SEEPAGE STUDY ON A ROCKFILL DAM: CASE STUDY OF SHIRORO DAM

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MAY 2004.

TITLE PAGE

SEEPAGE STUDY ON A ROCKFILL DAM: CASE STUDY OF SHIRORO DAM NIGER STATE, NIGERIA.

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Being a Project Report Submitted to the Department of Agricultural Engineering, School of Engineering And Engineering Technology, Federal University of Technology Minna Niger State of Nigeria.

In partial fulfillment of the requirement for the award of Post Graduate Diploma (PGD) in Agric Engineering (Soil and Water Engineering option)

Federal University of Technology Minna Niger State of Nigeria.

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DECLARATION

I hereby declared that this research project has been conducted by me under the guidance of my supervisor in person of Doctor Nosa Egharevba of the Department of Agricultural Engineering, School Of Engineering And Engineering Technology, Federal University Of Technology Minna and that, I have neither copied someone's work nor has someone else done it for me.

The writer whose works has been referred to in this project is hereby acknowledged.

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APPROVAL PAGE

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PROJECT SUPERVISOR

SIGN: ....

ENGR Dr. D. ADGIDZI DATE

HEAD OF DEPT. AGRIC. ENGINEERING.

DEDICATION

This project work is dedicated to Allah and the following people.

My parents: Mallam Bello Shehu (Father) and Late Malama ishetu Bello (Mother); My family: Mallama Habibat (Lami) Sani Bello osso (wife) Muhammad Sani Bello Bosso (son), Bello Sani Bosso (papa) son), Aishatu Sani Bosso (daughter), Sanusi Sani Bosso (son), bubakar Sadiq Sani Bosso (son) and Zainab Sani Bosso (daughter).

By

Sani Bello Bosso

ACKNOWLEDGEMENT

IN THE NAME OF ALLAH, MOST GRACIOUS, MOST MERCIFUL, I thank Allah for his mercy who enable me to undertake this course of study with the Federal University of Technology Minna to this project level successfully.

I wish to express my appreciation to the management and staff of Upper Niger River Basin Development Authority for giving me the opportunity to attend and complete this course. Also, I wish to thank the management and staff of Shiroro dam for their assistance during data obtaining or collection.

I am extremely grateful to Engr. Dr. Nosa Egharevba my project supervisor for his tolerance and patience at all time in helping in proof reading the write–up and his useful corrections, guidance and suggestions, I was able to make this project a reality.

My sincere and unreserved appreciation goes to my Head of Department Engr (Dr.) D. Adgidzi, as well as the post graduate programme course co-ordinator in person of Engr. Dr Mrs Osunde, Professors, Doctors, Engineers and Staff lecturers of Agricultural Engineering Department Federal University of Technology Minna for all their assistance in one way or the other in this programme achievement.

My due regard to my parent and family, my wife Habibat (Lami) and our children for their patient and endurance during this course. A lot of thanks to some of my brothers, colleague in person of Ahmed Idris (Ex. Labour Union President Upper Niger River Basin Authority U.N.R.B.A). For his moral and humble support or assistance rendered during this project research work. Of all, I wish to record my thanks to Almighty Allah for the knowledge, blessing and strength to me for the completion of this programme.

ABSTRACT

A Ten year data on seepage, elevation, reservoir capacity and Tail water race was obtained. The analysed data showed that the maximum seepage value was 7.2×10^{-2} m^3/hr while the minimum was 4.32×10^{-2} m^3/hr. The maximum and minimum elevation was 382m and 329m respectively. Similarly, the maximum head was 70m while the minimum was 17m. The maximum reservoir capacity showed 5.9×10^9 m^3 and the minimum was 1.5×10^9 m^3. Even at the maximum seepage value of 7.2×10^{-2} m^3/hr the dam is still structurally safe. However, the cumulative seepage value for the ten year period amounted to 73.8×10^{-2} m^3/hr. A wear box stationed at the down stream close to the turbine adequately takes care of the water loss due to seepage. The maximum head of 70m also showed that there was no any incident of over topping as it is still within the maximum design height of 115 m.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 A BRIEF HISTORY OF SHIRORO DAM PROJECT

In April 1957, the Northern Nigeria Government and the then Electricity Co-operation of Nigeria (ECN) jointly authorized an investigation of the hydroelectric potential of River Kaduna, a Shiroro Gorge. The investigation was carried out by Sir, Alexander Gibbs and partner in collaboration with Messers. Preece Cardew & Rider. In February 1959, preliminary report on Hydroelectric development of the Kaduna River at Shiroro Gorge was published by sir Alexander Gibbs & partners and Preece Cardew & Rider. In 1977, Design works and consultancy works was awarded to Messrs. Chas T. Main of Boston, Mass, U.S.A. respectively. By March 1978 the main civil works contracts for Shiroro Dam was awarded to Messrs J.V. Torno for Shiroro joint venture of TORNO Switzerland and TORNO Milano, Italy. TORNO started work at the dam site in 1978. By 1980, resettlement of the villagers displaced by the construction of the Shiroro Dam project commenced. Compensation were paid to the villagers as demanded by them. Within the same year, construction of the new tail road relocation commenced as the design of the dam demands.

In 1989 excavation and construction of the spillway, the Shiroro Dam power house commenced but its completion was held up due to lack of payment from the owner hence it was not completed as scheduled in the contract plan.

1984, the Shiroro Hydroelectric Dam lake reservoir was successfully impounded. As of 1985, demobilization civil contractor J.V. TORNO for Shiroro started after successfully completion of the civil works.

In 1988, a presidential Task force was set up by the then Head of State, General Ibrahim B. Babangida to oversee the completion of the Shiroro Dam Project which has suffered delay in completion due to lack of funds and other bureaucratic problems. The task force was headed by Engr. M.K. Ibrahim who performed creditably well towards the final completion of the shiroro project. His appointment was a booster and big relieve to all working at the shiroro Hydroelectric project and this contributed in no small way towards the completion of project, which was then 4 years behind schedule.

In 31st OCT. 1989; Unit No. 4 and the first unit to be completed was commissioned.

29th Nov. 1989; Unit No. 1 was commissioned and synchronized into the National Grid.

21st DEC.1989; Unit No. 3 was commissioned and synchronized into the National Grid.

21st January, 1990; Unit No. 2 was commissioned and synchronized into the National Grid.

20th June, 1990; Power station was commissioned by General Ibrahim Babangida, the then presidential and commander-in-chief of the Nigerian Armed Forces.

By 1991, two years maintenance contract was awarded to all contractors involved in the construction of the shiroro Hydroelectric project to undertake the Training of NEPA staff on the operation and maintenance of equipment installed by respective contractors. These was later extended for another two years, totaling 4 years by 1992.

1.2 BACKGROUND ON SEEPAGE STUDIES

The development of the water resource of a country parmount and crucial to the overall economic upliftment of the nation; this development includes improvement in its production and distribution process by harnessing the natural existing water (i.e. surface and sub surface) into dams, reservoir, underground storage e.t.c, and making it available for human uses at need or will.

Most dams are presently suffering from the much needed attention especially in terms of monitoring, maintenance as while as records keeping. This is as result of decreasing level of commitment on the part of staff and the supervising agencies of such existing structures or project.

The need to maximize the existing data by developing a relationship with other dependent variable can not therefore be overemphasized. A relationship so developed can be used to for cast seepage for example, at a future time. Where the future record is available, it forms a bases for comparison and where such future record is not there or absent, it gives a useful information.

1.3 CONSTRAINTS ON SEEPAGE STUDIES.

A reliable seepage information depends on the available data. The more the number of years of data, the more accuracy and reliability of future seepage forecasting. A twenty to 30 years seepage data is more authentic in studying seepage trend for future prediction or forecasting compared to the only 10 years seepage data that is available for this project study.

Record or information on piezometer reading would have enable during analysis to note the maximum head of seepage rise which should be generally less than one third of the total height of rock fill dam to guarantee safety of structure against pore-water pressure. But the information on this is completely non-existence, therefore forcing concentration on the recorded seepage measurement.

Note, seepage water will increase with the following:

(i) Volume of water available

(ii) Reservoir area under consideration

(iii) And head of water in the reservoir.

It therefore follows that seepage is dependent on the above three parameters if all other condition that promote seepage are constant e.g. void, low water table e.t.c.

Data record keeping or Data banking which has being manually done in Shiroro dam not by computer i.e. kept in hardcover note book) has seriously contributed to missing seepage data of some periods e.g. 1998 & 1999 years.

1.4.0 THE IMPACT OF SHIRORO DAM ON IT'S ENVIRONMENTS

1.4.1 THE METEROLOGICAL AND CLIMATIC EFFECTS:

The creation of Shiroro lake has led to a change of climatic condition in and around the lake area. The lake itself has four principal and about 8 minor tributaries contributing to its sum total capacity of about 8×10^9 m^3 inflow with Kaduna River being the major contributor of almost 70% of the total capacity.

The monthly rainfall schedule for the year can be divided into 4 periods namely:

i. January – April: Minimum rainfall period ranging from about 5mm in January to a maximum of about 70mm in April.

ii. May – July: Rainfall within this period varies from 180mm – 200mm.

iii. August – October: Rainfall about this period constitute the peak of the rainy season with rainfall ranging from 250mm – 400mm.

iv. Nov. – Dec: This period is similar to the first period of January – April and rainfall ranges between 5mm – 20mm.

The effects of the rainfall and the lake in Shiroro are:-

i. Siltation and sedimentation

ii. Excess water storage in the lake especially between July and October of each year.

iii. Depletion of the lake due to evaporation from November to May.

iv. Temperature effect.

The creation of the lake has modified the relative temperature of the catchments area resulting in cool/warm zone in the shiroro local Government Area. The Northern area where the lake is situated has a colder temperature than the southern part of the local government.

v. Humidity Factor.

The Shiroro lake catchment area records a higher humidity record than the southern area that falls outside the lake.

1.4.2 ECONOMIC AND SOCIAL IMPACT

These include the following:

i. The lake, power house and switch yard constitute a tourist centre where people from all works of life visit for tourism during holidays and weekends.

ii. The presence of the station has created job opportunities at various levels for indigenes, and non-indigenes too.

iii. The indigenes feel a sense of belonging by way of contributing to national development through power generation from shiroro power station.

iv. The station represent a unique engineering firm for students on excursion, and provider a good training ground for industrial training of students of engineering and allied courses of study as presently I have decided to embarked upon.

v. The station contributes immensely towards science education by providing higher institutions with instructional materials like old transformers, electric motors, pumps etc.

vi. The construction of shiroro Dam has resulted in improved revenue generation for the state and local government through taxes from civil servants and various levies from other settlers.

1.4.3 FISHING:

Fishing activities around shiroro on River Kaduna was almost non-existent before but with the creation of the lake, after the impounding of the dam in 1984, a total surface of about 320 sq. km at elevation 382m was covered with water which now forms the lake with a very strong avenue of fishing.

1.4.4 IMMIGRATION:

The creation of the lake has attracted immigrants from distant areas such as Edo State, Sokoto, Borno and even Niger and Mali countries outside Nigeria.

The creation of the Shiroro lake has therefore given rise to the following:

i. Commercial Fishing Activity.

ii. Improved nutritional value on the diet of the villagers.

iii. Alternative Commercial activity and source of income instead of the usual farming activity along.

iv. Improved Social Status since additional income is generated.

v. Improved social interaction with the immigration of people from far and wide settling among the local people.

1.4.5 AGRICULTURE

Before the improving of the lake, the vegetation of the land along the Kaduna River is mainly savannah with patches of few wood lands along its tributaries at Guni, Muye e.t.c.

However, the creation of the lake has improved the following agricultural activities in a large scale:

a. Livestock production

b. Fadama Farming.

c. All-year round farming by irrigation from the lake.

d. Normal rainy season farming, the major crops grown in the lake catchment area include maize, Rice, yam and Guinea-corn.

Also, the fadama area yield the following crops: sugar cane, vegetation, tomato, pepper e.t.c.

1.4.6 ECOLOGY OF SHIRORO

Wild life commonly found around shiroro catchment area are Monkyes, Antelopes, Baboons, Guine-Fowls and Grass cutters.] Concentration of reptiles such as snakes, various classes of lizards, are also found the around the vegetation close to lakes. The more deadly wild life like lions, Tigers and pythons which are usually common in river gorges have been kept at bay by the noise of construction works, the presence of human being in large number, and increased human activities within the area. This provides a remarkable improvement in the safety of villages within the shiroro lake environments.

1.4.7 HYDOLOGY OF SHIRORO LAKE:

The hydrological studies of a river is of prime importance to the effective planning, construction and operation of any hydro project. The longer the period of observation the better, especially as the adverse effect of any inadequate study could be catastrophic.

Hydrological studies of an man-made lake like shiroro Dam played vital role in the construction and operation of the reservoir proper maintenance culture, analysis of existing hydrological structure can also be ascertained from hydrological studies.

1.5.0 SCOPE OF WORK:

The problem of seepage water can best be appreciated by considering the various havoc that can result from excessive seepage from dams and reservoirs.

The washing away of slopes, sledging and piping failure, foundation failure, crushing and overturning of structures, lateral movement of retaining structure due to active seepage forces area all forms of failures associated to seepage.

In the light of above, seepage studies have gained much attention aimed eliminating or reducing the above risk in Earth and

Rock fill dams to the bearest minimum. Previous works on seepage by various scientific method shall be reviewed under chapter two.

1.6 AIMS AND OBJECTIVES

The aims and objectives of these seepage studies include the following:

(i). To analyze seepage records in relationship to head of water in the reservoir with respect to reservoir capacity.

(ii). To carry out an in depth analysis of seepage problem on Shiroro Dam (a rockfill dam) and proffer a long lasting solution within the limit of the available information or data.

(iii). To find out the period which seepage problems is well pronounced i.e considered peak and minimum values within a calendar year and its effect if any so that recommended solution can be drawn.

CHAPTER TWO

2.1 LITERATURE REVIEW ON SHIRORO DAM

The Dam is of the rock fill type and stands 115m high above the original river bed elevation, across Shiroro Gorge for a crest length of 700m.

The width of the dam at its toe is over 300meters whilst its crest, which accommodates a service road of 7.50m wide.

The crest of the dam has a heavily reinforced concrete parapet wall, more than 5m high, which is also designed to protect the top of the dam from the waves that will build up in the lake, under wind pressure.

The body of the dam has no central impervious core; The imperviousness of the structure is ensured by a continuous reinforced concrete slab placed with a special technique on its upstream face.

2.1.1 THE POWER INTAKE

The 60m high reinforced tower of the power intake with a 44 x 15m rectangular plan is located on the right bank in the proximity of the spillways structure.

At the bottom, there are four openings, 5.50m wide and 10m high, through which, and a transition area in the concrete structure, the water from the reservoir enters the circular penstocks to be finally conveyed to the turbines in the power house.

The bottom of the tower has a 1.50m diameter low water release outlet to maintain a flow, when the turbines are not turning to be used by people living along the river, down stream from the dam.

The intakes can be shut by means of gate operated by dranvic hoists located in chamber at the top of the tower which is accessible from the dam crest through a steel bridge.

2.3 ROCKFILL DAM

A dam with the diaphragm comprising mostly of rock materials is termed as rock fill dam. The term rockfill also refers to the dams constructed entirely of rock.

Alternatively, a rockfill dam can be defined as an embankment which uses rock of various sizes to provide stability and an impervious membrane to impart water tightness. The mass stability is developed by the friction and interaction of one particle on another rather than by any cementing agent binding the particles together. The water pressure is resisted only by the weight of the rock.

Rockfill dam are less flexible than earthen dams but more flexible than gravity dams. The foundation requirements are more rigid than earthen dams but not so strict and rigid as for gravity dams.

The foundation requirements for rock fill dams are:

(i) Essentially, the foundation consists of hard durable rock which is not softened or eroded appreciably by water percolating from the reservoir.

(ii) Foundation free from faults, shear zones or other structural weakness.

(iii) Minimum of foundation settlement.

(iv) Rock fill dams are suitable for areas where there is scarcity of earth fill materials but durable hard rock is available for construction of the dam.

(v) A rock fill dam is not suitable when the normal operation of the reservoir does not permit periodic inspection of the impervious membrane constructed on the upstream slope.

(vi) It is also essential that the dam is not overtopped in time of flood and as such spill way, usually of side channel type of adequate capacity is provided.

TYPE OF ROCKFILL DAM.

Based on the type of impervious layers in a rockfill dams, it can be classified in two main type:

1. Impervious membrane type.

2. The Earth core type.

2.4.1 THE IMPERVIOUS MEMBRANE TYPE

This is the type where the impervious layer consists of a membrane of concrete, as phatic concrete or occasionally steel, placed on the upstream scope of the rockfill. The membrane rest on a rubble cushion of hand placed stone which in turn responses on the dumped rockfill as shown below

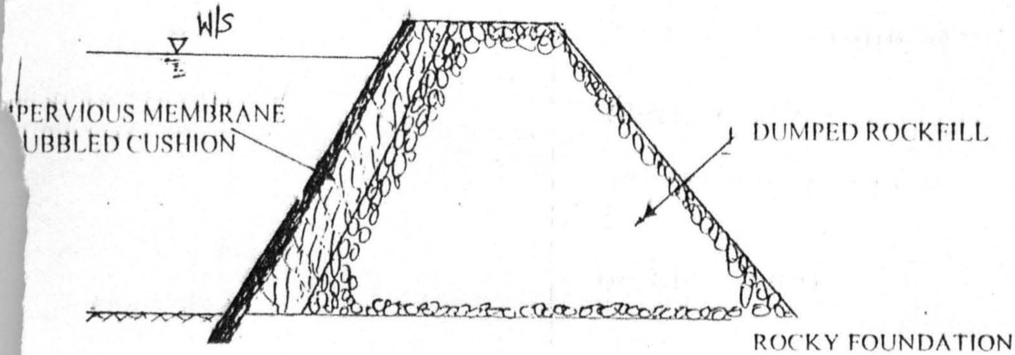


Fig.2.1 **IMPERVIOUS MEMBRANE TYPE**

2.4.2 THE EARTH CORE TYPE:

This is the type where the impervious layer is in the farm of a core of impervious earth in the body of the dam. Such a dam is also known as earth rock dam. The earth core may be central and vertical as in case of earth dams or unsystematically and sloping as shown below

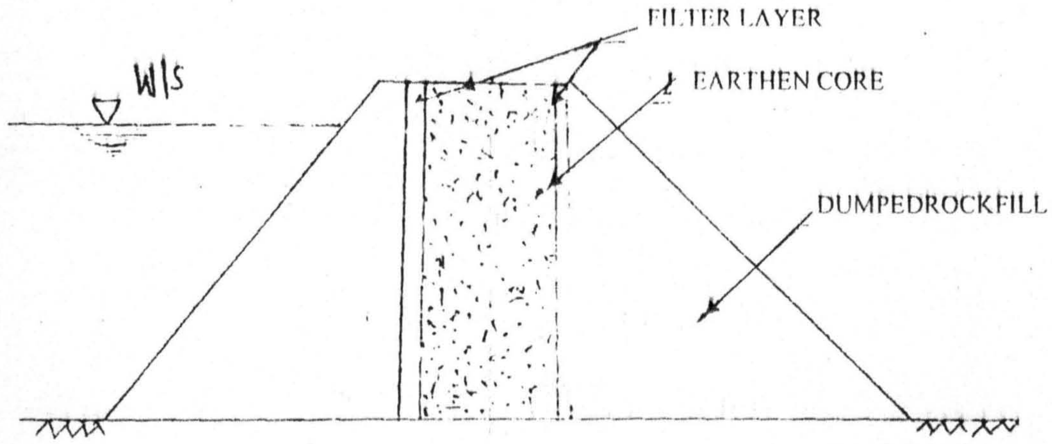


Fig. 2.2 A EARTH CORE TYPE (EARTH – ROCK)

2.5.0 SEEPAGE FROM DAMS:

The underground flow of water has significant consequence and refers to a wide range of problems. It is usual to classify ground water flow into two categories: seepage and ground water flow.

Seepage problems are generally classified as the percolation of water through dams, river banks or into excavation.

Controlling seepage is of great importance, one of the objective is to prevent or at least reduce it to a small value.

The control of seepage is not the only reason for analyzing seepage problems; other consequences such as excessive saturation, seepage forces and upliftment pressures can lead to failures from Dams. Frequently, seepage forces are only considered when they reach their final steady – State value. However, whenever seepage paths are disturbed the transition from the original to the new condition can take a significant time. In certain instances critical conditions can occur during this changes and it is therefore important to investigate time variant seepage behavior (Rushton and Redshaw, 1977).

2.5.1 SEEPAGE STUDIES ON ROCKFILL DAM

In Nigeria, Rockfill dam is not very common. This is due to the construction material requirement which in most cases are non available at economically haulage distance. The volume of granite rock adjacent shiroro Dam site necessitated the construction of the rockfill dam.

The committee on large dam (COLD) classified dam risk as follows (Umolu, 1985).

Causes of failure		% Rating
Foundation	-	40%
Inadequate spill way	-	23%
Poor construction method	-	12%
Uneven settlement	-	10%
Act of war	-	3%
Incpt Orunskillfull operation	-	2%
High pore pressure	-	5%

Figure 2.0 shows some proposed Dams and major Dam storage with Hazard potentials in the country (Nigeria).

Table 2.1 shows inventory of some major dam storage with hazard potentials in Nigeria.

And also table 2.2 shows some inventory of dam failure due to seepage problems. A well designed rock fill dam is one that is capable of withstanding the effect of water or that which has some built in measure for seepage reduction.

Most cases of practical solution to seepage problem are developed with flow nets Darcy's law. The laplace equation and flow net depend on the validity of Darcy's law and assumption that flow is lamina and not turbulent.

In rockfill dams, with coarse material formation and coarse open graded aggregates, it is likely that flow will sometimes vary from semi-turbulent to turbulent situation.
The idea is to adopt Darcy's law to solve this kind of situation.

Basically, when flow is lamina the velocity of flow increase in direct proportion to the hydraulic gradient. This means that, when the velocity is doubled, the hydraulic gradient is equally doubled.

But for semi-turbulent to turbulent flow, the seepage velocity increase at a smaller rate than at the hydraulic gradient.

For fully turbulent as open channel, the velocity increase to square root of the slope and hydraulic gradient as expressed by Chezy's formula.

$V = \sqrt{RS}$ ....equation 2.1

Where V = velocity

C = chezy coefficient

R = Hydraulic radius

S = Hydraulic gradient or slope

So a four fold increase in hydraulic gradient will only double the velocity. Various investigation have looked into flow condition in course gravel and rock to develop a variety of formulae to represent the average velocity in the pore space.

Lep (1973) gives a good summary of works done and presents a number of formula for estimating flow velocity in clean gravel or rock fill dam. He quoted that all investigation appears to agree that the basic equation for flow through rockfill is a formula for turbulent flow which can be expressed as follows:

$VA = WM^{0.5}i^{0.54}$.................................. equation 2.2

Where VA = average velocity in the void of rock.

W = empirical constant for a given material which depend on size and roughness of rock particles.

M = Hydraulic mean radius (R in Chezy formula).

i = Hydraulic gradient (S in chezy formula).

Apart from depending on above formula, a prototype laboratory work can be use to determine permeability of rock. When this is done the coefficient will have correct magnitude for estimating seepage from Darcy's law (Cedergren, 1967).

Further approach is to make permeability test for a range of hydraulic gradient. This will also include a low hydraulic gradient that will produce lamina flow to high gradient capable of producing various degree of turbulent.

The result can be presented in form of graph or histograph where hydraulic gradient (i) and the permeability (k) are plotted.

For semi – turbulent to turbulent flow Darcy's law does not hold but quasi – Darcy relationship can be applied.

Q = KiA or KCiA.................................equation 2.3

Where K = Lamina coefficient of permeability determined by test at a very small hydraulic gradient.

C = an experimental factor that varies with hydraulic gradient.

Ki = is the effective permeability equal to KC.

2.5.2 CAUSES OF SEEPAGE AND REMEDIAL MEASURES

The forces and pressure of water can pose a serious security to dams if not properly controlled. Therefore, seepage analysis and control are of considerable important in the design and construction of a safe rockfill dam.

The major cause of seepage in rockfill dam is its foundation. Most dam foundations are covered by gravely or sand, soil, and often, this layer of fine sand, silt or clay. The underlying bedrock is often relatively tight but it may be highly weathered, joined or fissured. It may also contain crevices, permeable zone, faulty plan or other hidden inconsistencies. Mineral soil or geological detail which exist in foundation of many dams, can cause dangerous seepage condition if not detected and controlled.

In Shiroro rock fill dam, the rockfill by injecting grouting to seal off the cracks.

One of the faulls has no traces of seepage water while the second is the present source of seepage (ISA Shiroro 1998).

The second source of seepage water in rockfill dam is the nature of upstream blanket material. Various impervious medium ranging from timber, stell plate or concrete impervious, are possible superior element: Lack of provision of this impervious element will cause serious seepage between each rock dumped.

2.5.2.1 REMEDIAL MEASURES AT SEEPAGE REDUCTION IN ROCKFILL DAMS

(i) The process generally involved in controlling seepage in rockfill dam are:

(A) Those that keep the water out or reduce the seepage quantities

(B) The application of drainage method to seepage.

From (A), above, the following means are undertaken to keep water or reduce seepage quantities.

(i) Cut off trench (COT):- These ensure proper foundation excavation and introduction of cut off wall at the upstream for poor foundation conditions.

(ii) Sheet – pit method:- This done to poor foundation where the depth of rock is so deep to attain a solid foundation.

(iii) Ground curtain:- This method involves pumping fluid paste through small diameter drilled holes into crevices and joints in rocks. This is generally the standard treatment for tightening a rocky foundation. In Shiroro rockfill dam this method was employed.

(iv) Upstream Blanket:- It is possible to case a thin later of concrete ranging from 5cm to 20cm thickness along the upstream of the dam. This was also used in Shiroro upstream face;

It can be placed as a form of pre-cast or insitut, general reinforced.

From (B) (The application of drainage method to seepage.)

Less emphasis is placed on filter in rockfill dam because there is less of small grain material that can be washed into solution as in the case of Earth dam where internal erosion are common. The level of filters arrangement or involvement in rockfill dams are those that are put in place at the toe of the down stream to check rains splash which can cause erosion of the foundation by removing soil under it. Most filter arrangements can be design by using Darcy's Law (state that the rate of water movement through a soil is proportional to the gradient of the soil water potential (which is the driving force behind the movement).

(a) Establish a trial thickness and calculate permeability.

$K = Q/IA$

Where K = coefficient of permeability

Q = volume of water (m^3)

I = hydraulic gradient

A = area (m^2)

Try various d (diameter) or A for various K values. Q is the infiltration rate which is already known.

(b) Select one or more permeability materials that will produce economically available local aggregate with acceptable grading to determine their thickness.

$A = Q/Ki$

Where A, Q, K, and I are as defined in (a) above.

The highest head that can safely develop drains without causing harmful hydrostatic pressure, L is the drain path length.

i.e. $I = H/L$

Where i = is as defined in above equation.

(2) Another method that can control seepage in rockfill or Earth dam is provision of relief wells along the downstream of the dam.

There is water rise in the well anytime seepage water increase within the dam, therefore reducing its effect to develop to hydrostatic or pore pressure forces.

In a highly seeping dam, a well spaced relief well are generally effective. The closer the relief well the more its effectiveness. At Shiroro Dam, there are three (3) Nos situated at the downstream toe in main faulty zone or associated shear zone extending to depth of 33m for seepage control.

(3) Other areas of seepage control or remediation is the ability and facilities for proper monitoring. Generally, analysis of seepage

through monitored data should be able to predict dangerous seepage.

Piezometer reading and interpretation are mostly effective as a monitoring tool of seepage. At shiroro dam, piezometer sensors are situated between 5m and 40m below bedrock in or adjacent to the main fault of Shiroro rockfill dam at the following locations.

(a) At the upstream toe of the dam, there are six (6) Nos which are at the upstream of the grounded curtain which are electrical operated and 4 numbers that are pneumatic (gas). At the downstream of the grout curtain, 9 numbers are electricity operated and 5 numbers are pneumatic.

(b) At the downstream toe 4 numbers are electricity operated and 4 numbers pneumatic. Tubes and wire extend from these sensors on the upstream toe of the dam, beneath reservoir to a read out station situated at the left abutment of the dam crest.

The vibrating wires are more sensitive than the pneumatic type but more vulnerable and prone to damage during construction or due to the natural element.

Installation of both type are suppose to allow for such premature damage but prior to this, enable a useful means of cross-checking results. But unfortunately during data collection at the dam site, both system are non functional. Information from the civil engineering dept of Shiroro dam during data collection indicate that they packed up, couples of year after the project was commissioned.

2.5.3 PAST STUDIES ON SEEPAGE

A wide range of techniques are available for the study of seepage. Each of the techniques is suited to a particular class of problem and may well lead to accurate result when applied in other situation.

The following methods have been used to analyzed seepage:

2.5.3.1 ANALYTICAL METHOD

Certain analytical solutions are available for seepage and ground water flow problems. In a few cases, analytical expression can be obtained by direct integration of the appropriate differential equation. A range of problems can also be analyzed by conformal transformation techniques. Polubarinova-Kochinc (1962) used analytical method to analyze seepage.

Also, Harr (1962), de wiest (1965) and Carlaws and Jaeger (1959) used analytical method to analyze seepage.

2.5.3.2 FLOW NETS:

Much of the understanding of seepage problems have been gained through the construction of flow nets. A thorough description of the methods of flow-nets construction was undertaken by Cederdgren (1977) and it shows how flow net can be investigated for a wide range of seepage problems.

2.5.3.3 PHYSICAL MODELS:

Sand tank model provides a useful means of examining flow of water in soil conducted studies by Prickette (1975).

The actual physical shape of the medium is modeled and the boundary conditions are simulated as head of water or as drains.

Simon (1982) in a steady seepage studies presented to A.B.U., a project thesis uses sand tank model to study steady seepage. Bear (1972) and Pricket (1975), have include seepage through dams, seepage dams, see water intrusion, regional water flow and multiple layer aquifers.

2.5.3.4 MATHEMATICAL MODEL

A lot of development in recent years in the analysis of seepage and ground water flow have been by means of mathematical models. An excellent review of the method was given by pricket (1975). Resistance and resistance-capacitance electrical network represent an analog model from work conducted by Karplus (1958), Rushton and Barrister (1970), and Prickett (1975). With analog computers the equation of electricity model is identical to a finite differential equations.

Digital mathematical models, where alternative method of solution simultaneous equations which present the flows process within the aquifer.

The earlier methods were based on finite difference approximations and solution to seepage problems were obtained by the head calculations of the relaxation method.

Allen 1954 used this to study seepage.

Also, Pricket and Ionnquist (1971), Thomas (1973) and Trescott et al (1976) applied this method to solve seepage problem.

Sienkiwiez (1977), Pinder and Gray (1977) and Davis (1975) used matrix techniques to solve seepage problem.

Kolina-Polubarinova (1952) correlated the exist point of the free surface to the characteristics dimension of the section in unconfined shallow foundation to solve seepage problem.

Zhukovsky (1949) applied a special mapping techniques to solve the problem of unconfined flow in a deep foundation.

Schottish Uginchus and Davo (1930) employed the method of part (segment) to calculated seepage in earth dam.

2.5.4 SEEPAGE MEASUREMENT AT SHIRORO ROCKFILL DAM

2.5.4.1 LOCATION OF STRUCTURES:

There are two numbers (2 Nos) of weir boxes downstream of the dam, one immediately

(1) adjacent to the Administration and control Building (Weir Box 1) and the other (2) adjacent to the toe of the dam at its deepest point. (Weir Box No. 2)

FUNCTION

Seepage water through or under the dam structure is channeled toward two deep collector trenches. These were excavated and concreted to form a cut-off at the two major faults zone from the original river valley.

Seepage water flows to the weir boxes which is designed to reduce turbulence in the flow and give a steady discharge over a V-notch. The seepage measurement is obtained by noting the water depth on the V-notch. It is not advisable and also not the practice to measure the depth of water directly on the V-notch as it will affect the flow.

A level is marked on the side wall of the weir, with already known level of V-notch base, the water depth can be obtained by measuring to the water level from the marked-off level.

The difference between the surface water level on the weir and the level at the base of the weir gives the depth of water in the V-notch.

Let d_1 be measure level to the water from the top of the weir.

It follows that d_1 to d_0 = 50cms

Where 50cm is the total depth of water in the V-notch from the base.

Water depth = 50cms – d_1

Seepage discharge therefore (Q) = 1.397 (d_0/100) 2.5m^3/sec.

Example: if 31.5cms are measured from the level mark to the top of water, the seepage flows is calculated as follows:

50 – 31.5 = 18.5cms (depth of water)

$18.5^{2.5}$ X 0.01397 = <u>20.56 litres/sec</u>

At higher discharge the buffer wall of the box does not eliminate entirely the formation of wave and it is necessary to record maximum and minimum value of d_1 over the space of a few minutes and then takes the means.

2.6 RISK OF DAMING

The impoundment of water in any form, imposes an element of risk to life and properties downstream and in some cases upstream, depending on number of circumstantial factors. According to Gruner (1963) this can be classified as follows:

(i) Geology: The physical, Chemical, Mechanical properties of rock and soil at site.

(ii) Hydraulic Features: Unexpected floods, overtopping, seepage piping, clogging, scouring, sloughing, wave action, artisan water e.t.c.

(iii) Type of dam and construction method which includes design features, dam size, quality control and construction techniques e.t.c.

2.7 DESIGN OF ROCKFILL DAMS

Rock fill dams originated in California (Golze 1905) about the middle of the nineteenth century as a result of the need to impound water for mining operations in remote areas. Suitable rocks were abundant and rock handling operation were familiar to the miners.

Some of the early dams were small and consisted of a loose, dumped rockfill forming the mass of the dam, and an impervious upstream facing.

The American Society of Civil Engineering (1960) defined rockfill dams as one that relies on rock either dumped in the lifts or compacted in layer as a major structural element. Included are rock fill dams with:

(i) Sloping earth core

(ii) Thin central core

(iii) Thick central core

Although the history of rock fill dam is short compared to that of other types of dams, the development of this type of dam during the last several decades has been rapid in the limited states than in other countries.

2.7.1 DESIGN PARAMETERS:

1. **Top Width**: The top width normally adopted, varies between 3m minimum for dam 30m high and 6m maximum.

2. **Slope**: The upstream slope usually has hand placed stones and as such slope of $^1/_2$: 1 to 1:1 is adopted. For dams over 50m height, the slope adopted is 13:1. The downstream slope made of dumped rock usually corresponds to the natural slope of the rock varying from 13 : 1 to 15 : 1. For high dams, beams are provided.

3. **Base Width**: The overall base width usually ranges between 2.5 to 3 times the dam height.

4. **Settlement**: Usually an allowance of 2 percent of height is provided to take care of settlement.

2.8 ROCKFILL DAM WITH IMPERVIOUS FACING:

Rock fill dam with impervious facing was defined by J.D. Galloway Goize, (1905) in his paper entitled "The Design of Rock fill Dams", published in 1939. As impervious face next to the water and a rubble cushion between the two.

In most cases rock is dumped loosely in position and there is no attempt to orderly arrange the individual rocks, nor is there any other material introduced to bind the rocks together. The mass of rock is some what consolidated when placed in position and further consolidation takes placed by settlement under self load and action of weather.

Resistance to the forces imposed by water is obtained from the weight of the mass of rock in the dam. There can be no arch action, nor can there be any action such as the cantilever offset of a gravity masonry dam.

As the mass of loose rock permits the free passage of water, it is necessary to provide the dam with an impervious element to make it water tight.

Several arrangements ranging from earth backed by rock fill have been used; but these arrangements are not properly rock fill dam. The most usual arrangement is to place the impervious element as a facing on the water side of the dam. The impervious face can be of timber and concrete. In recent year, it has been made of concrete usually reinforced. Steel sheet has also been used.

Gust (1905) lists 29 important rock fill dams in the United States, eleven (11) of which were in service or under construction before 1900. Seven (7) of the eleven dams had timber facing, one a rubble facing and two have steel core. Of the eighteen built between 1900 and 1932, 12 have concrete facings, 2 timber facing and one has both concrete facing and rubbed faced. Shiroro rock fill dam has reinforced concrete impervious face.

2.9 MATERIALS SELECTION FOR ROCKFILL DAM

There have been a considerate opinion among rockfill dam designers as to the optimum size and gradation of rock dumped. For example, Galloway in Golze (1905) states the nature of rockfill as one upon which difference of opinion will developed. It is believed that the rock should be composed of individual rocks fairly uniform in size one rock bearing directly on another, usually expressed as "Rock to Rock".

The specifications for cogs – well dam in (Gloze 1905) a 61m (200ft) structure completed in 1935 provide for material for the rock fill to consist of three classes: A, B, and C of Large rock with the maximum on the downstream face and toe; with derrick-place rock, commonly known as packed rock placed immediately below the facing.

The characteristics of all rock are to be hard, durable angular quarried rock, weighing not less than 2,562.9kg/m^3; to be unaffected by wind and moisture and of such toughness as to withstand dumping without undue sheltering or breakdown.

A minimum compressive strength of 351.5kg/m^3.

Class 'A' rock for general use through out the main fill of the dam was to be well graded mixture, 40% of which are to vary in weight from quarry chips 373.2 to 1119.6kg and the remaining 30% from 1119.6kg to 5224.8kg.

Class 'B' Rocks are selected from extra large rocks, one-half of which less than 5224.8 in weight while the other half's are less than 2239.2 kg.

The greatest dimensions of each pieces was not to be placed at the downstream toe and downstream face of the dam.

Class 'C' Rocks are to vary in weight from quarry chip to 5224.8kg. The relative proportion of the various size to be regulated according to the requirement of placing to result in a packed rock fill of maximum density.

2.10.0 ADVANTAGES AND DISADVANTAGES OF ROCKFILL DAMS

2.10.1 ADVANTAGES

This include the following:

(i) Cheaper where suitable hard rock is available.

(ii) Suitable where suitable materials for earth dam are not available.

(iii) Economical in remote locations where cost of cement for concrete dam is high.

(iv) Suitable where foundation is not suitable for concrete dam.

(v) Can be constructed with relatively unskilled labour.

(vi) Can be raised subsequently, if so required, with out much difficulties.

2.10.2 DISAVANTAGES

This also includes:

(i) Time taken in construction is usually 4 to 5 years more than that required for a concrete dam. This is a crucial factor.

(ii) More construction equipment is required.

(iii) Foundation requirements are more rigid than earthen dam.

(iv) High maintenance cost.

TABLE 2.1 PARTIAL INVENTORY OF NIGERIAN DAMS

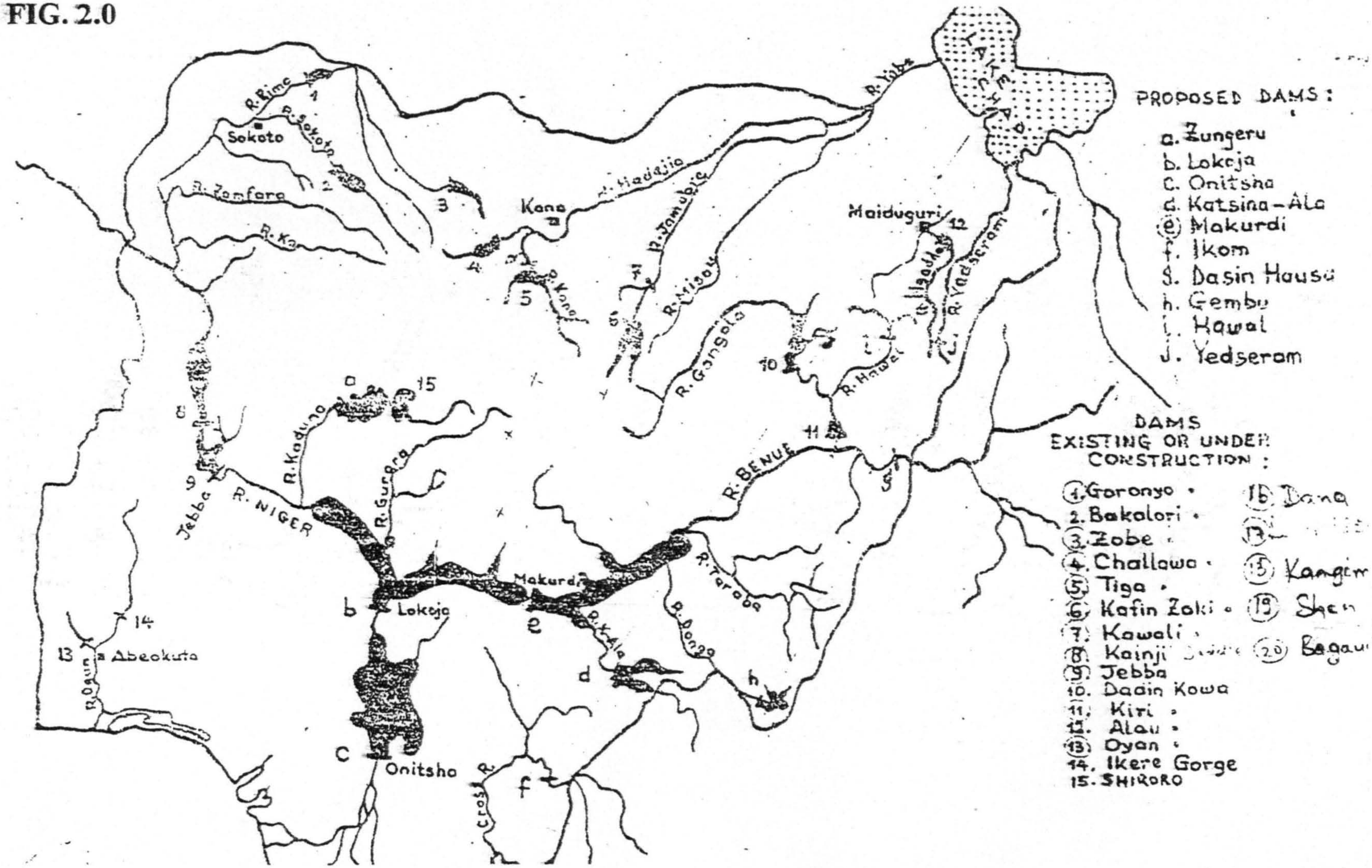
S/N	Name of Dam	River	State	Type	Reservoir Capacity mcm	Height m	Length	Purpose	Size	Remarks
1	Lower Usuman		Abuja	E	100	49	1350	Water supply WS	Large	
2	Gubi		Bauchi	E	30.4	27	3820	WS	L	
3	Dadin kawa		Bauchi	R						
4	Kafin Zaki		Bauchi	E			12500	Ir, WS	L	
5	Kawali		Bauchi	E				Irrig.		
6	Ikpoba	Ikpoba	Bendel	E	1.5	8	600	WS	Small	
7	Igara		Bendel							
8	Ojorami		Bendel							
9	Kiri		Gongola							
10	Ajiwe	Tagwai	Kaduna	E	22.7	14	786	WS,I,Recr	L	
11	Dutsin Ma	Dutsin Ma	Kaduna	E	1.6	10	1036	Ws,Irrig		
12	Dagoma	Kusheri	kaduna	E	5.5	17	2225	Ws,Irrig	L	
13	Zaria	Galma	Kaduna	E	15.9	15	549	Recreation	L	
14	Kangimi	Kangimi	Kaduna	E	59,2	19	1525	Ws,Irrig	L	
15	Kubani	Kubani	Kaduna	E		8.5	822	Ws	Median	
16	Mairuwa (Funtua)	Sokoto	Kaduna	E	5.5	13.7	457	WS, Irrig	Med	
17	Zobe		Kaduna	E	263	19	2700	Irrig	L	
18	Bomo	Bomai	Kaduna	E						
19	Kachia	Kogin Kachia	Kaduna	E						
20	Kainji	Niger	Niger Kwara	E R.c	15,000	66	7750	WS,HYDRO H,Irrig	L	
21	Jebba	Niger	Niger Kwara	R.C	1,000	40	1940	HYDRO	L	
22										
23	Okana	Okuhabi	Kwara	C	0.27	11		WS		
24	Aba		Kwara	C	77.3	19		WS		
25	Agba	Agba	Kwara	C				WS		
26	Oyun	Oyun	Kwara	C				WS		
27	Oriwa	Oriwa	Kwara	C				WS		
28	Sobi	Imaru	Kwara	C				WS		
29	Jibiya	Katsina	Katsina	C	121			WSIrrg	L	
30	Kubli/ Swashi	Swashi	Niger	C	75			Irrgi,WS		
31	Nasko	Nasko	Niger	E	2			WS,Irrig	Small	
32	Tagwai	TASBA	Niger	E	27			WS,irrg	L	
33	Tungan Kawo		Niger	E	21			WS, Irrig	L	

S/N	Name of Dam	River	State	Type	Reservoir Capacity mcm	Height m	Length m	Purpose	Size	Remarks
34	Shon		Plateau	E	3.4	36	1240	WS	L	
35	Pankahin		Plateau	R,E	5.0	(23) 31	(480) 840	WS	L	
36	Liberty		Plateau	R,E	9	27	(650) 500	WS	L	
37	Aukwil		Plateau	E	31	26	350	WS	L	
38	Grants House	Rafin Sanyi	Plateau	E	6.5	26	460	WS	L	
39	Lang Tang	Yolyem	Plateau	E, R	5.2	19	1220	WS	L	
40	Tanti		Plateau	E	14.2	14	8534	H,S	L	
41	Doma		Plateau	E					L	
42	Mada		Plateau						L	
43	Kogin Giri		Plateau	E		8	280		S_m	
44	Laminga		Plateau	E	0.17	11	410	WS	Med	
45	Oyan	Oyan	Ogun	C E	270	30	1844	H,F WS, Irrig	L	
46	Asajira	Oshun	Oye	E	32.9	26	853	WS	L	
47	Ejigbo	Are	Oyo	E	14.6	20	840	WS	L	
48	Awon	Awon	Oyo	E	9.8	(13) 15	326	WS	L	
49	Fawfaw	Fawfaw	Oyo	E	8.7	15	262	WS	L	
50	Otin	Otin	Oye	E	5.5	14	557	WS	L	
51	Oba	Oba	Oyo	E	4.5	13	500	WS	L	
52	Oshun	Oshun	Oyo	E	8.2	11	730	WS	L	
53	Eleyele		Oyo	E	7.05	13	244	WS	Med	
54	Iwo		Oyo	E	1.6	12	455	WS	Med	
55	Opaki Eruwa		Oyo	E	2.6	12	252	WS	Med	
56	Edo		Oyo	E	5.3	11	238	WS	Med	
57	Ekooudo		Oyo	E	5.5	13	556	WS	L	
58	Esa Odo		Oyo	E	8.2	11	732	WS	L	
59	Ikoro Gorge		Oyo						L	
60	Goronyo		Sokoto	E	(942)7 974	(20) 21	7218	Irrig	L	
61	Bakolori		Sokoto	E,C	450	48	(5260) 5491	Irrig	L	
62	Zuru		Sokoto	E	5.85	15	200	WS, Irrig	L	

TABLE 2.2 PARTIAL LIST OF DAM FAILURES DUE TO SEEPAGE ACTION.

