- The catchment, land cover and soil shapefiles were merged using the *Union* tool (*Toolbox → Analysis Tools → Overlay →Union*) and the resultant shapefile (*Lake_SCS_CN.shp*) was added to the ArcMap project.
- A new text field was added to *Lake_SCS_CN.shp* and named *CN_ID*. Using the field calculator, *CN_ID* was given the value equal to the concatenation of *Soil_Group.SCS_Soil_Class* and *LandCover.ID*.
- Lake_SCS_CN.shp was extended by joining it to *CN_Lookup* table on *CN_ID* with *CN_Lookup.CN_Group* as the foreign key.

CN_Lookup.CN_Value was set as the default label and was used accordingly as the CN values for surrounding catchment of Lake Bosumtwi.

Appendix 7. Land cover interpolation of Lake Bosumtwi's catchment

(a) Land cover classification of 29th December, 1986 Landsat image (Path: 155, Row: 54)

Soil Group	Land Cover - Dec, 1986	Area (m^2)	CN Value	CN_i x A_i	Weighted CN
B	Closed Forests	12,615,968.95	58	731,726,199.36	61.73
	Open Area / Grassland	4,419,554.74	69	304,949,277.30	
	Open Forests	3,841,926.22	65	249,725,204.07	
	Shrubs / Trees	428,964.20	61	26,166,815.94	
	Settlement / Urban Area	428,964.20	85	36,461,956.64	
	Shrubs / Trees*	9,952,387.98	61	607,095,666.59	
	Total Area w/ Unclassified	***21,735,378.31***			
A	Closed Forests	17,432,782.69	32	557,849,046.19	34.95
	Open Area / Grassland	1,255,543.19	49	61,521,616.24	
	Open Forests	1,748,165.35	44	76,919,275.24	
	Settlement / Urban Area	145,800.00	77	11,226,600.00	
	Shrubs / Trees	2,932,673.77	39	114,374,277.03	
	Unclassified / No Data	20.38	50	1,018.90	
	Total Area w/o Unclassified	***23,514,965.00***			

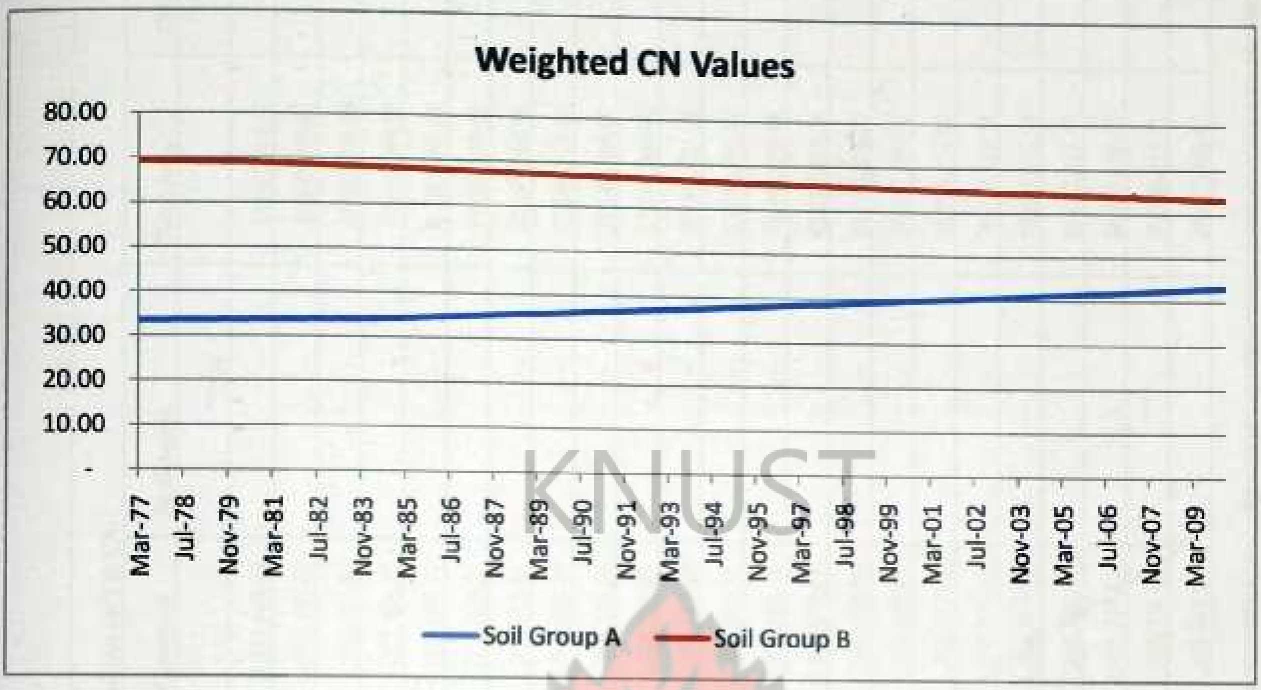
*Unclassified data were taken as Shrubs/Trees

(b) Land cover classification of 29th December, 1986 Landsat image (Path: 155, Row: 54)

Soil Group	Land Cover - May, 2007	Area (m2)	CN Value	CNi x Ai	Weighted CN
B	Closed Forests	1,310,289.33	58	75,996,781.08	64.24
	Open Area / Grassland	2,675,590.88	69	184,615,770.98	
	Open Forests	11,447,649.47	65	744,097,215.66	
	Settlement / Urban Area	1,604,891.24	85	136,415,755.45	
	Shrubs / Trees	14,333,310.09	61	874,331,915.33	
	Total Area	***31,371,731.01***			
A	Closed Forests	3,755,356.16	32	120,171,397.16	42.18
	Open Area / Grassland	1,135,094.30	49	55,619,620.69	
	Open Forests	13,781,232.89	44	606,374,247.08	
	Settlement / Urban Area	536,042.34	77	41,275,260.15	
	Shrubs / Trees	4,200,969.59	39	163,837,814.10	
	Total Area	***23,408,695.28***			

Appendix 8. CN value interpolation of Lake Bosumtwi's catchment

(a) Linear interpolation of CN Values of Lake Bosumtwi



(b) Equation for estimation of monthly CN values for Lake Bosumtwi

The equation uses March, 1977 as the base month (e.g. i = 1 for March, 1977; i = 118 for December, 1986; i = 363 for May, 2007)

$$CN_i = CN_o(1+r)^i$$

$$where \begin{cases} r = -0.00021651 \\ CN_o = 33.40 \Rightarrow Soil\ Group\ A \\ CN_o = 69.32 \Rightarrow Soil\ Group\ B \end{cases}$$

(c) Hydrologic Soil Groups of Lake Bosumtwi

(d) Land Cover interpolation of Soil Group A of Lake Bosumtwi

Year	Data Point	Soil Group A - Land Use (m^2) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.00021
Mar-77	1	23,964,451.69	-	2,326,997.81	1,313,063.68	-	27,604,513.17	33.40	35.85
Apr-77	2	23,908,625.46	-	2,332,174.52	1,312,572.05	-	27,553,372.03	33.40	35.84
May-77	3	23,852,799.23	-	2,337,351.24	1,312,080.42	-	27,502,230.89	33.41	35.83
Jun-77	4	23,796,973.00	-	2,342,527.96	1,311,588.79	-	27,451,089.75	33.41	35.83
Jul-77	5	23,741,146.77	-	2,347,704.68	1,311,097.17	-	27,399,948.61	33.41	35.82
Aug-77	6	23,685,320.54	-	2,352,881.39	1,310,605.54	-	27,348,807.47	33.42	35.81
Sep-77	7	23,629,494.31	-	2,358,058.11	1,310,113.91	-	27,297,666.33	33.42	35.80
Oct-77	8	23,573,668.08	-	2,363,234.83	1,309,622.28	-	27,246,525.19	33.42	35.79
Nov-77	9	23,517,841.84	-	2,368,411.55	1,309,130.65	-	27,195,384.04	33.43	35.79
Dec-77	10	23,462,015.61	-	2,373,588.26	1,308,639.03	-	27,144,242.90	33.43	35.78
Jan-78	11	23,406,189.38	-	2,378,764.98	1,308,147.40	-	27,093,101.76	33.44	35.77
Feb-78	12	23,350,363.15	-	2,383,941.70	1,307,655.77	-	27,041,960.62	33.44	35.76
Mar-78	13	23,294,536.92	-	2,389,118.42	1,307,164.14	-	26,990,819.48	33.44	35.76
Apr-78	14	23,238,710.69	-	2,394,295.14	1,306,672.51	-	26,939,678.34	33.45	35.75
May-78	15	23,182,884.46	-	2,399,471.85	1,306,180.88	-	26,888,537.20	33.45	35.74
Jun-78	16	23,127,058.23	-	2,404,648.57	1,305,689.26	-	26,837,396.06	33.45	35.73
Jul-78	17	23,071,232.00	-	2,409,825.29	1,305,197.63	-	26,786,254.92	33.46	35.72
Aug-78	18	23,015,405.77	-	2,415,002.01	1,304,706.00	-	26,735,113.77	33.46	35.72
Sep-78	19	22,959,579.54	-	2,420,178.72	1,304,214.37	-	26,683,972.63	33.47	35.71
Oct-78	20	22,903,753.31	-	2,425,355.44	1,303,722.74	-	26,632,831.49	33.47	35.70
Nov-78	21	22,847,927.08	-	2,430,532.16	1,303,231.12	-	26,581,690.35	33.47	35.69
Dec-78	22	22,792,100.84	-	2,435,708.88	1,302,739.49	-	26,530,549.21	33.48	35.69
Jan-79	23	22,736,274.61	-	2,440,885.59	1,302,247.86	-	26,479,408.07	33.48	35.68

Year	Data Point / Land Cover / CN Numbers	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	Interpolation Function
		Soil Group A - Land Use (m^2) & CN							$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.00021
Feb-79	24	22,680,448.38	-	2,446,062.31	1,301,756.23	-	26,428,266.93	33.49	35.67
Mar-79	25	22,624,622.15	-	2,451,239.03	1,301,264.60	-	26,377,125.79	33.49	35.66
Apr-79	26	22,568,795.92	-	2,456,415.75	1,300,772.98	-	26,325,984.64	33.49	35.66
May-79	27	22,512,969.69	-	2,461,592.46	1,300,281.35	852.85	26,275,696.35	33.50	35.65
Jun-79	28	22,457,143.46	-	2,466,769.18	1,299,789.72	2,445.67	26,226,148.03	33.51	35.64
Jul-79	29	22,401,317.23	-	2,471,945.90	1,299,298.09	4,038.50	26,176,599.72	33.51	35.63
Aug-79	30	22,345,491.00	-	2,477,122.62	1,298,806.46	5,631.32	26,127,051.40	33.52	35.62
Sep-79	31	22,289,664.77	-	2,482,299.34	1,298,314.83	7,224.15	26,077,503.09	33.53	35.62
Oct-79	32	22,233,838.54	-	2,487,476.05	1,297,823.21	8,816.97	26,027,954.77	33.53	35.61
Nov-79	33	22,178,012.31	-	2,492,652.77	1,297,331.58	10,409.80	25,978,406.46	33.54	35.60
Dec-79	34	22,122,186.08	-	2,497,829.49	1,296,839.95	12,002.63	25,928,858.14	33.55	35.59
Jan-80	35	22,066,359.85	-	2,503,006.21	1,296,348.32	13,595.45	25,879,309.83	33.55	35.59
Feb-80	36	22,010,533.61	-	2,508,182.92	1,295,856.69	15,188.28	25,829,761.51	33.56	35.58
Mar-80	37	21,954,707.38	-	2,513,359.64	1,295,365.07	16,781.10	25,780,213.19	33.57	35.57
Apr-80	38	21,898,881.15	-	2,518,536.36	1,294,873.44	18,373.93	25,730,664.88	33.57	35.56
May-80	39	21,843,054.92	-	2,523,713.08	1,294,381.81	19,966.76	25,681,116.56	33.58	35.55
Jun-80	40	21,787,228.69	-	2,528,889.79	1,293,890.18	21,559.58	25,631,568.25	33.59	35.55
Jul-80	41	21,731,402.46	-	2,534,066.51	1,293,398.55	23,152.41	25,582,019.93	33.59	35.54
Aug-80	42	21,675,576.23	-	2,539,243.23	1,292,906.93	24,745.23	25,532,471.62	33.60	35.53
Sep-80	43	21,619,750.00	-	2,544,419.95	1,292,415.30	26,338.06	25,482,923.30	33.61	35.52
Oct-80	44	21,563,923.77	-	2,549,596.66	1,291,923.67	27,930.89	25,433,374.99	33.61	35.52
Nov-80	45	21,508,097.54	-	2,554,773.38	1,291,432.04	29,523.71	25,383,826.67	33.62	35.51
Dec-80	46	21,452,271.31	-	2,559,950.10	1,290,940.41	31,116.54	25,334,278.36	33.63	35.50
Jan-81	47	21,396,445.08	-	2,565,126.82	1,290,448.78	32,709.36	25,284,730.04	33.64	35.49
Feb-81	48	21,340,618.85	-	2,570,303.53	1,289,957.16	34,302.19	25,235,181.73	33.64	35.49
Mar-81	49	21,284,792.61	-	2,575,480.25	1,289,465.53	35,895.01	25,185,633.41	33.65	35.48

Year	Data Point	Soil Group A - Land Use (m^2) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.00021
Apr-81	50	21,228,966.38	-	2,580,656.97	1,288,973.90	37,487.84	25,136,085.10	33.66	35.47
May-81	51	21,173,140.15	-	2,585,833.69	1,288,482.27	39,080.67	25,086,536.78	33.66	35.46
Jun-81	52	21,117,313.92	-	2,591,010.41	1,287,990.64	40,673.49	25,036,988.46	33.67	35.45
Jul-81	53	21,061,487.69	-	2,596,187.12	1,287,499.02	42,266.32	24,987,440.15	33.68	35.45
Aug-81	54	21,005,661.46	-	2,601,363.84	1,287,007.39	43,859.14	24,937,891.83	33.69	35.44
Sep-81	55	20,949,835.23	-	2,606,540.56	1,286,515.76	45,451.97	24,888,343.52	33.69	35.43
Oct-81	56	20,894,009.00	-	2,611,717.28	1,286,024.13	47,044.80	24,838,795.20	33.70	35.42
Nov-81	57	20,838,182.77	-	2,616,893.99	1,285,532.50	48,637.62	24,789,246.89	33.71	35.42
Dec-81	58	20,782,356.54	-	2,622,070.71	1,285,040.88	50,230.45	24,739,698.57	33.72	35.41
Jan-82	59	20,726,530.31	-	2,627,247.43	1,284,549.25	51,823.27	24,690,150.26	33.72	35.40
Feb-82	60	20,670,704.08	-	2,632,424.15	1,284,057.62	53,416.10	24,640,601.94	33.73	35.39
Mar-82	61	20,614,877.85	-	2,637,600.86	1,283,565.99	55,008.93	24,591,053.63	33.74	35.39
Apr-82	62	20,559,051.62	-	2,642,777.58	1,283,074.36	56,601.75	24,541,505.31	33.75	35.38
May-82	63	20,503,225.38	-	2,647,954.30	1,282,582.73	58,194.58	24,491,957.00	33.75	35.37
Jun-82	64	20,447,399.15	-	2,653,131.02	1,282,091.11	59,787.40	24,442,408.68	33.76	35.36
Jul-82	65	20,391,572.92	-	2,658,307.73	1,281,599.48	61,380.23	24,392,860.37	33.77	35.36
Aug-82	66	20,335,746.69	-	2,663,484.45	1,281,107.85	62,973.05	24,343,312.05	33.78	35.35
Sep-82	67	20,279,920.46	-	2,668,661.17	1,280,616.22	64,565.88	24,293,763.73	33.78	35.34
Oct-82	68	20,224,094.23	-	2,673,837.89	1,280,124.59	66,158.71	24,244,215.42	33.79	35.33
Nov-82	69	20,168,268.00	-	2,679,014.61	1,279,632.97	67,751.53	24,194,667.10	33.80	35.32
Dec-82	70	20,112,441.77	-	2,684,191.32	1,279,141.34	69,344.36	24,145,118.79	33.81	35.32
Jan-83	71	20,056,615.54	-	2,689,368.04	1,278,649.71	70,937.18	24,095,570.47	33.82	35.31
Feb-83	72	20,000,789.31	-	2,694,544.76	1,278,158.08	72,530.01	24,046,022.16	33.82	35.30
Mar-83	73	19,944,963.08	-	2,699,721.48	1,277,666.45	74,122.84	23,996,473.84	33.83	35.29
Apr-83	74	19,889,136.85	-	2,704,898.19	1,277,174.83	75,715.66	23,946,925.53	33.84	35.29
May-83	75	19,833,310.62	-	2,710,074.91	1,276,683.20	77,308.49	23,897,377.21	33.85	35.28

Year	Data Point / Land Cover / CN Numbers	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	Interpolation Function: $CN = CN_0(1+r)^t$
		Soil Group A - Land Use (m^2) & CN							
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.000216
Jun-83	76	19,777,484.38	-	2,715,251.63	1,276,191.57	78,901.31	23,847,828.90	33.86	35.27
Jul-83	77	19,721,658.15	-	2,720,428.35	1,275,699.94	80,494.14	23,798,280.58	33.86	35.26
Aug-83	78	19,665,831.92	-	2,725,605.06	1,275,208.31	82,086.96	23,748,732.27	33.87	35.26
Sep-83	79	19,610,005.69	-	2,730,781.78	1,274,716.69	83,679.79	23,699,183.95	33.88	35.25
Oct-83	80	19,554,179.46	-	2,735,958.50	1,274,225.06	85,272.62	23,649,635.63	33.89	35.24
Nov-83	81	19,498,353.23	-	2,741,135.22	1,273,733.43	86,865.44	23,600,087.32	33.90	35.23
Dec-83	82	19,442,527.00	-	2,746,311.93	1,273,241.80	88,458.27	23,550,539.00	33.90	35.23
Jan-84	83	19,386,700.77	29,155.70	2,751,488.65	1,272,750.17	90,051.09	23,530,146.39	33.93	35.22
Feb-84	84	19,330,874.54	78,270.26	2,756,665.37	1,272,258.54	91,643.92	23,529,712.63	33.95	35.21
Mar-84	85	19,275,048.31	127,384.82	2,761,842.09	1,271,766.92	93,236.75	23,529,278.88	33.98	35.20
Apr-84	86	19,219,222.08	176,499.38	2,767,018.81	1,271,275.29	94,829.57	23,528,845.12	34.01	35.19
May-84	87	19,163,395.85	225,613.94	2,772,195.52	1,270,783.66	96,422.40	23,528,411.37	34.04	35.19
Jun-84	88	19,107,569.62	274,728.50	2,777,372.24	1,270,292.03	98,015.22	23,527,977.62	34.07	35.18
Jul-84	89	19,051,743.38	323,843.07	2,782,548.96	1,269,800.40	99,608.05	23,527,543.86	34.10	35.17
Aug-84	90	18,995,917.15	372,957.63	2,787,725.68	1,269,308.78	101,200.88	23,527,110.11	34.13	35.16
Sep-84	91	18,940,090.92	422,072.19	2,792,902.39	1,268,817.15	102,793.70	23,526,676.35	34.16	35.16
Oct-84	92	18,884,264.69	471,186.75	2,798,079.11	1,268,325.52	104,386.53	23,526,242.60	34.19	35.15
Nov-84	93	18,828,438.46	520,301.31	2,803,255.83	1,267,833.89	105,979.35	23,525,808.85	34.22	35.14
Dec-84	94	13,772,612.23	569,415.87	2,808,432.55	1,267,342.26	107,572.18	23,525,375.09	34.25	35.13
Jan-85	95	18,716,786.00	618,530.43	2,813,609.26	1,266,850.64	109,165.00	23,524,941.34	34.28	35.13
Feb-85	96	18,660,959.77	667,645.00	2,818,785.98	1,266,359.01	110,757.83	23,524,507.59	34.31	35.12
Mar-85	97	18,605,133.54	716,759.56	2,823,962.70	1,265,867.38	112,350.66	23,524,073.83	34.34	35.11
Apr-85	98	18,549,307.31	765,874.12	2,829,139.42	1,265,375.75	113,943.48	23,523,640.08	34.36	35.10
May-85	99	18,493,481.08	814,988.68	2,834,316.13	1,264,884.12	115,536.31	23,523,206.32	34.39	35.10
Jun-85	100	18,437,654.85	864,103.24	2,839,492.85	1,264,392.49	117,129.13	23,522,772.57	34.42	35.09
Jul-85	101	18,381,828.62	913,217.80	2,844,669.57	1,263,900.87	118,721.96	23,522,338.82	34.45	35.08

Year	Data Point	Soil Group A - Land Use (m^2) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.00021
Aug-85	102	18,326,002.39	962,332.36	2,849,846.29	1,263,409.24	120,314.79	23,521,905.06	34.48	35.07
Sep-85	103	18,270,176.15	1,011,446.93	2,855,023.01	1,262,917.61	121,907.61	23,521,471.31	34.51	35.07
Oct-85	104	18,214,349.92	1,060,561.49	2,860,199.72	1,262,425.98	123,500.44	23,521,037.55	34.54	35.06
Nov-85	105	18,158,523.69	1,109,676.05	2,865,376.44	1,261,934.35	125,093.26	23,520,603.80	34.57	35.05
Dec-85	106	18,102,697.46	1,158,790.61	2,870,553.16	1,261,442.73	126,686.09	23,520,170.05	34.60	35.04
Jan-86	107	18,046,871.23	1,207,905.17	2,875,729.88	1,260,951.10	128,278.92	23,519,736.29	34.63	35.04
Feb-86	108	17,991,045.00	1,257,019.73	2,880,906.59	1,260,459.47	129,871.74	23,519,302.54	34.66	35.03
Mar-86	109	17,935,218.77	1,306,134.29	2,886,083.31	1,259,967.84	131,464.57	23,518,868.78	34.69	35.02
Apr-86	110	17,879,392.54	1,355,248.86	2,891,260.03	1,259,476.21	133,057.39	23,518,435.03	34.72	35.01
May-86	111	17,823,566.31	1,404,363.42	2,896,436.75	1,258,984.59	134,650.22	23,518,001.28	34.75	35.00
Jun-86	112	17,767,740.08	1,453,477.98	2,901,613.46	1,258,492.96	136,243.04	23,517,567.52	34.78	35.00
Jul-86	113	17,711,913.85	1,502,592.54	2,906,790.18	1,258,001.33	137,835.87	23,517,133.77	34.81	34.99
Aug-86	114	17,656,087.62	1,551,707.10	2,911,966.90	1,257,509.70	139,428.70	23,516,700.01	34.83	34.98
Sep-86	115	17,600,261.39	1,600,821.66	2,917,143.62	1,257,018.07	141,021.52	23,516,266.26	34.86	34.97
Oct-86	116	17,544,435.15	1,649,936.22	2,922,320.33	1,256,526.44	142,614.35	23,515,832.51	34.89	34.97
Nov-86	117	17,488,608.92	1,699,050.79	2,927,497.05	1,256,034.82	144,207.17	23,515,398.75	34.92	34.96
Dec-86	118	17,432,782.69	1,748,165.35	2,932,673.77	1,255,543.19	145,800.00	23,514,965.00	34.95	34.95
Jan-87	119	17,376,956.46	1,797,279.91	2,937,850.49	1,255,051.56	147,392.83	23,514,531.24	34.98	34.94
Feb-87	120	17,321,130.23	1,846,394.47	2,943,027.21	1,254,559.93	148,985.65	23,514,097.49	35.01	34.94
Mar-87	121	17,265,304.00	1,895,509.03	2,948,203.92	1,254,068.30	150,578.48	23,513,663.74	35.04	34.93
Apr-87	122	17,209,477.77	1,944,623.59	2,953,380.64	1,253,576.68	152,171.30	23,513,229.98	35.07	34.92
May-87	123	17,153,651.54	1,993,738.15	2,958,557.36	1,253,085.05	153,764.13	23,512,796.23	35.10	34.91
Jun-87	124	17,097,825.31	2,042,852.71	2,963,734.08	1,252,593.42	155,356.96	23,512,362.47	35.13	34.91
Jul-87	125	17,041,999.08	2,091,967.28	2,968,910.79	1,252,101.79	156,949.78	23,511,928.72	35.16	34.90
Aug-87	126	16,986,172.85	2,141,081.84	2,974,087.51	1,251,610.16	158,542.61	23,511,494.97	35.19	34.89
Sep-87	127	16,930,346.62	2,190,196.40	2,979,264.23	1,251,118.54	160,135.43	23,511,061.21	35.22	34.88

Year	Data Point	Soil Group A - Land Use (m²) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.00021
Oct-87	128	16,874,520.39	2,239,310.96	2,984,440.95	1,250,626.91	161,728.26	23,510,627.46	35.25	34.88
Nov-87	129	16,818,694.16	2,288,425.52	2,989,617.66	1,250,135.28	163,321.08	23,510,193.70	35.27	34.87
Dec-87	130	16,762,867.92	2,337,540.08	2,994,794.38	1,249,643.65	164,913.91	23,509,759.95	35.30	34.86
Jan-88	131	16,707,041.69	2,386,654.64	2,999,971.10	1,249,152.02	166,506.74	23,509,326.20	35.33	34.85
Feb-88	132	16,651,215.46	2,435,769.21	3,005,147.82	1,248,660.39	168,099.56	23,508,892.44	35.36	34.85
Mar-88	133	16,595,389.23	2,484,883.77	3,010,324.53	1,248,168.77	169,692.39	23,508,458.69	35.39	34.84
Apr-88	134	16,539,563.00	2,533,998.33	3,015,501.25	1,247,677.14	171,285.21	23,508,024.94	35.42	34.83
May-88	135	16,483,736.77	2,583,112.89	3,020,677.97	1,247,185.51	172,878.04	23,507,591.18	35.45	34.82
Jun-88	136	16,427,910.54	2,632,227.45	3,025,854.69	1,246,693.88	174,470.87	23,507,157.43	35.48	34.82
Jul-88	137	16,372,084.31	2,681,342.01	3,031,031.41	1,246,202.25	176,063.69	23,506,723.67	35.51	34.81
Aug-88	138	16,316,258.08	2,730,456.57	3,036,208.12	1,245,710.63	177,656.52	23,506,289.92	35.54	34.80
Sep-88	139	16,260,431.85	2,779,571.14	3,041,384.84	1,245,219.00	179,249.34	23,505,856.17	35.57	34.79
Oct-88	140	16,204,605.62	2,828,685.70	3,046,561.56	1,244,727.37	180,842.17	23,505,422.41	35.60	34.79
Nov-88	141	16,148,779.39	2,877,800.26	3,051,738.28	1,244,235.74	182,435.00	23,504,988.66	35.63	34.78
Dec-88	142	16,092,953.16	2,926,914.82	3,056,914.99	1,243,744.11	184,027.82	23,504,554.90	35.66	34.77
Jan-89	143	16,037,126.92	2,976,029.38	3,062,091.71	1,243,252.49	185,620.65	23,504,121.15	35.69	34.76
Feb-89	144	15,981,300.69	3,025,143.94	3,067,268.43	1,242,760.86	187,213.47	23,503,687.40	35.72	34.76
Mar-89	145	15,925,474.46	3,074,258.50	3,072,445.15	1,242,269.23	188,806.30	23,503,253.64	35.74	34.75
Apr-89	146	15,869,648.23	3,123,373.07	3,077,621.86	1,241,777.60	190,399.12	23,502,819.89	35.77	34.74
May-89	147	15,813,822.00	3,172,487.63	3,082,798.58	1,241,285.97	191,991.95	23,502,386.13	35.80	34.73
Jun-89	148	15,757,995.77	3,221,602.19	3,087,975.30	1,240,794.35	193,584.78	23,501,952.38	35.83	34.73
Jul-89	149	15,702,169.54	3,270,716.75	3,093,152.02	1,240,302.72	195,177.60	23,501,518.63	35.86	34.72
Aug-89	150	15,646,343.31	3,319,831.31	3,098,328.73	1,239,811.09	196,770.43	23,501,084.87	35.89	34.71
Sep-89	151	15,590,517.08	3,368,945.87	3,103,505.45	1,239,319.46	198,363.25	23,500,651.12	35.92	34.70
Oct-89	152	15,534,690.85	3,418,060.43	3,108,682.17	1,238,827.83	199,956.08	23,500,217.36	35.95	34.70
Nov-89	153	15,478,864.62	3,467,175.00	3,113,858.89	1,238,336.20	201,548.91	23,499,783.61	35.98	34.69

Year	Data Point	Soil Group A - Land Use (m^2) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.00021
Dec-89	154	15,423,038.39	3,516,289.56	3,119,035.61	1,237,844.58	203,141.73	23,499,349.86	36.01	34.68
Jan-90	155	15,367,212.16	3,565,404.12	3,124,212.32	1,237,352.95	204,734.56	23,498,916.10	36.04	34.67
Feb-90	156	15,311,385.93	3,614,518.68	3,129,389.04	1,236,861.32	206,327.38	23,498,482.35	36.07	34.67
Mar-90	157	15,255,559.69	3,663,633.24	3,134,565.76	1,236,369.69	207,920.21	23,498,048.59	36.10	34.66
Apr-90	158	15,199,733.46	3,712,747.80	3,139,742.48	1,235,878.06	209,513.04	23,497,614.84	36.13	34.65
May-90	159	15,143,907.23	3,761,862.36	3,144,919.19	1,235,386.44	211,105.86	23,497,181.09	36.16	34.64
Jun-90	160	15,088,081.00	3,810,976.92	3,150,095.91	1,234,894.81	212,698.69	23,496,747.33	36.19	34.64
Jul-90	161	15,032,254.77	3,860,091.49	3,155,272.63	1,234,403.18	214,291.51	23,496,313.58	36.21	34.63
Aug-90	162	14,976,428.54	3,909,206.05	3,160,449.35	1,233,911.55	215,884.34	23,495,879.82	36.24	34.62
Sep-90	163	14,920,602.31	3,958,320.61	3,165,626.06	1,233,419.92	217,477.16	23,495,446.07	36.27	34.61
Oct-90	164	14,864,776.08	4,007,435.17	3,170,802.78	1,232,928.30	219,069.99	23,495,012.32	36.30	34.61
Nov-90	165	14,808,949.85	4,056,549.73	3,175,979.50	1,232,436.67	220,662.82	23,494,578.56	36.33	34.60
Dec-90	166	14,753,123.62	4,105,664.29	3,181,156.22	1,231,945.04	222,255.64	23,494,144.81	36.36	34.59
Jan-91	167	14,697,297.39	4,154,778.85	3,186,332.93	1,231,453.41	223,848.47	23,493,711.05	36.39	34.58
Feb-91	168	14,641,471.16	4,203,893.42	3,191,509.65	1,230,961.78	225,441.29	23,493,277.30	36.42	34.58
Mar-91	169	14,585,644.93	4,253,007.98	3,196,686.37	1,230,470.15	227,034.12	23,492,843.55	36.45	34.57
Apr-91	170	14,529,818.69	4,302,122.54	3,201,863.09	1,229,978.53	228,626.95	23,492,409.79	36.48	34.56
May-91	171	14,473,992.46	4,351,237.10	3,207,039.80	1,229,486.90	230,219.77	23,491,976.04	36.51	34.55
Jun-91	172	14,418,166.23	4,400,351.66	3,212,216.52	1,228,995.27	231,812.60	23,491,542.29	36.54	34.55
Jul-91	173	14,362,340.00	4,449,466.22	3,217,393.24	1,228,503.64	233,405.42	23,491,108.53	36.57	34.54
Aug-91	174	14,306,513.77	4,498,580.78	3,222,569.96	1,228,012.01	234,998.25	23,490,674.78	36.60	34.53
Sep-91	175	14,250,687.54	4,547,695.35	3,227,746.68	1,227,520.39	236,591.07	23,490,241.02	36.63	34.52
Oct-91	176	14,194,861.31	4,596,809.91	3,232,923.39	1,227,028.76	238,183.90	23,489,807.27	36.66	34.52
Nov-91	177	14,139,035.08	4,645,924.47	3,238,100.11	1,226,537.13	239,776.73	23,489,373.52	36.69	34.51
Dec-91	178	14,083,208.85	4,695,039.03	3,243,276.83	1,226,045.50	241,369.55	23,488,939.76	36.71	34.50
Jan-92	179	14,027,382.62	4,744,153.59	3,248,453.55	1,225,553.87	242,962.38	23,488,506.01	36.74	34.49

