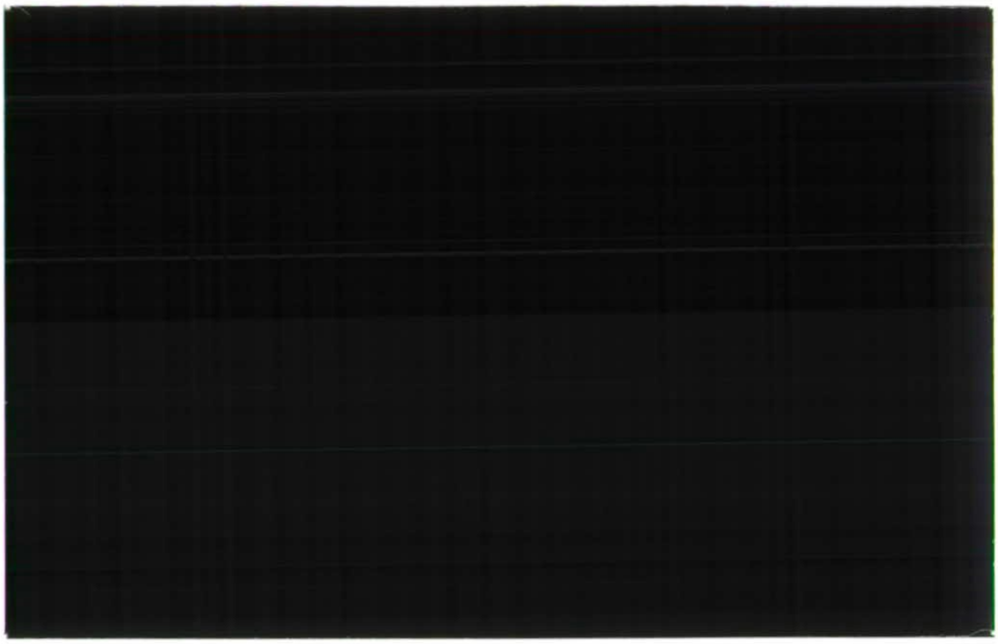
Institute of Hydrology



Natural Environment Research Council

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WORLD METEOROLOGICAL ORGANISATION

Water component for the implementation of the International Convention to Combat Desertification

Contribution by the southern Africa FRIEND Project by collaboration between University of Zimbabwe, Rhodes University (South Africa) the Institute of Hydrology (United Kingdom), and additionally by the International Union for the Conservation of Nature (Switzerland)

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Preface

This report is a product of collaboration between Mr Dominic Mazvimavi, Lecturer in Hydrology in the Geography Department at the University of Zimbabwe; Professor Denis Hughes of the Institute for Water Research, Rhodes University at Grahamstown (South Africa) and staff of the Institute of Hydrology (Dr Andy Bullock, Philippe de Hénaut and Tony Andrews) working on the Southern African FRIEND project. Section 2.4 is a contribution by IUCN - The World Conservation Union, based on a scoping workshop on the Save catchment redevelopment programme. Readers should note that the workshop has taken place and proceedings will soon be available directly from IUCN.

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1 Southern Africa FRIEND Project

The Southern Africa FRIEND project is a contribution to the Unesco International Hydrological Programme IV, targeting 'Hydrology and water resources for sustainable development in a changing environment'. Project H-5-5 has the particular objective of applications of methods of hydrological analysis using regional data sets, and is entitled FRIEND (Flow Regimes from International Experimental and Network Data). FRIEND projects are currently operating in Western and Northern Europe, the Mediterranean region (AMHY project), West Africa (AOC project) and Southern Africa.

The Southern Africa FRIEND project involves collaboration between countries (Figure 1.1) in Southern Africa Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland, South Africa, Tanzania, Zambia and Zimbabwe) and the Institute of Hydrology (U.K.) with the likely future participation of Angola. The project has five specific objectives, as follows;

- To create a common hydrological database (river flow time series and spatial data) for the region by bringing together existing data sets from individual countries.
- To analyse the flood data base to develop procedures which will enable staff to estimate flood frequency relationships throughout the region.
- To analyse the daily flow database to develop procedures which will enable local staff to estimate drought and water resource statistics throughout the region.
- To develop rainfall - runoff models to provide a basis for more detailed design studies and to address problems of the impact of land-use change.
- To train staff in the development and application of flood, water resource and modelling design technique.

