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Special Study on Sediment Discharge and Its Consequences (SedSS)

Technical Report Number 4

ANALYSIS AND RESULTS OF DISCHARGE AND SEDIMENT MONITORING ACTIVITIES IN THE SOUTHERN LAKE TANGANYIKA BASIN, ZAMBIA

by
H M Sichingabula
1999

Pollution Control and Other Measures to Protect Biodiversity in Lake Tanganyika (RAF/92/G32)
Lutte contre la pollution et autres mesures visant à protéger la biodiversité du Lac Tanganyika (RAF/92/G32)

Le Projet sur la diversité biologique du lac Tanganyika a été formulé pour aider les quatre Etats riverains (Burundi, Congo, Tanzanie et Zambie) à élaborer un système efficace et durable pour gérer et conserver la diversité biologique du lac Tanganyika dans un avenir prévisible. Il est financé par le GEF (Fonds pour l'environnement mondial) par le biais du Programme des Nations Unies pour le développement (PNUD)"	The Lake Tanganyika Biodiversity Project has been formulated to help the four riparian states (Burundi, Congo, Tanzania and Zambia) produce an effective and sustainable system for managing and conserving the biodiversity of Lake Tanganyika into the foreseeable future. It is funded by the Global Environmental Facility through the United Nations Development Programme.

Burundi: Institut National pour Environnement et Conservation de la Nature
D R Congo: Ministrie Environnement et Conservation de la Nature
Tanzania: Vice President's Office, Division of Environment
Zambia: Environmental Council of Zambia

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SYNOPSIS

Lake Tanganyika is among Zambia's important fisheries which require protection from adverse impacts. Sedimentation is one of the threats to Lake Tanganyika's biodiversity. This is because deposition of sediment clogs streams and reduces their capacities. Pollution by sediment is also one of the major factors causing deterioration in quality of streams and lakes. The sediment deposited into streams, lakes and reservoirs destroys the habitat for fish and other species. In aquatic environments, sediment impairs the dissolved oxygen balance and obscures the light needed for aquatic growth, both of which are detrimental to aquatic life forms. Additionally, heavier sediment particles blanket fish spawning areas and cover food supplies for many species.

Pesticides and nutrients origination from agricultural lands are carried off the land by sediment in surface runoff and add to the pollution of downstream waters. For example, phosphates are adsorbed by soil colloids and move into streams and lakes through erosion of soil particles on which it is adsorbed. Nitrogen fertilisers together with phosphorus are the major cause of eutrophication in lakes and rivers which is detrimental to aquatic species. Therefore, the prevention of soil erosion by good conservation practices are the most efficient means of controlling pollution from agricultural lands.

The physical characteristics of Lake Tanganyika basin are to a large extent controlled by the geology which is dominated by meta-quartzites of Precambrian ages. These rocks with the high rainfall regime experienced in the area have given rise to the high leached sandveldt soils which characterise the plateau area. These features of the physical environment in the lake Tanganyika basin are discussed in detail.

This report documents the activities of the Zambia Special Sediment Study undertaken in almost a period of one year. Methods of data collection an errors inherent in methods used are also discussed. The determination of volumes of discharge and sediment deposited in the lake employed on various statistical models in the development of rating curves. The models selected were tested for accuracy before they were applied to monitored water level data.

The study found that mean flow discharges on rivers draining into Lake Tanganyika ranged from 1.426 m^3 s^{-1} on Izi River to 98.563 m^3 s^{-1} on Lufubu River. The lowest and maximum discharges ranged from 0.183 m^3 s^{-1} on Lucheche River to 346.68 m^3 s^{-1} per day on Lufubu River. Similarly, quantities of clastic suspended sediment deposited by the five rivers into the lake between September, 1998 and May, 1999 were found to range from 0.082 tonnes on Kalambo River to 1,539.634 tonnes per day on Lufubu River. The mean values of sediment deposited into Lake Tanganyika were found to range from 1.248 tonnes on Izi River to 208.603 tonnes per day on Lufubu River.

Magnitude frequency analysis was used in the determination of the flow ranges which transport the most load in a single year. The effective discharge on the studied rivers was variable ranging from 0.78 m^3 s^{-1} on Izi River to 258 m^3 s^{-1} on the Lufubu River. The durations of these class-based effective discharges were found to range from 2.1% corresponding to the highest discharge, to 54.5% of the time on Izi River where the lowest event transported the most load. The sediment-discharge regimes for rivers in southern Lake Tanganyika basin were characterised by a uniform histogram having a well defined mode and a relatively frequent effective discharge. This was exemplified by Lucheche River. In cases where the regime in which the lower level flows were the effective discharge this was exemplified by Lunzua River

Izi River characterised an erratic sediment-discharge form due to discharges of widely differing durations transporting similar loads. Finally, Kalambo River and Lufubu rivers characterised the sediment-discharge form in which the extreme upper level events are the effective discharge. Kalambo River had this form because it is generally flashy in character while on Lufubu, large flow events transport the most load perhaps to due greater depths of scour experienced around the annual discharge peak. Deep scouring of the stream bed promotes increased sediment transport as lots of interstitial fine sediments are liberated and accessed by high flow at flood times.

Changes in bed elevations were found to range from 0.27 m on Kalambo to 1.4 m on Lufubu River with a mean of 0.61 m. These changes in given reaches if multiplied by average channel width would translate into large quantities of sediment being liberated from the bed and thus accessed by the high flows.

The study also found that in terms of specific sediment yield, the five rivers each supply or contribute between 1.2 and 9.6 tonnes of sediment per km^2. The data also shows that sediment yield decreases with drainage area. However, if the catchment are not protected from activities such as tree clearing for agriculture and settlements, the sediment yield rates could increase drastically. Fortunately, in Zambia the Lake Tanganyika basin is protected due the existence of National Parks and Forest reserves. The total area of National Forests is 162,971 hectares. The total area under protection of forest reserves and national parks is 0.36 million ha which is about 20% of the total catchment area of 1.76 million hectares. Sumbu National Park which is located on the western side of the southern Lake Tanganyika basin has an area of 2,020 km^2. The existence of this National Park and forest reserves in this basin, goes a long way in affording protection to headwaters regions of many rivers draining into Lake Tanganyika. This offers great potential in reducing amounts of sediment being removed by rivers.

It is concluded that, rivers in the southern Lake Tanganyika basin transport drain quite a considerable amount of discharge into Lake Tanganyika. This could partly be responsible for decreased lake levels observed at Mpulungu gauging station. Threats to and potentials of Lake Tanganyika in terms of biodiversity can best be addressed by linking the above findings to results of other interrelated studies in the basin.

It is recommended that low level scientific research on various aspects of the environment in the southern Lake Tanganyika basin, for the preservation and promotion of Lake Tanganyika's rich biodiversity, be supported.

1.0 INTRODUCTION

1.1 Introduction

This is the Final Report of the Zambia Special Sediment Study Team (Zambia SSS Team) which ends on 31 July, 1999. It covers the period starting from 1 August, 1997 when its activities commenced up to 31 July, 1999, the end of the study period. However, note that almost one year passed before the monitoring stations were established which meant that the period of actual work was considerably reduced. The Zambia SSS Team was mainly composed of two institutions, The University of Zambia, where the Team Leader, Dr. Henry M. Sichingabula, was based, and the Department of Water Affairs, which provided some logistical and technical staff required for discharge and sediment monitoring on a routine basis. The contact person in Water Affairs was Mr. Happy Sikazwe from the time he was Acting Officer-in-Charge of the Hydrological Section, at the Headquarters in Lusaka. The Water Affairs technical team which was based in Kasama was led by Mr. Sunday Ng'ambi, under the supervision of the Provincial Water Engineer, Mr. O. C. Mwansa.

The Lake Tanganyika Biodiversity Project (LTBP) in Mpulungu facilitated the study through its Project Administrator, Mr. Clement Mwelwa, who in 1998 replaced Mr. Martin Pierce who held the post before him. Mr. Olivier Drieu, the Sediment Studies Facilitator, based at Mpulungu office, and the Scientific Liaison Officer, Dr. Kelly West, Bujumbura office, helped with the study in the last year of its operations. The overall Coordinators of the project were Drs. Graeme Patterson, Natural Resources Institute (NRI) based at University of Greenwich in Chatham, UK, and Andrew Menz based at the LTBP regional office in Dar es Salaam, Tanzania.

The other institution which has also greatly helped with this study is the Department of Fisheries in Mpulungu headed by Mr. L. Mwape. The Department of Fisheries got involved in this study with analysis of suspended solids (SS) and total dissolved solids (TDS) because of the laboratory set up by the Project at its offices. The analysis of water samples was headed by Mr. Robert Sinyinza assisted by a number of fellow workers.

This report brings together the experiences, observations and findings of the Zambia SSS Team in the period of its investigations. It not only merges but also updates preliminary analyses of discharge and sediment data compiled in the seven Quarterly Reports prepared for the Project (Sichingabula, 1997; 1998a, b, c, d; 1999a, b). The Final Report also expands the analysis of primary and secondary data compiled for the study. It also evaluates the archival water level and discharge data, generously supplied by Water Affairs, in terms of volumes of water and magnitudes of sediment input into Lake Tanganyika by selected rivers in a medium- to long-term time scale.

Terms of Reference plus some of the justifications for this study are discussed in the sections following.

1.2 Terms of Reference

The study team's Terms of Reference were as follows:

1a) Conduct desk research for review report on available runoff and sediment data and related socio-economic conditions in the southern Lake Tanganyika drainage basin.

b) Assess the use of bathymetric information for the investigation of lacustrine processes in the southern portion of the lake.

c) Carry out familiarisation tour to existing and proposed stations on selected rivers, the southern coastline and to a number of coastal settlements. The tour also to assess local people's capacity to contribute positively to the project and be involved in the programme as well as select suitable sites for new gauging stations on rivers in 2a.

2a) Establish new and / or reactivate old discharge monitoring stations on selected rivers. A total of six sediment stations to be established.

b) Determine physical (pH, temperature levels, suspended sediment loads, etc) and chemical (total dissolved load, conductivity, etc) characteristics of water in streams draining into the lake on a regular short-term sampling interval.

c) Determine particle size distribution of bed material sediments transported by Lufubu, Lunzua, Lucheche and Chisala (Izi) rivers with sampling to be conducted near river mouths.

3. Make preliminary assessments of the impact of human activities such as tree cutting on the hydrological regimes and other related aspects of streams draining into the lake and liaise with the Socio-Economic Study group in this exercise.

4. Make recommendations for low level long-term monitoring programme for future sedimentological and hydrological modelling in the lake basin.

1.3 The Importance of Lake Tanganyika

Lake Tanganyika is among Zambia's important fisheries (Figure 1). In the 1970s, it supplied 70 per cent of commercial fish catches. In 1992, Zambia's annual fish cash on Lake Tanganyika was estimated at 9000 tonnes (Japanese International Cooperation Agency (JICA), 1995. Lake Tanganyika is important for its *cichlid* family of fish including *Saratherodon* and *Tilapia* and the two small (up to 9 cm) endemic genera and species of herring: *stolothrissa tanganicae* and *Limnothrissa miodon*, known in Zambia as 'Kapenta' or 'Daga' (Huckabay, 1979). In 1970, Kapenta contributed about 84 per cent of Zambia's fish production (Central Statistical Office, 1971). About 1000 tonnes of *Kapenta* is consumed locally, the rest are sun-dried or frozen and shipped to the major towns on the Copperbelt and to towns along the line of rail going to the south of the country. Today, a considerable amount of fish catches from the Lake are also exported to outside markets in Europe and other destinations.

In addition to the considerable upwelling, turbulence and internal waves alluded to by Coulter (1963; 1968) in the southern Lake Tanganyika, bring up nutrients from deeper waters. But other sources of nutrients are also believed to be important too. It has been suggested by Beadle (1974), that "airborne organic dust transported perhaps as far as the arid subtropical regions of northern and southern Africa", may be a significant contribution to the unusually high productivity of Lake Tanganyika pelagic waters. Similarly, the importance of fluvial suspended fine sediment in the Lake should not be underestimated. The suspended sediment deposited in Lake Tanganyika is important for fish productivity as nutrients adhere to sediment particles such that a lot of food is supplied to the lake by sediment. Any variations in sediment inputs and residence times in different fluvial and lacustrine environments influences the productivity of the fish and other aquatic species.

Lake Tanganyika is of great economic importance to all riparian countries, and it harbours one of the world's richest lacustrine fauna as well as some of the most remarkable of all freshwater animals (Fryer, 1972).

1.4 Theoretical Bases of Sediment Studies

General information on effects of man's activities such as land use practices, irrigation and drainage, on erosion and sedimentation processes in river basins are described in various sources including UNESCO (1985). This UNESCO report also describes methods of estimating and predicting changes in erosion and sedimentation processes following man-made changes in river basins - including changes in the watershed and river channels. Mean grain-size characteristics of bed load sediments for a number of streams in the south Lake Tanganyika basin were reported by Sichingabula (1998: 5-6) as part of this Project.

Clastic suspended sediment is composed of fine and coarse grained particles and is generally classified into three main categories, namely, (1) clay: <0.004 mm, (2) silt: 0.004-0.062 mm, and (3) sand: 0.062-2.0 mm. Sediments greater than than 2.00 mm belong to the gravel component which moves as bed load. The clay and silt components, also known as wash load, are transported by turbulent and viscous forces. The information on particle size of sediment is useful to planners of water resources and land use and to ecologists as it helps to improve the decision-making process as most development activities generate and are impacted by sediment.

Figure 1

Location map of sediment monitoring stations in the southern Lake Tanganyika Basin, Zambia

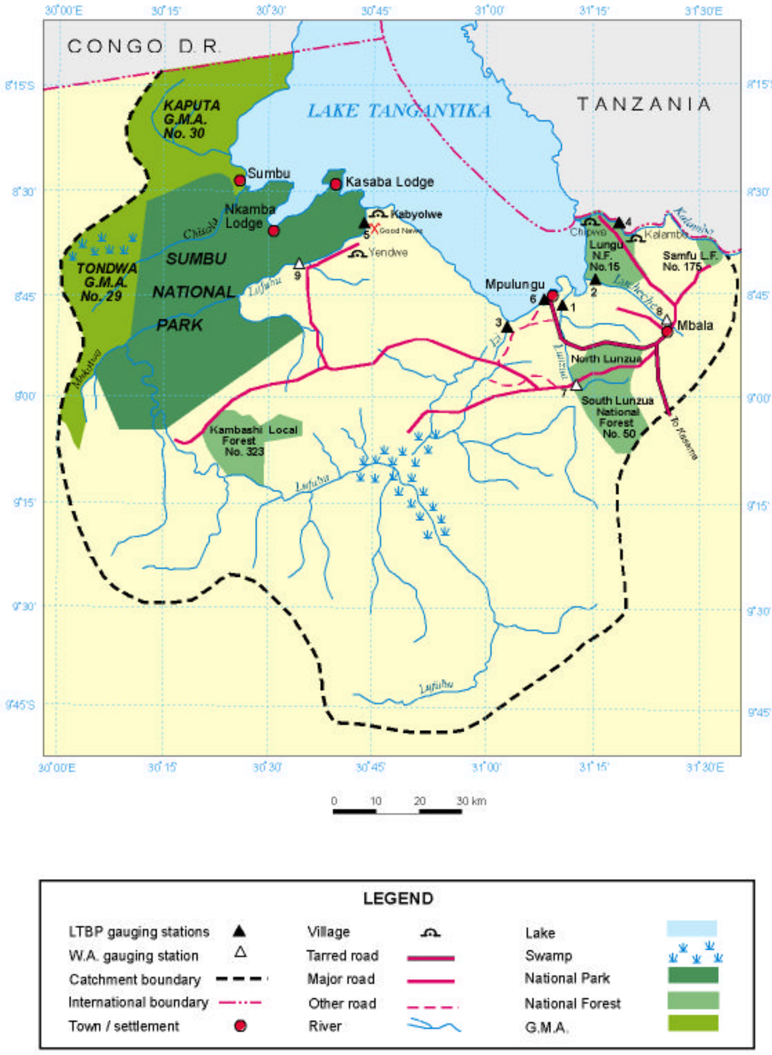


Figure 1. Location map of sediment monitoring stations in the southern Lake Tanganyika basin, Zambia.

1.4.1 Adverse Impact of Sediment

Sediment originates from the disintegration of rocks and is incorporated in the development of soils. The erosion of soil by water which results from the energy developed by the raindrops as they fall to the ground, leads to the deposition of sediment into rivers and lakes. The deposition of sediments clogs streams and reduces the capacity of reservoirs and lakes. Pollution by sediment is one of the major factors causing deterioration in quality of streams and lakes (Beasley, 1972).

Sedimentation resulting from soil erosion creates other problems. These problems include, first, increased costs of obtaining suitable water supply. This is because sediment pollution of streams and lakes increases the expense of treating these waters for supplies to municipalities and industry. Portable water must be free of sediment otherwise a lot of investment would be required to remove it for various industrial purposes.

Secondly, deposition of sediment into lakes reduces the value of land and streams as wildlife habitats are destroyed. This is because once soils are depleted by erosion, wildlife find it difficult to survive (Beasley, 1972). The sediment deposited into streams, lakes and reservoirs destroys the habitat for fish and other species. In aquatic environments, sediment impairs the dissolved oxygen balance and obscures the light needed for aquatic growth, both of which are detrimental to aquatic life forms. Additionally, heavier sediment particles blanket fish spawning areas and cover food supplies for many species. Thirdly, in areas where lakes and rivers are used for transportation sediment deposition increases the cost of maintaining channels and harbours by dredging.

1.4.2 Sediment as Source of Pollution

According to Beasley (1972), chemicals and pesticides are carried off the land by sediment or in surface runoff and add to the pollution of downstream waters. But the extent to which movement of sediment and their contribution to pollution problems is not well understood. Phosphates are adsorbed by soil colloids and move into streams and lakes through erosion of soil particles on which it is adsorbed. Nitrogen fertilizers together with phosphorus are the major cause of eutrophication in lakes and rivers which is detrimental to aquatic species. Therefore, the prevention of soil erosion by good conservation practices are the most efficient means of controlling pollution from agricultural lands.

1.4.3 Bathymetric and Hydrological Processes

Bathymetric data are available on the southern Lake Tanganyika basin and depth profiles of lake bottoms at two selected transect lines were constructed for this study (Sichingabula, 1998a). Figure 2 in Sichingabula (1998a) revealed that the southeastern part of Lake Tanganyika is characterized by shallow floor depths and especially across a peninsular of islands which extends below the water surface northward into the lake. Additionally, the profiles do provide an indication of different rates of sediment deposition into the Lake. Detailed analysis of available bathymetric data would be useful in characterizing the nature of Lake Tanganyika.

Bathymetric data if combined with other processes on the lake can yield a lot of information related to temperature regimes and productivity of the lake. To date, at least two studies have investigated the hydrological processes and relative productivity of the southern Lake Tanganyika basin (Coulter, 1963; 1968). Coulter (1968) analysed temperature measurements up to 150 m depth in the southeast direction and longitudinal axis of the lake. He observed two principal hydrological cycles, one between April and September when the epilimnion water moves northward in phase with southern Trade Winds forming a general downward tilt of the isotherm towards the north. The second cycle occurs between September and October characterized by long-period oscillations of isotherms which suggest existence of internal waves.

1.4.4 Potentials for Pollution Problems on Lake Tanganyika

The environmental degradation of the Lake cannot be ruled out if certain activities are not controlled (Cohen *et al*. 1993; Patterson, 1996; Patterson and Makin, 1998). For instance, Garbrecht (1971) observed that "anerobic and coliform counts on Lake Tanganyika water around Mpulungu leave no doubt that there exists a considerable pollution of the near-shore region where the water intake is located". The pollution results from sewage discharged directly or indirectly into the lake in form of leachates from pit latrines and by surface runoff. This is one of the reasons why cholera and other faecal diseases are not uncommon in Mpulungu area and other settlements dotted along the lake margin.

Therefore, protection of Lake Tanganyika waters is required if sustained economic benefits are to be assured. The creation of National Parks in some areas of the lake basin is one such method of protecting the Lake. Already large tracts of land are under protection by different institutions based in northern Zambia. But the enchroachment of agriculture and settlements in forest and wildlife reserves is counter productive to the intentions for which protected areas were created. This is a serious problem, especially in the eastern and western areas of the south Lake zone. In the east, in the Lungu National Forest, large tracts of land have been cleared of vegetation for charcoal burning and cultivation.

Another activity likely to lead to the pollution of Lake Tanganyika is the mining and exploitation of mineral resources located in the basin. Minerals found in the Mbala area include gold and tin whose exploitation could lead to the deposition of a lot of heavy metals in the lake which would be discharged by the mining and industrial operations. Some heavy metals could even result from agricultural activities in the area. Unfortunately, metal contamination in fisheries is not widely studied. Yet, it probably poses one of the greatest health risks to humans who feed on fish.

The physical characteristics of the southern Lake Tanganyika basin is the subject of discussion in the section following.

2.0 PHYSIOGRAPHIC SETTING

2.1 Introduction

Southern Lake Tanganyika basin is that portion of the Lake Tanganyika system which lies in Northern Province of Zambia (Figure 1). It is delineated to the northwest by Democratic Republic of Congo (Congo DR), small Lake catchments west of Lake Tanganyika, Lufubu River basin covering most of the area from the southwest to the southeastern region, Lunzua, Lucheche and Kalambo catchments to the east and going up to the border with Tanzania, which in the northwest joins the Zambia-Congo DR border. The whole region is characterized by a large expanse of water forming Lake Tanganyika, an extensive plateau, isolated hills and escarpments and lowlands at river mouths and localised swamps. Different aspects of these features are discussed below.

2.2 Geology

The geology of part of the southern lake Tanganyika basin has been previously described by Drystal *et al*. (1972). The geology and landforms of northern Zambia are the consequence of geological processes of faulting and other earth movements linked to the formation of the Great East Rift Valley in East Africa. This is what led to the formation of Lake Tanganyika which is one of the deepest lakes in the world.

The geology of south Lake Tanganyika basin is largely dominated by very few rock types (Figure 2.1). The most extensive geology are meta-quartzites of Precambrian ages. These rocks cover most of the Lufubu, Lunzua, Lucheche and Izi, the rivers which are the major focus of this study. The second largest rock coverage are the Lower and Upper quartzites followed by the Lower shales, all of the Muva formation which postdate Precambrian rock forming processes. These occur mostly in the Lufubu River basin. Igneous rocks of Precambrian ages comprising volcanics and meta-volcanics occur in the upper reaches of Kalambo basin and a sizeable area is also found north of Sumbu extending from the shoreline to the Congo DR border.

Other rock occurrences include granite found around Nkamba Bay, basic igneous and meta-igneous rocks and quartz veins in a number of places. The most recent rock types include alluvium, colluvium and laterite found mostly in inland drainage areas, swamps and other low lying areas. The largest occurrence of this is again found in the Lufubu basin.

The character of rocks in the basin determines the weathering processes and how much of the weathered material is removed by surface erosion into streams and lakes. The rocks which are more resistant to weathering generally yield less sediment than those that are highly weathered. An indication of how much sediment is supplied to the Lake from different geological areas is assessed in later sections from quantities of sediment transported by monitored rivers from the areas they access.

For a true picture of the types of rocks found east of the catchment, a slightly more detailed description of the geology of Mbala area is provided in the section below. Some of the geological structures in form of faults control the directions of stream flow in localized areas. But generally the block-slip which produced the Lake basin is the major control.

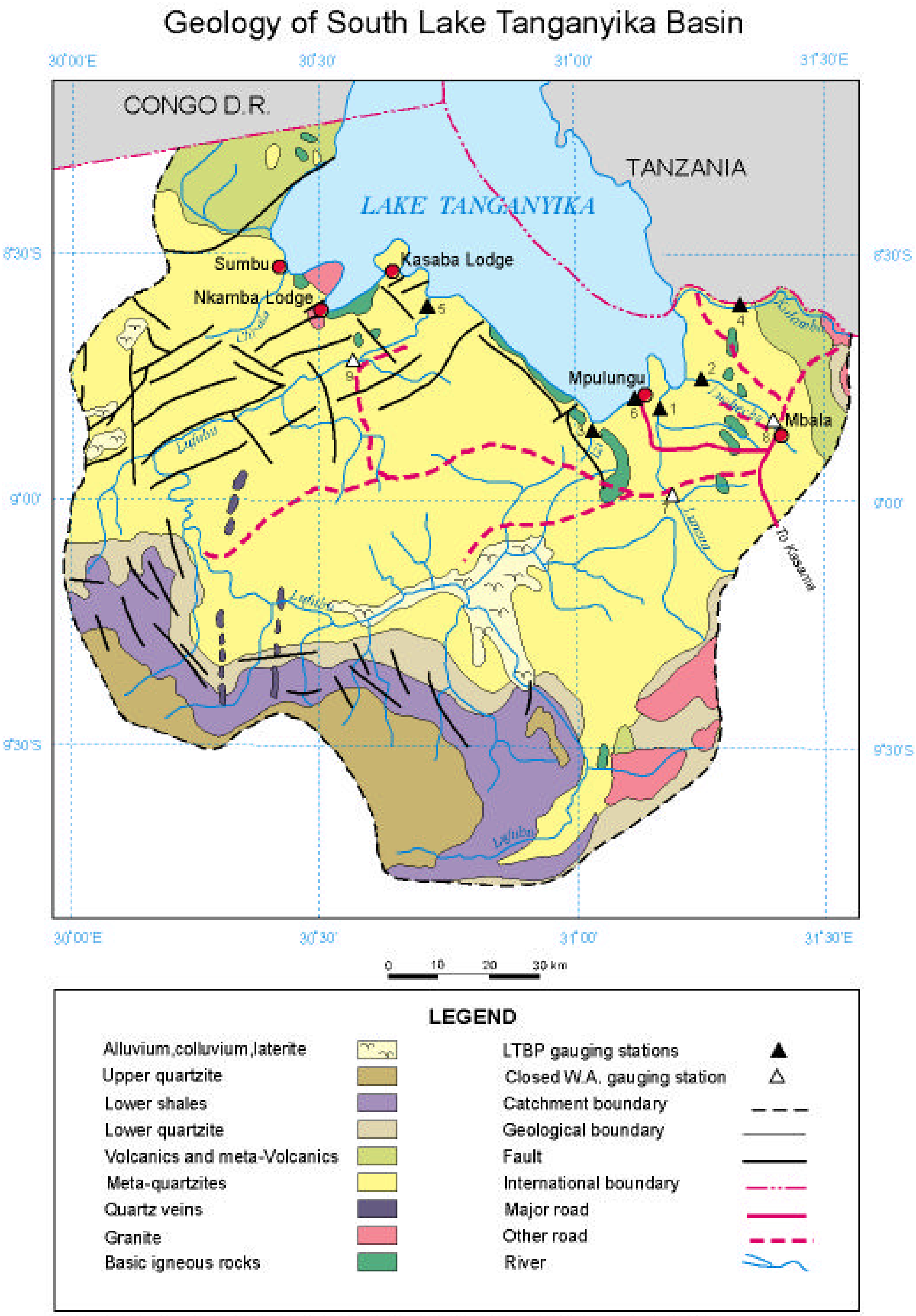


Figure 2.1 Geology map of the Southern Lake Tanganyika basin, Zambia.

2.2.1 Geology of Mbala Area

The description of the geology of Mbala area (Figure 2.2) is based on the geology map accompanying Geological Report No. 104 (Malik, in press). The map shows that the rocks of this area are highly variable unlike those given in Figure 2.1. The rock types traversed by the four study rivers located in Mbala area are described below. This description is done from one catchment to another starting with the Kalambo River located to the northeast and ending with Izi River catchment, west of the map.

The tributaries of Kalambo River from middle to lower reaches flow over four main rock types. The Kaluluzi River which forms the uppermost catchment on the Zambian side flows from the Porphroblastic granite through a narrow band of differently coloured quartzite rocks onto the Kate Porphry (Dacite), dark green, brown and purple in colour. It contains large amounts of placioclase and hornblend phenocrysts in very fine-grained matrix, in the lower reaches of the river up to the junction with Kalambo River. The Musipazi River which rises in the Kate Porphry geological region, in its lower reaches forms the boundary of this rock type with the red and purple mudstone, which runs up the headwaters of the catchment in a narrow strip from the Kalambo River. Mudstone is also the major rock type for the rest of Kalambo catchment including that of the Lucheche and part of Lunzua rivers which are located in the centre of the map (Figure 2.2). The rock type dividing the red and purple mudstone into two is the medium-grained pale grey to purple sandstone. The red and purple mudstone rock type dominates the geology for most of central Mbala region, east of the upper and lower western part of Lunzua river before it enters the Lake. It is also this geology which forms the headland west of Kapata Village at the mouth of the Lunzua River.

Moving westwards from Mbala to Mpulungu, one encounters the Mpulungu Chert, which forms a narrow strip of about 1-2 kilometres in width up to Mpulungu from the Lunzua Road bridge. The main road runs almost in the middle of the strip. To the west of the Mpulungu Chert is found a fan shaped Chibulula Sandstone which generally forms the low lying area around Mpulungu and along the Lake shore going westwards up to the foot of the escarpment where the Izi River cascades down to the alluvial plain. Most of the villages starting from Musende Village through Kasakalawe up to Mbete Village are all built on the Chibulula Sandstone which is purple and cream in colour. It is an easily weathered rock.