Year	Data Point	Soil Group A - Land Use (m^2) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.00021
Feb-92	180	13,971,556.39	4,793,268.15	3,253,630.26	1,225,062.25	244,555.20	23,488,072.25	36.77	34.49
Mar-92	181	13,915,730.16	4,842,382.71	3,258,806.98	1,224,570.62	246,148.03	23,487,638.50	36.80	34.48
Apr-92	182	13,859,903.93	4,891,497.28	3,263,983.70	1,224,078.99	247,740.86	23,487,204.75	36.83	34.47
May-92	183	13,804,077.70	4,940,611.84	3,269,160.42	1,223,587.36	249,333.68	23,486,770.99	36.86	34.46
Jun-92	184	13,748,251.46	4,989,726.40	3,274,337.13	1,223,095.73	250,926.51	23,486,337.24	36.89	34.46
Jul-92	185	13,692,425.23	5,038,840.96	3,279,513.85	1,222,604.10	252,519.33	23,485,903.48	36.92	34.45
Aug-92	186	13,636,599.00	5,087,955.52	3,284,690.57	1,222,112.48	254,112.16	23,485,469.73	36.95	34.44
Sep-92	187	13,580,772.77	5,137,070.08	3,289,867.29	1,221,620.85	255,704.99	23,485,035.98	36.98	34.43
Oct-92	188	13,524,946.54	5,186,184.64	3,295,044.00	1,221,129.22	257,297.81	23,484,602.22	37.01	34.43
Nov-92	189	13,469,120.31	5,235,299.21	3,300,220.72	1,220,637.59	258,890.64	23,484,168.47	37.04	34.42
Dec-92	190	13,413,294.08	5,284,413.77	3,305,397.44	1,220,145.96	260,483.46	23,483,734.71	37.07	34.41
Jan-93	191	13,357,467.85	5,333,528.33	3,310,574.16	1,219,654.34	262,076.29	23,483,300.96	37.10	34.40
Feb-93	192	13,301,641.62	5,382,642.89	3,315,750.88	1,219,162.71	263,669.11	23,482,867.21	37.13	34.40
Mar-93	193	13,245,815.39	5,431,757.45	3,320,927.59	1,218,671.08	265,261.94	23,482,433.45	37.16	34.39
Apr-93	194	13,189,989.16	5,480,872.01	3,326,104.31	1,218,179.45	266,854.77	23,481,999.70	37.19	34.38
May-93	195	13,134,162.93	5,529,986.57	3,331,281.03	1,217,687.82	268,447.59	23,481,565.94	37.22	34.37
Jun-93	196	13,078,336.70	5,579,101.14	3,336,457.75	1,217,196.20	270,040.42	23,481,132.19	37.24	34.37
Jul-93	197	13,022,510.46	5,628,215.70	3,341,634.46	1,216,704.57	271,633.24	23,480,698.44	37.27	34.36
Aug-93	198	12,966,684.23	5,677,330.26	3,346,811.18	1,216,212.94	273,226.07	23,480,264.68	37.30	34.35
Sep-93	199	12,910,858.00	5,726,444.82	3,351,987.90	1,215,721.31	274,818.90	23,479,830.93	37.33	34.34
Oct-93	200	12,855,031.77	5,775,559.38	3,357,164.62	1,215,229.68	276,411.72	23,479,397.17	37.36	34.34
Nov-93	201	12,799,205.54	5,824,673.94	3,362,341.33	1,214,738.05	278,004.55	23,478,963.42	37.39	34.33
Dec-93	202	12,743,379.31	5,873,788.50	3,367,518.05	1,214,246.43	279,597.37	23,478,529.67	37.42	34.32
Jan-94	203	12,687,553.08	5,922,903.06	3,372,694.77	1,213,754.80	281,190.20	23,478,095.91	37.45	34.31
Feb-94	204	12,631,726.85	5,972,017.63	3,377,871.49	1,213,263.17	282,783.03	23,477,662.16	37.48	34.31
Mar-94	205	12,575,900.62	6,021,132.19	3,383,048.20	1,212,771.54	284,375.85	23,477,228.40	37.51	34.30

Year	Data Point	Soil Group A - Land Use (m^2) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.00021
Apr-94	206	12,520,074.39	6,070,246.75	3,388,224.92	1,212,279.91	285,968.68	23,476,794.65	37.54	34.29
May-94	207	12,464,248.16	6,119,361.31	3,393,401.64	1,211,788.29	287,561.50	23,476,360.90	37.57	34.28
Jun-94	208	12,408,421.93	6,168,475.87	3,398,578.36	1,211,296.66	289,154.33	23,475,927.14	37.60	34.28
Jul-94	209	12,352,595.70	6,217,590.43	3,403,755.08	1,210,805.03	290,747.15	23,475,493.39	37.63	34.27
Aug-94	210	12,296,769.46	6,266,704.99	3,408,931.79	1,210,313.40	292,339.98	23,475,059.64	37.66	34.26
Sep-94	211	12,240,943.23	6,315,819.56	3,414,108.51	1,209,821.77	293,932.81	23,474,625.88	37.69	34.26
Oct-94	212	12,185,117.00	6,364,934.12	3,419,285.23	1,209,330.15	295,525.63	23,474,192.13	37.72	34.25
Nov-94	213	12,129,290.77	6,414,048.68	3,424,461.95	1,208,838.52	297,118.46	23,473,758.37	37.75	34.24
Dec-94	214	12,073,464.54	6,463,163.24	3,429,638.66	1,208,346.89	298,711.28	23,473,324.62	37.77	34.23
Jan-95	215	12,017,638.31	6,512,277.80	3,434,815.38	1,207,855.26	300,304.11	23,472,890.87	37.80	34.23
Feb-95	216	11,961,812.08	6,561,392.36	3,439,992.10	1,207,363.63	301,896.94	23,472,457.11	37.83	34.22
Mar-95	217	11,905,985.85	6,610,506.92	3,445,168.82	1,206,872.00	303,489.76	23,472,023.36	37.86	34.21
Apr-95	218	11,850,159.62	6,659,621.49	3,450,345.53	1,206,380.38	305,082.59	23,471,589.60	37.89	34.20
May-95	219	11,794,333.39	6,708,736.05	3,455,522.25	1,205,888.75	306,675.41	23,471,155.85	37.92	34.20
Jun-95	220	11,738,507.16	6,757,850.61	3,460,698.97	1,205,397.12	308,268.24	23,470,722.10	37.95	34.19
Jul-95	221	11,682,680.93	6,806,965.17	3,465,875.69	1,204,905.49	309,861.07	23,470,288.34	37.98	34.18
Aug-95	222	11,626,854.70	6,856,079.73	3,471,052.40	1,204,413.86	311,453.89	23,469,854.59	38.01	34.17
Sep-95	223	11,571,028.47	6,905,194.29	3,476,229.12	1,203,922.24	313,046.72	23,469,420.83	38.04	34.17
Oct-95	224	11,515,202.23	6,954,308.85	3,481,405.84	1,203,430.61	314,639.54	23,468,987.08	38.07	34.16
Nov-95	225	11,459,376.00	7,003,423.42	3,486,582.56	1,202,938.98	316,232.37	23,468,553.33	38.10	34.15
Dec-95	226	11,403,549.77	7,052,537.98	3,491,759.28	1,202,447.35	317,825.19	23,468,119.57	38.13	34.14
Jan-96	227	11,347,723.54	7,101,652.54	3,496,935.99	1,201,955.72	319,418.02	23,467,685.82	38.16	34.14
Feb-96	228	11,291,897.31	7,150,767.10	3,502,112.71	1,201,464.10	321,010.85	23,467,252.06	38.19	34.13
Mar-96	229	11,236,071.08	7,199,881.66	3,507,289.43	1,200,972.47	322,603.67	23,466,818.31	38.22	34.12
Apr-96	230	11,180,244.85	7,248,996.22	3,512,466.15	1,200,480.84	324,196.50	23,466,384.56	38.25	34.11
May-96	231	11,124,418.62	7,298,110.78	3,517,642.86	1,199,989.21	325,789.32	23,465,950.80	38.28	34.11

Year	Data Point	Soil Group A - Land Use (m^2) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.000216
Jun-96	232	11,068,592.39	7,347,225.35	3,522,819.58	1,199,497.58	327,382.15	23,465,517.05	38.31	34.10
Jul-96	233	11,012,766.16	7,396,339.91	3,527,996.30	1,199,005.96	328,974.98	23,465,083.29	38.33	34.09
Aug-96	234	10,956,939.93	7,445,454.47	3,533,173.02	1,198,514.33	330,567.80	23,464,649.54	38.36	34.08
Sep-96	235	10,901,113.70	7,494,569.03	3,538,349.73	1,198,022.70	332,160.63	23,464,215.79	38.39	34.08
Oct-96	236	10,845,287.47	7,543,683.59	3,543,526.45	1,197,531.07	333,753.45	23,463,782.03	38.42	34.07
Nov-96	237	10,789,461.23	7,592,798.15	3,548,703.17	1,197,039.44	335,346.28	23,463,348.28	38.45	34.06
Dec-96	238	10,733,635.00	7,641,912.71	3,553,879.89	1,196,547.81	336,939.11	23,462,914.52	38.48	34.06
Jan-97	239	10,677,808.77	7,691,027.28	3,559,056.60	1,196,056.19	338,531.93	23,462,480.77	38.51	34.05
Feb-97	240	10,621,982.54	7,740,141.84	3,564,233.32	1,195,564.56	340,124.76	23,462,047.02	38.54	34.04
Mar-97	241	10,566,156.31	7,789,256.40	3,569,410.04	1,195,072.93	341,717.58	23,461,613.26	38.57	34.03
Apr-97	242	10,510,330.08	7,838,370.96	3,574,586.76	1,194,581.30	343,310.41	23,461,179.51	38.60	34.03
May-97	243	10,454,503.85	7,887,485.52	3,579,763.48	1,194,089.67	344,903.23	23,460,745.75	38.63	34.02
Jun-97	244	10,398,677.62	7,936,600.08	3,584,940.19	1,193,598.05	346,496.06	23,460,312.00	38.66	34.01
Jul-97	245	10,342,851.39	7,985,714.64	3,590,116.91	1,193,106.42	348,088.89	23,459,878.25	38.69	34.00
Aug-97	246	10,287,025.16	8,034,829.20	3,595,293.63	1,192,614.79	349,681.71	23,459,444.49	38.72	34.00
Sep-97	247	10,231,198.93	8,083,943.77	3,600,470.35	1,192,123.16	351,274.54	23,459,010.74	38.75	33.99
Oct-97	248	10,175,372.70	8,133,058.33	3,605,647.06	1,191,631.53	352,867.36	23,458,576.99	38.78	33.98
Nov-97	249	10,119,546.47	8,182,172.89	3,610,823.78	1,191,139.91	354,460.19	23,458,143.23	38.81	33.97
Dec-97	250	10,063,720.24	8,231,287.45	3,616,000.50	1,190,648.28	356,053.02	23,457,709.48	38.84	33.97
Jan-98	251	10,007,894.00	8,280,402.01	3,621,177.22	1,190,156.65	357,645.84	23,457,275.72	38.87	33.96
Feb-98	252	9,952,067.77	8,329,516.57	3,626,353.93	1,189,665.02	359,238.67	23,456,841.97	38.89	33.95
Mar-98	253	9,896,241.54	8,378,631.13	3,631,530.65	1,189,173.39	360,831.49	23,456,408.22	38.92	33.94
Apr-98	254	9,840,415.31	8,427,745.70	3,636,707.37	1,188,681.76	362,424.32	23,455,974.46	38.95	33.94
May-98	255	9,784,589.08	8,476,860.26	3,641,884.09	1,188,190.14	364,017.15	23,455,540.71	38.98	33.93
Jun-98	256	9,728,762.85	8,525,974.82	3,647,060.80	1,187,698.51	365,609.97	23,455,106.95	39.01	33.92
Jul-98	257	9,672,936.62	8,575,089.38	3,652,237.52	1,187,206.88	367,202.80	23,454,673.20	39.04	33.92

Year	Data Point	Soil Group A - Land Use (m^2) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.000216
Aug-98	258	9,617,110.39	8,624,203.94	3,657,414.24	1,186,715.25	368,795.62	23,454,239.45	39.07	33.91
Sep-98	259	9,561,284.16	8,673,318.50	3,662,590.96	1,186,223.62	370,388.45	23,453,805.69	39.10	33.90
Oct-98	260	9,505,457.93	8,722,433.06	3,667,767.68	1,185,732.00	371,981.27	23,453,371.94	39.13	33.89
Nov-98	261	9,449,631.70	8,771,547.63	3,672,944.39	1,185,240.37	373,574.10	23,452,938.18	39.16	33.89
Dec-98	262	9,393,805.47	8,820,662.19	3,678,121.11	1,184,748.74	375,166.93	23,452,504.43	39.19	33.88
Jan-99	263	9,337,979.24	8,869,776.75	3,683,297.83	1,184,257.11	376,759.75	23,452,070.68	39.22	33.87
Feb-99	264	9,282,153.00	8,918,891.31	3,688,474.55	1,183,765.48	378,352.58	23,451,636.92	39.25	33.86
Mar-99	265	9,226,326.77	8,968,005.87	3,693,651.26	1,183,273.86	379,945.40	23,451,203.17	39.28	33.86
Apr-99	266	9,170,500.54	9,017,120.43	3,698,827.98	1,182,782.23	381,538.23	23,450,769.41	39.31	33.85
May-99	267	9,114,674.31	9,066,234.99	3,704,004.70	1,182,290.60	383,131.06	23,450,335.66	39.34	33.84
Jun-99	268	9,058,848.08	9,115,349.56	3,709,181.42	1,181,798.97	384,723.88	23,449,901.91	39.37	33.83
Jul-99	269	9,003,021.85	9,164,464.12	3,714,358.13	1,181,307.34	386,316.71	23,449,468.15	39.40	33.83
Aug-99	270	8,947,195.62	9,213,578.68	3,719,534.85	1,180,815.71	387,909.53	23,449,034.40	39.43	33.82
Sep-99	271	8,891,369.39	9,262,693.24	3,724,711.57	1,180,324.09	389,502.36	23,448,600.64	39.46	33.81
Oct-99	272	8,835,543.16	9,311,807.80	3,729,888.29	1,179,832.46	391,095.18	23,448,166.89	39.48	33.81
Nov-99	273	8,779,716.93	9,360,922.36	3,735,065.00	1,179,340.83	392,688.01	23,447,733.14	39.51	33.80
Dec-99	274	8,723,890.70	9,410,036.92	3,740,241.72	1,178,849.20	394,280.84	23,447,299.38	39.54	33.79
Jan-00	275	8,668,064.47	9,459,151.49	3,745,418.44	1,178,357.57	395,873.66	23,446,865.63	39.57	33.78
Feb-00	276	8,612,238.24	9,508,266.05	3,750,595.16	1,177,865.95	397,466.49	23,446,431.87	39.60	33.78
Mar-00	277	8,556,412.01	9,557,380.61	3,755,771.88	1,177,374.32	399,059.31	23,445,998.12	39.63	33.77
Apr-00	278	8,500,585.77	9,606,495.17	3,760,948.59	1,176,882.69	400,652.14	23,445,564.37	39.66	33.76
May-00	279	8,444,759.54	9,655,609.73	3,766,125.31	1,176,391.06	402,244.97	23,445,130.61	39.69	33.75
Jun-00	280	8,388,933.31	9,704,724.29	3,771,302.03	1,175,899.43	403,837.79	23,444,696.86	39.72	33.75
Jul-00	281	8,333,107.08	9,753,838.85	3,776,478.75	1,175,407.81	405,430.62	23,444,263.10	39.75	33.74
Aug-00	282	8,277,280.85	9,802,953.42	3,781,655.46	1,174,916.18	407,023.44	23,443,829.35	39.78	33.73
Sep-00	283	8,221,454.62	9,852,067.98	3,786,832.18	1,174,424.55	408,616.27	23,443,395.60	39.81	33.73

Year	Data Point / Land Cover / CN Numbers	Soil Group A - Land Use (m^2) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.000216
Oct-00	284	8,165,628.39	9,901,182.54	3,792,008.90	1,173,932.92	410,209.10	23,442,961.84	39.84	33.72
Nov-00	285	8,109,802.16	9,950,297.10	3,797,185.62	1,173,441.29	411,801.92	23,442,528.09	39.87	33.71
Dec-00	286	8,053,975.93	9,999,411.66	3,802,362.33	1,172,949.66	413,394.75	23,442,094.34	39.90	33.70
Jan-01	287	7,998,149.70	10,048,526.22	3,807,539.05	1,172,458.04	414,987.57	23,441,660.58	39.93	33.70
Feb-01	288	7,942,323.47	10,097,640.78	3,812,715.77	1,171,966.41	416,580.40	23,441,226.83	39.96	33.69
Mar-01	289	7,886,497.24	10,146,755.34	3,817,892.49	1,171,474.78	418,173.22	23,440,793.07	39.99	33.68
Apr-01	290	7,830,671.01	10,195,869.91	3,823,069.20	1,170,983.15	419,766.05	23,440,359.32	40.02	33.67
May-01	291	7,774,844.77	10,244,984.47	3,828,245.92	1,170,491.52	421,358.88	23,439,925.57	40.05	33.67
Jun-01	292	7,719,018.54	10,294,099.03	3,833,422.64	1,169,999.90	422,951.70	23,439,491.81	40.08	33.66
Jul-01	293	7,663,192.31	10,343,213.59	3,838,599.36	1,169,508.27	424,544.53	23,439,058.06	40.11	33.65
Aug-01	294	7,607,366.08	10,392,328.15	3,843,776.07	1,169,016.64	426,137.35	23,438,624.30	40.13	33.64
Sep-01	295	7,551,539.85	10,441,442.71	3,848,952.79	1,168,525.01	427,730.18	23,438,190.55	40.16	33.64
Oct-01	296	7,495,713.62	10,490,557.27	3,854,129.51	1,168,033.38	429,323.01	23,437,756.80	40.19	33.63
Nov-01	297	7,439,887.39	10,539,671.84	3,859,306.23	1,167,541.76	430,915.83	23,437,323.04	40.22	33.62
Dec-01	298	7,384,061.16	10,588,786.40	3,864,482.95	1,167,050.13	432,508.66	23,436,889.29	40.25	33.62
Jan-02	299	7,328,234.93	10,637,900.96	3,869,659.66	1,166,558.50	434,101.48	23,436,455.53	40.28	33.61
Feb-02	300	7,272,408.70	10,687,015.52	3,874,836.38	1,166,066.87	435,694.31	23,436,021.78	40.31	33.60
Mar-02	301	7,216,582.47	10,736,130.08	3,880,013.10	1,165,575.24	437,287.14	23,435,588.03	40.34	33.59
Apr-02	302	7,160,756.24	10,785,244.64	3,885,189.82	1,165,083.61	438,879.96	23,435,154.27	40.37	33.59
May-02	303	7,104,930.01	10,834,359.20	3,890,366.53	1,164,591.99	440,472.79	23,434,720.52	40.40	33.58
Jun-02	304	7,049,103.78	10,883,473.77	3,895,543.25	1,164,100.36	442,065.61	23,434,286.76	40.43	33.57
Jul-02	305	6,993,277.54	10,932,588.33	3,900,719.97	1,163,608.73	443,658.44	23,433,853.01	40.46	33.56
Aug-02	306	6,937,451.31	10,981,702.89	3,905,896.69	1,163,117.10	445,251.26	23,433,419.26	40.49	33.56
Sep-02	307	6,881,625.08	11,030,817.45	3,911,073.40	1,162,625.47	446,844.09	23,432,985.50	40.52	33.55
Oct-02	308	6,825,798.85	11,079,932.01	3,916,250.12	1,162,133.85	448,436.92	23,432,551.75	40.55	33.54
Nov-02	309	6,769,972.62	11,129,046.57	3,921,426.84	1,161,642.22	450,029.74	23,432,117.99	40.58	33.54

Year	Data Point	Soil Group A - Land Use (m^2) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.000216
Dec-02	310	6,714,146.39	11,178,161.13	3,926,603.56	1,161,150.59	451,622.57	23,431,684.24	40.61	33.53
Jan-03	311	6,658,320.16	11,227,275.70	3,931,780.27	1,160,658.96	453,215.39	23,431,250.49	40.64	33.52
Feb-03	312	6,602,493.93	11,276,390.26	3,936,956.99	1,160,167.33	454,808.22	23,430,816.73	40.67	33.51
Mar-03	313	6,546,667.70	11,325,504.82	3,942,133.71	1,159,675.71	456,401.05	23,430,382.98	40.70	33.51
Apr-03	314	6,490,841.47	11,374,619.38	3,947,310.43	1,159,184.08	457,993.87	23,429,949.22	40.73	33.50
May-03	315	6,435,015.24	11,423,733.94	3,952,487.15	1,158,692.45	459,586.70	23,429,515.47	40.76	33.49
Jun-03	316	6,379,189.01	11,472,848.50	3,957,663.86	1,158,200.82	461,179.52	23,429,081.72	40.78	33.48
Jul-03	317	6,323,362.78	11,521,963.06	3,962,840.58	1,157,709.19	462,772.35	23,428,647.96	40.81	33.48
Aug-03	318	6,267,536.54	11,571,077.63	3,968,017.30	1,157,217.57	464,365.18	23,428,214.21	40.84	33.47
Sep-03	319	6,211,710.31	11,620,192.19	3,973,194.02	1,156,725.94	465,958.00	23,427,780.45	40.87	33.46
Oct-03	320	6,155,884.08	11,669,306.75	3,978,370.73	1,156,234.31	467,550.83	23,427,346.70	40.90	33.46
Nov-03	321	6,100,057.85	11,718,421.31	3,983,547.45	1,155,742.68	469,143.65	23,426,912.95	40.93	33.45
Dec-03	322	6,044,231.62	11,767,535.87	3,988,724.17	1,155,251.05	470,736.48	23,426,479.19	40.96	33.44
Jan-04	323	5,988,405.39	11,816,650.43	3,993,900.89	1,154,759.42	472,329.30	23,426,045.44	40.99	33.43
Feb-04	324	5,932,579.16	11,865,764.99	3,999,077.60	1,154,267.80	473,922.13	23,425,611.69	41.02	33.43
Mar-04	325	5,876,752.93	11,914,879.56	4,004,254.32	1,153,776.17	475,514.96	23,425,177.93	41.05	33.42
Apr-04	326	5,820,926.70	11,963,994.12	4,009,431.04	1,153,284.54	477,107.78	23,424,744.18	41.08	33.41
May-04	327	5,765,100.47	12,013,108.68	4,014,607.76	1,152,792.91	478,700.61	23,424,310.42	41.11	33.41
Jun-04	328	5,709,274.24	12,062,223.24	4,019,784.47	1,152,301.28	480,293.43	23,423,876.67	41.14	33.40
Jul-04	329	5,653,448.01	12,111,337.80	4,024,961.19	1,151,809.66	481,886.26	23,423,442.92	41.17	33.39
Aug-04	330	5,597,621.78	12,160,452.36	4,030,137.91	1,151,318.03	483,479.09	23,423,009.16	41.20	33.38
Sep-04	331	5,541,795.54	12,209,566.92	4,035,314.63	1,150,826.40	485,071.91	23,422,575.41	41.23	33.38
Oct-04	332	5,485,969.31	12,258,681.48	4,040,491.35	1,150,334.77	486,664.74	23,422,141.65	41.26	33.37
Nov-04	333	5,430,143.08	12,307,796.05	4,045,668.06	1,149,843.14	488,257.56	23,421,707.90	41.29	33.36
Dec-04	334	5,374,316.85	12,356,910.61	4,050,844.78	1,149,351.52	489,850.39	23,421,274.15	41.32	33.35
Jan-05	335	5,318,490.62	12,406,025.17	4,056,021.50	1,148,859.89	491,443.22	23,420,840.39	41.35	33.35

Year	Data Point	Soil Group A - Land Use (m³) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.000216
Feb-05	336	5,262,664.39	12,455,139.73	4,061,198.22	1,148,368.26	493,036.04	23,420,406.64	41.38	33.34
Mar-05	337	5,206,838.16	12,504,254.29	4,066,374.93	1,147,876.63	494,628.87	23,419,972.88	41.41	33.33
Apr-05	338	5,151,011.93	12,553,368.85	4,071,551.65	1,147,385.00	496,221.69	23,419,539.13	41.44	33.33
May-05	339	5,095,185.70	12,602,483.41	4,076,728.37	1,146,893.37	497,814.52	23,419,105.38	41.47	33.32
Jun-05	340	5,039,359.47	12,651,597.98	4,081,905.09	1,146,401.75	499,407.34	23,418,671.62	41.49	33.31
Jul-05	341	4,983,533.24	12,700,712.54	4,087,081.80	1,145,910.12	501,000.17	23,418,237.87	41.52	33.30
Aug-05	342	4,927,707.01	12,749,827.10	4,092,258.52	1,145,418.49	502,593.00	23,417,804.11	41.55	33.30
Sep-05	343	4,871,880.78	12,798,941.66	4,097,435.24	1,144,926.86	504,185.82	23,417,370.36	41.58	33.29
Oct-05	344	4,816,054.55	12,848,056.22	4,102,611.96	1,144,435.23	505,778.65	23,416,936.61	41.61	33.28
Nov-05	345	4,760,228.31	12,897,170.78	4,107,788.67	1,143,943.61	507,371.47	23,416,502.85	41.64	33.28
Dec-05	346	4,704,402.08	12,946,285.34	4,112,965.39	1,143,451.98	508,964.30	23,416,069.10	41.67	33.27
Jan-06	347	4,648,575.85	12,995,399.91	4,118,142.11	1,142,960.35	510,557.13	23,415,635.34	41.70	33.26
Feb-06	348	4,592,749.62	13,044,514.47	4,123,318.83	1,142,468.72	512,149.95	23,415,201.59	41.73	33.25
Mar-06	349	4,536,923.39	13,093,629.03	4,128,495.55	1,141,977.09	513,742.78	23,414,767.84	41.76	33.25
Apr-06	350	4,481,097.16	13,142,743.59	4,133,672.26	1,141,485.47	515,335.60	23,414,334.08	41.79	33.24
May-06	351	4,425,270.93	13,191,858.15	4,138,848.98	1,140,993.84	516,928.43	23,413,900.33	41.82	33.23
Jun-06	352	4,369,444.70	13,240,972.71	4,144,025.70	1,140,502.21	518,521.26	23,413,466.57	41.85	33.22
Jul-06	353	4,313,618.47	13,290,087.27	4,149,202.42	1,140,010.58	520,114.08	23,413,032.82	41.88	33.22
Aug-06	354	4,257,792.24	13,339,201.84	4,154,379.13	1,139,518.95	521,706.91	23,412,599.07	41.91	33.21
Sep-06	355	4,201,966.01	13,388,316.40	4,159,555.85	1,139,027.32	523,299.73	23,412,165.31	41.94	33.20
Oct-06	356	4,146,139.78	13,437,430.96	4,164,732.57	1,138,535.70	524,892.56	23,411,731.56	41.97	33.20
Nov-06	357	4,090,313.55	13,486,545.52	4,169,909.29	1,138,044.07	526,485.38	23,411,297.80	42.00	33.19
Dec-06	358	4,034,487.31	13,535,660.08	4,175,086.00	1,137,552.44	528,078.21	23,410,864.05	42.03	33.18
Jan-07	359	3,978,661.08	13,584,774.64	4,180,262.72	1,137,060.81	529,671.04	23,410,430.30	42.06	33.17
Feb-07	360	3,922,834.85	13,633,889.20	4,185,439.44	1,136,569.18	531,263.86	23,409,996.54	42.09	33.17
Mar-07	361	3,867,008.62	13,683,003.77	4,190,616.16	1,136,077.56	532,856.69	23,409,562.79	42.12	33.16

Year	Data Point	Soil Group A - Land Use (m^2) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.000216
Apr-07	362	3,811,182.39	13,732,118.33	4,195,792.87	1,135,585.93	534,449.51	23,409,129.03	42.15	33.15
May-07	363	3,755,356.16	13,781,232.89	4,200,969.59	1,135,094.30	536,042.34	23,408,695.28	42.18	33.15
Jun-07	364	3,699,529.93	13,830,347.45	4,206,146.31	1,134,602.67	537,635.17	23,408,261.53	42.21	33.14
Jul-07	365	3,643,703.70	13,879,462.01	4,211,323.03	1,134,111.04	539,227.99	23,407,827.77	42.23	33.13
Aug-07	366	3,587,877.47	13,928,576.57	4,216,499.75	1,133,619.42	540,820.82	23,407,394.02	42.26	33.12
Sep-07	367	3,532,051.24	13,977,691.13	4,221,676.46	1,133,127.79	542,413.64	23,406,960.27	42.29	33.12
Oct-07	368	3,476,225.01	14,026,805.70	4,226,853.18	1,132,636.16	544,006.47	23,406,526.51	42.32	33.11
Nov-07	369	3,420,398.78	14,075,920.26	4,232,029.90	1,132,144.53	545,599.29	23,406,092.76	42.35	33.10
Dec-07	370	3,364,572.55	14,125,034.82	4,237,206.62	1,131,652.90	547,192.12	23,405,659.00	42.38	33.10
Jan-08	371	3,308,746.32	14,174,149.38	4,242,383.33	1,131,161.27	548,784.95	23,405,225.25	42.41	33.09
Feb-08	372	3,252,920.08	14,223,263.94	4,247,560.05	1,130,669.65	550,377.77	23,404,791.50	42.44	33.08
Mar-08	373	3,197,093.85	14,272,378.50	4,252,736.77	1,130,178.02	551,970.60	23,404,357.74	42.47	33.07
Apr-08	374	3,141,267.62	14,321,493.06	4,257,913.49	1,129,686.39	553,563.42	23,403,923.99	42.50	33.07
May-08	375	3,085,441.39	14,370,607.62	4,263,090.20	1,129,194.76	555,156.25	23,403,490.23	42.53	33.06
Jun-08	376	3,029,615.16	14,419,722.19	4,268,266.92	1,128,703.13	556,749.08	23,403,056.48	42.56	33.05
Jul-08	377	2,973,788.93	14,468,836.75	4,273,443.64	1,128,211.51	558,341.90	23,402,622.73	42.59	33.05
Aug-08	378	2,917,962.70	14,517,951.31	4,278,620.36	1,127,719.88	559,934.73	23,402,188.97	42.62	33.04
Sep-08	379	2,862,136.47	14,567,065.87	4,283,797.07	1,127,228.25	561,527.55	23,401,755.22	42.65	33.03
Oct-08	380	2,806,310.24	14,616,180.43	4,288,973.79	1,126,736.62	563,120.38	23,401,321.46	42.68	33.02
Nov-08	381	2,750,484.01	14,665,294.99	4,294,150.51	1,126,244.99	564,713.21	23,400,887.71	42.71	33.02
Dec-08	382	2,694,657.78	14,714,409.55	4,299,327.23	1,125,753.37	566,306.03	23,400,453.96	42.74	33.01
Jan-09	383	2,638,831.55	14,763,524.12	4,304,503.95	1,125,261.74	567,898.86	23,400,020.20	42.77	33.00
Feb-09	384	2,583,005.32	14,812,638.68	4,309,680.66	1,124,770.11	569,491.68	23,399,586.45	42.80	33.00
Mar-09	385	2,527,179.08	14,861,753.24	4,314,857.38	1,124,278.48	571,084.51	23,399,152.69	42.83	32.99
Apr-09	386	2,471,352.85	14,910,867.80	4,320,034.10	1,123,786.85	572,677.33	23,398,718.94	42.86	32.98
May-09	387	2,415,526.62	14,959,982.36	4,325,210.82	1,123,295.23	574,270.16	23,398,285.19	42.89	32.97