NO.	NAME	LOCATION	HT.	DATE OF FAILURE	CORE	REMARK	REFERENCES
1	Pleasant Valley	Utah	63	1928	Puddle cut off earth fill	Settlement & piping	Eng. News record
2	Woisse Pass River	Bohemia	42	1916	steel	Seepage along conduct	Idem vol. 77P. 139
3	Iyaman	Arizona	65	1915	puddled	Piping & sloughing	Idem vol. 73, p. 764
4	Horse creck	Colorado	56	1914	none	Piping & sloughing	Ideal vol. 71 p. 828
5	Lake Goorgy	Colorado	56	1914	puddled	piping	State Eng. Report
6	Hatch town	Utah	65	1914	-	Seepage along culvert	Eng. news record vo. 75 p. 60
7	Davis Reservoir	California	39	1914	-	piping	Idem, v. 72 p. 106
8	West Julesburg	Colorado	50	1910	none	Seepage along ledge rock	State Engr. report
9	Zuni	Back rock Mexico	70	1903	none	Rock piping	Engr. News vo. 602, p. 597
10	necaxa	Mexico	193	1909	clay	sloughing	Idem, v. 60 p. 1
11	Lake Avalon	New mexico	48	1904	-	piping	Idem, v. 54 p. 9
12	Creenlic scottsdalic	Pennsybaania	60	1904	-	Piping	Idem v. 52, p. 107
13	Lake Francis	California	50	1899	none	Seepage along outlet conduit	Trans. V. 58, 107
14	Swansea	South Wales Great Britain	80	1879	puddle	piping	Sanitary Engr. v. 3 p. 437.sssss

FIG. 2.0



SOME PROPOSED DAMS AND MAJOR DAMS STORAGES WITH HAZARD POTENTIALS IN NIGERIA

CHAPTER THREE

3.00 METHODOLOGY

3.10 INTRODUCTION

In the case of seepage, it is interested in:

a) What quantity of water is due to seepage at a particular time of interest and location?

b) What is the nature of or pattern of seepage? How does it relate to seasons, reservoir capacity, reservoir elevation, and head of water in the reservoir e.t.c?

c) It should be able to forecast a future occurrence.

3.20 PROJECT AREA DESCRIPTION.

Shiroro dam is located in the northern part of Niger state of Nigeria. It is of the rock fill type and stands 115 meters high above the original river bed elevation, across shiroro gorge for a crest length of 700 meters.

The width of the dam at its toe is over 300 meters; while its crest that accommodates a service road is 7.50m wide.

Thecrest of the dam has a heavy reinforced concrete parapet wall, more than 5m high, designed to protect the top of the dam from the wave that will be build up in the lake, under wind pressure.

The body of the dam has no central impervious core; the imperviousness of the structure is ensured by a continuous reinforced concrete slaps placed with a special technique on its up stream face.

The project is 550km down of this confluence of Kaduna River in Niger State and Dinya River.

The dam has a reservoir area of 312km^2 at normal operating elevation of EL.382. It has minimum operating range of 342.

The gross storage capacity is 7.0 billion m^3 and power storage capacity of 6.05 billion m^3 (chase-T- main international INC, Boston Massa chusetts manual on Shiroro Dam, 1985).

3.3.0 SEEPAGE AND HEAD.

Seepage is said to occur when there is a pressure difference, or when there is potential head difference. It can therefore be rightly said that the head of water in a reservoir is a deterministic factors of seepage if all other conditions causing prevailed e.g. the ground level at the adjacent area to answer above question, we have to analyze seepage to a particular trend.

3.4.0 METHOD OF DATA COLLECTION.

3.4.1 Personal Contact

Personal visit to shiroro dam project and verbal discussion with the staff of the project for permission to practically viewing of some project structure.

Also, request for hydrological data with the hydrology section was also made. This all, enables the obtaining of Seepage Data From Shiroro Dam which includes daily records of:

a) Reservoir elevation (m).

b) Reservoir capacity ($m^3 \times 10^9$).

c) Seepage flow ($m^3/s \times 10^{-5}$).

d) Tail water (m).

e) Weir box (H/cm).

The daily data obtained is per attached appendix A, B, C, D, E, F, G & H.

Similarly, evaporation and rainfall data as from 1985 to 2000 equally obtained as per attached appendix I & J.

3.5.0 METHOD USED FOR THE ANALYSIS.

3.5.1 By Arithmetic Average.

In Shiroro Dam, which is designed for electricity generation and other purposes, energy requirement varies from month to month. Therefore head of water in the reservoir decrease by amount of released for turning turbine. The amount of seepage therefore will vary with respect to head available.

In this analysis, the summation of all seepage water occurring in daily of the months of January for example divided by the number of available days i.e 31 days, gives the average seepage water for that month. These applied to all other month within the years of the available data and their average values obtained.

Similarly reservoir elevation, reservoir capacity, tail water race daily data were also averaged or computed the same as per above for all the years and values recorded in tabular form.

Also, the summation of all the seepage elevation, reservoir capacity, tail water race e.t.c. occurring per average month of a particular year e.g 1994, divided by the numbers of available months in that years i.e months gives the average for that parameter within the year.

3.5.2 HEAD VALUE COMPUTATION.

The ground surface elevation is confirmed to be 312 and for the head (m), we subtract the ground elevation from the reservoir elevations to gives a head (m) within that particular reservoir elevation. For example, in January 1994, average elevation for the month is 378. Therefore, 378 subtracted by ground surface elevation of 312 equals 66 i.e 378-312=66 which is the average head (m) of that reservoir elevation water in January 1994.

3.6.0 GROUP PARTTERN OF THE DATA.

3.6.1 YEARLY AND MONTHLY GROUPING.

After the computation, the data are grouped in tabular forms where the x-axis is the year and y-axis is the months of the year.

The average values are then recorded after the month and finally their table of values obtained as in table 4.1 to 4.19

3.6.2 MONTHLY AVAREGE GROUPING FOR ALL THE YEARS.

The average values for all the month in a year are re-grouped for all the available years. Its summation divided by the number of year and the average for that month of the year is obtained. For example, January average values for seepage elevation, head & reservoir capacity of all the years i.e 1994 --- 2003 are collected and grouped in a single table. The summation divided by 8 years of available data to give the average for January month.

Also that of February the same to December month and their tables of values obtained too.

3.7.0 GRAPHS.

3.7.1 METHOD USED IN PLOTTING.

Two methods are used for this graphical analysis which includes:

1 Line graph method.

2 Histograph method.

From the table of values for all the re-grouped data the graphs are plotted and displaced in chapter four as figures.

Finally the trend of behavior of the entire hydrological component obtained as a result in Shiroro dam fully discussed in the next chapter (four).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION OF RESULTS

4.1 INTRODUCTION:

After the data have been computed and grouped in tabular forms in mouths of year concern per the year of occurrence. The Table of value so obtained are then plotted in graphical forms and their figures also produced.

The table and figure will be discussed one after the other according to each hydrological parameter and the way they relate or affect each other with respect to season with the years.

4.2 Rainfall Data Analysis (1985- 2000).

The rainfall is for a period of 16 years and from figure 4.1, the rainfall intensity ranges between 8.2mm which is the lowest in 1987 to 146mm the highest in 1990. Also, the trend of rainfall within Shiroro Dam is in zig-zag form.

4.2.1 Monthly Rainfall.

(a) The months of January and Februarys of all the years only recorded rainfall once in January of 1988. Otherwise, their was no any form of rainfall recorded. (Table 4.1)

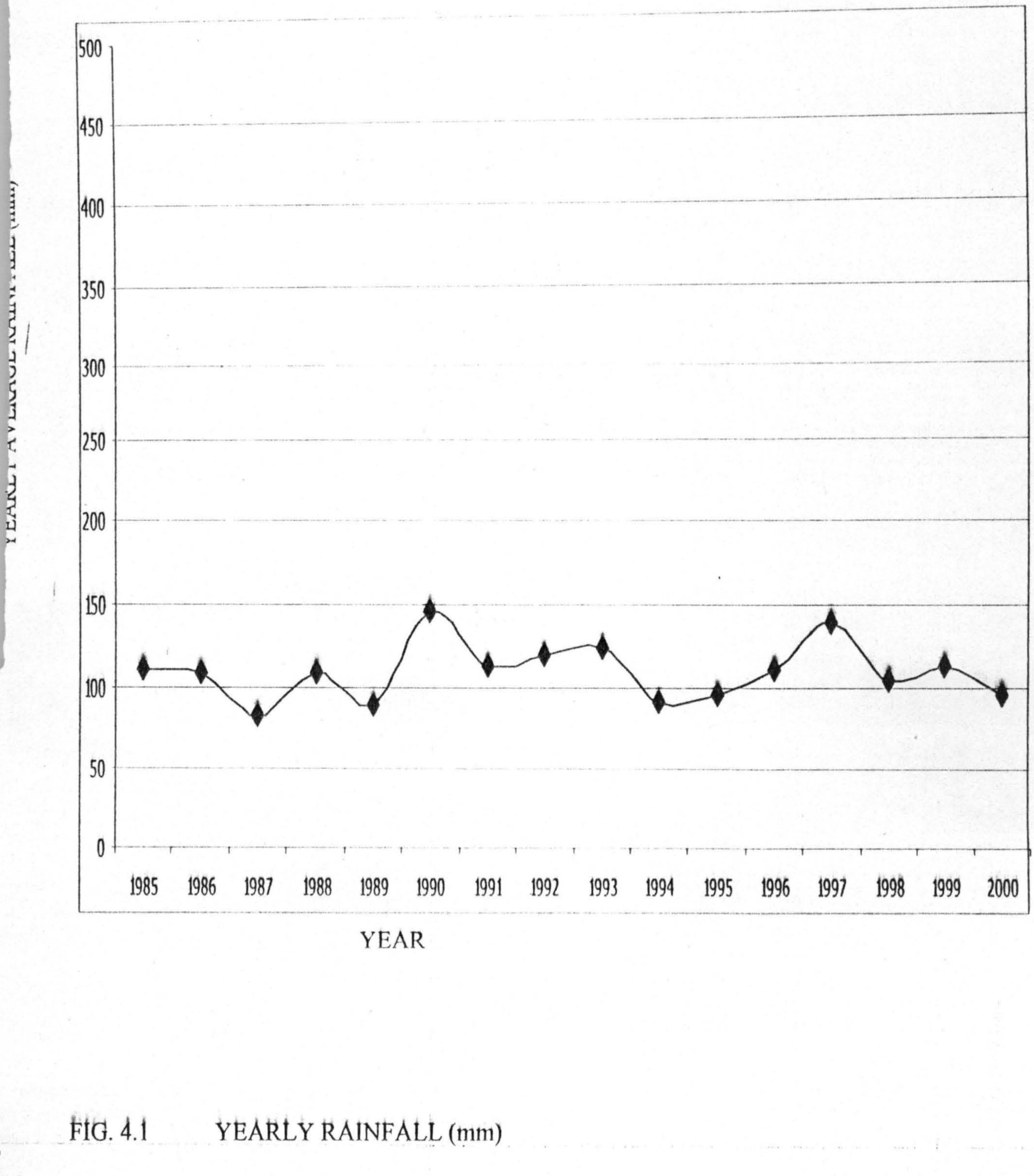


FIG. 4.1 YEARLY RAINFALL (mm)

TABLE 4.1 RAINFALL RECORD FROM SHIRORO DAM (mm) 1985 – 2000

MONTH	YEARS															
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
JANUARY				3												
FEBRAURY																
MARCH	34	13	13		3		6	3	22			1	42	1		
APRIL	14	59	14	155	91	175	22	75	27	59	2	44	63	69	37	10
MAY	119	66	63	88	190	160	300	198	69	75	108	165	192	103	111	113
JUNE	107	187	218	175	153	228	146	183	165	226	132	214	190	186	221	182
JULY	244	272	152	240	153	416	450	188	378	107	192	190	309	278	201	214
AUGUST	485	279	189	290	290	278	238	280	258	265	444	234	271	281	196	365
SEPTEMBER	367	350	245	361	118	350	158	363	335	209	178	307	473	195	411	168
OCTOBER	30	61	85	12	81	145	38	139	238	148	88	181	142	142	182	100
NOV		35														
DECEMBER						1										
YEARLY AVERAGE	112	110	82	110	90	146	113	119	124	91	95	111	140	105	113	96

(b) **March Rainfall**

The month recorded a scanty rainfall pattern intensity, in which the highest was in 1997 of 42mm and lowest of one (mm) in both 1996 of 1998 respectively as shown in figure 4.2.0,

(c) Similarly, April month recorded a different pattern of rainfall with 175mm as the highest rainfall in 1990 while 2mm rainfall being the lowest in 1995 as shown in figure 4.2.1.

(d) The may month recorded a highest rainfall in 1991 with 300mm intensity and lowest in 1987 of 62mm intensity i.e this gives the range for the many month for those numbers of years as per figure 4.2.2

(e) **June Months**

Rainfall pattern ranges between 226mm the highest 107mm the lowest in

Highest—226MM IN 1994

Lowest—107mm in 1985

The Rain fall gives the range between 226mm and 107mm as show in figure 4.2.3.

(f) **July Months.**

Highest Rainfall- 450mm in 1991,

Lowest Rainfall- 107mm in 1994

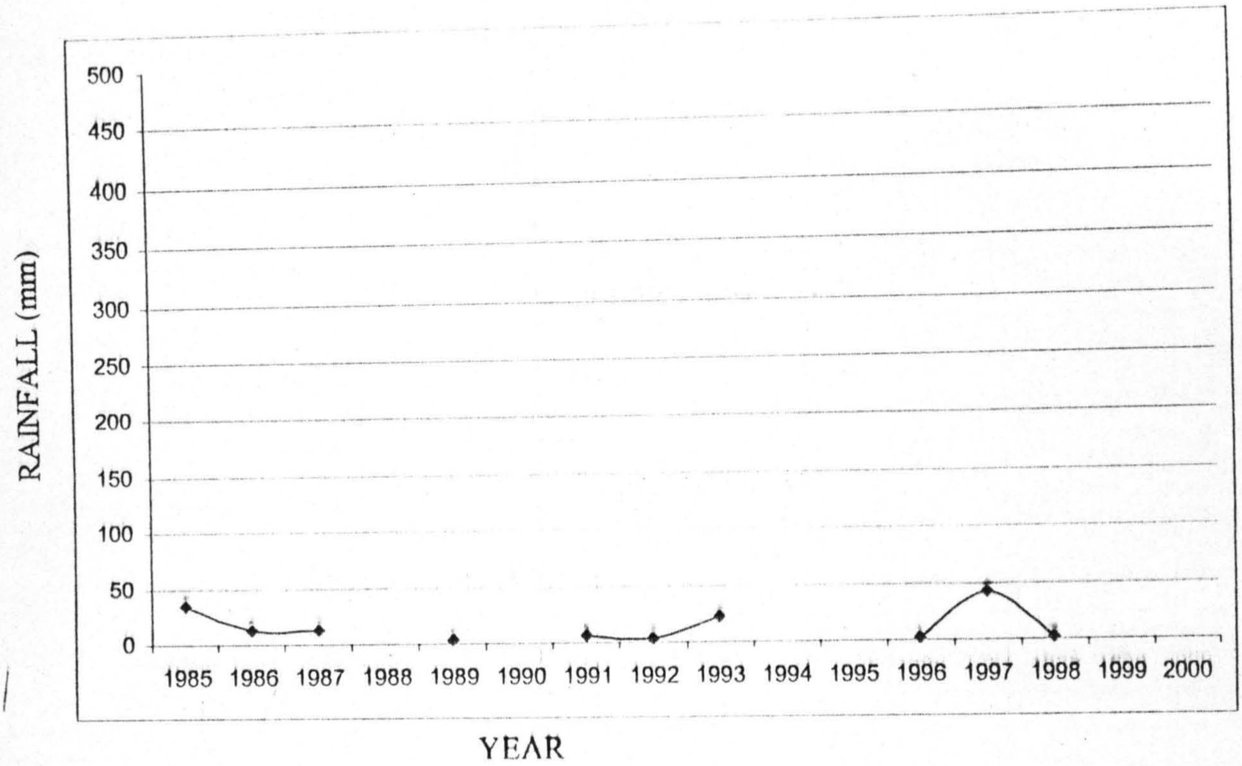


FIG. 4.2.0 RAINFALL (mm) FOR THE MONTH OF MARCH

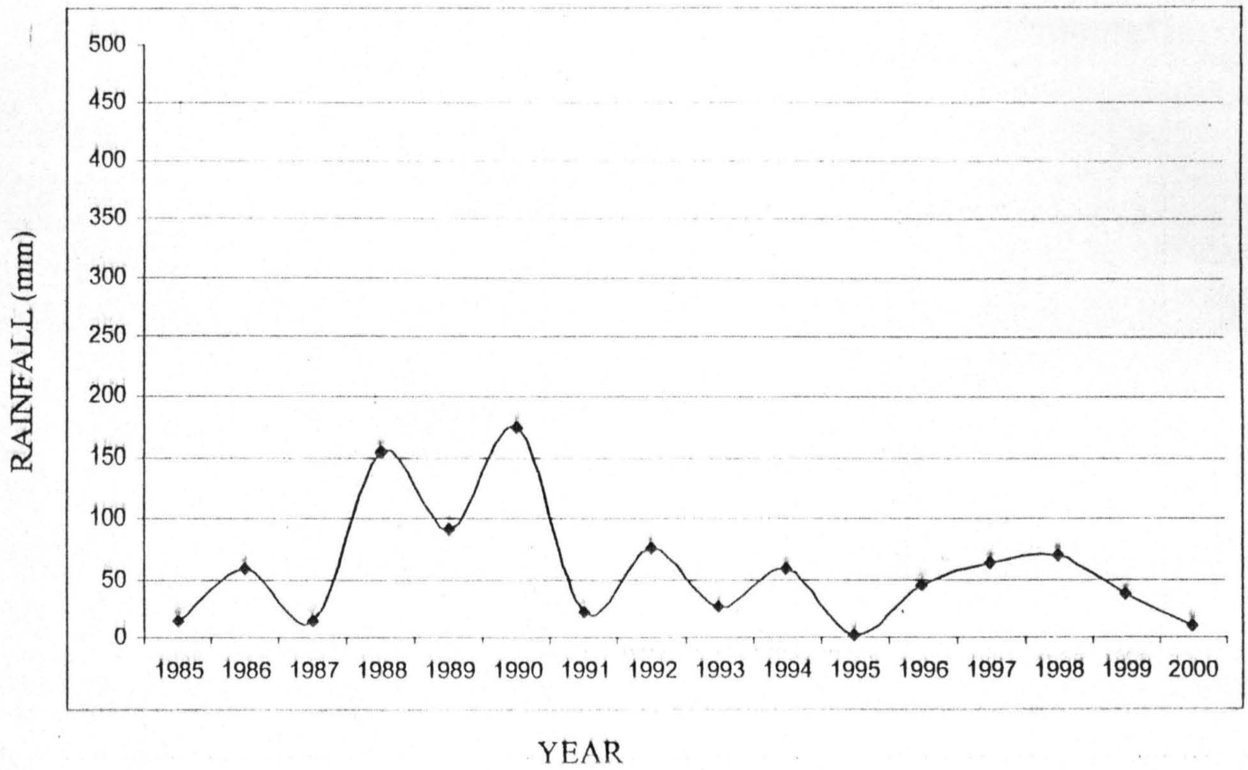


FIG. 4.2.1 RAINFALL (mm) FOR THE MONTH OF APRIL

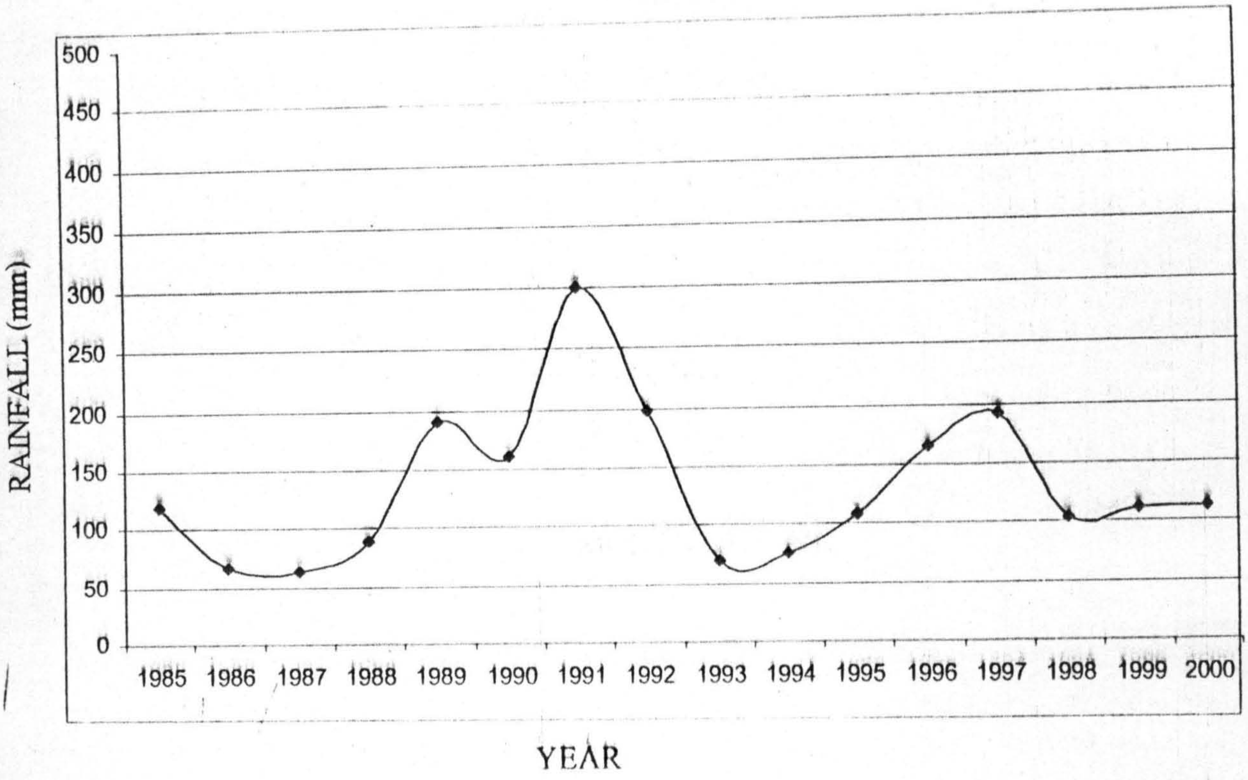


FIG. 4.2.2 RAINFALL (mm) FOR THE MONTH OF MAY

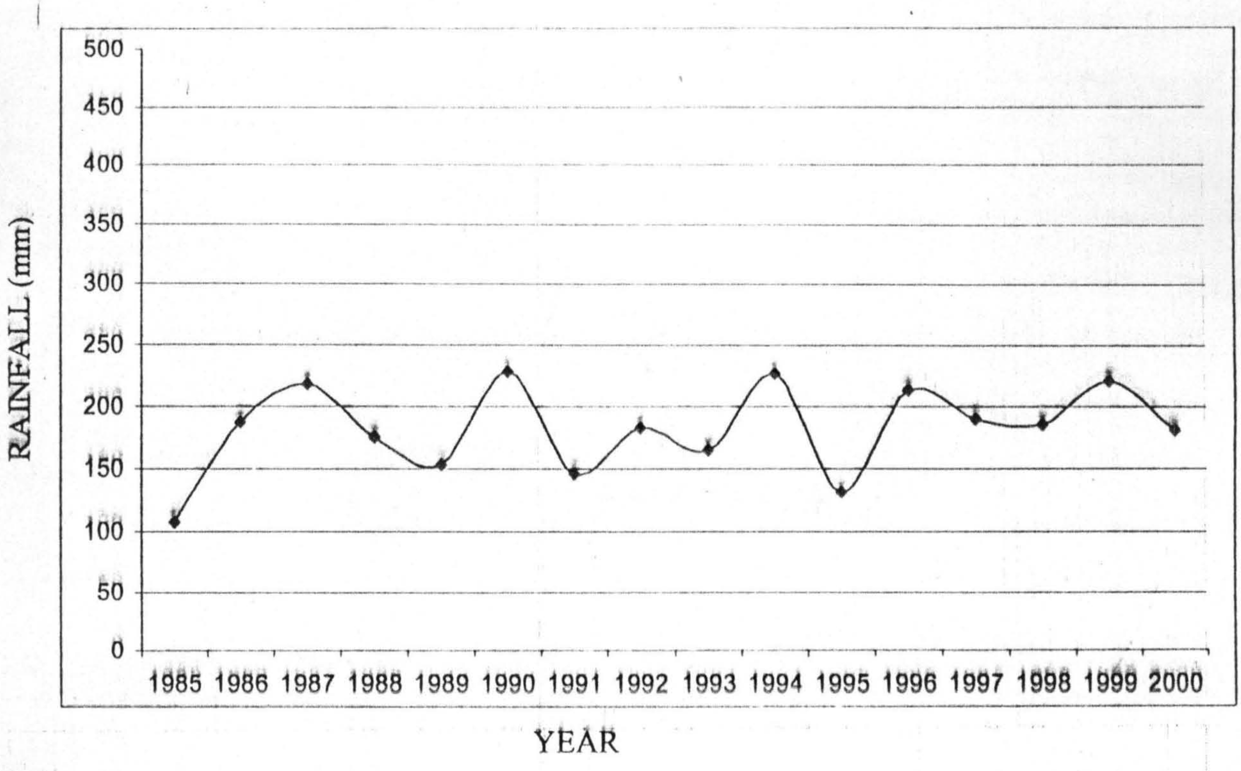


FIG. 4.2.3 RAINFALL (mm) FOR THE MONTH OF JUNE

This gives the range between 450mm and 107mm with those number of years as shown in figure 4.2.4.

(g) **August Months.**

Highest Rainfall -485mm in 1985

Lowest Rainfall- 189mm in 1987

This is the month that gives the highest intensity of rainfall with almost high pattern of rainfall as shown in figure 4.2.5.

(h) **September Months.**

Highest Rainfall – 473mm in 1997

Lowest Rainfall – 118mm in 1989

This gives the range of rainfall pattern within those years with a trend as shown in figure 4.2.6.

(i) **October Months**

Highest Rainfall- 238mm in 1993

Lowest Rainfall- 12mm in 1988

This also gives the range of rainfall pattern within those year and trend for September person of all the years as shown in figure 4.2.7.

(j) **November and December Months.**

This recorded only once rainfall within each of the month. November month once in 1986 i.e. 35mm rainfall and December month once in 1989 i.e. 1mm rainfall.

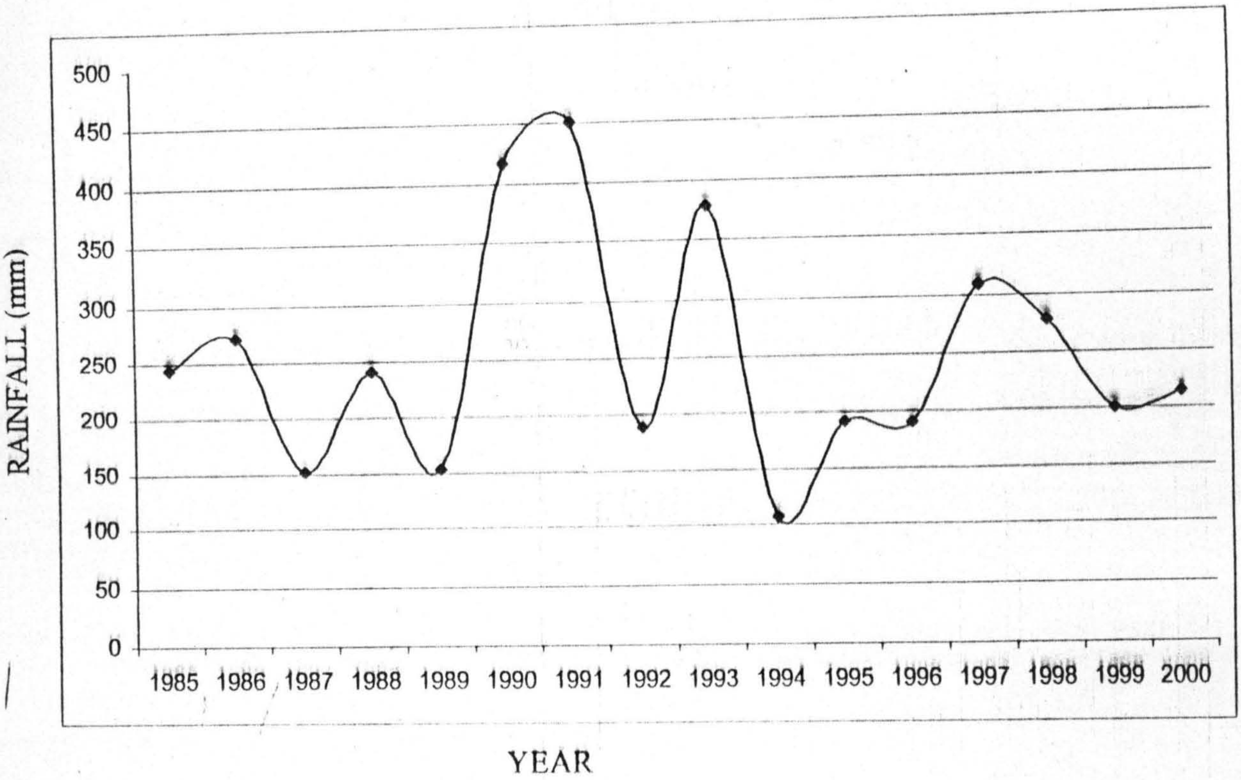


FIG. 4.2.4 RAINFALL (mm) FOR THE MONTH OF JULY

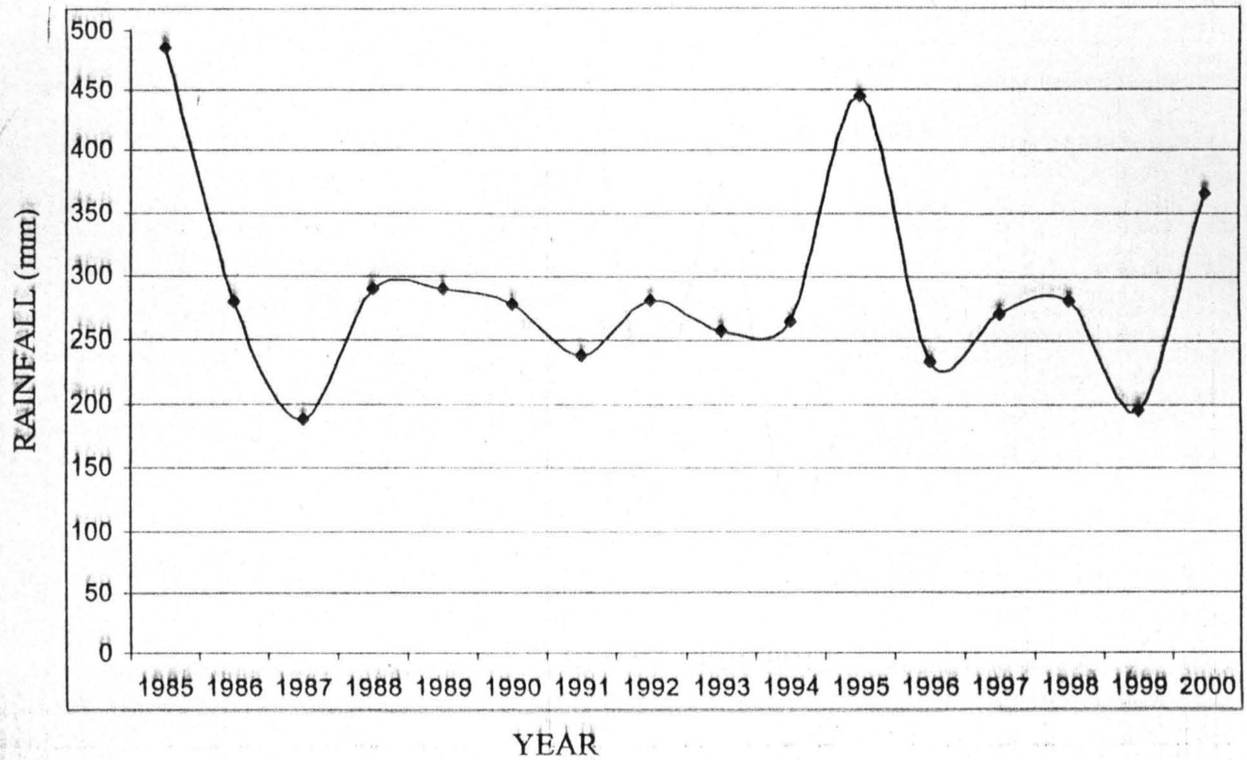


FIG. 4.2.5 RAINFALL (mm) FOR THE MONTH OF AUGUST

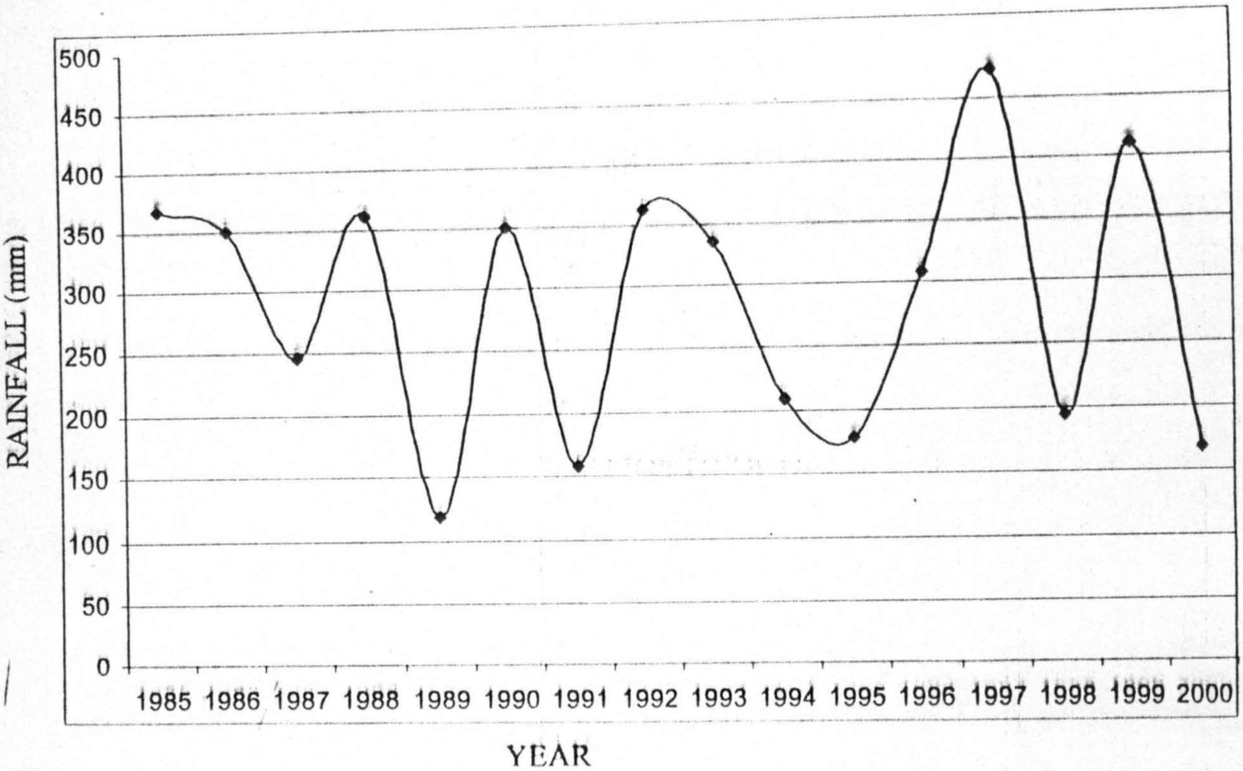
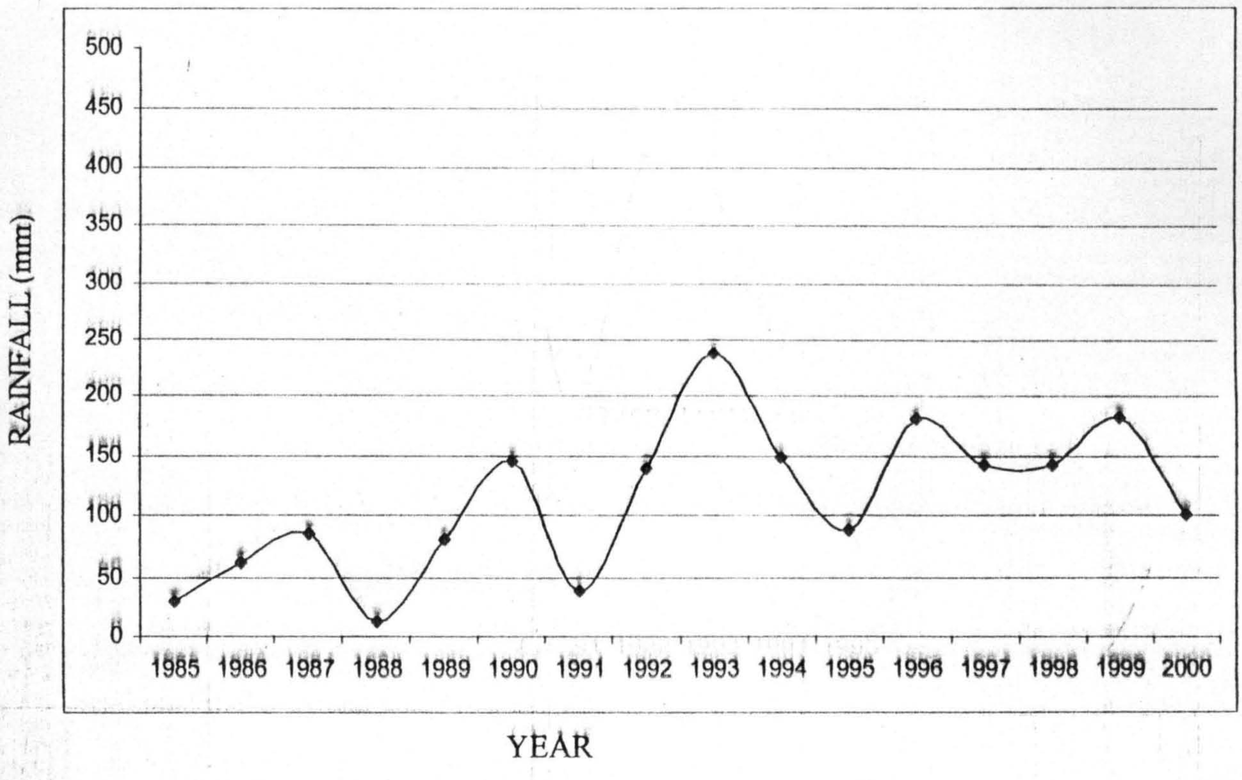


FIG. 4.2.6 RAINFALL (mm) FOR THE MONTH OF SEPTEMBER



0FIG. 4.2.7 RAINFALL (mm) FOR THE MONTH OF OCTOBER

4.3 Evaporation Analysis (1985-2000)

The Year 1991, 1992 and 1993 experienced missing data in almost all the months. This may not gives the actual picture of the evaporation trend expected but with the available data the highest evaporation was recorded in 1990. The lowest evaporation in 1991, 1992 and 1993 respectively as can be seen in Table 4.2 and figure 4.3 i.e. only October data available for those years. The trend of evaporation is shown in the same figure 4.3 and the range is between 8cm and 14.1cm.

4.3.1 Monthly Evaporation

(a) **January Months**

Highest evaporation- 21.41cm in 1990

Lowest evaporation – 8.09cm in 1985

This gives the range in which the evaporation occurs within those numbers of years as of January period, The trend is as shown in figure 4.3.1.

(b) **February Months**

Highest evaporation- 25. 2cm in 1990

Lowest evaporation- 9. 41cm in 1986

This also gives a range which evaporation occurs within those number of years as of February period. The trend of evaporation as in February is as shown in figure 4.3.2.