The source of Izi River on the plateau is underlain by the Misangu Sandstone which covers a large area south of Mpulungu. The scarp slopes of the Izi River and other smaller streams draining into the Lake from the south are underlain by the fine- to medium-grained Lunzua Quartzite, pink and white in colour. It forms a narrow strip which decreases in width going up into the hills on the western side upstream of Lunzua River from the Lunzua Road bridge.

Within the broad geological areas described above there also occurs a number of small basic rocks mainly dolerite and gabbro and quartz veins. Other features important to note in this area are surface depressions which include the Uningi Pans and Lake Chila, located south and northeast of Mbala, respectively. At the present moment these depressions act as sediment sinks, which, except for Lake Chila being drained by Lucheche River, have no outlets. In terms of sediment sources and supply to Lake Tanganyika, these depressions could be a major source of fine grained sediment in future should they be drained by the lowering of controlling base levels.

Figure 2.2 Geology of Mbala area, Zambia

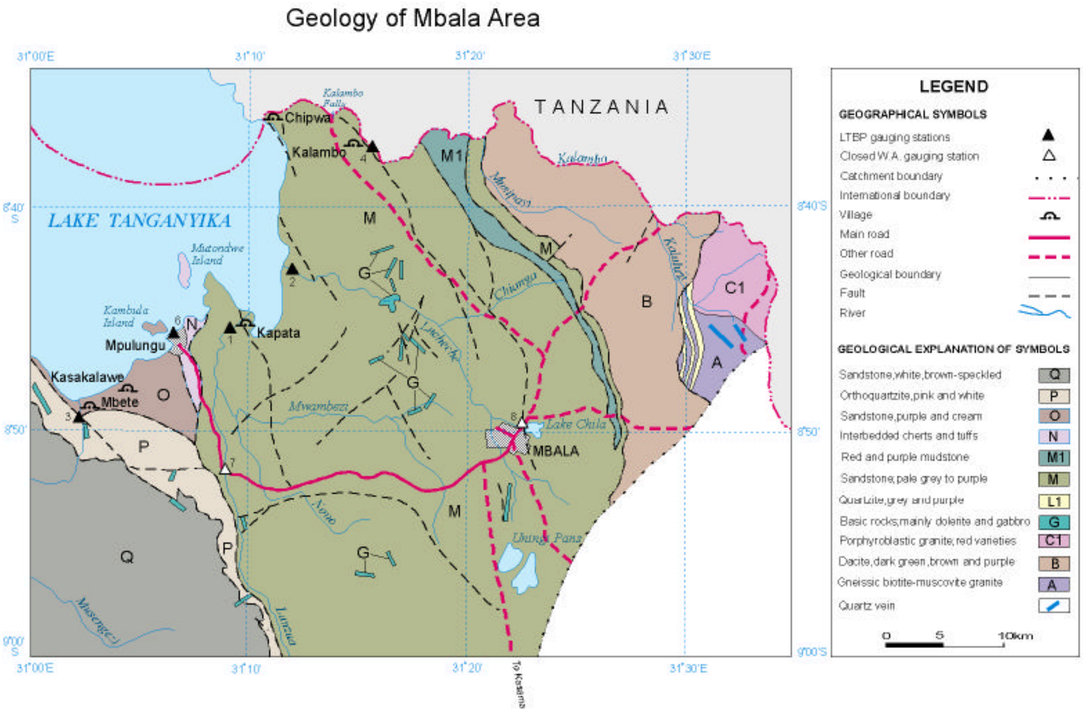


Figure 2.2. Geology map of Mbala area, Zambia.

2.3 Geomorphology

Southern Lake Tanganyika basin is located in the central southern Africa plateaux region lying generally above 1200 metres above sea level (masl) (Figure 3). The description of the topography of the catchment below is largely based on the work of Dalal-Clayton *et al.* (1985). The southern Lake margin east of Sumbu is bordered by an escarpment complex. This is characterised by steeply rising and deeply dissected rocky hills with v-shaped valleys formed largely by major faulting related to the Great East Rift Valley. The fault lines and blocks have been modified by subsequent erosional processes. Most of this area is not easily accessible and supports dense vegetation cover. A number of perennial and ephemeral streams cut across this zone to empty their waters into the Lake. The western side of the lake margin is characterised by the dissected hilly country underlain by meta-quartzite rocks of different ages (Figure 2.1).

Most of the area south of Mbala-Mpulungu area is characterised by level to undulating plateau lying between 1220 and 1830 masl. Common physical features include undulating topography with dendritic type of drainage pattern of *dambos* and streams separated by level or broadly convex interfluves. The lower parts of major rivers lie between 610 and 1220 masl unlike most valley floors which are between 1200 and 1830 masl. The highest elevations (>1830 masl) are located on the plateau south of the lake and in the northern area covering Mbala area. Slopes rarely exceed 5% in level but in undulating areas may range between 3/5% to 8/12% where streams are incised. Footslopes comprising colluvial material are also found at the foot of hills and ridges and slopes are normally between 5-12%. Surficial processes involving various types of sediment give rise to a variety of soils.

2.4 Soils and Vegetation

Soils which are derived from surficial geomorphological processes interacting closely with biotic and anthropogenic factors conditioned by underlying geological formations occur in a variety of classes. In the southern Lake Tanganyika basin, four major soils types exist (Figure 4) (Dalal-Clayton et al., 1985). Prominent soil types include rock and rubble characteristic of the broken hilly country and escarpments. In flatter areas the rock surface may be made of laterite which occurs in most parts of tropical areas characterised by dry and wet seasons. Most of the southern Lake Tanganyika catchment is overlain by the leached sandveldt soils. These are light sandy loams or loamy sands. Due to leaching caused by the high amount of rainfall (>1200 mm per year) experienced in this part of the country, these soils have low base saturation making them deficient in some major minerals. Consequently, the soils require lots of artificial fertilisers for crops to do well. The local people, being aware of the deficiencies of these soils have developed a *Chitemene* system of agriculture, slash and burn, to improve their fertility.

Another type of soil similar to the leached sandveldt is the leached red clays. This occurs in isolated areas especially south of Mbala. Lastly but not the least type of soil common in the area are floodplain soils. These are derived largely from siliceous rocks and form deep peaty organic horizons. An extensive area of these soils is found in the Lufubu basin in the south-central part of the southern Lake Tanganyika basin. Smaller pockets of these soils are also found in a number of local dambos and swamps.

Figure 3 The relief map of the Southern Lake Tanganyika basin, Zambia

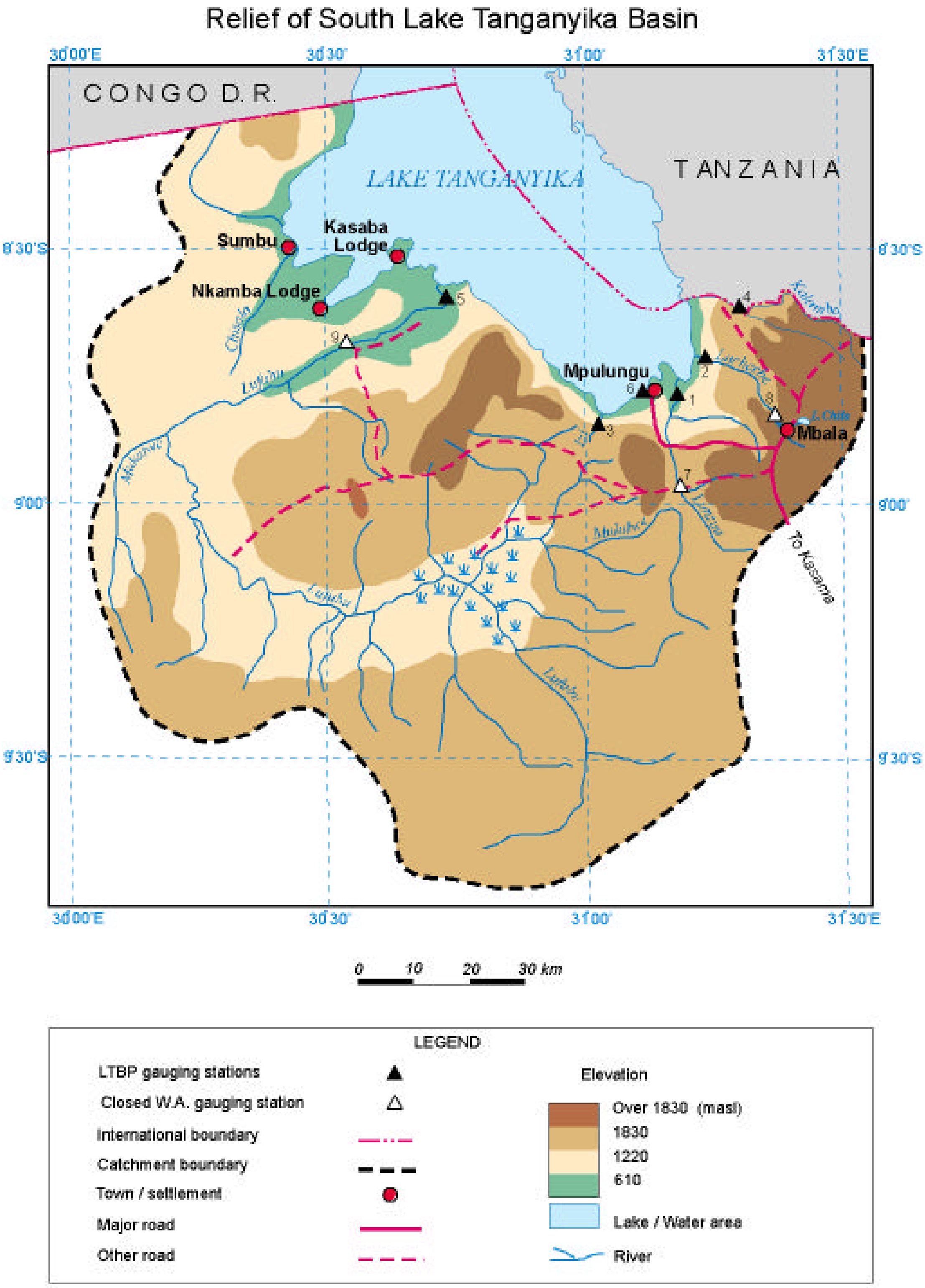


Figure 3. The relief map of the Southern Lake Tanganyika basin, Zambia.

Figure 4 Different soil types found in the Southern Lake Tanganyika basin, Zambia

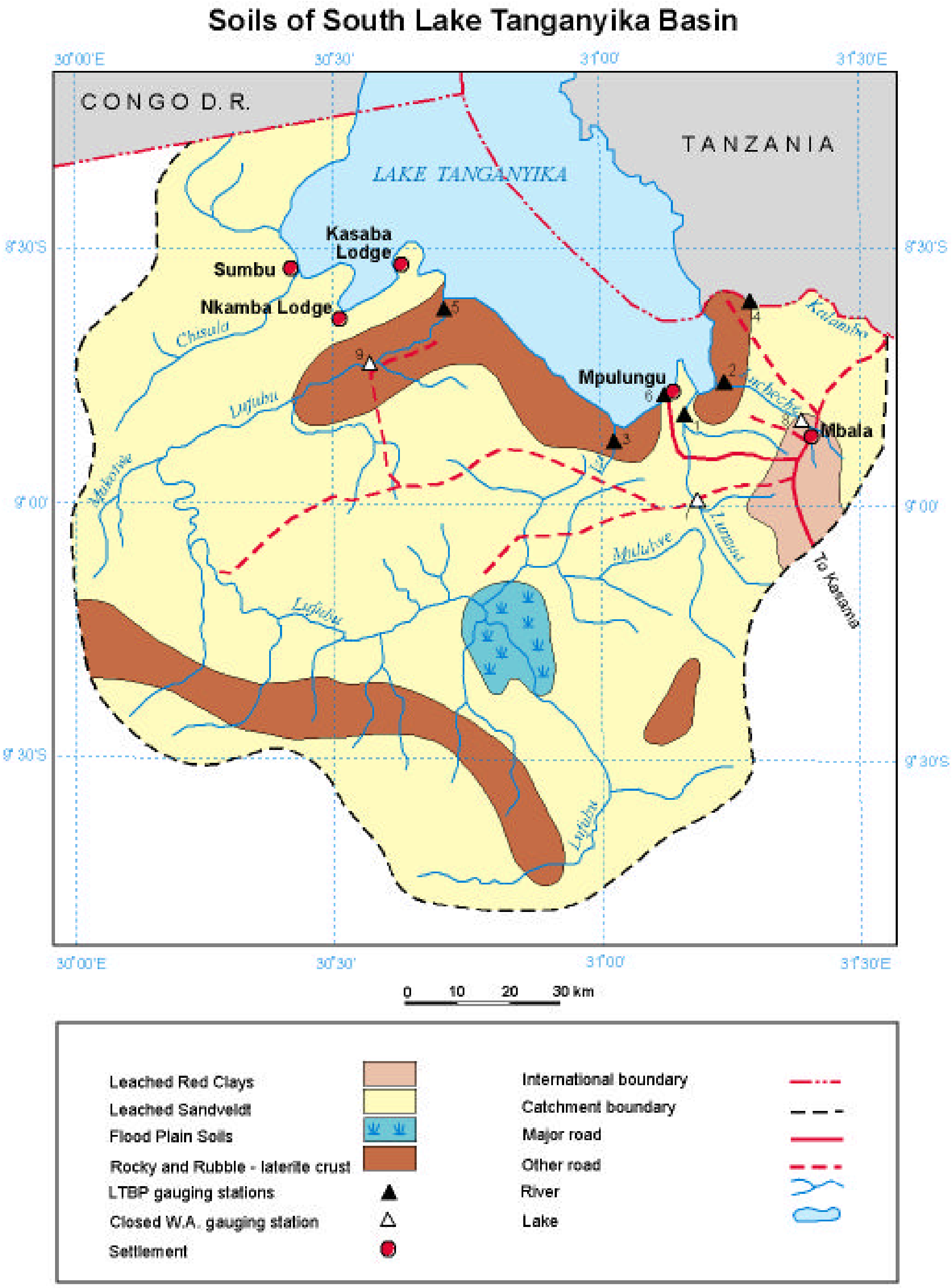


Figure 4. Different soil types found in the Southern Lake Tanganyika basin, Zambia.

2.5 Land use

Land use plays an important role in the quality of resources in the area. This is because certain landuse activities have an adverse impact on natural resources. The land use patterns in the south lake Tanganyika basin has been divided into agricultural and non-agricultural activities briefly described below (Figure 5).

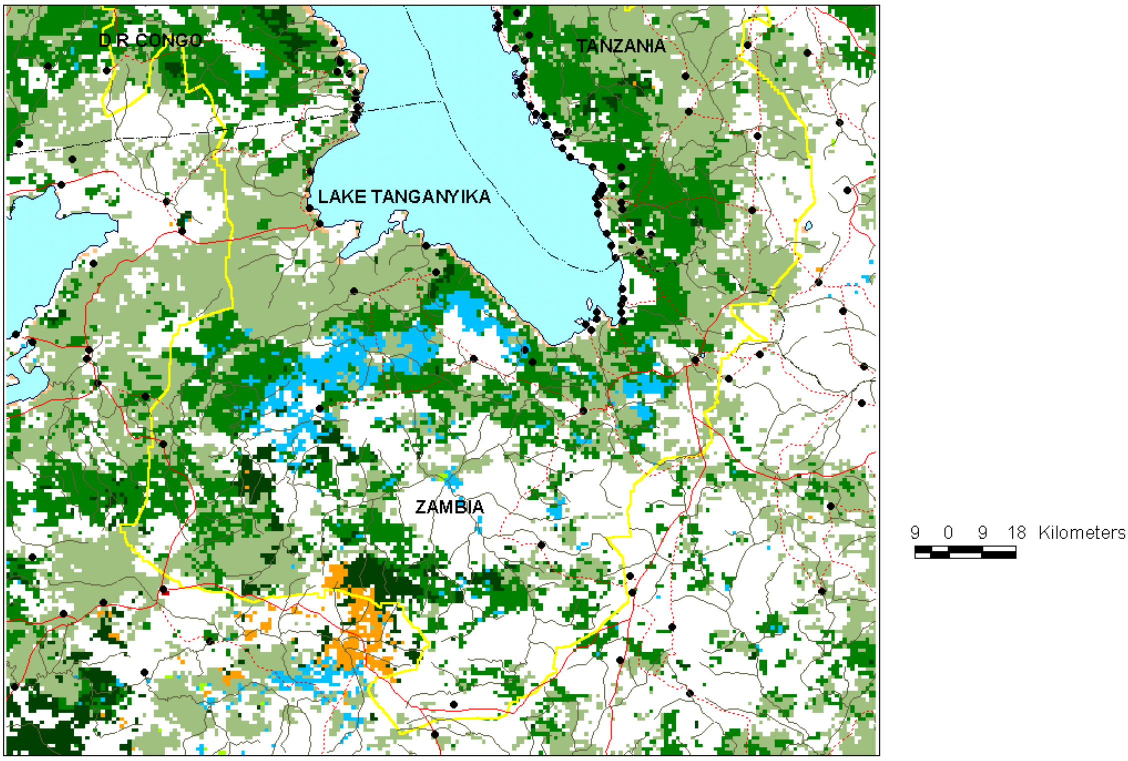
Among the non-agricultural land uses are protected areas. The Sumbu National Park is the largest protected area in the catchment. In this zone, no harvesting of natural resources such as wildlife, including fish, timber and fruits is allowed. The wildlife plus their habitats are protected by the law which is enforced by the National Parks and Wildlife Service stationed at Sumbu with a number of scout camps located in different parts of the Park and adjacent Game Management Areas. Other protected areas are the Forest Reserves which help in protecting sources of streams in the headwaters regions. Together the national park and forest reserve act as large nature conservation zone. If these are well managed they can greatly increase biodiversity and delay the degradation of lake ecosystem which is impacted by what happens in the catchment.

Other types of land use found in the area include hills and escarpments with no or marginal potential for cropping. These are areas with rock and rubble type of soils. Consequently, none of these areas are settled. Closely related to this is the area classified as woody area not cropped for a number of years. This is the largest portion of land use in the southern Lake Tanganyika basin. It is virtually devoid of human occupation. But with increasing population it might start being opened up for agriculture and settlements. The Lake and swamps make the remainder of non-agricultural land uses.

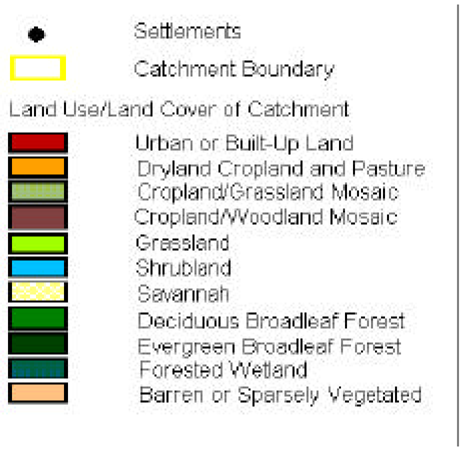
The agricultural types of land use are further divided into two. The land use covering most of the area is the large circle *Chitemene* system which is practiced in most parts of the plateau. This land use type is responsible for the clearing of woodland in the catchment. The second land use type is the isolated shifting cultivation on a semi- to permanent basis. This type of agriculture relies mostly on hoe cultivation. As as result, the plots of woodland cleared are generally small. But this is increasingly changing to more permanent forms of farming as inputs such as fertilisers become readily available on the market. Crops grown include cassava, maize, groundnuts, beans, rice, and finger millet.

The next section discusses various activities undertaken by the Zambia SSS Team in the duration of the Lake Tanganyika Biodiversity Project.

Figure 5. Land use map covering the southern Lake Tanganyika basin, Zambia. Source A. Mills , NRI.



Map legend



3.0 PROJECT ACTIVITIES

3.1 Reconnaissance and Establishment of Gauging Stations

The activities of the Zambia SSS Team effectively started in September, 1997 when a reconnaissance survey to Mpulungu was carried out with the sole objective of selecting suitable sites for Project stations for discharge and sediment monitoring. Reconnaissance work and the station installation and inspection exercises (Sichingabula, 1998a, b), took the Team to various places in the southern Lake Tanganyika basin. The places visited and surveyed included closed Water Affairs gauging stations (Figure 1). On Lunzua River, Kambole Bridge (7-005) was visited and discharge measured. Other explorations took the Team to the mouth of the Lunzua at Kapata Village, and Namukale Falls at the foot of the escarpment, before finally surveying the site around Simumbele Village which was later selected as the most suitable site for a station.

The other closed station visited was that on Lufubu River at Keso Falls (7-750). The long trip to this station by road took the Team half the day to arrive at Keso Falls as the road was in bad shape due to rugged terrain. It was unfortunate that the trip in 1997 was made at the time of wildfires, when the local people were preparing their *Chitemene* fields which involved cutting or lopping tree branches and heaping them in circular fashion before burning in order to replenish lost nutrients in the heavily leached sandveldt soils. It was by both wit and the hand of a Higher being that the Team survived the fire which almost engulfed all along a narrow track lined with tall grass. This was on the return journey after driving past a village part of which had already been gutted to ashes including a Reformed Church building, when the Team found itself between flames of fire towering above the vehicle on both sides of the track. The only way out was the bush to the rear left of the vehicle. The decision to bolt was taken in an instant as the Team Leader shouted to head for the bush as the heat and smoke in the vehicle was becoming unbearable. The whole episode left all tired and the Project vehicle was dented by hitting into tree stumps, the remnants of the *Chitemene* which were scarcely visible in the tall grass. Finally, the team managed to by-pass the fire in a circular fashion and got back to the track. Following this experience, it was later decided not to re-open the Keso Falls station.

On Kalambo River, the Team wondered for about three kilometres around Kalambo Village in search of a suitable site. This was a difficult task as Kalambo River was armoured for most of its course. However, after careful guidance from the local people a site was chosen taking into account the flood history of the river as narrated by the guides. The selected site is located at the point where the river issues out of the hills. It has served as a good station despite the problems it poses to high flow measurements (Sichingabula, 1999b: 14-19). A visit to Kalambo River also afforded the Team an opportunity to view the renowned Kalambo Falls for the first time for some members. An attempt to reach the Falls in the upstream direction from the mouth of Kalambo River at Chipwa Village failed due to the long distance and poor accessibility. At Chipwa it was observed that the Kalambo River has, over the years, formed a large extensive delta which is inhabited by large communities both on the Zambian and Tanzanian sides. This was an indication to the Team that Kalambo River carried large quantities of sediment, a suspicion which was later proven to be true by the results of analysis of discharge and sediment data monitored upstream of the Kalambo Falls.

The search of a suitable site on Lucheche River was perhaps the most difficult due to inaccessibility. The Team followed the river from its source, the Lake Chila near Mbala up the area past Motomoto Museum. But its mouth could not be reached due to lack of roads. Another attempt was made by following an old trail off Mbala-Kalambo road which disappeared in thickets and dense woodland and the search was aborted. Finally, it was decided to do this from the river's mouth at Kawe Village. Not much difficulty was encountered there as the assistance of the local people was most valuable and made the exercise easier than had been expected. The site which was eventually selected for a station near Kawe Village has to date proven less problematic than other stations (Figure 6a).

On Izi River, the reconnaissance survey had not selected any site due to limited time. This was done at the time of station installation in 1998 which delayed the exercise but was nonetheless done according to planned work schedule. Izi River has an incised channel which quickly fills up during heavy rainfalls but does not also pose problems during discharge measurements (Figure 6b). Izi River, though small has also built an extensive delta and flood plain which is habited by a large community comprising Mbete and Kasakalawe villages. Part of the delta surface forms the burial ground for the local chiefs.

The search of sites on the western side of the basin took the Team to Sumbu near Kasaba Bay. There Chisala River was surveyed and a site was selected. But the station was not established due to anticipated logistical problems that would have been faced by having a station far off from the base station at Mpulungu for routine discharge and sediment monitoring.

Figure 6 Photos

The survey of the lower reaches of the Lufubu River bordering the Sumbu National Park on the left bank was less problematic as this was done with the Silvershoal up to the location of the 'Good News' monument built by the London Missionary Society (LMS) in 1884 (Figure 1). Good News was the first ship to sail on Lake Tanganyika which is today lying at the bottom of the Lake's deep waters. Above this monument, the river was surveyed using the inflatable boat up to near Yendwe Village. But none of the upstream sections were found suitable due to unstable sandy banks (Figure 7a). Therefore, eventually the site 300 metres downstream of Good News was selected for a gauging station.

Having traversed across the catchment appreciating landforms and problems they pose to sediment monitoring activities, the Zambia SSS Team was now ready for the task ahead. However, the Kalambo River which the Team found frightening during the reconnaissance survey because of the large bed-calibre load it carries, proved to be so even during measurement of high flow discharges (Figure 7b) (Sichingabula, 1999b).

3.2 Discharge and Sediment Monitoring Activities

In the period of this study, the Water Affairs team in Kasama conducted discharge measurements and collection of water samples at five gauging stations according to the bi-weekly and weekly schedules set for the rainy and dry seasons, respectively. The laboratory analysts and the gauge readers at all the stations on five rivers and on the Lake at the Department of Fisheries offices in Mpulungu, carried out their duties remarkably well as evidenced by the good record of data being reported. Most of the collected data were being sent to the Team Leader at The University of Zambia and to Water Affairs in Lusaka for analysis and archiving. The locational details of the monitoring stations are given in Table 1.

During the course of this study the Team Leader made three trips to Mpulungu to undertake different activities. These field work campaigns to Mpulungu provided the Team chances to meet other members belonging to other Study Groups who visited the Project office in Mpulungu and included Project co-ordinators and administrators. The teamwork and good rapport developed among the people participating in the Project, in one way or another, greatly contributed the good fruition of this particular study. A sampling of people the Team had the privilege of meeting appear in Figure 8. The included the Project office staff at Mpulungu, Project Coordinators and Managers based at NRI, in the UK, Dar es Salaam and Bujumbura, and local staff were all represented during the meetings on the lakeshore, Department of Fisheries grounds (Figures 8a, b). Figure 8c shows the technical team based in Kasama with support staff.

Figure 7 - photos

Table 1. Locations and sizes of studied catchments in the southern Lake Tanganyika basin, Zambia.

No.	Station No.	River and Station	Location Latitude	Longitude	Elevation[¥] (masl)	Area (km^2)
1.	7-008	Lunzua R. at Simumbele Village	08° 46' 23"	31° 08' 49"	905	686.0
2.	7-022	Lucheche R. near Kawe Village	08° 48' 50"	31° 08' 49"	830	312.0
3.	7-015	Izi R. at Mbete Village	08° 48' 51"	31° 02' 29"	830	54.4
4.	7-030	Kalambo R. at Kalambo Village	08° 35' 55"	31° 15' 22"	1171	2,575.0†
5.	7-775	Lufubu R. near Kabyolwe Village	08° 35' 51"	30° 44' 09"	758	7,047.0
6.	7-010	Lake Tanganyika at Mpulungu Fisheries	08° 45' 49"	31° 06' 34"	795	-

¥ Elevations determined by GPS surveys.

† Area determined by GIS mapping by A. Mills at NRI.

Figure 8- Photos

The work reported herein is all because of the unreserved input of these people.

The work in Mpulungu was not always conducted in the field as there were times for briefings on progress and activities of the entire project by leaders of study groups and administrators (Figure 9.1). Local participants in the project were always in attendance with their good cheer (Figures 9.2).

Figure 9.1 Photos

Figure 9.2 Photos

4.0 METHODOLOGY

4.1 Measurement Techniques and Methods of Analysis

In this section the different methods used in the collection and analysis of data are discussed. Additionally, a consideration of types of errors inherent in collected data and how they come about is given so as to assess its reliability.

4.1.1 Methods of Data Collection and Compilation

Methods of Data collection used by Water Affairs in Zambia are similar to those employed in USA, Canada and elsewhere as described by (Corbel *et al*. 1962; Stichling, 1969). A comprehensive description of data collection and compilation procedures used by Water Affairs is unnecessary here, but those methods and techniques that are germane to the understanding of limitations inherent in the discharge and sediment data collected deserve consideration. Additionally, an understanding of data limitations is important because accuracy and reliability of the data dictates what types of analysis can be undertaken. In the sections following, methods of measurement and possible sources of error in discharge and sediment data are discussed.

4.1.2 Measurement of Water Levels

Water levels or gauge heights (Gh) of studied rivers and Lake Tanganyika at Mpulungu were determined by the use of manual gauge plates which were read three times a day, thus, at 06.00 hours, 12.00 hours and 18.00 hours by the gauge readers stationed at the measuring sites. The accuracy of readings were to the nearest 0.5 of a centimetre. This was because the staff involved were not highly educated. The three values were averaged to get the daily mean water level.

4.1.3 Measurement of River Discharge

Daily mean discharges at monitoring stations were computed from a rating curve relating flow to river stage or height. Generally, discharge is computed by the velocity-area method which involves field measurements of velocity, depth and width of flow. The frequency of discharge measurements used and especially for determining flow, velocity and stage are crucial in assessing the accuracy and reliability of sediment and discharge data. For this study, discharge measurements were conducted on a bi-weekly basis during the rainy season (November-April) and monthly during dry months (May-October).