Year	Data Point	Soil Group A - Land Use (m²) & CN							Interpolation Function
	Land Cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Numbers	32.00	44.00	39.00	49.00	77.00			Rate = -0.000216
Jun-09	388	2,359,700.39	15,009,096.92	4,330,387.53	1,122,803.60	575,862.99	23,397,851.43	42.92	32.97
Jul-09	389	2,303,874.16	15,058,211.48	4,335,564.25	1,122,311.97	577,455.81	23,397,417.68	42.95	32.96
Aug-09	390	2,248,047.93	15,107,326.05	4,340,740.97	1,121,820.34	579,048.64	23,396,983.92	42.98	32.95
Sep-09	391	2,192,221.70	15,156,440.61	4,345,917.69	1,121,328.71	580,641.46	23,396,550.17	43.01	32.95
Oct-09	392	2,136,395.47	15,205,555.17	4,351,094.40	1,120,837.08	582,234.29	23,396,116.42	43.04	32.94
Nov-09	393	2,080,569.24	15,254,669.73	4,356,271.12	1,120,345.46	583,827.12	23,395,682.66	43.06	32.93
Dec-09	394	2,024,743.01	15,303,784.29	4,361,447.84	1,119,853.83	585,419.94	23,395,248.91	43.09	32.92
Jan-10	395	1,968,916.78	15,352,898.85	4,366,624.56	1,119,362.20	587,012.77	23,394,815.15	43.12	32.92
Feb-10	396	1,913,090.55	15,402,013.41	4,371,801.27	1,118,870.57	588,605.59	23,394,381.40	43.15	32.91

(e) Land Cover interpolation of Soil Group B of Lake Bosumtwi

Year		Soil Group B - Land Use (m²) & CN							Interpolation Function
	Land cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
Mar-77	1	18,015,007.80	209,805.31	8,494,090.64	5,252,386.46	-	31,971,290.21	69.32	69.47
Apr-77	2	17,968,862.16	240,849.08	8,510,221.08	5,245,268.24	-	31,965,200.57	69.32	69.46
May-77	3	17,922,716.53	271,892.85	8,526,351.52	5,238,150.02	-	31,959,110.93	69.31	69.44
Jun-77	4	17,876,570.90	302,936.62	8,542,481.96	5,231,031.80	-	31,953,021.29	69.31	69.43
Jul-77	5	17,830,425.27	333,980.39	8,558,612.40	5,223,913.58	-	31,946,931.64	69.30	69.41
Aug-77	6	17,784,279.64	365,024.16	8,574,742.84	5,216,795.37	-	31,940,842.00	69.29	69.40
Sep-77	7	17,738,134.01	396,067.93	8,590,873.28	5,209,677.15	-	31,934,752.36	69.29	69.38
Oct-77	8	17,691,988.38	427,111.69	8,607,003.72	5,202,558.93	-	31,928,662.72	69.28	69.37
Nov-77	9	17,645,842.75	458,155.46	8,623,134.16	5,195,440.71	-	31,922,573.08	69.28	69.35
Dec-77	10	17,599,697.12	489,199.23	8,639,264.60	5,188,322.49	-	31,916,483.43	69.27	69.34

Year	Land cover	Soil Group B - Land Use (m^2) & CN							Interpolation Function
		Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
Jan-78	11	17,553,551.48	520,243.00	8,655,395.04	5,181,204.27	-	31,910,393.79	69.27	69.32
Feb-78	12	17,507,405.85	551,286.77	8,671,525.48	5,174,086.05	-	31,904,304.15	69.26	69.31
Mar-78	13	17,461,260.22	582,330.54	8,687,655.92	5,166,967.83	-	31,898,214.51	69.26	69.29
Apr-78	14	17,415,114.59	613,374.30	8,703,786.36	5,159,849.61	-	31,892,124.87	69.25	69.28
May-78	15	17,368,968.96	644,418.07	8,719,916.80	5,152,731.39	-	31,886,035.22	69.25	69.26
Jun-78	16	17,322,823.33	675,461.84	8,736,047.24	5,145,613.17	-	31,879,945.58	69.24	69.25
Jul-78	17	17,276,677.70	706,505.61	8,752,177.69	5,138,494.95	-	31,873,855.94	69.23	69.23
Aug-78	18	17,230,532.07	737,549.38	8,768,308.13	5,131,376.73	-	31,867,766.30	69.23	69.22
Sep-78	19	17,184,386.44	768,593.15	8,784,438.57	5,124,258.51	-	31,861,676.66	69.22	69.20
Oct-78	20	17,138,240.80	799,636.91	8,800,569.01	5,117,140.29	-	31,855,587.01	69.22	69.19
Nov-78	21	17,092,095.17	830,680.68	8,816,699.45	5,110,022.07	-	31,849,497.37	69.21	69.17
Dec-78	22	17,045,949.54	861,724.45	8,832,829.89	5,102,903.85	-	31,843,407.73	69.21	69.16
Jan-79	23	16,999,803.91	892,768.22	8,848,960.33	5,095,785.63	-	31,837,318.09	69.20	69.14
Feb-79	24	16,953,658.28	923,811.99	8,865,090.77	5,088,667.41	-	31,831,228.44	69.20	69.13
Mar-79	25	16,907,512.65	954,855.76	8,881,221.21	5,081,549.19	-	31,825,138.80	69.19	69.11
Apr-79	26	16,861,367.02	985,899.52	8,897,351.65	5,074,430.97	-	31,819,049.16	69.18	69.10
May-79	27	16,815,221.39	1,016,943.29	8,913,482.09	5,067,312.75	-	31,812,959.52	69.18	69.08
Jun-79	28	16,769,075.76	1,047,987.06	8,929,612.53	5,060,194.53	-	31,806,869.88	69.17	69.07
Jul-79	29	16,722,930.12	1,079,030.83	8,945,742.97	5,053,076.31	1,790.70	31,802,570.93	69.16	69.05
Aug-79	30	16,676,784.49	1,110,074.60	8,961,873.41	5,045,958.09	6,590.40	31,801,280.99	69.15	69.04
Sep-79	31	16,630,638.86	1,141,118.37	8,978,003.85	5,038,839.87	11,390.10	31,799,991.05	69.13	69.02
Oct-79	32	16,584,493.23	1,172,162.13	8,994,134.29	5,031,721.65	16,189.80	31,798,701.11	69.12	69.01
Nov-79	33	16,538,347.60	1,203,205.90	9,010,264.73	5,024,603.43	20,989.51	31,797,411.17	69.10	68.99
Dec-79	34	16,492,201.97	1,234,249.67	9,026,395.17	5,017,485.21	25,789.21	31,796,121.23	69.08	68.98
Jan-80	35	16,446,056.34	1,265,293.44	9,042,525.61	5,010,366.99	30,588.91	31,794,831.29	69.07	68.96
Feb-80	36	16,399,910.71	1,296,337.21	9,058,656.05	5,003,248.77	35,388.61	31,793,541.35	69.05	68.95

Year	Land cover	Soil Group B - Land Use (m^2) & CN							Interpolation Function
		Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
Mar-80	37	16,353,765.08	1,327,380.98	9,074,786.49	4,996,130.55	40,188.32	31,792,251.41	69.04	68.93
Apr-80	38	16,307,619.44	1,358,424.75	9,090,916.94	4,989,012.33	44,988.02	31,790,961.47	69.02	68.92
May-80	39	16,261,473.81	1,389,468.51	9,107,047.38	4,981,894.11	49,787.72	31,789,671.53	69.00	68.90
Jun-80	40	16,215,328.18	1,420,512.28	9,123,177.82	4,974,775.89	54,587.42	31,788,381.59	68.99	68.89
Jul-80	41	16,169,182.55	1,451,556.05	9,139,308.26	4,967,657.67	59,387.12	31,787,091.65	68.97	68.87
Aug-80	42	16,123,036.92	1,482,599.82	9,155,438.70	4,960,539.45	64,186.83	31,785,801.71	68.96	68.86
Sep-80	43	16,076,891.29	1,513,643.59	9,171,569.14	4,953,421.23	68,986.53	31,784,511.77	68.94	68.84
Oct-80	44	16,030,745.66	1,544,687.36	9,187,699.58	4,946,303.01	73,786.23	31,783,221.83	68.92	68.83
Nov-80	45	15,984,600.03	1,575,731.12	9,203,830.02	4,939,184.79	78,585.93	31,781,931.89	68.91	68.81
Dec-80	46	15,938,454.40	1,606,774.89	9,219,960.46	4,932,066.57	83,385.64	31,780,641.95	68.89	68.80
Jan-81	47	15,892,308.76	1,637,818.66	9,236,090.90	4,924,948.35	88,185.34	31,779,352.01	68.88	68.78
Feb-81	48	15,846,163.13	1,668,862.43	9,252,221.34	4,917,830.13	92,985.04	31,778,062.07	68.86	68.77
Mar-81	49	15,800,017.50	1,699,906.20	9,268,351.78	4,910,711.91	97,784.74	31,776,772.13	68.84	68.75
Apr-81	50	15,753,871.87	1,730,949.97	9,284,482.22	4,903,593.69	102,584.44	31,775,482.19	68.83	68.74
May-81	51	15,707,726.24	1,761,993.73	9,300,612.66	4,896,475.47	107,384.15	31,774,192.25	68.81	68.72
Jun-81	52	15,661,580.61	1,793,037.50	9,316,743.10	4,889,357.25	112,183.85	31,772,902.31	68.80	68.71
Jul-81	53	15,615,434.98	1,824,081.27	9,332,873.54	4,882,239.03	116,983.55	31,771,612.37	68.78	68.70
Aug-81	54	15,569,289.35	1,855,125.04	9,349,003.98	4,875,120.81	121,783.25	31,770,322.43	68.76	68.68
Sep-81	55	15,523,143.72	1,886,168.81	9,365,134.42	4,868,002.59	126,582.96	31,769,032.50	68.75	68.67
Oct-81	56	15,476,998.08	1,917,212.58	9,381,264.86	4,860,884.37	131,382.66	31,767,742.56	68.73	68.65
Nov-81	57	15,430,852.45	1,948,256.34	9,397,395.30	4,853,766.15	136,182.36	31,766,452.62	68.72	68.64
Dec-81	58	15,384,706.82	1,979,300.11	9,413,525.74	4,846,647.93	140,982.06	31,765,162.68	68.70	68.62
Jan-82	59	15,338,561.19	2,010,343.88	9,429,656.18	4,839,529.71	145,781.76	31,763,872.74	68.68	68.61
Feb-82	60	15,292,415.56	2,041,387.65	9,445,786.63	4,832,411.49	150,581.47	31,762,582.80	68.67	68.59
Mar-82	61	15,246,269.93	2,072,431.42	9,461,917.07	4,825,293.27	155,381.17	31,761,292.86	68.65	68.58
Apr-82	62	15,200,124.30	2,103,475.19	9,478,047.51	4,818,175.05	160,180.87	31,760,002.92	68.64	68.56

Year	Land cover	Soil Group B - Land Use (m²) & CN							Interpolation Function
		Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
May-82	63	15,153,978.67	2,134,518.96	9,494,177.95	4,811,056.83	164,980.57	31,758,712.98	68.62	68.55
Jun-82	64	15,107,833.04	2,165,562.72	9,510,308.39	4,803,938.61	169,780.28	31,757,423.04	68.60	68.53
Jul-82	65	15,061,687.40	2,196,606.49	9,526,438.83	4,796,820.39	174,579.98	31,756,133.10	68.59	68.52
Aug-82	66	15,015,541.77	2,227,650.26	9,542,569.27	4,789,702.17	179,379.68	31,754,843.16	68.57	68.50
Sep-82	67	14,969,396.14	2,258,694.03	9,558,699.71	4,782,583.96	184,179.38	31,753,553.22	68.55	68.49
Oct-82	68	14,923,250.51	2,289,737.80	9,574,830.15	4,775,465.74	188,979.08	31,752,263.28	68.54	68.47
Nov-82	69	14,877,104.88	2,320,781.57	9,590,960.59	4,768,347.52	193,778.79	31,750,973.34	68.52	68.46
Dec-82	70	14,830,959.25	2,351,825.33	9,607,091.03	4,761,229.30	198,578.49	31,749,683.40	68.51	68.44
Jan-83	71	14,784,813.62	2,382,869.10	9,623,221.47	4,754,111.08	203,378.19	31,748,393.46	68.49	68.43
Feb-83	72	14,738,667.99	2,413,912.87	9,639,351.91	4,746,992.86	208,177.89	31,747,103.52	68.47	68.41
Mar-83	73	14,692,522.36	2,444,956.64	9,655,482.35	4,739,874.64	212,977.60	31,745,813.58	68.46	68.40
Apr-83	74	14,646,376.72	2,476,000.41	9,671,612.79	4,732,756.42	217,777.30	31,744,523.64	68.44	68.38
May-83	75	14,600,231.09	2,507,044.18	9,687,743.23	4,725,638.20	222,577.00	31,743,233.70	68.43	68.37
Jun-83	76	14,554,085.46	2,538,087.94	9,703,873.67	4,718,519.98	227,376.70	31,741,943.76	68.41	68.35
Jul-83	77	14,507,939.83	2,569,131.71	9,720,004.11	4,711,401.76	232,176.40	31,740,653.82	68.39	68.34
Aug-83	78	14,461,794.20	2,600,175.48	9,736,134.55	4,704,283.54	236,976.11	31,739,363.88	68.38	68.32
Sep-83	79	14,415,648.57	2,631,219.25	9,752,264.99	4,697,165.32	241,775.81	31,738,073.94	68.36	68.31
Oct-83	80	14,369,502.94	2,662,263.02	9,768,395.43	4,690,047.10	246,575.51	31,736,784.00	68.35	68.29
Nov-83	81	14,323,357.31	2,693,306.79	9,784,525.88	4,682,928.88	251,375.21	31,735,494.06	68.33	68.28
Dec-83	82	14,277,211.67	2,724,350.55	9,800,656.32	4,675,810.66	256,174.92	31,734,204.12	68.31	68.27
Jan-84	83	14,231,066.04	2,755,394.32	9,816,786.76	4,668,692.44	260,974.62	31,732,914.18	68.30	68.25
Feb-84	84	14,184,920.41	2,786,438.09	9,832,917.20	4,661,574.22	265,774.32	31,731,624.24	68.28	68.24
Mar-84	85	14,138,774.78	2,817,481.86	9,849,047.64	4,654,456.00	270,574.02	31,730,334.30	68.27	68.22
Apr-84	86	14,092,629.15	2,848,525.63	9,865,178.08	4,647,337.78	275,373.72	31,729,044.36	68.25	68.21
May-84	87	14,046,483.52	2,879,569.40	9,881,308.52	4,640,219.56	280,173.43	31,727,754.42	68.23	68.19
Jun-84	88	14,000,337.89	2,910,613.16	9,897,438.96	4,633,101.34	284,973.13	31,726,464.48	68.22	68.18

Year	Land cover	Soil Group B - Land Use (m^2) & CN							Interpolation Function
		Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
Jul-84	89	13,954,192.26	2,941,656.93	9,913,569.40	4,625,983.12	289,772.83	31,725,174.54	68.20	68.16
Aug-84	90	13,908,046.63	2,972,700.70	9,929,699.84	4,618,864.90	294,572.53	31,723,884.60	68.19	68.15
Sep-84	91	13,861,900.99	3,003,744.47	9,945,830.28	4,611,746.68	299,372.24	31,722,594.66	68.17	68.13
Oct-84	92	13,815,755.36	3,034,788.24	9,961,960.72	4,604,628.46	304,171.94	31,721,304.72	68.15	68.12
Nov-84	93	13,769,609.73	3,065,832.01	9,978,091.16	4,597,510.24	308,971.64	31,720,014.78	68.14	68.10
Dec-84	94	13,723,464.10	3,096,875.78	9,994,221.60	4,590,392.02	313,771.34	31,718,724.84	68.12	68.09
Jan-85	95	13,677,318.47	3,127,919.54	10,010,352.04	4,583,273.80	318,571.04	31,717,434.90	68.11	68.07
Feb-85	96	13,631,172.84	3,158,963.31	10,026,482.48	4,576,155.58	323,370.75	31,716,144.96	68.09	68.06
Mar-85	97	13,585,027.21	3,190,007.08	10,042,612.92	4,569,037.36	328,170.45	31,714,855.02	68.07	68.04
Apr-85	98	13,538,881.58	3,221,050.85	10,058,743.36	4,561,919.14	332,970.15	31,713,565.08	68.06	68.03
May-85	99	13,492,735.95	3,252,094.62	10,074,873.80	4,554,800.92	337,769.85	31,712,275.14	68.04	68.01
Jun-85	100	13,446,590.31	3,283,138.39	10,091,004.24	4,547,682.70	342,569.56	31,710,985.20	68.02	68.00
Jul-85	101	13,400,444.68	3,314,182.15	10,107,134.68	4,540,564.48	347,369.26	31,709,695.26	68.01	67.98
Aug-85	102	13,354,299.05	3,345,225.92	10,123,265.13	4,533,446.26	352,168.96	31,708,405.32	67.99	67.97
Sep-85	103	13,308,153.42	3,376,269.69	10,139,395.57	4,526,328.04	356,968.66	31,707,115.38	67.98	67.96
Oct-85	104	13,262,007.79	3,407,313.46	10,155,526.01	4,519,209.82	361,768.36	31,705,825.44	67.96	67.94
Nov-85	105	13,215,862.16	3,438,357.23	10,171,656.45	4,512,091.60	366,568.07	31,704,535.50	67.94	67.93
Dec-85	106	13,169,716.53	3,469,401.00	10,187,786.89	4,504,973.38	371,367.77	31,703,245.56	67.93	67.91
Jan-86	107	13,123,570.90	3,500,444.76	10,203,917.33	4,497,855.16	376,167.47	31,701,955.62	67.91	67.90
Feb-86	108	13,077,425.27	3,531,488.53	10,220,047.77	4,490,736.94	380,967.17	31,700,665.68	67.90	67.88
Mar-86	109	13,031,279.63	3,562,532.30	10,236,178.21	4,483,618.72	385,766.88	31,699,375.74	67.88	67.87
Apr-86	110	12,985,134.00	3,593,576.07	10,252,308.65	4,476,500.50	390,566.58	31,698,085.80	67.86	67.85
May-86	111	12,938,988.37	3,624,619.84	10,268,439.09	4,469,382.28	395,366.28	31,696,795.86	67.85	67.84
Jun-86	112	12,892,842.74	3,655,663.61	10,284,569.53	4,462,264.06	400,165.98	31,695,505.92	67.83	67.82
Jul-86	113	12,846,697.11	3,686,707.37	10,300,699.97	4,455,145.84	404,965.68	31,694,215.98	67.82	67.81
Aug-86	114	12,800,551.48	3,717,751.14	10,316,830.41	4,448,027.62	409,765.39	31,692,926.04	67.80	67.79

Year	Land cover	Soil Group B - Land Use (m^2) & CN							Interpolation Function
		Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
Sep-86	115	12,754,405.85	3,748,794.91	10,332,960.85	4,440,909.40	414,565.09	31,691,636.10	67.78	67.78
Oct-86	116	12,708,260.22	3,779,838.68	10,349,091.29	4,433,791.18	419,364.79	31,690,346.16	67.77	67.76
Nov-86	117	12,662,114.59	3,810,882.45	10,365,221.73	4,426,672.96	424,164.49	31,689,056.22	67.75	67.75
Dec-86	118	12,615,968.95	3,841,926.22	10,381,352.17	4,419,554.74	428,964.20	31,687,766.28	67.74	67.74
Jan-87	119	12,569,823.32	3,872,969.98	10,397,482.61	4,412,436.52	433,763.90	31,686,476.34	67.72	67.72
Feb-87	120	12,523,677.69	3,904,013.75	10,413,613.05	4,405,318.30	438,563.60	31,685,186.40	67.70	67.71
Mar-87	121	12,477,532.06	3,935,057.52	10,429,743.49	4,398,200.08	443,363.30	31,683,896.46	67.69	67.69
Apr-87	122	12,431,386.43	3,966,101.29	10,445,873.93	4,391,081.86	448,163.00	31,682,606.52	67.67	67.68
May-87	123	12,385,240.80	3,997,145.06	10,462,004.37	4,383,963.64	452,962.71	31,681,316.58	67.65	67.66
Jun-87	124	12,339,095.17	4,028,188.83	10,478,134.82	4,376,845.42	457,762.41	31,680,026.64	67.64	67.65
Jul-87	125	12,292,949.54	4,059,232.60	10,494,265.26	4,369,727.20	462,562.11	31,678,736.70	67.62	67.63
Aug-87	126	12,246,803.91	4,090,276.36	10,510,395.70	4,362,608.98	467,361.81	31,677,446.76	67.61	67.62
Sep-87	127	12,200,658.27	4,121,320.13	10,526,526.14	4,355,490.76	472,161.52	31,676,156.82	67.59	67.60
Oct-87	128	12,154,512.64	4,152,363.90	10,542,656.58	4,348,372.55	476,961.22	31,674,866.88	67.57	67.59
Nov-87	129	12,108,367.01	4,183,407.67	10,558,787.02	4,341,254.33	481,760.92	31,673,576.94	67.56	67.57
Dec-87	130	12,062,221.38	4,214,451.44	10,574,917.46	4,334,136.11	486,560.62	31,672,287.00	67.54	67.56
Jan-88	131	12,016,075.75	4,245,495.21	10,591,047.90	4,327,017.89	491,360.32	31,670,997.06	67.53	67.54
Feb-88	132	11,969,930.12	4,276,538.97	10,607,178.34	4,319,899.67	496,160.03	31,669,707.12	67.51	67.53
Mar-88	133	11,923,784.49	4,307,582.74	10,623,308.78	4,312,781.45	500,959.73	31,668,417.18	67.49	67.52
Apr-88	134	11,877,638.86	4,338,626.51	10,639,439.22	4,305,663.23	505,759.43	31,667,127.24	67.48	67.50
May-88	135	11,831,493.23	4,369,670.28	10,655,569.66	4,298,545.01	510,559.13	31,665,837.30	67.46	67.49
Jun-88	136	11,785,347.59	4,400,714.05	10,671,700.10	4,291,426.79	515,358.84	31,664,547.36	67.44	67.47
Jul-88	137	11,739,201.96	4,431,757.82	10,687,830.54	4,284,308.57	520,158.54	31,663,257.43	67.43	67.46
Aug-88	138	11,693,056.33	4,462,801.58	10,703,960.98	4,277,190.35	524,958.24	31,661,967.49	67.41	67.44
Sep-88	139	11,646,910.70	4,493,845.35	10,720,091.42	4,270,072.13	529,757.94	31,660,677.55	67.40	67.43
Oct-88	140	11,600,765.07	4,524,889.12	10,736,221.86	4,262,953.91	534,557.64	31,659,387.61	67.38	67.41

Year	Land cover	Soil Group B - Land Use (m²) & CN							Interpolation Function
		Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
Nov-88	141	11,554,619.44	4,555,932.89	10,752,352.30	4,255,835.69	539,357.35	31,658,097.67	67.36	67.40
Dec-88	142	11,508,473.81	4,586,976.66	10,768,482.74	4,248,717.47	544,157.05	31,656,807.73	67.35	67.38
Jan-89	143	11,462,328.18	4,618,020.43	10,784,613.18	4,241,599.25	548,956.75	31,655,517.79	67.33	67.37
Feb-89	144	11,416,182.55	4,649,064.19	10,800,743.62	4,234,481.03	553,756.45	31,654,227.85	67.32	67.35
Mar-89	145	11,370,036.91	4,680,107.96	10,816,874.07	4,227,362.81	558,556.16	31,652,937.91	67.30	67.34
Apr-89	146	11,323,891.28	4,711,151.73	10,833,004.51	4,220,244.59	563,355.86	31,651,647.97	67.28	67.33
May-89	147	11,277,745.65	4,742,195.50	10,849,134.95	4,213,126.37	568,155.56	31,650,358.03	67.27	67.31
Jun-89	148	11,231,600.02	4,773,239.27	10,865,265.39	4,206,008.15	572,955.26	31,649,068.09	67.25	67.30
Jul-89	149	11,185,454.39	4,804,283.04	10,881,395.83	4,198,889.93	577,754.96	31,647,778.15	67.23	67.28
Aug-89	150	11,139,308.76	4,835,326.80	10,897,526.27	4,191,771.71	582,554.67	31,646,488.21	67.22	67.27
Sep-89	151	11,093,163.13	4,866,370.57	10,913,656.71	4,184,653.49	587,354.37	31,645,198.27	67.20	67.25
Oct-89	152	11,047,017.50	4,897,414.34	10,929,787.15	4,177,535.27	592,154.07	31,643,908.33	67.19	67.24
Nov-89	153	11,000,871.87	4,928,458.11	10,945,917.59	4,170,417.05	596,953.77	31,642,618.39	67.17	67.22
Dec-89	154	10,954,726.23	4,959,501.88	10,962,048.03	4,163,298.83	601,753.48	31,641,328.45	67.15	67.21
Jan-90	155	10,908,580.60	4,990,545.65	10,978,178.47	4,156,180.61	606,553.18	31,640,038.51	67.14	67.19
Feb-90	156	10,862,434.97	5,021,589.42	10,994,308.91	4,149,062.39	611,352.88	31,638,748.57	67.12	67.18
Mar-90	157	10,816,289.34	5,052,633.18	11,010,439.35	4,141,944.17	616,152.58	31,637,458.63	67.11	67.17
Apr-90	158	10,770,143.71	5,083,676.95	11,026,569.79	4,134,825.95	620,952.28	31,636,168.69	67.09	67.15
May-90	159	10,723,998.08	5,114,720.72	11,042,700.23	4,127,707.73	625,751.99	31,634,878.75	67.07	67.14
Jun-90	160	10,677,852.45	5,145,764.49	11,058,830.67	4,120,589.51	630,551.69	31,633,588.81	67.06	67.12
Jul-90	161	10,631,706.82	5,176,808.26	11,074,961.11	4,113,471.29	635,351.39	31,632,298.87	67.04	67.11
Aug-90	162	10,585,561.19	5,207,852.03	11,091,091.55	4,106,353.07	640,151.09	31,631,008.93	67.02	67.09
Sep-90	163	10,539,415.55	5,238,895.79	11,107,221.99	4,099,234.85	644,950.80	31,629,718.99	67.01	67.08
Oct-90	164	10,493,269.92	5,269,939.56	11,123,352.43	4,092,116.63	649,750.50	31,628,429.05	66.99	67.06
Nov-90	165	10,447,124.29	5,300,983.33	11,139,482.87	4,084,998.41	654,550.20	31,627,139.11	66.98	67.05
Dec-90	166	10,400,978.66	5,332,027.10	11,155,613.32	4,077,880.19	659,349.90	31,625,849.17	66.96	67.03

Year	Land cover	Soil Group B - Land Use (m^2) & CN							Interpolation Function
		Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
Jan-91	167	10,354,833.03	5,363,070.87	11,171,743.76	4,070,761.97	664,149.60	31,624,559.23	66.94	67.02
Feb-91	168	10,308,687.40	5,394,114.64	11,187,874.20	4,063,643.75	668,949.31	31,623,269.29	66.93	67.01
Mar-91	169	10,262,541.77	5,425,158.40	11,204,004.64	4,056,525.53	673,749.01	31,621,979.35	66.91	66.99
Apr-91	170	10,216,396.14	5,456,202.17	11,220,135.08	4,049,407.31	678,548.71	31,620,689.41	66.90	66.98
May-91	171	10,170,250.50	5,487,245.94	11,236,265.52	4,042,289.09	683,348.41	31,619,399.47	66.88	66.96
Jun-91	172	10,124,104.87	5,518,289.71	11,252,395.96	4,035,170.87	688,148.12	31,618,109.53	66.86	66.95
Jul-91	173	10,077,959.24	5,549,333.48	11,268,526.40	4,028,052.65	692,947.82	31,616,819.59	66.85	66.93
Aug-91	174	10,031,813.61	5,580,377.25	11,284,656.84	4,020,934.43	697,747.52	31,615,529.65	66.83	66.92
Sep-91	175	9,985,667.98	5,611,421.01	11,300,787.28	4,013,816.21	702,547.22	31,614,239.71	66.81	66.90
Oct-91	176	9,939,522.35	5,642,464.78	11,316,917.72	4,006,697.99	707,346.92	31,612,949.77	66.80	66.89
Nov-91	177	9,893,376.72	5,673,508.55	11,333,048.16	3,999,579.77	712,146.63	31,611,659.83	66.78	66.88
Dec-91	178	9,847,231.09	5,704,552.32	11,349,178.60	3,992,461.55	716,946.33	31,610,369.89	66.77	66.86
Jan-92	179	9,801,085.46	5,735,596.09	11,365,309.04	3,985,343.33	721,746.03	31,609,079.95	66.75	66.85
Feb-92	180	9,754,939.82	5,766,639.86	11,381,439.48	3,978,225.11	726,545.73	31,607,790.01	66.73	66.83
Mar-92	181	9,708,794.19	5,797,683.62	11,397,569.92	3,971,106.89	731,345.44	31,606,500.07	66.72	66.82
Apr-92	182	9,662,648.56	5,828,727.39	11,413,700.36	3,963,988.67	736,145.14	31,605,210.13	66.70	66.80
May-92	183	9,616,502.93	5,859,771.16	11,429,830.80	3,956,870.45	740,944.84	31,603,920.19	66.69	66.79
Jun-92	184	9,570,357.30	5,890,814.93	11,445,961.24	3,949,752.23	745,744.54	31,602,630.25	66.67	66.77
Jul-92	185	9,524,211.67	5,921,858.70	11,462,091.68	3,942,634.01	750,544.24	31,601,340.31	66.65	66.76
Aug-92	186	9,478,066.04	5,952,902.47	11,478,222.12	3,935,515.79	755,343.95	31,600,050.37	66.64	66.74
Sep-92	187	9,431,920.41	5,983,946.24	11,494,352.56	3,928,397.57	760,143.65	31,598,760.43	66.62	66.73
Oct-92	188	9,385,774.78	6,014,990.00	11,510,483.01	3,921,279.36	764,943.35	31,597,470.49	66.60	66.72
Nov-92	189	9,339,629.14	6,046,033.77	11,526,613.45	3,914,161.14	769,743.05	31,596,180.55	66.59	66.70
Dec-92	190	9,293,483.51	6,077,077.54	11,542,743.89	3,907,042.92	774,542.76	31,594,890.61	66.57	66.69
Jan-93	191	9,247,337.88	6,108,121.31	11,558,874.33	3,899,924.70	779,342.46	31,593,600.67	66.56	66.67
Feb-93	192	9,201,192.25	6,139,165.08	11,575,004.77	3,892,806.48	784,142.16	31,592,310.73	66.54	66.66