TABLE 4.2 MONTHLY AVERAGE EVAPORATION RECORDS FROM SHIRORO DAM (cm) 1985 – 2000

MONTHS	YEARS															
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
JANUARY	8.44	8.09	10.13	9.34	10.9	21.41				18.8	20.21	15.75	15.6	19.04	17.31	18.25
FEBRAURY	11.42	9.41	11.05	11.92	12.28	25.21				10.9	24.12	15.02	18.04	21.5	12.49	22.83
MARCH	9.1	8.11	10.49	11.2	10.23	25.6				10.52	21.76	21.11	11.14	19.7	14.66	20.75
APRIL	7.08	7.79	11.38	7.75	9.36	13.06				6.96	16.83	9.6	7.51	11.61	11.44	11.7
MAY	7.77	6.06	9.36	6.94	5.99	7.62				6.22	11.26	6.84	5.9	6.49	8.09	8.57
JUNE	4.83	5.38	6.12	5.51	4.68	6.94				5.58	7.04	5.48	4.2	3.14	6.31	5.75
JULY	7.7	4.16	4.77	5.32	3.94	5.87				4.91	4.59	4.84	4.7	3.92	4.25	4.24
AUGUST	7.74	4.71	4.39	5.85	6.31	7.32				7.08	4.99	5.12	5.04	5.54	4.06	5.15
SEPTEMBER	8.69	6.6	4.94	5.25	9.1	12.28				7.25	8.02	9.3	9.79	10.18	8.83	7.39
OCTOBER	5.82	5.19	5.95	6.12	11.31	13.13	13.3	12.31	13.94	12.04	10.14	12.03	12.64	11.19	11.73	9.9
NOVEMBER	8.54	6.21	7.89	7.95	19.12	15.92				16.36	11.16	17.94	12.41	15.94	15.32	15.79
DECEMBER	8.63	9.48	9.07	8.5	20.5	14.37				24.41	15.62	17.41	17.5	17.59	20.84	17.99
YEARLY AVERAGE	8	6.8	8	7.6	10.3	14.1	1.1	1	1.2	11	13	11	10.4	12.3	11.3	12.4

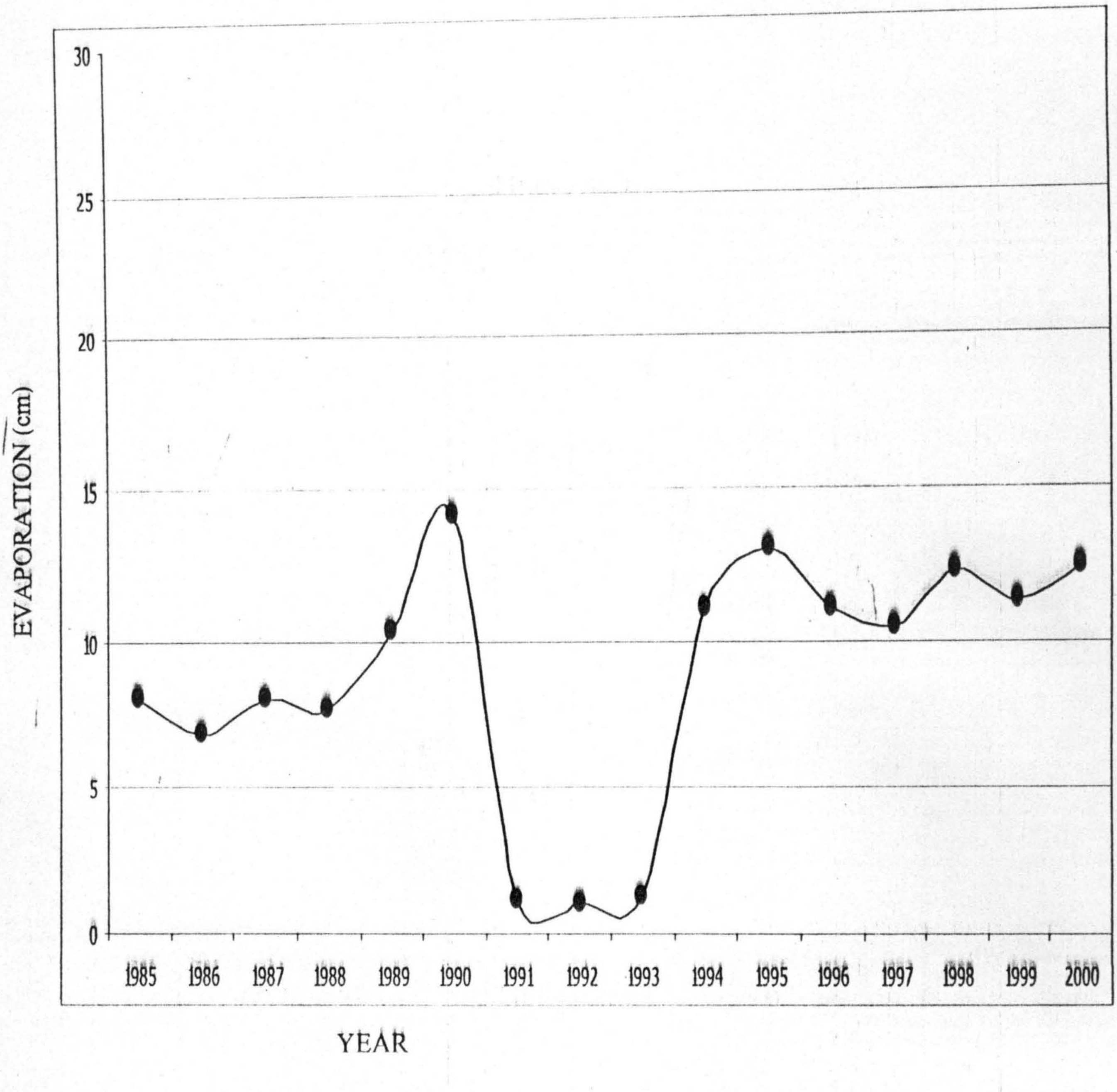


FIG. 4.3 YEARLY EVAPORATION (cm)

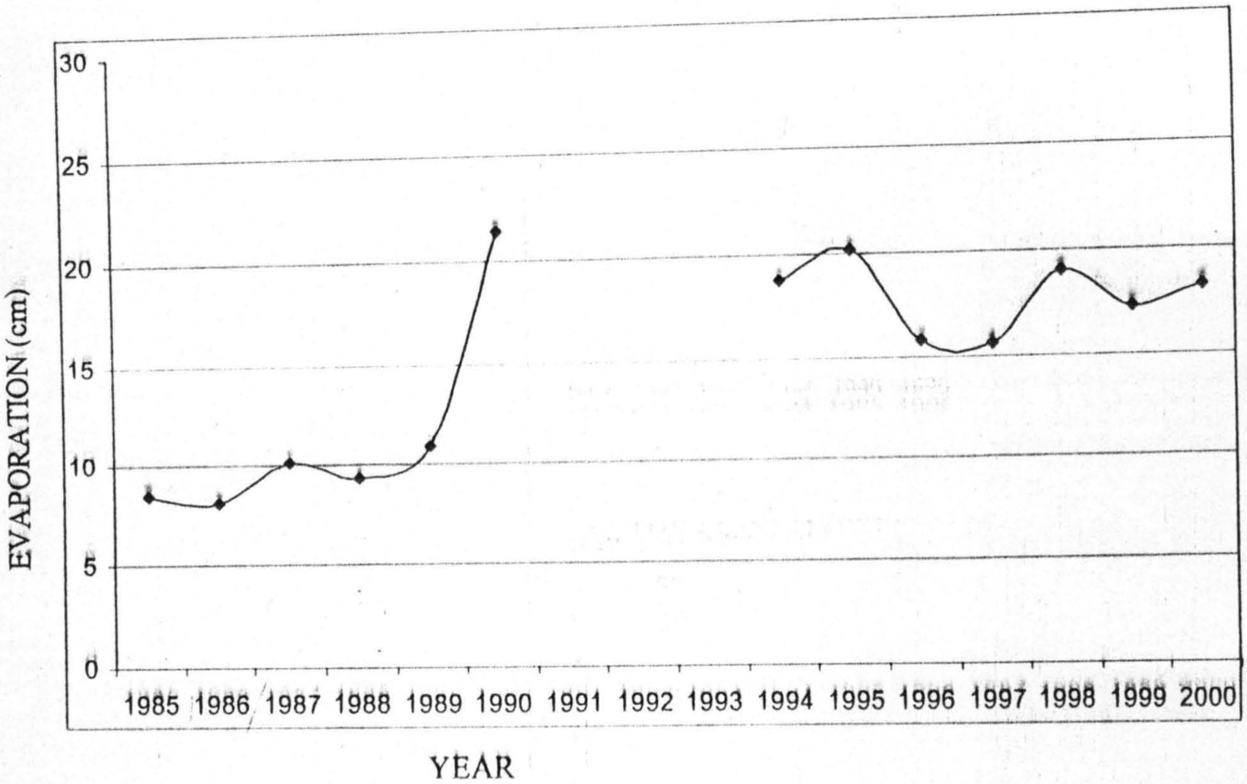


FIG. 4.3.1 EVAPORATION (cm) FOR THE MONTH OF JANUARY

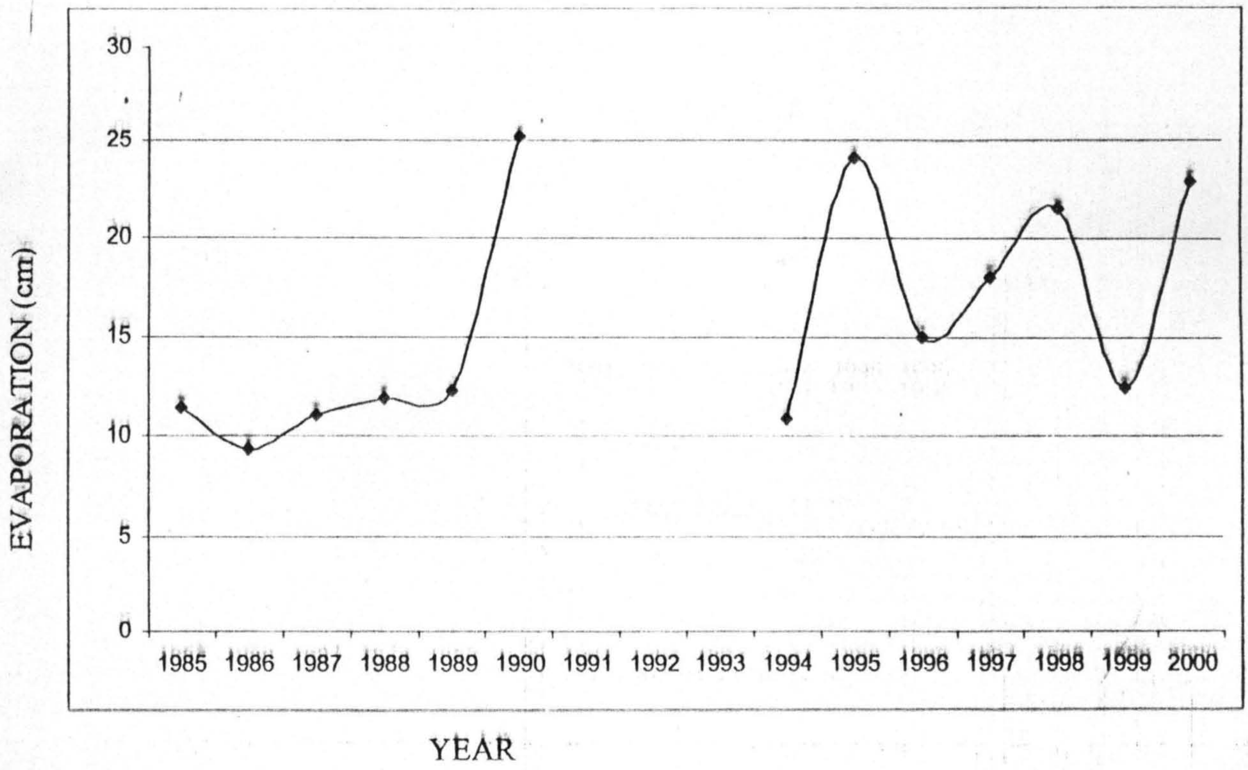


FIG. 4.3.2 EVAPORATION (cm) FOR THE MONTH OF FEBRUARY

(c) **March Months**

Highest evaporation- 25.6cm in 1990

Lowest evaporation- 8.11cm in 1996

The range of evaporation is between 25.6cm and 8.11cm within those period of years for March month period.

Trend of evaporation within the same period is as shown in figure 4.3.3.

(d) **April Months**

Highest evaporation- 16. 83 in 1995

Lowest evaporation- 6. 96 in 1994

This gives the range at which evaporation occurs within those years as of April month period. The trend of Evaporation for April months is as show in figure 4.3.4

(e). **May Months**

Highest Evaporation – 11.26cm in 1995

Lowest Evaporation – 5.9cm in 1997

The range of Evaporation occur within the above i.e 11.26 cm and 5.9 cm for the May Month period of those years. The trend of evaporation for May Month is as shown in figure 4. 3.5

(f) **June Months**

Highest Evaporation – 7.04cm in 1995.

Lowest Evaporation -------- 3.14cm in 1998

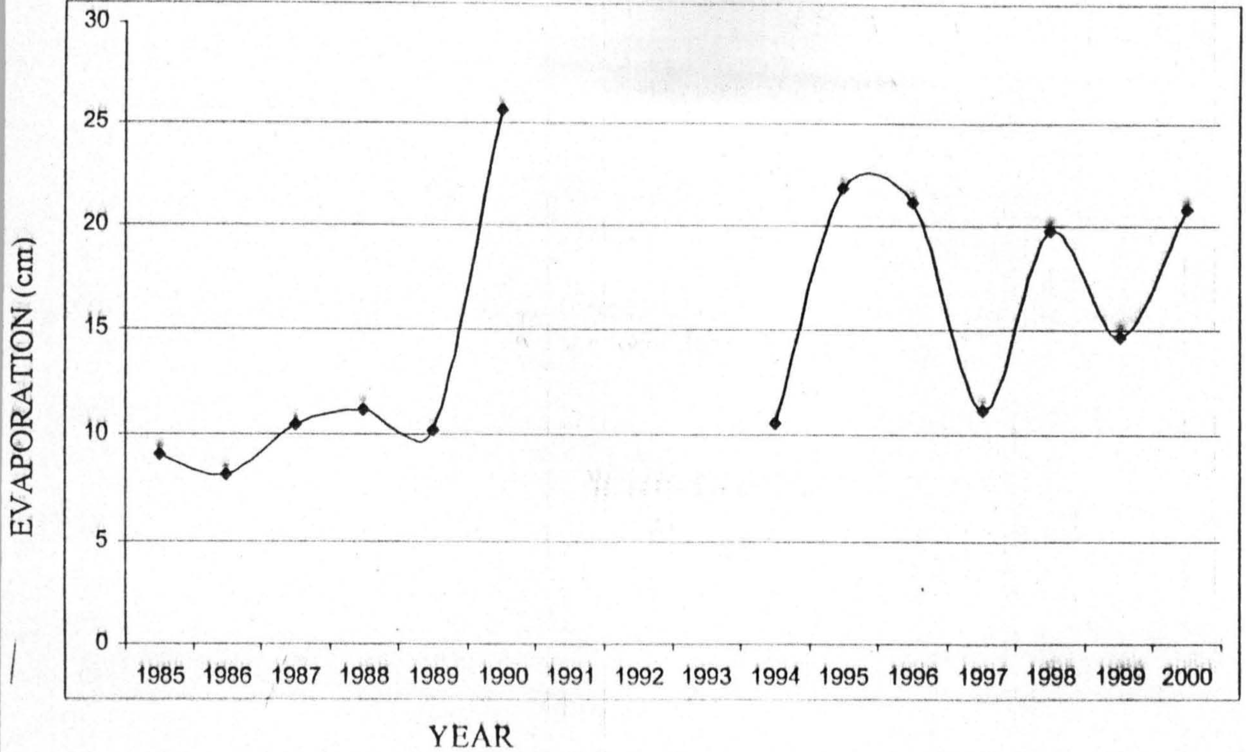


FIG. 4.3.3 EVAPORATION (cm) FOR THE MONTH OF MARCH

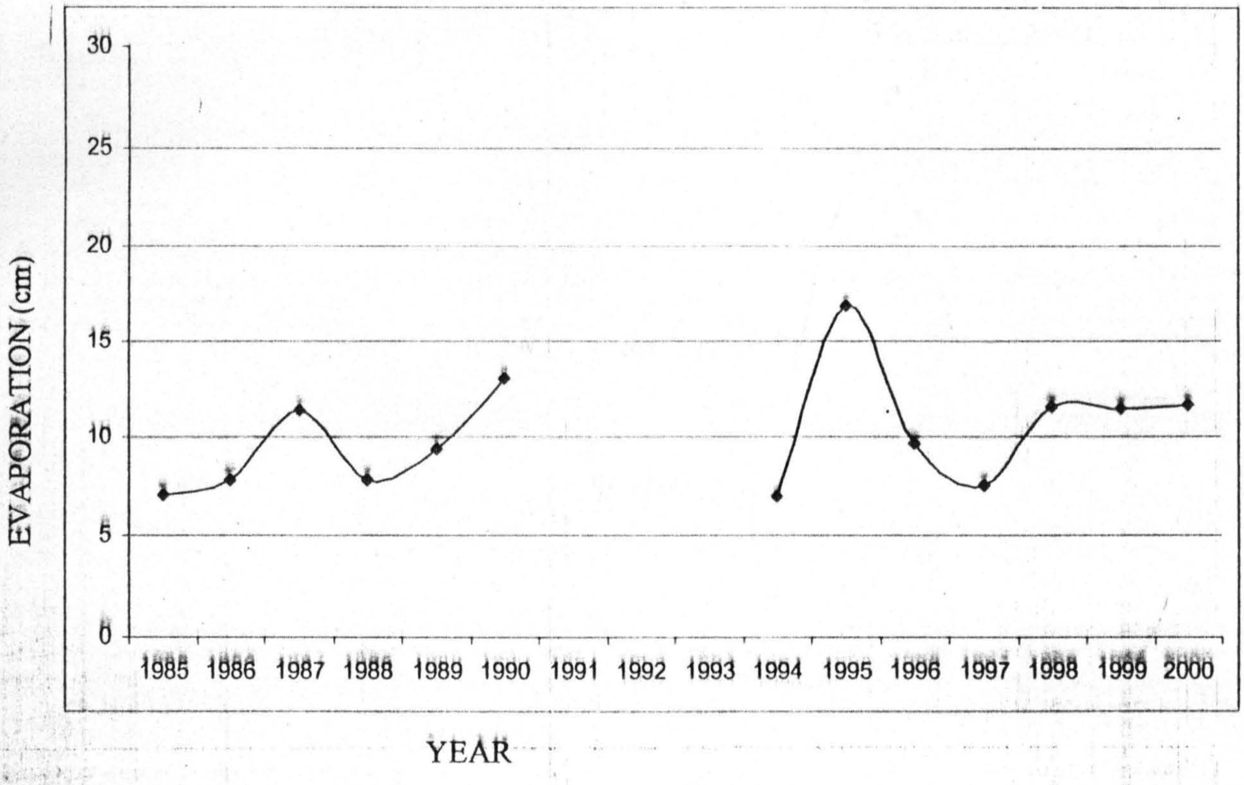
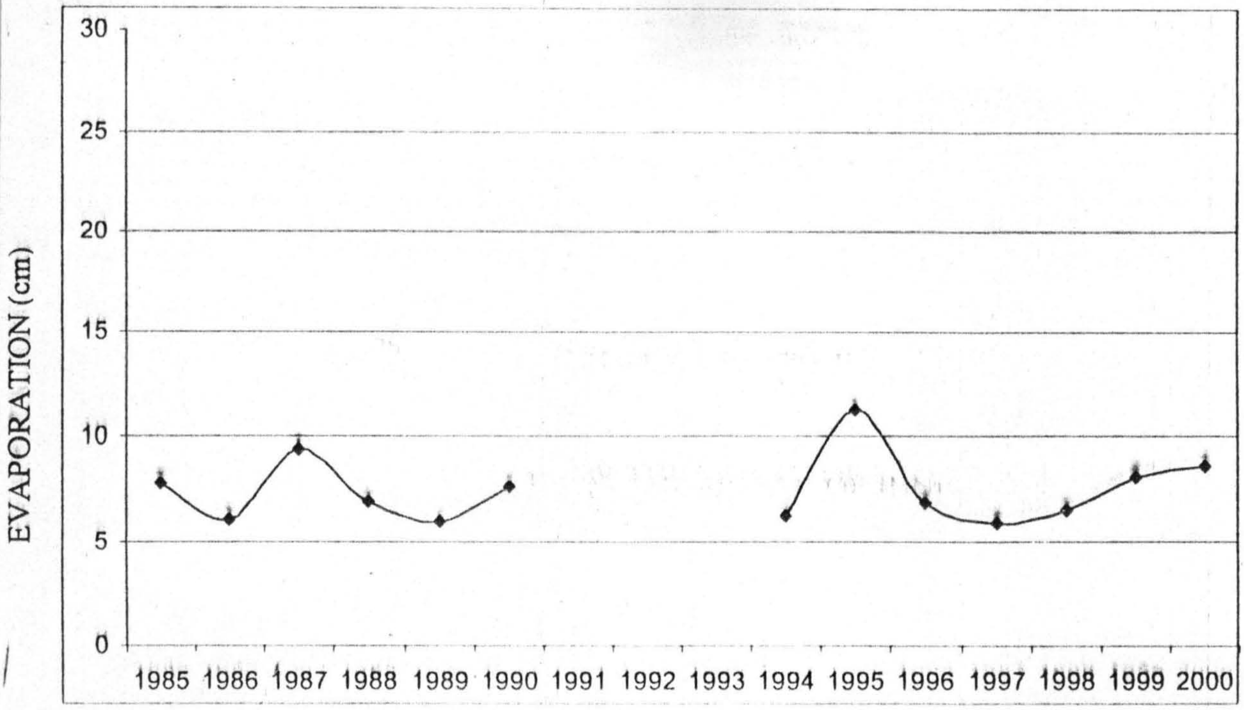
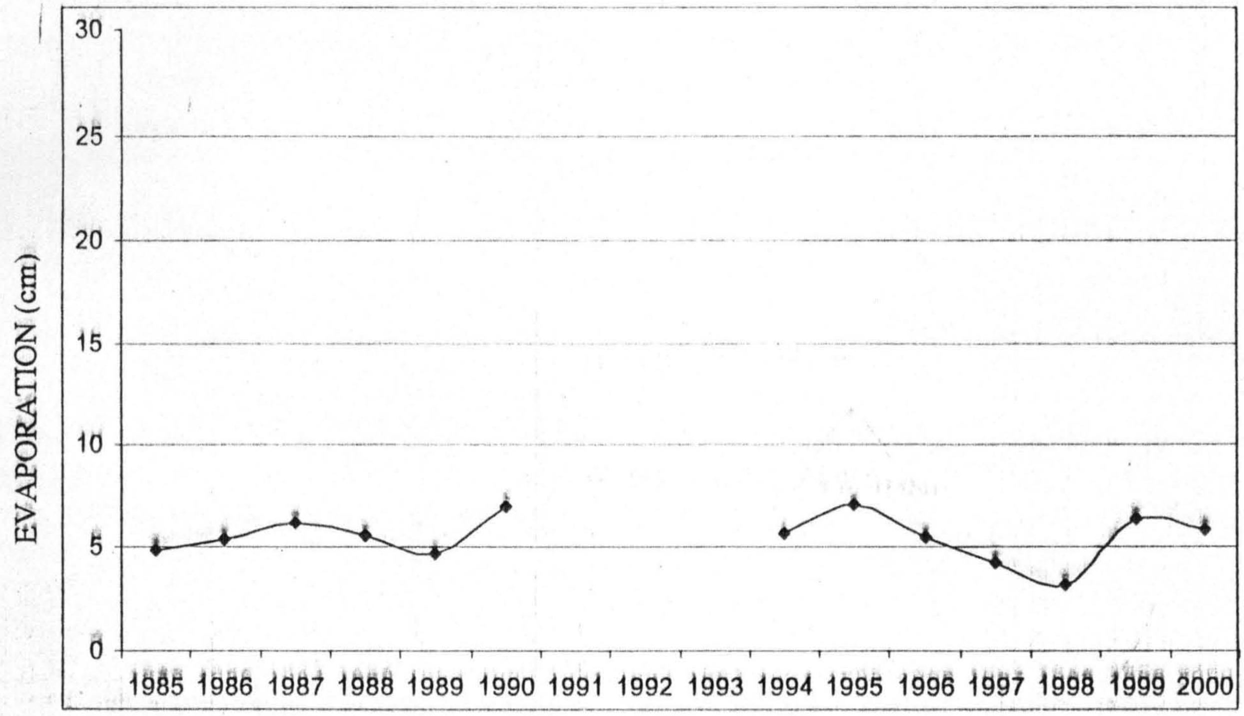


FIG. 4.3.4 EVAPORATION (cm) FOR THE MONTH OF APRIL



YEAR

FIG. 4.3.5 EVAPORATION (cm) FOR THE MONTH OF MAY



YEAR

FIG. 4.3.6 EVAPORATION (cm) FOR THE MONTH OF JUNE

This gives the range of Evaporation that occurs within May months of those years . The trends is as shown in figure 4.3.6.

(g). **July Months**

Highest Evaporation – 7.7cm in 1985

Lowest Evaporation – 3.94cm in 1998

The range of Evaporation is between 7.7cm and 3.9cm for July months of all the years. The trend is as shown in figure 4.3.7.

(h). **August Months.**

Highest Evaporation – 7.74cm in 1985

Lowest Evaporation – 4.06cm in 1999

The range at which Evaporation occurs is between this 7.74cm and 4.06cm for August months of all the years. The trend is as shown in figure 4.3.8.

(i) **September Months**

Highest Evaporation – 12.28cm in 1990

Lowest Evaporation – 4.98cm in 1987

The range at which Evaporation occurs is between this 12.28cm and 4,98cm for September period of all the years. The trend is as shown in figure 4.3.9.

(j). **October Months**

Highest Evaporation – 13.94cm in 1993

Lowest Evaporation – 5.19cm in 1986

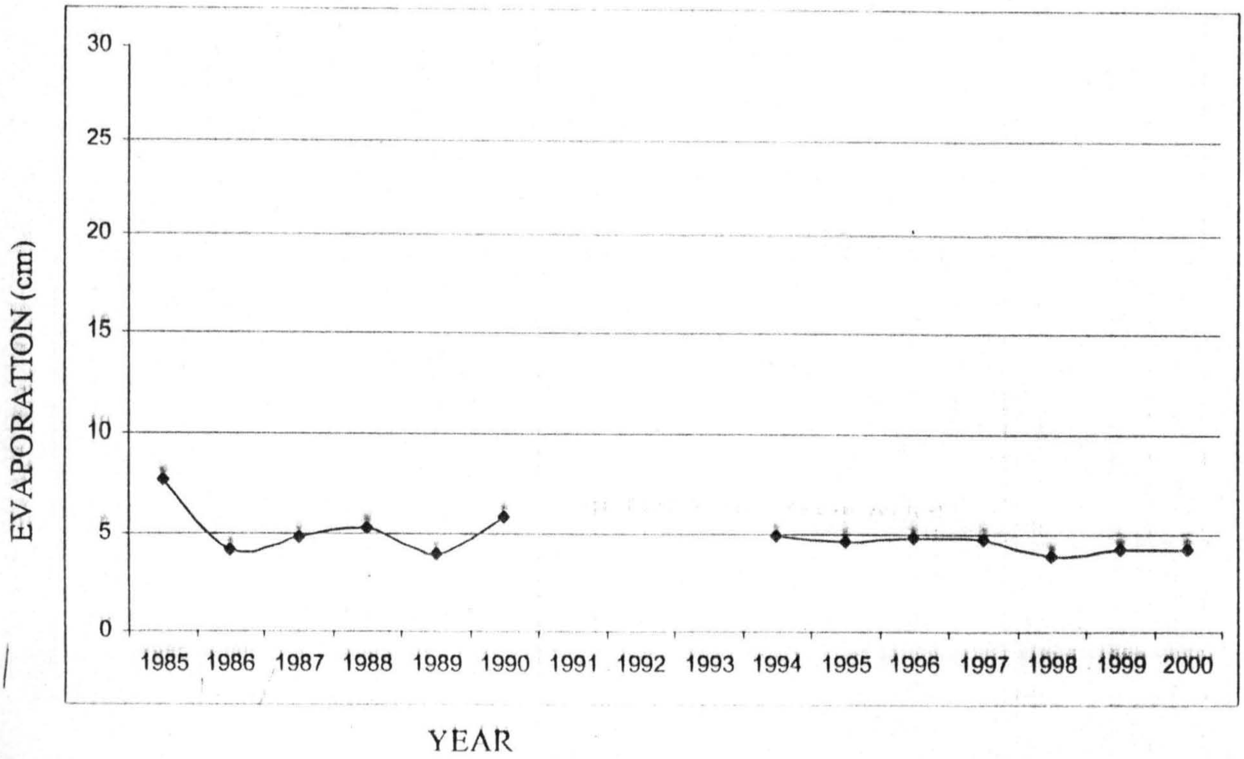


FIG. 4.3.7 EVAPORATION (cm) FOR THE MONTH OF JULY

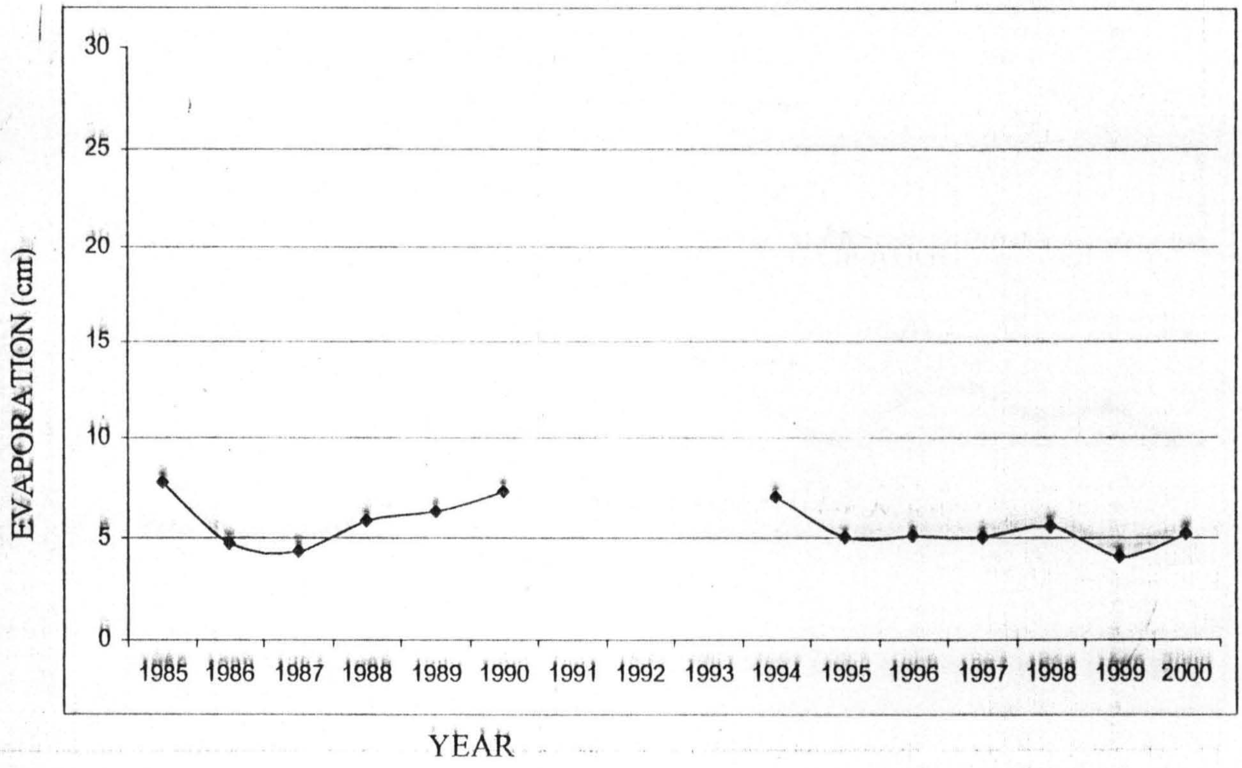


FIG. 4.3.8 EVAPORATION (cm) FOR THE MONTH OF AUGUST

The range at which Evaporation occurs is between the 13.94cm and 5.19cm for October months of all the years. The trend is as shown in figure 4.3.10.

(k). **November Months**

Highest Evaporation

Lowest Evaporation

The range of Evaporation occurs between 19.12cm and 6.12cm for November months of all the years. The trend is as shown in figure 4.3.11.

(l). **December Months**

Highest Evaporation – 24.41cm in 1994

Lowest Evaporation – 8.5cm in 1988

The range at which Evaporation occurs is between 24.41cm and 8.5cm for December period of all the year. The trend is as shown in figure 4.3.12.

4.4 SEEPAGE

Thus, faced with missing data of 1998 and 1999 as can be seen in Table 4.4, this discussion is based strictly on the available data.

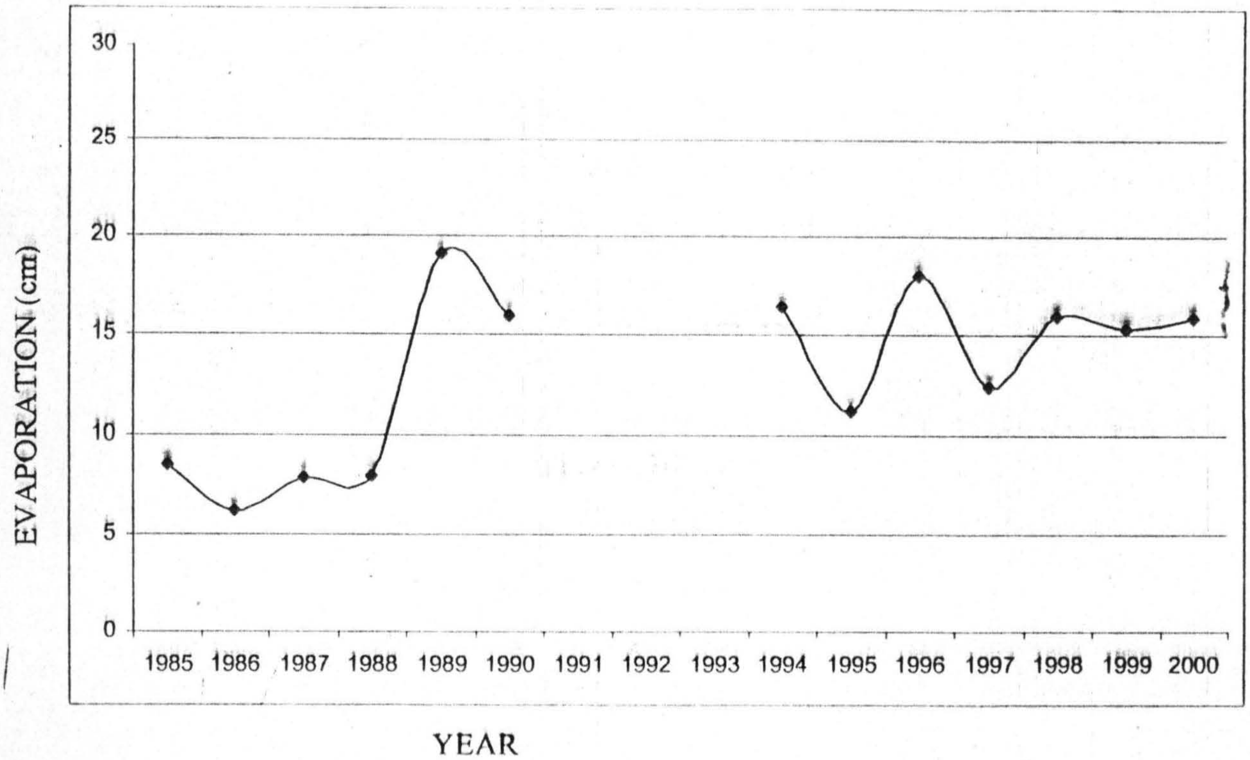


FIG. 4.3.11 EVAPORATION (cm) FOR THE MONTH OF NOVEMBER

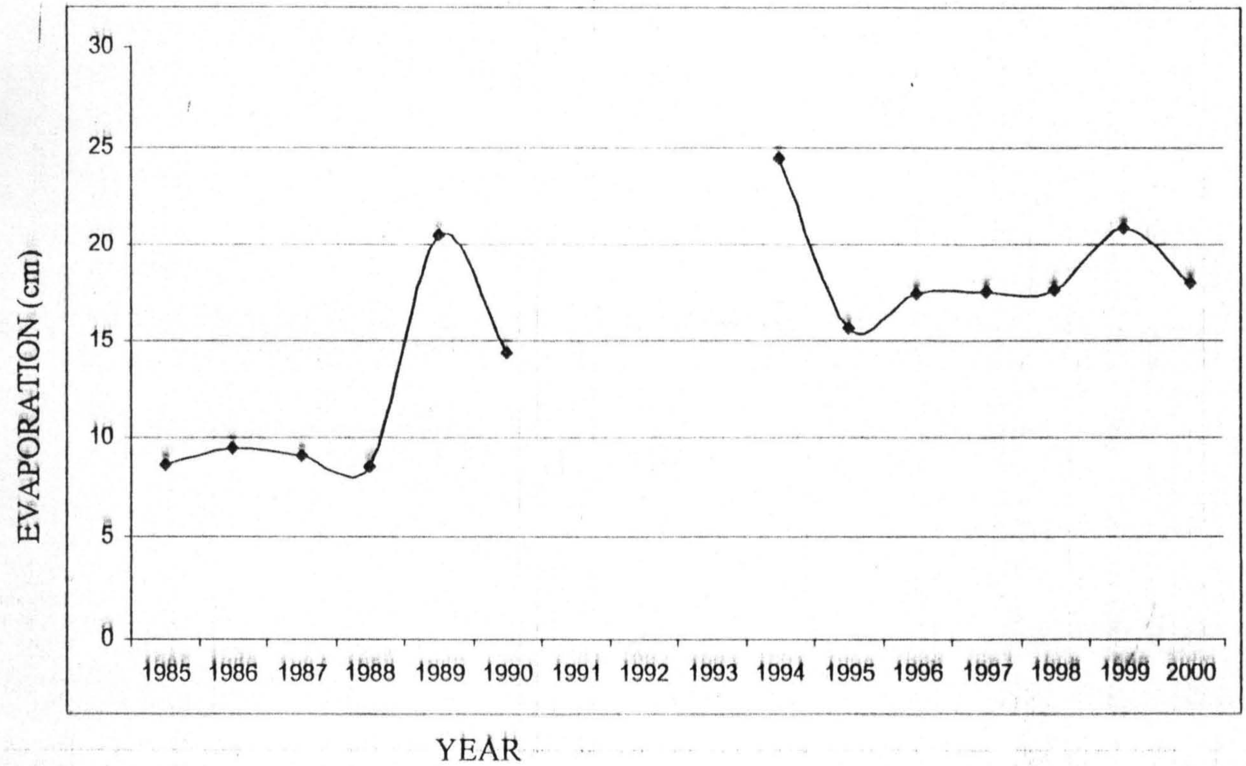


FIG. 4.3.12 EVAPORATION (cm) FOR THE MONTH OF DECEMBER

TABLE 4.3 AVERAGE MONTHLY SEEPAGE (m^3/s X 10^{-5})

	YEARS									
MONTH	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
JAN	1.9	1.6	1.46	1.66			1.71	1.56	1.45	1.52
FEB	1.99	1.6	1.45	1.54			1.62	1.53	1.4	1.48
MAR	1.95	1.6	1.45	1.46			1.45	1.46	1.38	1.45
APR	1.9	1.59	1.45	1.44			1.46	1.29	1.25	1.43
MAY	1.8	1.56	1.4	1.25			1.25	1.22	1.23	1.27
JUN	1.4	1.51	1.4	1.25			1.22	1.21	1.23	1.23
JUL	1.35	1.33	1.4	1.24			1.25	1.21	1.21	1.34
AUG	1.35	1.33	1.4	1.25			1.23	1.38	1.47	1.32
SEPT	1.516	1.38	1.53	1.43			1.43	1.49	1.56	1.49
OCT	1.66	1.49	1.56	1.64			1.61	1.42	1.56	1.49
NOV	1.67	1.56	1.65	1.65			1.56	1.58	1.56	1.49
DEC	1.66	1.56	1.66	1.56			1.56	1.52	1.56	1.49
AVERAGE	1.68	1.51	1.48	1.45			1.45	1.41	1.41	1.42

4.4.1 Yearly Seepage Analysis

The trend of seepage is as shown in figure 4.4. The highest seepage experienced for those numbers of years is $1.9m^3/s \times 10^{-5}$ in 1994, while the lowest is $1.45m^3/s \times 10^{-5}$ in 2002.

4.4.2 MONTHLY SEEPAGE

From figure 4.4.1 and figure 4.4.2, the monthly seepage analysis can be discussed as follows:

(a). **January Months**.

Highest seepage – 1.9 in 1994 as in figure 4.4.1

Lowest seepage – 1.45 in 2002 as in 2002 in figure 4.4.2

The range rating of seepage occurring in January month for the years (8 years as is between 1.9 and 1.45 $(m^3/s) \times 10^{-5}$. The trend is as shown in the both figure for those years.

(b). February months.

Highest seepage – $1.99(m^3/s) \times 10^{-5}$ in 1994 as in figure 4.4.1

Lowest seepage – $1.4(m^3/s) \times 10^{-5}$ in 2002 as in figure 4.4.2

The range at which seepage rating occur in the month of February is between 1.99 and 1.4 $(m^3/s) \times 10^{-5}$. The trend is as shown in figure 4.4.1 and 4.4.2 respectively.