4.1.3.1 Errors in Discharge Measurements

The reliability of discharge measurements is affected by a number of factors. The instability of the channel boundary at measuring stations is one possible source of error on the estimation of discharge by the rating curve method, necessitating revision of the rating curve from time to time. This is why the rating curves in the Sixth and Seventh Quarterly Reports were being updated (Sichingabula, 1999a, 1999b).

The second source of error is related to methods and instruments used in measuring flow velocities. This potential source of error, recently reviewed by Sichingabula (1993), has been investigated by Demet'ev (1962) in the former USSR and Carter and Anderson (1963) and Dickinson (1967a; 1967b) in the United States. With regard to errors in velocity measurements, it is generally known that, velocity fluctuations about the mean point in the section are random in time. Furthermore, velocity varies with the logarithm of depth so that the average of the 0.2 and 0.8 velocities closely approximate the mean velocity in the vertical. Carter and Anderson (1963) found that, if single discharge measurements (0.6 method) were made at a number of gauging stations and by the usual 0.2 and 0.8 methods, the errors of two-thirds of the measurements would be less than 2.2 percent. Thus, the measurements of stream velocity by the single and two point methods yield similar results without significant errors in the discharge measurements obtained.

Therefore, most of the errors present in the discharge data do not arise from velocity measurements, but rather from the type and stability of the stage gauge used, accuracy of observation and stage measurements. This is why particular attention was paid to the timing of the readings and the correctness of the way gauge readers recorded stage values. Note that water level data collected by a water-stage recorder, not used for this study, are more reliable and accurate than those using a manual gauge only, especially for small or flashy streams.

Some of the problems encountered by the Zambia SSS Team with the current meter had to do with the connections of the tailfin and the control unit as reported in the Fifth and Seventh Quarterly Reports (Sichingabula,1998c: 6-7; 1999b: 27-29). The amount errors this had on discharge measurements is not known, but was considered to be negligible.

4.1.4 Sampling of Suspended Sediment

For monitoring of suspended sediment, three different main sampling procedures are used, for instance in Canada (Inland Waters Directorate, 1990). The first is depth-integrating method. This is used for determining the average suspended sediment concentration in the water column, where the sample is drawn from near the bottom up the water surface at a uniform rate such that the water enters the sampler nozzle almost at the rate of the flow velocity. The second method is by taking single water samples at a selected vertical in the cross-section. This is usually used for determining the sediment concentration for days when comprehensive sediment load measurements are not taken. The last method, is the point-integrating method which is mainly used for cross-checking deph-integrated measurements.

A variety of sediment samplers are available. These include USDH-48 (wading type), USDH-59 (for handline sampling) on small and medium streams, while USD-59 and USD-74 are used on medium to large rivers on reel suspensions. There are also automatic pump samplers for unattended sample collection and bottling of individual water samples extracted from a fixed point in a stream.

For this study, at least two water samples were collected from the left, centre and right banks of the river, depending of the nature of the flow, by dipping the water bottle below the water surface. The daily mean sediment concentration was determined through laboratory analysis by the filtration method. The procedures followed are given in the Appendix of the Fifth Quarterly Report (Sichingabula,1998d: 26).

4.1.4.1 Errors in Suspended Sediment Data

One of the sources of errors in the suspended sediment measurements that is not related to the errors in discharge is the type of sampler used. In order to assess errors in the sediment data obtained, it is necessary to compare the results of dip sampling with that of either depth-integrating or point-integrating approach. Since such an exercise was outside the scope of this study, the amount errors involved in the data set were not assessed. Elsewhere, Knisel and Baird (1970) compared concentrations of suspended sediment collected with depth-integrating (USDH-48) and dip samplers, and found greater concentrations for the integrated than dip samples. Consequently, they concluded that for valid comparisons, sediment concentration data obtained with dip and depth-integrating samples during different time periods for a watershed ought to be adjusted.

Therefore, for rivers in northern Zambia where the dip method was the only one used, although it poses some questions, during analysis of the data it was assumed that the errors were small and that they were within unavoidable measurement errors.

4.2 Determination of Suspended Sediment Load

A fair amount of data on water levels, discharge and sediment concentration has so far been assembled since the study stations were opened in September, 1998 (Sichingabula, 1998c, 1998d). Part of this data has been previously analysed (Sichingabula, 1999a). In this report, earlier results of analysis were revised with the inclusion of more data.

In the present analysis, three daily water level readings or gauge heights (Gh) were averaged to get the mean daily water level at a station. The daily suspended sediment load (SSL), expressed in tonnes per day, were determined as suspended sediment concentration (C) multiplied by discharge (Q) and a conversion factor (0.0864). The obtained daily sediment loads were summed and averaged to get different descriptive statistics for each station and given in summary form. These statistics were discussed in terms of rates of discharge and sediment input into Lake Tanganyika by different rivers.

4.3 Determination of Total Dissolved Load

Total dissolved load (TDL) is the chemical part of sediment dissolved in water. It is also known as solute. The chemical load content of water in the laboratory can be determined by evaporating the water sample and measuring the weight of the residue and expressed as parts per million (ppm) or mg L^{-1}. For this study, this approach was not employed as it takes a lot of time and there could be enormous errors in measurements if done by inexperienced technicians.

Instead, a probe was used to read off the TDS concentration value after dipping it into the water sample. The probe used was the TDS meter which was calibrated at set room temperature and using a special solution. Because of the delay in the acquisition of the TDS meter, the monitoring of the dissolved load did not start until March, 1999. Consequently, not much data was generated up to the time of preparing this report. Just like for suspended sediment, the determination of total dissolved load, the TDS concentration (C) was multiplied by the associated discharge (Q) and the conversion factor (0.0864) to yield total dissolved load in tonnes per day.

Taken together the suspended sediment load and the total dissolved load provide the total sediment load transported by a river.

4.4 Determination of Bed Material Load Composition

Bed material load on rivers in the southern Lake Tanganyika basin varies greatly in particle size. Maximum grain sizes on studied rivers in reaches of gauging stations during field campaigns to Mpulungu, ranged from coarse sand on Lufubu, Lunzua, and Izi rivers to gravel and boulders on Lucheche and Kalambo rivers. Table 2 shows the composition of grain sizes below 2 mm collected during station installation exercise in 1998 (Sichingabula, 1998c). Analysis of grain-sizes were conducted in Geography Department at the University of Zambia using the Gravimetric method involving sieving and weighing.

Bed material load moves largely by rolling, sliding or skipping depending on its size and shape. Because of large size this type of sediment does not move in large quantities. On most rivers, this load is usually makes less than 5 percent of the total annual sediment load transported by rivers. For most of sediment moving in rivers, our interest was on grain-sizes below 2.00 mm.

Table 2. Particle size composition of bed material sediment collected from newly established gauging stations in the south Lake Tanganyika basin, Zambia.

No.	Date	River / station	Grain Size Composition (%)†						
			Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	Total
1.	06.10.98	Kalambo / Kalambo	0.1	0.4	20.7	74.3	3.4	1.1	100
2.	13.10.98	Izi / Mbete	0.3	0.5	18.0	80.2	1.0	0.0	100
3.	05.10.98	Lunzua / Simumbele	0.1	0.3	24.0	74.9	0.7	0.0	100
4.	12.10.98	Lucheche / Kawe	0.8	0.9	42.9	53.1	2.3	0.0	100
5.	11.10.98	Lufubu / Kabyolwe	0.3	0.6	37.0	59.5	2.3	0.3	100

† Analysis conducted by Mr. M. Nasitwitwi, Department of Geography, University of Zambia.

Since grain sizes for suspended and bed load materials form a continuum, the distinction between suspended and bed load materials is not well defined. Different standards also exist in different part of the world on classification of grain sizes, but the Wenthworh grade scale is commonly used (Wentworth, 1922). A grade scale is a systematic division of a continuous range of sizes into classes or grades, and the Wentworth grade scale provides a means of standardizing terminology. In this scale, each size grade or class differs from its predecessor by a constant ratio 1/2, and each has a specific name to identify particles falling within it (Krumbein and Sloss, 1963: 96).

In United States of America and Canada, sediment particles are generally classified into three: (1) clay: <0.004 mm, (2) silt: 0.004-0.062 mm, and sand: 0.062-2.0 mm and gravel: >2.00 mm. The clay and silt components, also known as wash load, are transported by turbulent and viscous forces and therefore are not considered to be capacity load. But the coarse component of sand which travels as bed-load by intermittent suspension and saltation on the bed could be considered as capacity load at certain flow levels.

4.5 Determination of Effective Discharge for Suspended Sediment Transport

Effective discharge (Q_{eff}) for suspended sediment transport has been defined as the mid-point of discharge class, which, over a period of time transports the greatest portion of sediment load (Pickup, 1976). For this study, effective discharge was determined in a number of ways. First, by dividing the discharge range at each station into 12 arbitrary non-overlapping classes of equal widths, finding the duration (frequency) of each discharge event, and finally multiplying the duration with the sediment load calculated for each class. Thereafter, histograms of discharge and sediment load for each class were constructed to determine the class-based Q_{eff}. The characteristics of the class-based effective discharge and the sediment-discharge regimes are discussed under section 5.0.

Results of analysis of monitored data are discussed in the section following.

5.0 RESULTS OF DISCHARGE AND SEDIMENT MONITORING

5.1 Introduction

This section describes methods of analysis employed in this study using different mathematical, statistical and graphical approaches. It deals with methods of determining discharge and sediment rating curves, suspended and dissolved sediment loads, magnitude and frequency characteristics of effective discharge for suspended sediment transport, and assessments of regional (basin-scale) sediment transport as well as sources of sediment supply.

5.2 Rating Curves and Magnitudes of Discharge and Sediment Loads

Analysis of collected data involved determining relationships among the measured variables which included water level or gauge height, discharge and sediment concentration of suspended and dissolved load which were deposited into Lake Tanganyika by different rivers.

The discussion of the analyses below by individual rivers starting with the Lucheche through to the Lufubu River, is in no particular order. The period of analysis is from the time stations on five study rivers were opened in September, 1998 to 31 May, 1999.

5.2.1 Lucheche River

For the Lucheche River, the simple regression model was found to be the best predictor of discharge from gauge heights. This simple regression model which was significant at $p = 0.0001$ is given in Equation 1 below and illustrated in Figure 10a. Equation 1 was applied to the observed daily water levels in order to estimate the discharge on unmeasured days.

$$Q(m^3\,s^{-1}) = 17.871Gh - 13.753 \qquad n = 16 \qquad r^2 = 0.956 \qquad (1)$$

Similarly, daily suspended sediment loads in the measurement period ending 31 May 1999 were determined using a polynomial relationship between measured discharge and measured suspended sediment load given in Equation 2. A graphical presentation of this model is shown in Figure 11a together with some of its statistics. The statistics given include r^2, the coefficient of determination, n, the number of observed values, SE, standard error of estimate in the units of the dependent variable and p as the level at which the regression equation was significant.

$$SSL(t/d) = 0.189 - 0.27Q + 0.451Q^2 \qquad n = 15 \quad r^2 = 0.854 \qquad (2)$$

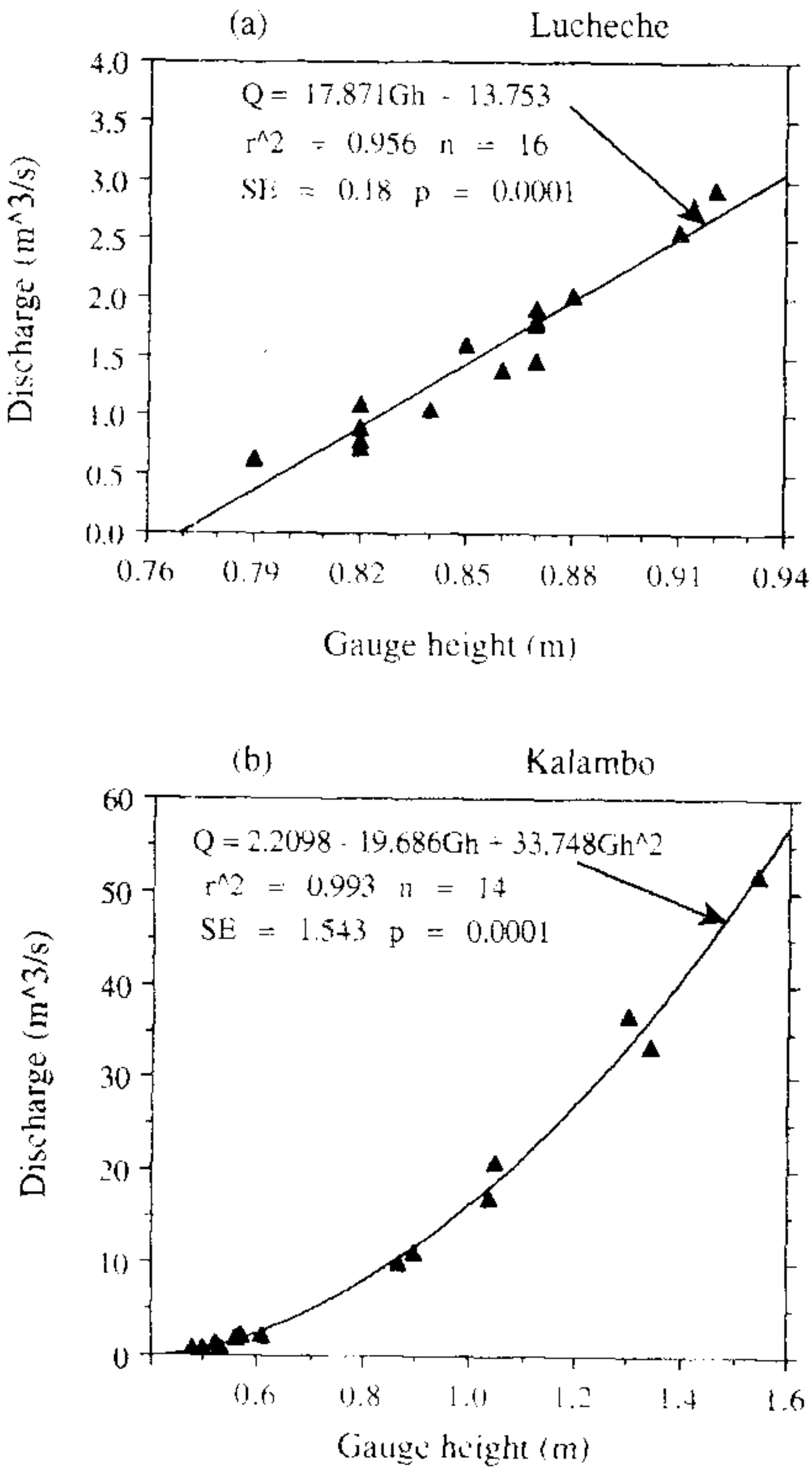


Figure 10 Discharge rating curves for (a) Lucheche River at Kawe Village, and (b) Kalambo River at Kalambo Village, September 1998 - May 1999.

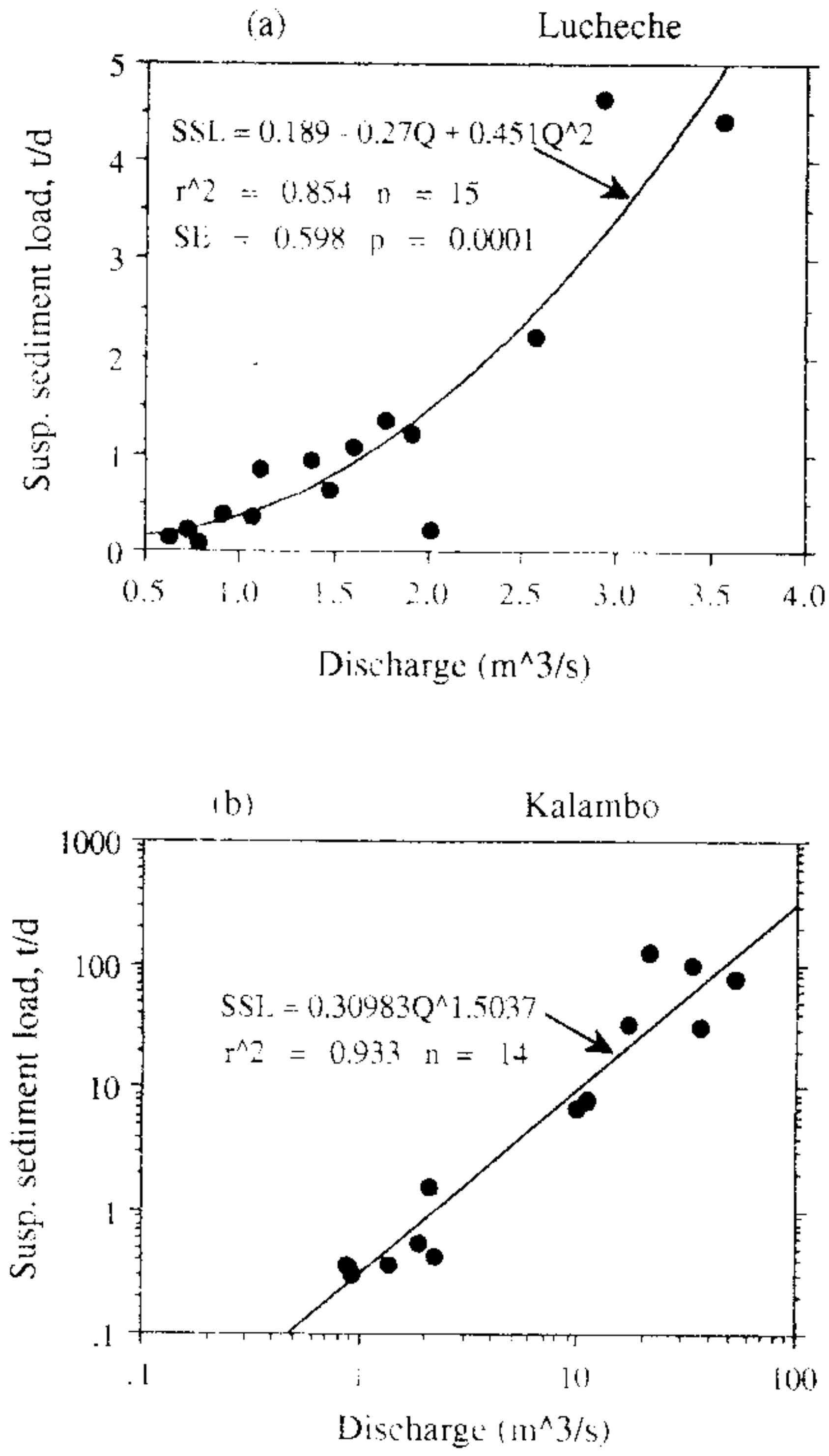


Figure 11 Suspended sediment rating curves for (a) Lucheche River at Kawe Village, and (b) Kalambo River at Kalambo Village, September 1998 - May 1999.

The total suspended sediment deposited into Lake Tanganyika by Lucheche River in the period of measurement up to 31 May, 1999, was found to be 358.8 tonnes while the total volume of discharge drained into the Lake was found to be 36.3 million cubic metres. Note that the cause of the change from the values given in the Seventh Report was largely the result of an error in the data entry of water levels for the month of December, 1998 which was repeated. The greater scrutiny of all analysed data for the Final Report made it possible to detect this particular error. However, any inconvenience caused is deeply regretted. Due to this error some figures in the Final Report for Lucheche River have decreased from those reported in the Seventh Report (Sichingabula, 1999b). This change in values also affected the sediment load per unit discharge which was now found to be 10.1 grammes per cubic metre of discharge deposited into the Lake. At this rate, the amount of discharge required to deposit 1 kg of sediment into Lake Tanganyika was found to be 101.1 m^3. The Lucheche River even after high flows have passed it still deposited the lowest volume of sediment into Lake Tanganyika largely because a considerable amount of its flow is the outflow from Lake Chila.

Summary statistics for Lucheche River of the monitored data are given in Tables 3 and 4, while a listing of mean daily water levels, discharge and suspended sediment is provided in Appendices 1a, 2a and 3a. Figure 12, prepared by Mr. H. Sikazwe, shows variations in water levels, discharge and suspended sediment load for Lucheche River in the period of measurement.

5.2.2 Kalambo River

For Kalambo river, discharge on unmeasured days was determined from the relationship between gauge height and discharge given by the polynomial Equation 3 shown below (Figure 10b).

$$Q(m^3 s^{-1}) = 2.2098 - 19.686Gh + 33.7681Gh^2 \quad n = 14 \quad r^2 = 0.993 \qquad (3)$$

This polynomial equation was found to be the best predictor of discharge when gauge height was known compared to other regression models for a variety of reasons previously discussed by Sichingabula (1999a).

Using measured and predicted discharge values, suspended sediment loads for unmeasured days in the period of measurement up to 31 May, 1999 were estimated using the logarithmic power Equation 4 given below and illustrated in Figure 11b.

$$SSL\ (t/d) = 0.30983Q^{1.5037} \quad n = 14 \quad r^2 = 0.933 \qquad (4)$$

Table 3. Summary data of water levels, discharge and sediment loads on rivers in southern Lake Tanganyika basin, Zambia.

	Station number	River	Period	Days	Water Level (m) Min	Water Level (m) Mean	Water Level (m) Max	Discharge (m3/s) Min	Discharge (m3/s) Mean	Discharge (m3/s) Max	Susp. Sed. Load (t/d) Min	Susp. Sed. Load (t/d) Mean	Susp. Sed. Load (t/d) Max
1.	7-022	Lucheche	18.09.98-31.05.99	257	0.78	0.86	1.18	0.186	1.634	7.335	0.149	1.396	22.472
2.	7-030	Kalambo	01.10.98-31.05.99	243	0.47	0.91	2.14	0.41	18.401	114.31	0.083	39.577	385.36
3.	7.015	Izi	18.09.98-31.05.99	255	0.65	0.92	1.48	0.601	1.426	4.680	0.309	1.248	5.279
4.	7.008	Lunzua	20.09.98-31.05.99	254	0.80	0.98	1.68	7.002	13.555	39.135	9.875	25.968	88.794
5.	7.775	Lufubu	16.09.98-31.05.99	258	5.00	5.26	5.81	20.143	90.563	346.680	1.686	208.603	1539.634

Table 4. Specific sediment yields by rivers in the southern Lake Tanganyika basin, Zambia.

No. no.	River	Period	No. of Days	Drainage area (km2)	Total Discharge (million m3)	Total sed. load (t)	Sed. load (t/km2)
1.7-022	Lucheche	18.09.98 - 31.05.99	257	312.0	36.3	358.8	1.2
2.7-030	Kalambo	01.10.98 - 31.05.99	243	2,550*	386.3	9,617.1	3.8
3.7.015	Izi	18.09.98 - 31.05.99	255	54.4	31.4	318.2	5.9
4.7.008	Lunzua	20.09.98 - 31.05.99	254	686.0	297.5	6,595.8	9.6
5.7.775	Lufubu	16.09.98 - 31.05.99	258	7,047.0	2.2 billion	53,819.7	7.6

*Estimate based on GIS mapping of the catchment by A. Mills at NRI.

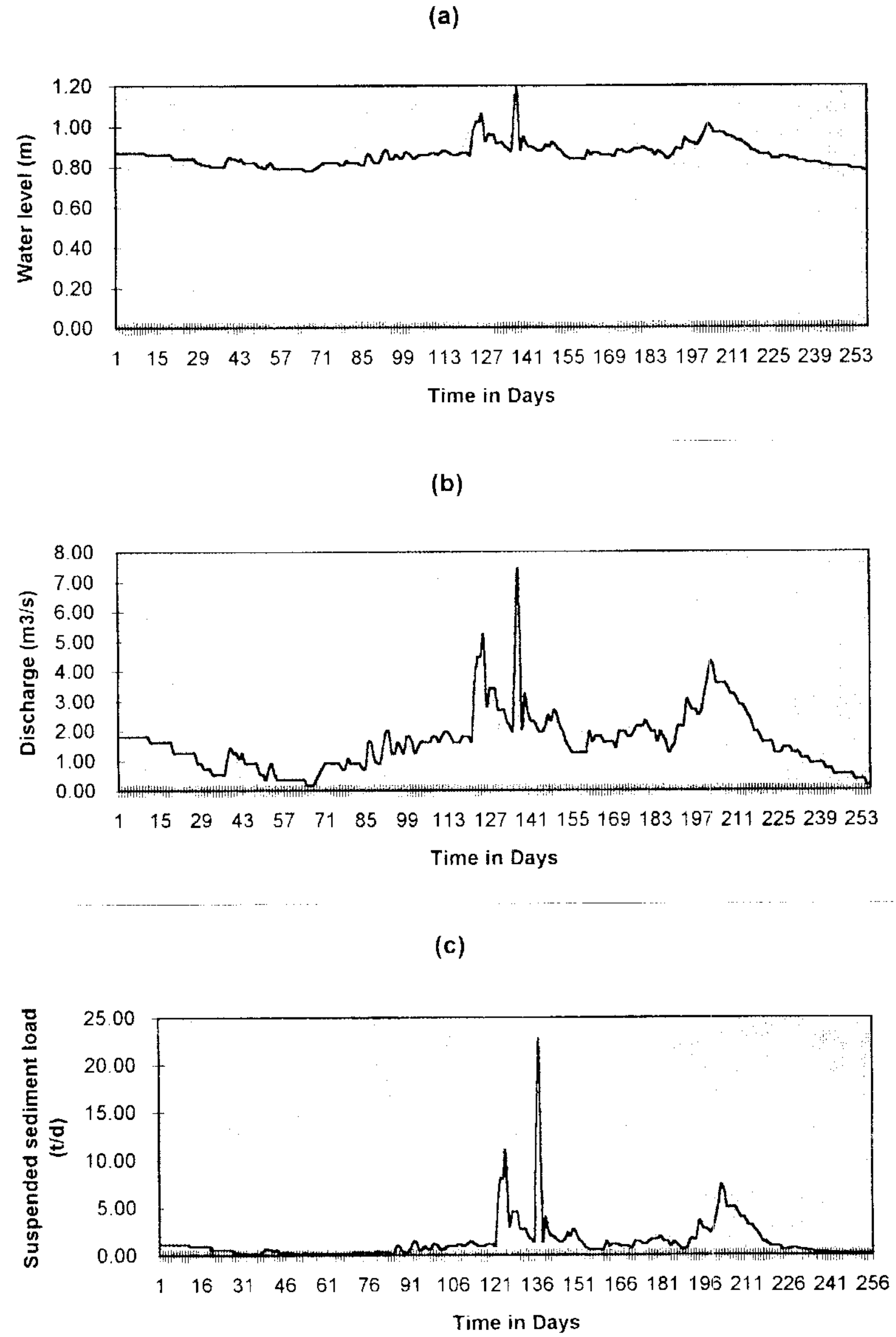


Figure 12. Graphs showing variations in (a) water levels, (b) discharge, and (c) suspended sediment load for Lucheche River at Kawe Village, 17 September 1998 - 31 May, 1999.

Predicted and measured suspended sediment loads in the period of analysis were found to be 9,617.1 tonnes with a corresponding discharge volume of 386.3 million cubic metres. In terms of unit measurements, this amounted to 24.9 grammes per cubic metre of river discharge. At this rate, a total of 40.2 m^3 of discharge is required for 1kg of sediment to be deposited into Lake Tanganyika by this river. Thus, Kalambo River has the highest rate of sediment transport as it has the lowest number of cubic metres of discharge for the deposition of 1 kg of suspended sediment load into Lake Tanganyika. Most of this load is transported by discharges in the moderate to high flow ranges.

Summary statistics for Kalambo River of the monitored data are given in Tables 3 and 4, while a listing of mean daily water levels, discharge and suspended sediment is provided in Appendices 1b, 2b and 3b. Figure 13, prepared by Mr. H. Sikazwe, shows variations in water levels, discharge and suspended sediment load for Kalambo River in the period of measurement.

5.2.3 Izi River

On Izi River, discharge on unmeasured days were estimated by the determined polynomial regression equation between measured discharge and gauge height given in Equation 5 (Figure 14a).

$$Q(m^3 s^{-1}) = 3.085 - 7.792Gh + 6.109Gh^2 \quad n = 16 \quad r^2 = 0.968 \qquad (5)$$

For the estimation of unmeasured sediment loads, a simple regression equation was found to be the best predictor. The determined simple regression equation between measured discharge and suspended sediment load is given in Equation 6 below and illustrated in Figure 15a.

$$SSL\ (t/d) = 1.138Q - 0.375 \quad n = 16 \quad r^2 = 0.668 \qquad (6)$$

Analysis has shown that in the period of measurement, a total of 31.4 million cubic metres of discharge was drained into Lake Tanganyika while the total suspended sediment deposited in the same period was 318.2 tonnes. In terms of mass volume, Izi River transported 10.1 grammes of suspended sediment per cubic metre of discharge volume. This means that it would require 98.7 m^3 of river discharge to deposit 1 kg of sediment into Lake Tanganyika. These figures are similar to those observed on the Lucheche which transports the lowest volume of sediment into the Lake.

Summary statistics for Izi River of the monitored data are given in Tables 3 and 4, while a listing of mean daily water levels, discharge and suspended sediment is provided in Appendices 1c, 2c and 3c. Figure 16, prepared by Mr. H. Sikazwe, shows variations in water levels, discharge and suspended sediment load for Izi River in the period of measurement.