Year	Land cover	Soil Group B - Land Use (m^2) & CN							Interpolation Function
	Land cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = - 0.00021651
Mar-93	193	9,155,046.62	6,170,208.85	11,591,135.21	3,885,688.26	788,941.86	31,591,020.79	66.52	66.64
Apr-93	194	9,108,900.99	6,201,252.61	11,607,265.65	3,878,570.04	793,741.56	31,589,730.85	66.51	66.63
May-93	195	9,062,755.36	6,232,296.38	11,623,396.09	3,871,451.82	798,541.27	31,588,440.91	66.49	66.62
Jun-93	196	9,016,609.73	6,263,340.15	11,639,526.53	3,864,333.60	803,340.97	31,587,150.97	66.47	66.60
Jul-93	197	8,970,464.10	6,294,383.92	11,655,656.97	3,857,215.38	808,140.67	31,585,861.03	66.46	66.59
Aug-93	198	8,924,318.46	6,325,427.69	11,671,787.41	3,850,097.16	812,940.37	31,584,571.09	66.44	66.57
Sep-93	199	8,878,172.83	6,356,471.46	11,687,917.85	3,842,978.94	817,740.08	31,583,281.15	66.43	66.56
Oct-93	200	8,832,027.20	6,387,515.22	11,704,048.29	3,835,860.72	822,539.78	31,581,991.21	66.41	66.54
Nov-93	201	8,785,881.57	6,418,558.99	11,720,178.73	3,828,742.50	827,339.48	31,580,701.27	66.39	66.53
Dec-93	202	8,739,735.94	6,449,602.76	11,736,309.17	3,821,624.28	832,139.18	31,579,411.33	66.38	66.51
Jan-94	203	8,693,590.31	6,480,646.53	11,752,439.61	3,814,506.06	836,938.88	31,578,121.39	66.36	66.50
Feb-94	204	8,647,444.68	6,511,690.30	11,768,570.05	3,807,387.84	841,738.59	31,576,831.45	66.34	66.49
Mar-94	205	8,601,299.05	6,542,734.07	11,784,700.49	3,800,269.62	846,538.29	31,575,541.51	66.33	66.47
Apr-94	206	8,555,153.42	6,573,777.83	11,800,830.93	3,793,151.40	851,337.99	31,574,251.57	66.31	66.46
May-94	207	8,509,007.78	6,604,821.60	11,816,961.37	3,786,033.18	856,137.69	31,572,961.63	66.30	66.44
Jun-94	208	8,462,862.15	6,635,865.37	11,833,091.81	3,778,914.96	860,937.40	31,571,671.69	66.28	66.43
Jul-94	209	8,416,716.52	6,666,909.14	11,849,222.26	3,771,796.74	865,737.10	31,570,381.75	66.26	66.41
Aug-94	210	8,370,570.89	6,697,952.91	11,865,352.70	3,764,678.52	870,536.80	31,569,091.81	66.25	66.40
Sep-94	211	8,324,425.26	6,728,996.68	11,881,483.14	3,757,560.30	875,336.50	31,567,801.87	66.23	66.38
Oct-94	212	8,278,279.63	6,760,040.44	11,897,613.58	3,750,442.08	880,136.20	31,566,511.93	66.21	66.37
Nov-94	213	8,232,134.00	6,791,084.21	11,913,744.02	3,743,323.86	884,935.91	31,565,221.99	66.20	66.36
Dec-94	214	8,185,988.37	6,822,127.98	11,929,874.46	3,736,205.64	889,735.61	31,563,932.05	66.18	66.34
Jan-95	215	8,139,842.74	6,853,171.75	11,946,004.90	3,729,087.42	894,535.31	31,562,642.11	66.17	66.33
Feb-95	216	8,093,697.10	6,884,215.52	11,962,135.34	3,721,969.20	899,335.01	31,561,352.17	66.15	66.31
Mar-95	217	8,047,551.47	6,915,259.29	11,978,265.78	3,714,850.98	904,134.72	31,560,062.23	66.13	66.30
Apr-95	218	8,001,405.84	6,946,303.06	11,994,396.22	3,707,732.76	908,934.42	31,558,772.29	66.12	66.28

Year	Land cover	Soil Group B - Land Use (m^2) & CN							Interpolation Function
		Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
May-95	219	7,955,260.21	6,977,346.82	12,010,526.66	3,700,614.54	913,734.12	31,557,482.35	66.10	66.27
Jun-95	220	7,909,114.58	7,008,390.59	12,026,657.10	3,693,496.32	918,533.82	31,556,192.42	66.08	66.26
Jul-95	221	7,862,968.95	7,039,434.36	12,042,787.54	3,686,378.10	923,333.52	31,554,902.48	66.07	66.24
Aug-95	222	7,816,823.32	7,070,478.13	12,058,917.98	3,679,259.88	928,133.23	31,553,612.54	66.05	66.23
Sep-95	223	7,770,677.69	7,101,521.90	12,075,048.42	3,672,141.66	932,932.93	31,552,322.60	66.04	66.21
Oct-95	224	7,724,532.06	7,132,565.67	12,091,178.86	3,665,023.44	937,732.63	31,551,032.66	66.02	66.20
Nov-95	225	7,678,386.42	7,163,609.43	12,107,309.30	3,657,905.22	942,532.33	31,549,742.72	66.00	66.18
Dec-95	226	7,632,240.79	7,194,653.20	12,123,439.74	3,650,787.00	947,332.04	31,548,452.78	65.99	66.17
Jan-96	227	7,586,095.16	7,225,696.97	12,139,570.18	3,643,668.78	952,131.74	31,547,162.84	65.97	66.16
Feb-96	228	7,539,949.53	7,256,740.74	12,155,700.62	3,636,550.56	956,931.44	31,545,872.90	65.95	66.14
Mar-96	229	7,493,803.90	7,287,784.51	12,171,831.06	3,629,432.34	961,731.14	31,544,582.96	65.94	66.13
Apr-96	230	7,447,658.27	7,318,828.28	12,187,961.51	3,622,314.12	966,530.84	31,543,293.02	65.92	66.11
May-96	231	7,401,512.64	7,349,872.04	12,204,091.95	3,615,195.90	971,330.55	31,542,003.08	65.91	66.10
Jun-96	232	7,355,367.01	7,380,915.81	12,220,222.39	3,608,077.68	976,130.25	31,540,713.14	65.89	66.08
Jul-96	233	7,309,221.38	7,411,959.58	12,236,352.83	3,600,959.46	980,929.95	31,539,423.20	65.87	66.07
Aug-96	234	7,263,075.74	7,443,003.35	12,252,483.27	3,593,841.24	985,729.65	31,538,133.26	65.86	66.05
Sep-96	235	7,216,930.11	7,474,047.12	12,268,613.71	3,586,723.02	990,529.36	31,536,843.32	65.84	66.04
Oct-96	236	7,170,784.48	7,505,090.89	12,284,744.15	3,579,604.80	995,329.06	31,535,553.38	65.82	66.03
Nov-96	237	7,124,638.85	7,536,134.65	12,300,874.59	3,572,486.58	1,000,128.76	31,534,263.44	65.81	66.01
Dec-96	238	7,078,493.22	7,567,178.42	12,317,005.03	3,565,368.36	1,004,928.46	31,532,973.50	65.79	66.00
Jan-97	239	7,032,347.59	7,598,222.19	12,333,135.47	3,558,250.14	1,009,728.16	31,531,683.56	65.78	65.98
Feb-97	240	6,986,201.96	7,629,265.96	12,349,265.91	3,551,131.92	1,014,527.87	31,530,393.62	65.76	65.97
Mar-97	241	6,940,056.33	7,660,309.73	12,365,396.35	3,544,013.70	1,019,327.57	31,529,103.68	65.74	65.95
Apr-97	242	6,893,910.70	7,691,353.50	12,381,526.79	3,536,895.48	1,024,127.27	31,527,813.74	65.73	65.94
May-97	243	6,847,765.06	7,722,397.27	12,397,657.23	3,529,777.26	1,028,926.97	31,526,523.80	65.71	65.93
Jun-97	244	6,801,619.43	7,753,441.03	12,413,787.67	3,522,659.04	1,033,726.68	31,525,233.86	65.69	65.91

Year	Land cover	Soil Group B - Land Use (m^2) & CN							Interpolation Function
		Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
Jul-97	245	6,755,473.80	7,784,484.80	12,429,918.11	3,515,540.82	1,038,526.38	31,523,943.92	65.68	65.90
Aug-97	246	6,709,328.17	7,815,528.57	12,446,048.55	3,508,422.60	1,043,326.08	31,522,653.98	65.66	65.88
Sep-97	247	6,663,182.54	7,846,572.34	12,462,178.99	3,501,304.38	1,048,125.78	31,521,364.04	65.65	65.87
Oct-97	248	6,617,036.91	7,877,616.11	12,478,309.43	3,494,186.16	1,052,925.48	31,520,074.10	65.63	65.85
Nov-97	249	6,570,891.28	7,908,659.88	12,494,439.87	3,487,067.95	1,057,725.19	31,518,784.16	65.61	65.84
Dec-97	250	6,524,745.65	7,939,703.64	12,510,570.31	3,479,949.73	1,062,524.89	31,517,494.22	65.60	65.83
Jan-98	251	6,478,600.01	7,970,747.41	12,526,700.75	3,472,831.51	1,067,324.59	31,516,204.28	65.58	65.81
Feb-98	252	6,432,454.38	8,001,791.18	12,542,831.20	3,465,713.29	1,072,124.29	31,514,914.34	65.56	65.80
Mar-98	253	6,386,308.75	8,032,834.95	12,558,961.64	3,458,595.07	1,076,924.00	31,513,624.40	65.55	65.78
Apr-98	254	6,340,163.12	8,063,878.72	12,575,092.08	3,451,476.85	1,081,723.70	31,512,334.46	65.53	65.77
May-98	255	6,294,017.49	8,094,922.49	12,591,222.52	3,444,358.63	1,086,523.40	31,511,044.52	65.52	65.76
Jun-98	256	6,247,871.86	8,125,966.25	12,607,352.96	3,437,240.41	1,091,323.10	31,509,754.58	65.50	65.74
Jul-98	257	6,201,726.23	8,157,010.02	12,623,483.40	3,430,122.19	1,096,122.80	31,508,464.64	65.48	65.73
Aug-98	258	6,155,580.60	8,188,053.79	12,639,613.84	3,423,003.97	1,100,922.51	31,507,174.70	65.47	65.71
Sep-98	259	6,109,434.97	8,219,097.56	12,655,744.28	3,415,885.75	1,105,722.21	31,505,884.76	65.45	65.70
Oct-98	260	6,063,289.33	8,250,141.33	12,671,874.72	3,408,767.53	1,110,521.91	31,504,594.82	65.43	65.68
Nov-98	261	6,017,143.70	8,281,185.10	12,688,005.16	3,401,649.31	1,115,321.61	31,503,304.88	65.42	65.67
Dec-98	262	5,970,998.07	8,312,228.86	12,704,135.60	3,394,531.09	1,120,121.32	31,502,014.94	65.40	65.66
Jan-99	263	5,924,852.44	8,343,272.63	12,720,266.04	3,387,412.87	1,124,921.02	31,500,725.00	65.39	65.64
Feb-99	264	5,878,706.81	8,374,316.40	12,736,396.48	3,380,294.65	1,129,720.72	31,499,435.06	65.37	65.63
Mar-99	265	5,832,561.18	8,405,360.17	12,752,526.92	3,373,176.43	1,134,520.42	31,498,145.12	65.35	65.61
Apr-99	266	5,786,415.55	8,436,403.94	12,768,657.36	3,366,058.21	1,139,320.12	31,496,855.18	65.34	65.60
May-99	267	5,740,269.92	8,467,447.71	12,784,787.80	3,358,939.99	1,144,119.83	31,495,565.24	65.32	65.58
Jun-99	268	5,694,124.29	8,498,491.47	12,800,918.24	3,351,821.77	1,148,919.53	31,494,275.30	65.30	65.57
Jul-99	269	5,647,978.65	8,529,535.24	12,817,048.68	3,344,703.55	1,153,719.23	31,492,985.36	65.29	65.56
Aug-99	270	5,601,833.02	8,560,579.01	12,833,179.12	3,337,585.33	1,158,518.93	31,491,695.42	65.27	65.54

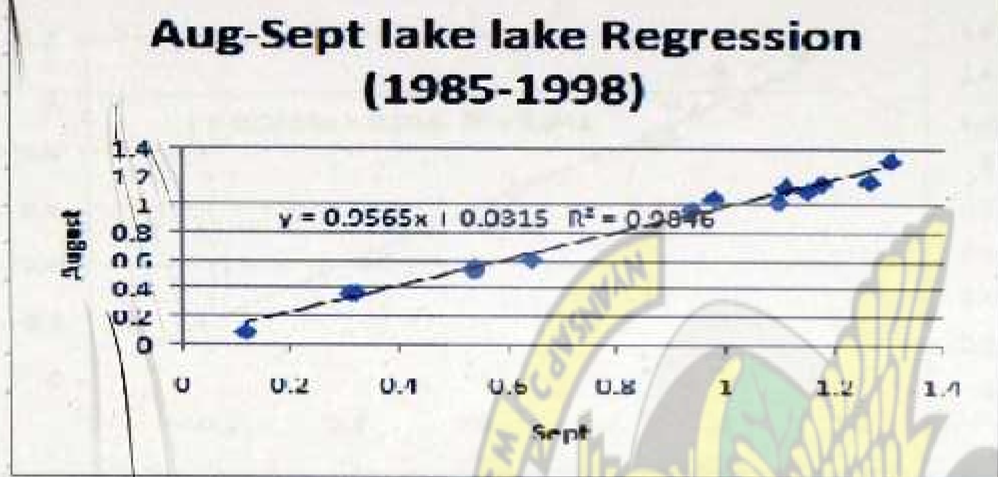
Year	Land cover	Soil Group B - Land Use (m^2) & CN							Interpolation Function
		Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
Nov-01	297	4,355,900.98	9,398,760.76	13,268,701.02	3,145,393.39	1,288,110.89	31,456,867.04	64.83	65.16
Dec-01	298	4,309,755.35	9,429,804.53	13,284,831.46	3,138,275.17	1,292,910.60	31,455,577.10	64.81	65.15
Jan-02	299	4,263,609.72	9,460,848.29	13,300,961.90	3,131,156.95	1,297,710.30	31,454,287.16	64.80	65.13
Feb-02	300	4,217,464.09	9,491,892.06	13,317,092.34	3,124,038.73	1,302,510.00	31,452,997.22	64.78	65.12
Mar-02	301	4,171,318.46	9,522,935.83	13,333,222.78	3,116,920.51	1,307,309.70	31,451,707.28	64.76	65.10
Apr-02	302	4,125,172.83	9,553,979.60	13,349,353.22	3,109,802.29	1,312,109.40	31,450,417.34	64.75	65.09
May-02	303	4,079,027.20	9,585,023.37	13,365,483.66	3,102,684.07	1,316,909.11	31,449,127.41	64.73	65.08
Jun-02	304	4,032,881.57	9,616,067.14	13,381,614.10	3,095,565.85	1,321,708.81	31,447,837.47	64.72	65.06
Jul-02	305	3,986,735.93	9,647,110.91	13,397,744.54	3,088,447.63	1,326,508.51	31,446,547.53	64.70	65.05
Aug-02	306	3,940,590.30	9,678,154.67	13,413,874.98	3,081,329.41	1,331,308.21	31,445,257.59	64.68	65.03
Sep-02	307	3,894,444.67	9,709,198.44	13,430,005.42	3,074,211.19	1,336,107.92	31,443,967.65	64.67	65.02
Oct-02	308	3,848,299.04	9,740,242.21	13,446,135.86	3,067,092.97	1,340,907.62	31,442,677.71	64.65	65.00
Nov-02	309	3,802,153.41	9,771,285.98	13,462,266.30	3,059,974.75	1,345,707.32	31,441,387.77	64.63	64.99
Dec-02	310	3,756,007.78	9,802,329.75	13,478,396.74	3,052,856.54	1,350,507.02	31,440,097.83	64.62	64.98
Jan-03	311	3,709,862.15	9,833,373.52	13,494,527.18	3,045,738.32	1,355,306.72	31,438,807.89	64.60	64.96
Feb-03	312	3,663,716.52	9,864,417.28	13,510,657.62	3,038,620.10	1,360,106.43	31,437,517.95	64.58	64.95
Mar-03	313	3,617,570.89	9,895,461.05	13,526,788.06	3,031,501.88	1,364,906.13	31,436,228.01	64.57	64.93
Apr-03	314	3,571,425.25	9,926,504.82	13,542,918.50	3,024,383.66	1,369,705.83	31,434,938.07	64.55	64.92
May-03	315	3,525,279.62	9,957,548.59	13,559,048.94	3,017,265.44	1,374,505.53	31,433,648.13	64.54	64.91
Jun-03	316	3,479,133.99	9,988,592.36	13,575,179.39	3,010,147.22	1,379,305.24	31,432,358.19	64.52	64.89
Jul-03	317	3,432,988.36	10,019,636.13	13,591,309.83	3,003,029.00	1,384,104.94	31,431,068.25	64.50	64.88
Aug-03	318	3,386,842.73	10,050,679.89	13,607,440.27	2,995,910.78	1,388,904.64	31,429,778.31	64.49	64.86
Sep-03	319	3,340,697.10	10,081,723.66	13,623,570.71	2,988,792.56	1,393,704.34	31,428,488.37	64.47	64.85
Oct-03	320	3,294,551.47	10,112,767.43	13,639,701.15	2,981,674.34	1,398,504.05	31,427,198.43	64.45	64.84
Nov-03	321	3,248,405.84	10,143,811.20	13,655,831.59	2,974,556.12	1,403,303.75	31,425,908.49	64.44	64.82
Dec-03	322	3,202,260.21	10,174,854.97	13,671,962.03	2,967,437.90	1,408,103.45	31,424,618.55	64.42	64.81

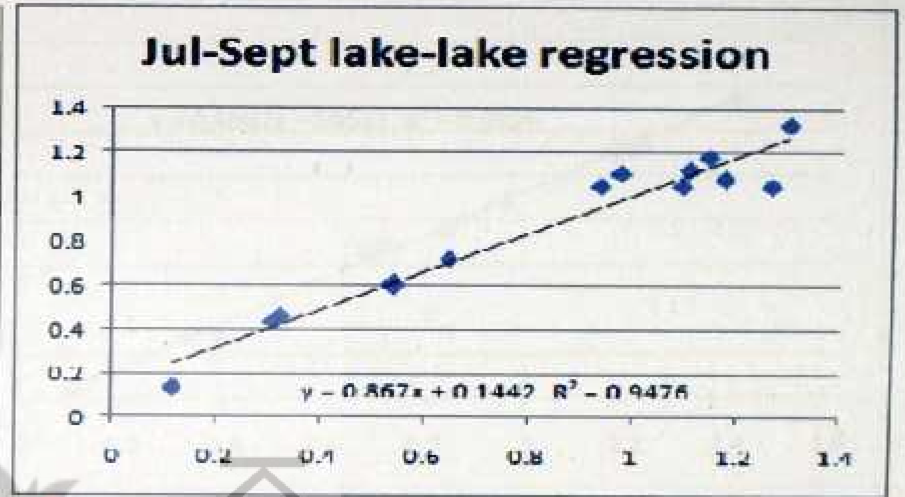
Year	Land cover	Soil Group B - Land Use (m^2) & CN							Interpolation Function
		Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
Jan-04	323	3,156,114.57	10,205,898.74	13,688,092.47	2,960,319.68	1,412,903.15	31,423,328.61	64.40	64.79
Feb-04	324	3,109,968.94	10,236,942.50	13,704,222.91	2,953,201.46	1,417,702.85	31,422,038.67	64.39	64.78
Mar-04	325	3,063,823.31	10,267,986.27	13,720,353.35	2,946,083.24	1,422,502.56	31,420,748.73	64.37	64.77
Apr-04	326	3,017,677.68	10,299,030.04	13,736,483.79	2,938,965.02	1,427,302.26	31,419,458.79	64.36	64.75
May-04	327	2,971,532.05	10,330,073.81	13,752,614.23	2,931,846.80	1,432,101.96	31,418,168.85	64.34	64.74
Jun-04	328	2,925,386.42	10,361,117.58	13,768,744.67	2,924,728.58	1,436,901.66	31,416,878.91	64.32	64.72
Jul-04	329	2,879,240.79	10,392,161.35	13,784,875.11	2,917,610.36	1,441,701.37	31,415,588.97	64.31	64.71
Aug-04	330	2,833,095.16	10,423,205.11	13,801,005.55	2,910,492.14	1,446,501.07	31,414,299.03	64.29	64.70
Sep-04	331	2,786,949.52	10,454,248.88	13,817,135.99	2,903,373.92	1,451,300.77	31,413,009.09	64.27	64.68
Oct-04	332	2,740,803.89	10,485,292.65	13,833,266.43	2,896,255.70	1,456,100.47	31,411,719.15	64.26	64.67
Nov-04	333	2,694,658.26	10,516,336.42	13,849,396.87	2,889,137.48	1,460,900.17	31,410,429.21	64.24	64.65
Dec-04	334	2,648,512.63	10,547,380.19	13,865,527.31	2,882,019.26	1,465,699.88	31,409,139.27	64.22	64.64
Jan-05	335	2,602,367.00	10,578,423.96	13,881,657.75	2,874,901.04	1,470,499.58	31,407,849.33	64.21	64.63
Feb-05	336	2,556,221.37	10,609,467.73	13,897,788.19	2,867,782.82	1,475,299.28	31,406,559.39	64.19	64.61
Mar-05	337	2,510,075.74	10,640,511.49	13,913,918.64	2,860,664.60	1,480,098.98	31,405,269.45	64.18	64.60
Apr-05	338	2,463,930.11	10,671,555.26	13,930,049.08	2,853,546.38	1,484,898.69	31,403,979.51	64.16	64.58
May-05	339	2,417,784.48	10,702,599.03	13,946,179.52	2,846,428.16	1,489,698.39	31,402,689.57	64.14	64.57
Jun-05	340	2,371,638.84	10,733,642.80	13,962,309.96	2,839,309.94	1,494,498.09	31,401,399.63	64.13	64.56
Jul-05	341	2,325,493.21	10,764,686.57	13,978,440.40	2,832,191.72	1,499,297.79	31,400,109.69	64.11	64.54
Aug-05	342	2,279,347.58	10,795,730.34	13,994,570.84	2,825,073.50	1,504,097.49	31,398,819.75	64.09	64.53
Sep-05	343	2,233,201.95	10,826,774.10	14,010,701.28	2,817,955.28	1,508,897.20	31,397,529.81	64.08	64.51
Oct-05	344	2,187,056.32	10,857,817.87	14,026,831.72	2,810,837.06	1,513,696.90	31,396,239.87	64.06	64.50
Nov-05	345	2,140,910.69	10,888,861.64	14,042,962.16	2,803,718.84	1,518,496.60	31,394,949.93	64.04	64.49
Dec-05	346	2,094,765.06	10,919,905.41	14,059,092.60	2,796,600.62	1,523,296.30	31,393,659.99	64.03	64.47
Jan-06	347	2,048,619.43	10,950,949.18	14,075,223.04	2,789,482.40	1,528,096.01	31,392,370.05	64.01	64.46
Feb-06	348	2,002,473.80	10,981,992.95	14,091,353.48	2,782,364.18	1,532,895.71	31,391,080.11	63.99	64.44

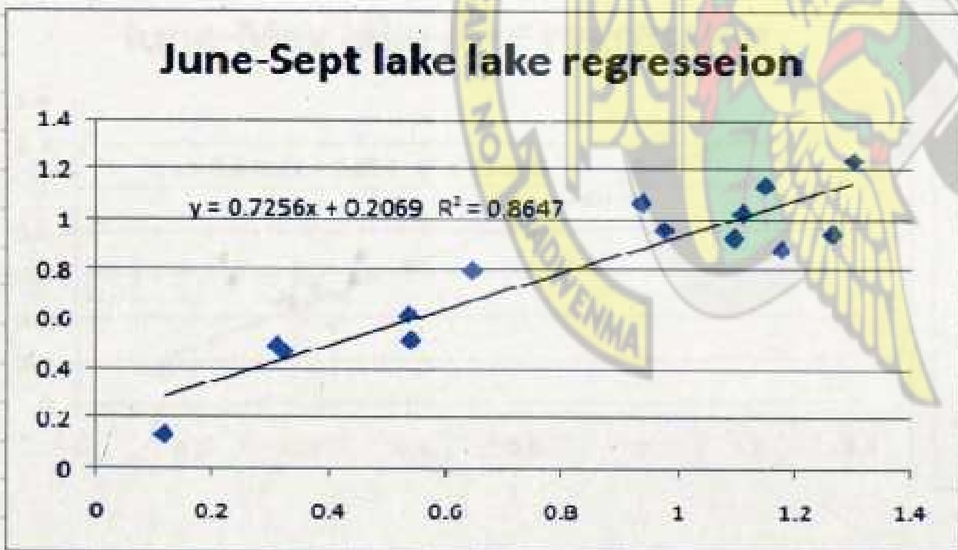
Year	Land cover	Soil Group B - Land Use (m²) & CN							Interpolation Function
		Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
Mar-06	349	1,956,328.16	11,013,036.71	14,107,483.92	2,775,245.96	1,537,695.41	31,389,790.17	63.98	64.43
Apr-06	350	1,910,182.53	11,044,080.48	14,123,614.36	2,768,127.74	1,542,495.11	31,388,500.23	63.96	64.42
May-06	351	1,864,036.90	11,075,124.25	14,139,744.80	2,761,009.52	1,547,294.81	31,387,210.29	63.95	64.40
Jun-06	352	1,817,891.27	11,106,168.02	14,155,875.24	2,753,891.30	1,552,094.52	31,385,920.35	63.93	64.39
Jul-06	353	1,771,745.64	11,137,211.79	14,172,005.68	2,746,773.08	1,556,894.22	31,384,630.41	63.91	64.37
Aug-06	354	1,725,600.01	11,168,255.56	14,188,136.12	2,739,654.86	1,561,693.92	31,383,340.47	63.90	64.36
Sep-06	355	1,679,454.38	11,199,299.32	14,204,266.56	2,732,536.64	1,566,493.62	31,382,050.53	63.88	64.35
Oct-06	356	1,633,308.75	11,230,343.09	14,220,397.00	2,725,418.42	1,571,293.33	31,380,760.59	63.86	64.33
Nov-06	357	1,587,163.12	11,261,386.86	14,236,527.44	2,718,300.20	1,576,093.03	31,379,470.65	63.85	64.32
Dec-06	358	1,541,017.48	11,292,430.63	14,252,657.88	2,711,181.98	1,580,892.73	31,378,180.71	63.83	64.30
Jan-07	359	1,494,871.85	11,323,474.40	14,268,788.33	2,704,063.76	1,585,692.43	31,376,890.77	63.81	64.29
Feb-07	360	1,448,726.22	11,354,518.17	14,284,918.77	2,696,945.54	1,590,492.13	31,375,600.83	63.80	64.28
Mar-07	361	1,402,580.59	11,385,561.93	14,301,049.21	2,689,827.32	1,595,291.84	31,374,310.89	63.78	64.26
Apr-07	362	1,356,434.96	11,416,605.70	14,317,179.65	2,682,709.10	1,600,091.54	31,373,020.95	63.76	64.25
May-07	363	1,310,289.33	11,447,649.47	14,333,310.09	2,675,590.88	1,604,891.24	31,371,731.01	64.24	64.24
Jun-07	364	1,264,143.70	11,478,693.24	14,349,440.53	2,668,472.66	1,609,690.94	31,370,441.07	63.73	64.22
Jul-07	365	1,217,998.07	11,509,737.01	14,365,570.97	2,661,354.44	1,614,490.65	31,369,151.13	63.72	64.21
Aug-07	366	1,171,852.44	11,540,780.78	14,381,701.41	2,654,236.22	1,619,290.35	31,367,861.19	63.70	64.19
Sep-07	367	1,125,706.80	11,571,824.55	14,397,831.85	2,647,118.00	1,624,090.05	31,366,571.25	63.68	64.18
Oct-07	368	1,079,561.17	11,602,868.31	14,413,962.29	2,639,999.78	1,628,889.75	31,365,281.31	63.67	64.17
Nov-07	369	1,033,415.54	11,633,912.08	14,430,092.73	2,632,881.56	1,633,689.45	31,363,991.37	63.65	64.15
Dec-07	370	987,269.91	11,664,955.85	14,446,223.17	2,625,763.34	1,638,489.16	31,362,701.43	63.63	64.14
Jan-08	371	941,124.28	11,695,999.62	14,462,353.61	2,618,645.13	1,643,288.86	31,361,411.49	63.62	64.12
Feb-08	372	894,978.65	11,727,043.39	14,478,484.05	2,611,526.91	1,648,088.56	31,360,121.55	63.60	64.11
Mar-08	373	848,833.02	11,758,087.16	14,494,614.49	2,604,408.69	1,652,888.26	31,358,831.61	63.58	64.10
Apr-08	374	802,687.39	11,789,130.92	14,510,744.93	2,597,290.47	1,657,687.97	31,357,541.67	63.57	64.08