(c). **March Months**

Highest seepage rate - 1.95 in 1994 as in figure 4.4.1

Lowest seepage rate- 1.38 in 2002 as in figure 4.4.2

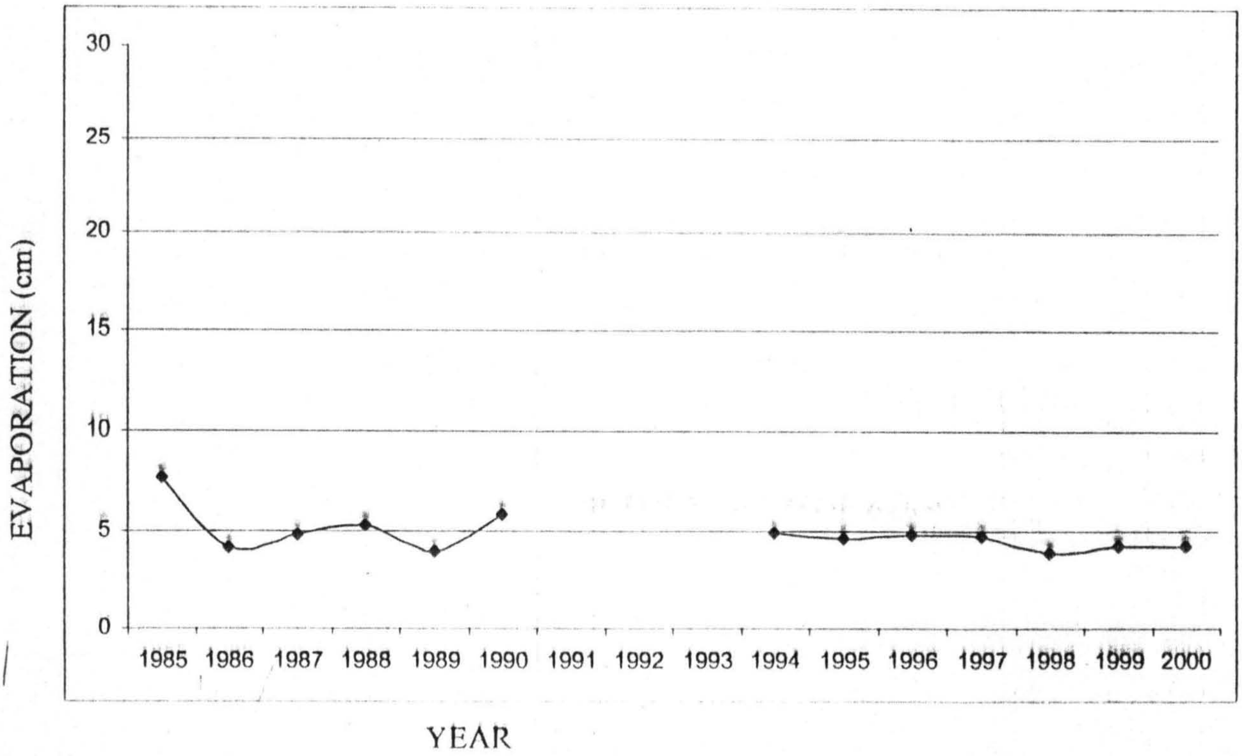


FIG. 4.3.7 EVAPORATION (cm) FOR THE MONTH OF JULY

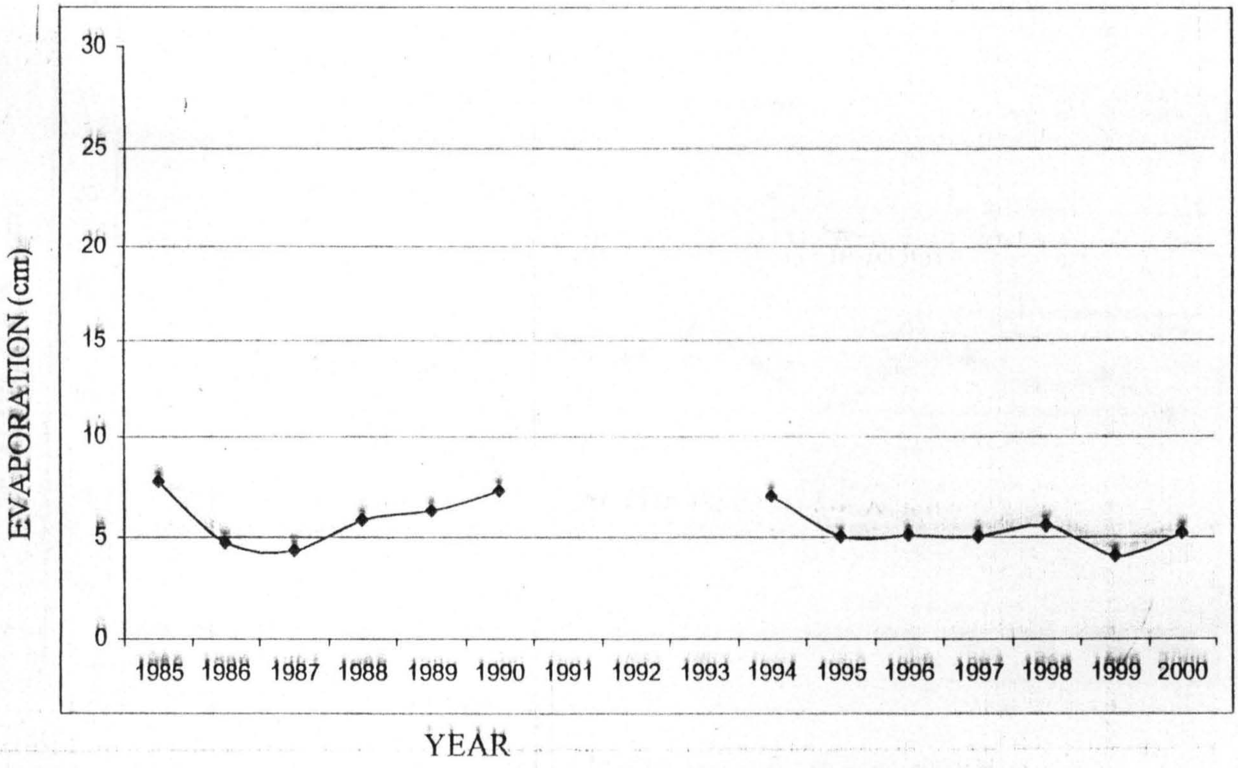


FIG. 4.3.8 EVAPORATION (cm) FOR THE MONTH OF AUGUST

The range of seepage occurring in the month of March is between 1.95m3x15^5. The trend is as shown in figure 4.4.1 and 4.42. In year 2001, 2003, 2000 and 1996 almost experienced the same seepage rating.

(d). **April months.**

Highest seepage rate- 1.9m^3/s x 10^{-5} in 1994 as in figure 4.4.1

Lowest Seepage rate – 1.9m^3/s x 10^{-5} in 2002 as in figure 4.4.2

The range of seepage occurring in the mouth of April is between 1.9 and 1.25 (m^3/s x 10^{-5}). The trend as shown in figures 4.4.1 and 4.4.2 respectively for all the years concerned.

(e). **May months.**

Highest seepage rate – 1.8 m^3/s x 10^{-5} in 1994 as in figure 4.4.1

Lowest seepage rate – 1.22 m^3/s x 10^{-5} in 2001

The range of seepage occurring in the month of May is between 1.8 and 1.22 (m^3/s x 10^{-5}). The trend is as shown in figure in figure 4.4.1 and 4.4.2.

(f). **June Months.**

Highest seepage rate 1.51 m^3/s x 10^{-5} in 1995 as in figure 4.4.1

Lowest seepage rate – 1.21 $m^3/s \times 10^{-5}$ in 2001 as in figure 4.4.2

The range of seepage occurring in the month of June is between 1.51 and 1.21 ($m^3/s \times 10^{-5}$). The trend is as shown in figure 4.4.1 and 4.4.2 respectively. Also by 2000 – 2003 the seepage rating almost be the same from May and June period.

(g). **July months.**

Highest seepage – 1.4 $m^3/s \times 10^{-5}$ in 1996 as in figure 4.4.1

Lowest seepage – 1.21 $m^3/s \times 10^{-5}$ in 2001 and 2003 as in fig. 4.4.2

The range of seepage occurring in the mouth of July is between 1.4 and 1.21 ($m^3/s x 10^{-5}$). The trend of seepage is as shown in figures 4.4.1 and 4.4.2.

(h). **August months.**

Highest seepage --- 1.47$m^3/s x 10$-5

Lowest seepage – 1.23 $m^3/s \times 10^{-5}$ in 2000 as in fig. 4.4.2

The range of seepage occurring within these month is between 1.47 and 1.23 ($m^3/s \times 10^{-5}$). The trend is as shown in figure 4.4.1 and 4.4.2.

(i). **September Months.**

Highest seepage – 1.56 $m^3/s \times 10^{-5}$ in 2002 as in figure 4.4.2

Lowest seepage – 1.38 $m^3/s \times 10^{-5}$ in 1995 as in fig. 4.4.1

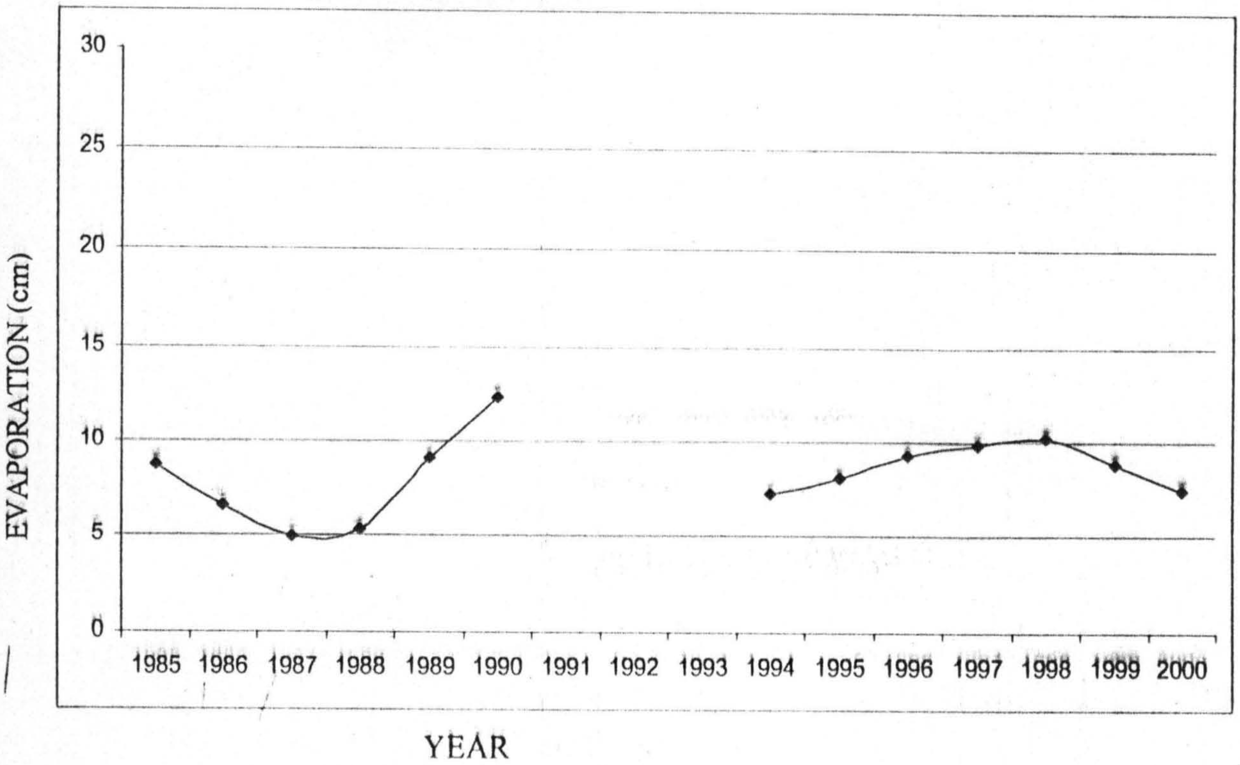


FIG. 4.3.9 EVAPORATION (cm) FOR THE MONTH OF SEPTEMBER

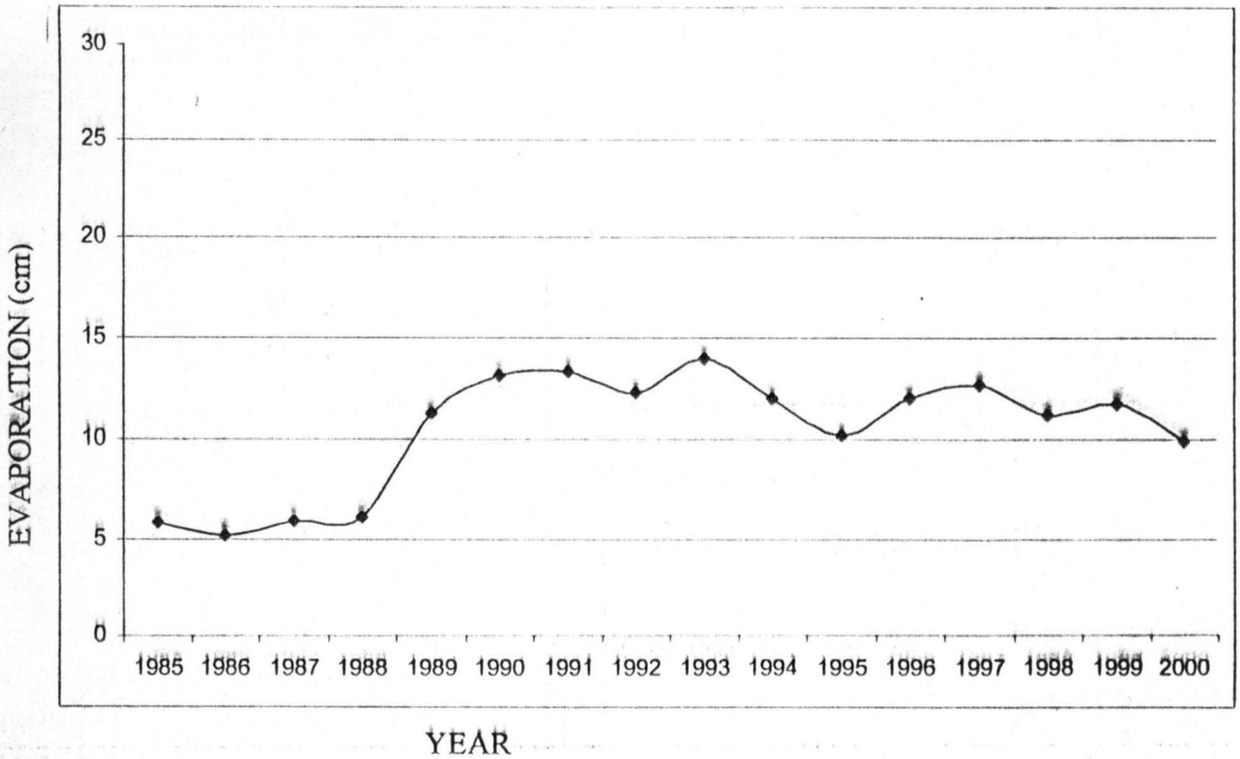


FIG. 4.3.10 EVAPORATION (cm) FOR THE MONTH OF OCTOBER

The range of seepage for the month (Sept.) is 1.56 and 1.38 ($m^3/s \times 10^{-5}$). The trend is as shown in fig. 4.4.1 and 4.4.2.

(j). **October Months.**

Highest seepage – 1.66 $m^3/s \times 10^{-5}$ in 1994 as in fig. 4.4.1

Lowest seepage – 1.42 $m^3/s \times 10^{-5}$ in 2001 as in figure 4.4.2

The range of seepage for the month (Oct.) is between 1.66 and 1.42 ($m^3/s \times 10^{-5}$). The trend is as shown in figure 4.4.1 and 4.4.2 respectively.

(k). **November Months.**

Highest seepage – 1.67 $m^3/s \times 10^{-5}$ in 1994 as in fig. 4.4.1

Lowest seepage – 1.49 $m^3/s \times 10^{-5}$ in 2003 as in fig. 4.4.2

The range of seepage for these month is between 1.67 and 1.49 ($m^3/s \times 10^{-5}$). The trend is as shown in figure 4.4.1 and 4.4.2 respectively.

(l) **December Months**

Highest seepage – 1.68 $m^3/s \times 10^{-5}$ in 1994 as in fig. 4.4.1

Lowest seepage – 1.41 $m^3/s \times 10^{-5}$ in 2001 and 2002 as in fig. 4.4.2

The range of seepage for the month of December is between 1.68 and 1.41 ($m^3/s \times 10^{-5}$). The trend is as shown in figure 4.4.1 and 4.4.2

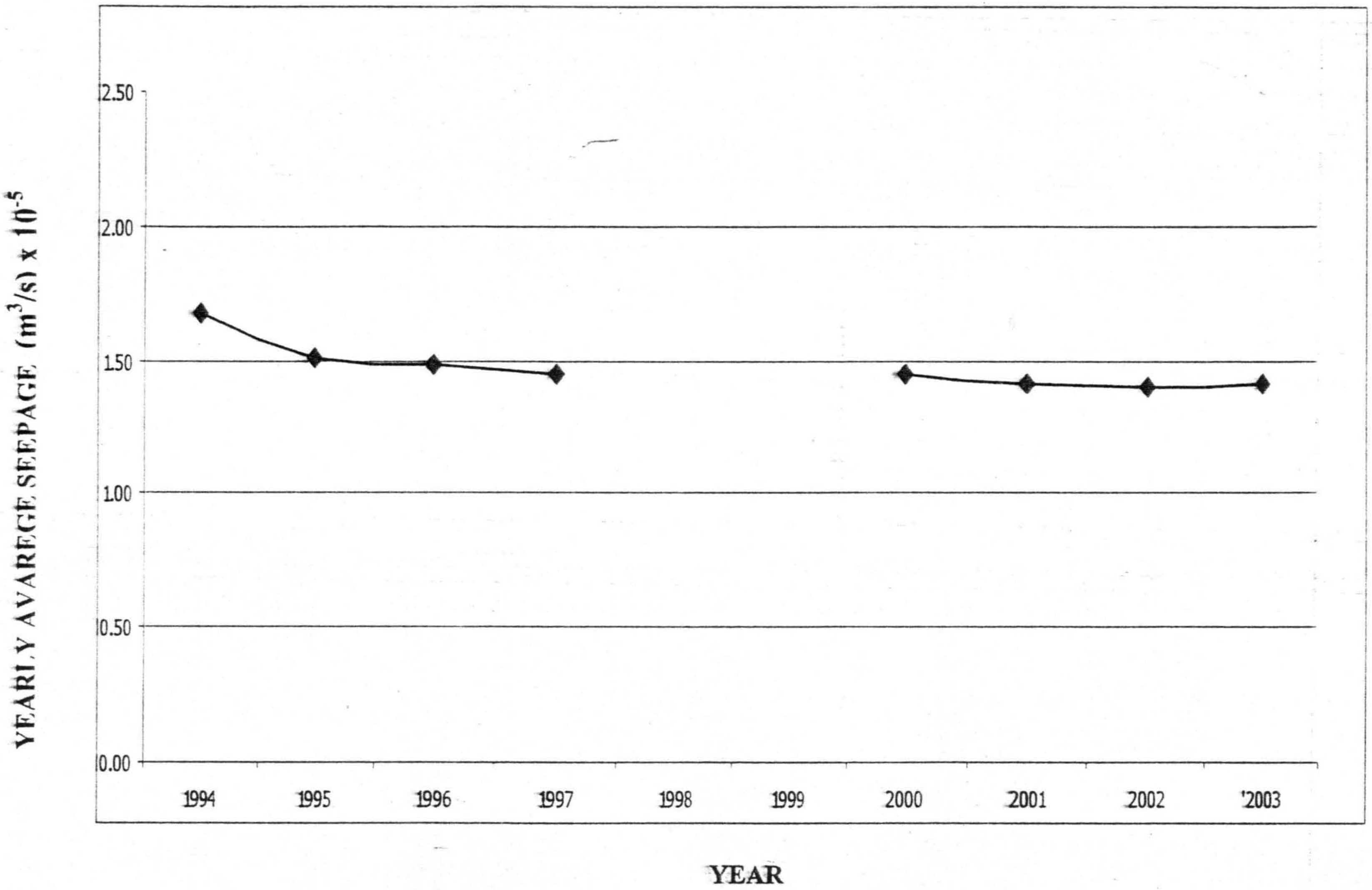


FIG. 4.4 YEARLY SEEPAGE (m^3/s) x 10^{-5}

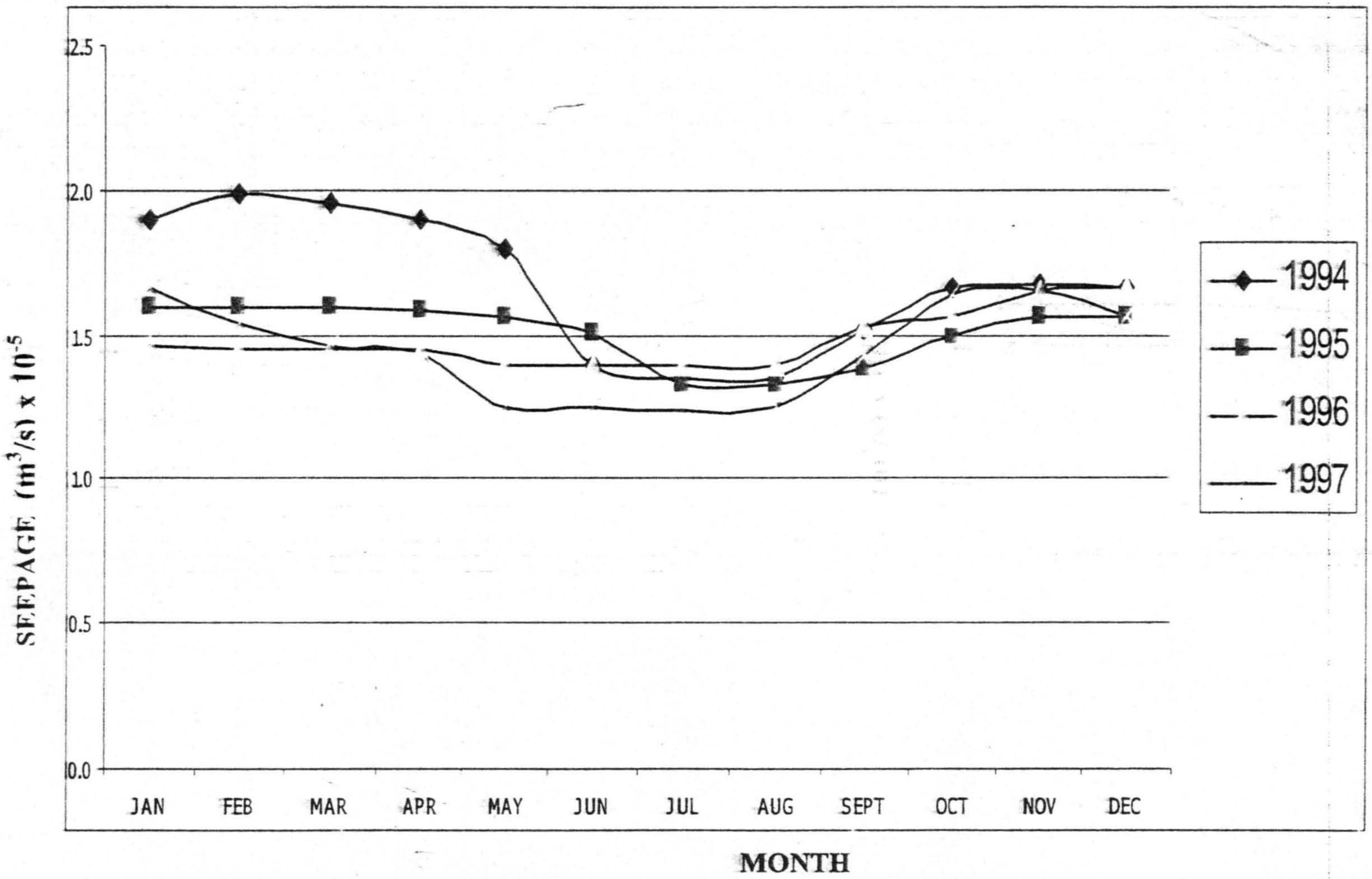
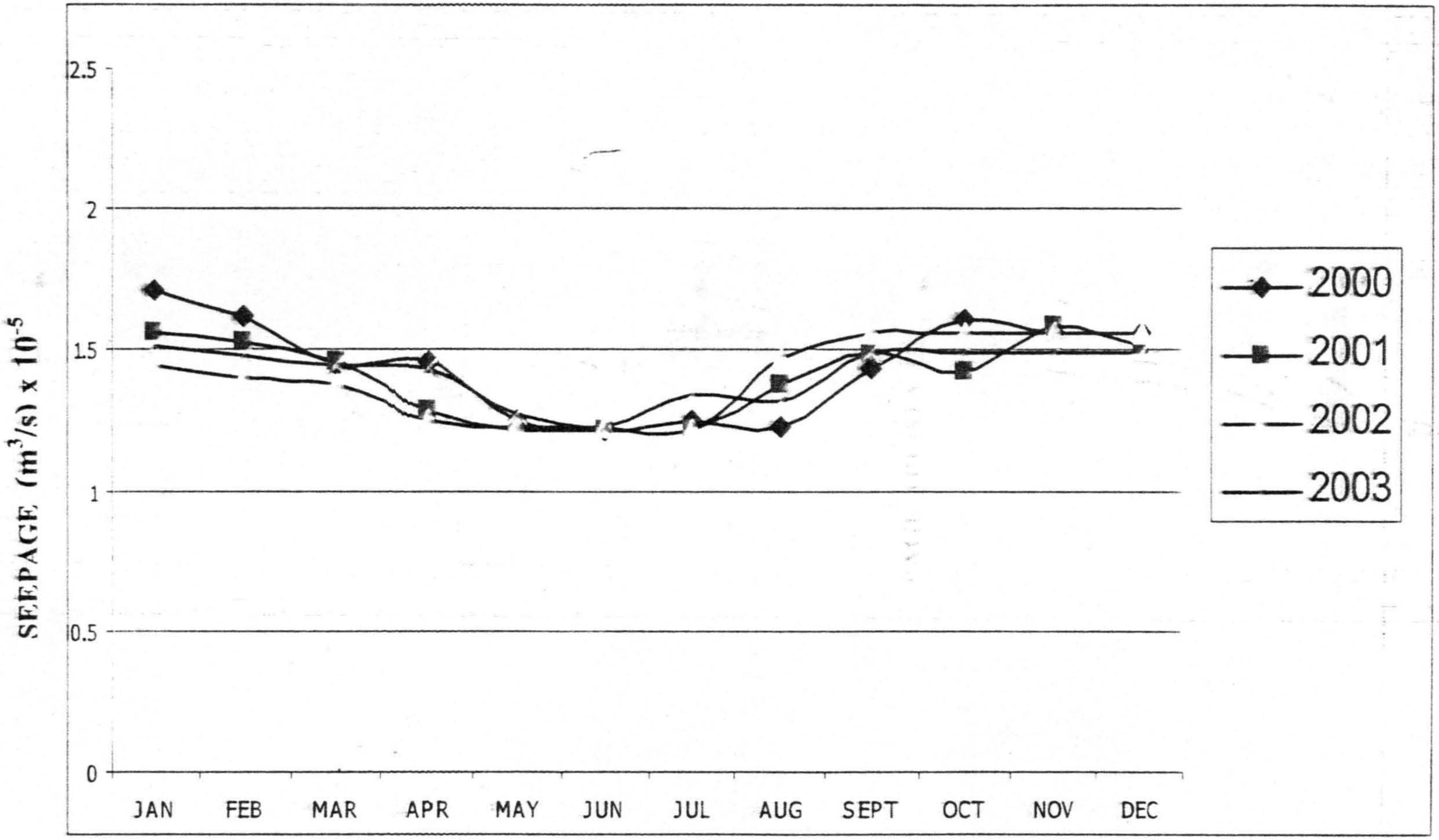


FIG. 4.4.1 MONTHLY SEEPAGE (m^3/s) X 10^{-5}



MONTH

FIG. 4.4.2 MONTHLY SEEPAGE (m^3/s) X 10^{-5}

The general trend of seepage right from January 1994 to 2003 is that the seepage time have been from the highest to the lowest and that their line of action have being crossing each other.

4.5 RESERVOIR ELEVATION (Note, the ground surface Elevation (EL) is 312)

From Figure 4.5, 1998 and 1999 data are missing as can be seen in Table 4.4. The analysis is also strictly based on the available data.

4.5.1 Yearly Reservoir Elevation

From figure 4.5 the lowest Elevation is 368m in 1994 and the highest elevation is 374 in 1995. The range of elevation within the available years is within 368m and 374m. The trend is as shown in the same figure 4.5.

Relating Elevation to seepage, the higher the seepage the lower is the elevation neglecting rainfall as this analysis has physically seen in figure 4.4 and figure 4.5 i.e. 1994 experience a higher seepage rate while 1994 reservoir elevation dropped lower.

4.5.2 Monthly Reservoir Elevation.

(a). **January Months**

Between 1994 to 2003, the January period experienced the highest Elevation of 382 in 1995 and the lowest of 359m in 1996. The range of Reservoir Elevation within this period of available data is 382 and 359(m). The trend is as shown in figure 4.5.1 and 4.5.2 respectively.

(b). **February Months**.

Similarly, Highest Reservoir Elevation – 379m in 1995

Lowest Reservoir Elevation – 368m in 2002

The Range as of this period (Feb) for those years – 379 and 368(m)

Trend is as shown in figure 4.5.1 and 4.5.2

(c). **March Months**.

Also, Highest Reservoir Elevation – 378m in 1995

Lowest Reservoir Elevation – 366m in 1997 and 2002

The Range as of this period (March) for those years – 378 and 366(m).

The trend is as shown in figure 4.5.1 and 4.5.2

(d). **April Months**.

The highest Reservoir Elevation – 375m in 1995

Lowest Reservoir elevation – 352m in 2002

Range for the month – 375 and 352(m)

The trend is shown in figure 4.5.1 and 4.5.2

(e). **May Months**

Highest Reservoir Elevation – 372m in 1995

Lowest Reservoir Elevation – 329m in 1994

range for the month – 372 and 229(m)

The trend is as shown in figure 4.5.1 and 4.5.2. The Elevation drastically comes down due to the effect of low pattern of rainfall experienced in 1993, 1994 and 1995 as shown in figure 4.2.3; their was evaporation too as shown in figure 4.3.5, coupled with seepage within the same month of that year 1994.

(f). **June Months**

Highest Reservoir Elevation – 366m in 1995.

Lowest Reservoir Elevation – 360 in 1994, 1997 and 2003.

Range for the month – 366 and 360 (m).

Trend of action is as shown in figure 4.5.1 and 4.5.2.

(g). **July Months.**

Highest Reservoir Elevation – 364m in 1996

Lowest Reservoir Elevation – 360 in 1994

Range for the month – 364 and 360(m)

The trend is as shown in figure 4.5.1 and 4.5.2. Thus, the Elevation stand very closely to each other as of this month for those years.

(h). **August Months**

Highest Reservoir Elevation – 371m in 2002

Lowest Reservoir Elevation – 360m in 1994

Range for the month – 371 and 360(m) within the years. Trend of action is as shown in figure 4.5.1 and 4.5.2. The Elevation starts rising as of this month due to increase in rainfall as shown in figure 4.2.5, 4.2.6 and 4.2.7.

(i). **September Months.**

Highest Reservoir Elevation – 381m in 2003

Lowest Reservoir Elevation – 373 in 1995

Range for the month – 381 and 373(m)

Trend of action is as shown in figure 4.5.1 and 4.5.2. The Elevation also increased as a result of high rainfall fig. 4.2.7 less evaporation figure 4.3.9 plus less seepage figure 4.4.1 and 4.4.2.

(j). **October Months.**

Highest Reservoir Elevation – 382m in 1994, 1996, 1997, 2000, 2001 and 2003.

Lowest Reservoir Elevation – 378m in 1995

Ranges for the month –

Trend is as shown in figure 4.5.1 and 4.5.2. The reservoir elevation is still high as reservoir elevation is still high as result of high rainfall less seepage, less evaporation and probably less other climatic condition e.g. Relative humidity and temperature e.t.c.

(k). **November Months.**

Highest Reservoir Elevation – 382m in 1994 and 1997

Lowest Reservoir Elevation – 378m in 1995

Range for the month 387 and 378(m).

TABLE 4.4 MONTHLY AVERAGE RESERVOIR ELEVATION (m)

	YEARS									
MONTH	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
JAN	378	382	359	376			378	376	370	374
FEB	374	379	371	371			375	372	368	372
MAR	370	378	369	366			372	368	366	368
APR	365	375	365	363			369	365	352	363
MAY	329	372	363	361			365	363	363	360
JUN	360	366	363	360			363	362	361	360
JUL	360	361	364	361			362	362	362	363
AUG	360	364	369	367			367	369	371	369
SEPT	374	373	377	377			378	377	376	381
OCT	382	378	382	382			382	382	381	382
NOV	382	378	381	382			381	379	380	381
DEC	381	376	379	380			379	377	379	379
AVERAGE	368	374	370	371			373	371	369	370

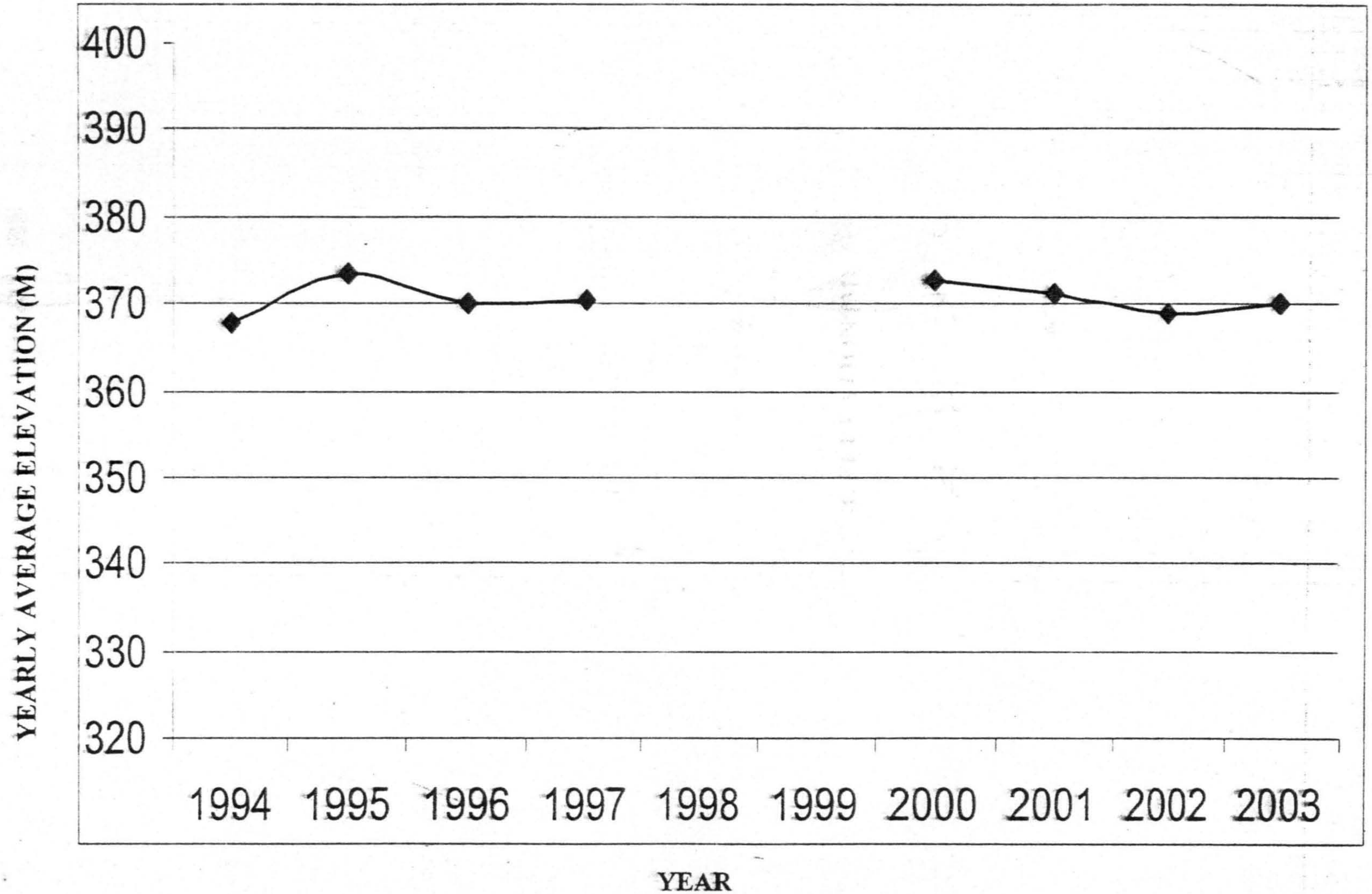


FIG. 4.5 YEARLY RESERVOIR ELEVATION (m)

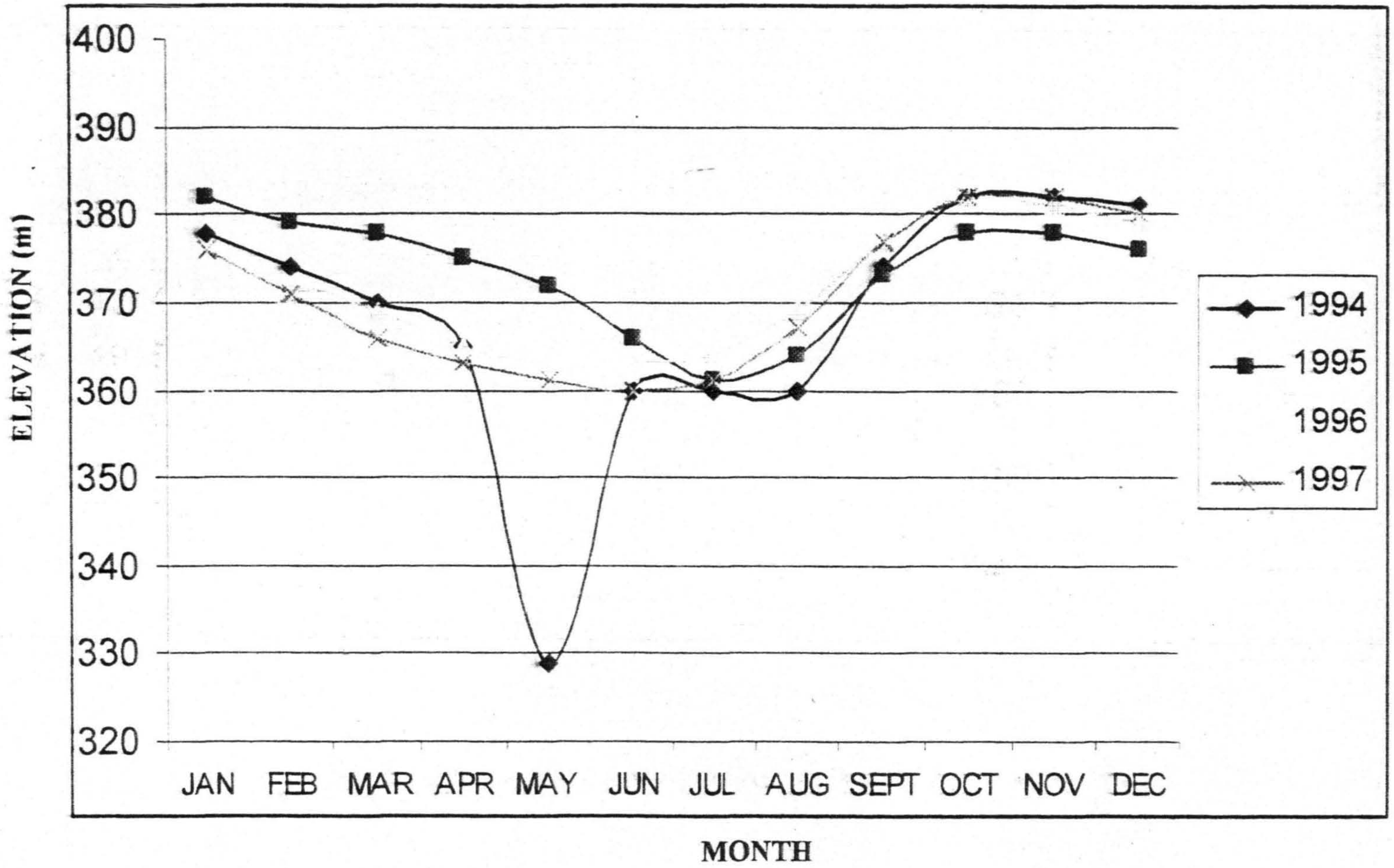


FIG. 4.5.1 MONTHLY ELEVATION (m)

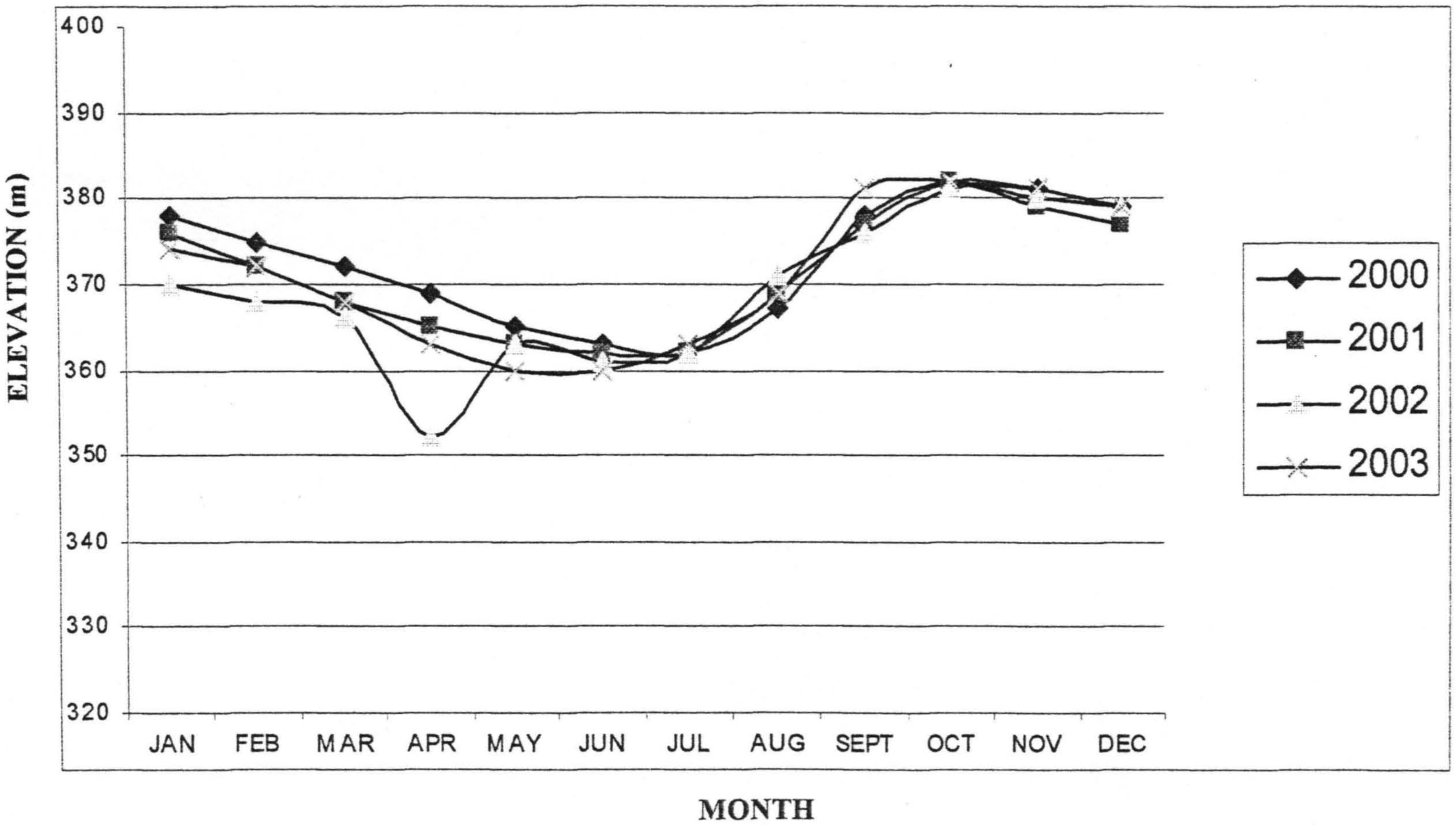


FIG. 4.5.2 MONTHLY ELEVATION (m)

Thus the elevation still maintain its level but it start dropping within some of the years e.g. 1996 with one meter, 2001 with 3m e.t.c. This is as a result of lack of rainfall, Evaporation and figure 4.3.1 seepage 4.4.1 and 4.4.2 still takes place e.t.c.

The trend is as shown in figure 4.5.1 and 4.5.2.

(l). **December Months.**

Highest Reservoir Elevation – 381m in 1994

Lowest Reservoir Elevation – 376m in 1995

Range for the month (Dec.) – 381 and 376(m)

No rainfall as of this month but the elevation level is still fairly maintained thus there is reduction as other condition still prevailed e.g. seepage figure 4.4.1 and 4.4.2 and evaporation figure 4.3.12.

The trend of action is as shown in fig. 4.5.1 and 4.5.2

4.6 RESERVOIR CAPACITY

The missing data for 1998 and 1999 as seen in Table 4.5 still affect this analysis. Thus, the discussion is still strictly based on the available data.