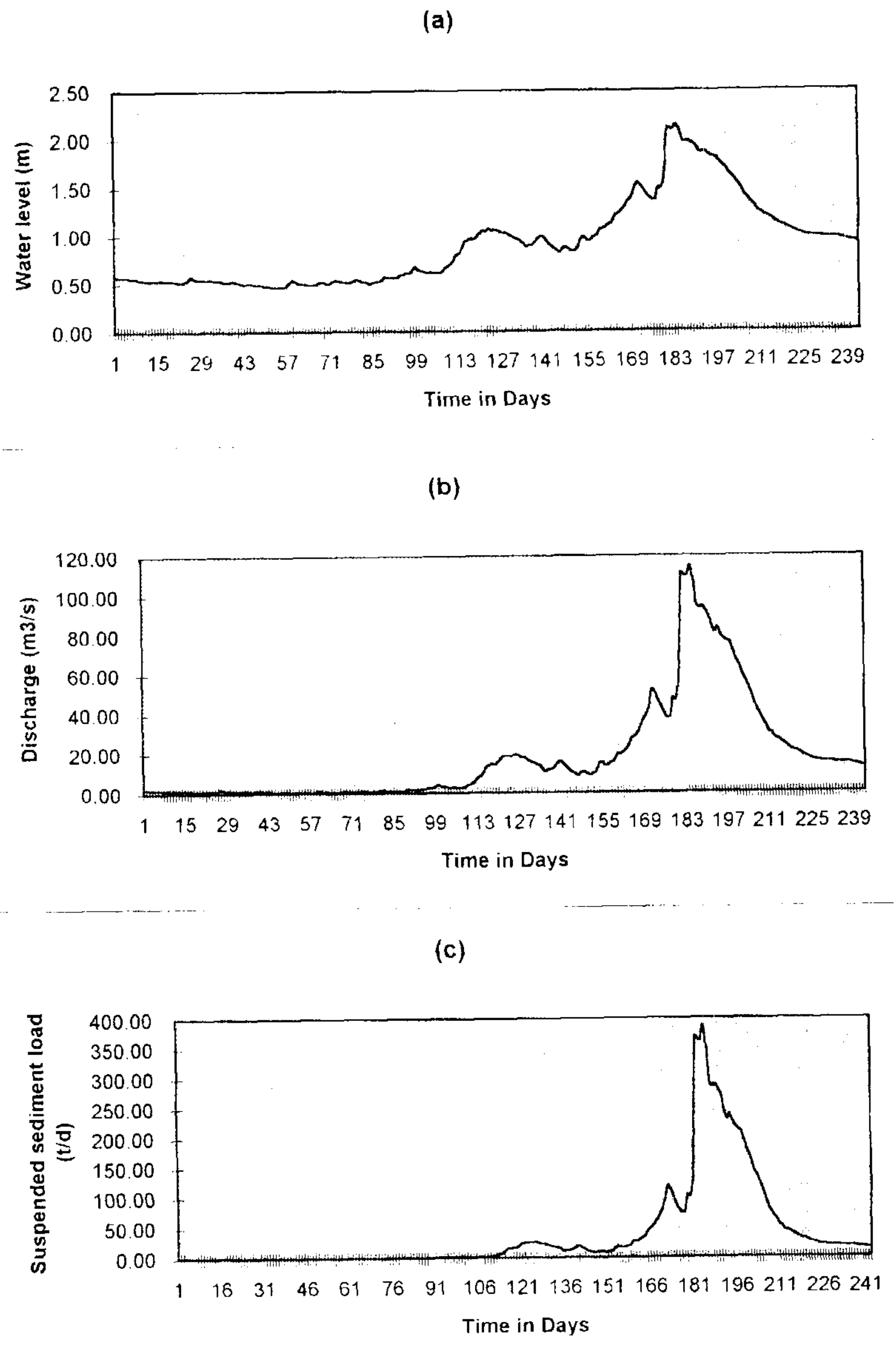


Figure 13. Graphs showing variations in (a) water levels, (b) discharge, and (c) suspended sediment load for Kalambo River at Kalambo Village, 1 October 1998 - 31 May, 1999.

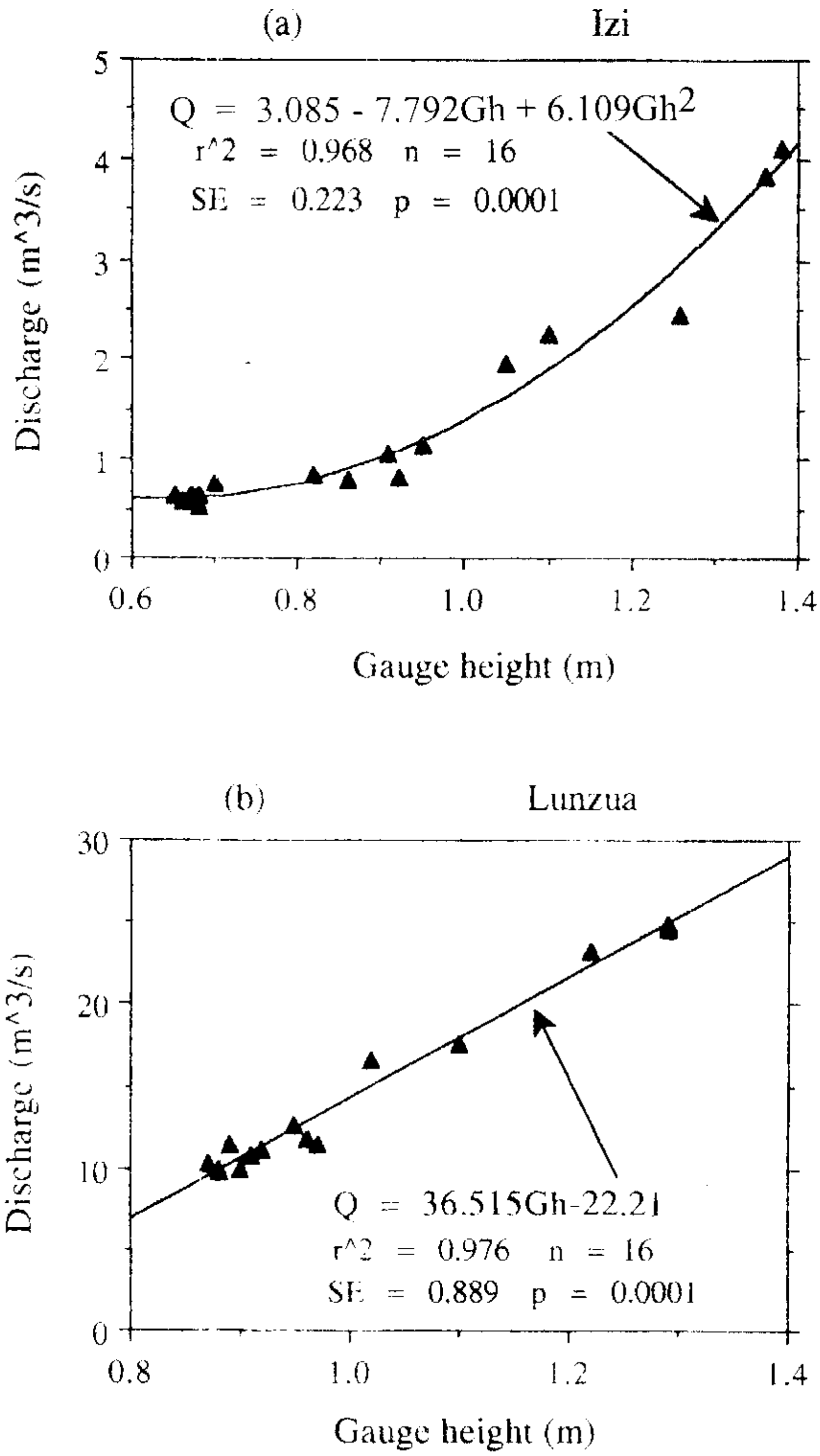


Figure 14. Discharge rating curves for (a) Izi River at Mbete Village, and (b) Lunzua River at Simumbele Village, September 1998 - May, 1999.

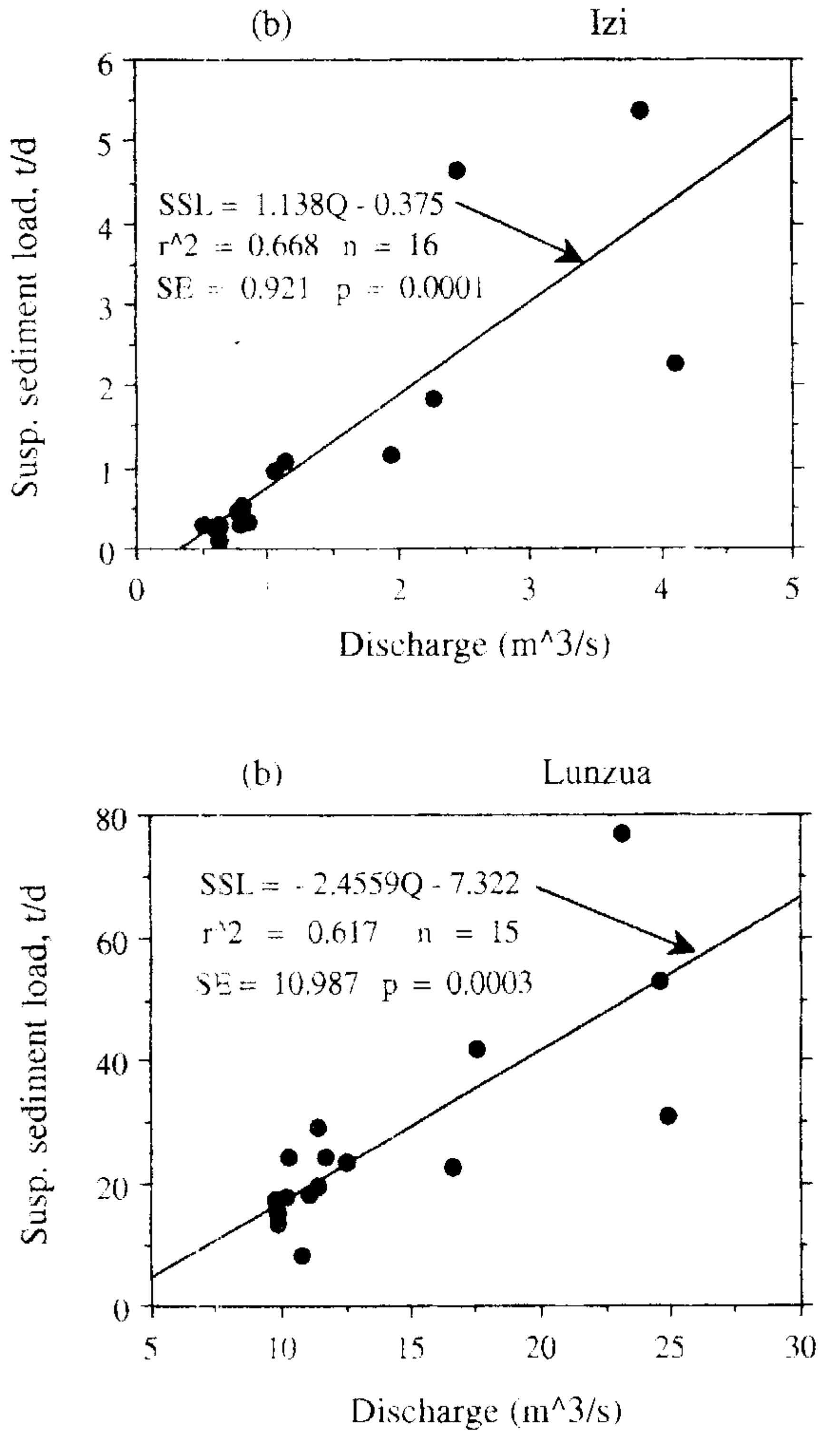


Figure 15 Suspended sediment rating curves for (a) Izi River at Mbete Village, and (b) Lunzua River at Simumbele Village, September 1998 - May, 1999.

5.2.4 Lunzua River

On Lunzua River, the relationship between gauge height and discharge was found to be very strong (r^2 = 0.976) with the simple regression equation determined being significant at the p = 0.0001 level (Equation 7) given below and illustrated in Figure 14b.

$$Q(m^3 s^{-1}) = 36.515Gh - 22.21 \qquad n = 16 \quad r^2 = 0.976 \qquad (7)$$

Equation 7 was applied to the daily water level in the period of measurement up to 31 May, 1999 and associated unmeasured discharges were calculated.

Similarly, in order to determine the volume suspended sediment load deposited into Lake Tanganyika, a simple regression model was applied to the daily discharges. The relationship between suspended sediment load and discharge was found to be moderate (r^2 = 0.617) and is shown in Equation 8 below (Figure 15b).

$$SSL (t/d) = 2.456Q - 7.322 \qquad n = 16 \quad r^2 = 0.617 \qquad (8)$$

In the period of study, an estimated total of 297.5 million cubic metres of discharge drained into Lake Tanganyika and a total of 6,595.8 tonnes of suspended sediment load was deposited into the Lake by the Lunzua River. Analysis has shown that sediment discharge into the Lake was about 22.2 grammes per cubic metre of discharge volume. This figure has not changed much from that of the period up to January and May 1999. At the present rate, a total of 45.1 m^3 of river discharge would be required to deposit 1 kg of suspended sediment. This time Lunzua River still ranks number three after Kalambo and Lufubu rivers which respectively rank first and second as far as suspended sediment transport into Lake Tanganyika is concerned.

Summary statistics for Lunzua River of the monitored data are given in Tables 3 and 4, while a listing of mean daily water levels, discharge and suspended sediment is provided in Appendices 1d, 2d and 3d. Figure 17, prepared by Mr. H. Sikazwe, shows variations in water levels, discharge and suspended sediment load for Lunzua River in the period of measurement.

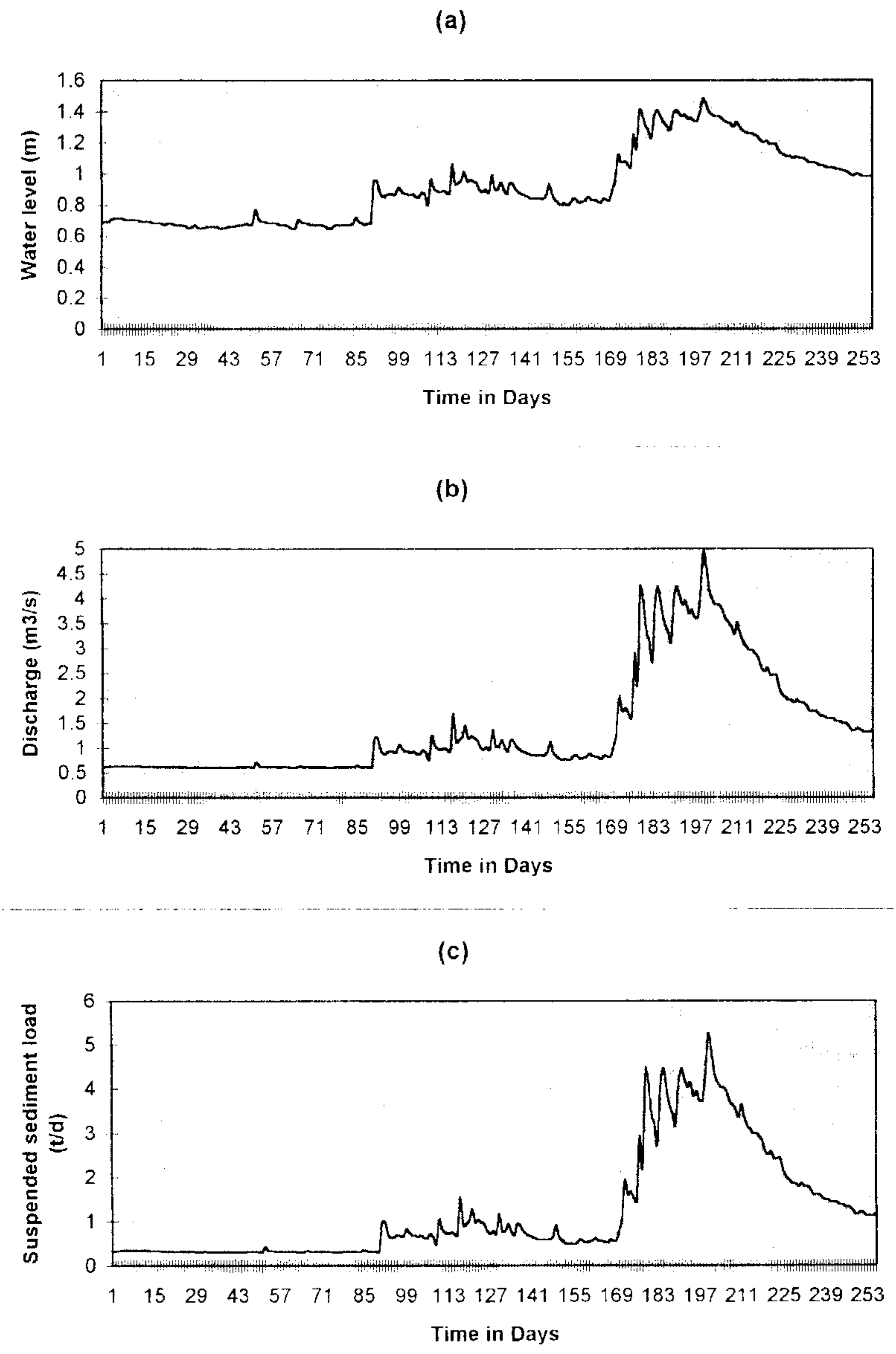


Figure 16. Graphs showing variations in (a) water levels, (b) discharge, and (c) suspended sediment load for Izi River at Mbete Village, 18 September 1998 - 31 May, 1999.

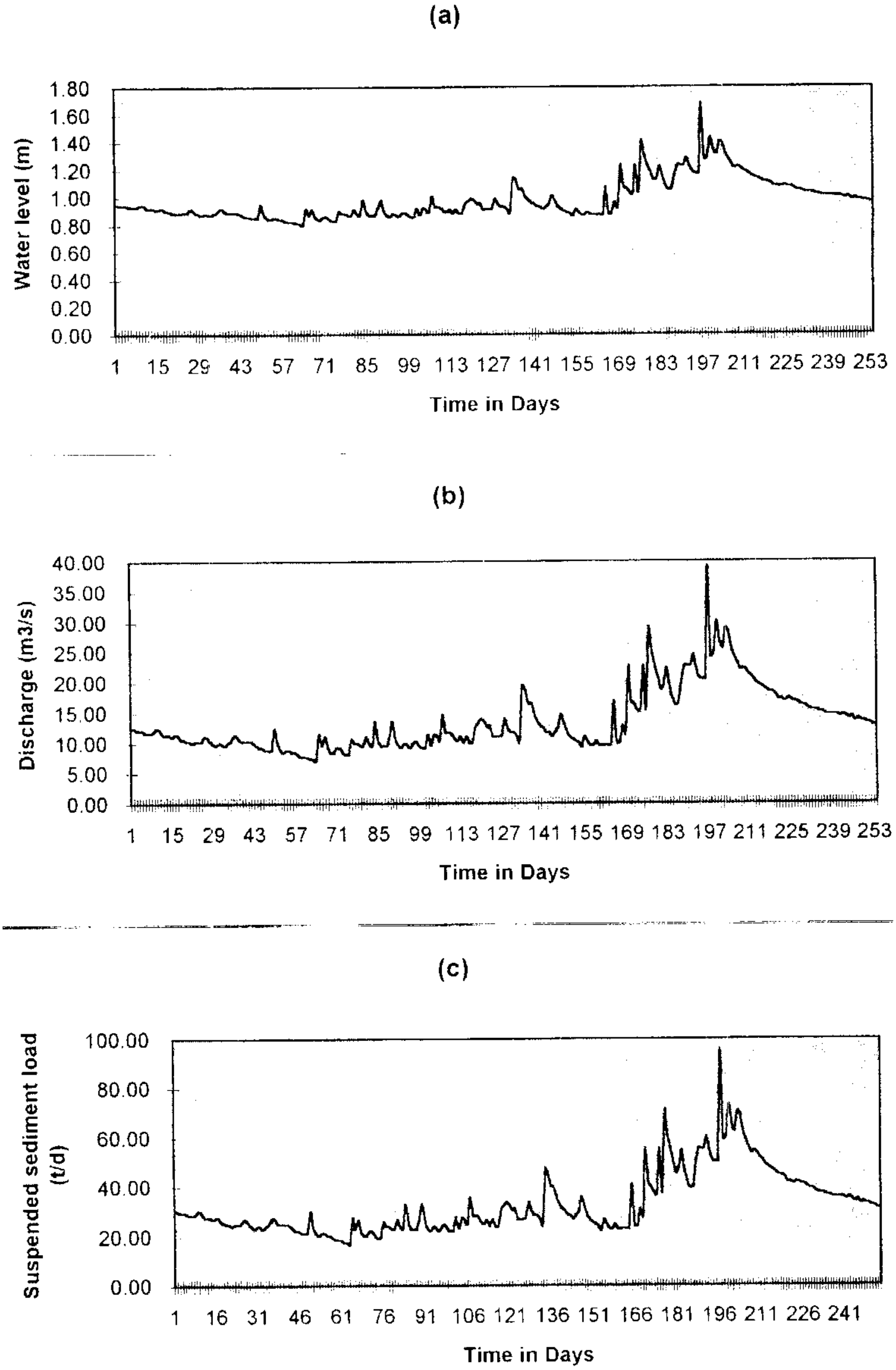


Figure 17. Graphs showing variations in (a) water levels, (b) discharge, and (c) suspended sediment load for Lunzua River at Simumbele Village, 20 September 1998 - 31 May, 1999.

5.2.5 Lufubu River

The simple regression Equation between gauge height and discharge obtained in the period up to 31 May, 1999 has been replaced by a second degree polynomial found to be the best predictor of discharge in the period of the Project. This is given in Equation 9 below and

$$Q(m^3 s^{-1}) = 5201.298 - 2277.071Gh - 248.168Gh^2 \quad n = 21 \quad r^2 = 0.864 \quad (9)$$

illustrated in Figure 18a. Similarly, daily sediment loads on unmeasured days were estimated from discharge levels using another polynomial in Equation 10 given below (Figure 18b). Due to underestimation of sediment loads, a power function relationship between discharge and suspended sediment load could not be used on Lufubu River. The equation also yielded negative values below 5.00 m of gauge height.

$$SSL\ (t/d) = -9.387 + 0.308Q + 0.012Q^2 \quad n = 21 \quad r^2 = 0.94 \quad (10)$$

Analysis of discharge and suspended sediment load revealed that in the period of study the total discharge deposited into the Lake was 2.2 billion cubic metres while deposited suspended sediment load was 53,819.7 tonnes. In terms of mass per unit volume, Lufubu River transported 24.5 grammes of suspended sediment per cubic metre of discharge. At the current rate of sediment transport, 40.8 m^3 of discharge would be required for the river to deposit 1 kg of sediment into the lake.

Summary statistics for Lufubu River of the monitored data are given in Tables 3 and 4, while a listing of mean daily water levels, discharge and suspended sediment is provided in Appendices 1e, 2e and 3e. Figure 19, prepared by Mr. H. Sikazwe, shows variations in water levels, discharge and suspended sediment load for Lufubu in the period of measurement. Similarly, in Figure 20a lake water levels monitored between November 1998 and May 1999, show a variation of about 0.54 m. The long-term record shows that water levels have decreased by about 10.0 m since 1960s and appear to be on an increase today (Figure 20b). The observation of recent increase in water levels on Lake Tanganyika is consistent with the 10-day temporal resolution TOPEX / POSEIDON satellite based measurents undertaken by NASA between 1992 and 1998 (Birkett *et al*. 1999).

Overall, there is controversy about the magnitude of flucuations of the levels of lake Tanganyika. Based on palaeohydrological data back to 40 kyr BP, from carbon data record of organic matter in diatomaceous cores, Gasse *et al*. (1989) have argued that water levels on Lake Tanganyika have been considerably variable in the past. They concluded that water level balance of Lake Tanganyika reflects the hydrological ocean variations that are due to the glaciation / deglaciation processes and the related greater availablity of global atmospheric moisture during warmer global climatic changes. However, it is not yet possible to equate the recent (1957-1999) water level fluctuations on Lake Tanganyika to any of the factors attributed to above, but the effects of deglaciation on large world ice-fields caused by a general tendency of the world getting warmer such that, in the long run, would not be an unplausible linkage.

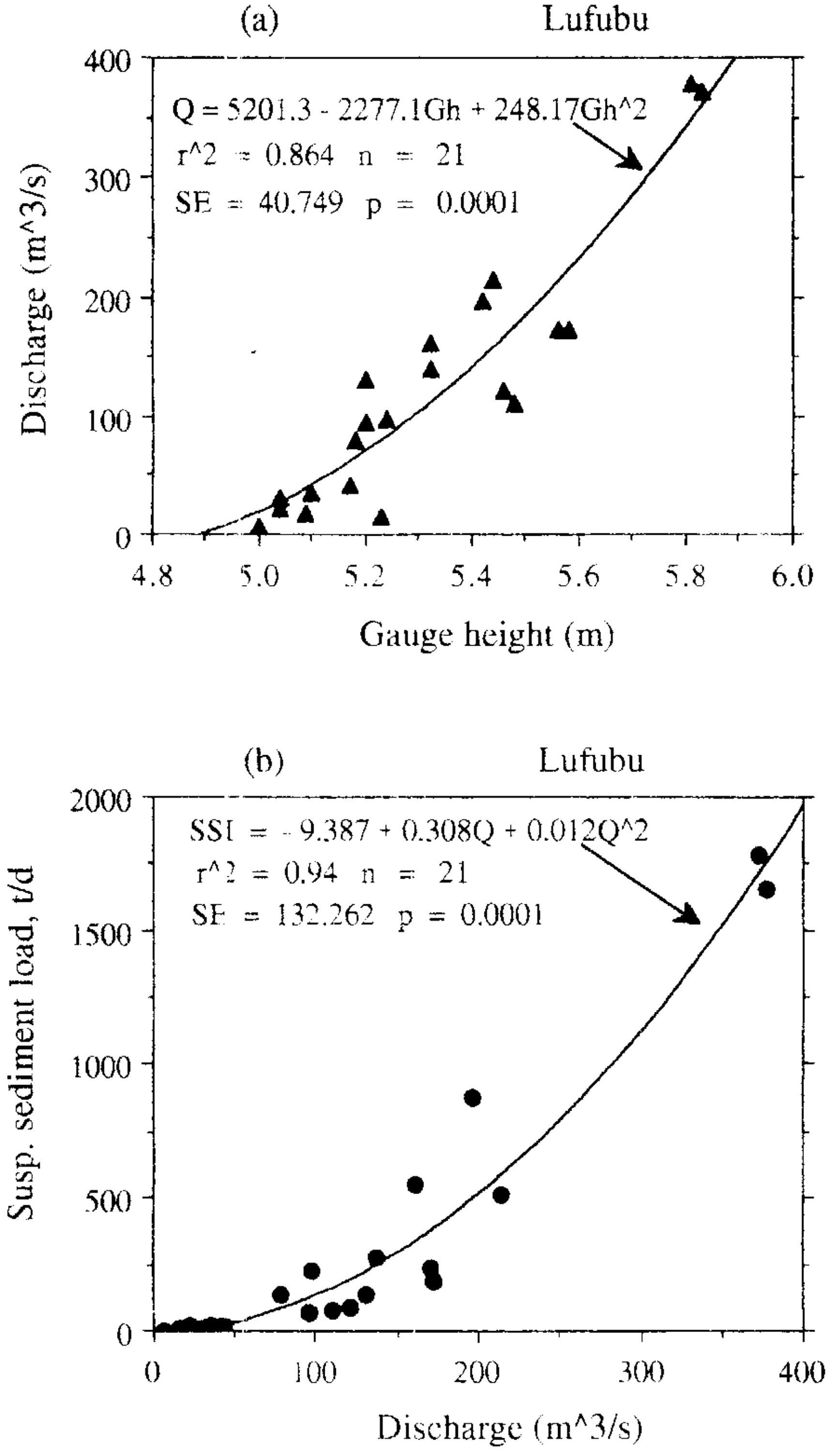


Figure 18 Discharge (a) and suspended sediment (b) rating curves for Lufubu River at Kabyolwe Village, September 1998 - May, 1999.