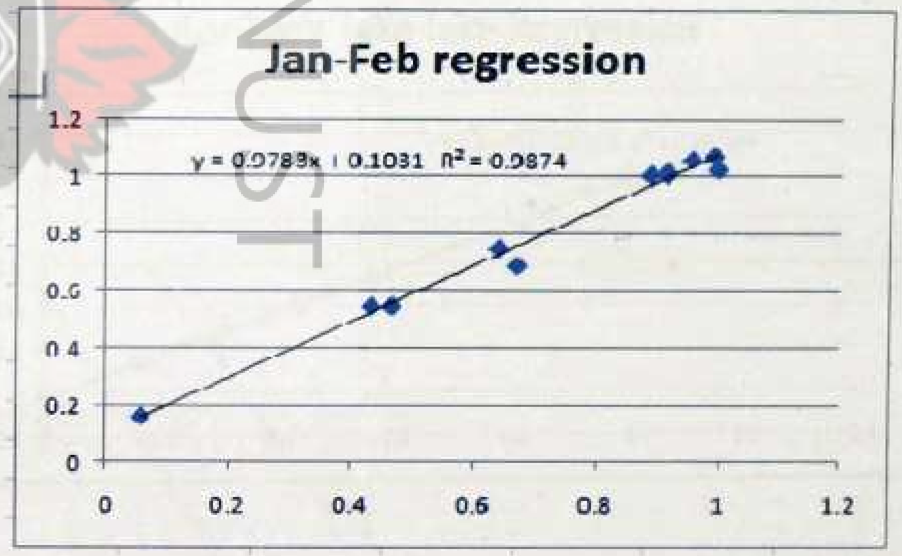
Year		Soil Group B - Land Use (m²) & CN							Interpolation Function
	Land cover	Closed Forests	Open Forests	Shrubs / Trees	Open Areas / Grassland	Settlements	Total Area	CN_w	$CN = CN_0(1+r)^t$
	CN Value	58.00	65.00	61.00	69.00	85.00			Rate = -0.00021651
May-08	375	756,541.76	11,820,174.69	14,526,875.37	2,590,172.25	1,662,487.67	31,356,251.73	63.55	64.07
Jun-08	376	710,396.12	11,851,218.46	14,543,005.81	2,583,054.03	1,667,287.37	31,354,961.79	63.53	64.05
Jul-08	377	664,250.49	11,882,262.23	14,559,136.25	2,575,935.81	1,672,087.07	31,353,671.85	63.52	64.04
Aug-08	378	618,104.86	11,913,306.00	14,575,266.69	2,568,817.59	1,676,886.77	31,352,381.91	63.50	64.03
Sep-08	379	571,959.23	11,944,349.77	14,591,397.13	2,561,699.37	1,681,686.48	31,351,091.97	63.49	64.01
Oct-08	380	525,813.60	11,975,393.53	14,607,527.58	2,554,581.15	1,686,486.18	31,349,802.03	63.47	64.00
Nov-08	381	479,667.97	12,006,437.30	14,623,658.02	2,547,462.93	1,691,285.88	31,348,512.09	63.45	63.99
Dec-08	382	433,522.34	12,037,481.07	14,639,788.46	2,540,344.71	1,696,085.58	31,347,222.15	63.44	63.97
Jan-09	383	387,376.71	12,068,524.84	14,655,918.90	2,533,226.49	1,700,885.29	31,345,932.21	63.42	63.96
Feb-09	384	341,231.08	12,099,568.61	14,672,049.34	2,526,108.27	1,705,684.99	31,344,642.27	63.40	63.94
Mar-09	385	295,085.44	12,130,612.38	14,688,179.78	2,518,990.05	1,710,484.69	31,343,352.34	63.39	63.93
Apr-09	386	248,939.81	12,161,656.14	14,704,310.22	2,511,871.83	1,715,284.39	31,342,062.40	63.37	63.92
May-09	387	202,794.18	12,192,699.91	14,720,440.66	2,504,753.61	1,720,084.09	31,340,772.46	63.35	63.90
Jun-09	388	156,648.55	12,223,743.68	14,736,571.10	2,497,635.39	1,724,883.80	31,339,482.52	63.34	63.89
Jul-09	389	110,502.92	12,254,787.45	14,752,701.54	2,490,517.17	1,729,683.50	31,338,192.58	63.32	63.87
Aug-09	390	64,357.29	12,285,831.22	14,768,831.98	2,483,398.95	1,734,483.20	31,336,902.64	63.30	63.86
Sep-09	391	18,211.66	12,316,874.99	14,784,962.42	2,476,280.73	1,739,282.90	31,335,612.70	63.29	63.85
Oct-09	392	-27,933.97	12,347,918.76	14,801,092.86	2,469,162.51	1,744,082.61	31,334,322.76	63.27	63.83
Nov-09	393	-74,079.60	12,378,962.52	14,817,223.30	2,462,044.29	1,748,882.31	31,333,032.82	63.25	63.82
Dec-09	394	-120,225.24	12,410,006.29	14,833,353.74	2,454,926.07	1,753,682.01	31,331,742.88	63.24	63.81
Jan-10	395	-166,370.87	12,441,050.06	14,849,484.18	2,447,807.85	1,758,481.71	31,330,452.94	63.22	63.79
Feb-10	396	-212,516.50	12,472,093.83	14,865,614.62	2,440,689.63	1,763,281.41	31,329,163.00	63.21	63.78

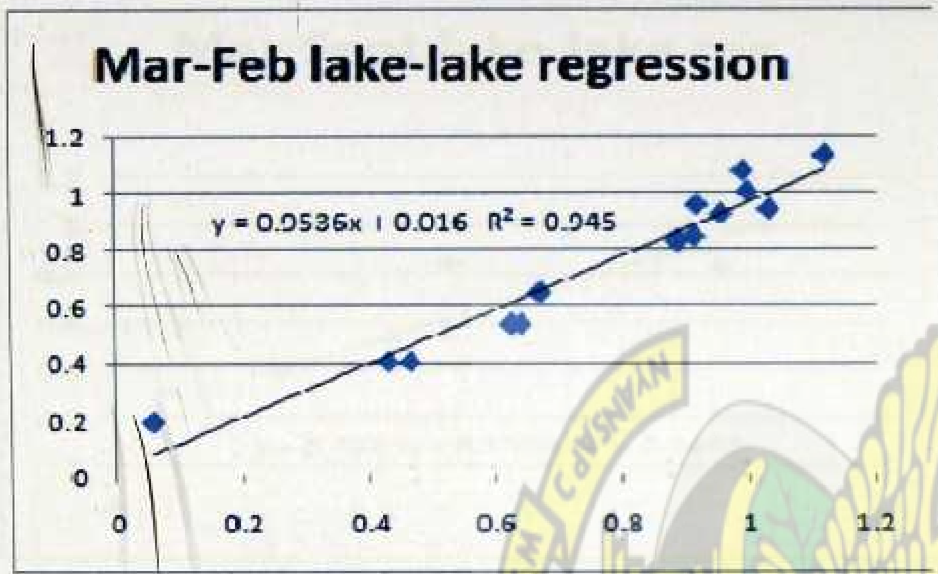
(b) Estimation of missing lake level records by regression analysis

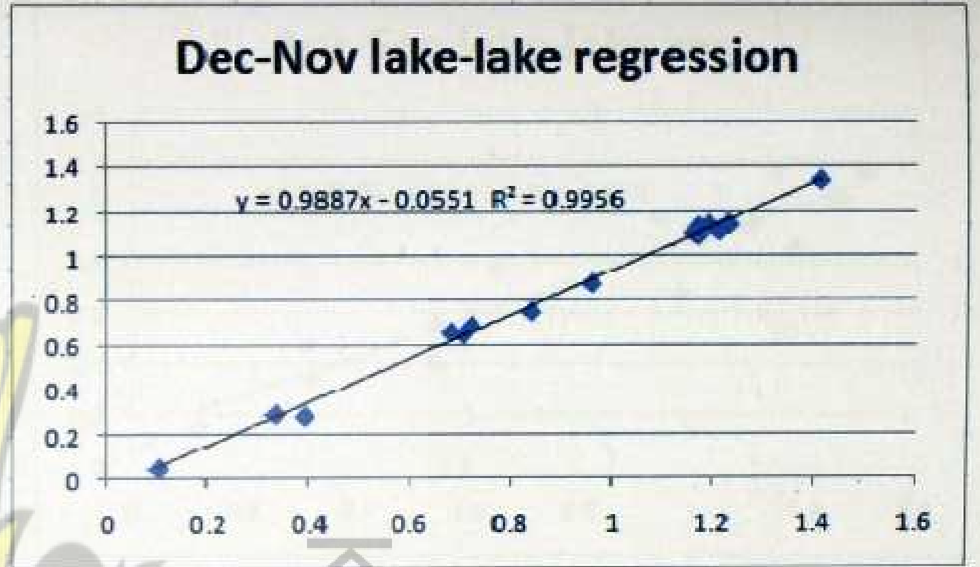


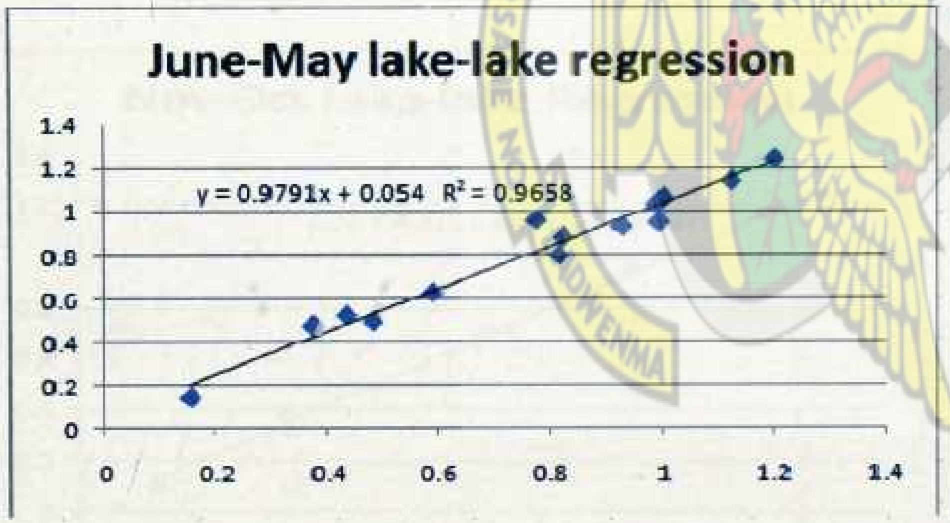


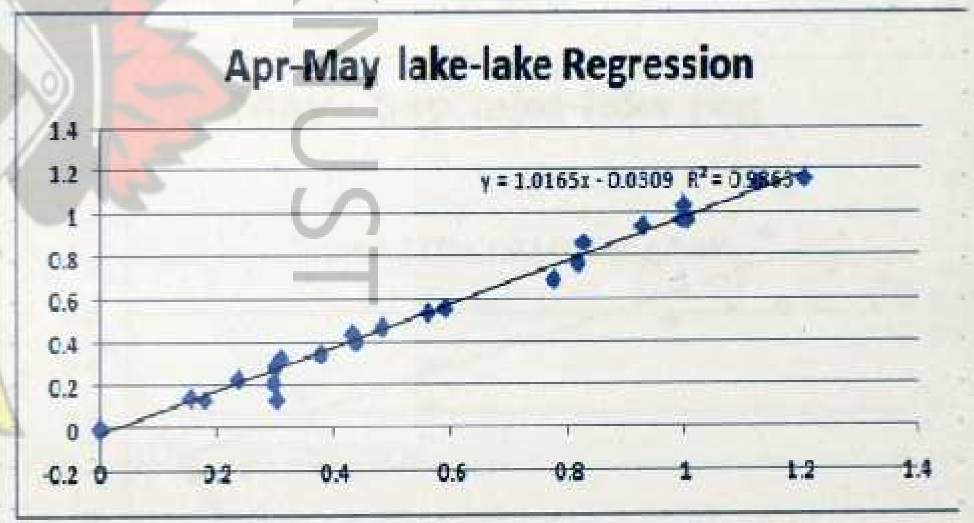


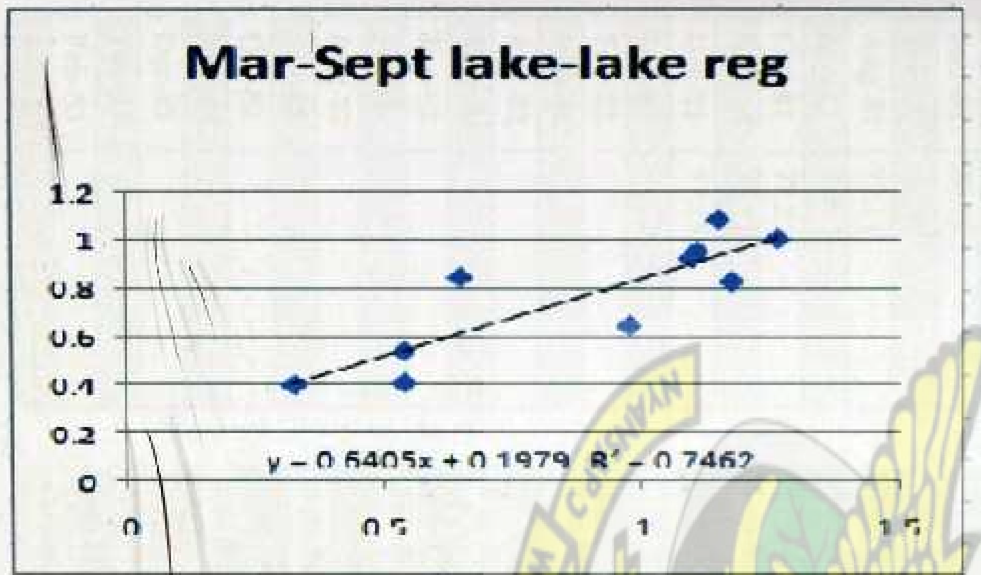


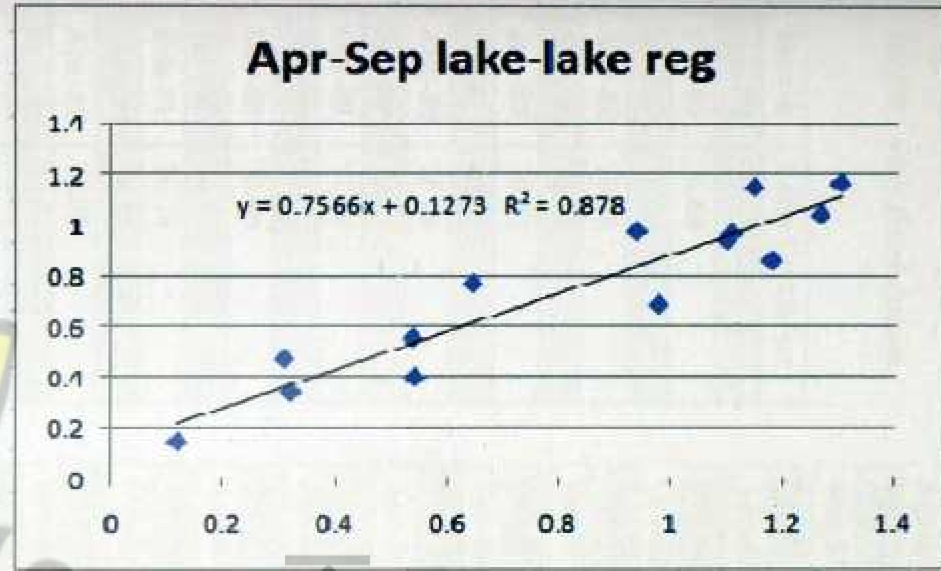

Mar-Feb lake-lake regression
y = 0.9536x + 0.016 R² = 0.945
0 0.2 0.4 0.6 0.8 1 1.2

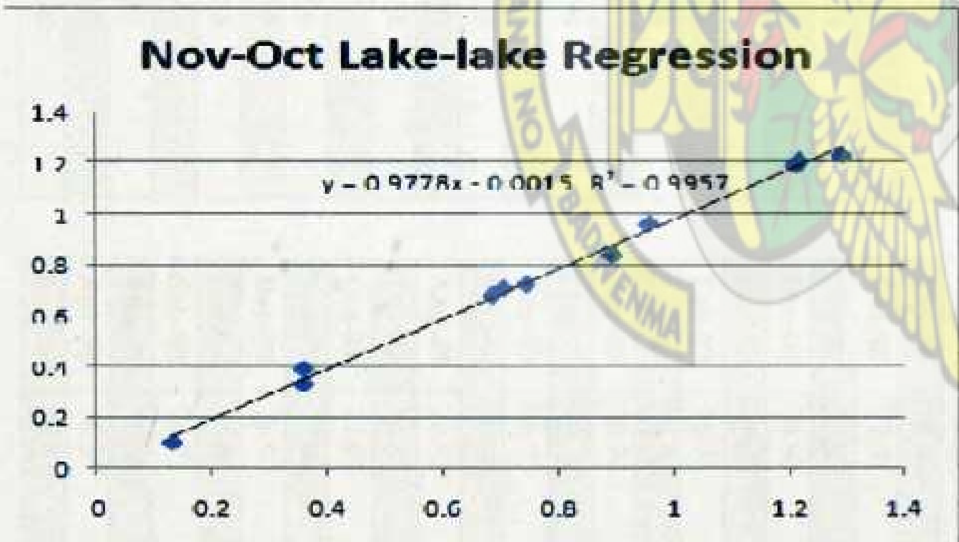

Dec-Nov lake-lake regression
y = 0.9887x - 0.0551 R² = 0.9956
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6

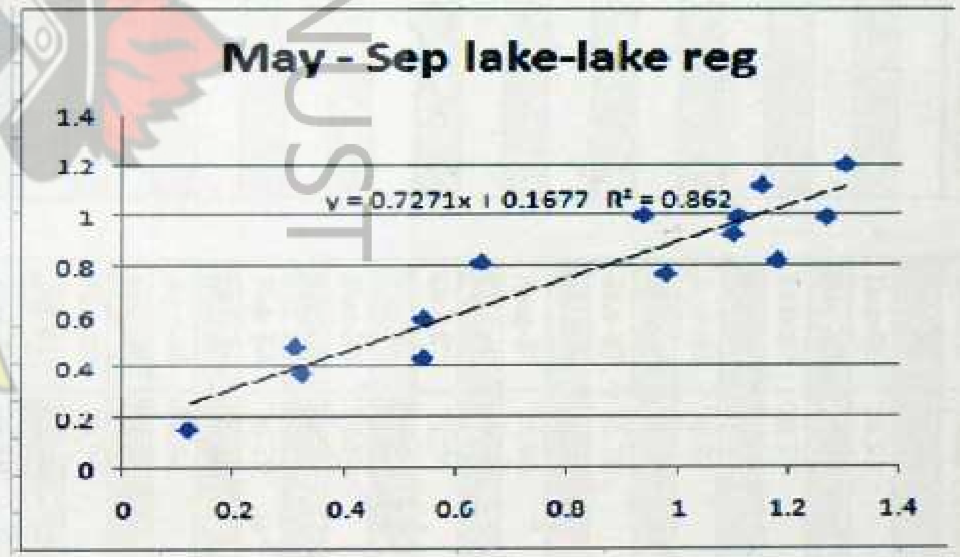

June-May lake-lake regression
y = 0.9791x + 0.054 R² = 0.9658
0 0.2 0.4 0.6 0.8 1 1.2 1.4


Apr-May lake-lake Regression
y = 1.0165x - 0.0309 R² =
0 0.2 0.4 0.6 0.8 1 1.2 1.4


Mar-Sept lake-lake reg
y = 0.6405x + 0.1979 R² = 0.7462


Apr-Sep lake-lake reg
y = 0.7566x + 0.1273 R² = 0.878


Nov-Oct Lake-lake Regression
y = 0.9778x - 0.0015 R² = 0.9957


May - Sep lake-lake reg
y = 0.7271x + 0.1677 R² = 0.862

(d) Lake level records (depth) with fixed datum

Month	Lake Levels (m)
Jan-80	76.91
Feb-80	76.68
Mar-80	76.66
Apr-80	76.68
May-80	76.66
Jun-80	76.70
Jul-80	76.67
Aug-80	76.66
Sep-80	76.67
Oct-80	77.00
Nov-80	77.03
Dec-80	76.96
Jan-81	76.85
Feb-81	76.74
Mar-81	76.85
Apr-81	76.93
May-81	76.95
Jun-81	76.98
Jul-81	77.04
Aug-81	77.11
Sep-81	77.15
Oct-81	77.22
Nov-81	77.21
Dec-81	77.14
Jan-82	
Feb-82	
Mar-82	
Apr-82	
May-82	
Jun-82	
Jul-82	
Aug-82	
Sep-82	
Oct-82	
Nov-82	
Dec-82	
Jan-83	
Feb-83	
Mar-83	

Month	Lake Levels (m)
Apr-83	
May-83	
Jun-83	
Jul-83	
Aug-83	
Sep-83	
Oct-83	
Nov-83	
Dec-83	
Jan-84	76.82
Feb-84	76.71
Mar-84	76.75
Apr-84	76.77
May-84	76.79
Jun-84	76.83
Jul-84	76.92
Aug-84	76.92
Sep-84	76.90
Oct-84	76.96
Nov-84	76.97
Dec-84	76.89
Jan-85	76.81
Feb-85	76.70
Mar-85	76.69
Apr-85	76.74
May-85	76.75
Jun-85	76.79
Jul-85	76.88
Aug-85	76.86
Sep-85	76.88
Oct-85	76.98
Nov-85	76.95
Dec-85	76.90
Jan-86	76.80
Feb-86	76.68
Mar-86	76.63
Apr-86	76.66
May-86	76.62
Jun-86	76.68
Jul-86	76.88
Aug-86	76.95
Sep-86	76.97
Oct-86	76.98

Month	Lake Levels (m)
Nov-86	76.97
Dec-86	76.93
Jan-87	76.82
Feb-87	76.79
Mar-87	76.80
Apr-87	76.84
May-87	76.79
Jun-87	76.74
Jul-87	76.85
Aug-87	76.96
Sep-87	77.06
Oct-87	77.24
Nov-87	77.21
Dec-87	77.14
Jan-88	76.87
Feb-88	76.79
Mar-88	76.88
Apr-88	76.94
May-88	76.92
Jun-88	76.93
Jul-88	76.98
Aug-88	76.89
Sep-88	76.94
Oct-88	77.01
Nov-88	76.99
Dec-88	76.94
Jan-89	76.86
Feb-89	76.75
Mar-89	76.72
Apr-89	76.74
May-89	76.72
Jun-89	76.73
Jul-89	76.85
Aug-89	76.82
Sep-89	76.89
Oct-89	77.01
Nov-89	77.01
Dec-89	76.90
Jan-90	76.80
Feb-90	76.71
Mar-90	76.64
Apr-90	76.57
May-90	76.61

Month	Lake Levels (m)
Jun-90	76.59
Jul-90	76.52
Aug-90	76.41
Sep-90	76.44
Oct-90	76.54
Nov-90	76.52
Dec-90	76.48
Jan-91	76.49
Feb-91	76.47
Mar-91	76.44
Apr-91	76.49
May-91	76.57
Jun-91	76.75
Jul-91	76.90
Aug-91	76.84
Sep-91	76.77
Oct-91	76.76
Nov-91	76.76
Dec-91	76.67
Jan-92	76.54
Feb-92	76.44
Mar-92	76.33
Apr-92	76.35
May-92	76.39
Jun-92	76.42
Jul-92	76.39
Aug-92	76.32
Sep-92	76.34
Oct-92	76.50
Nov-92	76.50
Dec-92	76.45
Jan-93	76.34
Feb-93	76.23
Mar-93	76.20
Apr-93	76.20
May-93	76.23
Jun-93	76.31
Jul-93	76.41
Aug-93	76.35
Sep-93	76.34
Oct-93	76.48
Nov-93	76.47
Dec-93	76.45

Month	Lake Levels (m)
Jan-94	76.35
Feb-94	76.26
Mar-94	76.20
Apr-94	76.14
May-94	76.17
Jun-94	76.27
Jul-94	76.26
Aug-94	76.17
Sep-94	76.12
Oct-94	76.16
Nov-94	76.19
Dec-94	76.08
Jan-95	75.96
Feb-95	75.86
Mar-95	75.99
Apr-95	75.94
May-95	75.95
Jun-95	75.94
Jul-95	75.94
Aug-95	75.89
Sep-95	75.92
Oct-95	75.93
Nov-95	75.90
Dec-95	75.84
Jan-96	75.99
Feb-96	75.92
Mar-96	75.93
Apr-96	75.96
May-96	76.00
Jun-96	76.03
Jul-96	76.13
Aug-96	76.12
Sep-96	76.10
Oct-96	76.09
Nov-96	76.03
Dec-96	75.93
Jan-97	75.90
Feb-97	75.83
Mar-97	75.74
Apr-97	75.77
May-97	75.80
Jun-97	75.86
Jul-97	75.85

Month	Lake Levels (m)
Aug-97	75.77
Sep-97	75.73
Oct-97	75.69
Nov-97	75.64
Dec-97	75.55
Jan-98	75.47
Feb-98	75.42
Mar-98	75.33
Apr-98	75.27
May-98	75.28
Jun-98	75.29
Jul-98	75.24
Aug-98	75.17
Sep-98	75.11
Oct-98	75.16
Nov-98	75.13
Dec-98	75.08
Jan-99	
Feb-99	
Mar-99	
Apr-99	
May-99	
Jun-99	
Jul-99	
Aug-99	
Sep-99	
Oct-99	
Nov-99	
Dec-99	
Jan-00	
Feb-00	
Mar-00	
Apr-00	
May-00	
Jun-00	
Jul-00	
Aug-00	
Sep-00	
Oct-00	
Nov-00	
Dec-00	
Jan-01	
Feb-01	

Month	Lake Levels (m)
Mar-01	
Apr-01	
May-01	
Jun-01	
Jul-01	
Aug-01	
Sep-01	
Oct-01	
Nov-01	
Dec-01	
Jan-02	74.52
Feb-02	74.43
Mar-02	74.38
Apr-02	74.33
May-02	74.36
Jun-02	74.40
Jul-02	74.52
Aug-02	74.52
Sep-02	74.50
Oct-02	74.52
Nov-02	74.55
Dec-02	74.46
Jan-03	74.40
Feb-03	74.34
Mar-03	74.23
Apr-03	74.24
May-03	74.23
Jun-03	74.27
Jul-03	74.25
Aug-03	74.18
Sep-03	74.12
Oct-03	74.20
Nov-03	74.25
Dec-03	74.20

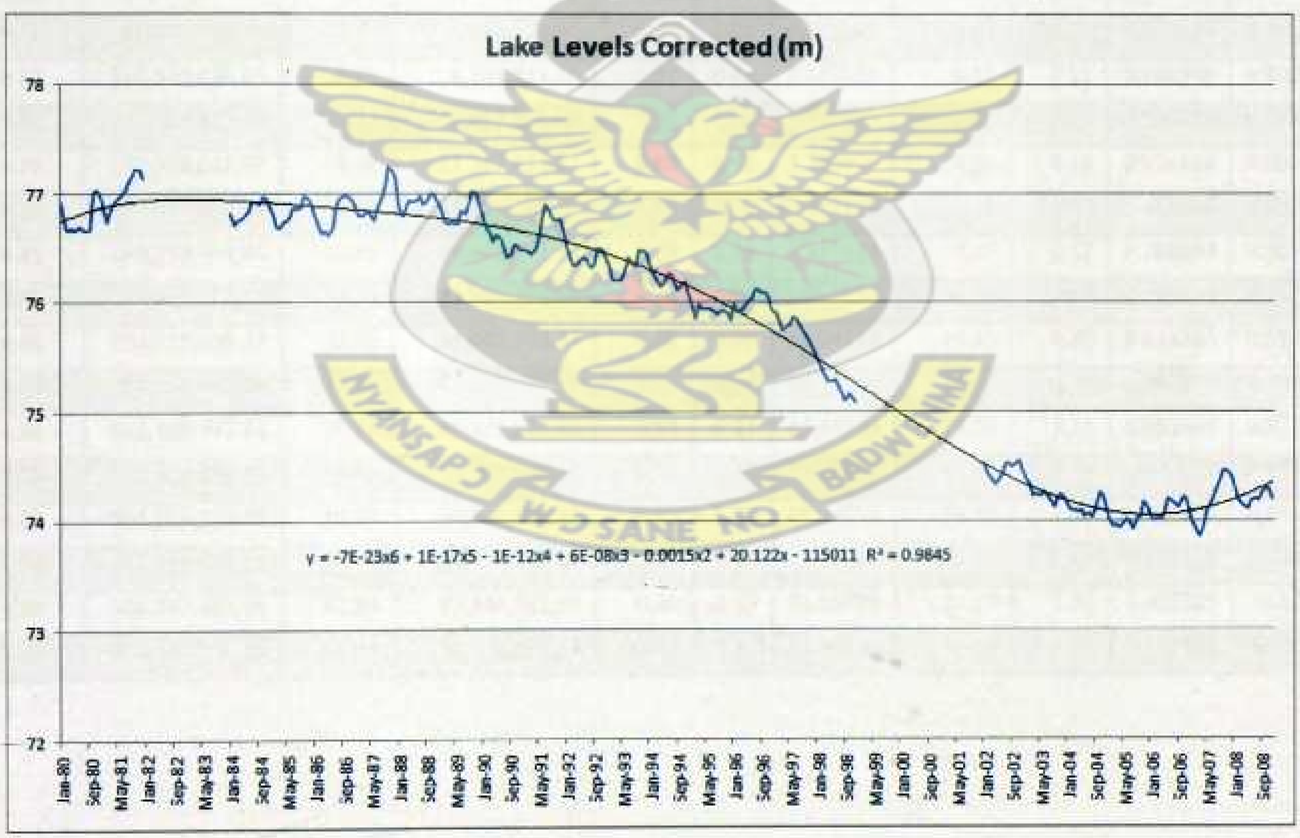
Month	Lake Levels (m)
Jan-04	74.14
Feb-04	74.10
Mar-04	74.09
Apr-04	74.08
May-04	74.10
Jun-04	74.04
Jul-04	74.07
Aug-04	74.03
Sep-04	74.09
Oct-04	74.26
Nov-04	74.23
Dec-04	74.13
Jan-05	74.01
Feb-05	73.95
Mar-05	73.97
Apr-05	73.93
May-05	73.98
Jun-05	74.02
Jul-05	73.98
Aug-05	73.92
Sep-05	74.03
Oct-05	74.03
Nov-05	74.17
Dec-05	74.11
Jan-06	74.03
Feb-06	74.00
Mar-06	74.03
Apr-06	74.01
May-06	74.10
Jun-06	74.20
Jul-06	74.18
Aug-06	74.15
Sep-06	74.12
Oct-06	74.21

Month	Lake Levels (m)
Nov-06	74.20
Dec-06	74.10
Jan-07	73.98
Feb-07	73.91
Mar-07	73.86
Apr-07	73.93
May-07	74.10
Jun-07	74.15
Jul-07	74.21
Aug-07	74.29
Sep-07	74.39
Oct-07	74.47
Nov-07	74.46
Dec-07	74.41
Jan-08	74.31
Feb-08	74.22
Mar-08	74.16
Apr-08	74.13
May-08	74.11
Jun-08	74.19
Jul-08	74.20
Aug-08	74.19
Sep-08	74.26
Oct-08	74.31
Nov-08	74.28
Dec-08	74.21

(e) Lake levels records (1932 - 2004)

(Source: Shanahan *et al.,* 2007)

(f) Lake level records (with datum fixed) (1984 -1998)



Appendix 10. Performance of ΔV with λ

λ	Lake Volume (m^3)					Lake Level (m)				
	RMSE	PRMSE	RB	D	R^2	RMSE	PRMSE	RB	D	R^2
0	363,523,502.94	17.18	-27,095,442.13	0.68	0.61	7.876699	10.31	-0.59	0.676702	0.605763
0.001	360,009,243.20	17.02	-26,833,504.68	0.68	0.61	7.797628	10.20	-0.58	0.680343	0.609741
0.01	328,874,166.46	15.55	-24,512,833.08	0.72	0.64	7.096832	9.29	-0.53	0.712271	0.643915
0.02	295,213,782.81	13.96	-22,003,936.21	0.75	0.68	6.338679	8.29	-0.47	0.745509	0.678514
0.03	262,479,097.87	12.41	-19,564,036.85	0.78	0.71	5.600867	7.33	-0.42	0.77587	0.709627
0.04	230,659,204.02	10.90	-17,192,321.99	0.81	0.74	4.883196	6.39	-0.36	0.802159	0.737382
0.05	199,756,239.33	9.44	-14,888,951.00	0.83	0.76	4.18576	5.48	-0.31	0.824141	0.761961
0.06	169,613,981.67	8.02	-12,642,279.77	0.85	0.78	3.505042	4.59	-0.26	0.842037	0.784024
0.07	140,405,187.09	6.64	-10,465,184.76	0.86	0.80	2.845021	3.72	-0.21	0.855767	0.803013
0.08	111,959,818.58	5.29	-8,344,992.17	0.88	0.82	2.201865	2.88	-0.16	0.865773	0.819607
0.09	84,273,899.36	3.98	-6,281,405.59	0.88	0.83	1.575514	2.06	-0.12	0.872342	0.834038
0.10	57,358,291.92	2.71	-4,275,234.66	0.89	0.85	0.966243	1.26	-0.07	0.87583	0.846521
0.11	31,204,693.79	1.48	-2,325,860.55	0.89	0.86	0.3739	0.49	-0.03	0.876632	0.857266
0.12	5,788,529.83	0.27	-431,451.54	0.89	0.87	0.202046	0.26	0.02	0.875119	0.866479
0.13	18,907,631.12	0.89	1,409,291.62	0.89	0.87	0.761962	1.00	0.06	0.871649	0.874342
0.14	42,880,897.38	2.03	3,196,153.38	0.88	0.88	1.305756	1.71	0.10	0.866559	0.881011
0.15	66,136,817.52	3.13	4,929,547.33	0.88	0.89	1.833527	2.40	0.14	0.860149	0.886627
0.16	88,699,066.30	4.19	6,611,238.06	0.87	0.89	2.345793	3.07	0.17	0.852684	0.891319
0.17	110,574,456.83	5.23	8,241,733.40	0.87	0.89	2.842685	3.72	0.21	0.844398	0.895205
0.18	131,788,822.46	6.23	9,822,958.86	0.86	0.90	3.324771	4.35	0.25	0.835486	0.898385
0.19	152,378,645.67	7.20	11,357,633.67	0.85	0.90	3.792862	4.96	0.28	0.826104	0.900946
0.20	172,352,098.10	8.15	12,846,366.91	0.84	0.90	4.247128	5.56	0.32	0.8164	0.902964
0.25	263,259,999.84	12.45	19,622,241.85	0.79	0.91	6.317012	8.27	0.47	0.766894	0.907155
0.30	341,373,522.95	16.14	25,444,480.10	0.75	0.90	8.098613	10.60	0.60	0.720816	0.905301
0.40	470,118,609.39	22.22	35,040,572.27	0.68	0.89	11.04175	14.45	0.82	0.646105	0.894989
0.50	575,310,082.80	27.20	42,881,081.78	0.62	0.88	13.45278	17.60	1.00	0.591377	0.882476
0.60	663,109,773.34	31.35	49,425,284.32	0.58	0.87	15.46949	20.24	1.15	0.551634	0.870415
0.70	742,029,138.23	35.08	55,307,586.48	0.55	0.86	17.28307	22.62	1.29	0.52027	0.857157
0.80	805,285,353.79	38.07	60,022,426.41	0.52	0.84	18.74032	24.52	1.40	0.496679	0.846831
0.90	861,148,188.51	40.71	64,186,196.27	0.50	0.83	20.0281	26.21	1.49	0.477272	0.834851
1.00	906,207,682.04	42.84	67,544,732.63	0.49	0.83	21.06891	27.57	1.57	0.462705	0.82766
1.10	942,348,759.15	44.55	70,238,529.47	0.48	0.82	21.90376	28.66	1.63	0.451592	0.820438