4.6.1 Yearly Reservoir Capacity.

From figure 4.6, the lowest reservoir capacity is 3.1 $m^3 \times 10^9$ in 1996 and 2002 respectively. While the highest is 3.8 $m^3 \times 10^9$ also in 1995 and 2000 respectively. Therefore the range of Reservoir capacity within those years is 3.8 and 3.1 ($m^3 \times 10^9$)/

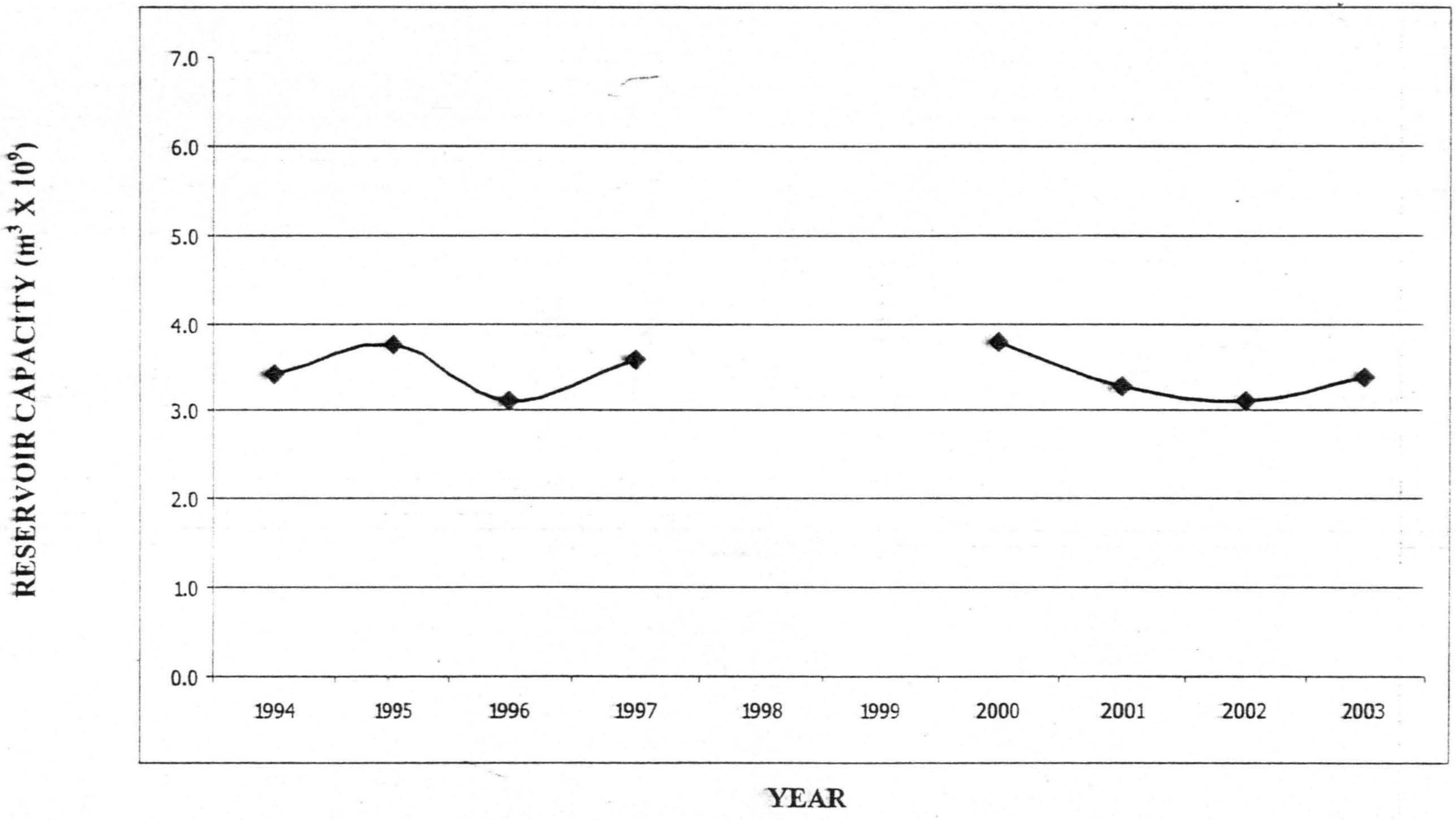


FIG. 4.6 YEARLY RESERVOIR CAPACITY (m^3 x 10^{-5})

TABLE 4.5 AVERAGE MONTHLY RESERVOIR CAPACITY (m^3 X 10^9)

	YEARS									
MONTH	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
JAN	4.6	5.12	3.79	4.12			4.59	4.12	3.11	3.85
FEB	3.84	4.83	3.29	3.21			4.08	3.44	2.67	3.34
MAR	3	4.54	2.79	2.38			3.49	2.77	2.31	2.6
APR	2.13	4.06	2.26	1.87			2.85	2.15	2.06	1.85
MAY	1.59	3.37	1.84	1.68			2.15	1.84	1.84	1.52
JUN	1.51	2.42	1.87	1.46			1.82	1.49	1.68	1.52
JUL	1.63	1.62	2.05	1.64			1.71	1.8	1.82	1.61
AUG	2.05	2.05	2.05	5.83			2.55	2.77	2.83	2.95
SEPT	3.92	3.58	2.76	4.4			6.32	4.53	4.22	5.35
OCT	5.69	4.65	4.52	5.68			5.71	5.55	5.3	5.9
NOV	5.72	4.67	5.48	5.58			5.44	4.96	5.04	5.36
DEC	5.42	4.28	4.82	4.99			4.84	3.9	4.43	4.82
AVERAGE	3.4	3.8	3.1	3.6			3.8	3.3	3.1	3.4

4.6.2 Monthly Reservoir Capacity ($m^3 \times 10^9$)

(a). **January Months.**

Highest Reservoir Capacity – 5.12 in 1995

Lowest Reservoir Capacity – 3.11 in 2002

Range for the month 5.12 and 3.11 ($m^3 \times 10^9$)

The trend is as shown in figure 4.6.1 and 4.6.2

(b). **February Months.**

Highest Reservoir Capacity – 4.83 $m^3 \times 10^9$ in 1995

Lowest Reservoir Capacity – 3.21 $m^3 \times 10^9$ in 1997

Range for February month 4.83 and 3.21 ($m^3 \times 10^9$)

The trend is as shown in figure 4.6.1 and 4.6.2.

(c). **March Months.**

Highest Reservoir Capacity – 4.54 $m^3 \times 10^9$ in 1995

Lowest Reservoir Capacity – 2.31 $m^3 \times 10^9$ in 2002

Range for the month – 4.54 and 2.31 ($m^3 \times 10^9$)

The trend of action is shown in figure 4.6.1 and 4.6.2

(d). **April Months**

Highest Reservoir Capacity – 4.06 $m^3 \times 10^9$ in 1995

Lowest Reservoir Capacity – 1.85 $m^3 \times 10^9$ in 2003

The range is 4.06 and 1.85($m^3 \times 10^9$) for the month of the years

Trend is as shown in figure 4.6.1 and 4.6.2

(e). **May Months.**

Highest Reservoir Capacity – 3.37 $m^3 \times 10^9$ in 1995

Lowest Reservoir Capacity – 152$m^3 x10^9$ in 2003.

Range for the month is between 3.37 and 1.52 [$m^3 x10^9$] with those years.

Trend is as shown in figure 4.6.1 and 4.6.2.

(f). **June Months.**

Highest Reservoir Capacity --- 2.42$m^3 x10^9$ in 1995

Lowest Reservoir Capacity --- 1.46m^3 in 1997

Range for the month is between 2.42 and 1.46 [$m^3 x\ 10^9$] within those years.

The trend is as shown in figure 4.6.1 and 4.6.2.

(g). **July Months**

Highest Reservoir Capacity --- 2.05$m^3 x\ 10^9$ in 1996

Lowest Reservoir Capacity --- 1.61$m^3 x10^9$ in 2003

Range for the month --- 2.05 and 1.61[$m^3 x10^9$] within those years.

Trend of action is as shown in figure 4.6.1 and 4.6.2.

(h). **August Months.**

Highest Reservoir Capacity --- 5.83$m^3 x10^9$ in 1998

Lowest Reservoir Capacity --- 2.05$m^3 x10^9$ in 1994-6

Range for the month is 5.83 and 2.05[$m^3 x10^9$]. Figure 4.6.1 and 4.6.2 shows the trend of the Reservoir Capacity.

(i) **September Months**

Highest Reservoir Capacity --- 6.32m^3x 10^9 in 2000

Lowest Reservoir Capacity --- 2.76m^3x10^9 in 1996

Range for the month is between 6.32 and 2.76[m^3x10^9].

The trend is as shown in figure 4.6.1and 4.6.1.

(j). **October Months**.

Highest Reservoir Capacity --- 5.9m^3x10^9 in 2003

Lowest Reservoir Capacity --- 4.52m^3x10^9 in 1996

The range for the month is between 5.9 and 4.52[m^3x10^9] and the trend shown as in figure 4.6.1 and 4.6.2.

(k) **November Months**.

Highest Reservoir Capacity ---5.72m^3x10^9 in 1994

Lowest Reservoir Capacity ---4.67m^3x10^9 in 1995

Range for the month is between 5.75 and 4.67[m^3x10^9] and the trend shown in figure 4.6.1 and 4.6.2.

(l). **December Months**.

Highest Reservoir Capacity --- 5.42m^3x10^9 in 1994

Lowest Reservoir Capacity --- 3.9m^3x10^9 in 2001

Range for the month is between 5.42 and 3.9 [m^3x10^9] and the trend is as shown in figure 4.6.1 and 4.6.2.

Generally, between January and July of all the years concern, i.e. 1994—2003, the reservoir capacity continuous to

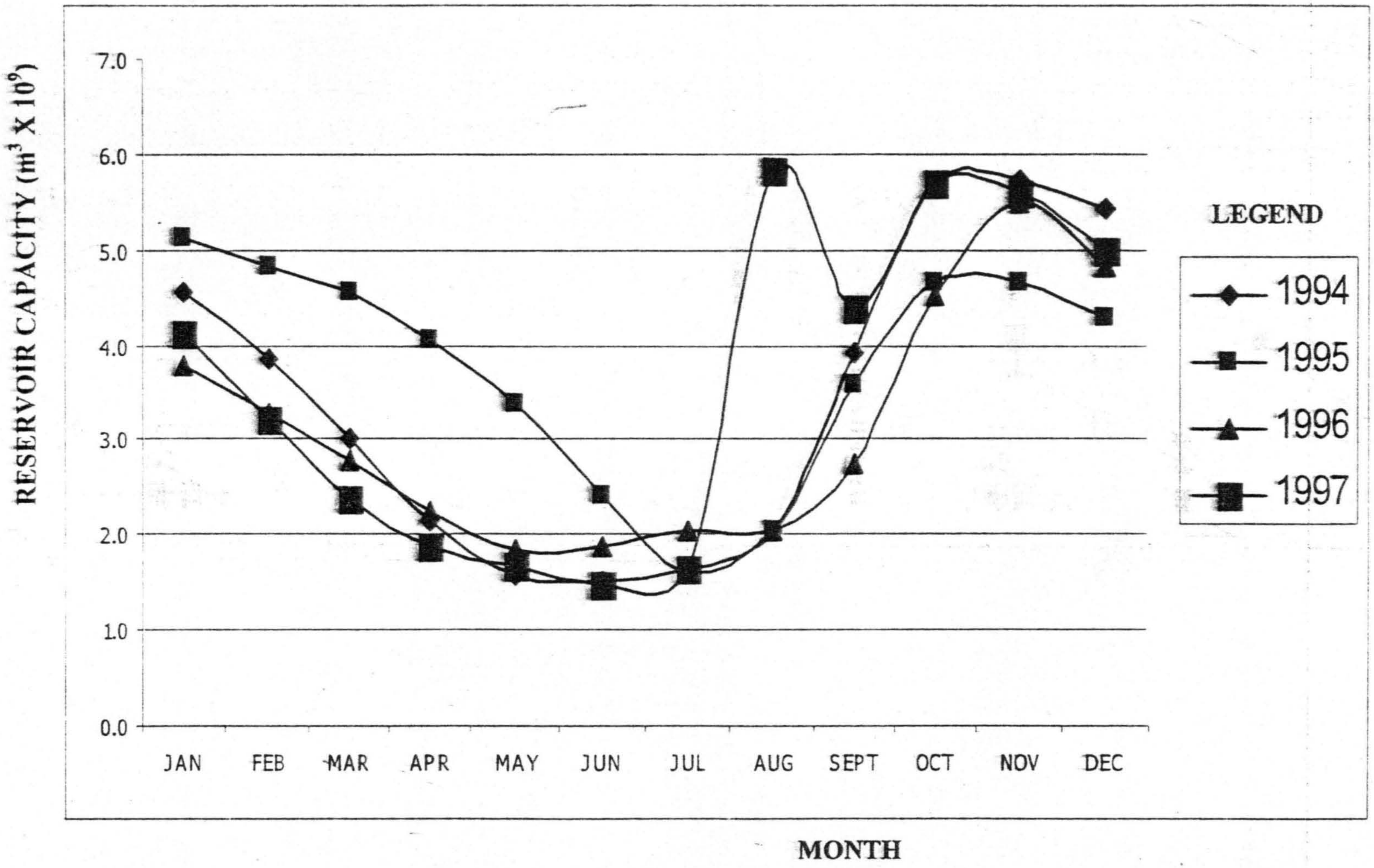


FIG. 4.6.1 MONTHLY RESERVOIR CAPACITY (m^3 X 10^9)

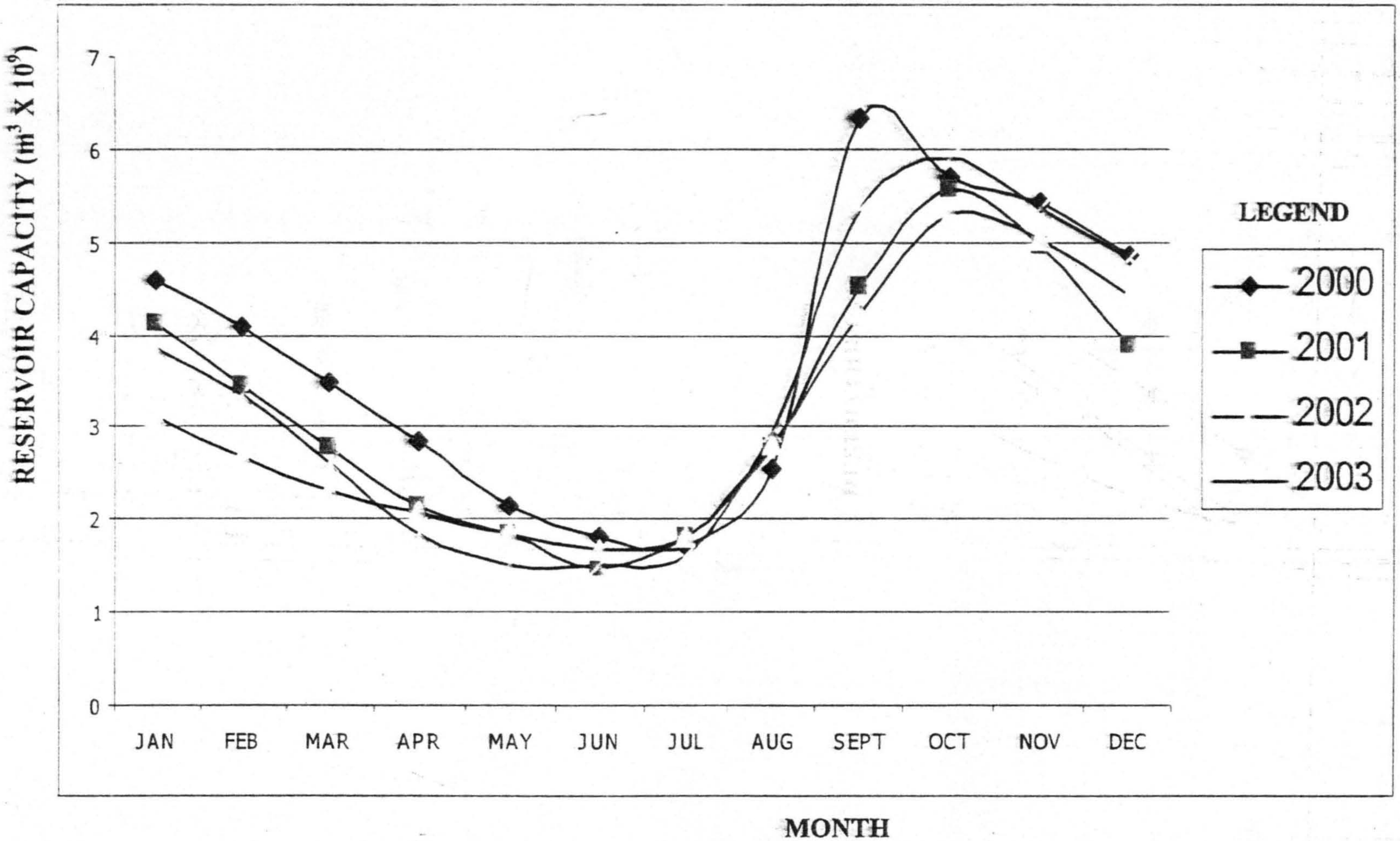


FIG. 4.6.2 MONTHLY RESERVOIR CAPACITY ($m^3 \times 10^9$)

decrease in volume and between August to October, it starts increasing. Later by November and December it start decreasing again.

Those shown that the rainfall pattern between January to June of all the years have being decreasing and increasing as from August and October of all the years.

4.7 TAIL WATER RACE

From Table 4.6, 1998 and 1999 data are missing as can be seen in figure 4.7. The discussion is based on the available data.

4.7.1 Yearly Tail Water Race

From figure 4.7, the highest Tail race m is 370.33m in 2001 and lowest is 269.15m in 1996. The range of elevation within the available years is within 370.33m and 269.15m, and the trend is as shown in figure 4.7.

4.7.2 Monthly Tail Water Race

(a). **January Months.**

Highest Tail Race (m) – 278.10m in 1995

Lowest Tail Race (m) – 269.68m in 2003

Range for the month is within 278.10 and 269.68(m) and the trend is as shown in figures 4.7.1 and 4.7.2.

(b). **February Months.**

Highest Tail Race – 270.51m in 1997

TABLE 4.6 AVERAGE MONTHLY TAIL WATER RACE(M)

	YEARS									
MONTH	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
JAN	270.06	278.10	269.72	270.46			269.71	270.40	269.95	269.68
FEB	270.41	269.50	269.85	270.51			269.70	270.15	269.70	270.34
MAR	271.99	269.25	269.80	270.50			270.05	270.39	269.59	270.34
APR	270.14	269.88	269.80	269.68			269.91	269.90	268.96	269.97
MAY	269.64	270.78	269.60	261.09			270.22	269.33	268.94	268.54
JUN	269.01	271.03	269.67	269.65			270.30	269.73	270.28	270.17
JUL	270.05	261.96	270.67	269.99			270.35	270.29	271.06	262.25
AUG	270.49	270.35	270.80	270.00			270.38	270.17	271.00	270.95
SEPT	268.90	260.80	269.14	270.15			270.32	270.88	270.83	272.38
OCT	270.60	269.45	261.65	270.48			270.33	270.71	271.72	271.18
NOV	272.97	269.18	268.97	270.31			270.20	271.07	270.48	270.23
DEC	269.50	269.98	270.08	270.06			270.18	270.93	270.36	269.87
AVERAGE	270.31	269.19	269.15	269.41			270.14	270.33	270.24	269.66

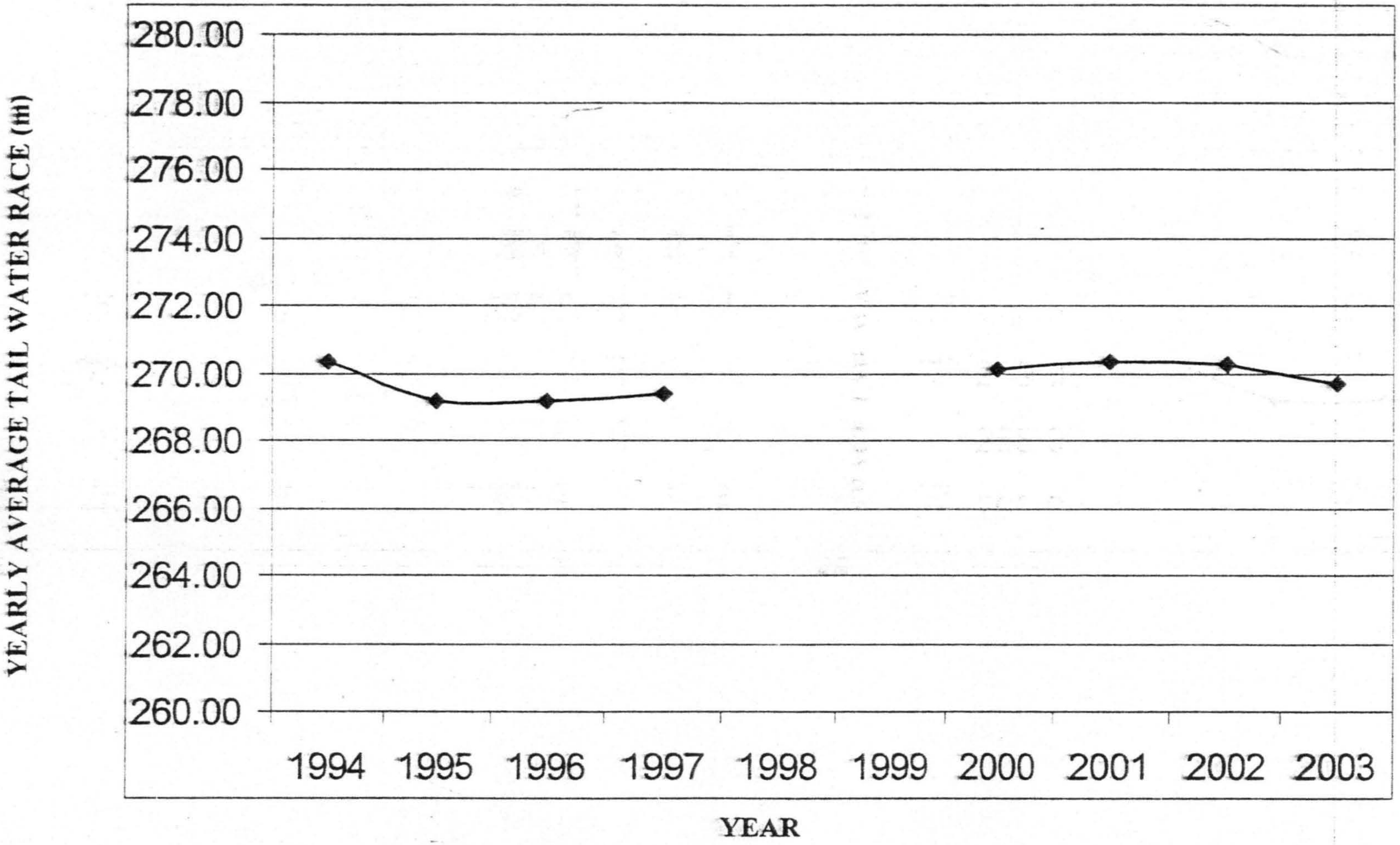


FIG. 4.7 YEARLY TAIL WATER RACE (m)

Lowest Tail Race - 269.50m in 1995

Range for the month is between 270.51 and 269.50 (m) and the trend is almost very closed to each other as shown in figure 4.7.1 and 4.7.2.

(c). **March Months**.

The highest Tail race - 271.99m in 1994.

Lowest Tail race - 269.25m in 1995.

The range is between 271.99 and 269.25 (m) and the trend is as shown in the same fig. 4.7.1 and 4.7.2.

(d). **April Months**.

Highest Tail Race - 270.14m in 1994

Lowest Tail Race - 269.68m in 1997

The range is within 270.14 and 269.68(m) and the reservoir elevation and capacity start to decrease as shown in trend of figure 4.5.1, 4.5.2, 4.6.1 and 4.6.2 respectively.

(e). **May Months**.

Highest Tail race - 270.78m in 1995

Lowest Tail race - 261.09m in 1997.

Range for the elevation and capacity continues to decreasing 1997 as in figure 4.6.1, 4.6.2, 4.5.1 and 4.5.2. The trend is as shown in figure 4.7.1 and 4.7.2.

(f). **June Months.**

Highest Tail Race – 271.03m in 1995

Lowest Tail Race – 269.01m in 1994

Range for June period within the year is between 271.03 and 269.01(m). The race increases in year 1995 and the trend is as shown in figure 4.7.1 and 4.7.2.

(g). **July Months.**

Highest Tail Water race – 271.06m in 2002

Lowest Tail water race – 261.96m in 1995

Range for the July period within the years is between 271.06 and 261.96m and the tail race decreases in 1995 and 2003 but only stabilizes between 270 and 271(m) in the remaining years. The trend is as shown in figure 4.7.1 and 4.7.2.

(h). **August Months.**

Highest Tail water race – 271m in 2002

Lowest Tail water race – 270m in 1997

Range for the month is 271 and 270(m) and the race was high as a result of high rainfall experience within August period as in figure 4.2.6 (August rainfall analysis).

(i). **September Months.**

Highest Tail race – 272.38m in 2003

Lowest Tail race – 260.80m in 1995

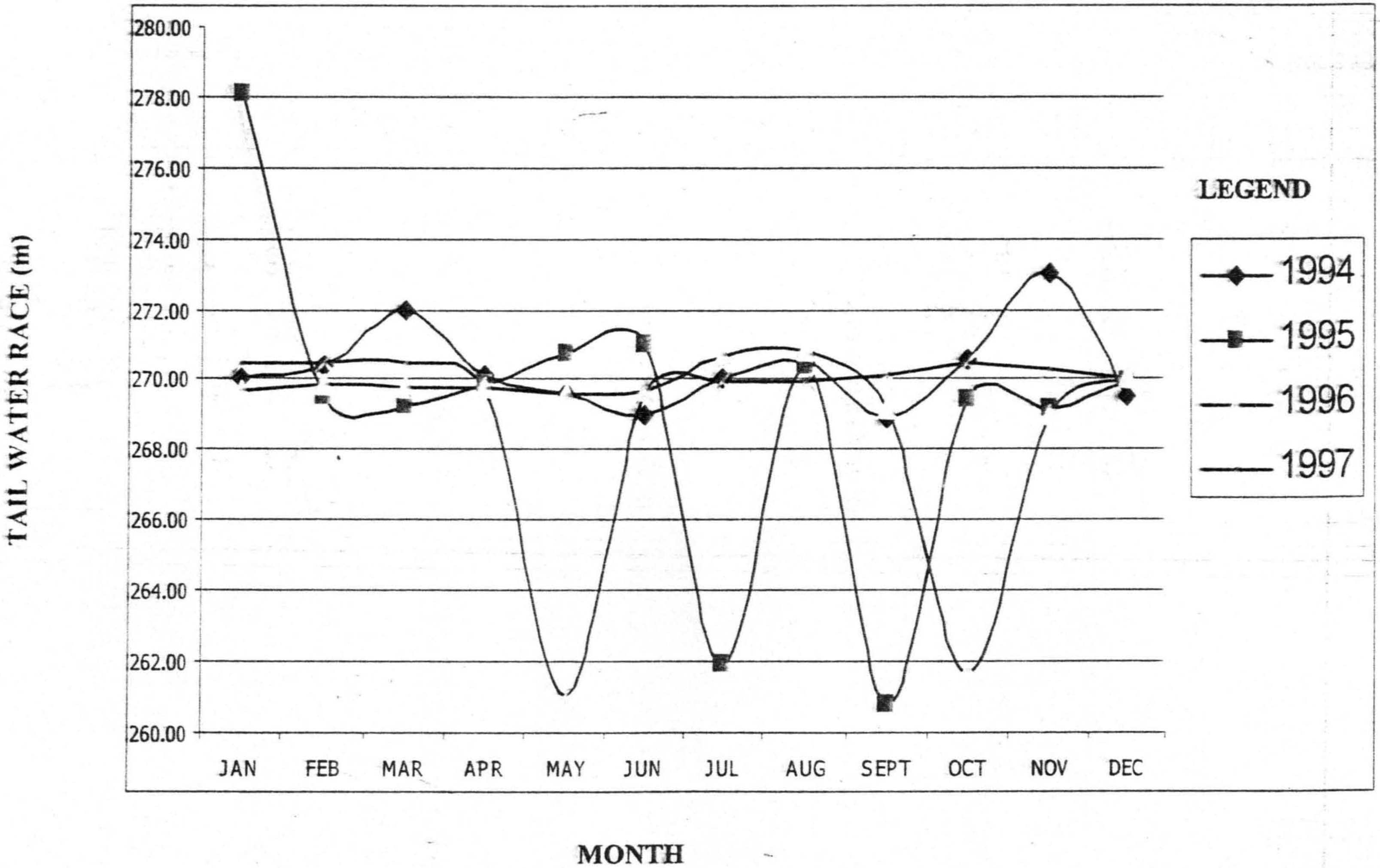


FIG. 4.7.1 MONTHLY TAIL WATER RACE RECORD (m)

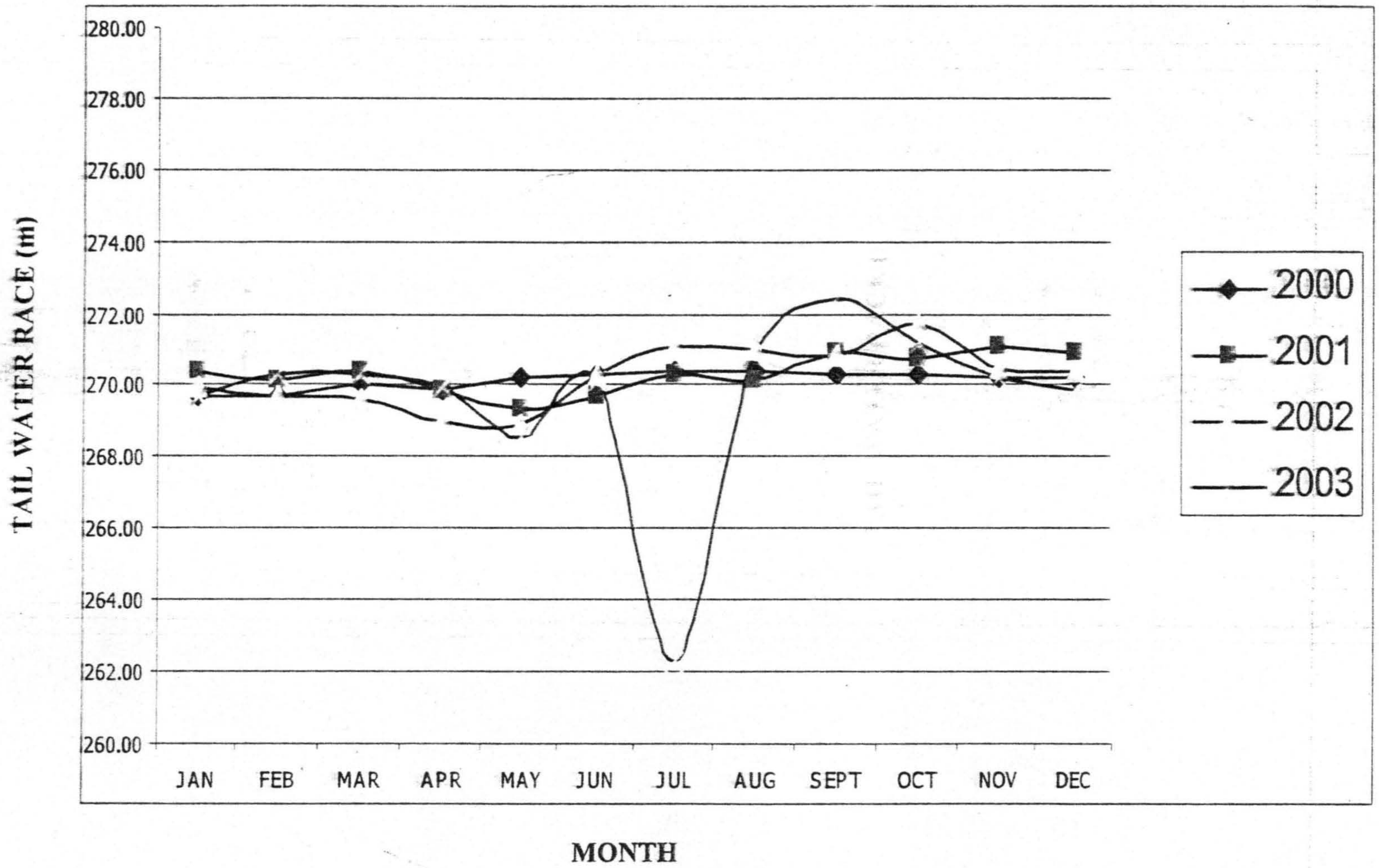


FIG. 4.7.2 MONTHLY TAIL WATER RACE RECORD (m)

Range for the month is 272.38 and 260.80(m) and the trend is as shown in figure 4.7.1 and 4.7.2.

(j). **October Months.**

Highest Tail water race – 271.72m in 2002

Lowest Tail water race – 261.65m in 1996

Ranger for the month is between 271.72 and 261.61(m) and the trend is as shown in figure 4.7.1 and 4.7.2.

(k). **November Months.**

Highest Tail water race – 272.97m in 1994

Lowest Tail water race – 268.97 in 1996

Range for the month is between 272.97 and 268.97(m) and the trend is shown in figure 4.7.1 and 4.7.2.

(l). **December Months.**

Highest Tail water race – 270.93m in 2001

Lowest Tail water race – 269.50m in 1994

The range for December period of the years is between 270.93m and 269.50m and the trend is as shown in figure 4.7.1 and 4.7.2

4.8 Monthly Averages(1994-2003)

(a) **January Period**

From Table 4.7, figure 4.8.0, 4.8.1, 4.8.2 and 4.8.3;

The maximum seepage = $1.9m^3/s \times 10^{-5}$

TABLE 4.7 MONTHLY AVERAGE DATA FOR ALL THE YEARS

MONTHS OF JANUARY				
YEAR	SEEPAGE m^3/s (x 10^{-5})	ELEVATION(m)	HEAD(M)	RESERVOIR CAPACITY m^3/s
1994	1.9	378	66	4.6
1995	1.6	382	70	5.1
1996	1.5	359	47	3.8
1997	1.7	376	64	4.1
1998				
1999				
2000	1.7	378	66	4.6
2001	1.6	376	64	4.1
2002	1.5	370	58	3.1
2003	1.5	374	62	3.9
AVERAGE	1.6	374	62	4.2

NOTE: Ground Surface Elevation (EL) = 312

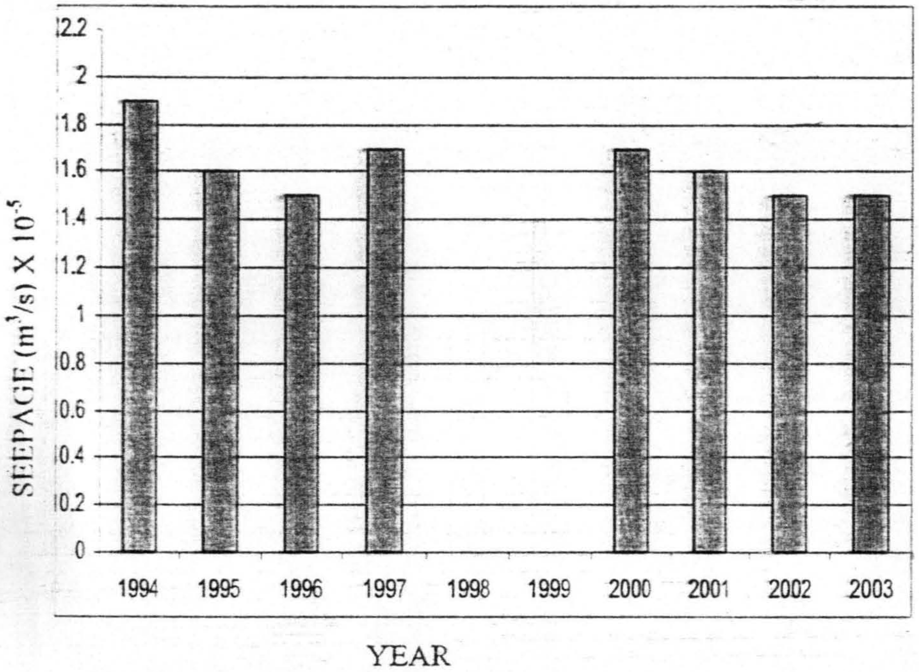


FIG. 4.8.0 SEEPAGE (m^3/s) X 10^{-5}
FOR THE MONTH OF JANUARY

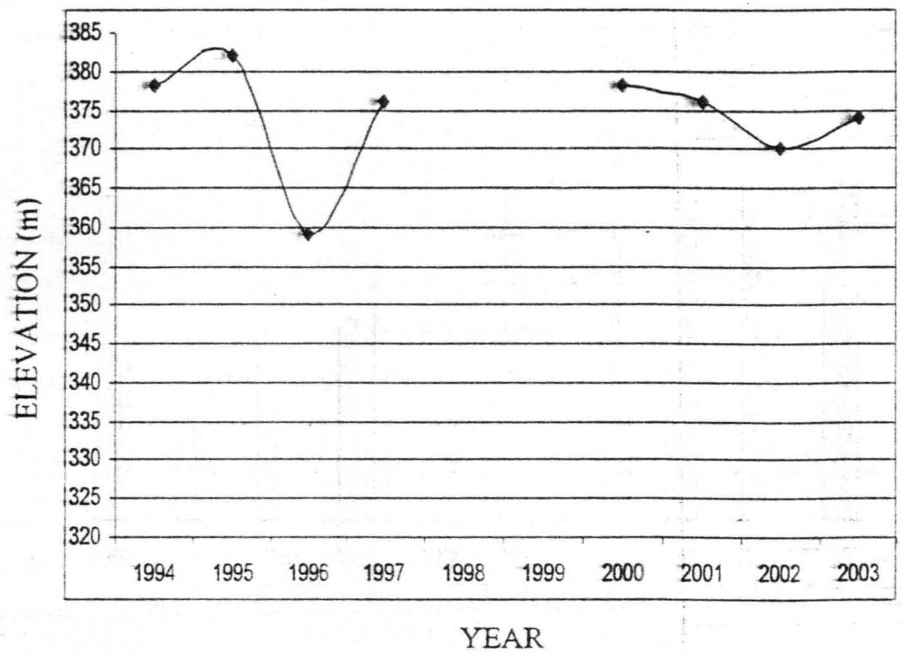


FIG. 4.8.1 ELEVATION (m) FOR
THE MONTH OF JANUARY

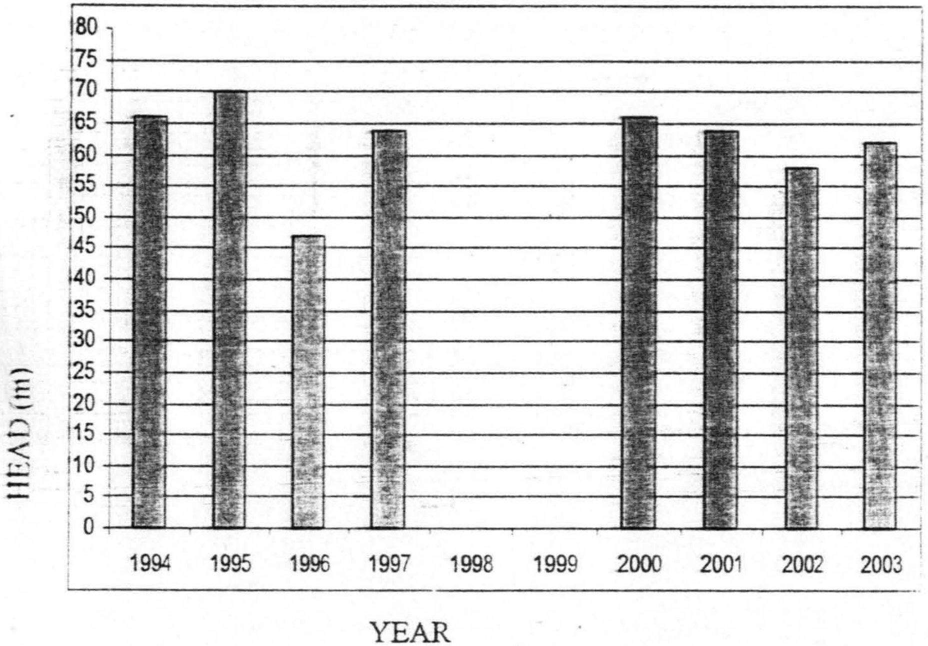


FIG. 4.8.2 HEAD (m) FOR THE MONTH OF JANUARY

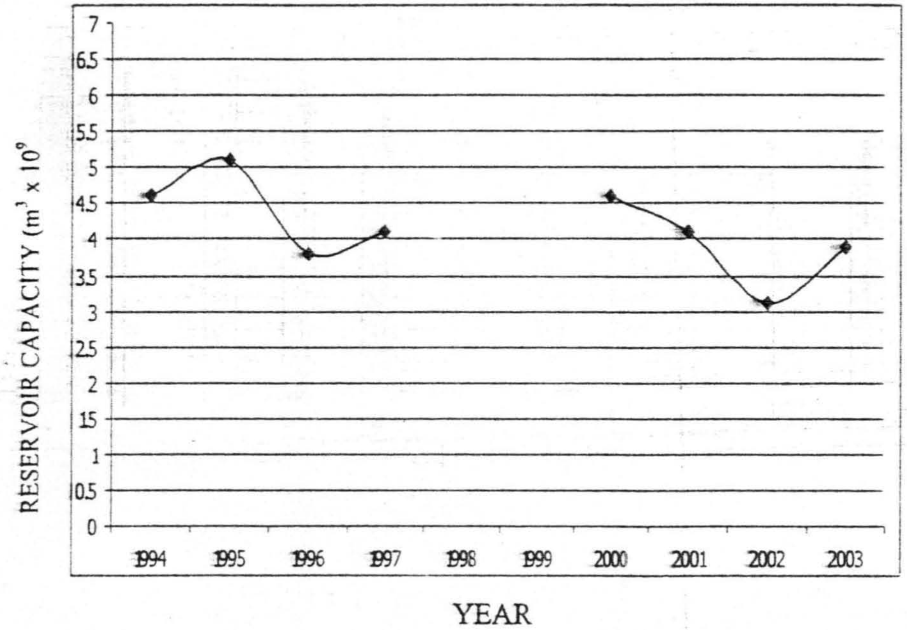


FIG. 4.8.3 RESERVOIR CAPACITY ($m^3 \times 10^9$) FOR THE MONTH OF JANUARY

minimum seepage = $1.5m^3/s \times 10^{-5}$ in 1996, 2002 and 2003 respectively. i.e Figure 4.8.0

The mean average seepage Elevation, Head and Reservoir capacity are $1.6m^3/s \times 10^{-5}$, 374m, 62m, and $4.2m^3 \times 10^9$.

Also the maximum elevation, Head and reservoir capacity are 382m , 70m and $5.1m^3 \times 10^9$ minimum elevation, Head and reservoir capacity are 359m in 1996, 58m in 2002, and $3.1m^3 x 10^9$ in 2002.

As of 1994, seepage rating was high ($1.9m^{3/5}x10^{-5}$ and starts to come down to $1.5m^3/5x10^{-5}$ in 1996. In 1997 it rises to $1.7m^3/5x10^{-5}$ and starblizes up to year 2000. By year 2001, it started decreasing back to $1.5m^3/5x10^{-5}$ again as of 2003 , when seepage is high, elevation, head and reservoir capacity decreases and vis- visa; When elevation, head and reservoir capacity increases seepage, 10-decreases as can be seen in the trends, this may be as a result of evaporation rating within the year as can also be seen in figure 4.3.1 (January evaporation rating).

(b) **February Period**

From table 4.8, figure 4.9.0, 4.9.1, 4.9.2 and 4.9.3. the maximum seepage = $2.0m^3/sx10^{-5}$ in 1994 and minimum seepage = $1.4m^3/s$ $x10^{-5}$ in 2002, Similarly, maximum elevation head and reservoir capacity are 379m in 1995, 67m in1995 are $4.8m^3x10^9$ in 1995 too . Minimum elevation, head and reservoir capacity are 368m in

2002, 56m in 2002 and $2.7m^3 \times 10^9$ in 2002 ,The mean average seepage, elevation, head and reservoir capacity for the month are $1.3m^3/s \times 10^{-5}$, 373m, 61m and $3.6m^3 \times 10^9$.

In 1994, seepage was high up to $2.0m^3/s \times 10^{-5}$ and continue to decrease up to 1997; By year 2000 it then increases to $4.6m^3/s \times 10^{-5}$ and later decreases to $1.4m^3/s \times 10^{-5}$ by 2002, rises to $1.5m^3/s \times 10^{-5}$ as of year 2003. The trends of action is as shown in the figures.

The decreases in seepage is as the result of non-rainfall within the month and high evaporation rating as in figure 4.3.2 (February evaporation).