This project to establish the water component for the implementation of the International Convention to Combat Desertification benefits from the first of those objectives. The Southern African FRIEND project has so far succeeded in establishing an international database of river flows for over 750 gauging stations in nine countries. This comprises over 15,000 years of daily river flow data. Historic river flow records, dating back over 20 years, for the rivers Save and Groot are used to contribute to the water balance calculations.

Southern African-wide coverage of computer-based geographical information (river boundaries, rainfall, evaporation, geology, soils and topography) have been established using ARCINFO-Geographical Information System. These coverages (de Hénaut, 1995) are used to illustrate the characteristics of the Save catchment in this report.

The Southern African FRIEND project, through establishment of region-wide databases has the capability to provide similar information for up to 750 gauged catchments (and other ungauged locations) throughout Southern Africa. Clearly, when data from one country only is required, then the first point of contact should be the National Hydrological Services. Southern African FRIEND provides the capability for international retrievals in a consistent manner.

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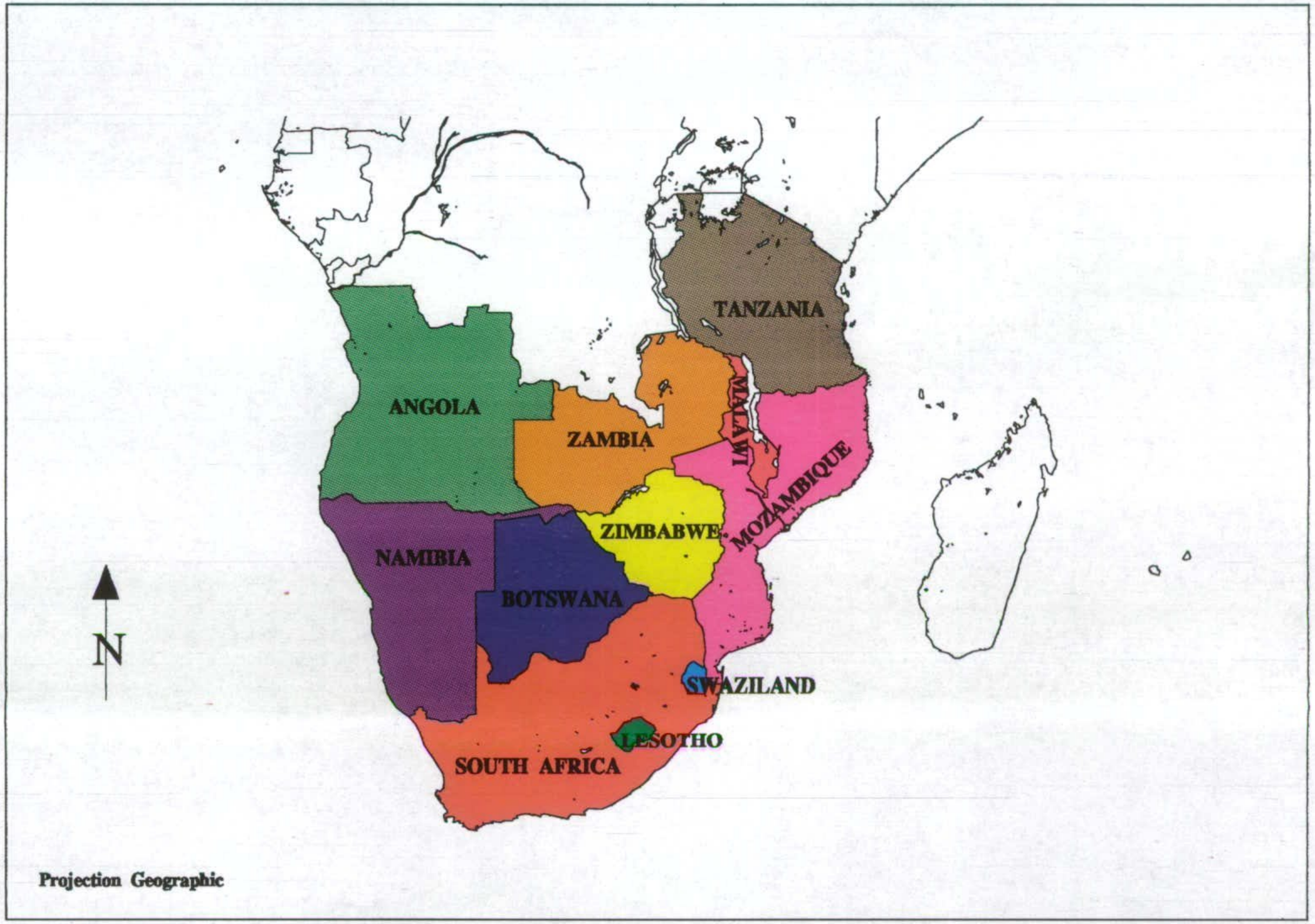