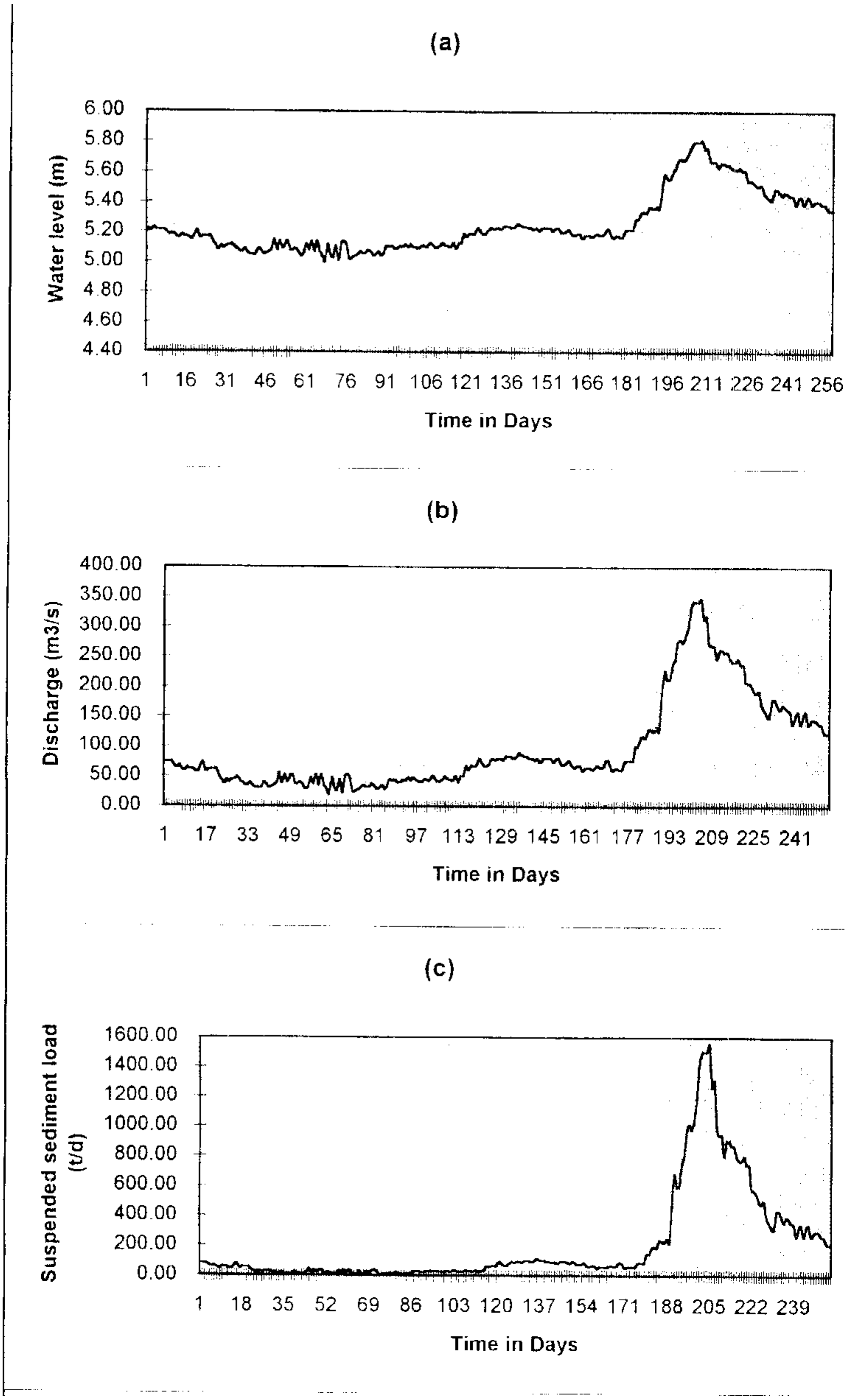
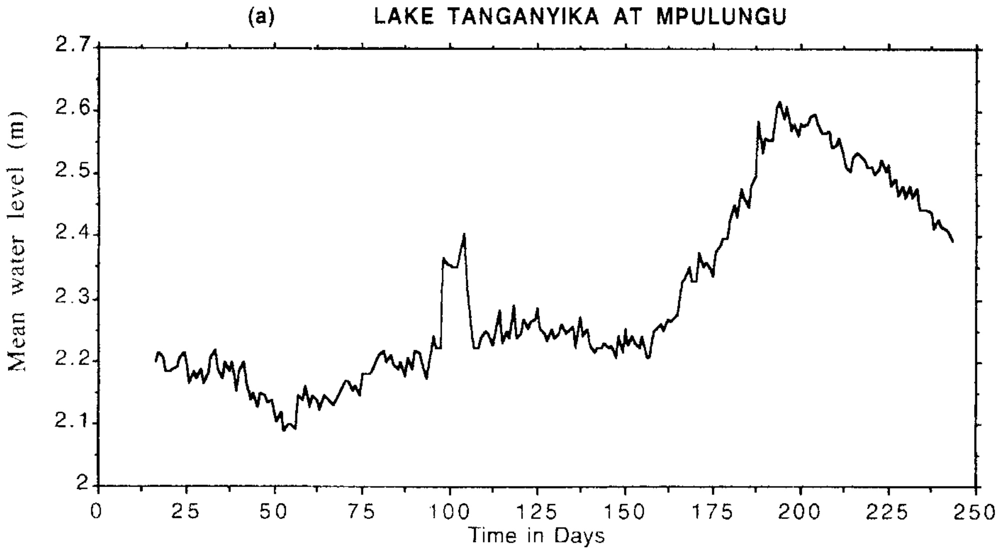


Figure 19. Graphs showing variations in (a) water levels, (b) discharge, and (c) suspended sediment load for Lufubu River at Kabyolwe Village, 16 September 1998 - 31 May, 1999.



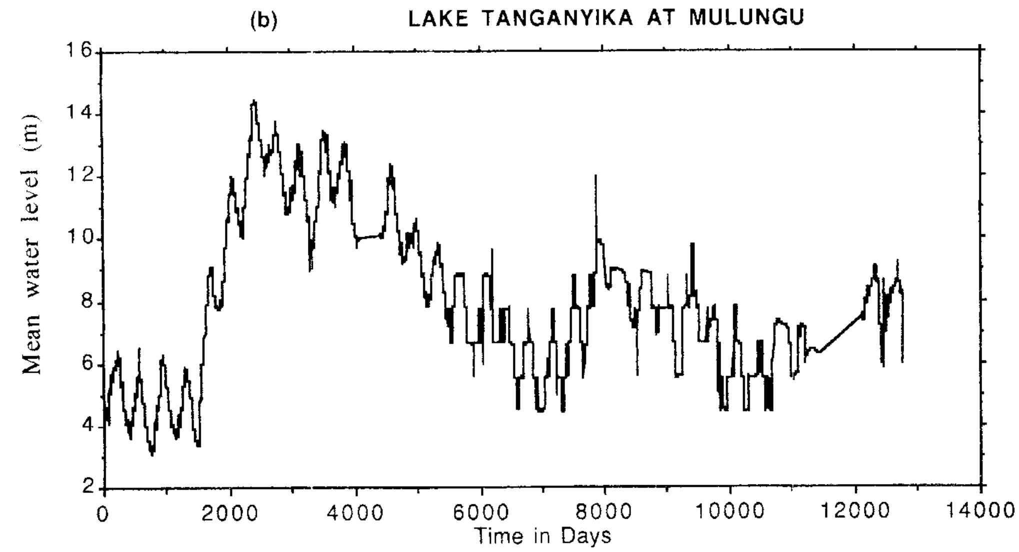


Figure 20 Graphs showing (a) short-term (November, 1998 - May, 1999) and (b) long-term (1957-1992) variations in mean water levels on Lake Tanganyika at Mpulungu station.

5.3 Total Dissolved Sediment Load

Measurement of total dissolved loads using the TDS meter commenced during high flow measurement in the month of March, 1999. The delay of this exercise was caused by the late receipt of the necessary equipment which was requested for purchase in 1998. Knowledge of dissolved sediment transported by rivers is important for assessing the total load deposited into the lake. Total sediment input into the lake is composed of bed material load, which moves by saltation, rolling and sliding on the river bed; clastic suspended sediment which is transported in the flow by turbulent and viscous forces; and lastly is the dissolved, chemical or solute load which moves as part of the flow.

The largest portion of total sediment load is suspended load which accounts for 90 to 95% of the load on most rivers. This is followed by bed load which makes 5 to 10% while dissolved load contributes less than 5%. However, the contribution of dissolved load is not well understood due to limited data available. But on some rivers, especially in drier environments and in carbonaceous regions, dissolved loads make the largest portion of total loads transported by rivers. Additionally, the impacts of these different types of sediment on the biodiversity of the Lake are variable and will have to be assessed at some time in the future. It is realised that without data on all types of sediment entering the lake, such an assessment may not be possible.

As discussed in the sections above, very good suspended sediment data in the period of measurement have been collected by the Zambia SSS Team. For dissolved data, the four sets of data on four of the five stations so far collected were not enough to permit robust statistical analysis of the data. This analysis will have to wait for the availability of more data.

However, the magnitudes of the dissolved sediment load on a few measured days will be reported. The data are presented in Table 5 below. Generally, Table 5 shows that dissolved loads are lower than suspended sediment loads for the same discharge. However, in a majority of cases the dissolved sediment loads transported by the rivers were in the same orders of magnitude as the suspended sediment loads. When the two values SSL and TDL are added together, they yield the total sediment load transported by rivers into Lake Tanganyika.

Table 5. Measured daily total dissolved loads on study rivers compared to suspended sediment loads for measured discharge.

No.	Date	River	Water T °C	Q ($m^3 s^{-1}$)	SSL (t/d)	TDS (mg/L)	TDL (t/d)
1.	18.03.99	Lucheche	28.0	2.20	0.21	13.5	2.57
2.	22.03.99	Lucheche	29.0	1.91	1.22	13.6	2.25
3.	10.04.99	Lucheche	27.0	3.56	4.42	11.2	3.44
4.	02.05.99	Lucheche	27.1	1.61	1.08	12.6	1.75
5.	19.06.99	Lucheche	25.0	0.39	1.05	14.8	15.3
6.	17.03.99	Kalambo	28.0	33.44	98.81	48.8	140.99
7.	27.04.99	Kalambo	27.0	36.71	31.71	8.7	27.59
8.	11.05.99	Kalambo	28.0	20.98	124.73	10.5	19.04
9.	16.06.99	Kalambo	23.8	7.57	2.88	11.7	7.65
10.	18.03.99	Izi	29.0	2.44	4.64	16.8	3.54
11.	22.03.99	Izi	28.2	3.85	5.05	15.5	5.15
12.	10.04.99	Izi	27.0	4.11	2.27	11.0	3.90
13.	02.05.99	Izi	27.1	2.26	1.84	16.1	3.15
14.	19.06.99	Izi	25.0	1.43	0.74	14.7	1.81
15.	21.03.99	Lunzua	29.0	23.14	76.78	8.8	17.60
16.	06.04.99	Lunzua	25.2	24.94	31.03	8.3	17.88
17.	26.04.99	Lunzua	27.1	17.51	42.06	8.4	12.71
18.	10.05.99	Lunzua	26.5	16.65	22.73	8.5	12.23
19.	15.06.99	Lunzua	25.4	10.82	12.90	14.7	13.74
20.	19.03.99	Lufubu	28.0	138.39	272.62	10.9	130.33
21.	20.03.99	Lufubu	28.0	162.16	554.81	10.2	142.91
22.	25.03.99	Lufubu	27.8	196.12	874.33	10.0	169.44
23.	26.03.99	Lufubu	28.0	214.92	516.21	10.1	187.54
24.	08.04.99	Lufubu	28.0	377.00	1654.70	10.5	342.02
25.	09.04.99	Lufubu	28.0	372.14	1794.11	10.1	324.74
26.	28.04.99	Lufubu	28.0	172.73	191.02	10.4	155.21
27.	29.04.99	Lufubu	28.0	171.58	237.19	10.1	149.73
28.	12.05.99	Lufubu	27.5	111.08	74.86	10.5	100.77

5.4 Bed Material Load Composition

Generally, the composition of bed material sediment on studied rivers were found to range from clay to boulders. Rivers such as the Lufubu and Izi mostly transport sand due to the nature of areas they access while the rest transport largely a mixture of particle sizes. Largest bed load materials were found on Kalambo River which has the capacity to transport large calibre bed load given the high velocities associated with high flood events. This load only moves at high flows. For most of the time it acts as an armour to the interstitial fine-grained fraction which are liberated by the scouring of the bed at different discharge threshold levels.

Table 6 reports the results of particle size analysis of a large sample collection of bed material sediment collected from a number of points along each of the studied rivers during the reconnaissance survey (Sichingabula, 1997). The composition of grain sizes varied even within the same river reaches. It is also interesting to note changes in sediment particles of rivers, especially at river mouths on Lake Tanganyika. Generally, at river mouths the large fraction sediment is found because fine-grained materials are transported further into the lake by fluvial currents and viscous forces where they later settle to the bottom of the lake.

Table 6. Results of particle size analysis of bed load samples collected from the southern Lake Tanganyika basin[1].

No.	Date	Name of River and Location of Sample	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	Total
			GRAIN SIZE COMPOSITION (%)						
1.	30.08.97	Lunzua R. at Kapata Village / L/B Namukale Falls	0.1	0.3	40.8	58.5	0.3	0.0	100
2	30.08.97	Lunzua River at Kapata Village /R/B Namukale Falls	1.0	1.3	61.0	36.0	0.6	0.1	100
3.	01.09.97	Lunzua River at Kambole Bridge	0.3	0.4	39.0	42.1	2.4	15.8	100
4.	03.09.97	Lunzua River at Simumbele Village	1.7	2.2	86.1	10.0	0.0	0.0	100
5.	30.08.97	Lucheche River at mouth / Kawe Village	0.0	0.0	5.0	87.8	5.2	2.0	100
6.	30.08.97	Kalambo River 1 km above mouth	0.4	0.5	27.4	65.7	4.9	1.1	100
7.	30.08.97	Kalambo River at mouth / Chipwa Village	0.1	0.3	15.4	62.0	20.9	1.3	100
8.	04.09.97	Kalambo River at Kalambo Village	0.0	0.0	4.2	23.4	16.3	56.1	100
9.	05.09.97	Lufubu River at Keso Falls station	0.2	0.3	10.9	79.6	7.9	1.1	100
10.	05.09.97	Lufubu River downstream of Keso Falls	0.1	0.2	65.0	25.7	6.7	1.1	100

Table 6 concluded

			GRAIN SIZE COMPOSITION (%)						
No.	Date	Name of River and Location of Sample	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	Total
11.	08.09.97	Lufubu River below Yendwe Village Harbour 2	0.2	0.5	44.2	45.8	8.4	0.9	100
12.	08.09.97	Lufubu River at Kabyolwe Village / mouth	0.0	0.0	0.2	96.7	3.0	0.1	100
13.	09.09.97	Izi River at Mbete Village L/B	0.1	0.1	3.0	96.0	0.6	0.2	100
14.	09.09.97	Izi River at Mbete Village -Centre	0.0	0.1	6.6	76.1	5.0	12.2	100

1 Analyses conducted in the Department of Geography at the University of Zambia.

L/B = Left bank; R/B = Right bank.

6.0 DISCUSSION AND INTERPRETATION

6.1 Introduction

Compiled discharge and suspended sediment data is subjected to further analysis in order to make sense of the nature of sediment transport in the southern Lake Tanganyika basin. This is done by conducting analysis which utilize the estimated data and makes interpretation of findings based on a number of data manipulations. These include determination of the most effective discharge class in the transportation of suspended load, specific sediment yield per unit area at basin scale, and change in stream bed elevations. The analyses are related to aspects and factors within the larger catchment which help in explaining why discharge and sediment data are at the current levels. Each one of these analyses are discussed below together with related issues.

6.2 Magnitude and Frequency Characteristics of Suspended Sediment Transport

The concept of magnitude frequency characteristics of sediment transport by rivers was first introduced by Wolman and Miller (1960). Wolman and Miller argued that the amount of sediment transported by flows of a given magnitude depends upon the form of the relationship between discharge and sediment concentration, as well as on the form of the frequency distribution of the discharge events. Moderate flows of low frequency were predicted to be the most effective in the transportation of suspended sediment load. This classical work was followed by studies which emphasized the effectiveness of fluvial events in modifying landscapes (e.g., Gupta and Fox, 1974; Baker, 1977; Wolman and Gerson, 1978; Hickin and Sichingabula, 1988, Beven, 1981). Although the utility of this concept to the understanding of dominant (effective) discharge (Q_{eff}) of many rivers was questioned by Benson and Thomas (1966), the approach continued to be used for at least thirty years. Many studies (e.g., Andrews, 1980; Webb and Walling, 1982; Pickup and Warner, 1976), complemented Wolman and Miller's (1960) work.

However, Ashmore and Day (1988) concluded that the concept of a simple effective discharge was not applicable to the Saskatchewan streams and that, in many cases, the effective discharge histograms were not the unimodal distribution envisaged by Wolman and Miller (1960). More recently, Sichingabula (1999c) has criticised and showed the limitations of the class-based approach of determining the effective discharge. He has proposed alternate approaches of determining effective discharge for suspended sediment transport. However, none of the proposed approaches have been applied on rivers in northern Zambia due to limited data available.

Table 7 shows that the effective discharge on the five studied rivers was variable ranging from 0.78 $m^3 s^{-1}$ on Izi River to 258 $m^3 s^{-1}$ on the Lufubu River. The durations of these class-based effective discharges were found to range from 2.1% corresponding to the highest discharge, to 54.5% of the time on Izi River where the lowest event transported the most load. The sediment-discharge regimes for rivers in southern Lake Tanganyika basin exhibited four forms previously identified by Ashmore and Day (1988). The first form (1) is one characterised by a uniform histogram having a well defined mode and a relatively frequent effective discharge. This was exemplified by Lucheche River which resembled what was envisaged by Wolman and Miller (1960) (Figure 21a). The second form (2) is one in which the lower level flows are the effective discharge (Figure

21b). Lunzua River depicted this category quite clearly. It represents rivers where the low flows of high frequency do the most work of sediment transport.

The third form (3) is one characterised by an erratic form due to discharges of widely differing durations transporting similar loads. This was exemplified by Izi River which had a bimodal distribution of effective discharge (Figure 21c). The final sediment-discharge form (4) is one in which the extreme upper level events are the effective discharge. Kalambo River illustrates this form very clearly where the largest event transported the most load in the period of study (Figure 22a). The Lufubu River also belongs to this category but it is less flashy because of its large size, it has an above average effective discharge of low frequency (Figure 22b).

The above analysis has revealed that different flow events were responsible for the transportation of largest portions of suspended sediment load into Lake Tanganyika. There is also need to assess the relationship of the effective discharges with bankfull discharges (Williams, 1978). This should be able to be done as more discharge data, especially the annual floods required for statistical determination of bankfull discharge, increase. Alternatively, field survey data could be used including some botanical evidence (Sigafoos, 1964), to determine bankfull discharges at each station.

Note that the events which belong to the moderate and extreme upper flow levels, can easily be measured by conducting a number of field campaigns for high flow discharge measurements as was done in March, 1999 by the Zambia SSS Team (Sichingabula, 1999b). As more discharge and sediment data accumulate more detailed analysis will be conducted on other aspects of the sediment problem (Walling, 1983) in the southern Lake Tanganyika basin.

Table 7. Magnitude and frequency characteristics of class-based effective discharge for suspended sediment transport on rivers in the southern Lake Tanganyika basin, Zambia.

No.	Station No.	River	Drainage Area (km^2)	Period of record	Class-based Q_{eff} (m^3s^{-1})	% Freq
1.	7-022	Lucheche	312.0	18.09.98-31.05.99	1.68	31.5
2.	7-030	Kalambo	2,550	01.10.98-31.05.99	109.65	2.1
3.	7-015	Izi	54.4	18.09.98-31.05.99	0.78	54.5
4.	7-008	Lunzua	686.0	20.09.98-31.05.99	11.20	38.0
5.	7-008	Lufubu	7,047	16.09.98-31.05.99	258.00	4.3

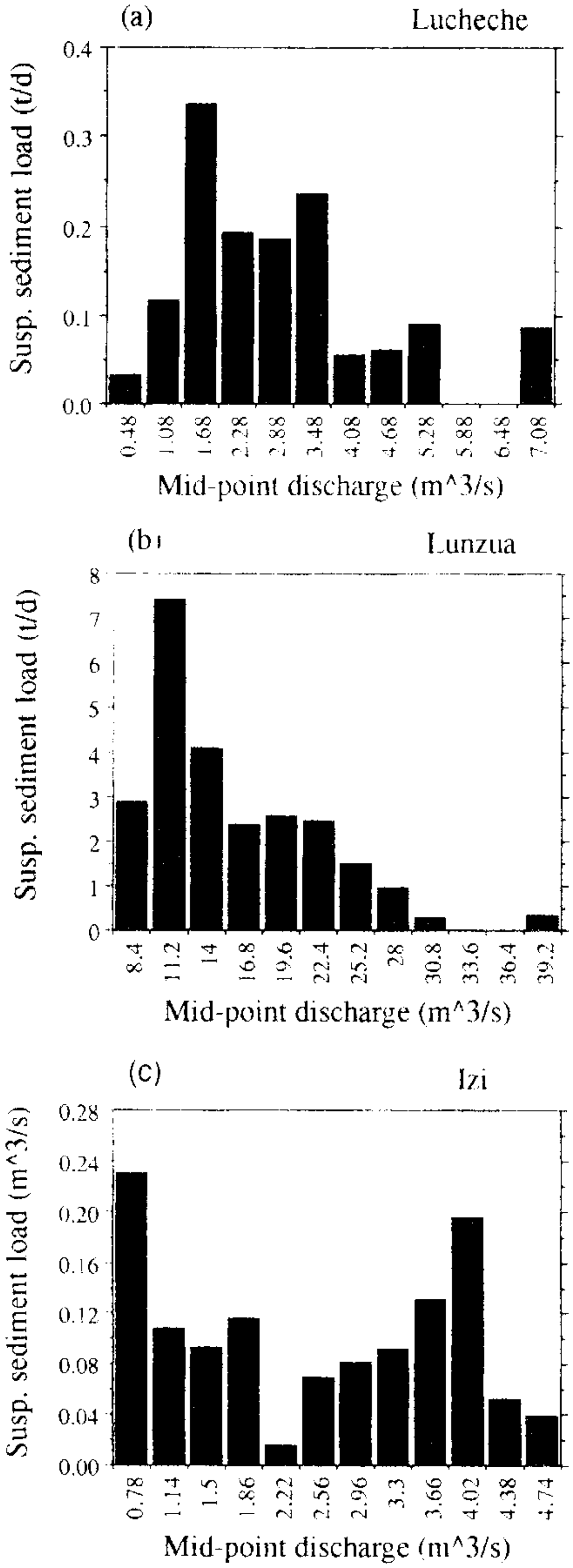


Figure 21. Sediment-discharge regimes for (a) Lucheche River at Kawe Village, (b) Lunzua River at Simumbele Village, and (c) Izi River at Mbete Village, September 1998 - May 1999.

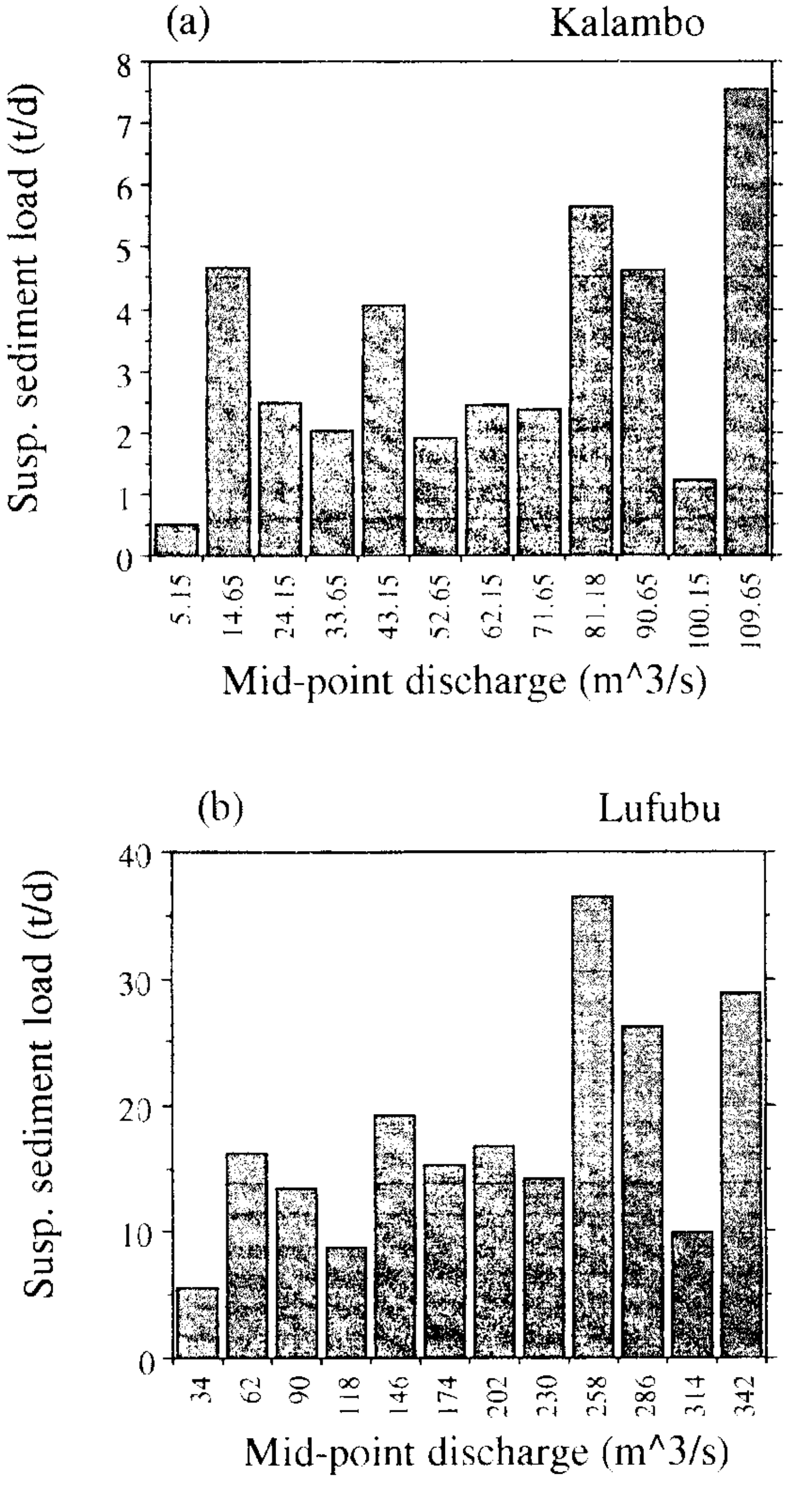


Figure 22. Sediment-discharge regimes for (a) Kalambo River at Kalambo Village, and (b) Lufubu River at Kabyolwe Village, September 1998 - May 1999.

6.3 Regional Assessments of Sediment Transport

The regional assessment of sediment transport that is possible with available data is at catchment scale. Table 3 summarizes total discharge and sediment loads transported by the five rivers in the period of measurement. It also reports of the amount of sediment contributed by each catchment per unit kilometre.

The five catchments in South Lake Tanganyika basin contribute between 1.2 and 9.6 tonnes of sediment per km^2. The data also shows that sediment yield decreases with drainage area. This is not uncommon as sediment transport generally decreases with catchment size. This is because larger catchments have greater potential for sediment storage such that only a limited amount is evacuated from the system. However, this is not the case for all rivers. Church and Slaymaker (1989) and Church *et al*. (1989) observed an increasing trend for river up to 10 km^2, and a declining trend for much larger rivers, in the formerly glaciated regions of British Columbia. There is need to evaluate what obtains in the Lake Tanganyika basin.

6.4 Sources of Sediment Supply

The sediment transported by rivers is recruited from different sources within catchments. A number of factors control the processes of sediment supply which can be classified into major areas, namely, factors relating to the nature of the catchments and channel processes. These are discussed below.

6.4.1 Drainage Basin Characteristics

The physical characteristics of catchments vary between rivers based on types of rocks, landforms, soils and land use types found in a particular river basin. Rocks which are easily weathered such as sandstones and meta-sediments generally experience higher amount of erosion than areas of fine-grained rocks. Most of the southern Lake Tanganyika basin is underlain by sandstone and therefore has a higher potential for soil erosion and sediment yield. This situation coupled with high relief in hilly and escarpment areas and the high amount of rainfall received in the area makes the catchment susceptible to increased amounts of sediment transport by rivers.

The other factor influencing the rates of sediment transport in the catchment are mining activities. A few minerals found in the Mbala area include gold and tin whose exploitation could lead to the deposition of a lot of heavy metals in the lake. It is important that appropriate measures are taken to reduce generation of sediment and its eventual deposition into the Lake.

Furthermore, the landuse types such as the *Chitemene* type of agriculture practiced in most of the basin, promotes the generation of sediment which is transported by runoff. Human activities of settlement creation, agricultural expansion also lead to deforestation and general degradation of the environment. The causes of deforestation are however varied. For instance in Mbala about 93% of the population use wood for most of their energy requirements (Central Statistical Office, 1990), which leads to deforestation. The annual deforestation per household ranges from 4.15 to 8.3 hectares (Stormgaard, 1989; 1984). It has been reported that early burning (April-July) destroys about 25% of the available herbage biomass while late burning (August-October) destroys 84% of the herbage (Rose-Inness, 1972). Burning also promotes soil erosion by wind in the dry season and by water at the onset of the rainy season before sufficient herbage cover develops (Chiti *et al*. 1989). The implication of this is that early burning should be practised instead of the latter.