Appendix 11. Performance of ΔV after calibration, validation and evaluation

Date	Inputs (m^3)		Outputs (m^3)	Lake Levels (m)		
	P	*R*	*E*	*Lsim - RB*	*Lsim*	*Lobs*
Mar-77	4,146,481.71	317,421.63	8,493,723.69		76.77	
Apr-77	4,233,878.28	954,970.41	8,764,874.01		76.68	
May-77	4,782,534.53	1,227,402.40	8,677,430.90		76.62	
Jun-77	11,128,496.58	5,670,530.53	6,860,189.69		76.85	
Jul-77	1,830,472.61	129,984.26	6,089,963.82		76.76	
Aug-77	1,466,320.23	64,783.03	5,441,266.49		76.67	
Sep-77	8,404,636.82	3,529,334.63	6,461,240.32		76.79	
Oct-77	8,851,330.40	3,856,234.91	7,430,512.10		76.91	
Nov-77	888,531.80	5,401.93	8,331,103.30		76.74	
Dec-77	738,015.48	549.83	7,300,460.71		76.59	
Jan-78	72,830.48	0.00	8,047,831.58		76.41	
Feb-78	7,758,873.27	1,273,343.08	8,580,140.14		76.42	
Mar-78	3,753,197.15	730,065.50	8,721,148.05		76.33	
Apr-78	5,049,579.60	1,355,370.16	7,768,472.12		76.30	
May-78	12,716,200.94	6,947,760.22	8,201,730.05		76.56	
Jun-78	10,307,939.90	4,948,366.10	6,457,492.37		76.76	
Jul-78	2,777,268.78	369,770.71	6,042,330.83		76.69	
Aug-78	864,254.97	4,082.14	5,833,050.13		76.58	
Sep-78	10,545,852.78	5,124,112.48	6,580,977.80		76.78	
Oct-78	10,210,832.60	4,853,908.05	6,917,948.87		76.97	
Nov-78	1,976,133.56	157,440.25	7,642,616.74		76.84	
Dec-78	752,581.58	691.22	6,804,535.29		76.71	
Jan-79	704,027.93	10,399.50	7,124,860.92		76.56	
Feb-79	1,874,170.89	306,149.79	9,257,799.75		76.40	
Mar-79	4,894,207.92	1,259,539.05	9,244,816.62		76.33	
Apr-79	4,850,509.64	1,235,694.81	8,732,906.94		76.27	
May-79	5,802,161.18	1,759,028.81	8,093,150.59		76.26	
Jun-79	6,918,895.13	2,446,436.59	6,329,251.47		76.33	
Jul-79	14,585,516.46	8,484,548.40	5,950,486.74		76.71	
Aug-79	9,526,226.13	4,284,397.13	5,956,271.45		76.89	
Sep-79	16,085,824.25	9,820,215.69	6,961,421.77		77.32	
Oct-79	5,035,013.51	1,325,431.28	7,445,049.13		77.29	
Nov-79	4,000,820.76	822,046.53	7,542,143.43		77.23	
Dec-79	407,850.66	0.00	7,068,353.77		77.08	
Jan-80	247,623.62	0.00	7,344,226.94		76.92	76.91
Feb-80	4,899,063.29	410,227.53	8,145,732.61		76.86	76.68
Mar-80	2,379,128.85	250,467.88	8,630,078.17		76.72	76.66
Apr-80	2,612,186.37	313,719.72	9,109,775.73		76.58	76.68
May-80	5,826,438.00	1,756,115.65	7,678,754.18		76.58	76.66
Jun-80	13,910,620.73	7,822,687.97	6,783,087.17		76.92	76.70
Jul-80	6,307,119.14	2,038,911.41	5,833,100.53		76.98	76.67
Aug-80	1,864,460.16	129,871.17	6,204,133.77		76.88	76.66
Sep-80	8,292,963.42	3,343,646.66	6,446,805.82		77.00	76.67
Oct-80	5,700,198.51	1,676,741.52	7,239,579.87		77.00	77.00
Nov-80	3,287,082.11	528,273.03	7,595,425.88		76.92	77.03
Dec-80	1,048,758.84	13,901.05	7,728,333.94		76.77	76.96
Jan-81	0.00	0.00	9,103,562.66		76.56	76.85
Feb-81	1,121,589.32	0.00	7,882,806.64		76.41	76.74
Mar-81	8,351,227.80	3,369,043.99	8,634,039.17		76.48	76.85
Apr-81	2,184,914.25	198,737.43	8,775,815.27		76.33	76.93

May-81	12,361,759.29	6,450,298.02	7,965,508.39		76.58	76.95
Jun-81	7,860,835.94	3,022,065.39	7,172,493.46		76.66	76.98
Jul-81	10,084,593.11	4,629,703.58	5,121,417.46		76.88	77.04
Aug-81	2,058,674.76	168,771.45	5,462,216.50		76.81	77.11
Sep-81	7,258,770.68	2,614,037.84	6,348,419.22		76.88	77.15
Oct-81	4,670,861.13	1,116,236.94	7,953,701.52		76.84	77.22
Nov-81	378,718.47	0.00	7,637,256.82		76.67	77.21
Dec-81	1,505,163.15	185,863.72	6,453,293.91		76.56	77.14
Jan-82	0.00	0.00	9,503,345.26		76.35	
Feb-82	6,564,453.48	829,666.95	8,876,257.14		76.32	
Mar-82	2,655,884.66	318,954.58	8,902,630.51		76.18	
Apr-82	3,753,197.15	698,650.42	8,368,371.85		76.09	
May-82	6,831,498.56	2,325,396.53	7,533,414.85		76.13	
Jun-82	6,710,114.43	2,247,937.67	6,556,089.72		76.18	
Jul-82	2,422,827.14	254,331.64	5,578,208.61		76.12	
Aug-82	3,704,643.50	676,716.37	4,989,791.07		76.11	
Sep-82	708,883.29	19.25	5,795,321.70		75.99	
Oct-82	8,846,475.03	5,320,120.92	7,364,423.60		76.14	
Nov-82	679,751.10	0.00	7,314,145.14		75.99	
Dec-82	407,850.66	2,303.42	7,533,642.17		75.83	
Jan-83	0.00	0.00	9,108,030.29		75.63	
Feb-83	2,578,198.82	36,379.68	9,438,807.40		75.47	
Mar-83	3,262,805.28	506,803.35	9,219,408.35		75.35	
Apr-83	5,379,744.42	1,462,223.00	9,243,135.58		75.29	
May-83	5,641,934.13	1,603,816.69	8,324,372.06		75.27	
Jun-83	11,211,037.79	5,409,998.05	6,343,373.45		75.50	
Jul-83	1,645,968.74	84,343.24	6,313,937.07		75.40	
Aug-83	2,306,298.38	221,457.41	5,692,282.14		75.32	
Sep-83	4,593,175.29	1,058,396.38	5,888,897.84		75.32	
Oct-83	2,102,373.05	173,101.20	7,432,223.24		75.20	
Nov-83	3,267,660.65	504,930.24	7,431,914.32		75.12	
Dec-83	4,190,180.00	871,040.99	6,683,011.26		75.08	
Jan-84	0.00	0.00	8,215,127.73	76.82	76.82	76.82
Feb-84	432,127.49	0.00	9,945,475.96	76.63	76.61	76.71
Mar-84	6,520,755.20	3,261,200.85	8,809,495.54	76.76	76.63	76.75
Apr-84	3,908,568.83	748,011.17	8,316,240.34	76.69	76.54	76.77
May-84	6,433,358.63	2,043,556.26	7,987,158.61	76.80	76.56	76.79
Jun-84	8,734,801.64	3,539,853.97	6,718,064.05	76.94	76.68	76.83
Jul-84	13,425,084.23	7,146,810.61	7,661,760.61	77.15	76.97	76.92
Aug-84	8,312,384.88	3,244,995.09	6,413,410.25	77.08	77.09	76.92
Sep-84	10,429,324.02	4,767,878.04	6,494,946.13	77.16	77.28	76.90
Oct-84	6,739,246.62	2,222,443.23	7,196,420.78	76.98	77.32	76.96
Nov-84	2,155,782.06	182,365.28	7,425,343.01	76.89	77.21	76.97
Dec-84	63,119.75	0.00	6,989,726.65	76.85	77.05	76.89
Jan-85	898,242.53	0.00	7,811,181.71	76.77	76.90	76.81
Feb-85	2,209,191.08	193,980.08	9,039,111.67	76.69	76.75	76.70
Mar-85	12,012,173.01	5,982,925.44	8,025,900.88	76.95	76.97	76.69
Apr-85	8,103,604.19	3,091,925.84	8,452,305.41	76.77	77.03	76.74
May-85	5,107,843.98	1,296,353.82	7,736,986.39	76.73	77.00	76.75
Jun-85	7,729,741.08	2,840,671.59	7,110,570.84	76.85	77.08	76.79
Jul-85	20,251,727.42	13,125,138.55	6,240,954.31	77.43	77.69	76.88
Aug-85	4,685,427.23	1,085,114.67	6,127,246.44	76.90	77.68	76.86
Sep-85	9,846,680.22	4,312,629.82	6,348,284.87	77.07	77.86	76.88
Oct-85	4,840,798.91	1,158,798.95	7,581,445.90	76.87	77.82	76.98
Nov-85	5,360,322.96	1,422,175.46	7,365,160.48	77.01	77.81	76.95
Dec-85	0.00	0.00	7,434,194.97	76.83	77.64	76.90
Jan-86	0.00	0.00	8,729,980.49	76.73	77.45	76.80

Feb-86	6,413,937.17	750,199.29	9,359,271.33	76.78	77.40	76.68
Mar-86	3,126,855.06	445,567.01	7,963,500.83	76.61	77.30	76.63
Apr-86	3,432,743.06	550,643.25	9,053,693.47	76.53	77.19	76.66
May-86	7,516,105.02	2,686,998.59	8,666,982.30	76.71	77.22	76.62
Jun-86	13,012,378.20	6,755,413.52	7,433,876.70	76.92	77.50	76.68
Jul-86	8,560,008.50	3,380,434.48	5,578,208.61	76.84	77.64	76.88
Aug-86	1,427,477.31	48,006.79	5,907,196.24	76.82	77.54	76.95
Sep-86	5,544,826.83	1,511,341.93	6,458,978.79	77.00	77.55	76.97
Oct-86	8,283,252.69	3,187,181.86	6,938,965.44	77.11	77.65	76.98
Nov-86	631,197.45	0.00	7,734,383.24	76.86	77.49	76.97
Dec-86	0.00	0.00	8,099,857.91	76.82	77.31	76.93
Jan-87	286,466.54	0.00	7,965,416.54	76.79	77.14	76.82
Feb-87	3,146,276.52	82,914.32	8,859,537.60	76.73	77.01	76.79
Mar-87	5,340,901.50	1,398,021.32	8,917,610.56	76.77	76.97	76.80
Apr-87	8,302,674.15	3,191,601.80	8,788,455.60	76.89	77.03	76.84
May-87	2,248,034.00	196,926.70	8,505,642.73	76.73	76.89	76.79
Jun-87	11,939,342.54	5,868,834.15	7,036,729.31	77.06	77.13	76.74
Jul-87	7,613,212.32	2,731,278.68	6,430,757.31	76.86	77.22	76.85
Aug-87	9,327,156.17	3,897,664.16	6,034,322.82	77.05	77.38	76.96
Sep-87	9,162,073.76	3,778,773.62	6,622,244.99	77.14	77.52	77.06
Oct-87	3,612,391.56	608,354.70	7,407,950.49	77.03	77.45	77.24
Nov-87	145,660.95	0.00	8,068,054.63	77.12	77.27	77.21
Dec-87	655,474.28	0.00	7,587,961.41	77.11	77.12	77.14
Jan-88	0.00	0.00	8,082,367.28	77.01	76.94	76.87
Feb-88	485,536.50	0.00	9,392,832.32	76.70	76.74	76.79
Mar-88	15,027,354.68	11,058,440.65	8,474,696.07	77.21	77.13	76.88
Apr-88	6,588,730.31	2,083,732.76	8,613,088.05	76.91	77.13	76.94
May-88	5,374,889.06	1,403,607.21	8,420,976.10	76.94	77.10	76.92
Jun-88	16,590,782.21	9,724,269.31	6,893,706.14	77.39	77.53	76.93
Jul-88	6,739,246.62	2,170,406.59	6,196,044.30	77.03	77.59	76.98
Aug-88	728,304.75	0.00	5,482,357.66	76.91	77.49	76.89
Sep-88	9,006,702.08	5,316,790.60	6,238,660.53	77.11	77.67	76.94
Oct-88	6,622,717.86	2,097,245.87	7,608,766.40	77.01	77.69	77.01
Nov-88	1,874,170.89	115,181.32	7,761,104.03	76.92	77.56	76.99
Dec-88	3,830,882.99	685,459.82	7,436,819.21	76.96	77.50	76.94
Jan-89	2,607,331.01	281,251.00	8,945,593.63	76.84	77.36	76.86
Feb-89	111,673.40	0.00	9,594,998.74	76.68	77.15	76.75
Mar-89	5,467,140.99	483,664.07	9,617,126.11	76.69	77.07	76.72
Apr-89	3,748,341.78	651,107.12	8,856,976.62	76.64	76.97	76.74
May-89	6,127,470.63	1,802,020.00	8,390,767.56	76.75	76.96	76.72
Jun-89	15,071,052.96	8,382,869.29	6,807,183.11	77.12	77.33	76.73
Jul-89	4,335,840.95	892,277.80	6,662,227.21	76.72	77.30	76.85
Aug-89	8,593,996.05	3,348,284.33	6,177,381.14	77.01	77.43	76.82
Sep-89	13,653,286.38	7,190,741.72	5,832,909.70	77.19	77.76	76.89
Oct-89	9,045,545.00	3,657,104.86	6,947,348.33	77.06	77.89	77.01
Nov-89	1,917,869.18	121,428.12	7,950,765.50	76.92	77.76	77.01
Dec-89	398,139.93	0.00	7,691,242.18	76.88	77.60	76.90
Jan-90	1,738,220.67	230,389.00	8,191,297.72	76.80	77.46	76.80
Feb-90	3,355,057.22	502,789.46	9,314,917.70	76.71	77.34	76.71
Mar-90	5,350,612.23	1,372,100.87	9,628,438.75	76.67	77.27	76.64
Apr-90	9,667,031.72	4,088,031.13	8,588,702.99	76.77	77.39	76.57
May-90	5,598,235.85	1,499,920.48	8,111,970.83	76.56	77.36	76.61
Jun-90	6,137,181.36	1,794,316.42	7,276,167.28	76.64	77.38	76.59
Jul-90	1,097,312.49	12,391.11	5,567,258.85	76.51	77.28	76.52
Aug-90	1,437,188.04	44,883.80	5,552,561.64	76.44	77.19	76.41
Sep-90	7,720,030.35	2,749,991.05	6,209,087.98	76.51	77.28	76.44
Oct-90	6,676,126.88	2,102,125.33	7,456,435.46	76.48	77.31	76.54

Nov-90	5,083,567.16	1,230,647.84	7,602,438.44	76.52	77.28	76.52
Dec-90	4,049,374.41	760,171.99	7,234,864.80	76.47	77.23	76.48
Jan-91	2,660,740.02	288,583.40	8,159,013.31	76.37	77.11	76.49
Feb-91	4,073,651.24	769,007.40	8,821,002.87	76.41	77.02	76.47
Mar-91	3,777,473.97	650,471.09	8,851,837.70	76.37	76.92	76.44
Apr-91	6,472,201.55	1,975,776.42	8,670,646.29	76.44	76.92	76.49
May-91	14,901,115.19	8,181,299.64	7,424,444.98	76.85	77.27	76.57
Jun-91	8,341,517.07	3,145,567.97	7,028,525.91	76.68	77.37	76.75
Jul-91	4,277,576.57	851,837.00	6,360,206.22	76.75	77.34	76.90
Aug-91	3,384,189.41	505,063.62	5,401,030.37	76.90	77.31	76.84
Sep-91	6,952,882.68	2,255,463.10	6,357,374.02	76.94	77.37	76.77
Oct-91	5,947,822.13	1,673,011.49	6,662,588.41	76.82	77.39	76.76
Nov-91	1,150,721.51	15,492.47	7,080,397.57	76.65	77.26	76.76
Dec-91	4,855.37	0.00	7,259,939.51	76.62	77.10	76.67
Jan-92	174,793.14	0.00	8,812,285.64	76.49	76.90	76.54
Feb-92	267,045.08	0.00	9,521,037.78	76.35	76.70	76.44
Mar-92	3,607,536.20	126,229.41	8,517,684.35	76.33	76.59	76.33
Apr-92	7,418,997.72	2,534,233.69	8,401,582.63	76.37	76.62	76.35
May-92	7,297,613.60	2,457,273.64	7,952,818.34	76.39	76.66	76.39
Jun-92	6,443,069.36	1,943,948.60	6,468,664.97	76.43	76.71	76.42
Jul-92	3,845,449.08	668,393.41	4,839,672.38	76.41	76.70	76.39
Aug-92	1,476,030.96	47,537.88	5,334,205.30	76.31	76.61	76.32
Sep-92	15,187,581.72	8,382,778.98	6,145,692.06	76.72	77.01	76.34
Oct-92	2,388,839.58	214,890.92	7,367,201.91	76.23	76.90	76.50
Nov-92	3,185,119.44	433,272.93	7,462,426.91	76.42	76.81	76.50
Dec-92	344,730.92	0.00	6,872,648.42	76.36	76.66	76.45
Jan-93	97,107.30	0.00	9,090,995.44	76.25	76.46	76.34
Feb-93	2,578,198.82	24,404.18	9,443,681.58	76.19	76.31	76.23
Mar-93	5,705,053.88	1,525,859.79	8,692,166.69	76.19	76.27	76.20
Apr-93	7,414,142.36	2,516,189.06	8,659,583.72	76.22	76.30	76.20
May-93	6,797,511.00	2,139,361.79	8,268,554.00	76.20	76.32	76.23
Jun-93	16,454,831.99	9,442,525.97	7,049,538.34	76.65	76.74	76.31
Jul-93	1,505,163.15	50,195.11	5,333,630.29	76.22	76.66	76.41
Aug-93	4,981,604.49	1,155,352.90	5,049,456.21	76.44	76.68	76.35
Sep-93	8,157,013.20	2,985,340.81	6,369,336.95	76.45	76.79	76.34
Oct-93	12,483,143.42	6,138,409.19	7,752,613.84	76.58	77.03	76.48
Nov-93	2,544,211.26	249,346.66	7,580,205.34	76.38	76.93	76.47
Dec-93	1,296,382.46	26,516.08	7,189,987.85	76.35	76.80	76.45
Jan-94	0.00	0.00	8,515,088.83	76.26	76.60	76.35
Feb-94	354,441.65	0.00	8,807,222.09	76.15	76.41	76.26
Mar-94	2,529,645.17	20,472.67	9,244,779.74	76.10	76.26	76.20
Apr-94	9,463,106.39	3,863,830.46	7,876,187.82	76.31	76.38	76.14
May-94	10,142,857.49	4,348,139.39	7,924,015.55	76.28	76.53	76.17
Jun-94	5,637,078.77	1,476,531.16	7,108,296.36	76.16	76.53	76.27
Jul-94	4,685,427.23	1,008,767.53	5,498,937.79	76.26	76.54	76.26
Aug-94	3,063,735.32	388,182.87	5,611,638.51	76.20	76.49	76.17
Sep-94	7,579,224.77	2,598,202.21	5,739,911.01	76.26	76.59	76.12
Oct-94	8,691,103.35	3,322,191.21	6,862,763.12	76.22	76.70	76.16
Nov-94	1,709,088.48	77,115.27	8,230,555.35	76.00	76.56	76.19
Dec-94	0.00	0.00	8,422,582.26	75.99	76.37	76.08
Jan-95	0.00	0.00	9,978,276.56	75.84	76.14	75.96
Feb-95	33,987.56	0.00	10,441,697.72	75.70	75.91	75.86
Mar-95	5,904,123.84	546,573.24	8,988,304.31	75.76	75.85	75.99
Apr-95	9,652,465.62	3,977,936.56	8,644,585.35	76.08	75.96	75.94
May-95	8,535,731.67	3,207,686.54	8,419,258.90	75.99	76.04	75.95
Jun-95	7,530,671.12	2,556,411.33	6,951,771.91	76.00	76.11	75.94
Jul-95	6,632,428.59	2,013,793.53	6,377,829.10	75.96	76.16	75.94

Aug-95	7,210,217.03	2,356,260.58	5,711,040.63	76.00	76.25	75.89
Sep-95	6,739,246.62	2,073,824.97	6,471,749.38	75.91	76.30	75.92
Oct-95	4,646,584.31	980,944.33	7,328,922.59	75.85	76.26	75.93
Nov-95	1,942,146.00	114,387.01	8,128,611.37	75.76	76.13	75.90
Dec-95	5,612,801.94	1,448,014.87	7,712,907.88	75.85	76.11	75.84
Jan-96	179,648.51	0.00	7,003,695.44	75.65	75.96	75.99
Feb-96	3,894,002.73	153,707.84	8,639,757.69	75.86	75.85	75.92
Mar-96	3,505,573.53	522,960.14	8,194,932.12	75.79	75.76	75.93
Apr-96	5,428,298.07	1,350,136.10	8,231,079.86	75.87	75.72	75.96
May-96	7,074,266.81	2,263,418.87	8,122,578.08	75.96	75.75	76.00
Jun-96	5,146,686.90	1,208,993.23	6,482,609.11	75.97	75.75	76.03
Jul-96	9,841,824.86	4,087,508.98	6,514,738.27	76.18	75.92	76.13
Aug-96	5,321,480.04	1,293,289.81	5,884,485.48	76.13	75.93	76.12
Sep-96	3,520,139.63	525,354.50	5,902,974.61	76.06	75.89	76.10
Oct-96	3,971,688.57	690,498.03	7,034,432.44	76.02	75.84	76.09
Nov-96	135,950.22	0.00	8,622,347.35	75.88	75.64	76.03
Dec-96	2,519,934.44	17,455.83	6,556,545.25	75.91	75.55	75.93
Jan-97	2,607,331.01	255,183.96	7,477,874.88	75.80	75.45	75.90
Feb-97	1,602,270.45	58,709.56	9,430,456.87	75.70	75.27	75.83
Mar-97	6,700,403.70	2,031,526.75	8,619,825.16	75.79	75.27	75.74
Apr-97	14,405,867.96	7,595,240.04	8,408,627.03	76.01	75.58	75.77
May-97	10,618,683.26	4,631,885.15	8,082,337.62	75.89	75.75	75.80
Jun-97	12,152,978.60	5,788,439.70	6,166,885.65	76.03	76.01	75.86
Jul-97	3,563,837.91	536,053.95	6,368,195.99	75.78	75.96	75.85
Aug-97	2,864,665.35	320,016.88	5,814,584.52	75.76	75.90	75.77
Sep-97	4,675,716.50	978,476.11	6,507,295.57	75.71	75.88	75.73
Oct-97	7,875,402.03	2,737,634.32	7,676,611.17	75.76	75.95	75.69
Nov-97	538,945.52	0.00	8,042,789.97	75.47	75.78	75.64
Dec-97	548,656.25	84.22	7,786,944.73	75.42	75.61	75.55
Jan-98	2,515,079.07	485,231.03	8,686,760.80	75.36	75.48	75.47
Feb-98	1,291,527.09	23,024.97	9,229,839.38	75.23	75.30	75.42
Mar-98	1,743,076.04	77,426.92	9,401,622.00	75.19	75.13	75.33
Apr-98	12,983,246.01	6,418,078.54	9,067,668.31	75.50	75.37	75.27
May-98	8,899,884.05	3,399,294.56	8,268,779.82	75.29	75.46	75.28
Jun-98	9,162,073.76	3,575,989.14	6,977,032.01	75.34	75.59	75.29
Jul-98	2,743,281.23	284,764.83	5,966,000.41	75.15	75.52	75.24
Aug-98	3,670,655.94	567,656.34	5,593,126.75	75.13	75.49	75.17
Sep-98	3,626,957.66	551,794.83	6,229,698.81	75.04	75.45	75.11
Oct-98	3,714,354.23	582,320.08	7,108,302.42	74.96	75.38	75.16
Nov-98	1,141,010.78	11,255.92	8,214,956.37	74.91	75.22	75.13
Dec-98	1,539,150.71	48,453.37	7,439,888.30	74.91	75.09	75.08

Appendix 12. Sample Microsoft Excel VBA programs for evaporation calculations.

```
Public Function Lake_Surface_Area(levels As Double) As Double
Dim A, D As Double
If IsNumeric(levels) Then
    D = levels
    A = (13.744 * (D ^ 3) - 5805.7 * (D ^ 2) + (1000000#) * D)  'Published in T.M Shanahan et al
        'A = 0.012 * (d ^ 3) - 6.411 * (d ^ 2) + 1242 * d - 23622
        'A = -5.586 * d ^ 2 + 985.5 * d
        'A = 0# * (d ^ 4) + 0# * (d ^ 3) - 4.268 * (d ^ 2) + 942.1 * d
        'A = 0.012 * (d ^ 3) - 5.607 * (d ^ 2) + 987.4 * d - 47.98
    Lake_Surface_Area = A
Else
    MsgBox "Input Not Numeric", vbExclamation, "Lake Surface Area Calculation"
    Exit Function
End If
'Return
End Function
```

```
Function Storage_from_Area(A As Double)
On Error GoTo errorhandler
Storage_from_Area = -7E-37 * A ^ 6 + 1E-28 * A ^ 5 - 6E-21 * A ^ 4 + 0.0000000000001 * A ^ 3 + _
0.0000004 * A ^ 2 - 4.9738 * A + 6000000#

Exit Function
errorhandler:
    MsgBox "Storage from Area Calculation. Error is " & err.Description, vbOKOnly
    Resume Next
End Function
```



```
Function Area_from_Storage(Storage As Double)
On Error GoTo errorhandler
Dim S As Double
S = Storage
Area_from_Storage = -5E-51 * S ^ 6 + 1E-40 * S ^ 5 - 2E-30 * S ^ 4 + 1E-20 * S ^ 3 - _
0.00000000004 * S ^ 2 + 0.0624 * S + 3000000#

Exit Function
errorhandler:
    MsgBox "Area from Storage Calculation. Error is " & err.Description, vbOKOnly
    Resume Next
End Function
```

```
Sub Surface_Area(D As Double)
    Lake_Surface_Area (D)
End Sub
```

```
''' Elevations above sea level
Function Elevation(L As Double)
    Elevation = L + 21.2
End Function
```

```
'''Atmospheric Pressure
Function P_atm(z)
    P_atm = 101.3 * ((293 - 0.0065 * CDbl(z)) / 293) ^ 5.26
End Function
```



```
'''Atmospheric Pressure
Function P_atm(z)
    P_atm = 101.3 * ((293 - 0.0065 * CDbl(z)) / 293) ^ 5.26
End Function
```



```
''' Drag Coefficient here refered to as CCd
Function CCd(Optional Zr As Double = 2#, Optional Zo As Double = 0.00006, Optional use_ref As Boolean = False)
    Dim k, Cd As Double
    If use_ref = True Then
        k = 0.4
        Cd = k ^ 2 * Log((Zr / Zo) ^ (-2))
        CCd = Cd
    Else
        CCd = 0.00073
    End If
End Function
```

```
''' Drag Coefficient here refered to as CCd
Function CCd(Optional Zr As Double = 2#, Optional Zo As Double = 0.00006, Optional use_ref As Boolean = False)
    Dim k, Cd As Double
    If use_ref = True Then
        k = 0.4
        Cd = k ^ 2 * Log((Zr / Zo) ^ (-2))
        CCd = Cd
    Else
        CCd = 0.00073
    End If
'''Bulk Transfer Estimate of Evaporation
Function Bulk_Transfer_Estimate_Evaporation(Tw, Ta, RH, U, Cd, Optional f As Double = 1#, Optional R As Double = 8.31451)
On Error GoTo errorhandler
    Bulk_Transfer_Estimate_Evaporation = ((0.622 * Cd * U * f) / (R * Ta)) * (es(CDbl(Tw)) + CDbl(RH) * es(CDbl(Ta)))

errorhandler:
    MsgBox "Bulk Transfer Calculation. Error is " & err.Description, vbOKOnly
    Resume Next
End Function

'''Saturated Vapour Pressure
Function es(T As Double)
    es = 0.6108 * Exp((17.269 * T) / (T + 237.3))
End Function
''' Ea
Function ea(Tmin, Tmax, RHmin, RHmax)
ea = (es(CDbl(Tmin)) * (CDbl(RHmax) / 100) + es(CDbl(Tmax)) * (CDbl(RHmin) / 100)) / 2
End Function

'''Outgoing_Sensible_Heatflux
Function H(Patm, Cd, U, Tw, Ta, Optional Cair As Double = 1.005, Optional R As Double = 8.31451)
    H = ((Patm * Cd * U * Cair) / (R * Ta)) * (Tw - Ta)
End Function

'''Latent Heat of Evaporation of Water LamdaV
Function Lv(Optional Tw As Double, Optional L_v As Double = 2.45) 'Optional Tw As Double)
    If Tw <= 0 Then
        Lv = 597.3 - 0.564 * Tw
    Else
    Lv = L_v
    End If
End Function

'''Mass Transfer Evaporation
Function Mass_Transfer_Evaporation(U2 As Double, A As Double, es As Double, ea As Double)
    On Error GoTo errorhandler
    Mass_Transfer_Evaporation = (2.909 * (A ^ (-0.05))) * U2 * (es - ea)

    Exit Function
errorhandler:
    MsgBox "Mass Transfer Evaporation. Error is " & err.Description, vbOKOnly
    Resume Next
End Function

''' Energy Budget Evaporation
Function Energy_Budget_Evaporation(Rn, Patm, Cd, U, Tw, Ta, _
 Optional Cair As Double = 1.005, Optional R As Double = 8.31451)
On Error GoTo errorhandler
Dim LH As Double
    Energy_Budget_Evaporation = (Rn - H(Patm, Cd, U, Tw, Ta, Cair, R)) / Lv(CDbl(Tw))
    Exit Function
errorhandler:

    MsgBox "Energy Budget Evaporation. Error is " & err.Description, vbOKOnly
    Resume Next
End Function
```

```
''' Slope of the saturation vapour curve
Function Sat_Slope(Tw As Double) As Double
    Sat_Slope = (((25083) / (Tw + 237.3) ^ 2) * Exp((17.3 * Tw) / (Tw + 237.3)))
'''Psychometric Constant
Function Psycho_const(Cair, Patm, LamdaV)
    Pshcho_const = ((Cair * Patm) / (0.622 * 1000 * LamdaV))
End Function
```

```
''' Drying power of Air Refered to as DEa
Function DEa(U2, var_Es, var_Ea)
    DEa = 0.26 * (1 + 0.54 * U2) * (var_Es - var_Ea)
End Function
```

```
'''Priestly Taylor Evaporation Model
Function Priestly_Taylor_Evaporation(Tw, Patm, Rn, Optional Cair As Double = 1.005, _
 Optional alpha_const As Double = 1.26) As Double
On Error GoTo errorhandler
    Priestly_Taylor_Evaporation = alpha_const * ((Sat_Slope(CDbl(Tw)) / (Sat_Slope(CDbl(Tw)) _
    + Psycho_const(Cair, CDbl(Patm), Lv(CDbl(Tw)))) * (CDbl(Rn) / (998# * Lv(CDbl(Tw))))) * 86.4
    Exit Function
errorhandler:
    MsgBox "Priestly Taylor Evaporation. Error is " & err.Description, vbOKOnly
    Resume Next
End Function
```



```
'''Pennman Evaporation Model
Function Pennman_Evaporation(Tw, Patm, Rn, U2, var_Es, var_Ea, Optional Cair As Double = 1.005)
On Error GoTo errorhandler
    Pennman_Evaporation = (Rn / Lv(CDbl(Tw))) * (Sat_Slope(CDbl(Tw)) / (Sat_Slope(CDbl(Tw)) + _
    Psycho_const(Cair, Patm, Lv(CDbl(Tw))))) + (DEa(U2, var_Es, var_Ea) * (Psycho_const(Cair, Patm, _
    Lv(CDbl(Tw)) / (Psycho_const(Cair, Patm, Lv(CDbl(Tw))) + Sat_Slope(CDbl(Tw)))))))
Exit Function
errorhandler:
    MsgBox "Pennman Evaporation. Error is " & err.Description, vbOKOnly
    Resume Next
End Function
```

```
Function Simplified_Pennman(Ta As Double, Rs As Double, Ra As Double, RH As Double)
On Error GoTo errorhandler
    Simplified_Pennman = 0.047 * Rs * Sqr(Ta + 9.5) - 2.4 * ((Rs / Ra) ^ 2) + 0.09 * (Ta + 20) * (1 - (RH / 100))
Exit Function
errorhandler:
    MsgBox "Simplified Pennman Evporation. Error is " & err.Description & ". Error Source is: " & err.Source, vbCritical
    Resume Next
End Function
```

```
''' Annual Heat Index
Function AHI(ParamArray Ta_Array())
On Error GoTo errorhandler
Dim I As Double, x As Integer
x = 0
I = 0

For x = 0 To 11 Step 1
    I = I + (CDbl(Ta_Array(x)) / 5) ^ 1.514
Next x

AHI = I

Exit Function
errorhandler:
    MsgBox "Error is " & err.Description & ". Error Source is: " & err.Source, vbCritical
    Resume Next
End Function
```

```
''' Thornwaite Matter Evaporation
Function Thornwaite_Evaporation(Ta As Double, I As Double, D As Integer)
On Error GoTo errorhandler
    Thornwaite_Evaporation = ((1.6 * ((10 * Ta) / I) ^ ((6.75 * 10 ^ (-7) * _
    (I ^ 3)) - (7.71 * 10 ^ (-5) * (I ^ 2)) + (1.79 * 10 ^ (-2) * I) + 0.49))) * (10 / D)
Exit Function
errorhandler:
    MsgBox "Thornwaite Evaporation. Error is " & err.Description & ". Error Source is: " & err.Source, vbCritical
    Resume Next
End Function
```