(c) **March Period**

From Table 4.9 figure 4.10.0, 4.10.1, 4.10.2 and 4.10.3.The maximum seepage = $2.0m^3/s \times 10^{-5}$ in 1994, the minimum seepage = $1.4m^3/s \times 10^{-5}$ in 2004. Also The maximum elevation, head and reservoir capacity within the same period (March) are 378m in 1995, 66m in 1995 and $4.5m^3 \times 10^9$ in 1995 minimum elevation, head are reservoir capacity within March are 366m in 2000, 54m in 2000 and $2.3m^3 \times 10^9$ in 2000 respectively.

The mean average seepage, elevation, head and reservoir capacity between 1994 and 2003 are $1.3m^3 \times 10^{-5}$, 370m, 58m, and $3.0m^3 \times 10^9$ respectively. 1994 experience the maximum seepage

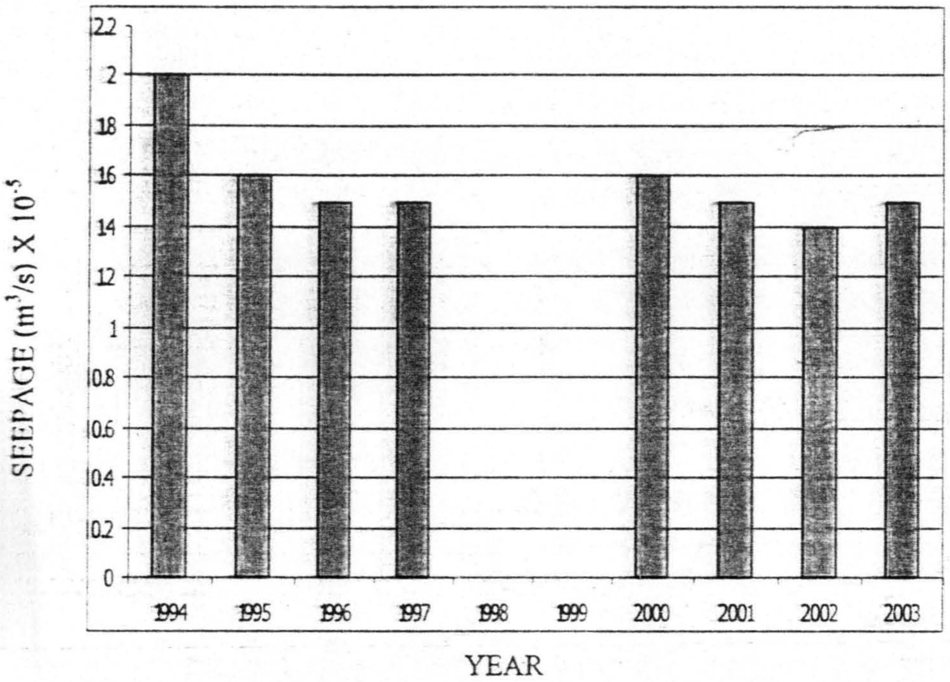
TABLE 4.8 MONTHLY RE-GROUPING OF AVERAGE DATA FOR ALL THE YEARS

MONTHS OF FEBRUARY				
YEAR	SEEPAGE m^3/s $(x\ 10^{-5})$	ELEVATION(m)	HEAD(m)	RESERVOIR CAPACITY($m^3 \times 10^9$)
1994	2	374	62	3.8
1995	1.6	379	67	4.8
1996	1.5	371	59	3.2
1997	1.5	371	59	3.2
1998				
1999				
2000	1.6	375	63	4.1
2001	1.5	372	60	3.4
2002	1.4	368	56	2.7
2003	1.5	372	60	3.3
AVERAGE	1.3	373	61	3.6

TABLE 4.9

MONTHS OF MARCH				
YEAR	SEEPAGE m^3/s $x\ 10^{-5}$	ELEVATION(m)	HEAD(m)	RESERVOIR CAPACITY($m^3 \times 10^9$)
1994	2	370	58	3
1995	1.6	378	66	4.5
1996	1.5	369	57	2.8
1997	1.5	366	54	2.4
1998				
1999				
2000	1.5	372	60	3.5
2001	1.5	368	56	2.8
2002	1.4	366	54	2.3
2003	1.5	368	56	2.6
AVERAGE	1.3	370	58	3

NOTE: Ground Surface Elevation (EL) = 312



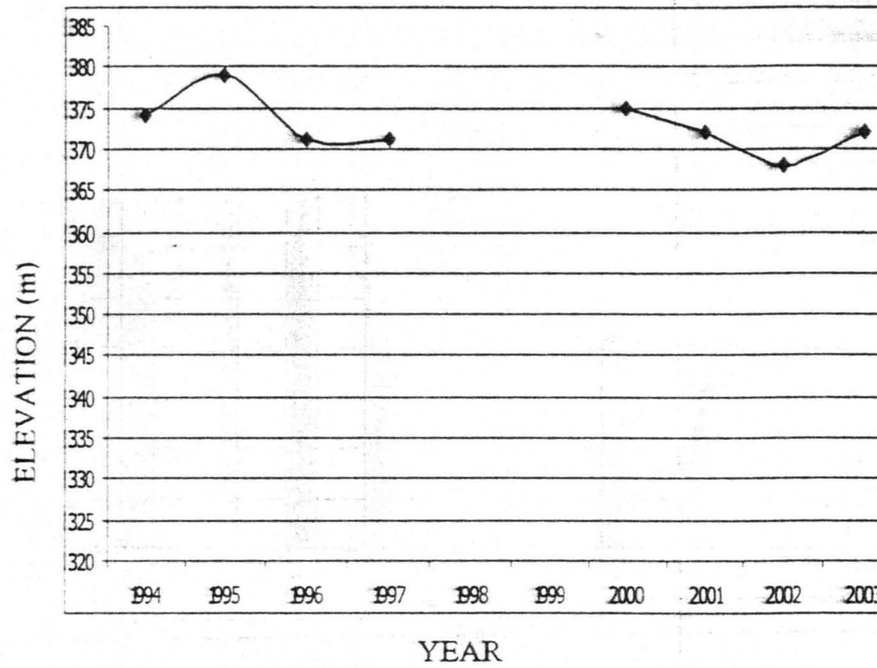


FIG. 4.9.0SEEPAGE (m^3/s) X 10^{-5} FOR THE MONTH OF FEBRUARY

FIG. 4.9.1 ELEVATION (m) FOR THE MONTH OF FEBRUARY

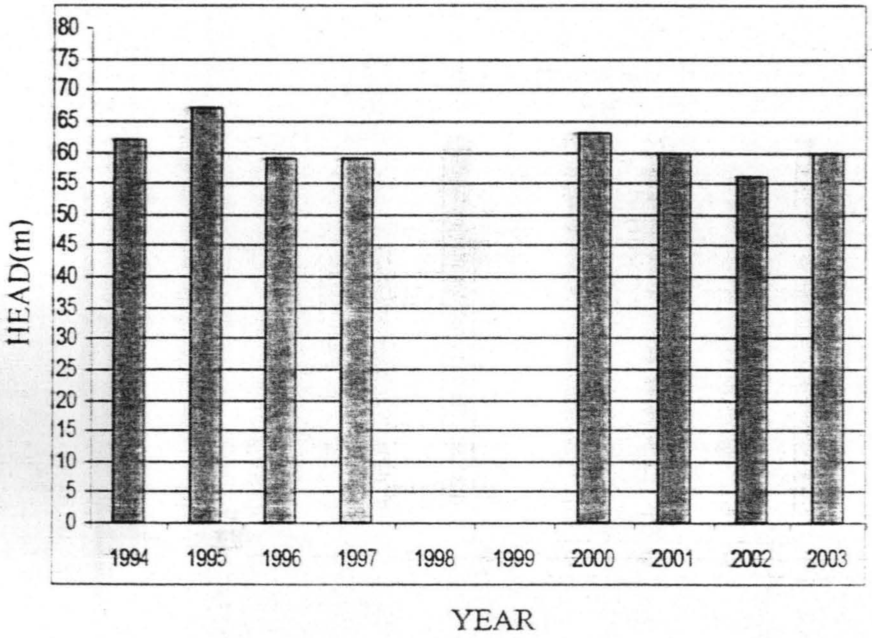


FIG. 4.9.2 HEAD (m) FOR THE MONTH OF FEBRUARY

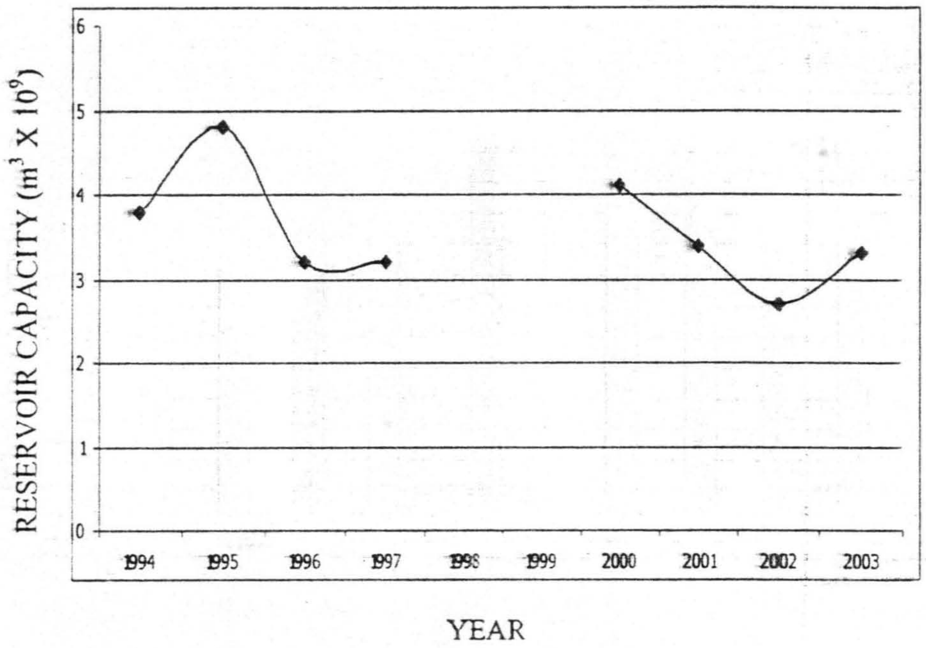


FIG. 4.9.3 RESERVOIR CAPACITY ($m^3 \times 10^9$) FOR THE MONTH OF FEBRUARY

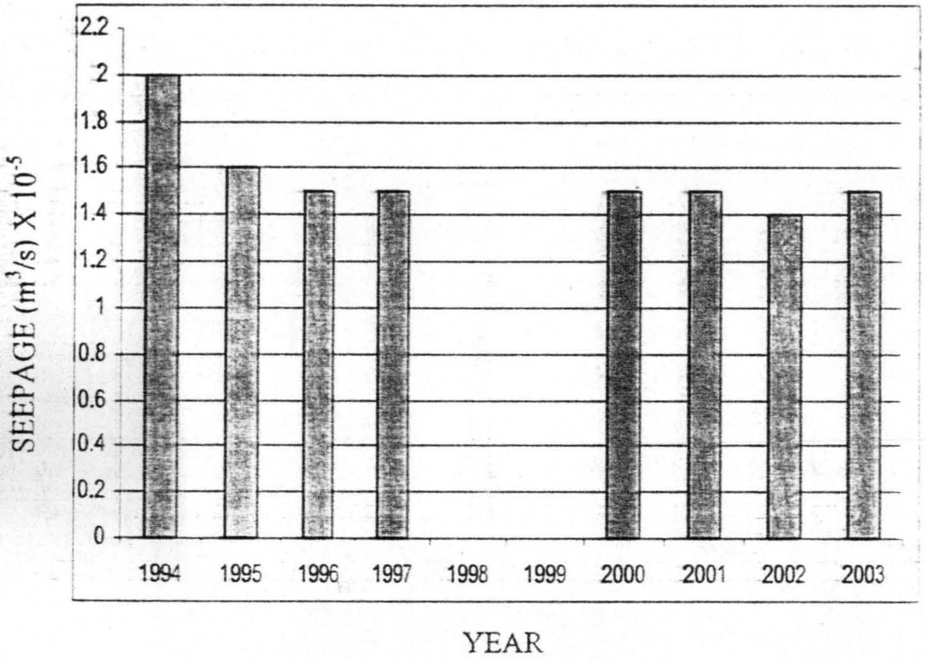


FIG. 4.10.0 SEEPAGE (m^3/s) X 10^{-5}
FOR THE MONTH OF MARCH

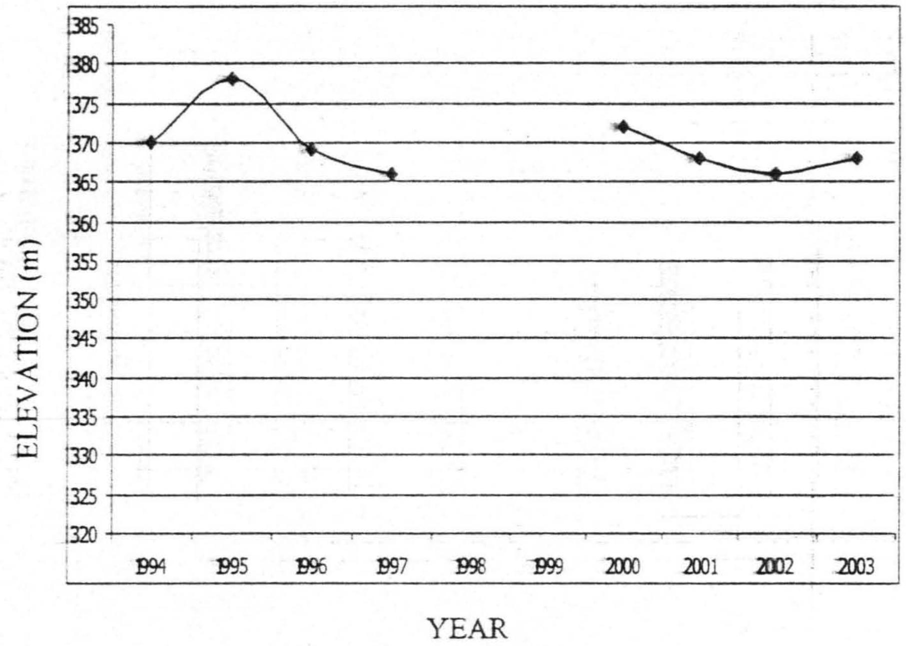


FIG. 4.10.1 ELEVATION (m) FOR
THE MONTH OF MARCH

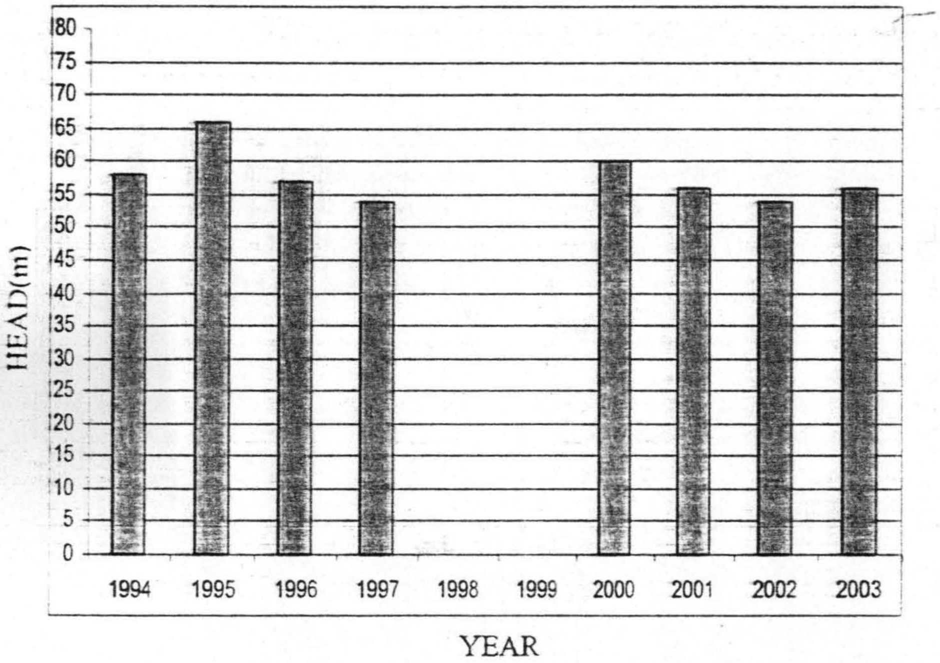


FIG. 4.10.2 HEAD (m) FOR THE MONTH OF MARCH

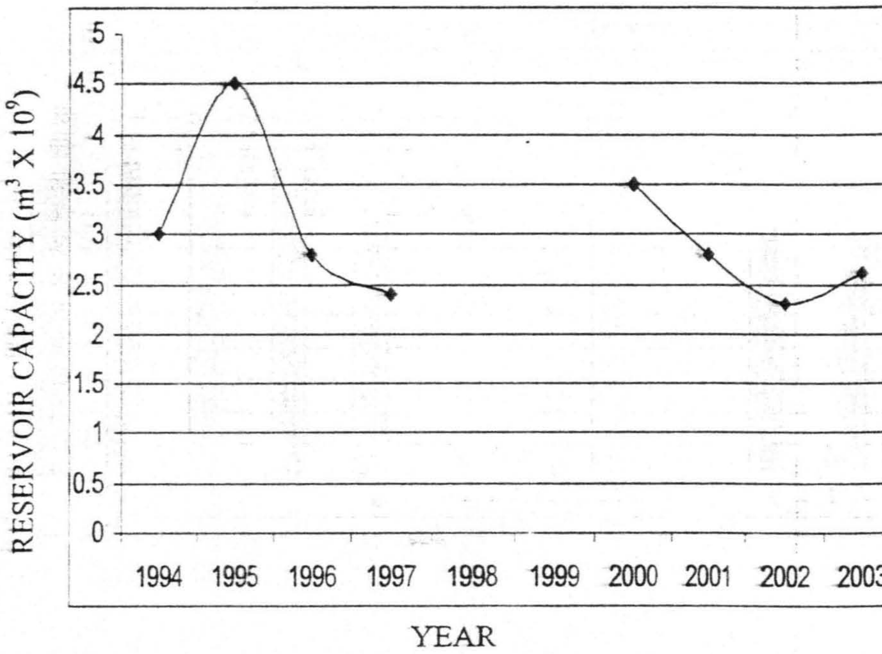


FIG. 4.10.3 RESERVOIR CAPACITY ($m^3 \times 10^9$) FOR THE MONTH OF MARCH

and then fall down to 1996. It then stabilized from 1996 to 2001, after which it later falls to 1.4 by 2002 and then rises back to 1.5 again at 2003.

The reasons for this trend of seepage, elevation, head and reservoir capacity is due to very low rainfall intensity pattern experienced and high evaporation rate within the same period as per figure 4.2 (rainfall) and 4.3 (evaporation) plus other contributing factors e.g high temperature e.t.c .

(d) **April Period**

From Table 4.10, figure 4.11.0, 4.11.1, 4.11.2 and 4.11.3. The maximum seepage = 1.9m^3 x 10^{-5} in 1994 and the minimum seepage = 1.3m^{3}x10^{-5} in 2002. Also, the maximum elevation, head and reservoir capacity within the same period (April) are 375m in 1995, 63m in 1995, and 4.1m^3 x 10^9 in 1995. Minimum elevation, head and reservoir capacity within April are 353m in 2002, 40m in 2002 and 1.9m^3 x10^9 in 2003 respectively.

Mean average seepage, elevation, head and reservoir capacity between 1994 and 2003 are 1.4m^3 x 10^9, 365m , 52m and 2.4m^3 x 10^9 1994experienced the highest maximum seepage and then continue to fall down to 1997. As of year 2000 it rises very small (1.5) then falls again down to 1.3 up to 2002 and later rises back to 1.4 as 2003.

The reason for the rises and falls of the trend of seepage elevation, head and reservoir capacity experienced as per very low pattern of rain fall intensity and also high evaporation rates experienced within the same period as per figure 4.2.2 (Rainfall for the month of April) and figure 4.3 yearly evaporation figure 4.3.4 evaporation for the month of April.

(e) **May Period**

From Table 4.11, figure 4.12.0, 4.12.1, 4.12.2 and 4.12.3. The maximum seepage = $1.6m^3/s \times 10^{-5}$ in 1994 and minimum seepage $=1.2m^3$ in 2003. Also, the maximum elevation, head and reservoir capacity within the same May period are 372m in 1995,60m in 1995,$3.4m^3 \times 10^9$ in 1995 respectively.

Mean average seepage, elevation head and reservoir capacity between 1994 to 2003 are:-$1.4^3/s \times 10^{-5}$,360m, 48m and $2.0m^3 \times 10^9$.

1994 and 1995 experience the maximum seepage of 1.6; it them falls down to 1.3 in 1997 to year 2000 and later falls again down to $1.2m^3/s \times 10^{-5}$ as of 2001 and 2002 before it finally rises up to 1.3 again by year 2003.

TABLE 4.10 MONTHLY RE-GROUPING OF AVERAGE DATA FOR ALL THE YEARS

MONTH OF APRIL				
YEAR	SEEPAGE m^3/s $\times 10^{-5}$	ELEVATION(m)	HEAD(m)	RESERVOIR CAPACITY($m^3 \times 10^9$)
1994	1.9	365	53	2.1
1995	1.6	375	63	4.1
1996	1.5	365	44	2.3
1997	1.4	363	51	1.9
1998				
1999				
2000	1.5	369	57	2.9
2001	1.3	365	53	2.2
2002	1.3	352	40	2.1
2003	1.4	363	51	1.9
AVERAGE	1.4	365	52	2.4

TABLE 4.11

MONTH OF MAY				
YEAR	SEEPAGE m^3/s $\times 10^{-5}$	ELEVATION(m)	HEAD(m)	RESERVOIR CAPACITY($m^3 \times 10^9$)
1994	1.6	329	17	1.6
1995	1.6	372	60	3.4
1996	1.4	363	51	1.8
1997	1.3	361	49	1.7
1998				
1999				
2000	1.3	365	53	2.2
2001	1.2	363	51	1.8
2002	1.2	363	51	1.8
2003	1.3	360	48	1.5
AVERAGE	1.4	360	48	2

NOTE: Ground Surface Elevation (EL) = 312

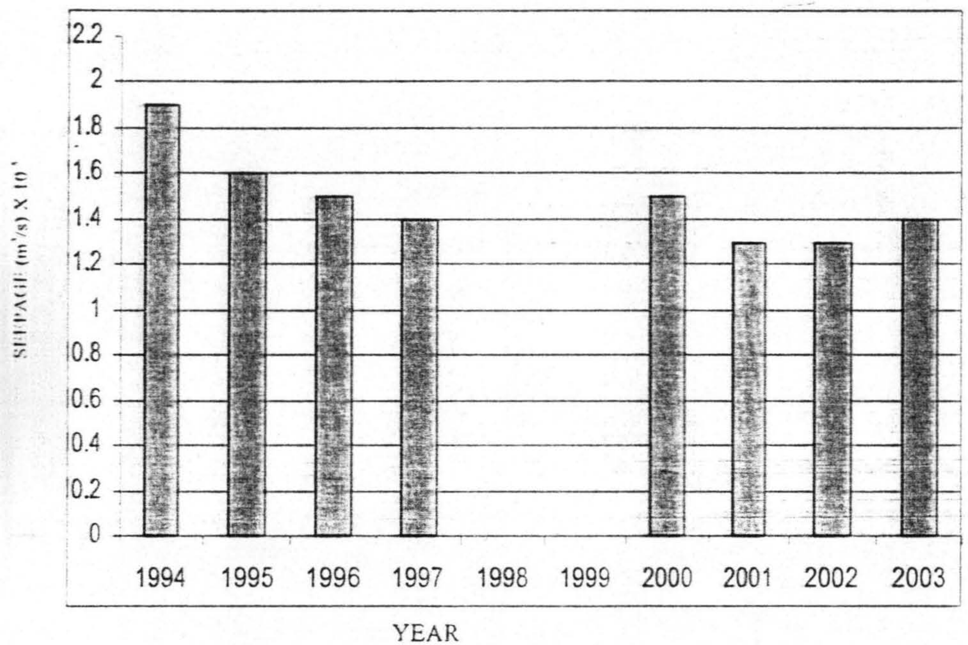


FIG. 4.11.0 SEEPAGE (m^3/s) X 10^{-5}
FOR THE MONTH OF APRIL

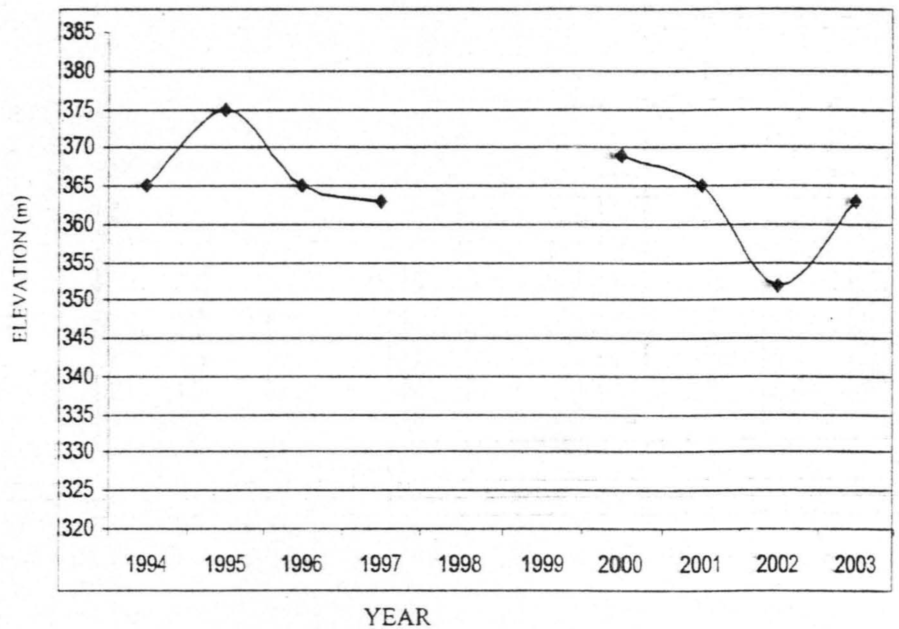


FIG. 4.11.1 ELEVATION (m) FOR
THE MONTH OF APRIL

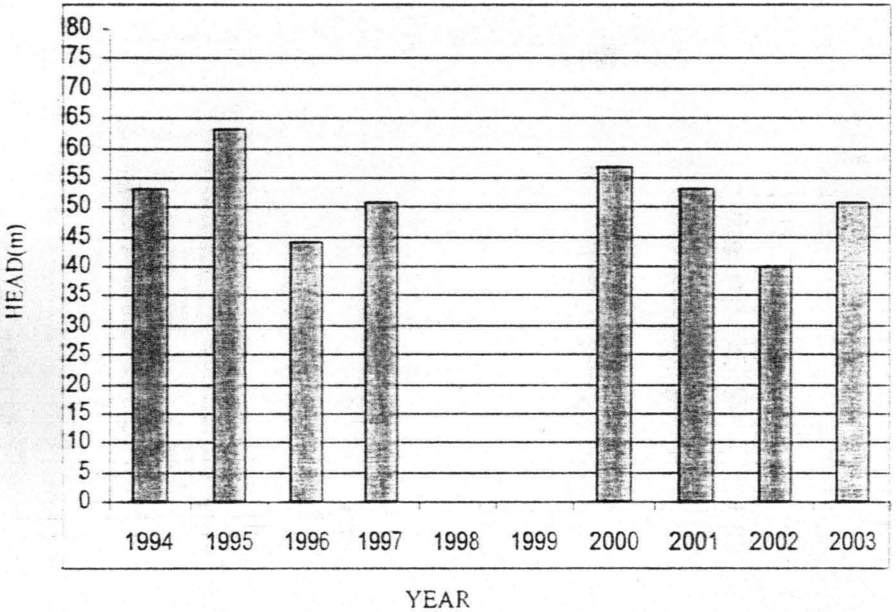


FIG. 4.11.2 HEAD (m) FOR THE MONTH OF APRIL

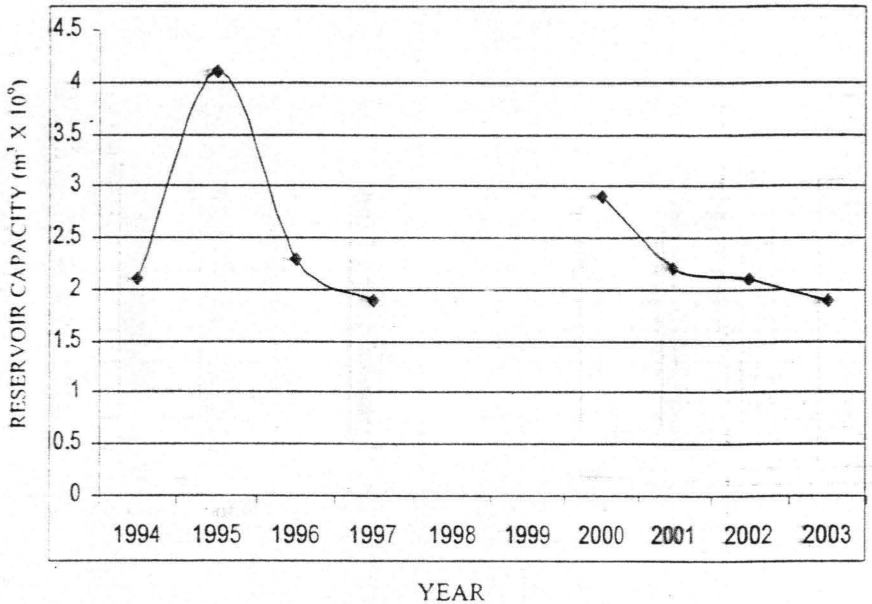


FIG. 4.11.3 RESERVOIR CAPACITY ($m^3 \times 10^9$) FOR THE MONTH OF APRIL

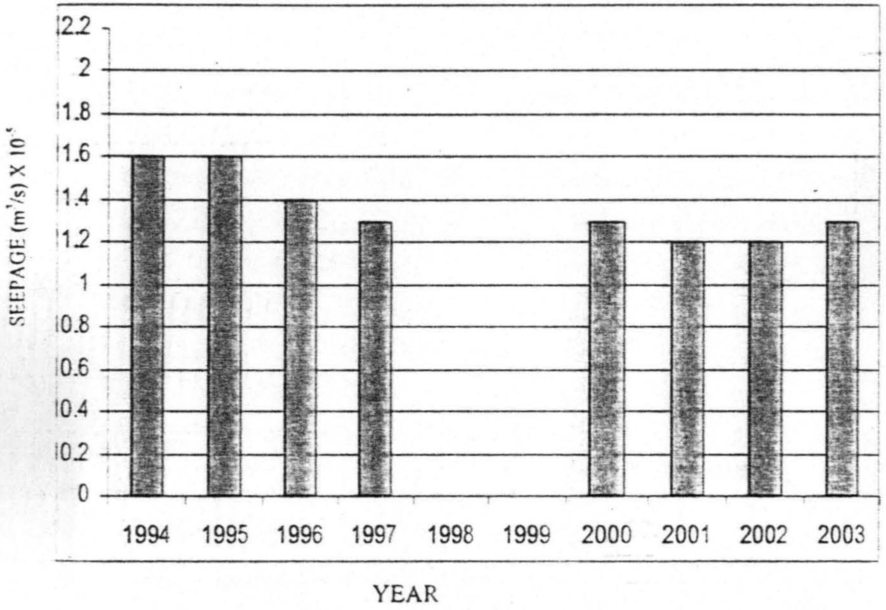


FIG. 4.12.0 SEEPAGE (m^3/s) X 10^{-5} FOR THE MONTH OF MAY

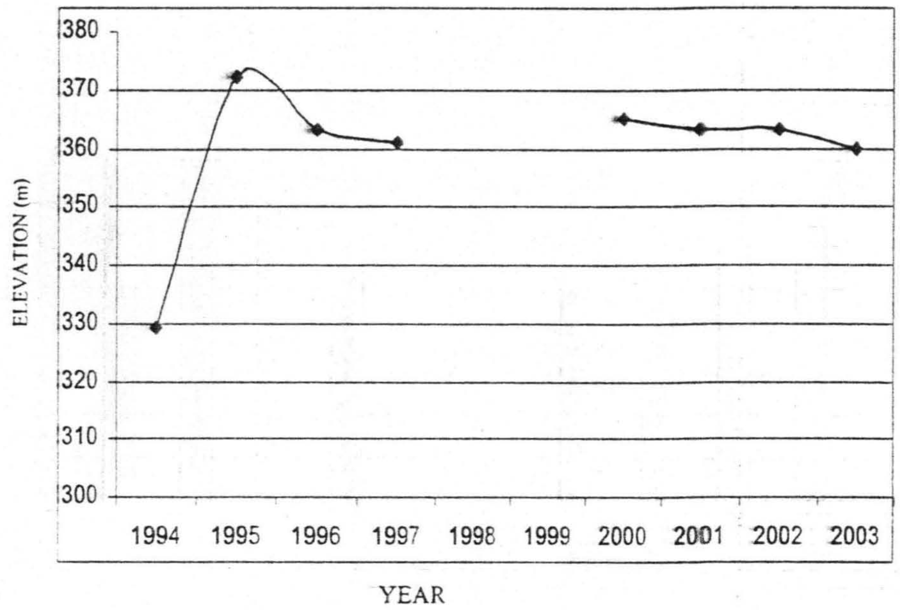


FIG. 4.12.1 ELEVATION (m) FOR THE MONTH OF MAY

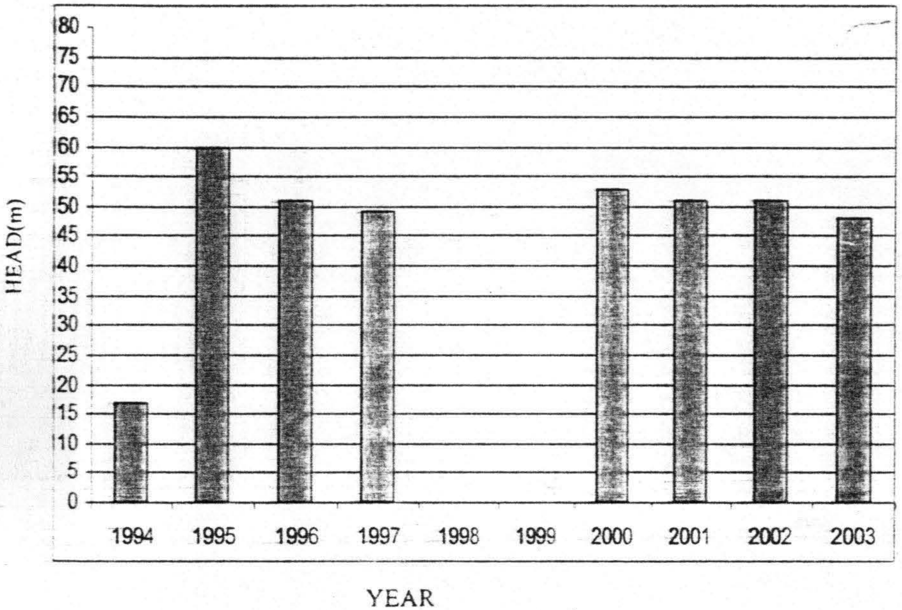


FIG. 4.12.2 HEAD (m) FOR THE MONTH OF MAY

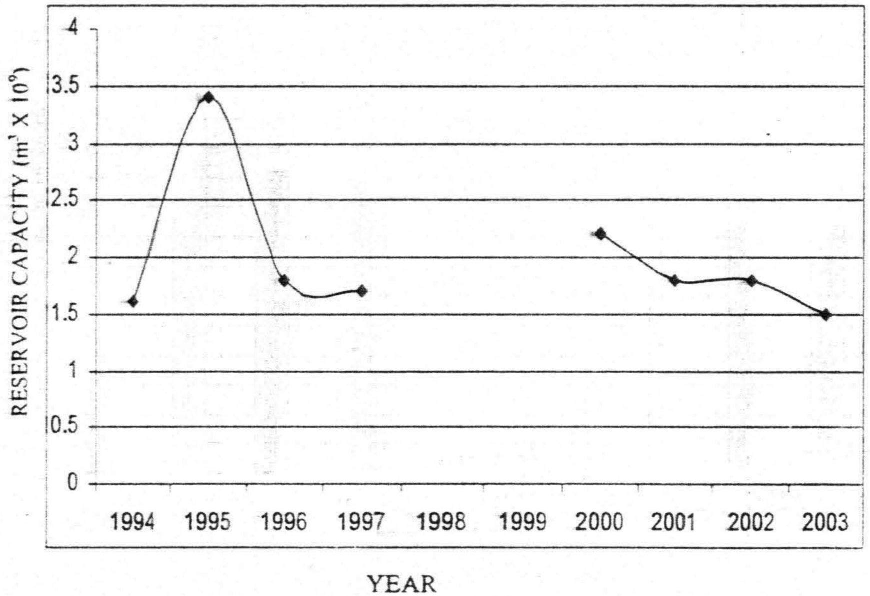


FIG. 4.12.3 RESERVOIR CAPACITY ($m^3 \times 10^9$) FOR THE MONTH OF MAY

(f) **June Period**

From Table 4.12, figure 4.13.0, 4.13.1, 4.13.2 and 4.13.3. Maximum seepage = $1.5m^3/s \times 10^{-5}$ in 1995 and minimum seepage = $1.2m^3/s \times 10^{-5}$ in 2000 to 2003.

Similarly, the maximum elevation, Head and Reservoir capacity within the same period are:- 366m, 54m and $2.4m^3 \times 10^9$ respectively.

The mean average seepage, elevation, Head and reservoir capacity are $1.3m^3/s \times 10^{-5}$, 362m, 50m and $1.7m^3 \times 10^9$.

1994 seepage falls to 1.4 and rise to 1.5 in 1995; later started falling in 1996, 1997 and stabilizes at 1.2 by 2000 to 2003. This is as a result in increases in rainfall intensity as compared to previous month as in figure 4.2.4 (June rainfall).

Evaporation rate also tends to decreases as also related to previous month before June as figure 4.3.6 (evaporation for June).

(g) **July Period.**

From Table 4.13, figure v4.14.0, 4.14.1, 4.14.2 and 4.14.3.The maximum seepage = $1.4m^2/s \times 10^{-5}$ in 1994 and 1996 and minimum seepage = $1.2m^2/s \times 10^{-5}$ in 1997, 2002 and 2002. Also, maximum elevation, Head and Reservoir capacity are 362m, 50m and $1.7m^3 \times 10^9$ the same as that of June period.

Seepage within this period July stabilizes between the range 1.2 and 1.4($m^3/s \times 10^{-5}$) like wise elevation between 360 and 362(m). Head between 48 and 52(m) and Reservoir capacity between 1.5 and 2.1($m^3 \times 10^9$). This is as a result of high intensity pattern of rainfall as in figure 4.2.5 and very low evaporation rate as also in figure 4.3.7.

(h) **August Period.**

From Table 4.14, figure 4.15.0, 4.15.1, 4.15.2 and 4.15.3. The maximum seepage = 1.5$m^3/s \times 10^{-5}$ in 2002 and the minimum seepage = 1.2$m^2/s \times 10^{-5}$ in 2000.

Similarly, maximum elevation, Head and reservoir capacity are:- 371m in 2002, 59m in 2002 and 5.8 $m^3 \times 10^9$ and minimum elevation, Head and reservoir capacity are;- 357m in 2003, 45m in 2002 and 2.1$m^3 \times 10^9$ in 1994 – 1996.

The mean average seepage, elevation, head and reservoir capacity are 1.4$m^3/s \times 10^{-5}$, 366m, 54m and 2.9$m^3 \times 10^9$ and is higher than that of April, May, June and July periods.