In Zambia, the future of *Chitemene* is uncertain. Government policy is against the continuation of this agricultural practice. But this method of farming is practised mostly by rural farmers who cannot afford to buy expensive inputs such as fertilisers and pesticides. Perhaps instead of trying to stop *chitemene*, efforts should be directed at how it can be improved. For instance, Stromgaard (1984) has suggested that possible ways of improving *chitemene* is by involving new methods of clearing the bush, rotations with legumes and minimum tillage practices, or technological changes in the form of introducing oxen which are labour-saving in order to overcome seasonal labour shortages.

The issue of deforestation is also highly debatable. For instance, Radulovich (1990), argues that this problem will not be solved by better management of forests, no matter how beneficial in economic terms such management may be. This is because there are more serious problems like poverty and malnutrition facing developing countries including Zambia than deforestation. The major concern of leaders in developing countries is that deforestation should not be considered in isolation, ignoring the other realities of life.

6.4.2 Protection of Lake Tanganyika

Degradation of the environment can be minimized by conserving natural resources such as forests which offer protection to soils. The Lake Tanganyika basin in Zambia is very fortunate in that a sizeable area in under protection by the Department of Forestry and National Parks and Wildlife Services. The areas of forest reserves in the two districts which form a large part of the basin, Mbala and Kaputa, each have 188,028 ha and 26,548 ha, respectively (Ministry of Lands and Natural Resources, 1983). In the part of the catchment there are twelve national forests (N.F) including local forest reserves (L.F.). These include Lungu, N.F., Chitimbwa N.F., Mpulungu N.F., Samfu N.F., Lunzua N.F., Chikwalala N.F., Chinakila N.F., Mbala N.F., Mukalize N.F., Mwenze N.F., Isoka L.F. and Chila L.F. The total area of National Forests is 162,971 hectares. The total area under protection of forest reserves and national parks is 0.36 million ha which is about 20% of the total catchment area of 1.76 million ha (Chidumayo, 1997).

Sumbu National Park which is located on the western side of the southern Lake Tanganyika basin has an area of 2,020 km^2. The existence of this National Park and forest reserves in this basin, goes a long way in affording protection to sources of many rivers draining into Lake Tanganyika.

6.5 Channel Scour and Fill Processes

General stream-bed scour is defined as the lowering of the bed elevation due to erosion and filling and the rising of the bed due to deposition (Sichingabula, 1993). Methods of determining stream-bed scour and fill and the threshold discharge, the discharge above which scour contributes local boundary sediment directly to suspended sediment load (Sichingabula, 1993), and seasonal scour and fill regimes have previously been described (Colby, 1964; Leopold and Maddock, 1953; Maddock, 1969, Alvarez, and Alfaro 1973; Andrews, 1979; Laczay, 1973; Hickin, 1995).

A number of the above studies have observed that generally channels scour as discharge increases and fill as discharge declines. Rapid stream-bed scour is usually associated with the exceedance of threshold discharge for stream-bed scour (Q_{t1}) and bankfull discharge linked to the threshold level (Q_{t2}) at which dune forms are destroyed. A better understanding of these processes is essential to proper assessment of quantities of suspended sediment liberated from the river bed for transport in suspension.

Sichingabula (1993) has shown that stream cross-sections which do not experience seasonal net deposition or net scour of the stream-bed in the Fraser River, British Columbia, were characterised by 'single-valued' relationship of bed elevations in the seasonal cycle of scour and fill. This implies that the amount of sediment scoured during rising discharge were equal to those deposited in the falling stage. But at cross-sections where filling of the bed occurred, anticlockwise hysterisis in the bed elevation plotted against discharge was observed and a clockwise hysterisis in the case of channel degradation. Similar analyses conducted on the Luangwa and Kafue rivers yielded comparable results (Sichingabula, in prep). On the Kafue River at Hook bridge station (4-669) (1973-1981) and the Luangwa River at Mfuwe station (5-650) (1978-1984) revealed scouring and filling of the channel at both stations occurred during low and high flow regimes. But on the Luangwa River at the Great East Road station (5-940), the paths of bed filling retraced the scouring paths in step-like fashion. The implication is that there was no net deposition nor net scour of the river bed in the period of study.

On Fraser River, Sichingabula (1993) found the overall mean bed change in bed elevation to be 0.447 m while on Kafue River River and Luangwa Rivers, this was found to be 1.726 m. Explanations for these variations are not well known, but it is probable that this could be attributed to the entrenchment of the Kafue and Luangwa rivers owing to the greater depths of weathering in the tropics than in temperate areas. This knowledge is applied to studied rivers in the southern Lake Tanganyika basin.

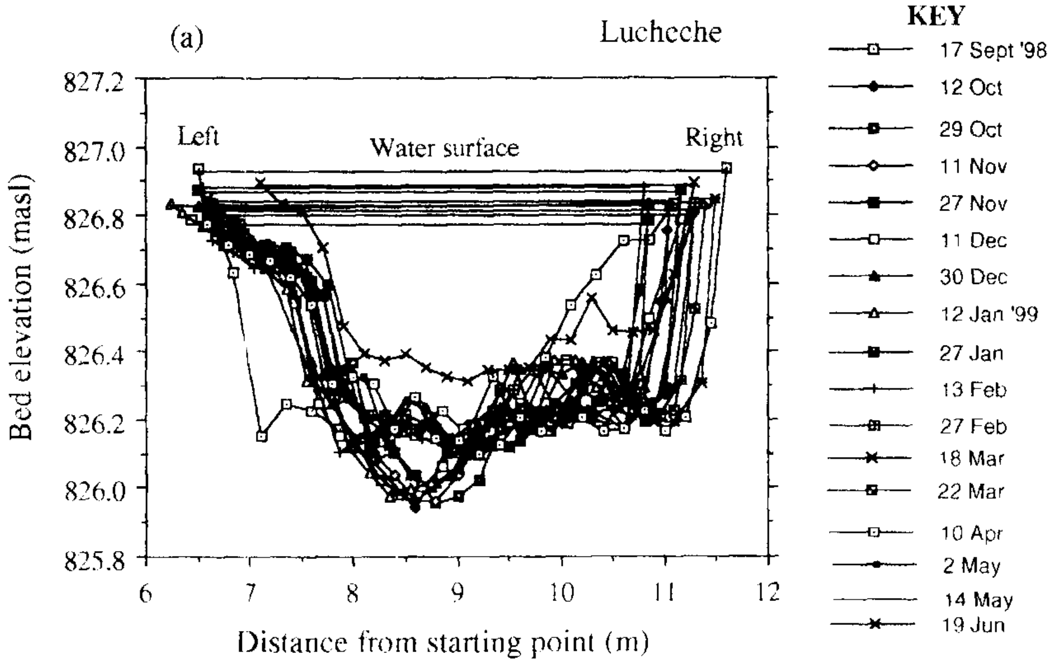
6.5.1 Water Level Changes

Water levels on all study rivers in the southern Lake Tanganyika basin have exhibited seasonal variations largely attributed amount of runoff generated from rainfall received. Analysis of cross-sectional data has revealed considerable variations in water levels ranging from 0.18 m on Lucheche River to 0.8 m on Kalambo River (Figures 23 and 24). The largest fluctuations in water levels were observed on Kalambo River (0.80 m) and Izi (0.71 m). These large variations in water levels may be attributed to the fact that, in case of the Izi River, it has an incised channel. But it is not clear whether these variations correspond to changes in the bed elevations (_B_e) as well. The changes in channel bed elevations are discussed in the following section.

6.5.2 River Channel Bed Changes

In the southern Lake Tanganyika basin, this study has assessed bed change elevation at the five sediment monitoring stations for one season. Lack of data has precluded precise determination of threshold discharges for bed scour. However, the available data permitted rough estimates of the scour and fill processes using bed elevation records monitored in the 1998/99 season.

Bed elevation changes (_B_e) were assessed from plots of distance from starting points of discharge measuring point, as the abscissa, and bed elevation measurements tied



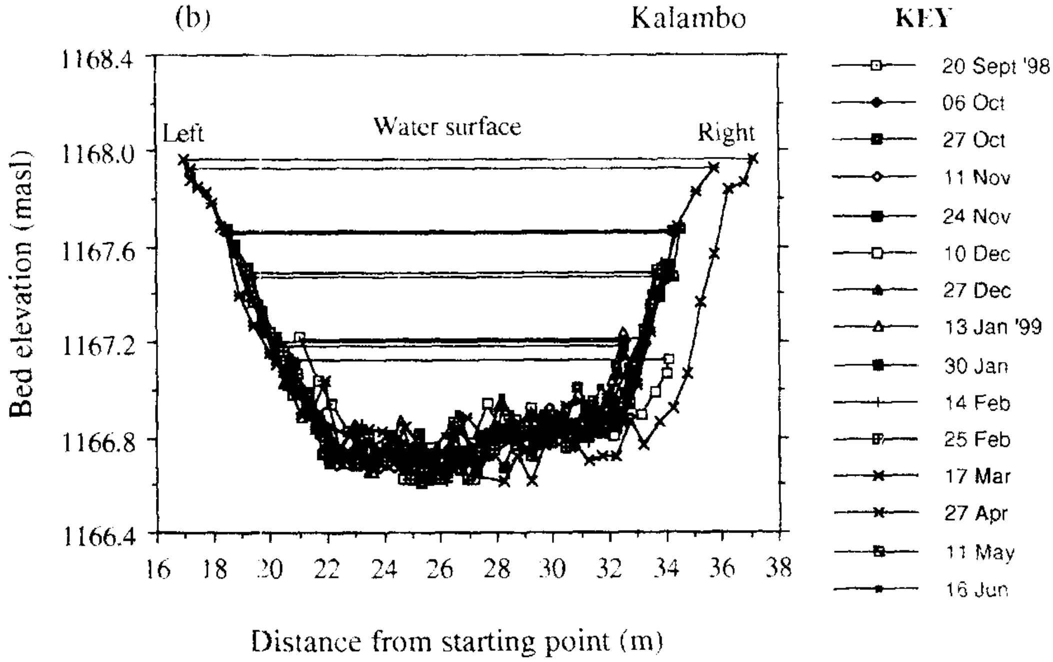


Figure 23. Changes in water levels and bed elevations for (a) Lucheche River at Kawe Village, and (b) Kalambo River at Kalambo Village, September 1998 - May, 1999.

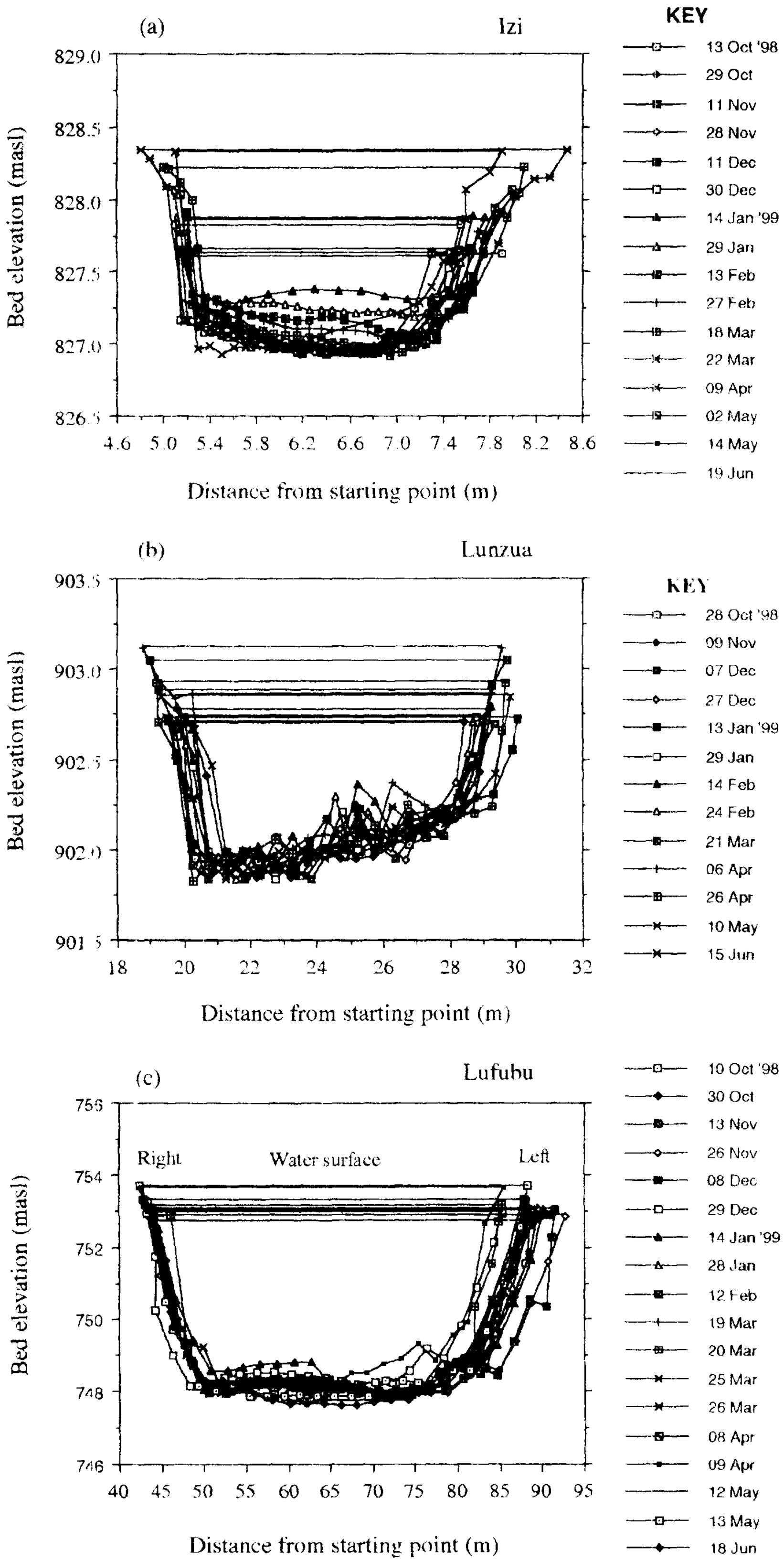


Figure 24. Changes in water levels and bed elevations for (a) Izi River at Mbete Village, and (b) Lunzua River at Simumbele Village, and (c) Lufubu River at Kabyolwe Village, September 1998 - May, 1999.

to the elevation above mean sea level given by the local datum or bench mark at each station, as the ordinate. The bed elevation was determined as gauge height (Gh) minus water depth (d). Figures 23(a), (b) and 24(a), (b) and (c) illustrate bed cross-sectional variations on Lunzua, Kalambo, Lucheche, Izi and Lufubu rivers.

Bed change elevations were found to range from 0.27 m on Kalambo to 1.4 m on Lufubu River with a mean of 0.61 m (Table 8). These changes in given reaches if multiplied by average channel width also given in Table 8 would translate into large quantities of sediment being liberated from the bed and thus accessed by the high flows. The quantities would even be higher if the changes in banklines are taken into account. This would so, especially if the maximum widths of channels at or near bankfull stages, also given in the above table, are incorporated in the calculations. The calculation of sediment derived from the river bed requires detailed survey data of the river bed in particular reaches of interest. This is an undertaking left for future investigations.

Table 8. Observed cross-sectional and stream-bed changes on rivers in northern, Zambia.

No.	Station	River	Elevation (masl)	Period	A (m)	B (m)	C (m)	D (m)
1.	7-022	Lucheche	830	Sept. 98-Jun 99	0.53	0.18	3.30	4.70
2.	7-030	Kalambo	1171	Sept. 98-Jun 99	0.27	0.80	11.00	18.00
3.	7-015	Izi	830	Oct. 98-Jun 99	0.55	0.71	2.30	3.25
4.	7-008	Lunzua	905	Sept. 98-Jun 99	0.28	0.35	8.80	10.00
5.	7-008	Lufubu	758	Oct. 98-Jun 99	1.40	0.66	35.00	47.00
	Mean				0.61	0.54	12.08	16.59

NOTE:

A is the maximum change in bed elevation (ΔBe) (m);

B is the maximum change in water level (m);

C is the maximum top channel width (m);

D is the average width of the channel bed (m).

On a seasonal scour and fill regime, the following can be said about the rivers in the southern Lake Tanganyika basin. The scour cycle begins during the dry season at low river flows when the river beds are shallow and filled with sediment. The bed is generally stable at an elevation probably equal to the 'mean' bed elevation. After the onset of rains, due to filling the bed begins to rise up to end of January or early February just before the annual discharge peak arrives. Thereafter, declines in bed elevations are observed resulting from scour processes related to the effects of medium to high flows. The lowest elevations are reached at the end of April or early May when the rains end, after which the channels quickly fill up again to about the mean level which is maintained during the remainder of the dry season.

The filling of the bed after the onset of rains occurs in earnest in November up to the time of effective rainfall, which precedes the effective discharge (Wolman and Miller, 1960, Benson and Thomas, 1966, Sichingabula, 1998e), is largely the consequence of the in-wash of fines from slopes and, especially bank collapse. These are the major sources of sediment supply in the rising stages of annual hydrographs. The major river process during this time is deposition albeit an increase in sediment transport caused by the exceedance of the threshold for stream-bed scour (Q_{t1}).

It is probable that when the effective rainfall is reached in January / February the exceedance of the threshold discharge (Q_{t2}) associated with bankfull level wipes out the dune forms on the bed. Dunes generally store large quantities of fine interstitial sediment, which once they are destroyed lead to the observed rapid lowering of bed elevations. In the subsequent period, the major source of sediment supply was the river bed itself due to intensive scouring processes. But not all sediment are transported at a time as storage in some sections of the river channel still takes place until peak discharge is reached. On Fraser River, British Columbia, Church *et al*. (1987) found that substantial quantities of sand-sized fraction were being stored in the lower reaches on the rising limb of the freshet and then deflated from the reach *en masse* on the falling limb. This could apply to other rivers too.

Findings of this study are summarized in the sections following.

7.0 SUMMARY AND CONCLUSIONS

This report has described all project activities carried out in the period of investigation, experiences and observations made during station establishment and monitoring of low to high discharge levels, findings of analysis of collected discharge and sediment data. The report has also covered other related aspects of the investigation including assessment of medium to long-term water levels and discharge input into Lake Tanganyika by Lufubu River at Keso Falls and Lunzua River at Kambole bridge, for which archival data exists in the archives of the Department of Water Affairs. Lack of good sediment record data precluded the assessment of medim- to long-term deposition of suspended and dissolved sediment loads into Lake Tanganyika by these two rivers. Observations and findings on different aspects of the study are itemized below.

7.1 Summary

i. The Terms of Reference given to the Zambia SSS Team for this particular investigation were successfully achieved as evidenced by the preparation of the Final Report within the stipulated period. The only aspect not adequately dealt with is the medium- to long-term assessment of suspended sediment load by rivers draining into Lake Tanganyika as reported above.

ii. The observed water levels on the five river stations in the period of record were found to range from 0.47 m on Kalambo River to 5.81 m on Lufubu River.

iii. The mean flow discharges drained into Lake Tanganyika by the five study rivers in the period of investigation were found to range from 1.426 $m^3 s^{-1}$ on Izi to 98.563 $m^3 s^{-1}$ on Lufubu River. The lowest and maximum discharges ranged from 0.183 $m^3 s^{-1}$ on Lucheche to 346.68 $m^3 s^{-1}$ per day on Lufubu River.

iv. The determined quantities of clastic suspended sediment deposited by the five rivers into the Lake from September, 1998 to April, 1999 were found to range from 0.082 tonnes on Kalambo River to 1,539.634 tonnes per day on Lufubu River. The mean values of suspended sediment deposited into Lake Tanganyika in the period September 1998 to May 1999 ranged from 1.248 tonnes on Izi River to 208.603 tonnes per day on Lufubu River.

v. The unit mass of determined suspended sediment input into Lake Tanganyika on the five rivers from September 1998 to April, 1999 was found to range from 9.9 grammes on Lucheche River to 26.2 grammes on Kalambo River, per cubic metre of discharge drained into the Lake.

vi. The total volume of discharge drained into the Lake between September 1998 and May, 1999 by the Lucheche, Kalambo, Izi, Lunzua and Lufubu rivers were found to be 36.3, 386.3, 31.4, 297.0 million, and 2.2 billion cubic metres, respectively.

vii. The total sediment load deposited into Lake Tanganyika between September 1998 and May 1999 by the Lucheche, Kalambo, Izi, Lunzua and Lufubu rivers were found to be 358.8, 9,617.1, 318.2, 6,595.8 and 53.819.7 tonnes, respectively.

viii. The specific suspended sediment yield generated by Lucheche, Kalambo, Izi, Lunzua and Lufubu rivers were found to be 1.2, 3.8, 5.9, 9.6 and 7.6 t/km^2, respectively.

ix. The class-based effective discharge (Q_{eff}) for suspended sediment transport in the southern Lake Tanganyika basin were found to range from 0.78 m^3 s^{-1} with a duration of 54.5% on Izi River to 258.0 m^3 s^{-1} with 4.3% of occurrence on Lufubu River. With the exception of the Kalambo River where the effective discharge was the highest flow event of low duration, for the rest of the rivers, the effective discharges were medium flows with moderate frequencies of occurrence.

x. The change in bed elevation (ΔBe), closely related to the depth of bed scour, was found to range from 0.27 m on Kalambo River to 1.40 m on Lufubu River with a regional mean of 0.61 m. The maximum change in water levels was found to range from 0.18 m on Lucheche to 0.80 m on Kalambo River. These changes suggest that a considerable amount of sediment deposited into Lake Tanganyika could be originating from the river beds.

xi. Water levels on Lake Tanganyika fluctuate from time to time, ranging from seasonal to medium- and long-term time scales quite possibly remotely related to glaciation / deglaciation processes and the related greater availability of global atmospheric moisture during warmer global climatic phases. In the last 30 years water level have varied up to about 10.0 m.

7.2 Conclusion

It is concluded that, rivers in the southern Lake Tanganyika basin transport drain quite a considerable amount of discharge into Lake Tanganyika. This could partly be responsible for increased lake levels observed at Mpulungu gauging station. However, most of the water drained into the lake are lost by evaporation from the open waters on the Lake. Threats and potentials of Lake Tanganyika in terms of biodiversity can best be addressed by linking the above findings to results of other Study Groups which are already in progress.

8.0 RECOMMENDATIONS

The Zambia Sediment Special Study according to the Terms of Reference signed by participating institutions comes to an end with the submission of the Final Report by 31 July, 1999. At the present moment, it is not clear what other activities will require to be conducted by the Team while awaiting other study groups to complete their studies too. In view of this, the Team Leader following consultations with his members and in particular Sediment Study Facilitator in Mpulungu and the Provincial Water Engineer in Kasama, makes the following recommendations and proposals for consideration by Project coordinators, so that meaningful results and conclusions of special studies can be made at the termination of all activities of the Project.

1. Since water level measurements in the South Lake Tanganyika basin will continue to be made up to December, 1999, it is recommended that the same be done for discharge measurement by the Kasama technical team. Additionally, considering that discharge measurement were conducted only for one rainy season, every effort should be made to ensure that another season of measurement be undertaken to permit generalisation of findings.

2. In order that the GRZ vehicle attached to the Project for use by Water Affairs technical team continues to perform its functions at least up to October, 1999, the Project should seek an extension of the loan period from the Director of Water Affairs in Lusaka as soon as possible. This is important so that the Kasama office can continue to supervise and monitor the maintenance of hydrometric stations until Project support is fully withdrawn. Without the involvement of Kasama office there is no way the stations can continue functioning.

3. The gauge readers have done a commendable job in the performance of their duties without presenting the Project and the Water Affairs office in Kasama any problems whatsoever. It is gratifying that they will be allowed to continue working up to the end of the dry season. When Project activities cease in Lake Tanganyika basin, it is recommended that the Government of the Republic of Zambia through Water Affairs finds a mechanism to keep them employed at these stations to keep them operational. This would ensure that the long-term record of discharge and sediment transport required for future development in the region is maintained.

4. It is also recommended that the Project also continues to support Fisheries Department in Mpulungu for payments of PRAs to the team analysing water samples for the Special Sediment Group. This is important as water level data will require to be related to sediment transport on the study rivers. This is the more good reason why discharge measurements should also continue. The three activities of water level monitoring, discharge measurement and sediment analysis are related and jointly form a complete whole in sediment studies.

5. For future analysis of all assembled data, it is recommended that key members of the Zambia SSS Team be retained for sometime under a new agreement to facilitate smooth phasing away of the Project while other investigations by other study groups are still underway.

6. The Project should continue to support low level scientific research on different aspects of the environment in the southern Lake Tanganyika basin for the preservation and promotion of Lake Tanganyika's rich biodiversity.

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APPENDIX 1a. Water levels, Lucheche River at Kawe Village, September 1998 - May 1999.

Station Number: 7-022 — **Name: Lucheche River at Kawe Village**

Latitude: 08:42':48"S — Longitudue: 31:12':34"E

Mean Daily Water Levels
Stage readings in metres

Year: 1997/98 — Year: 1998/99

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		0.86	0.82	0.82	0.86	1.18	0.87	0.92	0.84					
2		0.86	0.82	0.82	0.86	0.89	0.86	0.92	0.85					
3		0.86	0.82	0.81	0.87	0.95	0.86	0.91	0.85					
4		0.86	0.82	0.81	0.87	0.92	0.86	0.92	0.85					
5		0.86	0.80	0.83	0.86	0.90	0.86	0.95	0.84					
6		0.86	0.80	0.82	0.87	0.90	0.85	0.98	0.84					
7		0.84	0.79	0.82	0.88	0.89	0.88	1.01	0.84					
8		0.84	0.81	0.82	0.88	0.88	0.88	1.00	0.83					
9		0.84	0.82	0.82	0.87	0.88	0.88	0.97	0.83					
10		0.84	0.80	0.81	0.86	0.89	0.87	0.97	0.83					
11		0.84	0.79	0.81	0.86	0.91	0.87	0.97	0.82					
12		0.84	0.79	0.86	0.86	0.90	0.88	0.97	0.82					
13		0.84	0.79	0.86	0.87	0.92	0.89	0.96	0.82					
14		0.84	0.79	0.83	0.87	0.91	0.89	0.95	0.82					
15		0.82	0.79	0.82	0.87	0.89	0.89	0.95	0.82					
16		0.82	0.79	0.82	0.86	0.88	0.90	0.94	0.81					
17	0.87	0.81	0.79	0.85	0.97	0.86	0.89	0.93	0.81					
18	0.87	0.81	0.79	0.88	1.02	0.85	0.88	0.93	0.81					
19	0.87	0.81	0.79	0.88	1.02	0.84	0.88	0.92	0.80					
20	0.87	0.80	0.79	0.84	1.06	0.84	0.86	0.91	0.80					
21	0.87	0.80	0.78	0.84	0.93	0.84	0.88	0.90	0.80					
22	0.87	0.80	0.78	0.86	0.96	0.84	0.87	0.88	0.80					
23	0.87	0.80	0.78	0.85	0.96	0.84	0.86	0.88	0.80					
24	0.87	0.80	0.79	0.84	0.96	0.84	0.84	0.87	0.80					
25	0.87	0.83	0.80	0.87	0.92	0.88	0.85	0.86	0.80					
26	0.87	0.85	0.81	0.87	0.92	0.86	0.86	0.86	0.79					
27	0.87	0.84	0.82	0.86	0.92	0.87	0.89	0.86	0.79					
28	0.86	0.84	0.82	0.84	0.90	0.87	0.89	0.86	0.79					
29	0.86	0.83	0.82	0.85	0.89		0.89	0.84	0.79					
30	0.86	0.84	0.82	0.86	0.88		0.94	0.84	0.78					
31		0.82		0.86	1.08		0.93		0.78					
MEAN		0.83	0.80	0.84	0.91	0.89	0.88	0.92	0.81					0.86
MAX		0.86	0.82	0.88	1.08	1.18	0.94	1.01	0.85					1.18
MIN		0.80	0.78	0.81	0.86	0.84	0.84	0.84	0.78					0.78

APPENDIX 1b. Water levels, Kalambo River at Kalambo Village, October 1998 - May 1999.