Appendix 13. Radiation Calculations

(a) Ra –Extraterrestrial Radiation (MJ m^{-2} day^{-1})

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1962	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1963	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1964	33.360	35.507	37.307	37.669	36.724	35.827	36.019	36.955	37.253	36.047	33.933	32.706
1965	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1966	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1967	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1968	33.360	35.507	37.307	37.669	36.724	35.827	36.019	36.955	37.253	36.047	33.933	32.706
1969	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1970	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1971	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1972	33.360	35.507	37.307	37.669	36.724	35.827	36.019	36.955	37.253	36.047	33.933	32.706
1973	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1974	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1975	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1976	33.360	35.507	37.307	37.669	36.724	35.827	36.019	36.955	37.253	36.047	33.933	32.706
1977	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1978	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1979	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1980	33.360	35.507	37.307	37.669	36.724	35.827	36.019	36.955	37.253	36.047	33.933	32.706
1981	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1982	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1983	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1984	33.360	35.507	37.307	37.669	36.724	35.827	36.019	36.955	37.253	36.047	33.933	32.706
1985	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1986	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1987	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1988	33.360	35.507	37.307	37.669	36.724	35.827	36.019	36.955	37.253	36.047	33.933	32.706
1989	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1990	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1991	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1992	33.360	35.507	37.307	37.669	36.724	35.827	36.019	36.955	37.253	36.047	33.933	32.706
1993	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1994	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1995	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1996	33.360	35.507	37.307	37.669	36.724	35.827	36.019	36.955	37.253	36.047	33.933	32.706
1997	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1998	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
1999	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	33.360	35.507	37.307	37.669	36.724	35.827	36.019	36.955	37.253	36.047	33.933	32.706
2001	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
2002	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
2003	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
2004	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
2005	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
2006	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
2007	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
2008	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
2009	33.360	35.507	37.265	37.685	36.762	35.841	35.996	36.926	37.267	36.108	33.998	32.719
Average	33.360	35.507	37.275	37.681	36.753	35.838	36.001	36.933	37.264	36.094	33.982	32.716

(b) Rs – Shortwave or Solar Radiation (MJ m^{-2} day^{-1})

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	17.355	19.723	19.766	19.825	19.063	16.491	13.080	13.159	14.886	18.006	18.230	17.326
1962	18.500	20.928	20.234	19.825	19.063	14.753	15.558	13.763	13.803	16.637	16.923	18.311
1963	15.495	19.422	20.546	20.602	18.764	16.926	15.558	15.274	16.588	17.397	18.956	16.482
1964	17.498	19.873	21.031	20.588	19.488	16.050	14.986	13.322	15.348	15.548	17.038	14.929
1965	17.069	19.120	20.390	19.515	20.110	16.057	13.517	13.763	15.969	17.702	18.230	16.904
1966	16.926	19.873	20.390	21.223	20.559	16.347	13.809	13.461	15.041	16.941	18.375	16.622
1967	18.357	18.970	18.986	20.136	19.661	16.636	14.246	12.102	13.184	16.180	18.084	15.497
1968	17.928	19.572	19.003	19.657	19.338	15.905	14.986	14.078	16.276	18.588	17.183	15.069
1969	16.926	18.066	20.078	20.602	19.661	16.636	12.789	12.253	13.958	16.028	17.794	15.778
1970	15.638	17.915	18.518	18.738	18.165	17.360	14.100	12.253	13.958	17.550	18.084	16.200
1971	18.500	19.120	19.922	20.291	20.708	17.216	15.412	14.065	13.494	17.854	17.939	16.904
1972	17.642	19.271	19.159	19.192	18.442	16.050	12.944	12.717	15.193	16.916	17.328	15.913
1973	17.642	19.271	17.582	19.670	20.259	15.478	15.412	14.519	14.886	17.702	19.537	17.607
1974	15.638	16.710	20.390	20.757	19.212	16.926	14.829	15.425	15.041	17.093	18.665	16.482
1975	19.502	20.325	20.234	20.291	18.764	17.650	15.558	13.008	14.732	18.006	18.230	16.763
1976	18.500	19.271	20.563	19.502	18.890	15.616	13.673	13.625	14.574	14.180	17.038	16.335
1977	16.211	18.066	16.803	18.272	19.661	15.767	13.955	12.253	14.732	17.245	18.520	15.919
1978	16.926	18.216	19.610	17.341	18.913	14.898	13.955	13.008	15.196	16.028	17.358	15.215
1979	15.352	19.572	19.766	19.515	18.764	14.464	13.517	13.461	16.124	16.941	17.358	15.637
1980	16.067	16.861	19.159	19.967	17.546	15.761	13.235	14.229	14.574	16.764	17.328	16.476
1981	18.214	16.258	18.518	19.670	18.464	16.636	11.768	12.404	14.422	18.311	16.923	14.230
1982	19.216	18.066	19.298	18.272	17.417	15.043	12.643	11.497	13.030	16.637	16.777	15.215
1983	14.493	18.819	17.582	20.602	18.464	14.174	13.955	12.253	13.030	16.484	16.487	14.512
1984	16.211	17.765	18.534	17.640	17.994	15.326	18.633	14.532	14.419	16.308	16.458	13.803
1985	15.495	17.463	16.959	18.894	17.567	16.347	14.538	14.065	14.267	17.397	16.923	14.230
1986	16.067	19.873	17.271	20.291	20.110	17.360	12.643	13.159	14.422	15.571	17.068	16.060
1987	15.924	18.970	19.142	19.049	19.212	16.347	14.683	14.065	15.350	17.245	17.649	15.919
1988	14.636	18.367	18.378	19.502	19.488	16.195	14.694	12.566	14.265	17.676	17.473	16.757

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	18.214	17.915	21.014	19.825	19.362	16.057	15.558	14.519	13.494	16.484	18.084	16.904
1990	17.642	19.271	20.078	19.359	18.614	16.926	12.789	12.404	14.113	17.245	17.649	16.622
1991	17.785	19.422	19.766	20.136	17.118	16.202	14.683	12.404	14.267	15.419	15.761	14.934
1992	15.495	18.970	17.286	18.881	18.143	14.892	11.047	11.961	14.110	16.460	16.603	14.929
1993	17.498	19.723	18.986	19.670	18.764	16.347	11.914	11.346	14.732	18.006	17.358	15.497
1994	17.642	17.162	19.610	17.341	18.464	16.491	12.351	12.102	13.030	16.180	18.665	17.326
1995	19.502	21.079	19.610	19.825	19.661	15.912	14.829	13.461	14.886	16.941	18.520	17.467
1996	15.781	19.271	18.222	18.571	18.591	15.037	15.132	13.776	13.336	16.308	18.779	14.647
1997	16.497	18.367	17.582	19.670	18.764	14.319	14.975	13.612	14.732	17.702	18.375	16.763
1998	16.926	19.422	18.830	19.981	19.212	16.202	13.517	12.857	14.113	16.180	18.084	16.341
1999	17.928	18.970	20.390	19.981	17.866	17.071	13.809	13.461	13.494	15.723	18.375	17.185
2000	16.640	20.476	18.847	20.433	19.189	15.616	14.694	13.927	13.800	16.916	18.634	16.195
2001	18.214	19.873	20.234	20.446	19.212	16.202	14.975	12.706	14.113	18.158	18.520	16.904
2002	16.211	20.024	20.234	19.981	19.661	17.071	14.538	13.763	14.886	18.767	18.665	17.467
Average	17.045	18.945	19.250	19.608	18.961	16.066	14.131	13.252	14.473	16.939	17.763	16.102

(c) Rn – Net Radiation (MJ m^{-2} day^{-1})

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	10.232	11.595	12.204	12.678	12.165	10.698	8.679	8.723	9.773	11.358	11.239	10.439
1962	10.810	12.084	12.629	12.678	12.087	9.623	10.107	9.083	9.177	10.685	10.654	10.867
1963	9.691	12.076	12.731	13.001	12.011	10.914	10.091	10.062	10.888	11.154	11.522	10.068
1964	10.365	11.828	13.176	13.035	12.364	10.381	9.683	8.873	9.997	10.028	10.608	9.304
1965	10.252	11.783	12.731	12.294	12.710	10.429	8.899	9.144	10.396	11.264	11.252	10.165
1966	10.079	11.710	12.791	13.404	12.993	10.581	9.172	9.015	9.887	10.867	11.304	10.178
1967	10.250	11.503	11.935	12.716	12.461	10.685	9.290	8.223	8.855	10.389	11.067	9.489
1968	10.314	12.035	12.032	12.518	12.264	10.328	9.789	9.400	10.629	11.743	10.747	9.482
1969	10.282	11.184	12.616	13.072	12.512	10.783	8.508	8.335	9.290	10.379	10.958	9.825
1970	9.759	11.134	11.873	12.101	11.689	11.155	9.174	8.309	9.324	11.155	11.104	9.786
1971	10.667	11.675	12.515	12.813	12.931	11.005	9.881	9.262	9.025	11.274	10.983	10.071
1972	10.605	11.786	12.092	12.249	11.811	10.400	8.597	8.553	9.984	10.856	10.805	9.748
1973	10.248	11.844	11.015	12.587	12.690	10.076	10.026	9.591	9.848	11.276	11.709	10.444
1974	8.891	10.165	12.784	13.141	12.228	10.906	9.616	10.055	9.912	10.922	11.406	9.783
1975	10.370	12.161	12.653	12.883	11.975	11.302	9.995	8.698	9.677	11.376	11.209	10.184
1976	10.584	11.706	12.863	12.426	12.017	10.111	8.962	9.019	9.607	9.333	10.576	9.873
1977	9.970	11.018	10.602	11.575	12.389	10.237	9.122	8.295	9.736	11.013	11.253	9.577
1978	10.254	11.316	12.345	11.262	12.058	9.727	9.123	8.707	9.944	10.366	10.706	9.556
1979	9.648	11.851	12.330	12.511	12.010	9.544	8.964	9.019	10.543	10.894	10.853	9.538
1980	10.018	10.512	12.143	12.660	11.349	10.293	8.796	9.413	9.673	10.755	10.750	9.628
1981	10.006	10.314	11.722	12.603	11.821	10.836	7.938	8.406	9.558	11.534	10.405	9.045
1982	10.402	11.008	12.120	11.711	11.243	9.842	8.452	7.906	8.788	10.621	10.545	9.113
1983	7.840	11.264	10.989	13.061	11.853	9.248	9.197	8.267	8.793	10.545	10.307	9.106
1984	9.626	10.479	11.692	11.398	11.479	9.975	11.698	9.621	9.517	10.552	10.244	8.385
1985	9.296	10.368	10.892	12.046	11.362	10.580	9.432	9.362	9.478	11.058	10.638	8.401

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986	9.015	12.035	11.070	12.850	12.661	11.132	8.410	8.780	9.541	10.016	10.526	9.214
1987	9.626	11.640	12.077	12.191	12.271	10.632	9.637	9.419	10.185	11.120	11.014	9.574
1988	8.569	11.112	11.803	12.545	12.509	10.554	9.600	8.523	9.520	11.320	10.875	10.081
1989	10.317	10.428	13.023	12.654	12.343	10.447	10.145	9.637	9.109	10.760	11.373	10.309
1990	10.573	11.412	12.589	12.485	11.987	11.042	8.545	8.427	9.450	11.071	11.128	10.213
1991	10.698	12.135	12.607	12.975	11.229	10.629	9.650	8.462	9.543	10.055	10.027	9.192
1992	8.744	11.466	11.058	12.235	11.711	9.863	7.582	8.150	9.407	10.566	10.266	9.324
1993	9.744	11.991	11.927	12.552	12.079	10.672	8.058	7.854	9.803	11.503	10.897	9.508
1994	10.324	10.501	12.340	11.341	11.872	10.727	8.305	8.233	8.861	10.562	11.416	9.996
1995	10.323	12.313	12.437	12.824	12.609	10.421	9.696	9.059	9.893	10.884	11.429	10.570
1996	9.959	12.055	11.805	12.095	11.988	9.869	9.916	9.250	8.987	10.538	11.346	9.326
1997	10.252	10.875	11.171	12.663	12.058	9.488	9.781	9.118	9.801	11.400	11.431	10.226
1998	9.836	11.941	11.923	12.960	12.462	10.605	8.994	8.691	9.467	10.524	11.214	10.131
1999	10.825	11.407	12.948	12.845	11.543	11.113	9.140	9.002	9.103	10.244	11.429	10.319
2000	10.240	11.641	11.889	13.093	12.270	10.218	9.607	9.282	9.271	10.907	11.543	9.825
2001	10.691	11.632	12.798	13.154	12.324	10.644	9.764	8.615	9.427	11.606	11.517	10.532
2002	9.666	12.042	12.900	12.882	12.551	11.027	9.534	9.168	9.836	11.929	11.554	10.509
Average	9.997	11.453	12.139	12.542	12.118	10.446	9.275	8.881	9.607	10.867	10.996	9.784

Appendix 14. Air Temperature and Relative Humidity

(a) Ta – Air Temperature (°C) (Source: GMA, Kumasi)

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	26.05	27.15	28.10	26.90	26.75	25.10	24.00	23.15	24.25	25.50	25.65	25.25
1962	26.05	27.05	26.70	27.35	26.00	24.30	24.70	23.65	24.55	25.50	25.90	25.45
1963	25.15	26.70	26.60	26.90	26.40	25.30	25.10	25.10	25.70	25.65	26.05	26.10
1964	25.30	27.05	27.30	26.95	26.20	25.10	23.80	23.55	24.15	24.80	25.35	24.70
1965	25.30	26.25	26.95	26.85	26.45	25.30	24.40	23.95	24.70	25.80	26.55	25.00
1966	25.85	26.75	27.20	27.05	26.70	25.20	25.05	24.00	24.65	25.65	26.05	25.85
1967	24.75	27.35	26.65	27.00	26.35	25.05	24.00	23.60	24.25	25.35	26.45	25.55
1968	25.25	26.90	26.45	26.20	26.35	25.45	24.90	24.75	24.85	25.80	25.90	26.25
1969	26.40	27.70	27.60	27.25	26.85	25.55	24.25	24.05	24.45	25.30	26.30	26.55
1970	26.65	27.70	27.25	27.40	26.10	26.15	24.40	24.20	24.65	25.85	26.05	25.60
1971	25.70	27.15	27.25	26.80	26.60	25.50	24.40	23.90	24.40	25.40	26.50	25.20
1972	26.25	27.20	26.75	26.50	26.55	25.30	24.60	23.95	25.05	25.95	26.50	26.05
1973	26.10	28.15	28.10	27.45	27.45	25.70	25.10	24.85	25.00	25.95	26.60	26.05
1974	25.45	27.90	27.25	26.75	26.05	25.65	24.50	24.70	24.60	25.65	26.65	25.30
1975	25.25	27.05	27.45	26.85	26.20	25.75	24.50	23.75	24.75	25.40	26.40	25.85
1976	25.60	27.00	27.20	26.65	26.65	25.10	24.10	23.85	24.55	24.95	25.45	25.60
1977	26.25	28.00	28.15	28.05	27.25	25.65	24.45	23.90	25.20	25.90	27.10	25.35
1978	27.50	28.05	27.05	26.85	26.85	25.35	24.00	24.45	24.65	25.60	26.20	26.50
1979	27.05	28.25	28.15	27.85	26.85	25.75	25.05	25.05	25.60	26.55	26.60	25.60
1980	27.00	27.60	27.40	28.15	26.90	26.05	24.80	24.70	25.55	25.85	26.40	25.10
1981	25.65	28.05	27.80	27.80	26.60	25.95	23.95	24.20	25.10	26.20	26.25	26.40
1982	26.30	28.25	27.70	27.45	26.30	25.55	24.50	23.60	24.80	25.95	26.45	26.25
1983	25.80	28.70	29.60	28.10	27.90	25.65	24.90	24.40	25.15	26.40	26.65	26.30
1984	27.40	30.40	28.10	28.15	26.75	25.65	25.10	25.45	25.10	26.45	26.45	25.45
1985	27.00	28.10	27.55	27.05	27.05	25.70	24.65	25.05	25.30	26.00	26.50	25.10
1986	26.40	28.30	27.00	27.70	26.85	25.50	24.50	24.40	25.30	25.50	26.65	25.65
1987	27.60	27.90	28.15	28.20	27.70	26.35	25.70	25.30	25.90	26.45	28.05	26.40
1988	26.50	29.35	28.10	27.70	27.60	25.80	24.85	24.45	25.40	26.50	27.10	25.40
1989	26.35	28.30	28.20	27.80	27.20	25.95	25.50	24.95	25.10	26.15	27.80	27.00
1990	26.95	27.60	29.60	27.85	27.35	26.55	24.80	24.85	25.60	26.35	27.10	26.00
1991	26.85	28.40	28.05	27.55	27.20	26.95	25.60	24.80	25.95	25.60	26.90	26.95
1992	26.90	29.55	28.75	27.85	27.30	25.75	24.15	24.10	25.00	26.45	26.15	26.55
1993	26.50	28.95	27.15	27.20	27.70	26.20	24.80	24.55	25.45	26.55	26.90	26.20
1994	26.85	28.70	28.70	27.70	26.75	26.05	25.00	25.00	25.45	26.00	26.95	26.50
1995	26.80	29.70	28.25	27.85	27.40	26.30	25.60	24.65	25.65	26.10	27.20	26.35
1996	26.70	27.90	27.80	27.80	27.50	26.00	25.40	25.05	25.15	25.85	27.75	26.70
1997	27.00	28.55	28.55	26.95	27.00	25.80	24.80	24.60	25.90	26.95	27.35	27.35
1998	27.40	28.80	30.20	29.15	27.80	26.50	25.50	24.60	25.80	26.55	27.90	27.35
1999	27.85	27.80	28.10	27.35	27.20	26.45	25.50	25.10	25.10	25.60	26.95	27.30
2000	27.40	28.10	29.20	27.95	27.15	25.65	24.55	24.65	25.05	25.80	26.90	26.30
2001	27.65	28.80	28.25	27.30	27.45	26.45	25.40	24.45	24.80	26.60	27.60	28.10
2002	27.70	29.55	28.70	28.10	27.35	25.95	25.35	24.25	25.50	26.50	27.10	27.90
Average	26.439	28.017	27.835	27.436	26.919	25.738	24.767	24.418	25.074	25.926	26.650	26.105

(b) RH – Relative Humidity (%) (Source: GMA, Kumasi)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1961	67	65	68	79	80	84	86	82	83	80	80	77
1962	69	61	74	78	80	86	84	82	82	82	82	75
1963	80	77	73	77	81	83	85	85	85	83	77	76
1964	71	67	75	77	81	83	84	84	82	82	81	81
1965	73	75	74	74	80	82	85	85	83	81	77	76
1966	69	65	75	77	80	85	85	87	83	82	78	78
1967	61	69	74	76	80	83	83	85	84	81	75	75
1968	65	74	77	79	80	84	84	86	85	81	81	80
1969	73	71	74	77	80	82	85	86	84	83	77	78
1970	76	71	77	78	82	80	82	83	85	80	77	74
1971	67	71	74	76	77	80	82	82	83	80	75	73
1972	73	71	75	78	80	82	84	83	82	81	78	75
1973	65	70	66	77	75	84	82	83	84	80	73	72
1974	54	63	75	78	81	82	83	82	84	81	76	71
1975	52	68	73	78	81	82	83	83	81	80	77	76
1976	64	70	74	78	79	82	82	82	82	83	79	74
1977	74	67	66	70	76	81	82	83	82	80	73	72
1978	70	71	75	78	79	83	82	82	82	82	76	79
1979	76	67	70	76	80	83	83	83	82	80	79	75
1980	76	70	75	73	80	83	83	83	82	81	77	67
1981	54	72	72	76	80	81	86	84	82	78	74	79
1982	54	66	72	75	81	82	84	86	83	78	79	66
1983	36	62	62	74	77	81	79	80	82	77	76	77
1984	63	53	70	74	77	81	82	82	80	80	76	66
1985	65	60	73	76	80	80	83	84	82	79	79	60
1986	52	67	75	75	77	80	84	81	81	79	74	60
1987	66	70	72	74	77	83	83	86	84	82	75	69
1988	55	62	75	78	80	83	85	85	84	81	77	74
1989	59	54	70	76	79	84	83	85	86	85	78	74
1990	70	63	69	78	80	82	85	84	84	81	80	78
1991	71	74	76	80	83	83	84	86	83	83	79	71
1992	49	63	70	78	80	83	87	84	84	78	75	76
1993	53	67	72	77	79	82	84	86	84	80	79	73
1994	64	63	70	78	81	82	84	81	85	84	75	63
1995	49	60	73	79	80	82	84	87	84	81	76	75
1996	79	75	78	79	80	84	83	86	84	82	71	80
1997	76	59	69	80	80	85	84	86	83	81	77	72
1998	59	68	67	76	81	83	84	85	84	81	74	76
1999	70	64	75	79	79	82	85	82	85	83	78	70
2000	72	55	69	77	79	85	85	85	85	83	78	73
2001	66	59	74	80	79	83	85	86	85	81	77	76
2002	63	64	74	78	79	82	84	85	82	80	77	69
Average	64.560	65.988	72.190	76.702	79.214	82.429	83.500	83.774	82.964	80.619	76.714	73.083

Appendix 15. Simplified Penman (mm/day)

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1961	5.582	6.378	6.407	5.865	5.612	4.701	3.796	3.948	4.359	5.249	5.232	5.064
1962	5.731	6.764	6.107	5.951	5.521	4.203	4.472	4.098	4.198	4.874	4.902	5.379
1963	4.582	5.762	6.205	6.117	5.452	4.851	4.462	4.441	4.788	5.010	5.540	5.009
1964	5.374	6.293	6.298	6.097	5.608	4.646	4.280	3.915	4.492	4.579	4.918	4.388
1965	5.225	5.718	6.166	5.983	5.806	4.704	3.980	4.021	4.653	5.170	5.418	4.998
1966	5.391	6.366	6.170	6.243	5.925	4.637	4.070	3.878	4.423	4.952	5.360	4.954
1967	5.893	6.070	5.834	6.069	5.681	4.768	4.173	3.603	3.957	4.803	5.462	4.819
1968	5.699	5.939	5.715	5.740	5.632	4.601	4.362	4.088	4.651	5.356	4.995	4.579
1969	5.276	5.824	6.186	6.131	5.749	4.850	3.786	3.646	4.146	4.664	5.326	4.837
1970	4.920	5.770	5.662	5.695	5.255	5.139	4.230	3.755	4.120	5.183	5.342	5.010
1971	5.799	5.996	6.096	6.061	6.072	5.052	4.497	4.183	4.057	5.208	5.458	5.138
1972	5.431	6.012	5.840	5.710	5.437	4.723	3.905	3.845	4.528	5.012	5.181	4.927
1973	5.749	6.151	6.005	5.948	6.148	4.526	4.572	4.314	4.395	5.204	5.878	5.420
1974	5.699	5.867	6.175	6.092	5.516	4.921	4.338	4.545	4.379	5.026	5.580	5.163
1975	6.538	6.344	6.248	6.003	5.455	5.105	4.516	3.897	4.462	5.220	5.425	5.045
1976	5.891	6.034	6.230	5.812	5.606	4.592	4.094	4.082	4.351	4.228	4.988	5.017
1977	5.071	6.026	5.831	6.017	5.957	4.710	4.181	3.736	4.436	5.101	5.720	5.012
1978	5.525	5.890	5.987	5.333	5.631	4.433	4.148	4.005	4.518	4.749	5.247	4.671
1979	4.891	6.356	6.347	5.995	5.556	4.345	4.085	4.089	4.779	5.111	5.178	4.853
1980	5.042	5.592	5.925	6.254	5.272	4.657	4.005	4.259	4.426	4.970	5.214	5.306
1981	6.250	5.412	5.927	6.025	5.469	4.924	3.516	3.750	4.358	5.460	5.243	4.430
1982	6.524	6.094	6.112	5.745	5.172	4.501	3.830	3.426	3.979	5.056	5.021	5.172
1983	6.253	6.480	6.329	6.346	5.715	4.355	4.335	3.908	4.043	5.102	5.102	4.588
1984	5.640	6.828	6.048	5.709	5.483	4.612	5.260	4.403	4.459	4.941	5.098	4.799
1985	5.363	6.206	5.510	5.803	5.312	4.882	4.285	4.207	4.358	5.205	5.056	5.104
1986	5.993	6.425	5.467	6.216	5.950	5.104	3.830	4.055	4.434	4.764	5.310	5.561
1987	5.468	6.082	6.122	6.034	5.839	4.831	4.415	4.143	4.546	5.086	5.539	5.209
1988	5.549	6.448	5.818	5.913	5.781	4.733	4.254	3.764	4.283	5.224	5.328	5.106
1989	6.141	6.587	6.602	6.081	5.760	4.673	4.574	4.241	4.004	4.770	5.458	5.280
1990	5.624	6.395	6.610	5.896	5.569	4.995	3.822	3.812	4.263	5.119	5.219	4.967
1991	5.601	6.056	6.077	5.953	5.097	4.825	4.366	3.708	4.365	4.574	4.861	4.984
1992	6.050	6.536	5.848	5.768	5.460	4.441	3.323	3.662	4.219	5.058	5.123	4.718
1993	6.241	6.483	5.967	5.945	5.677	4.840	3.662	3.467	4.373	5.322	5.204	4.936
1994	5.846	6.046	6.347	5.407	5.440	4.880	3.775	3.853	3.941	4.711	5.650	5.782
1995	6.850	7.168	6.171	5.935	5.780	4.773	4.379	3.921	4.443	5.031	5.581	5.295
1996	4.808	5.931	5.626	5.651	5.576	4.450	4.473	4.040	4.053	4.829	5.919	4.501
1997	5.134	6.474	5.918	5.773	5.549	4.234	4.372	3.992	4.467	5.270	5.522	5.346
1998	5.964	6.337	6.454	6.225	5.677	4.790	4.096	3.840	4.277	4.880	5.640	5.108
1999	5.748	6.309	6.240	5.921	5.412	5.019	4.121	4.133	4.025	4.621	5.443	5.515
2000	5.348	7.051	6.293	6.163	5.696	4.532	4.252	4.107	4.091	4.917	5.489	5.112
2001	5.982	6.829	6.286	5.975	5.730	4.807	4.376	3.755	4.145	5.339	5.596	5.270
2002	5.690	6.746	6.310	6.058	5.839	4.977	4.316	4.042	4.514	5.481	5.559	5.673
Average	5.652	6.240	6.084	5.944	5.616	4.722	4.180	3.966	4.328	5.010	5.341	5.049

Appendix 16. Precipitation (mm)

(Source: GMA, Kumasi and Glowa Volta Project, Germany)