Seepage within this period (August) starts in 1.4, falls to 1.3, rises back to 1.4, falls again back to 1.3 and down to 1.2 and later rises to 1.4, 1.5 in 2001 and 2002; and finally falls down to 1.3 in 2003. This is as a result of high rainfall pattern sparsely

TABLE 4.12 MONTHLY RE-GROUPING OF AVERAGE DATA FOR ALL THE YEARS

MONTHS OF JUNE				
YEAR	SEEPAGE $m^3/s \times 10^{-5}$	ELEVATION(m)	HEAD(m)	RESERVOIR CAPACITY($m^3 \times 10^9$)
1994	1.4	360	48	1.5
1995	1.5	366	54	2.4
1996	1.4	363	51	1.9
1997	1.3	360	48	1.5
1998				
1999				
2000	1.2	363	51	1.8
2001	1.2	362	50	1.5
2002	1.2	361	49	1.7
2003	1.2	360	48	1.5
AVERAGE	1.3	362	50	1.7

TABLE 4.13

MONTHS OF JULY				
YEAR	SEEPAGE $m^3/s \times 10^{-5}$	ELEVATION(m)	HEAD(m)	RESERVOIR CAPACITY($m^3 \times 10^9$)
1994	1.4	360	48	1.6
1995	1.3	361	49	1.6
1996	1.4	364	52	2.1
1997	1.2	361	49	1.6
1998				
1999				
2000	1.3	362	50	1.7
2001	1.2	362	50	1.8
2002	1.2	362	50	1.8
2003	1.3	363	51	1.6
AVERAGE	1.3	362	50	1.7

NOTE: Ground Surface Elevation (EL) = 312

TABLE 4.14 MONTHLY RE-GROUPING OF AVERAGE DATA FOR ALL THE YEARS

MONTH OF AUGUST				
YEAR	SEEPAGE m^3/s x 10-5	ELEVATION(m)	HEAD(m)	RESERVOIR CAPACITY(m^3 x 10^9)
1994	1.4	360	48	2.1
1995	1.3	364	52	2.1
1996	1.4	369	57	2.1
1997	1.3	367	55	5.8
1998				
1999				
2000	1.2	367	55	2.6
2001	1.4	369	57	2.8
2002	1.5	371	59	2.8
2003	1.3	357	45	3.0
AVERAGE	1.4	366	54	2.9

TABLE 4.15

MONTHS OF SEPTEMBER				
YEAR	SEEPAGE m^3/s x 10^{-5}	ELEVATION(m)	HEAD(m)	RESERVOIR CAPACITY(m^3 x 10^9)
1994	1.5	374	62	3.9
1995	1.4	373	61	3.6
1996	1.5	377	65	2.8
1997	1.4	377	65	4.4
1998				
1999				
2000	1.4	378	66	6.3
2001	1.5	377	65	4.5
2002	1.6	376	64	4.2
2003	1.5	381	69	5.4
AVERAGE	1.5	377	65	4.4

NOTE: Ground Surface Elevation (EL) = 312

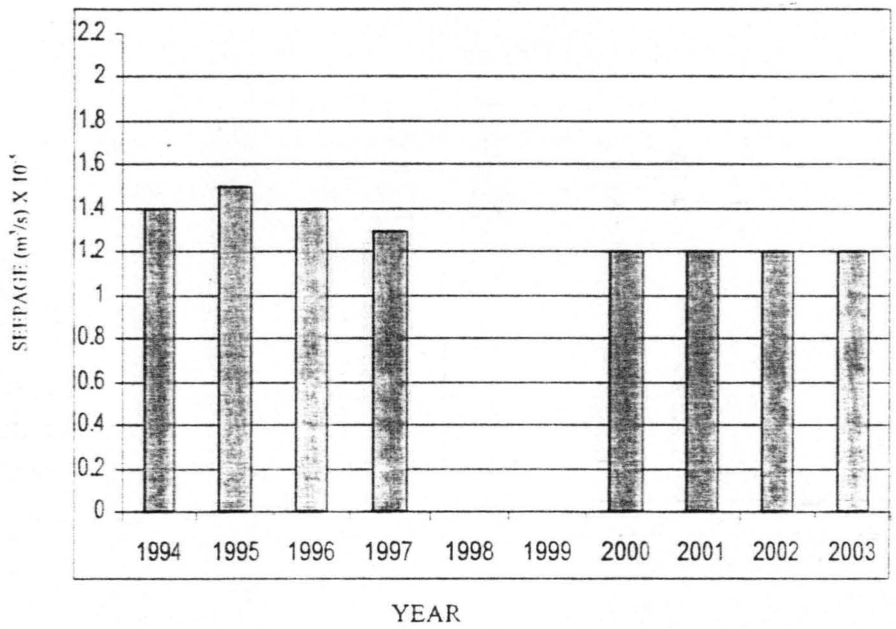


FIG. 4.13.0 SEEPAGE (m^3/s) X 10^{-5}
FOR THE MONTH OF JUNE

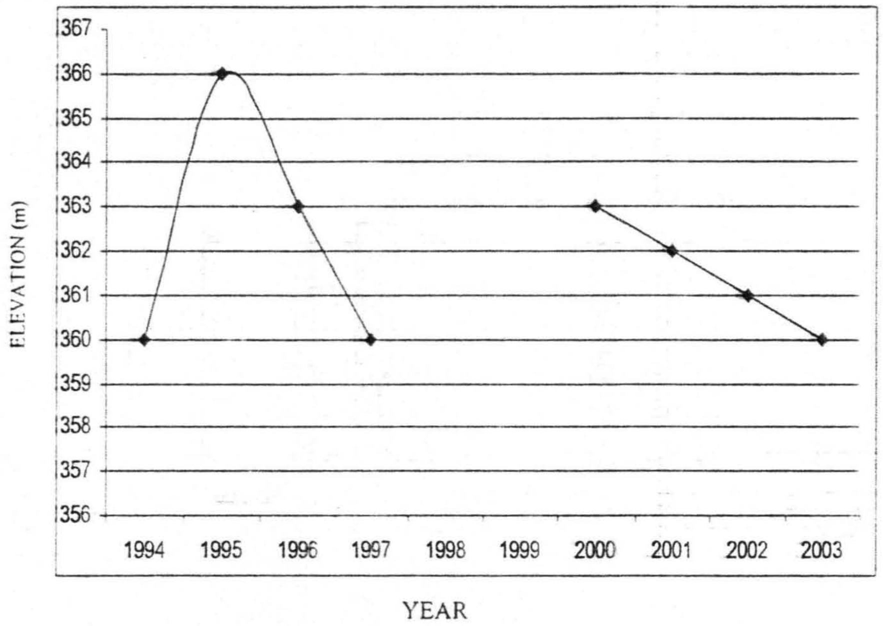


FIG. 4.13.1 ELEVATION (m) FOR
THE MONTH OF JUNE

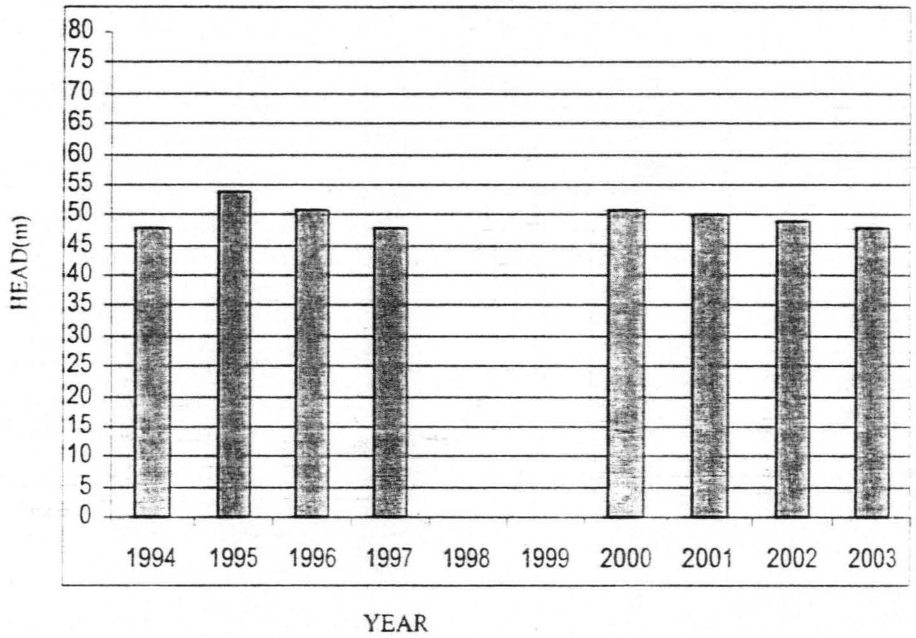


FIG. 4.13.2 HEAD (m) FOR THE MONTH OF JUNE

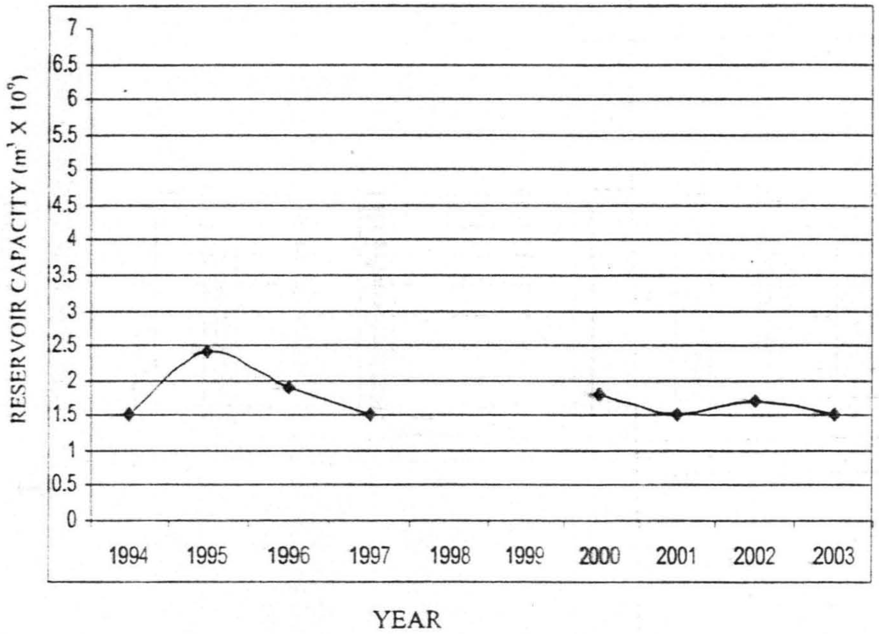


FIG. 4.13.3 RESERVOIR CAPACITY ($m^3 \times 10^9$) FOR THE MONTH OF JUNE

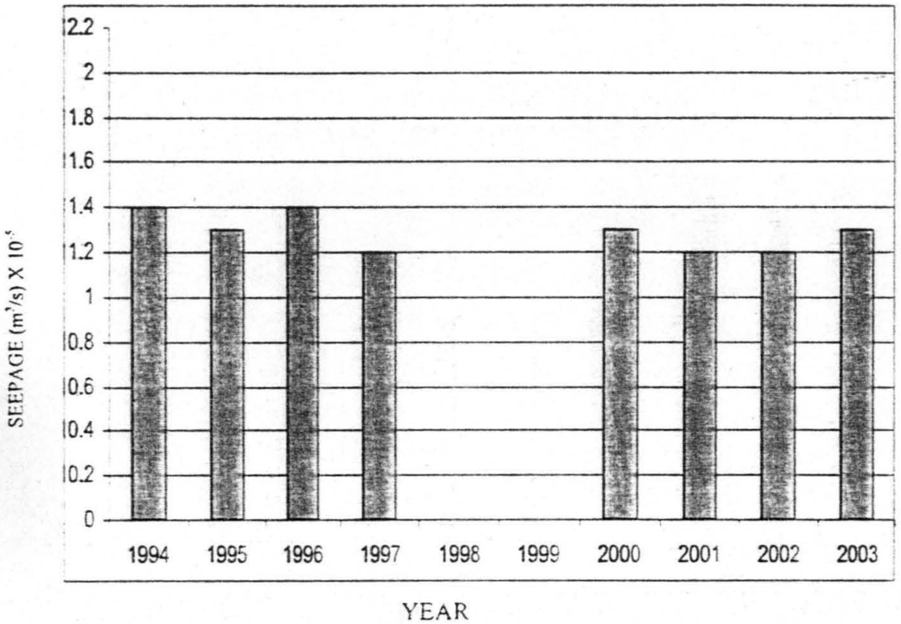


FIG. 4.14.0 SEEPAGE(m^3/s) X 10^{-5} FOR THE MONTH OF JULY

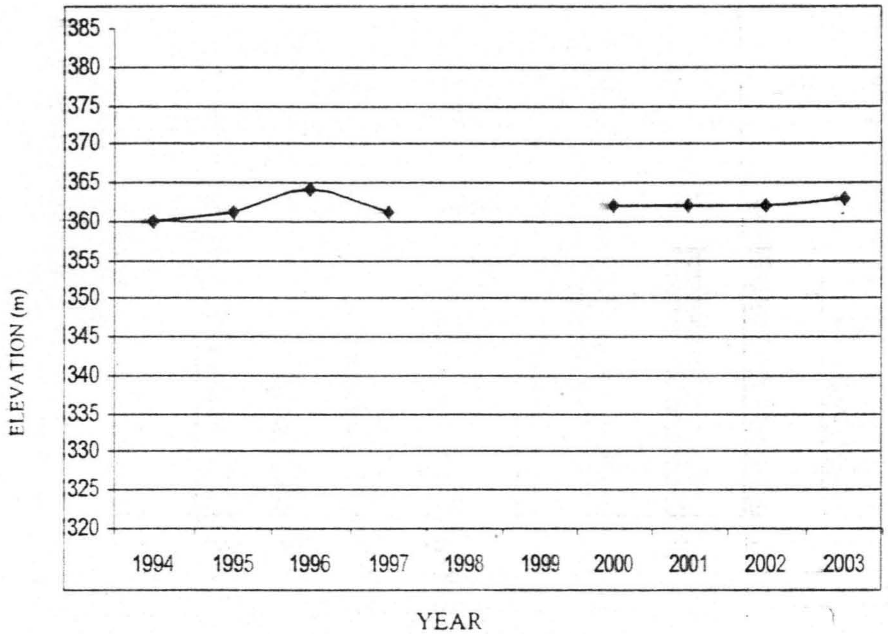


FIG. 4.14.1 ELEVATION (m) FOR THE MONTH OF JULY

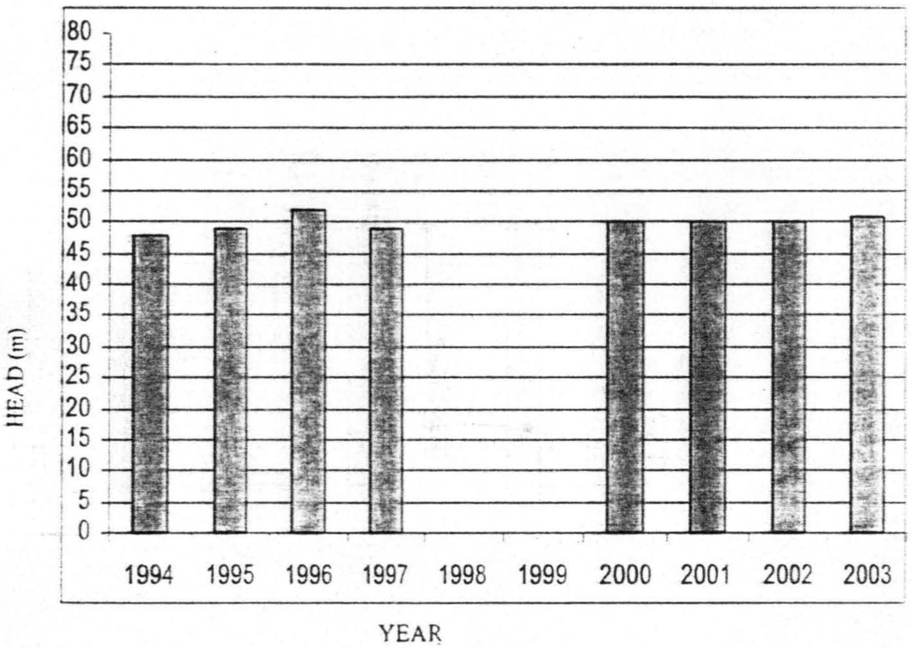


FIG. 4.14.2 HEAD (m) FOR THE MONTH OF JULY

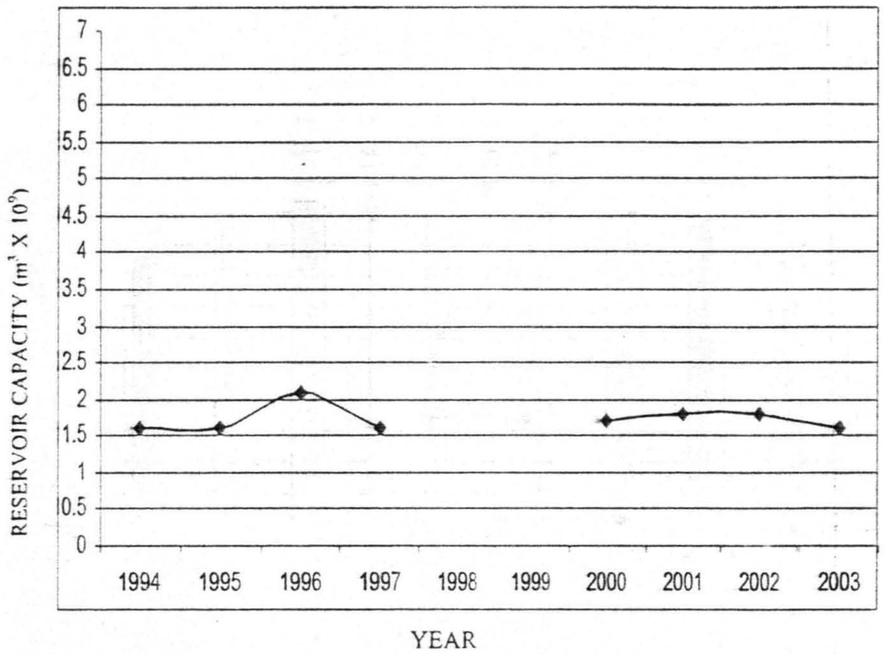


FIG. 4.14.3 RESERVOIR CAPACITY ($m^3 \times 10^9$) FOR THE MONTH OF JULY

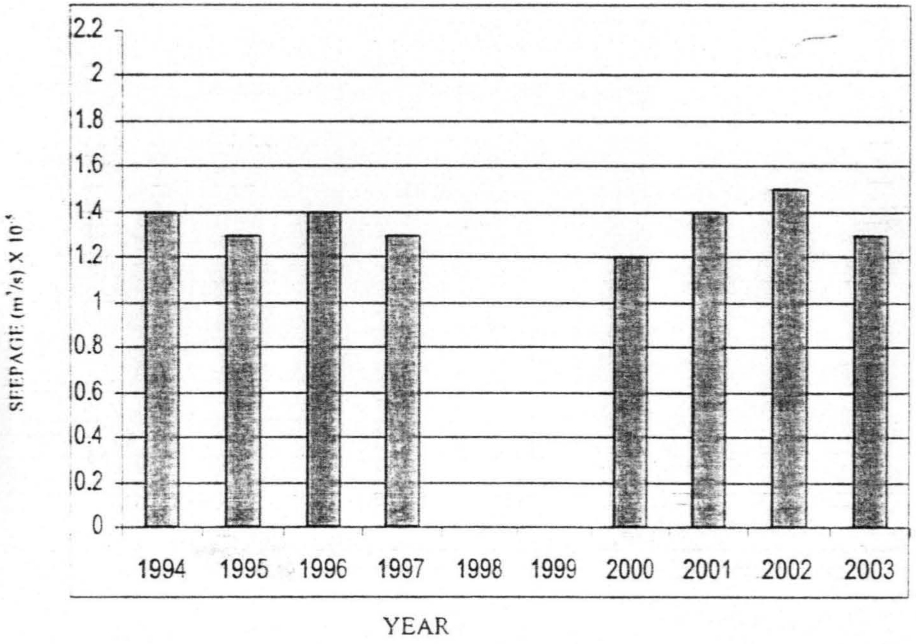


FIG. 4.15.0 SEEPAGE (m^3/s) X 10^{-5} FOR THE MONTH OF AUGUST

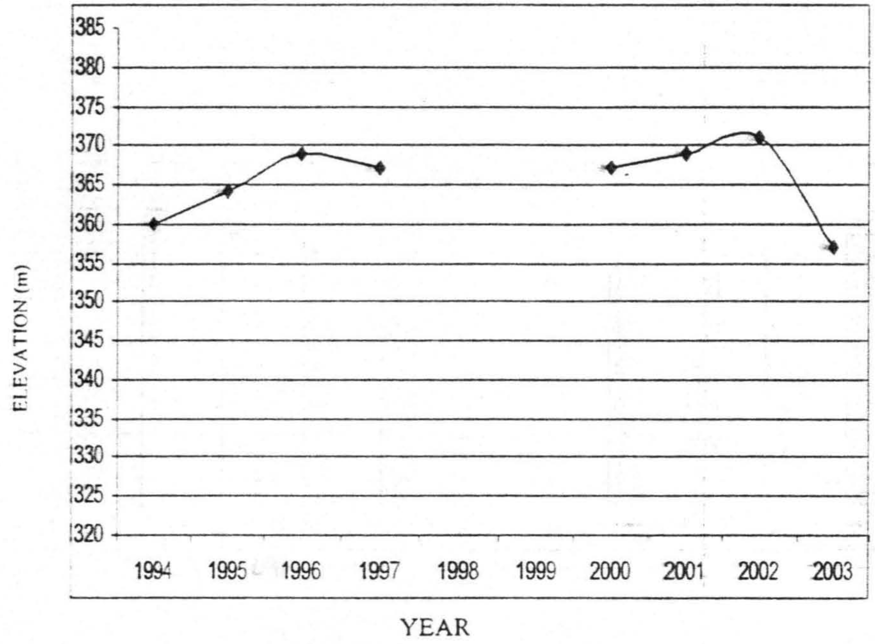


FIG. 4.15.1 ELEVATION (m) FOR THE MONTH OF AUGUST

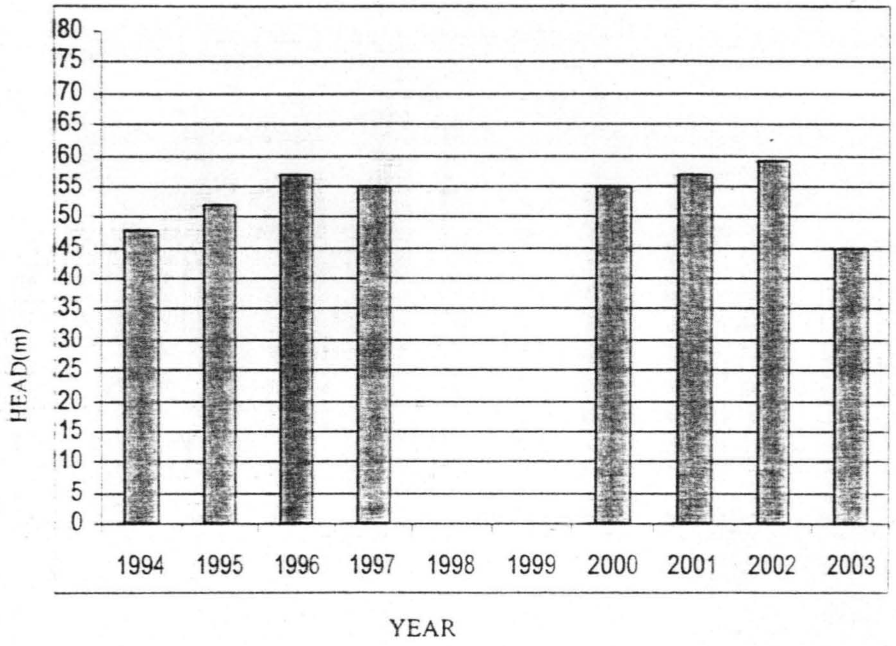


FIG. 4.15.2 HEAD (m) FOR THE MONTH OF AUGUST

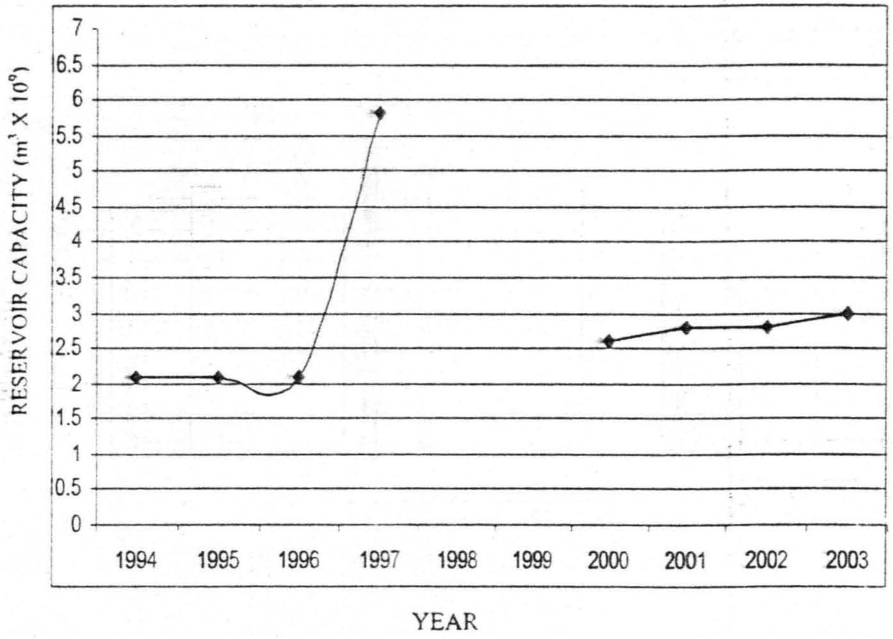


FIG. 4.15.3 RESERVOIR CAPACITY ($m^3 \times 10^9$) FOR THE MONTH OF AUGUST

distributed within the years as of August period. Figure 4.2.6 (August rainfall). Also, evaporation rate in August is very low.

(i) **September Period**

From Table 4.15, figure 4.16.0, 4.16.1, 4.16.2 and 4.16.3, maximum seepage = $1.6m^3/s \times 10^{-5}$ in 2002 and minimum seepage = $1.4m^3/s \times 10^{-5}$ in 1995, 1997 and 2000. Also maximum elevation, head and reservoir capacity are 381m in 2003, 69m in 2003 and $6.3m^3 \times 10^9$ in 2000 and minimum elevation, head and reservoir capacity are 373m in 1995, 61m in 1995 and $2.8m^3 \times 10^9$ in 1996 respectively.

Mean average seepage, elevation, head and reservoir capacity are $1.5m^3/s \times 10^{-5}$, 377m, 65m and $4.4m^3 \times 10^9$ higher than August but lower than October.

The trend of seepage action is the same as that of August period. Thus, rainfall intensity also very high within the years as can be seen in figure 4.2.7 and evaporation rate very low.

(j) **October Period**

From table 4.16, figure 4.17.0, 4.17.1, 4.17.2 and 4.17.3

The maximum seepage = $1.7m^3/s \times 10^{-5}$ in 1994

Minimum seepage = $1.4m^3/s \times 10^{-5}$ in 2001

Similarly, maximum elevation, head, reservoir capacity are:- 382m in 1994, 1996, 2000 and 2003; 70m in 1994, 1996 - 2000 and 2003; $5.9m^3 \times 10^9$ in 2003.

Also minimum elevation, head, and reservoir capacity are 378m in 1995, 66m in 1995, $4.5m^3 \times 10^9$ in 1996.

The mean average seepage, elevation, head, and reservoir capacity stands at $1.6m^3/s \times 10^{-5}$, 381m, 69m and $5.4m^3 \times 10^9$ respectively.

The seepage trend by 1994, was high $1.7m^3/s \times 10^{-5}$ and falls to $1.5m^3/s \times 10^{-5}$, rises to $1.6m^3/s \times 10^{-5}$ by 1996 - 2000, decreases to $1.4m^3/s \times 10^{-5}$ as at 2001, then back $1.6m^3/s \times 10^{-5}$ by 2002 and back to $1.5m^3/s \times 10^{-5}$ by 2003. this rise and fall is as a result of high rainfall intensity experience during the month September/October itself thus October rainfall intensity has seriously decreases compared to September figure 4.2.7 and 4.2.8 rainfall for the mouth of September and October.

(k) **November Period**

Form Table 4.17, figure 4.18.0, 4.18.1, 4.18.2 and 4.18.3

Maximum seepage = $1.7m^3/s \times 10^{-5}$ in 1994, 1996 and 1997 and minimum seepage = $1.5\ m^3/s \times 10^{-5}$ in 2003.

Also, maximum elevation, head and reservoir capacity are 382m in 1994 and 1997, 70m in 1994 and 1997, $5.7m^3 \times 10^9$ in

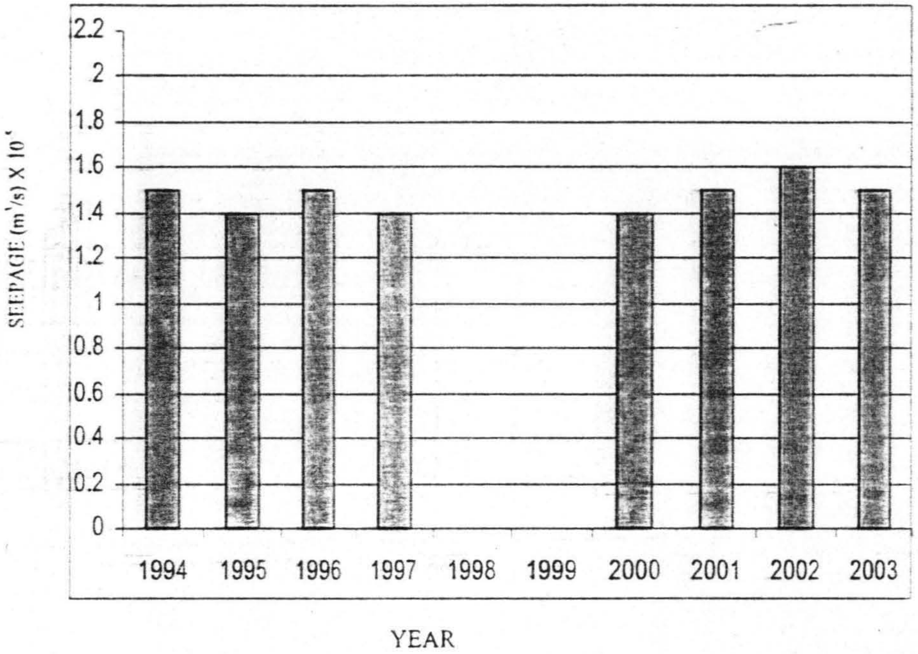
TABLE 4.16 MONTHLY RE-GROUPING OF AVERAGE DATA FOR ALL THE YEARS

MONTHS OF OCTOBER				
YEAR	SEEPAGE $m^3/s \times 10^{-5}$	ELEVATION(m)	HEAD(m)	RESERVOIR CAPACITY($m^3 \times 10^9$)
1994	1.7	382	70	5.7
1995	1.5	378	66	4.7
1996	1.6	382	70	4.5
1997	1.6	382	70	5.7
1998				
1999				
2000	1.6	382	70	5.7
2001	1.4	382	70	5.6
2002	1.6	381	69	5.3
2003	1.5	382	70	5.9
AVERAGE	1.6	381	69	5.4

TABLE 4.17

MONTH OF NOVEMBER				
YEAR	SEEPAGE $m^3/s \times 10^{-5}$	ELEVATION(m)	HEAD(m)	RESERVOIR CAPACITY($m^3 \times 10^9$)
1994	1.7	382	70	5.7
1995	1.6	378	66	4.7
1996	1.7	381	69	5.5
1997	1.7	382	70	5.6
1998				
1999				
2000	1.6	381	69	5.4
2001	1.6	379	67	5
2002	1.6	380	68	5
2003	1.5	381	69	5.4
AVERAGE	1.6	381	69	5.3

NOTE: Ground Surface Elevation (EL) = 312



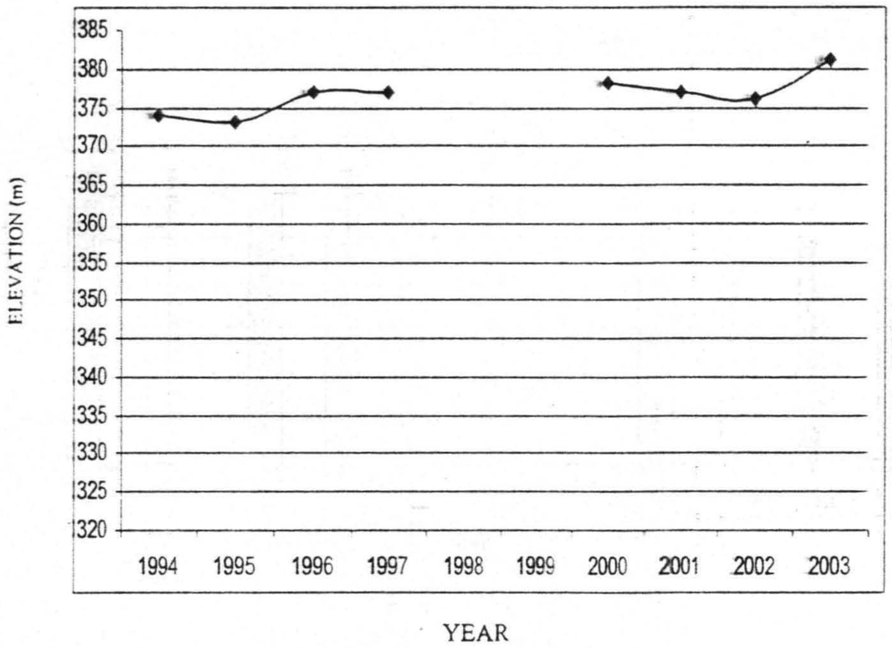


FIG. 4.16.0 SEEPAGE (m^3/s) X 10^{-5} FOR THE MONTH OF SEPTEMBER

FIG. 4.16.1 ELEVATION (m) FOR THE MONTH OF SEPTEMBER

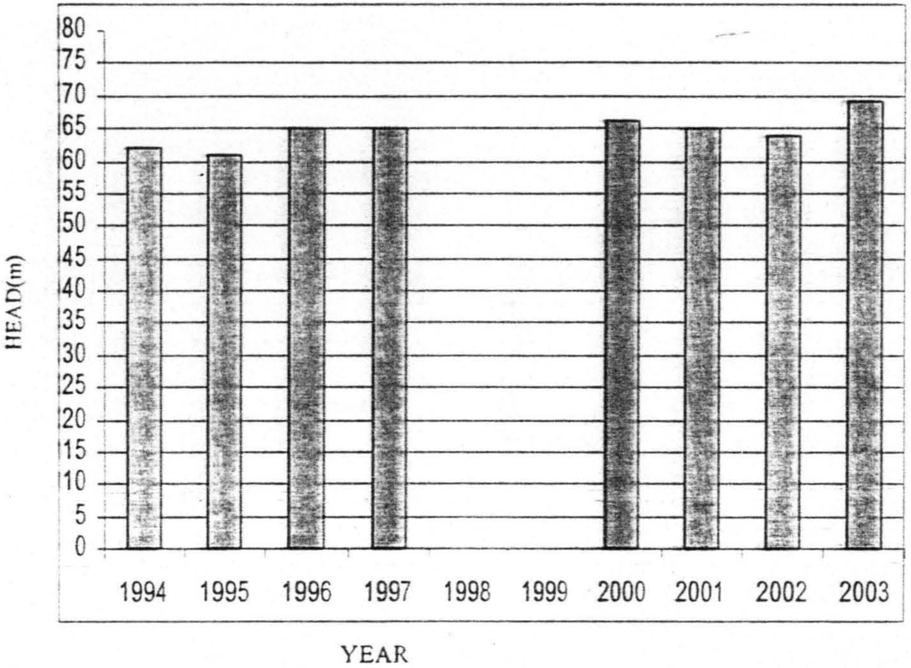


FIG. 4.16.2 HEAD (m) FOR THE MONTH OF SEPTEMBER

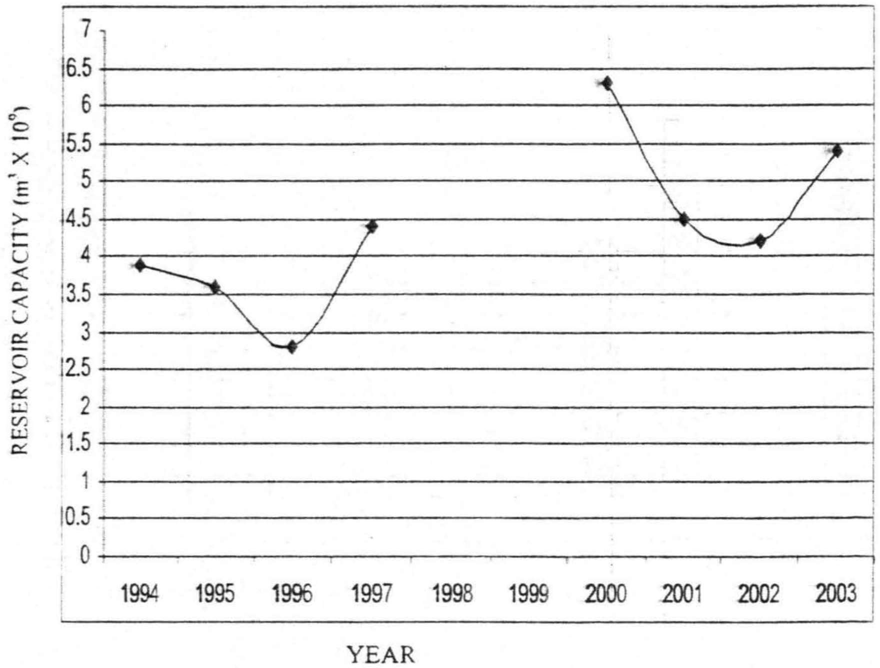


FIG. 4.16.3 RESERVOIR CAPACITY (m^3 x 10^9) FOR THE MONTH OF SEPTEMBER

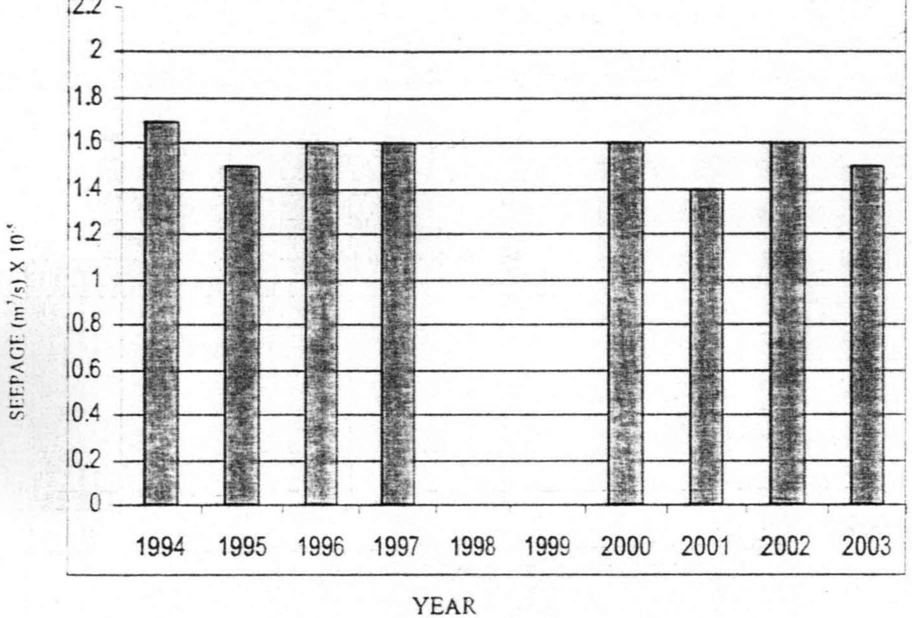


FIG. 4.17.0 SEEPAGE (m^3/s) X 10^{-5}
FOR THE MONTH OF OCTOBER

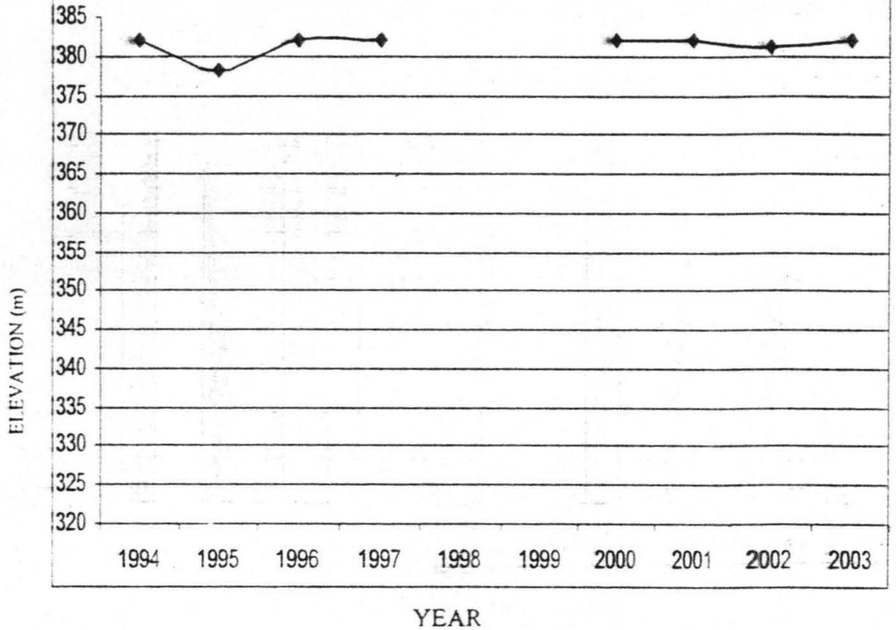


FIG. 4.17.1 ELEVATION (m) FOR
THE MONTH OF OCTOBER

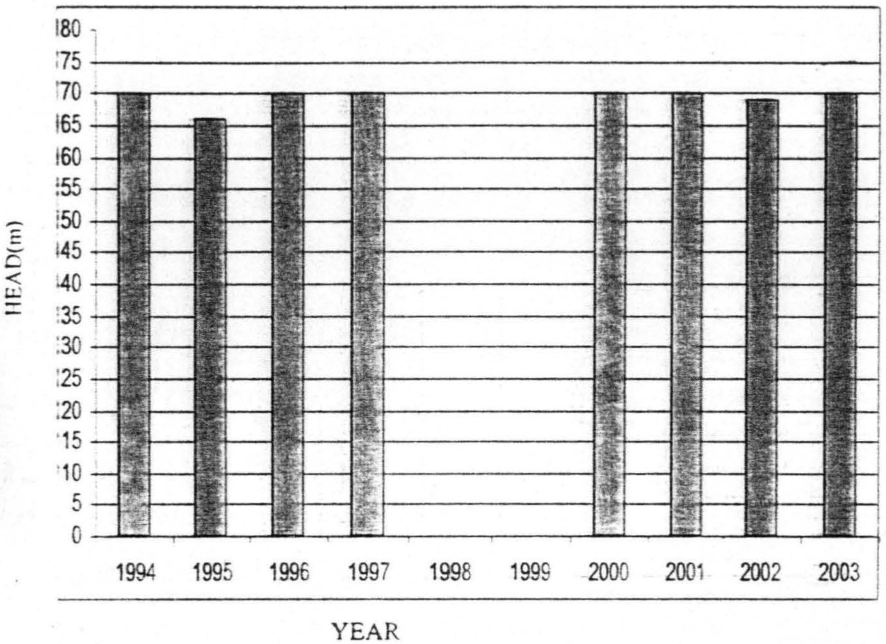


FIG. 4.17.2 HEAD (m) FOR THE MONTH OF OCTOMBER

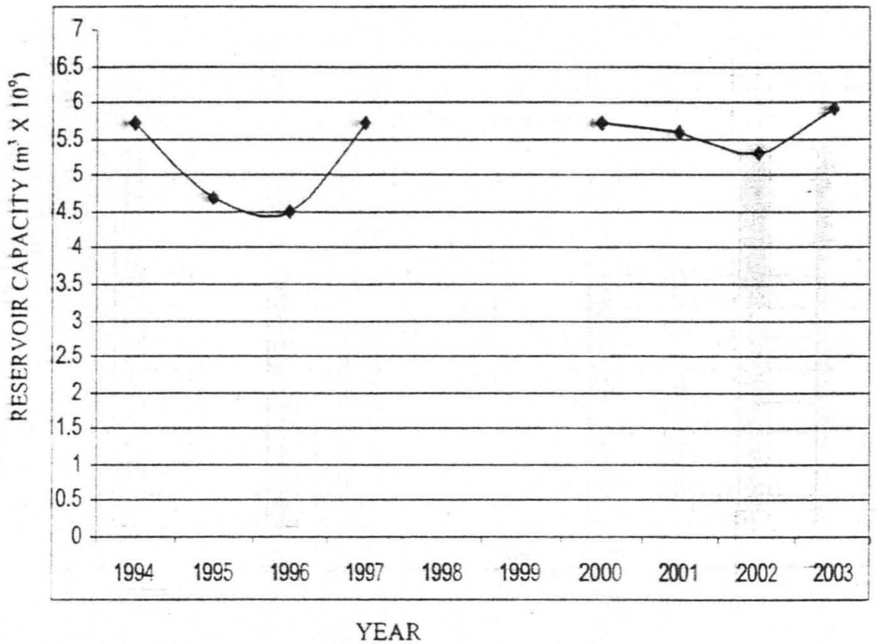


FIG. 4.17.3 RESERVOIR CAPACITY ($m^3 \times 10^9$) FOR THE MONTH OF OCTOMBER

1994. The minimum elevation, head and reservoir capacity are 378 in 1995, 66m in 1995, 4.7m^3 x 10^9 in 1995.

Mean average seepage, elevation, head and reservoir capacity are 1.6m^3/s x 10^{-5}, 381m, 69m and 5.3m^3 x 10^9.

Seepage rate from 1.7 m^3/s x 10^{-5} in 1994 falls to 1.6m^3/s x 10^{-5}; increase back to 1.7m^3/s x 10^{-5} in 1996 and 1997. Later falls down to 1.6m^3/s x 10^{-5} as of 2000 - 2002 and finally falls back to 1.5m^3/s x 10^{-5} by 2003. This period experienced high seepage rating, elevation, head and reservoir capacity as a result of the high rainfall intensity experienced in September and October month. Thus, there was not any rainfall recorded but only, evaporation rate as per figure 4.3.11.

(l) **December Period**

From Table 4.18 and figures 4.19.0, 4.19.1, 4.19.2 and 4.19.3.

The maximum seepage = 1.7 m^3/s x 10^{-5} in 1994 and 1996.

Minimum seepage = 1.4 m^3/s x 10^{-5} in 2001 and 2003.

Also, the maximum elevation, head, and reservoir capacity are 381m in 1994, 69m in 1994, 5.4m^3 x 10^9 in 1994

Minimum elevation, head, and reservoir capacity are 376m in 1995, 64m in 1995, 3.9 in 2001 respectively.