Station Number: 7-030
Latitude: 08:35':55"S

Name: Kalambo River at Kalambo Village
Longitudue: 31:15':22"E

Mean Daily Water Levels
Stage readings in metres

Year: 1998/99

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	0.58	0.55	0.50	0.56	1.05	0.88	2.10	1.19					
2	0.58	0.54	0.50	0.59	1.06	0.97	2.14	1.18					
3	0.57	0.54	0.49	0.59	1.05	0.98	2.08	1.16					
4	0.57	0.54	0.49	0.61	1.03	0.94	1.98	1.14					
5	0.57	0.53	0.49	0.61	1.03	0.95	1.96	1.12					
6	0.57	0.52	0.50	0.63	1.01	0.98	1.97	1.10					
7	0.56	0.52	0.52	0.68	0.99	0.99	1.95	1.09					
8	0.56	0.53	0.52	0.64	0.98	1.06	1.93	1.08					
9	0.55	0.53	0.50	0.63	0.96	1.06	1.88	1.06					
10	0.55	0.52	0.50	0.62	0.95	1.08	1.85	1.04					
11	0.54	0.51	0.52	0.61	0.92	1.11	1.87	1.03					
12	0.54	0.50	0.53	0.62	0.88	1.14	1.84	1.01					
13	0.54	0.50	0.53	0.61	0.90	1.20	1.82	1.00					
14	0.54	0.50	0.52	0.61	0.90	1.22	1.81	0.99					
15	0.54	0.50	0.52	0.61	0.93	1.25	1.80	0.99					
16	0.54	0.49	0.51	0.63	0.97	1.30	1.76	0.98					
17	0.53	0.49	0.52	0.67	0.99	1.35	1.72	0.98					
18	0.53	0.49	0.53	0.69	0.97	1.38	1.69	0.98					
19	0.53	0.48	0.55	0.72	0.93	1.45	1.64	0.98					
20	0.53	0.48	0.54	0.79	0.89	1.54	1.61	0.97					
21	0.53	0.47	0.52	0.81	0.86	1.52	1.57	0.97					
22	0.52	0.47	0.52	0.85	0.84	1.48	1.53	0.97					
23	0.52	0.47	0.50	0.93	0.82	1.43	1.48	0.97					
24	0.53	0.47	0.51	0.95	0.86	1.39	1.42	0.97					
25	0.55	0.47	0.52	0.97	0.87	1.36	1.38	0.97					
26	0.58	0.48	0.52	0.96	0.85	1.37	1.34	0.96					
27	0.56	0.51	0.53	0.99	0.83	1.49	1.31	0.95					
28	0.55	0.54	0.57	1.03	0.84	1.48	1.26	0.94					
29	0.55	0.52	0.56	1.05		1.61	1.24	0.93					
30	0.55	0.50	0.56	1.04		2.11	1.22	0.92					
31	0.54		0.56	1.07		2.10		0.91					
MEAN	0.55	0.51	0.52	0.75	0.93	1.30	1.71	1.02					0.91
MAX	0.58	0.55	0.57	1.07	1.06	2.11	2.14	1.19					2.14
MIN	0.52	0.47	0.49	0.56	0.82	0.88	1.22	0.91					0.47

APPENDIX 1c. Water levels, Izi River at Mbete Village, September 1998 - May 1999.

Station Number: 7-015
Latitude: 08:48':50"S

Name: Izi river at Mbete Village
Longitudue: 31:02':29"E

Mean Daily Water Levels
Stage readings in metres

Year: 1997/98 Year: 1998/99

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		0.69	0.66	0.66	0.85	0.92	0.82	1.36	1.13					
2		0.69	0.67	0.65	0.88	0.90e	0.81	1.34	1.12					
3		0.69	0.67	0.65	0.86	0.88	0.84	1.34	1.11					
4		0.69	0.67	0.67	1.08	0.87	0.83	1.40	1.11					
5		0.68	0.68	0.67	0.96	0.86	0.83	1.48	1.10					
6		0.68	0.67	0.67	0.91	0.85	0.90	1.45	1.11					
7		0.68	0.68	0.67	0.89	0.84	0.97	1.45	1.10					
8		0.68	0.77	0.67	0.88	0.84	1.12	1.40	1.10					
9		0.67	0.71	0.67	0.89	0.84	1.07	1.38	1.09					
10		0.67e	0.69	0.68	0.88	0.84	1.08	1.37	1.07					
11		0.67e	0.69	0.72	0.87	0.84	1.06	1.36	1.07					
12		0.67	0.68	0.69	1.06	0.87	1.04	1.34	1.07					
13		0.67	0.68	0.68	0.93	0.93	1.25	1.33	1.06					
14		0.67	0.68	0.67	0.94	0.86	1.16	1.32	1.05					
15		0.67	0.68	0.68	0.96	0.83	1.41	1.30	1.05					
16		0.66	0.67	0.68	1.01	0.81	1.38	1.33	1.04					
17		0.65	0.67	0.95	0.95	0.80	1.31	1.30	1.04					
18	0.68	0.66	0.67	0.95	0.96	0.81	1.28	1.28	1.04					
19	0.69	0.67	0.67	0.88	0.95	0.80	1.23	1.27	1.03					
20	0.69	0.65	0.66	0.85	0.94	0.81	1.38	1.26	1.03					
21	0.70	0.65	0.65	0.86	0.90	0.84	1.41	1.26	1.02					
22	0.71	0.65	0.65	0.87	0.88	0.83	1.37	1.25	1.02					
23	0.71	0.66	0.69	0.86	0.90	0.81	1.33	1.24	1.01					
24	0.71	0.66	0.68	0.86	0.88	0.82	1.31	1.21	0.99					
25	0.71	0.66	0.68	0.91	0.99	0.83	1.28	1.20	0.99					
26	0.70	0.66	0.68	0.89	0.90	0.85	1.38	1.21	1.00					
27	0.70	0.65	0.67	0.87	0.90	0.83	1.41	1.19	0.99					
28	0.70	0.65	0.67	0.87	0.94	0.83	1.39	1.19	0.98					
29	0.70	0.65	0.67	0.86	0.90		1.37	1.19	0.98					
30	0.70	0.66	0.67	0.87	0.87		1.38	1.15	0.98					
31		0.66		0.85	0.94		1.35		0.99					
MEAN		0.67	0.68	0.77	0.92	0.84	1.19	1.31	1.05					0.93
MAX		0.69	0.77	0.95	1.08	0.93	1.41	1.48	1.13					1.48
MIN		0.65	0.65	0.65	0.85	0.80	0.81	1.15	0.98					0.65

e = Estimated

APPENDIX 1d. Water levels, Lunzua River at Simumbele Village, September 1998 - May 1999.

Station Number: 7-008
Latitude: 08:46':23"S

Name: Lunzua River at Simumbele Village
Longitudue: 31:08':49"E

Mean Daily Water Levels
Stage readings in metres

Year: 1997/98 Year: 1998/99

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		0.92	0.88	0.84	0.92	1.12	0.87	1.18	1.08					
2		0.92	0.87	0.83	0.91	1.06	0.87	1.17	1.08					
3		0.92	0.86	0.83	0.89	1.06	1.07	1.17	1.07					
4		0.91	0.86	0.90	1.01	1.01	0.88	1.68	1.07					
5		0.92	0.85	0.88	0.93	0.98	0.88	1.27	1.06					
6		0.92	0.85	0.88	0.93	0.96	0.96	1.29	1.05					
7		0.90	0.85	0.87	0.92	0.95	0.92	1.43	1.05					
8		0.90	0.95	0.87	0.90	0.93	1.23	1.34	1.04					
9		0.89	0.88	0.91	0.89	0.93	1.07	1.31	1.03					
10		0.89	0.85	0.88	0.91	0.91	1.06	1.40	1.03					
11		0.88	0.84	0.87	0.88	0.93	1.03	1.38	1.03					
12		0.89	0.85	0.98	0.91	0.95	1.02	1.31	1.02					
13		0.89	0.85	0.90	0.90	1.01	1.23	1.27	1.02					
14		0.89	0.84	0.87	0.88	0.97	1.03	1.24	1.01					
15		0.91	0.84	0.87	0.95	0.93	1.40	1.21	1.01					
16		0.91	0.83	0.87	0.97	0.91	1.30	1.22	1.01					
17		0.89	0.82	0.93	0.99	0.90	1.23	1.21	1.01					
18		0.88	0.82	0.98	0.98	0.89	1.18	1.19	1.01					
19		0.87	0.82	0.90	0.95	0.88	1.12	1.18	1.00					
20	0.95	0.88	0.81	0.87	0.96	0.86	1.14	1.16	1.01					
21	0.95	0.88	0.81	0.86	0.91	0.91	1.22	1.15	1.00					
22	0.94	0.87	0.80	0.88	0.91	0.89	1.14	1.14	0.99					
23	0.94	0.88	0.92	0.87	0.91	0.87	1.08	1.13	1.00					
24	0.94	0.89	0.87	0.86	0.92	0.87	1.05	1.12	0.98					
25	0.93	0.91	0.91	0.88	0.99	0.89	1.06	1.11	0.99					
26	0.93	0.92	0.86	0.89	0.95	0.87	1.15	1.11	0.98					
27	0.93	0.90	0.84	0.89	0.93	0.87	1.23	1.10	0.98					
28	0.94	0.89	0.84	0.87	0.93	0.87	1.23	1.08	0.97					
29	0.95	0.89	0.86	0.86	0.91		1.23	1.08	0.97					
30	0.94	0.89	0.86	0.92	0.88		1.28	1.07	0.96					
31		0.89		0.87	1.14		1.22		0.96					
MEAN		0.90	0.85	0.88	0.93	0.94	1.11	1.22	1.02					0.98
MAX		0.92	0.95	0.98	1.14	1.12	1.40	1.68	1.08					1.68
MIN		0.87	0.80	0.83	0.88	0.86	0.87	1.07	0.96					0.80

APPENDIX 1e. Water levels, Lufubu River at Kabyolwe Village, September 1998 - May 1999.

Station Number: 7-775 | **Name: Lufubu River at Kabyolwe Village**

Latitude: 08:35':51"S | Longitudue: 30:44':09"E

Mean Daily Water Levels
Stage readings in metres

Year: 1997/98 Year: 1998/99

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		5.17	5.07	5.02	5.12	5.24	5.18	5.61	5.54					
2		5.16	5.09	5.03	5.10	5.26	5.17	5.63	5.52					
3		5.15	5.15	5.04	5.10	5.25	5.19	5.68	5.51					
4		5.19	5.08	5.05	5.11	5.24	5.19	5.69	5.52					
5		5.21	5.14	5.07	5.13	5.24	5.18	5.68	5.47					
6		5.16	5.09	5.06	5.11	5.23	5.19	5.70	5.45					
7		5.17	5.12	5.06	5.11	5.23	5.22	5.73	5.43					
8		5.17	5.14	5.08	5.10	5.22	5.22	5.78	5.42					
9		5.17	5.08	5.07	5.13	5.23	5.17	5.80	5.49					
10		5.17	5.08	5.04	5.09	5.21	5.17	5.80	5.49					
11		5.13	5.09	5.05	5.13	5.23	5.18	5.80	5.47					
12		5.11	5.07	5.07	5.13	5.23	5.17	5.81	5.45					
13		5.08	5.04	5.04	5.19	5.23	5.17	5.75	5.47					
14		5.11	5.06	5.07	5.17	5.23	5.21	5.76	5.46					
15		5.09	5.12	5.11	5.19	5.21	5.22	5.68	5.45					
16	5.22	5.11	5.08	5.10	5.19	5.23	5.22	5.67	5.44					
17	5.22	5.11	5.14	5.11	5.19	5.23	5.22	5.67	5.39					
18	5.21	5.12	5.07	5.09	5.23	5.20	5.29	5.63	5.43					
19	5.23	5.10	5.14	5.09	5.21	5.20	5.29	5.66	5.44					
20	5.21	5.09	5.07	5.11	5.19	5.21	5.33	5.66	5.41					
21	5.21	5.07	5.04	5.10	5.19	5.22	5.34	5.65	5.43					
22	5.21	5.07	5.00	5.12	5.21	5.19	5.33e	5.65	5.42					
23	5.21	5.09	5.12	5.10	5.23	5.18	5.36	5.63	5.39					
24	5.19	5.06	5.05	5.12	5.22	5.19	5.37	5.62	5.41					
25	5.18	5.05	5.03	5.10	5.23	5.19	5.36	5.62	5.41					
26	5.19	5.05	5.11	5.10	5.23	5.16	5.36	5.63	5.41					
27	5.17	5.05	5.01	5.09	5.22	5.18	5.38	5.61	5.39					
28	5.16	5.09	5.12	5.11	5.24	5.18	5.36	5.61	5.39					
29	5.18	5.08	5.14	5.11	5.24		5.50	5.55	5.36e					
30	5.17	5.05	5.11	5.10	5.24		5.59	5.55	5.35					
31		5.06		5.13	5.23		5.56		5.36					
MEAN		5.11	5.09	5.08	5.17	5.22	5.28	5.68	5.44					5.26
MAX		5.21	5.15	5.13	5.24	5.26	5.59	5.81	5.54					5.81
MIN		5.05	5.00	5.02	5.09	5.16	5.17	5.55	5.35					5.00

e = Estimated

APPENDIX 1f. Water levels, Lake Tanganyika at Mpulungu, October 1998 - May 1999.

Station Number: 7-010 | **Name: Lake Tanganyika at Mpulungu**
Latitude: 08:46': 0"S | Longitudue: 31:06': 0"E

Mean Daily Water Levels
Stage readings in metres

Year: 1998/99

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		2.21	2.14	2.17	2.27	2.24	2.48	2.51					
2		2.22	2.12	2.2	2.29	2.23	2.46	2.51					
3		2.19	2.15	2.24	2.25	2.22	2.45	2.53					
4		2.17	2.14	2.22	2.25	2.24	2.48	2.54					
5		2.20	2.13	2.22	2.23	2.21	2.50	2.53					
6		2.18	2.13	2.37	2.25	2.21	2.59	2.52					
7		2.20	2.15	2.36	2.24	2.25	2.54	2.51					
8		2.15	2.15	2.36	2.25	2.25	2.56	2.51					
9		2.18	2.17	2.35	2.26	2.26	2.47	2.50					
10		2.20	2.17	2.35	2.25	2.25	2.55	2.51					
11		2.17	2.15	2.37	2.25	2.27	2.61	2.52					
12		2.14	2.14	2.41	2.26	2.26	2.62	2.50					
13		2.15	2.15	2.33	2.22	2.27	2.59	2.52					
14		2.13	2.18	2.25	2.27	2.28	2.61	2.48					
15		2.15	2.18	2.22	2.24	2.33	2.57	2.49					
16	2.20	2.15	2.18	2.22	2.25	2.33	2.58	2.47					
17	2.21	2.13	2.18	2.24	2.23	2.35	2.56	2.48					
18	2.21	2.14	2.20	2.25	2.21	2.33	2.58	2.46					
19	2.18	2.12	2.21	2.24	2.22	2.33	2.58e	2.48					
20	2.18	2.10	2.22	2.23	2.22	2.37	2.58	2.46					
21	2.19	2.12	2.20	2.25	2.23	2.35	2.59	2.48					
22	2.19	2.09	2.21	2.28	2.22	2.36	2.60	2.44					
23	2.21	2.10	2.20	2.23	2.23	2.35	2.58	2.44					
24	2.21	2.10	2.19	2.25	2.24	2.34	2.57	2.44					
25	2.19	2.09	2.20	2.24	2.24	2.37	2.57	2.44					
26	2.16	2.15	2.18	2.29	2.21	2.39	2.57	2.41					
27	2.18	2.14	2.21	2.24	2.25	2.40	2.54	2.43					
28	2.17	2.16	2.19	2.25	2.23	2.40	2.55	2.42					
29	2.19	2.13	2.22	2.27		2.43	2.56	2.41					
30	2.16	2.15	2.21	2.25		2.45	2.53	2.41					
31	2.18		2.20	2.26e		2.43		2.39					
MEAN		2.15	2.18	2.27	2.24	2.31	2.55	2.48					2.31
MAX		2.22	2.22	2.41	2.29	2.45	2.62	2.54					2.62
MIN		2.09	2.12	2.17	2.21	2.21	2.45	2.39					2.09

e = Estimated

APPENDIX 2a. Discharge, Lucheche River at Kawe Village, September 1998 - May 1999.

Station Number: 7-022
Latitude: 08:42':48"S

Name: Lucheche River at Kawe Village
Longitudue: 31:12':34"E

Annual summary of daily data - flow
Flows in cubic metres per second

Year: 1997/98 | Year: 1998/99

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		1.62	0.90	0.90	1.62	7.33	1.79	2.69	1.26					
2		1.62	0.90	0.90	1.62	2.15	1.62	2.69	1.44					
3		1.62	0.90	0.72	1.79	3.22	1.62	2.51	1.44					
4		1.62	0.90	0.72	1.79	2.69	1.62	2.69	1.44					
5		1.62	0.54	1.08	1.62	2.33	1.62	3.22	1.26					
6		1.62	0.54	0.90	1.79	2.33	1.44	3.76	1.26					
7		1.26	0.37	0.90	1.97	2.15	1.97	4.30	1.26					
8		1.26	0.72	0.90	1.97	1.97	1.97	4.12	1.08					
9		1.26	0.90	0.90	1.79	1.97	1.97	3.58	1.08					
10		1.26	0.54	0.72	1.62	2.15	1.79	3.58	1.08					
11		1.26	0.37	0.72	1.62	2.51	1.79	3.58	0.90					
12		1.26	0.37	1.62	1.62	2.33	1.97	3.58	0.90					
13		1.26	0.37	1.62	1.79	2.69	2.15	3.40	0.90					
14		1.26	0.37	1.08	1.79	2.51	2.15	3.22	0.90					
15		0.90	0.37	0.90	1.79	2.15	2.15	3.22	0.90					
16		0.90	0.37	0.90	1.62	1.97	2.33	3.05	0.72					
17	1.79	0.72	0.37	1.44	3.58	1.62	2.15	2.87	0.72					
18	1.79	0.72	0.37	1.97	4.48	1.44	1.97	2.87	0.72					
19	1.79	0.72	0.37	1.97	4.48	1.26	1.97	2.69	0.54					
20	1.79	0.54	0.37	1.26	5.19	1.26	1.62	2.51	0.54					
21	1.79	0.54	0.19	1.26	2.87	1.26	1.97	2.33	0.54					
22	1.79	0.54	0.19	1.62	3.40	1.26	1.79	1.97	0.54					
23	1.79	0.54	0.19	1.44	3.40	1.26	1.62	1.97	0.54					
24	1.79	0.54	0.37	1.26	3.40	1.26	1.26	1.79	0.54					
25	1.79	1.08	0.54	1.79	2.69	1.97	1.44	1.62	0.54					
26	1.79	1.44	0.72	1.79	2.69	1.62	1.62	1.62	0.37					
27	1.79	1.26	0.90	1.62	2.69	1.79	2.15	1.62	0.37					
28	1.62	1.26	0.90	1.26	2.33	1.79	2.15	1.62	0.37					
29	1.62	1.08	0.90	1.44	2.15		2.15	1.26	0.37					
30	1.62	1.26	0.90	1.62	1.97		3.05	1.26	0.19					
31		0.90		1.62	5.55		2.87		0.19					
SUM		34.73	16.67	38.84	78.69	60.26	59.75	81.19	24.90					395.03
MEAN		1.12	0.56	1.25	2.54	2.15	1.93	2.71	0.80					1.63
MAX		1.62	0.90	1.97	5.55	7.33	3.05	4.30	1.44					7.33
MIN		0.54	0.19	0.72	1.62	1.26	1.26	1.26	0.19					0.19

APPENDIX 2b. Discharge, Kalambo River at Kalambo Village, October 1998 - May 1999.

Station Number: 7-030 | **Name: Kalambo River at Kalambo Village**
Latitude: 08:35':55"S | Longitudue: 31:15':22"E

Annual summary of daily data - flow
Flows in cubic metres per second

Year: 1998/99

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	2.14	1.59	0.80	1.77	18.75	11.02	109.70	26.57					
2	2.14	1.42	0.80	2.34	19.26	14.87	114.63	25.97					
3	1.95	1.42	0.67	2.34	18.75	15.33	107.27	24.79					
4	1.95	1.42	0.67	2.76	17.74	13.52	95.54	23.63					
5	1.95	1.26	0.67	2.76	17.74	13.97	93.27	22.49					
6	1.95	1.10	0.80	3.20	16.75	15.33	94.40	21.39					
7	1.77	1.10	1.10	4.43	15.80	15.80	92.15	20.85					
8	1.77	1.26	1.10	3.43	15.33	19.26	89.92	20.31					
9	1.59	1.26	0.80	3.20	14.41	19.26	84.48	19.26					
10	1.59	1.10	0.80	2.98	13.97	20.31	81.29	18.24					
11	1.42	0.95	1.10	2.76	12.66	21.94	83.41	17.74					
12	1.42	0.80	1.26	2.98	11.02	23.63	80.24	16.75					
13	1.42	0.80	1.26	2.76	11.83	27.18	78.17	16.27					
14	1.42	0.80	1.10	2.76	11.83	28.42	77.14	15.80					
15	1.42	0.80	1.10	2.76	13.09	30.33	76.12	15.80					
16	1.42	0.67	0.95	3.20	14.87	33.65	72.10	15.33					
17	1.26	0.67	1.10	4.17	15.80	37.14	68.19	15.33					
18	1.26	0.67	1.26	4.69	14.87	39.31	65.33	15.33					
19	1.26	0.54	1.59	5.53	13.09	44.62	60.69	15.33					
20	1.26	0.54	1.42	7.72	11.42	51.93	57.99	14.87					
21	1.26	0.41	1.10	8.41	10.24	50.26	54.49	14.87					
22	1.10	0.41	1.10	9.86	9.49	47.00	51.09	14.87					
23	1.10	0.41	0.80	13.09	8.76	43.07	47.00	14.87					
24	1.26	0.41	0.95	13.97	10.24	40.05	42.31	14.87					
25	1.59	0.41	1.10	14.87	10.63	37.86	39.31	14.87					
26	2.14	0.54	1.10	14.41	9.86	38.58	36.43	14.41					
27	1.77	0.95	1.26	15.80	9.12	47.80	34.34	13.97					
28	1.59	1.42	1.95	17.74	9.49	47.00	30.98	13.52					
29	1.59	1.10	1.77	18.75		57.99	29.69	13.09					
30	1.59	0.80	1.77	18.24		110.92	28.42	12.66					
31	1.42		1.77	19.78		109.70		12.24					
SUM	48.78	27.02	35.00	233.45	376.78	1127.06	2076.10	536.28					4411.69
MEAN	1.57	0.90	1.13	7.53	13.46	36.36	69.20	17.30					18.43
MAX	2.14	1.59	1.95	19.78	19.26	110.92	114.63	26.57					114.63
MIN	1.10	0.41	0.67	1.77	8.76	11.02	28.42	12.24					0.41

APPENDIX 2c. Discharge, Izi River at Mbete Village, September 1998 - May 1999.

Station Number: 7-015 | **Name: Izi river at Mbete Village**

Latitude: 08:48':50"S | Longitudue: 31:02':29"E

Annual summary of daily data - flow
Flows in cubic metres per second

Year: 1997/98 Year: 1998/99

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		0.62	0.60	0.60	0.88	1.09	0.80	3.79	2.08					
2		0.62	0.61	0.60	0.96	1.02e	0.78	3.61	2.02					
3		0.62	0.61	0.60	0.90	0.96	0.85	3.61	1.96					
4		0.62	0.61	0.61	1.80	0.93	0.83	4.15	1.96					
5		0.61	0.61	0.61	1.23	0.90	0.83	4.93	1.91					
6		0.61	0.61	0.61	1.05	0.88	1.02	4.63	1.96					
7		0.61	0.61	0.61	0.99	0.85	1.27	4.63	1.91					
8		0.61	0.71	0.61	0.96	0.85	2.02	4.15	1.91					
9		0.61	0.63	0.61	0.99	0.85	1.74	3.97	1.85					
10		0.61e	0.62	0.61	0.96	0.85	1.80	3.88	1.74					
11		0.61e	0.62	0.64	0.93	0.85	1.69	3.79	1.74					
12		0.61	0.61	0.62	1.69	0.93	1.59	3.61	1.74					
13		0.61	0.61	0.61	1.12	1.12	2.89	3.53	1.69					
14		0.61	0.61	0.61	1.16	0.90	2.27	3.44	1.64					
15		0.61	0.61	0.61	1.23	0.83	4.24	3.28	1.64					
16		0.60	0.61	0.61	1.45	0.78	3.97	3.53	1.59					
17		0.60	0.61	1.20	1.20	0.76	3.36	3.28	1.59					
18	0.61	0.60	0.61	1.20	1.23	0.78	3.12	3.12	1.59					
19	0.62	0.61	0.61	0.96	1.20	0.76	2.74	3.04	1.54					
20	0.62	0.60	0.61	0.88	1.16	0.78	3.97	2.97	1.54					
21	0.62	0.60	0.60	0.90	1.02	0.85	4.24	2.97	1.49					
22	0.63	0.60	0.60	0.93	0.96	0.83	3.88	2.89	1.49					
23	0.63	0.60	0.62	0.91	1.02	0.78	3.53	2.82	1.45					
24	0.63	0.60	0.61	0.90	0.96	0.80	3.36	2.60	1.36					
25	0.63	0.60	0.61	1.05	1.36	0.83	3.12	2.53	1.36					
26	0.62	0.60	0.60	0.99	1.02	0.88	3.97	2.60	1.40					
27	0.62	0.60	0.61	0.93	1.02	0.83	4.24	2.46	1.36					
28	0.62	0.60	0.61	0.93	1.16	0.83	4.06	2.46	1.32					
29	0.62	0.60	0.61	0.90	1.02		3.88	2.46	1.32					
30	0.62	0.60	0.61	0.93	0.93		3.97	2.20	1.32					
31		0.60		0.88	1.16		3.70		1.36					
SUM		17.59	18.39	24.24	34.71	23.27	83.71	100.94	50.81					353.65
MEAN		0.61	0.61	0.78	1.12	0.86	2.70	3.36	1.64					1.46
MAX		0.62	0.71	1.20	1.80	1.12	4.24	4.93	2.08					4.93
MIN		0.60	0.60	0.60	0.88	0.76	0.78	2.20	1.32					0.60

e = Estimated

APPENDIX 2d. Discharge, Lunzua River at Simumbele Village, September 1998 - May 1999.

Station Number: 7-008	**Name: Lunzua River at Simumbele Village**
Latitude: 08:46':23"S	Longitudue: 31:08':49"E

Annual summary of daily data - flow
Flows in cubic metres per second

Year: 1997/98 Year: 1998/99

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		11.38	9.92	8.46	11.38	18.69	9.56	20.88	17.23					
2		11.38	9.56	8.10	11.02	16.50	9.56	20.51	17.23					
3		11.38	9.19	8.10	10.29	16.50	16.86	20.51	16.86					
4		11.02	9.19	10.65	14.67	14.67	9.92	39.14	16.86					
5		11.38	8.83	9.92	11.75	13.57	9.92	24.16	16.50					
6		11.38	8.83	9.92	11.75	12.84	12.84	24.89	16.13					
7		10.65	8.83	9.56	11.38	12.48	11.38	30.01	16.13					
8		10.65	12.48	9.56	10.65	11.75	22.70	26.72	15.77					
9		10.29	9.92	11.02	10.29	11.75	16.86	25.62	15.40					
10		10.29	8.83	9.92	11.02	11.02	16.50	28.91	15.40					
11		9.92	8.46	9.56	9.92	11.75	15.40	28.18	15.40					
12		10.29	8.83	13.57	11.02	12.48	15.04	25.62	15.04					
13		10.29	8.83	10.65	10.65	14.67	22.70	24.16	15.04					
14		10.29	8.46	9.56	9.92	13.21	15.40	23.07	14.67					
15		11.02	8.46	9.56	12.48	11.75	28.91	21.97	14.67					
16		11.02	8.10	9.56	13.21	11.02	25.26	22.34	14.67					
17		10.29	7.73	11.75	13.94	10.65	22.70	21.97	14.67					
18		9.92	7.73	13.57	13.57	10.29	20.88	21.24	14.67					
19		9.56	7.73	10.65	12.48	9.92	18.69	20.88	14.31					
20	12.48	9.92	7.37	9.56	12.84	9.19	19.42	20.15	14.67					
21	12.48	9.92	7.37	9.19	11.02	11.02	22.34	19.78	14.31					
22	12.11	9.56	7.00	9.92	11.02	10.29	19.42	19.42	13.94					
23	12.11	9.92	11.38	9.56	11.02	9.56	17.23	19.05	14.31					
24	12.11	10.29	9.56	9.19	11.38	9.56	16.13	18.69	13.57					
25	11.75	11.02	11.02	9.92	13.94	10.29	16.50	18.32	13.94					
26	11.75	11.38	9.19	10.29	12.48	9.56	19.78	18.32	13.57					
27	11.75	10.65	8.46	10.29	11.75	9.56	22.70	17.96	13.57					
28	12.11	10.29	8.46	9.56	11.75	9.56	22.70	17.23	13.21					
29	12.48	10.29	9.19	9.19	11.02		22.70	17.23	13.21					
30	12.11	10.29	9.19	11.38	9.92		24.53	16.86	12.84					
31		10.29		9.56	19.42		22.34		12.84					
SUM		326.24	268.12	311.27	368.96	334.08	566.88	673.80	460.62					3309.97
MEAN		10.52	8.94	10.03	11.90	11.93	18.29	22.46	14.86					13.62
MAX		11.38	12.48	13.57	19.42	18.69	28.91	39.14	17.23					39.14
MIN		9.56	7.00	8.10	9.92	9.19	9.56	16.86	12.84					7.00

APPENDIX 2e. Discharge, Lufubu River at Kabyolwe Village, September 1998 - May 1999.