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Jan-45	41.7		41.7
Feb-45	51.8		51.8
Mar-45	51.8		51.8
Apr-45	169.7		169.7
May-45	189		189
Jun-45	190.5		190.5
Jul-45	60.2		60.2
Aug-45	20.8		20.8
Sep-45	212.3		212.3
Oct-45	194.8		194.8
Nov-45	91.7		91.7
Dec-45	2		2
Jan-46	44.2		44.2
Feb-46	39.9		39.9
Mar-46	110.7		110.7
Apr-46	95.8		95.8
May-46	142.7		142.7
Jun-46	276.1		276.1
Jul-46	50		50
Aug-46	33.8		33.8
Sep-46	102.9		102.9
Oct-46	318.8		318.8
Nov-46	36.8		36.8
Dec-46	1.5		1.5
Jan-47	6.6		6.6
Feb-47	115.6		115.6
Mar-47	170.2		170.2
Apr-47	125.5		125.5
May-47	206.2		206.2
Jun-47	177		177
Jul-47	208		208
Aug-47	199.6		199.6
Sep-47	315		315
Oct-47	144.5		144.5
Nov-47	125		125
Dec-47	23.1		23.1
Jan-48	0		0
Feb-48	89.7		89.7
Mar-48	74.4		74.4
Apr-48	207.5		207.5
May-48	131.1		131.1
Jun-48	350.8		350.8
Jul-48	74.9		74.9
Aug-48	23.6		23.6
Sep-48	73.7		73.7
Oct-48	94		94

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Nov-48	183.1		183.1
Dec-48	30.2		30.2
Jan-49	0		0
Feb-49	29.2		29.2
Mar-49	196.6		196.6
Apr-49	138.9		138.9
May-49	225.8		225.8
Jun-49	203.2		203.2
Jul-49	212.9		212.9
Aug-49	196.6		196.6
Sep-49	136.4		136.4
Oct-49	221		221
Nov-49	73.9		73.9
Dec-49	23.6		23.6
Jan-50	55.1		55.1
Feb-50	16		16
Mar-50	102.4		102.4
Apr-50	191.3		191.3
May-50	141		141
Jun-50	164.8		164.8
Jul-50	74.7		74.7
Aug-50	118.9		118.9
Sep-50	85.9		85.9
Oct-50	189.5		189.5
Nov-50	76.5		76.5
Dec-50	22.4		22.4
Jan-51	31.5		31.5
Feb-51	106.9		106.9
Mar-51	139.4		139.4
Apr-51	120.1		120.1
May-51	288.5		288.5
Jun-51	153.4		153.4
Jul-51	239		239
Aug-51	52.8		52.8
Sep-51	164.8		164.8
Oct-51	124.2		124.2
Nov-51	104.1		104.1
Dec-51	0		0
Jan-52	3.8		3.8
Feb-52	80.3		80.3
Mar-52	148.3		148.3
Apr-52	158.8		158.8
May-52	206		206
Jun-52	233.4		233.4
Jul-52	248.9		248.9
Aug-52	57.9		57.9

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Sep-52	177		177
Oct-52	376.9		376.9
Nov-52	68.1		68.1
Dec-52	62.7		62.7
Jan-53	0		0
Feb-53	76.2		76.2
Mar-53	126.7		126.7
Apr-53	80.8		80.8
May-53	127		127
Jun-53	305.8		305.8
Jul-53	181.6		181.6
Aug-53	29		29
Sep-53	135.1		135.1
Oct-53	212.1		212.1
Nov-53	160.8		160.8
Dec-53	55.9		55.9
Jan-54	3.6		3.6
Feb-54	32.3		32.3
Mar-54	143.3		143.3
Apr-54	158		158
May-54	143.8		143.8
Jun-54	351		351
Jul-54	49.5		49.5
Aug-54	29.2		29.2
Sep-54	138.9		138.9
Oct-54	382.8		382.8
Nov-54	90.9		90.9
Dec-54	58.7		58.7
Jan-55	6.1		6.1
Feb-55	65		65
Mar-55	115.6		115.6
Apr-55	157.5		157.5
May-55	214.6		214.6
Jun-55	227.1		227.1
Jul-55	113.8		113.8
Aug-55	141.7		141.7
Sep-55	99.3		99.3
Oct-55	248.7		248.7
Nov-55	84.6		84.6
Dec-55	26.2		26.2
Jan-56	19.1		19.1
Feb-56	96.3		96.3
Mar-56	244.9		244.9
Apr-56	109.7		109.7
May-56	196.3		196.3
Jun-56	142.7		142.7
Jul-56	43.7		43.7
Aug-56	35.8		35.8
Sep-56	134.1		134.1
Oct-56	199.4		199.4
Nov-56	41.7		41.7

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Dec-56	16.5		16.5
Jan-57	10.7		10.7
Feb-57	42.4		42.4
Mar-57	168.4		168.4
Apr-57	265.2		265.2
May-57	142.2		142.2
Jun-57	216.2		216.2
Jul-57	111.5		111.5
Aug-57	105.2		105.2
Sep-57	220		220
Oct-57	267.2		267.2
Nov-57	131.3		131.3
Dec-57	35.3		35.3
Jan-58	102.6		102.6
Feb-58	13.5		13.5
Mar-58	115.1		115.1
Apr-58	128		128
May-58	412.5		412.5
Jun-58	149.6		149.6
Jul-58	0.5		0.5
Aug-58	14		14
Sep-58	94.7		94.7
Oct-58	153.4		153.4
Nov-58	184.7		184.7
Dec-58	20.1		20.1
Jan-59	11.2		11.2
Feb-59	144.5		144.5
Mar-59	112.8		112.8
Apr-59	153.2		153.2
May-59	122.7		122.7
Jun-59	104.1		104.1
Jul-59	230.9		230.9
Aug-59	36.3		36.3
Sep-59	291.3		291.3
Oct-59	130.3		130.3
Nov-59	107.2		107.2
Dec-59	35.1		35.1
Jan-60	70.6		70.6
Feb-60	14.2		14.2
Mar-60	124.5		124.5
Apr-60	213.9		213.9
May-60	102.9		102.9
Jun-60	328.2		328.2
Jul-60	23.4		23.4
Aug-60	113		113
Sep-60	180.8		180.8
Oct-60	191.3		191.3
Nov-60	48.8		48.8
Dec-60	104.1		104.1
Jan-61	10.7		10.7
Feb-61	13.7		13.7

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Mar-61	125.2		125.2
Apr-61	139.7		139.7
May-61	187.5		187.5
Jun-61	188.0		188
Jul-61	150.6		150.6
Aug-61	6.6		6.6
Sep-61	123.4		123.4
Oct-61	126.7		126.7
Nov-61	74.7		74.7
Dec-61	41.9		41.9
Jan-62	4.8		4.8
Feb-62	52.3		52.3
Mar-62	171.7		171.7
Apr-62	259.8		259.8
May-62	232.9		232.9
Jun-62	365.0		365
Jul-62	134.4		134.4
Aug-62	62.2		62.2
Sep-62	63.3		63.3
Oct-62	131.3		131.3
Nov-62	168.9		168.9
Dec-62	52.6		52.6
Jan-63	52.8		52.8
Feb-63	112.5		112.5
Mar-63	168.0		168
Apr-63	126.2		126.2
May-63	164.6		164.6
Jun-63	312.2		312.2
Jul-63	265.9		265.9
Aug-63	97.3		97.3
Sep-63	230.6		230.6
Oct-63	335.8		335.8
Nov-63	106.2	46.5	106.2
Dec-63	18.3	25.8	18.3
Jan-64	70.4	72.1	70.4
Feb-64	20.8	32.2	20.8
Mar-64	278.9	150.1	278.9
Apr-64	83.8	82.8	83.8
May-64	188.0	304.4	188
Jun-64	307.9	258.7	307.9
Jul-64	114.1	69.2	114.1
Aug-64	90.7	69.9	90.7
Sep-64	84.3	47.8	84.3
Oct-64	155.2	126.5	155.2
Nov-64	146.8	0	146.8
Dec-64	42.2	39.8	42.2
Jan-65	3.8	27.4	3.8
Feb-65	102.4	88.4	102.4
Mar-65	116.6	169.9	116.6
Apr-65	108.2	220.6	108.2
May-65	210.8	120.3	210.8

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Jun-65	204.5	283.7	204.5
Jul-65	127.3	183.1	127.3
Aug-65	157.0	274.5	157
Sep-65	162.1	144.5	162.1
Oct-65	281.2	171.7	281.2
Nov-65	45.7	101.5	45.7
Dec-65	23.9	89.4	23.9
Jan-66	4.6	0	4.6
Feb-66	93.7	49	93.7
Mar-66	132.1	174.9	132.1
Apr-66	259.1	175.5	259.1
May-66	192.0	305.1	192
Jun-66	339.9	226.8	339.9
Jul-66	446.3	247.5	446.3
Aug-66	123.4	75.9	123.4
Sep-66	85.3	265.6	85.3
Oct-66	177.8	153.3	177.8
Nov-66	140.5	136.9	140.5
Dec-66	26.9	47.7	26.9
Jan-67	0.0	0	0
Feb-67	103.6	7.1	103.6
Mar-67	108.0	84.6	108
Apr-67	127.3	164.4	127.3
May-67	156.5	186.7	156.5
Jun-67	259.1	160.1	259.1
Jul-67	40.6	103.9	40.6
Aug-67	19.1	46.7	19.1
Sep-67	111.5	83.1	111.5
Oct-67	127.5	119.5	127.5
Nov-67	53.1	43.9	53.1
Dec-67	39.6	83.9	39.6
Jan-68	48.8	22.4	48.8
Feb-68	128.3	130.6	128.3
Mar-68	105.4	111.5	105.4
Apr-68	173.2	107.9	173.2
May-68	295.7	298.2	295.7
Jun-68	281.7	256.3	281.7
Jul-68	315.2	242.2	315.2
Aug-68	400.3	267.3	400.3
Sep-68	356.4	296.9	356.4
Oct-68	125.2	237.9	125.2
Nov-68	112.5	123.8	112.5
Dec-68	1.0	5.1	1
Jan-69	12.5	16.3	12.5
Feb-69	15.0	69.9	15
Mar-69	106.4	0	106.4
Apr-69	172.0	0	172
May-69	266.2	0	266.2
Jun-69	119.6	0	119.6
Jul-69	60.2	69.7	60.2
Aug-69	59.2	54.2	59.2

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Sep-69	101.6	21.8	101.6
Oct-69	193.8	197.2	193.8
Nov-69	73.1	94.6	73.1
Dec-69	17.0	9.2	17
Jan-70	4.1	22.6	4.1
Feb-70	47.5	120.7	47.5
Mar-70	196.6	0	196.6
Apr-70	98.3	0	98.3
May-70	305.6	0	305.6
Jun-70	63.3	95	63.3
Jul-70	121.2	61.5	121.2
Aug-70	47.2	67.3	47.2
Sep-70	177.0	178.8	177
Oct-70	152.1	228.4	152.1
Nov-70	112.5	79.2	112.5
Dec-70	0.0	0	0
Jan-71	1.8	32	1.8
Feb-71	48.5	100.6	48.5
Mar-71	103.4	79.2	103.4
Apr-71	97.0	131.8	97
May-71	111.8	247.7	111.8
Jun-71	116.6	149	116.6
Jul-71	95.5	180.1	95.5
Aug-71	80.5	60.5	80.5
Sep-71	219.5	138.4	219.5
Oct-71	145.6	54.6	145.6
Nov-71	27.7	55.6	27.7
Dec-71	38.3	15.3	38.3
Jan-72	60.7	15.2	60.7
Feb-72	83.8	65.5	83.8
Mar-72	117.3	211	117.3
Apr-72	132.3	380.8	132.3
May-72	275.8	147.3	275.8
Jun-72	201.7	156.2	201.7
Jul-72	159.8	82.3	159.8
Aug-72	27.4	18.5	27.4
Sep-72	174.7	79.7	174.7
Oct-72	219.2	121.3	219.2
Nov-72	130.6	43	130.6
Dec-72	45.7	30.7	45.7
Jan-73	0.0	0	0
Feb-73	98.0	59	98
Mar-73	175.8	150.2	175.8
Apr-73	109.0	139.7	109
May-73	114.8	102.3	114.8
Jun-73	122.9	246	122.9
Jul-73	154.7	151.3	154.7
Aug-73	138.2	235.7	138.2
Sep-73	204.2	138.5	204.2
Oct-73	167.9	185.7	167.9
Nov-73	55.9	9.5	55.9
Dec-73	11.9	7.4	11.9
Jan-74	0.0	24.9	0
Feb-74	26.2	2	26.2
Mar-74	180.9	282.2	180.9
Apr-74	152.7	175.8	152.7
May-74	216.7	146.3	216.7
Jun-74	157.2	176.6	157.2
Jul-74	211.1	142.4	211.1
Aug-74	173.5	110.5	173.5
Sep-74	138.2	243.9	138.2
Oct-74	109.7	146.1	109.7
Nov-74	54.9	16.5	54.9
Dec-74	35.1	27	35.1
Jan-75	0.0	0	0
Feb-75	120.9	73.6	120.9
Mar-75	164.3	127.8	164.3
Apr-75	248.2	198.5	248.2
May-75	138.2	148.9	138.2
Jun-75	135.9	158.1	135.9
Jul-75	195.8	255	195.8
Aug-75	17.0	45.8	17
Sep-75	154.1	72.9	154.1
Oct-75	231.6	210.3	231.6
Nov-75	60.5	40.4	60.5
Dec-75	6.1	8.1	6.1
Jan-76	22.9	8.1	22.9
Feb-76	65.3	76.9	65.3
Mar-76	139.0	170.7	139
Apr-76	111.8	243.6	111.8
May-76	273.4	262.5	273.4
Jun-76	222.0	127.7	222
Jul-76	38.2	25.1	38.2
Aug-76	39.5	26.9	39.5
Sep-76	123.7	19.3	123.7
Oct-76	95.1	33.2	95.1
Nov-76	213.4	13.4	213.4
Dec-76	3.1	28.8	3.1
Jan-77	21.2	0	21.2
Feb-77	13.7	92.7	13.7
Mar-77	85.4	61.1	85.4
Apr-77	87.2	73.4	87.2
May-77	98.5	136	98.5
Jun-77	229.2	138.3	229.2
Jul-77	37.7	27.2	37.7
Aug-77	30.2	84.5	30.2
Sep-77	173.1	161.9	173.1
Oct-77	182.3	214.4	182.3
Nov-77	18.3	21.6	18.3
Dec-77	15.2	75.2	15.2
Jan-78	1.5	0	1.5
Feb-78	159.8	35.7	159.8

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Mar-78	77.3	151	77.3
Apr-78	104.0	167.5	104
May-78	261.9	195.4	261.9
Jun-78	212.3	304.1	212.3
Jul-78	57.2	64	57.2
Aug-78	17.8	18.5	17.8
Sep-78	217.2	288.6	217.2
Oct-78	210.3	184	210.3
Nov-78	40.7	48.1	40.7
Dec-78	15.5	19.3	15.5
Jan-79	14.5	7.3	14.5
Feb-79	38.6	39.1	38.6
Mar-79	100.8	77.6	100.8
Apr-79	99.9	74.4	99.9
May-79	119.5	169.4	119.5
Jun-79	142.5	272.3	142.5
Jul-79	300.4	153	300.4
Aug-79	196.2	123.6	196.2
Sep-79	331.3	340.5	331.3
Oct-79	103.7	212.4	103.7
Nov-79	82.4	103.6	82.4
Dec-79	8.4	0	8.4
Jan-80	5.1	8.1	5.1
Feb-80	100.9	34.3	100.9
Mar-80	49.0	165.9	49
Apr-80	53.8	200	53.8
May-80	120.0	205	120
Jun-80	286.5	192.1	286.5
Jul-80	129.9	92.1	129.9
Aug-80	38.4	75	38.4
Sep-80	170.8	213.9	170.8
Oct-80	117.4	125.8	117.4
Nov-80	67.7	76.5	67.7
Dec-80	21.6	10.9	21.6
Jan-81	0.0	0.5	0
Feb-81	23.1	22.9	23.1
Mar-81	172.0	247.2	172
Apr-81	45.0	38.7	45
May-81	254.6	180.3	254.6
Jun-81	161.9	126.4	161.9
Jul-81	207.7	188.9	207.7
Aug-81	42.4	89.1	42.4
Sep-81	149.5	188.8	149.5
Oct-81	96.2	177.7	96.2
Nov-81	7.8	64.3	7.8
Dec-81	31.0	20.6	31
Jan-82	0.0	0	0
Feb-82	135.2	56.8	135.2
Mar-82	54.7	133.1	54.7
Apr-82	77.3	66.7	77.3
May-82	140.7	188.4	140.7

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Jun-82	138.2	198.2	138.2
Jul-82	49.9	144.4	49.9
Aug-82	76.3	141.4	76.3
Sep-82	14.6	15.6	14.6
Oct-82	182.2	215.6	182.2
Nov-82	14.0	72.9	14
Dec-82	8.4	1	8.4
Jan-83	0.0	0	0
Feb-83	53.1	38.9	53.1
Mar-83	67.2	6.9	67.2
Apr-83	110.8	101.9	110.8
May-83	116.2	138.1	116.2
Jun-83	230.9	214.7	230.9
Jul-83	33.9	29.5	33.9
Aug-83	47.5	21	47.5
Sep-83	94.6	94.2	94.6
Oct-83	43.3	61.1	43.3
Nov-83	67.3	116.6	67.3
Dec-83	86.3	41.1	86.3
Jan-84	0.0	0	0
Feb-84	8.9	14	8.9
Mar-84	134.3	148.4	134.3
Apr-84	80.5	122.3	80.5
May-84	132.5	120.1	132.5
Jun-84	179.9	196.5	179.9
Jul-84	276.5	291.4	276.5
Aug-84	171.2	129.3	171.2
Sep-84	214.8	122	214.8
Oct-84	138.8	199.5	138.8
Nov-84	44.4	65.7	44.4
Dec-84	1.3	0	1.3
Jan-85	18.5	26.9	18.5
Feb-85	45.5	9.4	45.5
Mar-85	247.4	95.7	247.4
Apr-85	166.9	106.1	166.9
May-85	105.2	90.7	105.2
Jun-85	159.2	181.8	159.2
Jul-85	417.1	190	417.1
Aug-85	96.5	101.7	96.5
Sep-85	202.8	167.3	202.8
Oct-85	99.7	54.2	99.7
Nov-85	110.4	43.7	110.4
Dec-85	0.0	0	0
Jan-86	0.0	0	0
Feb-86	132.1	117.1	132.1
Mar-86	64.4	103	64.4
Apr-86	70.7	54.6	70.7
May-86	154.8	0	154.8
Jun-86	268.0	0	268
Jul-86	176.3	80.2	176.3
Aug-86	29.4	47.9	29.4

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Sep-86	114.2		114.2
Oct-86	170.6		170.6
Nov-86	13.0		13
Dec-86	0.0		0
Jan-87	5.9		5.9
Feb-87	64.8		64.8
Mar-87	110.0		110
Apr-87	171.0		171
May-87	46.3		46.3
Jun-87	245.9		245.9
Jul-87	156.8		156.8
Aug-87	192.1		192.1
Sep-87	188.7		188.7
Oct-87	74.4		74.4
Nov-87	3.0		3
Dec-87	13.5		13.5
Jan-88	0.0		0
Feb-88	10.0		10
Mar-88	309.5		309.5
Apr-88	135.7		135.7
May-88	110.7		110.7
Jun-88	341.7		341.7
Jul-88	138.8		138.8
Aug-88	15.0		15
Sep-88	185.5		185.5
Oct-88	136.4		136.4
Nov-88	38.6		38.6
Dec-88	78.9	7.2	78.9
Jan-89	53.7	21.8	53.7
Feb-89	2.3	8.9	2.3
Mar-89	112.6	129	112.6
Apr-89	77.2	132.1	77.2
May-89	126.2	48.5	126.2
Jun-89	310.4	260.9	310.4
Jul-89	89.3	177.9	89.3
Aug-89	177.0	150.6	177
Sep-89	281.2	142.6	281.2
Oct-89	186.3	106.5	186.3
Nov-89	39.5	60.8	39.5
Dec-89	8.2	9.6	8.2
Jan-90	35.8	26.9	35.8
Feb-90	69.1	54.3	69.1
Mar-90	110.2	46.2	110.2
Apr-90	199.1	141.4	199.1
May-90	115.3	144	115.3
Jun-90	126.4	91.4	126.4
Jul-90	22.6	23.2	22.6
Aug-90	29.6	50.4	29.6
Sep-90	159.0	185.8	159
Oct-90	137.5	143.3	137.5
Nov-90	104.7	80	104.7

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Dec-90	83.4	89.7	83.4
Jan-91	54.8	7.4	54.8
Feb-91	83.9	123.9	83.9
Mar-91	77.8	114.9	77.8
Apr-91	133.3	230.2	133.3
May-91	306.9	368.9	306.9
Jun-91	171.8	160.7	171.8
Jul-91	88.1	64	88.1
Aug-91	69.7	55	69.7
Sep-91	143.2	92.7	143.2
Oct-91	122.5	166.9	122.5
Nov-91	23.7	67.2	23.7
Dec-91	0.1	0	0.1
Jan-92	3.6	0	3.6
Feb-92	5.5	12.6	5.5
Mar-92	74.3	76.4	74.3
Apr-92	152.8	266.1	152.8
May-92	150.3	270.9	150.3
Jun-92	132.7	122.3	132.7
Jul-92	79.2	35	79.2
Aug-92	30.4	12.4	30.4
Sep-92	312.8	219.8	312.8
Oct-92	49.2		49.2
Nov-92	65.6		65.6
Dec-92	7.1		7.1
Jan-93	2.0		2
Feb-93	53.1		53.1
Mar-93	117.5		117.5
Apr-93	152.7		152.7
May-93	140.0		140
Jun-93	338.9		338.9
Jul-93	31.0		31
Aug-93	102.6		102.6
Sep-93	168.0		168
Oct-93	257.1		257.1
Nov-93	52.4		52.4
Dec-93	26.7		26.7
Jan-94	0.0		0
Feb-94	7.3		7.3
Mar-94	52.1		52.1
Apr-94	194.9		194.9
May-94	208.9		208.9
Jun-94	116.1		116.1
Jul-94	96.5		96.5
Aug-94	63.1		63.1
Sep-94	156.1		156.1
Oct-94	179.0		179
Nov-94	35.2		35.2
Dec-94	0.0		0
Jan-95	0.0		0
Feb-95	0.7		0.7

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Mar-95	121.6		121.6
Apr-95	198.8		198.8
May-95	175.8		175.8
Jun-95	155.1		155.1
Jul-95	136.6		136.6
Aug-95	148.5		148.5
Sep-95	138.8		138.8
Oct-95	95.7		95.7
Nov-95	40.0		40
Dec-95	115.6		115.6
Jan-96	3.7		3.7
Feb-96	80.2		80.2
Mar-96	72.2		72.2
Apr-96	111.8		111.8
May-96	145.7		145.7
Jun-96	106.0		106
Jul-96	202.7		202.7
Aug-96	109.6		109.6
Sep-96	72.5		72.5
Oct-96	81.8		81.8
Nov-96	2.8		2.8
Dec-96	51.9		51.9
Jan-97	53.7		53.7
Feb-97	33.0		33
Mar-97	138.0		138
Apr-97	296.7		296.7
May-97	218.7		218.7
Jun-97	250.3		250.3
Jul-97	73.4		73.4
Aug-97	59.0		59
Sep-97	96.3		96.3
Oct-97	162.2		162.2
Nov-97	11.1		11.1
Dec-97	11.3		11.3
Jan-98	51.8		51.8
Feb-98	26.6		26.6
Mar-98	35.9		35.9
Apr-98	267.4		267.4
May-98	183.3		183.3
Jun-98	188.7		188.7
Jul-98	56.5		56.5
Aug-98	75.6		75.6
Sep-98	74.7		74.7
Oct-98	76.5		76.5
Nov-98	23.5		23.5
Dec-98	31.7		31.7
Jan-99	61.3		61.3
Feb-99	25.9		25.9
Mar-99	109.9		109.9
Apr-99	217.0		217
May-99	101.7		101.7

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Jun-99	217.9		217.9
Jul-99	202.6		202.6
Aug-99	114.1		114.1
Sep-99	135.2		135.2
Oct-99	204.3		204.3
Nov-99	39.0		39
Dec-99	0.0		0
Jan-00	62.4		62.4
Feb-00	7.2		7.2
Mar-00	110.6		110.6
Apr-00	206.2		206.2
May-00	168.6		168.6
Jun-00	373.2		373.2
Jul-00	153.2		153.2
Aug-00	65.3		65.3
Sep-00	144.1		144.1
Oct-00	119.9		119.9
Nov-00	77.8		77.8
Dec-00	0.0		0
Jan-01	0.0		0
Feb-01	21.5		21.5
Mar-01	220.1		220.1
Apr-01	163.0		163
May-01	106.7		106.7
Jun-01	149.7		149.7
Jul-01	112.5		112.5
Aug-01	48.6		48.6
Sep-01	216.9		216.9
Oct-01	112.9		112.9
Nov-01	15.5		15.5
Dec-01	18.4		18.4
Jan-02	1.6		1.6
Feb-02	7.6		7.6
Mar-02	99.7		99.7
Apr-02	238.9		238.9
May-02	204.6		204.6
Jun-02	265.5		265.5
Jul-02	281.4		281.4
Aug-02	75.8		75.8
Sep-02	123.5		123.5
Oct-02	319.1		319.1
Nov-02	45.2		45.2
Dec-02	5.4		5.4
Jan-03	32.9		32.9
Feb-03	74.5		74.5
Mar-03	73.1		73.1
Apr-03	129.5		129.5
May-03	188.8		188.8
Jun-03	254.6		254.6
Jul-03	95.3		95.3
Aug-03	26.8		26.8

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Sep-03	99.5		99.5
Oct-03	180.1		180.1
Nov-03	163.2		163.2
Dec-03	30.9		30.9
Jan-04	25.8		25.8
Feb-04	70.8		70.8
Mar-04	164.3		164.3
Apr-04	100.7		100.7
May-04	72.3		72.3
Jun-04	41.1		41.1
Jul-04	229.4		229.4
Aug-04	115		115
Sep-04	243.5		243.5
Oct-04	232.4		232.4
Nov-04	43.5		43.5
Dec-04	76.5		76.5
Jan-05	12.5		12.5
Feb-05	48.9		48.9
Mar-05	84.2		84.2
Apr-05	146.4		146.4
May-05	272.1		272.1
Jun-05	121.3		121.3
Jul-05	18.3		18.3
Aug-05	36.7		36.7
Sep-05	174.1		174.1
Oct-05	236.9		236.9
Nov-05	49.8		49.8

Month-Year	Kumasi Rainfall (mm)	Bekwai Rainfall (mm)	Rainfall (mm)
Dec-05	29.8		29.8
Jan-06	111.1		111.1
Feb-06	98.4		98.4
Mar-06	112.8		112.8
Apr-06	66.9		66.9
May-06	187.3		187.3
Jun-06	145.4		145.4
Jul-06	66.7		66.7
Aug-06	65.2		65.2
Sep-06	111.4		111.4
Oct-06	158.4		158.4
Nov-06	32.5		32.5
Dec-06	3.7		3.7
Jan-07	0.2		0.2
Feb-07	16.4		16.4
Mar-07	56.2		56.2
Apr-07	310.9		310.9
May-07	164.2		164.2
Jun-07	176		176
Jul-07	192.9		192.9
Aug-07	117.7		117.7
Sep-07	534.5		534.5
Oct-07	153.9		153.9
Nov-07	51.7		51.7
Dec-07	19.8		19.8

Appendix 17. Sample Results of Statistical Data Analysis of Precipitation (F-test)

(a) Data Statistics

Data Disc.	Years	Dataset	Mean	Variance	Standard Deviation	Maximum	Minimum
Rainfall (Raw Data)							
Annual	1945 - 2007	63	1404.92	72989.6709	270.1660062	2343.7	891.5
January	1945 - 2007	63	21.2429	740.835392	27.21829149	111.1	0
February	1945 - 2007	63	58.173	1748.46813	41.81468798	159.8	0.7
March	1945 - 2007	63	126.187	3087.22016	55.56275874	309.5	35.9
April	1945 - 2007	63	149.833	3767.10774	61.37676875	310.9	45
May	1945 - 2007	63	178.113	4626.41855	68.0177811	412.5	46.3
June	1945 - 2007	63	209.662	6530.33175	80.81046808	373.2	41.1
July	1945 - 2007	63	139.124	9183.98346	95.83310209	446.3	0.5
August	1945 - 2007	63	83.0254	4570.36934	67.60450684	400.3	6.6
September	1945 - 2007	63	166.897	7008.06451	83.71418342	534.5	14.6
October	1945 - 2007	63	172.152	5478.51189	74.01697028	382.8	43.3
November	1945 - 2007	63	73.1825	2486.53437	49.86516186	213.4	2.8
December	1945 - 2007	63	27.327	27.3269841	26.86639709	115.6	0
Rainfall (Corrected)							
Annual	1977 -2007	31	1298.45	47708.9732	218.4238386	1794.4	891.5
March	1977 -2007	31	110.165	3641.1177	60.34167464	309.5	35.9
May	1977 -2007	31	158.01	3662.3009	60.51694724	306.9	46.3
October	1977 -2007	31	149.065	3972.2337	63.02565905	319.1	43.3
November	1977 -2007	31	45.9452	1226.22123	35.01744174	163.2	2.8

(b) F - Test

Notes: a) F (lower limit) = 0.486; F(upper limit) = 2.066; b)NS = Not significant; Sig = significant

Data Disc.	Years	Dataset	Subset 1	Subset 2	F (Computed)	Var 1	Var 2	Result	Subset 1 (From - To)	Subset 2 (From - To)	F(Lower)	F(Upper)
(Raw Data)												
Annual	1945 - 2007	63	32	31	1.624	77491.615	47708.973	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}
January	1945 - 2007	63	32	31	1.019	745.477	759.418	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}
February	1945 - 2007	63	32	31	1.207	1536.176	1854.456	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}
March	1945 - 2007	63	32	31	1.697	2145.342	3641.118	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}
April	1945 - 2007	63	32	31	1.797	2746.269	4934.72	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}
May	1945 - 2007	63	32	31	1.342	4913.041	3662.301	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}
June	1945 - 2007	63	32	31	1.13	6960.329	6158.121	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}
July	1945 - 2007	63	32	31	1.046	9531.331	9108.976	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}
August	1945 - 2007	63	32	31	2.0318	6438.861	2776.673	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}
September	1945 - 2007	63	32	31	1.854	4963.411	9201.749	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}
October	1945 - 2007	63	32	31	1.526	6063.485	2972.234	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}
November	1945 - 2007	63	32	31	1.897	2325.84	1226.221	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}
December	1945 - 2007	63	32	31	1.897	514.496	955.496	NS	1 -32(1945 - 1976)	33 - 63(1977 - 2007)	f{31,2.5%}	f{30,97.5%}

Data Disc.	*Years*	*Dataset*	*Subset 1*	*Subset 2*	*F (Computed)*	*Var 1*	*Var 2*	*Result*	*Subset 1 (From - To)*	*Subset 2 (From - To)*	*F(Lower)*	*F(Upper)*
(Corrected Data)												
Annual	1977 - 2007	31	16	15	1.082	4219.142	4583.758	NS	1 -16	17 - 31	f{15,2.5%}	f{14,97.5%}
March	1977 - 2007	31	16	15	2.338	5160.602	2207.663	NS	1 -16	17 - 31	f{15,2.5%}	f{14,97.5%}
May	1977 - 2007	31	16	15	1.812	4672.995	2578.884	NS	1 -16	17 - 31	f{15,2.5%}	f{14,97.5%}
October	1977 - 2007	31	16	15	1.965	2463.45	4841.85	NS	1 -16	17 - 31	f{15,2.5%}	f{14,97.5%}
November	1977 - 2007	31	16	15	1.242	1135.907	1410.244	NS	1 -16	17 - 31	f{15,2.5%}	f{14,97.5%}