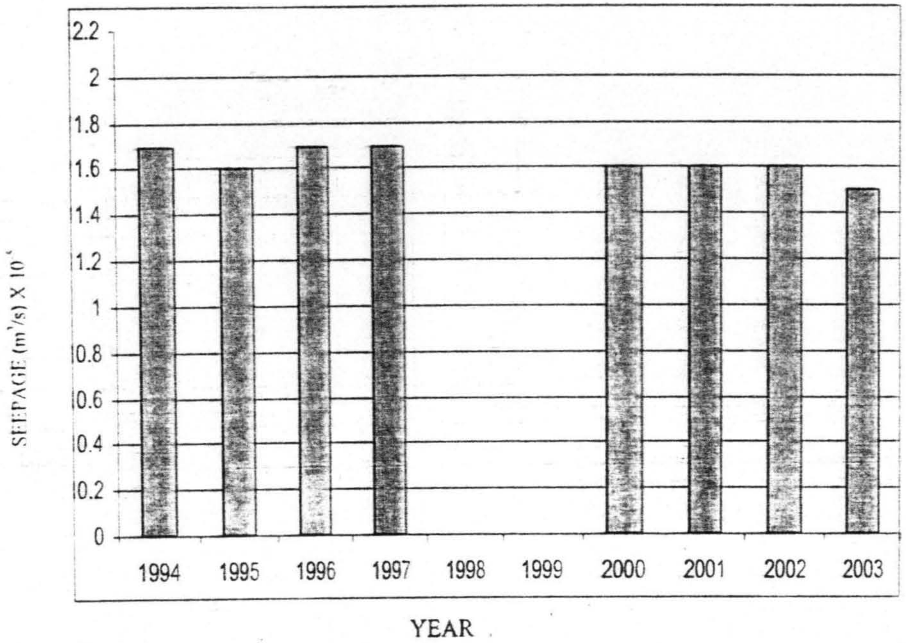
The mean average seepage, elevation, head, and reservoir capacity are m^3/s x 10^{-5}, 379m, 67m, 4.7m^3 x 10^9.

There was no rainfall by December it was only evaporation that occur as per figure 4.3.12. The trend of action for seepage elevation, head and reservoir capacity is as shown in the above figures.

TABLE 4.18 MONTHLY RE-GROUPING OF AVERAGE DATA FOR ALL THE YEARS

MONTH OF DECEMBER				
YEAR	SEEPAGE $m^3/s \times 10^{-5}$	ELEVATION(m)	HEAD(m)	RESERVOIR CAPACITY($m^3 \times 10^9$)
1994	1.7	381	69	5.4
1995	1.6	376	64	4.3
1996	1.7	379	67	4.8
1997	1.6	380	68	5
1998				
1999				
2000	1.6	379	67	4.8
2001	1.5	377	65	3.9
2002	1.6	379	67	4.4
2003	1.5	379	67	4.8
AVERAGE	1.6	379	67	4.7

NOTE: Ground Surface Elevation (EL) = 312



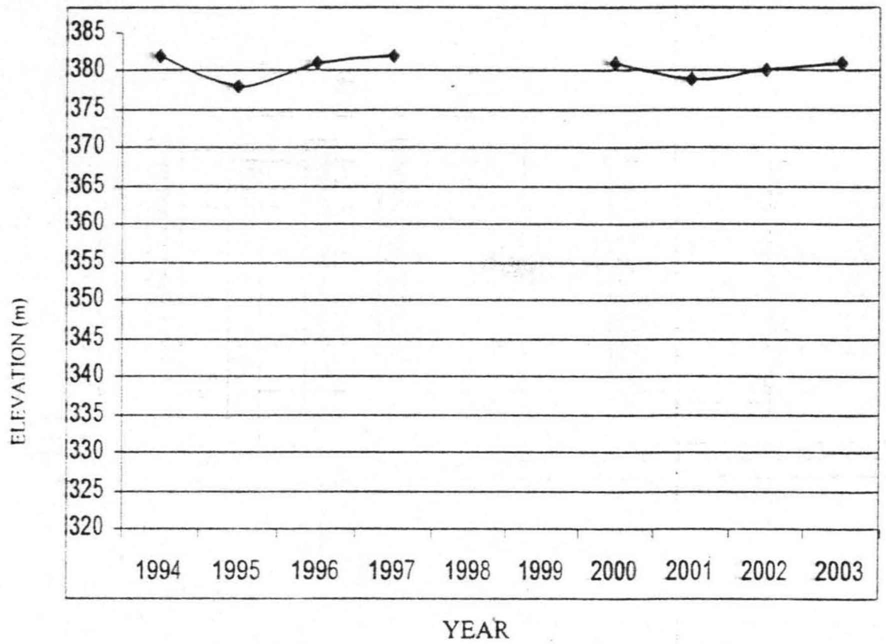


FIG. 4.18.0 SEEPAGE (m^3/s) X 10^{-5} FOR THE MONTH OF NOVEMBER

FIG. 4.18.1 ELEVATION (m) FOR THE MONTH OF NOVEMBER

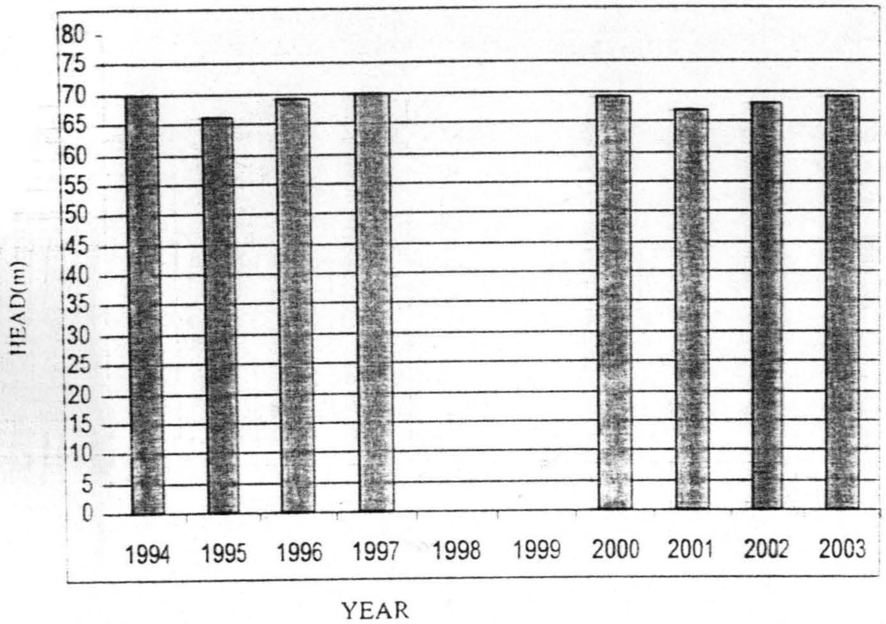


FIG. 4.18.2 HEAD (m) FOR THE MONTH OF NOVEMBER

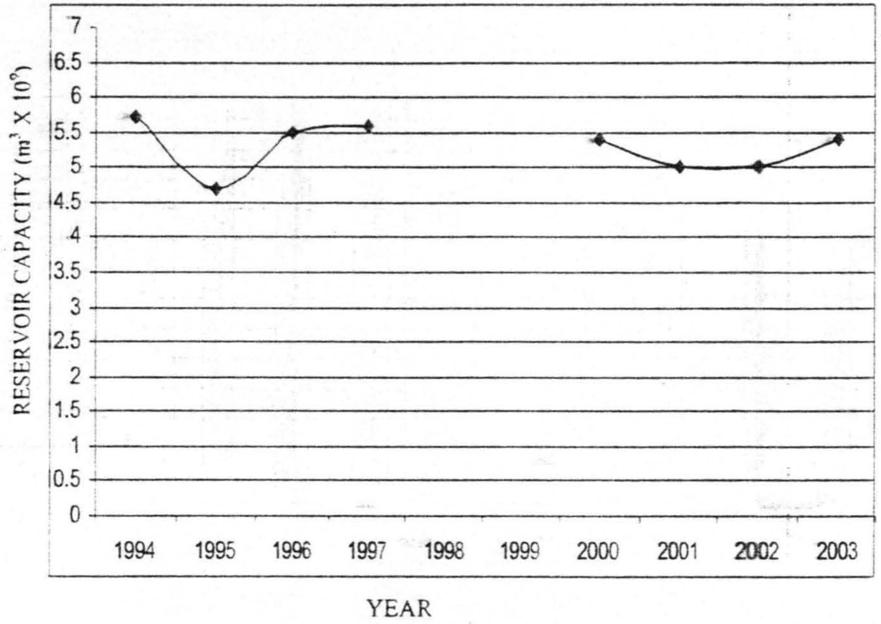


FIG. 4.18.3 RESERVOIR CAPACITY ($m^3 \times 10^9$) FOR THE MONTH OF NOVEMBER

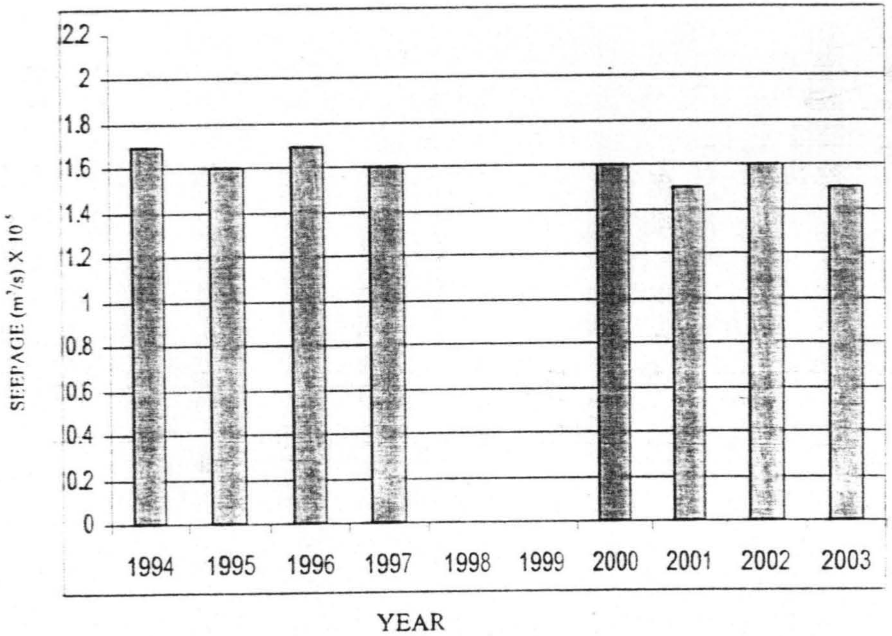


FIG. 4.19.0 SEEPAGE(m^3/s) X 10^{-5}

FOR THE MONTH OF DECEMBER

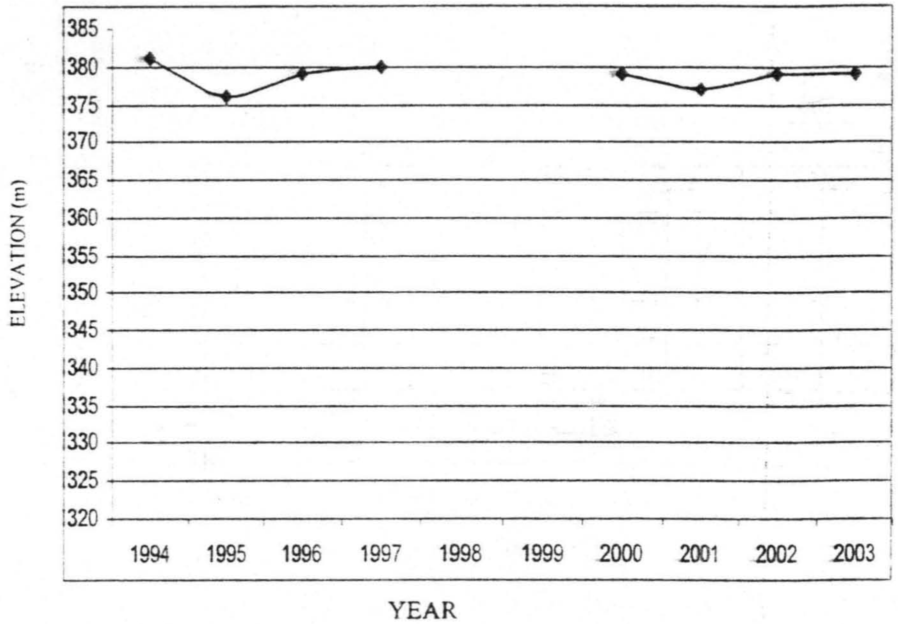


FIG. 4.19.1 ELEVATION (m) FOR

THE MONTH OF DECEMBER

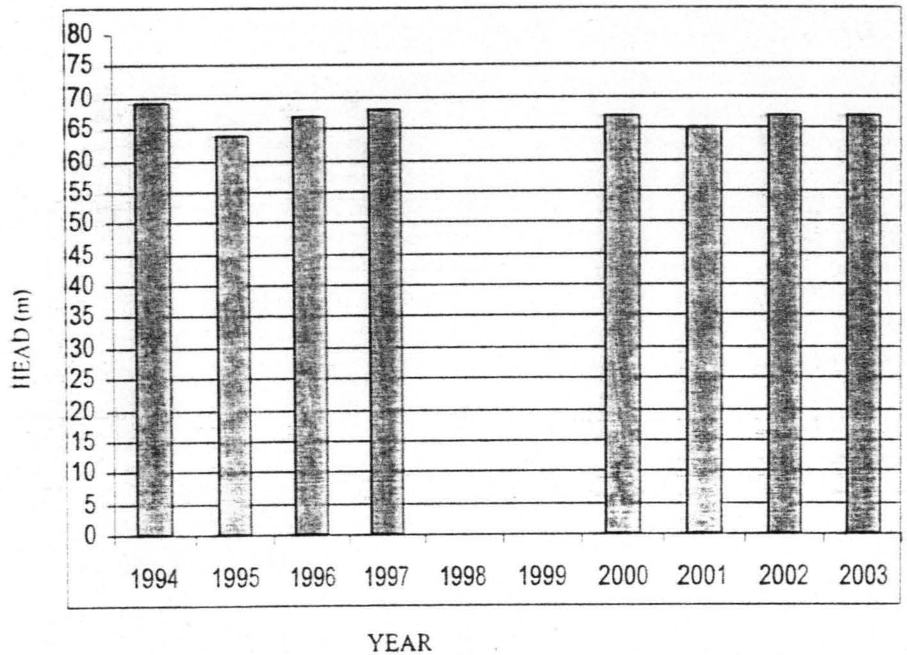


FIG. 4.19.2 HEAD (m) FOR THE MONTH OF DECEMBER

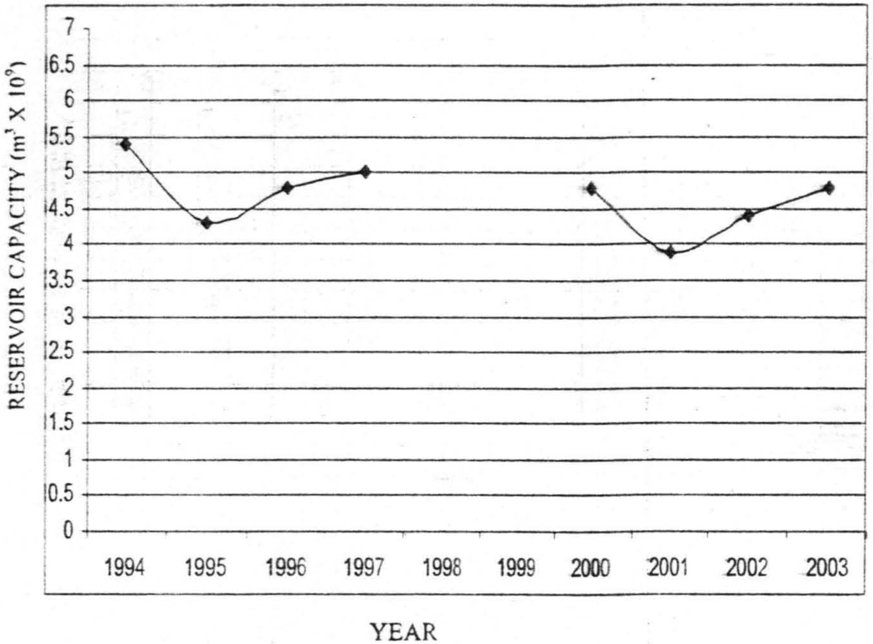


FIG. 4.19.3 RESERVOIR ($m^3 \times 10^9$) FOR THE MONTH OF DECEMBER

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

This chapter presents conclusion and recommendation based on the Data analysed for the period under study.

5.1 CONCLUSION

The following conclusions were deduced:

1. The relationship, between seepage and head had been developed for each month and years. (1994-2003).

2. The Month of January, February, March and April are the periods that always experienced the maximum seepage of 7.2 x 10^{-2} m^3/hr at Shiroro Dam reservoir, May, June and August experienced the minimum seepage of 4.32 x 10^{-2} m^3/hr.

3. Similarly, January, October and November period also experienced the maximum and minimum elevation of 382m and 329m respectively. January and November period has the maximum head of 70m and May month with a minimum head of 17m. The month of September showed the maximum reservoir capacity of 6.3 10^9 m^3 while the minimum of 1.5 x 10^9 m3 in the month of May and June.

4. Seepage is as a function of head and can be transformed into linear relationship.

5. With the maximum seepage value of 7.2×10^{-2} m^3/hr the Shiroro Dam is still structurally safe, with the proper channeling of the water lost from the Dam to a wear box down stream close to the turbine adequately take care of the seepage water.

RECOMMENDATION

1. It is advisable that further studies on seepage be conducted with further data input in the subsequent years experiencing when the available data is up to between 25 to 30 years. This will facilitate an authentic research studies and long term data base.
2. It is also recommended that NEPA should look at the possibility of converting the sophisticated gas/electrical piezometer sensor which are presently out of use to manual one's so that water level in the piezometer can be obtained by survey instrument.
3. Also, the present water release from the dam should be used for practicing irrigation farming downstream of the dam project (relevant agent e.g Federal ministry of water resources, State ministry of Agriculture e.t.c should take it up).

4. The only information on piezometer level or reading can estimate the approximate seepage line (pheratic line) in rockfill dam, unlike Earth dam where information like an reservoir head and tail water level can give an idea of seepage line pheratic line).

5. With a prototype laboratory work on rockfill in place, to determine permeability of the rock is conducted, a modified equation of Darcy's Law can be used to determine seepage quantity, viz.,

Darcy's equation $q = kiA$.

Where q = quantity of seepage (m^3/s),
K = permeability coefficient,
i = the hydraulic gradient (h/L) and
A = surface area considered (m^2).

Modified equation of Darcy's Law: $q = K_C IA$.

Where q = quantity of seepage (m^3/s)
K_C = permeability coefficient of specific rock determine in laboratory,
i = the hydraulic gradient (h/c) and
A = surface area considered (m^2).

6. That data record keeping g in Shiroro Dan should be with the aid of computer to enable proper data handling and processing plus other research studies.

REFERENCES

1. Jorme Umolu (1985) – "Dam Safety in Nigeria" General Issue and Case Studies by Federal Ministry of Water Resources, Report. Pp.21-28

2. Rushton K.R. and S.C. Redshaw (1977): "Seepage and ground water flow. Mc Graw – Hill Book Coy. Inc. New York. Pp. 142-150

3. Uginchus, A.A. (1980): "Seepage through the Earth dam" 2nd Edition Keter Press Ltd. Jerusalem. Pp. 89-102.

4. Zienkiwwicz (1987) "Seepage by Matrix Journal on Ground Water". Studies V58, No.17 Pp. 14-27.

5. R.K. Sharma and T.K. Sharma (1989) "Text book of Irrigation Engineering" Revised Version (Volume II) Dam Engineering" Pp 173-205.

6. Ray K. Linsley, JR. Max a. Kohler Joseph L.H. Paulhus (1981) Third Edition "Hydrology for Engineers." Pp. 137-140.

7. Pinder and Grary (1977): "Journal of Water Resources" Vol. 124 No 188 Pp. 32-37.

8. Oimolu Jorme (1985) "Report of Committee on Large Dams by Federal Ministry of Water Resources. Pp. 17-23.

9. Sower G.F. (1979) "Introduction to Soil Mech. and Foundation". 4th Edition Macmillan publishing CO. New York. Pp. 127-131.

10. Glenn O. Schwab, Delmar D. Fangmeirer, willian J. Elliot (1992) "Soil and Water Conservation Engineering 4th Edition" Pp. 195-199.

SEEPAGE DATA FROM SHIRORO DAM FOR THE YEAR 1994.

January	Reservoir elevation	Reservoir capacity	Weir box	Flow		
Date	m	m^3 X 10^9	H / cm	L / sec.	m^3 X 10^9	Tail Race
1.	378.760	4.8120	48.0	230	0.0000199	269.80
2.	378.710	4.8020	48.0	230	0.0000199	269.80
3.	378.650	4.7875	48.0	230	0.0000199	269.80
4.	378.590	4.7727	48.0	230	0.0000199	269.60
5.	378.550	4.7635	48.0	230	0.0000199	269.80
6.	378.480	4.7476	48.0	230	0.0000199	270.30
7.	378.390	4.7273	48.0	230	0.0000199	270.30
8.	378.330	4.7111	48.0	230	0.0000199	269.70
9.	378.260	4.6938	48.0	230	0.0000199	269.80
10.	378.180	4.6758	48.0	230	0.0000199	269.80
11.	378.120	4.6632	48.0	230	0.0000199	270.30
12.	378.030	4.6436	48.0	230	0.0000199	270.20
13.	377.930	4.6216	48.0	230	0.0000199	270.40
14.	377.810	4.5938	48.0	230	0.0000199	270.80
15.	377.750	4.5805	48.0	230	0.0000199	269.70
16.	377.670	4.5636	48.0	230	0.0000199	269.80
17.	377.610	4.5507	48.0	230	0.0000199	269.90
18.	377.530	4.5321	48.0	230	0.0000199	269.70
19.	377.430	4.5089	48.0	230	0.0000199	270.40
20.	377.340	4.4888	48.0	230	0.0000199	270.50
21.	377.250	4.4700	48.0	230	0.0000199	270.20
22.	377.170	4.4534	48.0	230	0.0000199	270.00
23.	377.100	4.4380	48.0	230	0.0000199	270.00
24.	377.010	4.4182	48.0	230	0.0000199	270.30
25.	376.920	4.4094	48.0	230	0.0000199	270.30
26.	376.820	4.3790	48.0	230	0.0000199	269.80
27.	376.710	4.3543	48.0	230	0.0000199	270.20
28.	376.621	4.3344	48.0	230	0.0000199	269.80
29.	376.430	4.3060	48.0	230	0.0000199	270.40
30.	376.350	4.2800	48.0	230	0.0000199	270.30
31.	376.220	4.2524	48.0	230	0.0000199	270.30

SEEPAGE DATA FROM SHIRORO DAM FOR THE YEAR 1995.

January	Reservoir elevation	Reservoir capacity	Weir box	Flow		
Date	m	m^3 X 10^9	H / cm	L / sec.	m^3 X 10^9	Tail Race
1.	380.560	5.2830	44.5	192	0.0000166	268.50
2.	380.550	5.2800	44.0	186	0.0000160	268.50
3.	380.540	5.2770	44.0	186	0.0000160	268.50
4.	380.520	5.2710	44.0	186	0.0000160	269.80
5.	380.480	5.22590	44.0	186	0.0000160	269.80
6.	380.440	5.2470	44.0	186	0.0000160	269.50
7.	380.390	5.2318	44.0	186	0.0000160	268.80
8.	380.360	5.2220	44.0	186	0.0000160	269.40
9.	380.320	5.2090	44.0	186	0.0000160	269.80
10.	380.280	5.1970	44.0	186	0.0000160	270.40
11.	.380.180	5.1695	44.0	186	0.0000160	270.00
12.	380.140	5.1585	44.0	186	0.0000160	269.00
13.	380.110	5.1503	44.0	186	0.0000160	269.60
14.	380.080	5.1420	44.0	186	0.0000160	269.80
15.	380.040	5.1310	44.0	186	0.0000160	270.40
16.	380.000	5.1200	44.0	186	0.0000160	270.40
17.	379.920	5.0976	44.0	186	0.0000160	269.80
18.	379.890	5.0896	44.0	186	0.0000160	269.80
19.	379.820	5.0728	44.0	186	0.0000160	269.80
20.	379.770	5.0596	44.0	186	0.0000160	269.00
21.	379.750	5.0540	44.0	186	0.0000160	268.60
22.	379.730	5.0484	44.0	186	0.0000160	268.60
23.	379.690	5.0370	44.0	186	0.0000160	269.50
24.	379.670	5.0310	44.0	186	0.0000160	269.50
25.	379.620	5.0160	44.0	186	0.0000160	269.30
26.	379.600	5.0100	44.0	186	0.0000160	269.30
27.	379.590	5.0080	44.0	186	0.0000160	269.00
28.	379.570	5.0040	44.0	186	0.0000160	268.50
29.	379.550	5.0000	44.0	186	0.0000160	268.50
30.	379.510	4.9920	44.0	186	0.0000160	269.00
31.	379.480	4.9840	44.0	186	0.0000160	269.60

SEEPAGE DATA FROM SHIRORO DAM FOR THE YEAR 1996.

January	Reservoir elevation	Reservoir capacity	Weir box	Flow		
Date.	m	m^3 X 10^9	H / cm	L / sec.	m^3 X 10^9	Tail Race
32.	375.18	4.0304	43.5	180	0.0000156	269.80
33.	375.12	4.0166	43.5	180	0.0000156	270.00
34.	375.06	4.0010	43.5	180	0.0000156	269.80
35.	375.00	3.9910	43.5	180	0.0000156	269.80
36.	374.94	3.9810	42.5	170	0.0000147	270.00
37.	374.85	3.9625	42.5	170	0.0000147	270.00
38.	374.76	3.9410	42.5	170	0.0000147	269.50
39.	374.69	3.9253	42.5	170	0.0000147	270.00
40.	374.60	3.9208	42.5	170	0.0000147	270.00
41.	374.49	3.8846	42.5	170	0.0000147	270.30
42.	374.40	3.8768	42.5	170	0.0000147	269.80
43.	374.29	3.8428	42.5	170	0.0000147	270.00
44.	374.19	3.8208	42.5	170	0.0000147	269.50
45.	374.13	3.8103	42.5	170	0.0000147	270.00
46.	374.06	3.7962	42.5	170	0.0000147	269.80
47.	373.98	3.7788	42.5	170	0.0000147	270.00
48.	373.91	3.7641	42.5	170	0.0000147	268.80
49.	373.84	3.7506	42.5	170	0.0000147	270.00
50.	373.75	3.7330	42.5	170	0.0000147	269.00
51.	373.68	3.7188	42.5	170	0.0000147	269.50
52.	373.65	3.7128	42.5	170	0.0000147	269.50
53.	373.59	3.7001	42.5	170	0.0000147	269.80
54.	373.50	3.6828	42.0	168	0.0000145	269.80
55.	373.40	3.6600	42.0	168	0.0000145	269.80
56.	373.30	3.6425	42.0	168	0.0000145	268.50
57.	373.18	3.6206	42.0	168	0.0000145	269.60
58.	373.11	3.6052	42.0	168	0.0000145	269.60
59.	373.04	3.5892	42.0	168	0.0000145	269.50
60.	372.96	3.5740	42.0	168	0.0000145	269.80
61.	372.87	3.5598	42.0	168	0.0000145	270.00
62.	372.77	3.5432	42.0	168	0.0000145	269.80

SEEPAGE DATA FROM SHIRORO DAM FOR THE YEAR 1997.

January	Reservoir elevation	Reservoir capacity	Weir box	Flow		
Date	m	m^3 X 10^9	H / cm	L / sec.	m^3 X 10^9	Tail Race
1.	377.49	4.5227	44.5	192	0.0000166	269.50
2.	377.41	4.5043	44.5	192	0.0000166	269.50
3.	377.35	4.4910	44.5	192	0.0000166	269.90
4.	377.30	4.4800	44.5	192	0.0000166	269.60
5.	377.26	4.4720	44.5	192	0.0000166	269.90
6.	377.19	4.4578	44.5	192	0.0000166	269.70
7.	377.14	4.4468	44.5	192	0.0000166	269.90
8.	376.98	4.4118	44.5	192	0.0000166	271.20
9.	376.82	4.3790	44.5	192	0.0000166	271.50
10.	376.67	4.3454	44.5	192	0.0000166	270.80
11.	376.52	4.3140	44.5	192	0.0000166	270.60
12.	376.40	4.2900	44.5	192	0.0000166	270.00
13.	376.26	4.2612	44.5	192	0.0000166	270.80
14.	376.14	4.2333	44.5	192	0.0000166	270.50
15.	375.95	4.1920	44.5	192	0.0000166	270.80
16.	375.84	4.1694	44.5	192	0.0000166	270.80
17.	375.67	4.1311	44.5	192	0.0000166	271.00
18.	375.48	4.0924	44.5	192	0.0000166	271.50
19.	375.30	4.0560	44.5	192	0.0000166	270.80
20.	375.16	4.0258	44.5	192	0.0000166	270.20
21.	374.97	3.9855	44.5	192	0.0000166	270.20
22.	374.78	3.9455	44.5	192	0.0000166	271.50
23.	374.55	3.8958	44.5	192	0.0000166	271.50
24.	374.32	3.8494	44.5	192	0.0000166	271.00
25.	374.11	3.8068	44.5	192	0.0000166	271.50
26.	373.90	3.7620	44.5	192	0.0000166	271.50
27.	373.65	3.7125	44.5	192	0.0000166	271.00
28.	373.52	3.6864	44.5	192	0.0000166	269.90
29.	373.38	3.6565	44.5	192	0.0000166	270.00
30.	373.24	3.6320	44.5	192	0.0000166	269.70
31.	373.12	3.6074	44.5	192	0.0000166	269.40

SEEPAGE DATA FROM SHIRORO DAM FOR THE YEAR 2000.

January	Reservoir Elevation	Reservoir Capacity	Weir Box	Flow		Tail Water Race
Date	M	$M^3 \times 10^9$	H/cm	L/sec	$M^3 \times 10^9$	M
1	378.87	4.8375	46.0	205	0.0000177	269.70
2	378.81	4.8225	46.0	205	0.0000177	269.70
3	378.74	4.8080	45.0	198	0.0000171	269.70
4	378.68	4.7950	45.0	198	0.0000171	269.60
5	378.61	4.7775	45.0	198	0.0000171	269.60
6	378.53	4.7589	45.0	198	0.0000171	269.30
7	378.43	4.7366	45.0	198	0.0000171	269.30
8	378.36	4.7192	45.0	198	0.0000171	269.70
9	378.27	4.6984	45.0	198	0.0000171	269.50
10	378.18	4.6758	45.0	198	0.0000171	269.50
11	378.11	4.6611	45.0	198	0.0000171	269.50
12	378.03	4.6436	45.0	198	0.0000171	269.30
13	377.98	4.6326	45.0	198	0.0000171	269.60
14	377.93	4.6216	45.0	198	0.0000171	269.60
15	377.86	4.6054	45.0	198	0.0000171	269.70
16	377.80	4.5910	45.0	198	0.0000171	269.70
17	377.74	4.5784	45.0	198	0.0000171	269.70
18	377.66	4.5614	45.0	198	0.0000171	269.70
19	377.58	4.5438	45.0	198	0.0000171	269.70
20	377.50	4.5250	45.0	198	0.0000171	269.70
21	377.43	4.5089	45.0	198	0.0000171	269.30
22	377.34	4.4888	45.0	198	0.0000171	269.70
23	377.27	4.4740	45.0	198	0.0000171	269.70
24	377.19	4.4578	45.0	198	0.0000171	269.70
25	377.11	4.4402	45.0	198	0.0000171	269.70
26	377.04	4.4248	45.0	198	0.0000171	269.60
27	376.96	4.4076	45.0	198	0.0000171	269.60
28	376.89	4.3930	45.0	198	0.0000171	269.60
29	376.82	4.3790	45.0	198	0.0000171	269.60
30	376.75	4.3635	45.0	198	0.0000171	269.60
31	376.66	4.3432	45.0	198	0.0000171	269.60

SEEPAGE DATA FROM SHIRORO DAM FOR THE YEAR 2001.

January	Reservoir Elevation	Reservoir Capacity	Weir Box	Flow		Tail Water Race
Date	M	$M^3 \times 10^9$	H/cm	L/sec	$M^3 \times 10^9$	M
1	377.42	4.5066	43.5	180	0.0000156	270.80
2	377.31	4.4822	43.5	180	0.0000156	270.40
3	377.20	4.4600	43.5	180	0.0000156	270.20
4	377.09	4.4358	43.5	180	0.0000156	270.40
5	376.98	4.4118	43.5	180	0.0000156	270.40
6	376.88	4.3910	43.5	180	0.0000156	270.40
7	376.77	4.3681	43.5	180	0.0000156	270.40
8	376.65	4.3910	43.5	180	0.0000156	270.40
9	376.55	4.3200	43.5	180	0.0000156	270.40
10	376.44	4.2980	43.5	180	0.0000156	270.40
11	376.33	4.2760	43.5	180	0.0000156	270.30
12	376.23	4.2546	43.5	180	0.0000156	270.40
13	376.12	4.2284	43.5	180	0.0000156	270.40
14	376.01	4.2042	43.5	180	0.0000156	270.40
15	375.89	4.1799	43.5	180	0.0000156	270.40
16	375.79	4.1587	43.5	180	0.0000156	270.40
17	375.68	4.1334	43.5	180	0.0000156	270.40
18	375.56	4.1074	43.5	180	0.0000156	270.40
19	375.45	4.0870	43.5	180	0.0000156	270.40
20	375.32	4.0604	43.5	180	0.0000156	270.40
21	375.20	4.0350	43.5	180	0.0000156	270.40
22	375.08	4.0076	43.5	180	0.0000156	270.40
23	374.95	3.9825	43.5	180	0.0000156	270.40
24	374.84	3.9600	43.5	180	0.0000156	270.40
25	374.71	3.9298	43.5	180	0.0000156	270.40
26	374.58	3.9013	43.5	180	0.0000156	270.40
27	374.45	3.8768	43.5	180	0.0000156	270.40
28	374.33	3.8516	43.5	180	0.0000156	270.40
29	374.21	3.8248	43.5	180	0.0000156	270.40
30	374.08	3.8006	43.5	180	0.0000156	270.40
31	373.95	3.7725	43.5	180	0.0000156	270.40

SEEPAGE DATA FROM SHIRORO DAM FOR THE YEAR 2002.

January	Reservoir Elevation	Reservoir Capacity	Weir Box	Flow		Tail Water Race
Date	m	$M^3 \times 10^9$	H/cm	L/sec	$M^3 \times 10^9$	M
1	372.22	3.4334	43.0	176	0.0000152	270.00
2	372.10	3.4100	42.5	170	0.0000147	270.00
3	371.99	3.3907	42.5	170	0.0000147	270.80
4	371.84	3.3610	42.5	170	0.0000147	270.30
5	371.70	3.3330	42.5	170	0.0000147	271.00
6	371.50	3.3000	42.5	170	0.0000147	270.40
7	371.35	3.2695	42.5	170	0.0000147	270.40
8	371.15	3.2305	42.5	170	0.0000147	271.40
9	370.90	3.1875	42.5	170	0.0000147	271.00
10	370.80	3.1680	42.5	170	0.0000147	269.70
11	370.73	3.1554	42.5	170	0.0000147	269.70
12	370.66	3.1420	42.5	170	0.0000147	269.70
13	370.58	3.1260	42.5	170	0.0000147	269.70
14	370.50	3.1100	42.5	170	0.0000147	269.70
15	370.42	3.0964	42.5	170	0.0000147	269.70
16	370.35	3.0840	42.5	170	0.0000147	269.70
17	370.26	3.0680	42.5	170	0.0000147	269.70
18	370.18	3.0534	42.5	170	0.0000147	269.70
19	370.11	3.0391	42.5	170	0.0000147	269.70
20	370.05	3.0285	42.5	170	0.0000147	269.70
21	369.98	3.0160	42.5	170	0.0000147	269.70
22	369.91	3.0020	41.5	162	0.0000140	269.70
23	369.84	3.9910	41.5	162	0.0000140	269.70
24	369.74	3.9745	41.5	162	0.0000140	269.70
25	369.64	3.9576	41.5	162	0.0000140	270.40
26	369.52	3.9345	41.5	162	0.0000140	269.70
27	369.44	3.9229	41.5	162	0.0000140	269.80
28	369.37	3.9115	41.5	162	0.0000140	269.70
29	369.32	3.9015	41.5	162	0.0000140	269.70
30	369.25	38878	41.5	162	0.0000140	269.70
31	369.18	3.8740	41.5	162	0.0000140	269.70

SEEPAGE DATA FROM SHIRORO DAM FOR THE YEAR 2003.

January	Reservoir Elevation	Reservoir Capacity	Weir Box	Flow		Tail Water Race
Date	M	$M^3 \times 10^9$	H/cm	L/sec	$M^3 \times 10^9$	M
1	375.68	4.1334	43.5	180	0.0000156	269.80
2	375.59	4.1131	43.5	180	0.0000156	270.40
3	375.43	4.0924	43.5	180	0.0000156	270.40
4	375.42	4.0816	43.5	180	0.0000156	269.80
5	375.37	4.0714	43.5	180	0.0000156	269.80
6	375.30	4.0560	43.5	180	0.0000156	269.80
7	375.21	4.0371	43.5	180	0.0000156	269.60
8	375.14	4.0212	43.5	180	0.0000156	269.80
9	375.05	4.0010	43.5	180	0.0000156	270.40
10	374.95	3.9825	43.5	180	0.0000156	270.40
11	374.85	3.9625	43.5	180	0.0000156	270.40
12	374.74	3.9365	43.5	180	0.0000156	270.40
13	374.62	3.9096	43.5	180	0.0000156	270.40
14	374.51	3.8884	43.5	180	0.0000156	270.40
15	374.39	3.8688	43.5	180	0.0000156	270.40
16	374.27	3.8383	43.0	176	0.0000149	270.40
17	374.15	3.8138	43.0	176	0.0000149	270.40
18	374.02	3.7874	43.0	176	0.0000149	270.40
19	373.95	3.7725	43.0	176	0.0000149	269.60
20	373.88	3.7582	43.0	176	0.0000149	269.60
21	373.80	3.7430	43.0	176	0.0000149	269.80
22	373.75	3.7330	43.0	176	0.0000149	269.80
23	373.69	3.7188	43.0	176	0.0000149	269.80
24	373.62	3.7062	43.0	176	0.0000149	269.80
25	373.49	3.6803	43.0	176	0.0000149	270.40
26	373.41	3.6623	43.0	176	0.0000149	269.90
27	373.33	3.6478	43.0	176	0.0000149	270.40
28	373.24	3.6320	43.0	176	0.0000149	269.80
29	373.16	3.6162	43.0	176	0.0000149	269.80
30	373.10	3.6030	43.0	176	0.0000149	269.80
31	373.06	3.5846	43.0	176	0.0000149	269.80

APPENDIX I

TOTAL: MONTHLY EVAPORATION LOSS RATE RECORD FROM 1985 TO 2000

	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	
	263.19	319.73	273.05	212.47	240.75	144.76	238.63	240.06	260.8	180.55	256.15	267.64	TOTAL
1985	8.49	11.42	9.1	7.08	7.77	4.83	7.70	7.74	8.69	5.82	8.54	8.63	AVERAGE
	250.93	263.4	243.23	233.58	187.86	161.29	128.91	145.9	197.88	160.77	186.15	293.99	TOTAL
1986	8.09	9.41	8.11	7.79	6.06	5.38	4.16	14.71	6.60	5.19	6.21	9.48	AVERAGE
	313.92	309.43	314.59	341.25	290.23	183.22	147.74	136.16	148.26	184.45	236.72	281.24	TOTAL
1987	10.13	11.05	10.49	11.38	9.36	6.12	4.77	4.39	4.94	5.95	7.89	9.07	AVERAGE
	289.68	333.66	335.89	232.55	215.25	165.2	164.81	181.48	157.51	189.58	238.38	263.51	TOTAL
1988	9.34	11.92	11.20	7.75	6.94	5.51	5.32	5.85	5.25	6.12	7.95	8.50	AVERAGE
	337.92	343.81	306.94	280.77	185.55	140.32	122.02	195.55	272.90	350.71	573.51	635.49	TOTAL
1989	10.90	12.28	10.23	9.36	5.99	4.68	3.94	6.31	9.10	11.31	19.12	20.50	AVERAGE
	663.73	705.78	768.01	391.92	236.31	208.07	182.03	226.77	368.32	406.94	477.59	445.58	TOTAL
1990	21.41	25.21	25.60	13.06	7.62	6.94	5.87	7.32	12.28	13.13	15.92	14.37	AVERAGE
										412.32			TOTAL
1991										13.30			AVERAGE
										381.48			TOTAL
1992										12.31			AVERAGE
										432.12			TOTAL
1993										13.94			AVERAGE
	583.04	305.18	326.66	208.66	192.86	167.48	152.1	219.43	373.13	490.93	756.69	756.69	TOTAL
1994	18.8	10.9	10.52	6.92	6.22	5.58	4.91	7.08	7.25	12.04	16.36	24.41	AVERAGE
	626.37	675.32	674.64	504.91	349.02	211.09	142.41	154.68	240.67	314.37	334.33	484.33	TOTAL
1995	20.21	24.12	21.76	16.83	11.26	7.04	4.59	4.99	8.02	10.14	11.16	15.62	AVERAGE
	488.17	420.47	375.33	287.87	211.94	164.52	150.03	158.6	279.64	373.02	538.69	539.69	TOTAL
1996	15.75	15.02	12.11	9.60	6.84	5.48	4.84	5.12	9.3	12.03	17.94	17.41	AVERAGE
	483.46	505.1	345.25	225.38	182.91	126.3	145.71	156.37	293.84	391.84	372.26	543.37	TOTAL
1997	15.60	18.04	11.14	7.51	5.90	4.2	4.7	5.04	9.79	12.64	12.41	17.5	AVERAGE
	591.92	602.16	610.63	348.18	201.12	154.06	121.46	171.88	305.52	346.76	479.76	545.22	TOTAL
1998	19.04	21.5	19.7	11.61	6.49	5.14	3.92	5.54	10.18	11.19	15.99	17.59	AVERAGE
	536.7	349.76	454.51	343.33	250.73	189.41	312.04	125.88	264.77	363.27	465.48	645.89	TOTAL
1999	17.31	12.49	14.66	11.44	8.09	6.31	4.25	4.06	8.83	11.73	15.52	20.84	AVERAGE
	565.86	662.12	643.33	350.96	265.59	172.57	131.33	159.8	221.63	306.75	473.65	557.6	TOTAL
2000	18.25	22.83	20.75	11.7	8.57	5.75	4.24	5.15	7.39	9.9	15.79	17.99	AVERAGE

APPENDIX J

TOTAL MONTHLY RAINFALL RECORD SHIRORO DAM FROM 1985 - 2000. (mm)

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	Total	Average Rainfall
1985	NIL	NIL	34.2	13.5	118.9	107.3	244.4	485.1	367.4	30.4	NIL	NIL	1401	117
1986	NIL	NIL	13.4	58.8	66.4	186.9	277.6	279	350.2	60.1	34.5	-	1327	111
1987	NIL	NIL	12.5	13.5	62.5	217.5	151.5	188.7	245	84.5	NIL	NIL	976	81
1988	NIL	NIL	NIL	155.1	88.2	174.9	239.6	289.5	361.4	11.7	NIL	NIL	1320	110
1989	NIL	NIL	2.5	91.2	189.8	152.6	152.5	289.6	118	80.5	NIL	NIL	1077	90
1990	NIL	NIL	NIL	175	160	228	416	278	350	145	NIL	1	1749	146
1991	NIL	NIL	6	22	300	146	450	238	158	38	NIL	NIL	1358	113
1992	NIL	NIL	3	75	198	183	188	280	363	139	NIL	NIL	1442	120
1993	NIL	NIL	22	27	69	165	378	258	335	238	NIL	NIL	1327	111
1994	NIL	NIL	NIL	59	75	226	107	265	209	148	NIL	NIL	1179	98
1995	NIL	NIL	NIL	2	108	132	192	444	178	88	NIL	NIL	1204	100
1996	NIL	NIL	1	44	165	214	190	234	307	181	NIL	NIL	1243	104
1997	NIL	NIL	42	63	192	190	309	271	473	142	NIL	NIL	1722	144
1998	NIL	NIL	1	69	103	186	278	281	195	142	NIL	NIL	1255	105
1999	NIL	NIL	NIL	37	111	221	201	196	411	182	NIL	NIL	1357	113
2000	NIL	NIL	NIL	9.7	112.8	181.6	213.8	364.7	168.2	99.72	NIL	NIL	1151	96