Station Number: 7-775 | **Name: Lufubu River at Kabyolwe Village**

Latitude: 08:35':51"S | Longitude: 30:44':09"E

Annual summary of daily data - flow
Flows in cubic metres per second

Year: 1997/98 | Year: 1998/99

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		62.00	35.59	24.24	48.18	83.45	64.92	237.20	202.90					
2		59.14	40.47	26.41	42.99	90.02	62.00	247.45	193.55					
3		56.32	56.32	28.63	42.99	86.71	67.88	273.93	188.95					
4		67.88	38.01	30.90	45.56	83.45	67.88	279.38	193.55					
5		73.96	53.56	35.59	50.84	83.45	64.92	273.93	171.03					
6		59.14	40.47	33.22	45.56	80.24	67.88	284.87	162.37					
7		62.00	48.18	33.22	45.56	80.24	77.07	301.66	153.91					
8		62.00	53.56	38.01	42.99	77.07	77.07	330.62	149.76					
9		62.00	38.01	35.59	50.84	80.24	62.00	342.56	179.89					
10		62.00	38.01	28.63	40.47	73.96	62.00	342.56	179.89					
11		50.84	40.47	30.90	50.84	80.24	64.92	342.56	171.03					
12		45.56	35.59	35.59	50.84	80.24	62.00	348.60	162.37					
13		38.01	28.63	28.63	67.88	80.24	62.00	313.10	171.03					
14		45.56	33.22	35.59	62.00	80.24	73.96	318.89	166.68					
15		40.47	48.18	45.56	67.88	73.96	77.07	273.93	162.37					
16	77.07	45.56	38.01	42.99	67.88	80.24	77.07	268.54	158.12					
17	77.07	45.56	53.56	45.56	67.88	80.24	77.07	268.54	137.59					
18	73.96	48.18	35.59	40.47	80.24	70.90	100.26	247.45	153.91					
19	80.24	42.99	53.56	40.47	73.96	70.90	100.26	263.19	158.12					
20	73.96	40.47	35.59	45.56	67.88	73.96	114.59	263.19	145.65					
21	73.96	35.59	28.63	42.99	67.88	77.07	118.30	257.89	153.91					
22	73.96	35.59	20.05	48.18	73.96	67.88	114.59e	257.89	149.76					
23	73.96	40.47	48.18	42.99	80.24	64.92	114.59	247.45	137.59					
24	67.88	33.22	30.90	48.18	77.07	67.88	129.73	242.30	145.65					
25	64.92	30.90	26.41	42.99	80.24	67.88	125.87	242.30	145.65					
26	67.88	30.90	45.56	42.99	80.24	59.14	125.87	247.45	145.65					
27	62.00	30.90	22.12	40.47	77.07	64.92	133.63	237.20	137.59					
28	59.14	40.47	48.18	45.56	83.45	64.92	125.87	237.20	137.59					
29	64.92	38.01	53.56	45.56	83.45		207.65	207.65	133.63					
30	62.00	30.90	45.56	42.99	83.45		227.15	207.65	122.06					
31		33.22		50.84	80.24		212.45		125.87					
SUM		1449.84	1213.70	1199.50	1980.57	2124.57	3003.98	8207.11	4897.66					24076.92
MEAN		46.77	40.46	38.69	63.89	75.88	100.13	273.57	157.99					99.67
MAX		73.96	56.32	50.84	83.45	90.02	227.15	348.60	202.90					348.60
MIN		30.90	20.05	24.24	40.47	59.14	62.00	207.65	122.06					20.05

e = Estimated

APPENDIX 3a. Suspended Sediment Load, Lucheche River at Kawe Village, September 1998 - May 1999.

Station Number: 7-022	**Name: Lucheche River at Kawe Village**
Latitude: 08:42':48"S	Longitudue: 31:12':34"E

Suspended Sediment Load
Sediment in tonnes per day

Year: 1997/98 Year: 1998/99

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		0.93	0.31	0.31	0.93	22.47	1.16	2.72	0.56					
2		0.93	0.31	0.31	0.93	1.70	0.93	2.72	0.73					
3		0.93	0.31	0.23	1.16	4.01	0.93	2.35	0.73					
4		0.93	0.31	0.23	1.16	2.72	0.93	2.72	0.73					
5		0.93	0.18	0.42	0.93	2.01	0.93	4.01	0.56					
6		0.93	0.18	0.31	1.16	2.01	0.73	5.55	0.56					
7		0.56	0.15	0.31	1.41	1.70	1.41	7.36	0.56					
8		0.56	0.23	0.31	1.41	1.41	1.41	6.73	0.42					
9		0.56	0.31	0.31	1.16	1.41	1.41	5.01	0.42					
10		0.56	0.18	0.23	0.93	1.70	1.16	5.01	0.42					
11		0.56	0.15	0.23	0.93	2.35	1.16	5.01	0.31					
12		0.56	0.15	0.93	0.93	2.01	1.41	5.01	0.31					
13		0.56	0.15	0.93	1.16	2.72	1.70	4.49	0.31					
14		0.56	0.15	0.42	1.16	2.35	1.70	4.01	0.31					
15		0.31	0.15	0.31	1.16	1.70	1.70	4.01	0.31					
16		0.31	0.15	0.31	0.93	1.41	2.01	3.55	0.23					
17	1.16	0.23	0.15	0.73	5.01	0.93	1.70	3.12	0.23					
18	1.16	0.23	0.15	1.41	8.01	0.73	1.41	3.12	0.23					
19	1.16	0.23	0.15	1.41	8.01	0.56	1.41	2.72	0.18					
20	1.16	0.18	0.15	0.56	10.94	0.56	0.93	2.35	0.18					
21	1.16	0.18	0.15	0.56	3.12	0.56	1.41	2.01	0.18					
22	1.16	0.18	0.15	0.93	4.49	0.56	1.16	1.41	0.18					
23	1.16	0.18	0.15	0.73	4.49	0.56	0.93	1.41	0.18					
24	1.16	0.18	0.15	0.56	4.49	0.56	0.56	1.16	0.18					
25	1.16	0.42	0.18	1.16	2.72	1.41	0.73	0.93	0.18					
26	1.16	0.73	0.23	1.16	2.72	0.93	0.93	0.93	0.15					
27	1.16	0.56	0.31	0.93	2.72	1.16	1.70	0.93	0.15					
28	0.93	0.56	0.31	0.56	2.01	1.16	1.70	0.93	0.15					
29	0.93	0.42	0.31	0.73	1.70		1.70	0.56	0.15					
30	0.93	0.56	0.31	0.93	1.41		3.55	0.56	0.15					
31		0.31		0.93	12.57		3.12		0.15					
SUM		15.86	6.24	19.44	91.87	63.39	43.62	92.41	10.11					342.94
MEAN		0.51	0.21	0.63	2.96	2.26	1.41	3.08	0.33					1.42
MAX		0.93	0.31	1.41	12.57	22.47	3.55	7.36	0.73					22.47
MIN		0.18	0.15	0.23	0.93	0.56	0.56	0.56	0.15					0.15

APPENDIX 3b. Suspended Sediment Load, Kalambo River at Kalambo Village, October 1998 - May 1999.

Station Number: 7-030
Latitude: 08:35':55"S

Name: Kalambo River at Kalambo Village
Longitudue: 31:15':22"E

Suspended Sediment Load
Sediment in tonnes per day

Year: 1998/99

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1	0.98	0.62	0.22	0.73	25.42	11.44	362.22	42.96					
2	0.98	0.53	0.22	1.11	26.48	17.94	387.00	41.50					
3	0.85	0.53	0.17	1.11	25.42	18.78	350.23	38.69					
4	0.85	0.53	0.17	1.43	23.39	15.56	294.24	36.00					
5	0.85	0.44	0.17	1.43	23.39	16.33	283.82	33.44					
6	0.85	0.36	0.22	1.78	21.47	18.78	289.00	31.00					
7	0.73	0.36	0.36	2.90	19.65	19.65	278.69	29.83					
8	0.73	0.44	0.36	1.98	18.78	26.48	268.64	28.68					
9	0.62	0.44	0.22	1.78	17.12	26.48	244.55	26.48					
10	0.62	0.36	0.22	1.60	16.33	28.68	230.82	24.39					
11	0.53	0.29	0.36	1.43	14.09	32.20	239.92	23.39					
12	0.53	0.22	0.44	1.60	11.44	36.00	226.36	21.47					
13	0.53	0.22	0.44	1.43	12.72	44.45	217.61	20.55					
14	0.53	0.22	0.36	1.43	12.72	47.54	213.32	19.65					
15	0.53	0.22	0.36	1.43	14.81	52.42	209.08	19.65					
16	0.53	0.17	0.29	1.78	17.94	61.28	192.71	18.78					
17	0.44	0.17	0.36	2.65	19.65	71.07	177.21	18.78					
18	0.44	0.17	0.44	3.17	17.94	77.41	166.15	18.78					
19	0.44	0.12	0.62	4.06	14.81	93.65	148.74	18.78					
20	0.44	0.12	0.53	6.70	12.07	117.65	138.90	17.94					
21	0.44	0.08	0.36	7.61	10.24	112.00	126.47	17.94					
22	0.36	0.08	0.36	9.67	9.13	101.25	114.80	17.94					
23	0.36	0.08	0.22	14.81	8.10	88.80	101.25	17.94					
24	0.44	0.08	0.29	16.33	10.24	79.61	86.44	17.94					
25	0.62	0.08	0.36	17.94	10.83	73.14	77.41	17.94					
26	0.98	0.12	0.36	17.12	9.67	75.26	69.03	17.12					
27	0.73	0.29	0.44	19.65	8.60	103.87	63.16	16.33					
28	0.62	0.53	0.85	23.39	9.13	101.25	54.12	15.56					
29	0.62	0.36	0.73	25.42		138.90	50.76	14.81					
30	0.62	0.22	0.73	24.39		368.31	47.54	14.09					
31	0.53		0.73	27.57		362.22		13.39					
SUM	19.26	8.43	11.92	245.43	441.60	1569.01	5710.20	711.78					8698.36
MEAN	0.62	0.28	0.38	7.92	15.77	80.90	190.34	22.99					39.90
MAX	0.98	0.62	0.85	27.57	26.48	368.31	387.00	42.96					387.00
MIN	0.36	0.08	0.17	0.73	8.10	15.56	47.54	13.39					0.08

APPENDIX 3c. Suspended Sediment Load, Izi River at Mbete Village, September 1998 - May 1999.

Station Number: 7-015
Name: Izi river at Mbete Village
Latitude: 08:48':50"S
Longitudue: 31:02':29"E

Suspended Sediment Load
Sediment in tonnes per day

Year: 1997/98 Year: 1998/99

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		0.33	0.31	0.31	0.62	0.86	0.54	3.93	1.99					
2		0.33	0.32	0.31	0.72	0.79e	0.51	3.74	1.92					
3		0.33	0.32	0.31	0.65	0.72	0.59	3.74	1.86					
4		0.33	0.32	0.32	1.67	0.68	0.57	4.35	1.86					
5		0.32	0.32	0.32	1.03	0.65	0.57	5.24	1.79					
6		0.32	0.32	0.32	0.82	0.62	0.79	4.89	1.86					
7		0.32	0.32	0.32	0.75	0.59	1.08	4.89	1.79					
8		0.32	0.43	0.32	0.72	0.59	1.92	4.35	1.79					
9		0.32	0.34	0.32	0.75	0.59	1.61	4.14	1.73					
10		0.32e	0.33	0.32	0.72	0.59	1.67	4.04	1.61					
11		0.32e	0.33	0.36	0.68	0.59	1.55	3.93	1.61					
12		0.32	0.32	0.33	1.55	0.68	1.43	3.74	1.61					
13		0.32	0.32	0.32	0.90	0.90	2.91	3.64	1.55					
14		0.32	0.32	0.32	0.94	0.65	2.20	3.54	1.49					
15		0.32	0.32	0.32	1.03	0.57	4.45	3.36	1.49					
16		0.31	0.32	0.32	1.27	0.51	4.14	3.64	1.43					
17		0.31	0.32	0.99	0.99	0.49	3.45	3.36	1.43					
18	0.32	0.31	0.32	0.99	1.03	0.51	3.18	3.18	1.43					
19	0.33	0.32	0.32	0.72	0.99	0.49	2.75	3.09	1.38					
20	0.33	0.31	0.31	0.62	0.94	0.51	4.14	3.00	1.38					
21	0.34	0.31	0.31	0.65	0.79	0.59	4.45	3.00	1.32					
22	0.34	0.31	0.31	0.68	0.72	0.57	4.04	2.91	1.32					
23	0.34	0.31	0.34	0.66	0.79	0.51	3.64	2.83	1.27					
24	0.34	0.31	0.32	0.65	0.72	0.54	3.45	2.58	1.17					
25	0.34	0.31	0.32	0.82	1.17	0.57	3.18	2.51	1.17					
26	0.34	0.31	0.32	0.75	0.79	0.62	4.14	2.58	1.22					
27	0.34	0.31	0.32	0.68	0.79	0.57	4.45	2.43	1.17					
28	0.34	0.31	0.32	0.68	0.94	0.57	4.24	2.43	1.12					
29	0.34	0.31	0.32	0.65	0.79		4.04	2.43	1.12					
30	0.34	0.31	0.32	0.68	0.68		4.14	2.13	1.12					
31		0.31		0.62	0.94		3.83		1.17					
SUM		9.14	9.68	15.96	27.87	16.35	83.64	103.62	46.20					312.45
MEAN		0.32	0.32	0.51	0.90	0.61	2.70	3.45	1.49					1.29
MAX		0.33	0.43	0.99	1.67	0.90	4.45	5.24	1.99					5.24
MIN		0.31	0.31	0.31	0.62	0.49	0.51	2.13	1.12					0.31

e = Estimated

APPENDIX 3d. Suspended Sediment Load, Lunzua River at Simumbele Village, September 1998 - May 1999.

Station Number: 7-008
Latitude: 08:46':23"S

Name: Lunzua River at Simumbele Village
Longitudue: 31:08':49"E

Suspended Sediment Load
Sediment in tonnes per day

Year: 1997/98 Year: 1998/99

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		27.58	24.00	20.41	27.58	45.52	23.10	50.90	41.93					
2		27.58	23.10	19.51	26.69	40.14	23.10	50.00	41.93					
3		27.58	22.20	19.51	24.89	40.14	41.03	50.00	41.03					
4		26.69	22.20	25.79	35.65	35.65	24.00	95.74	41.03					
5		27.58	21.31	24.00	28.48	32.96	24.00	58.97	40.14					
6		27.58	21.31	24.00	28.48	31.17	31.17	60.76	39.24					
7		25.79	21.31	23.10	27.58	30.27	27.58	73.32	39.24					
8		25.79	30.27	23.10	25.79	28.48	55.38	65.25	38.34					
9		24.89	24.00	26.69	24.89	28.48	41.03	62.56	37.45					
10		24.89	21.31	24.00	26.69	26.69	40.14	70.63	37.45					
11		24.00	20.41	23.10	24.00	28.48	37.45	68.83	37.45					
12		24.89	21.31	32.96	26.69	30.27	36.55	62.56	36.55					
13		24.89	21.31	25.79	25.79	35.65	55.38	58.97	36.55					
14		24.89	20.41	23.10	24.00	32.07	37.45	56.28	35.65					
15		26.69	20.41	23.10	30.27	28.48	70.63	53.59	35.65					
16		26.69	19.51	23.10	32.07	26.69	61.66	54.49	35.65					
17		24.89	18.61	28.48	33.86	25.79	55.38	53.59	35.65					
18		24.00	18.61	32.96	32.96	24.89	50.90	51.80	35.65					
19		23.10	18.61	25.79	30.27	24.00	45.52	50.90	34.76					
20	30.27	24.00	17.72	23.10	31.17	22.20	47.31	49.10	35.65					
21	30.27	24.00	17.72	22.20	26.69	26.69	54.49	48.21	34.76					
22	29.38	23.10	16.82	24.00	26.69	24.89	47.31	47.31	33.86					
23	29.38	24.00	27.58	23.10	26.69	23.10	41.93	46.41	34.76					
24	29.38	24.89	23.10	22.20	27.58	23.10	39.24	45.52	32.96					
25	28.48	26.69	26.69	24.00	33.86	24.89	40.14	44.62	33.86					
26	28.48	27.58	22.20	24.89	30.27	23.10	48.21	44.62	32.96					
27	28.48	25.79	20.41	24.89	28.48	23.10	55.38	43.72	32.96					
28	29.38	24.89	20.41	23.10	28.48	23.10	55.38	41.93	32.07					
29	30.27	24.89	22.20	22.20	26.69		55.38	41.93	32.07					
30	29.38	24.89	22.20	27.58	24.00		59.87	41.03	31.17					
31		24.89		23.10	47.31		54.49		31.17					
SUM		789.59	647.22	752.82	894.51	809.97	1380.57	1643.54	1119.60					8037.83
MEAN		25.47	21.57	24.28	28.86	28.93	44.53	54.78	36.12					33.07
MAX		27.58	30.27	32.96	47.31	45.52	70.63	95.74	41.93					95.74
MIN		23.10	16.82	19.51	24.00	22.20	23.10	41.03	31.17					16.82

APPENDIX 3e. Suspended Sediment Load, Lufubu River at Kabyolwe Village, September 1998 - May 1999.

Station Number: 7-775 | **Name: Lufubu River at Kabyolwe Village**

Latitude: 08:35':51"S | Longitudue: 30:44':09"E

Suspended Sediment Load
Sediment in tonnes per day

Year: 1997/98 Year: 1998/99

DAY	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
1		55.84	16.77	5.13	33.30	99.88	61.18	738.84	547.13					
2		50.80	22.74	7.12	26.03	115.59	55.84	801.58	499.75					
3		46.03	46.03	9.27	26.03	107.54	66.82	975.45	477.21					
4		66.82	19.65	11.59	29.55	99.88	66.82	1013.28	499.75					
5		79.03	41.53	16.77	37.29	99.88	61.18	975.45	394.32					
6		50.80	22.74	14.09	29.55	92.58	66.82	1052.19	357.01					
7		55.84	33.30	14.09	29.55	92.58	85.64	1175.49	322.30					
8		55.84	41.53	19.65	26.03	85.64	85.64	1404.20	305.87					
9		55.84	19.65	16.77	37.29	92.58	55.84	1504.28	434.34					
10		55.84	19.65	9.27	22.74	79.03	55.84	1504.28	434.34					
11		37.29	22.74	11.59	37.29	92.58	61.18	1504.28	394.32					
12		29.55	16.77	16.77	37.29	92.58	55.84	1556.25	357.01					
13		19.65	9.27	9.27	66.82	92.58	55.84	1263.39	394.32					
14		29.55	14.09	16.77	55.84	92.58	79.03	1309.11	375.33					
15		22.74	33.30	29.55	66.82	79.03	85.64	975.45	357.01					
16	85.64	29.55	19.65	26.03	66.82	92.58	85.64	938.66	339.34					
17	85.64	29.55	41.53	29.55	66.82	92.58	85.64	938.66	260.17					
18	79.03	33.30	16.77	22.74	92.58	72.77	142.10	801.58	322.30					
19	92.58	26.03	41.53	22.74	79.03	72.77	142.10	902.90	339.34					
20	79.03	22.74	16.77	29.55	66.82	79.03	183.49	902.90	290.05					
21	79.03	16.77	9.27	26.03	66.82	85.64	195.00	868.14	322.30					
22	79.03	16.77	1.61	33.30	79.03	66.82	183.48e	868.14	305.87					
23	79.03	22.74	33.30	26.03	92.58	61.18	183.48	801.58	260.17					
24	66.82	14.09	11.59	33.30	85.64	66.82	232.52	769.74	290.05					
25	61.18	11.59	7.12	26.03	92.58	66.82	219.50	769.74	290.05					
26	66.82	11.59	29.55	26.03	92.58	50.80	219.50	801.58	290.05					
27	55.84	11.59	3.30	22.74	85.64	61.18	246.07	738.84	260.17					
28	50.80	22.74	33.30	29.55	99.88	61.18	219.50	738.84	260.17					
29	61.18	19.65	41.53	29.55	99.88		572.00	572.00	246.07					
30	55.84	11.59	29.55	26.03	99.88		679.75	572.00	206.99					
31		14.09		37.29	92.58		597.68		219.50					
SUM		1025.86	716.15	654.22	1920.59	2344.69	5003.12	29738.82	10652.58					52056.01
MEAN		33.09	23.87	21.10	61.95	83.74	166.77	991.29	343.63					215.68
MAX		79.03	46.03	37.29	99.88	115.59	679.75	1556.25	547.13					1556.25
MIN		11.59	1.61	5.13	22.74	50.80	55.84	572.00	206.99					1.61

e = Estimated

APPENDIX 4. Estimated mean monthly flow, Lufubu River at Keso Falls, November 1957 - July 1992.

Station number : 7-750 | Station name : Lufubu River at Keso Falls

Latitude : 08:41': 0 S | Longitude : 30:36': 0 E

PERIOD FROM NOVEMBER 1957 - JULY 1992.

Mean monthly flow in cubic metres per second

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL MEAN
1957/58		14.56	20.80	50.81	50.80	101.89	123.56	73.17	33.97	23.03	15.75	11.31	47.24
1958/59	8.65	8.14	19.03	37.36	45.61	87.60	78.04	39.97	22.87	14.45	10.41	6.98	31.59
1959/60	6.70	8.51	21.13	43.94	99.60	200.72	191.09	62.51	41.03	31.22	21.11	15.12	61.89
1960/61	11.77	12.45	16.31	24.01	76.59	118.78	110.09	61.92	34.58	23.92	16.75	11.99	43.26
1961/62	9.59	18.12	118.13	372.25	319.43	427.57	288.65	123.14	70.20	49.52	37.89	30.01	155.38
1962/63	26.64	28.32	61.13	190.88	200.99	312.29	222.45	103.83	63.06	47.50	36.52	28.68	110.19
1963/64	23.33	37.67	104.14	253.60	234.40	341.92	202.11	88.90	57.83	43.54	34.73	27.13	120.78
1964/65	21.30	23.91	28.42	41.90	60.04	108.28	111.56	55.75	35.27	25.57	19.03	16.08	45.59
1965/66	14.25	15.45	25.06	51.34	83.98	232.67	205.93	77.78	53.08	37.11	28.09	20.87	70.47
1966/67	17.72	18.48	24.31	33.65	43.81	79.51	130.47	79.85	43.53	30.97	22.39	17.84	45.21
1967/68	14.49	18.75	83.86	153.61	245.68	407.64	243.07	136.77	76.79	52.58	38.33	29.77	125.11
1968/69	23.60	23.60	36.16	49.19	92.03	145.48	143.58	76.60	46.37	34.01	24.51	19.25	59.53
1969/70	16.97	19.49	31.24	63.46	142.05	205.84	158.49	70.90	45.31	33.76	25.26	19.40	69.35
1970/71	15.74	19.40	50.58	122.04	142.77	249.50	164.68	86.25	54.44	38.54	28.71	22.03	82.89
1971/72	15.79	20.67	50.49	119.84	143.63	249.66	164.41	86.51	54.47	38.54	28.71	22.05	82.90
1972/73	18.91	23.20	39.92	90.58	106.56	143.44	102.24	56.97	38.42	28.87	22.94	18.20	57.52
1973/74	15.59	19.69	24.39	33.93	42.21	36.52	67.39	66.80	34.33	28.45	20.68	16.08	33.84
1974/75	13.25	14.80	23.04	44.09	48.31	98.15	93.55	59.14	35.67	24.55	18.32	14.48	40.61
1975/76	12.50	12.33	19.69	31.12	51.53	94.27	131.95	70.43	41.01	28.97	20.87	16.38	44.25
1976/77	13.94	13.29	17.67	26.99	44.95	50.91	83.00	60.94	31.80	20.79	15.41	11.72	32.62
1977/78	9.85	14.58	33.73	72.91	131.11	186.40	178.68	73.69	45.11	33.47	24.97	18.49	68.58
1978/79	15.47	22.28	40.68	60.81	190.40	316.35	230.77	130.68	66.25	46.79			112.05
1979/80				105.87	119.03	110.49	159.28	91.59					117.25
1980/81		20.37	32.13	43.18					39.25	28.51	21.19	16.25	28.70
1981/82	13.62		21.68	23.86	35.08	47.67			29.26	18.93	13.62	10.26	23.78
1982/83	9.29	17.20	102.88	228.33	150.55	121.80	105.46	65.47	40.71	29.72	23.89	17.78	76.09
1983/84	15.93	15.85	25.24		114.08	187.49	99.94	54.52	35.33	25.25	18.48	14.02	55.10
1984/85	11.32	15.63	24.53	35.71	65.67	123.14	148.50	64.51	38.82	25.92	18.33	14.26	48.86
1985/86	10.90	15.04	28.10	47.51	84.58	101.71	100.89	59.37	37.01	25.31	18.13	13.34	45.16
1986/87	12.56	17.49	52.04	94.42	163.25	215.38	169.77	82.76	50.17	37.27	27.76	20.69	78.63
1987/88	20.08	18.46	24.11	36.78	64.74	95.33	121.55	51.48	33.71		18.32	14.38	45.36
1988/89	12.90	17.13	25.77	51.93	89.63	109.23	375.19	98.46	59.72				93.33
1989/90	79.57	111.57	136.50										109.21
1990/91	11.53	17.34	41.04	78.05	85.48	186.27	71.04	44.87	30.58	21.85	16.02		54.92
1991/92	17.76	19.39	37.85			126.51	108.62	86.38	50.00	33.86			60.05
Sum	541.51	693.16	1441.78	2713.95	3568.57	5620.41	4886	2441.91	1469.95	982.77	687.12	514.84	2377.28
Mean	16.92	21.00	42.41	84.81	111.52	170.31	152.69	76.31	44.54	31.70	22.90	17.75	67.92
Max	79.57	111.57	136.5	372.25	319.43	427.57	375.19	136.77	76.79	52.58	38.33	30.01	155.38

Min	6.7	8.14	16.31	23.86	35.08	36.52	67.39	39.97	22.87	14.45	10.41	6.98	23.78

APPENDIX 5. Estimated mean monthly flow, Lunzua River at Kambole Rd. Brg., Oct. 1970 - Aug. 1991.

Station number : 7-005
Latitude : 08:57': 0 S

Station name : Lunzua River at Kambole Road Bridge
Longitude : 31:11': 0 E

PERIOD FROM OCTOBER 1970 - AUGUST 1991

Mean monthly flow in cubic metres per second

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL MEAN
1970/71	2.13	2.07	3.53	3.86	5.47	6.30	5.79	4.48	3.59	2.91	2.38	1.90	3.70
1971/72	1.49	1.51	2.68	3.83	5.91	8.28	8.31	6.25	4.96	4.00	3.27	2.69	4.43
1972/73	2.15	2.13	3.96	4.41	5.21	6.66	7.57	5.84	4.60	3.71	2.97	2.28	4.29
1973/74	1.67	1.69	1.67	2.24	2.73	3.70	4.95	5.90	4.39	3.59	2.81	2.16	3.13
1974/75	1.77	1.48	2.67	4.35	4.54	6.46	6.74	5.70	4.44	3.56	2.87	2.21	3.90
1975/76	1.82	1.56	2.13	2.65	3.85	4.66	6.39	5.09	3.89	3.11	2.51	1.98	3.30
1976/77	1.53	1.26	1.38	2.81	3.95	5.61	5.78	5.07	3.68	2.95	2.23	1.75	3.17
1977/78	1.38	1.97	3.49	4.92	6.29	8.60	8.35	6.26	4.86	3.98	3.22	2.58	4.66
1978/79	2.02	2.27	3.63	3.79	5.68	9.28	10.05	8.19	6.12	4.82	3.97	3.26	5.26
1979/80	2.65	2.74	3.51	3.93	4.40	4.88	5.29	4.71	3.80	3.02	2.51	2.04	3.62
1980/81	1.57	1.57	2.22	2.82	4.41	7.48	6.41	4.83	3.68	3.06	2.51	1.84	3.53
1981/82	1.59	1.37	1.57	1.62	2.65	2.85	3.86	3.19	2.31	1.82	1.32	1.06	2.10
1982/83	1.22	1.80	6.17	9.79	7.19	7.33	7.72	5.77	4.38	3.47	3.31	2.42	5.05
1983/84	2.01	1.75	2.57	4.50	4.48	6.44	5.83	4.44	3.54	2.82	2.29	1.75	3.54
1984/85	1.38	2.56	2.26	3.27	4.71	7.81	8.32	6.63	5.42	4.53	3.85	3.24	4.50
1985/86	2.66	2.74	3.46	5.90	7.67	9.90	8.10	6.40	5.20	3.93	3.23	2.52	5.14
1986/87	2.08	2.30	3.86	6.39	8.51	9.59	10.83	8.20	6.34	5.08	4.15	3.43	5.90
1987/88	3.15	2.87	3.17	4.28	4.68	6.88	7.37	5.41	4.25	3.41	2.73	2.12	4.19
1988/89	1.90	2.05	2.02	3.63	4.28	5.45	10.35	7.59	5.83	4.69	3.81	3.12	4.56
1989/90		2.36	3.33	3.30	4.38	5.40	6.64	5.33	4.09	3.28	2.68	2.14	3.90
1990/91	1.70	1.66	2.08	3.03	4.10	4.49	5.78	4.64	3.67	2.99	2.35	1.60	3.17
1991/92							5.76	5.52	4.23	3.32	1.26		4.02
Sum	37.87	41.71	61.36	85.32	105.09	138.05	156.19	125.44	97.27	78.05	62.23	48.09	89.06
Mean	1.8935	1.9862	2.9219	4.0629	5.0043	6.5738	7.0995	5.70182	4.4214	3.5477	2.8286	2.29	4.05
Max	3.15	2.87	6.17	9.79	8.51	9.9	10.83	8.2	6.34	5.08	4.15	3.43	5.90
Min	1.22	1.26	1.38	1.62	2.65	2.85	3.86	3.19	2.31	1.82	1.26	1.06	2.10