Figure 1.1 Countries participating in Southern Africa FRIEND

2 Save River Basin, Zimbabwe

2.1 SUMMARY

The Save river is an international river rising in Zimbabwe and flowing into the Indian Ocean in Mozambique. Within Zimbabwe there are two main branches of the Save - the Save itself and the Runde - which form a confluence at the Mozambique border. This report deals solely with the Save branch (excluding the Runde) within Zimbabwe (Figure 2.1), with a catchment area of approximately 45,000 km^2. This river was gauged by the Zimbabwe authorities at Save Gorge (station E43) for the period 1959-1978, with an area of 44,000 km^2, and these data form the basis of the preliminary annual water budget. There are many (over 30) other gauging stations within the catchment, over 100 raingauges and 10 meteorological stations, but these data are not analysed here. The Save river is considered as the most degraded of Zimbabwe's rivers, and has been the subject of substantial redevelopment planning.

2.1.1 Geology and hydrogeology

The geology and hydrogeology of the Save catchment are depicted in Figure 2.2, with summaries of the areal extent of the different units in Tables 2.1. and 2.2 respectively. The Save is predominantly Precambrian gneisses of the crystalline basement complex.

Table 2.1 *Areal extent of geological formations in the Save catchment*

Geology	Area Km^2
Alluvium	1628.66
Kalahari Sand	3.27
Upper Karoo Basalt	1036.74
Upper Karoo Sandstone	517.29
Lower Karoo Mudstone	121.60
Umkondo Assemblage	2643.89
Deweras Metavolc., Arkose, Grits & Shales	294.39
Bulawayan Metavolc	691.60
Shamvaian Metavolc. & Metaseds	152.26
Precambrian Older Gneiss - Limpopo	30666.66
Precambrian Older Gneiss	2187.00
Mashonaland Dolerite	3556.26
Surface Waters	26.29
Total area	43525.91

Table 2.2 *Areal extent of hydrogeological units in the Save catchment*

Hydrogeology	Area Km^2
Alluvium	1628.66
Kalahari Sand	3.27
Karoo Basalt	1036.74
Karoo Sediments	638.89
Transvaal & Watenberg Group	2643.89
Metavolc. & Metaseds	843.86
Precambrian Older Gneiss	32853.66
Unclassified	3850.65
Surface Waters	26.29
Total area	43525.91

2.1.2 Soils

Figure 2.3 depicts the distribution of soil types of the Save catchment, using the standard FAO classification scheme (Soil map of the World; Vol. V1 Africa, FAO 1977). The dominant soils are rhodic ferralsols (Fr 6-2/3ac) in the northern catchment, and ferric luvisols (Lf10-1a and Lf81-2a) in the central and southern catchment. Ferrasols represent the final stages of ferralitic weathering and are widely distributed throughout central Africa, and generally have a limited potential fertility. The agricultural value of rhodic ferralsols is higher than that of other ferralsols, and are suitable for the establishment of good pastures and the cultivation of maize and other crops. The upper portion of the catchment is characterised by the extensive distribution of dambos (seasonal headwater wetlands), which provide an additional potential agricultural resource if such usage were not prohibited by Zimbabwe legislation. Luvisols occur under unfavourable ecoclimatic conditions where the irrigation water needed for the intensification of agriculture is often lacking.

2.2 PRELIMINARY ANNUAL WATER BUDGET FOR THE SAVE RIVER ABOVE SAVE GORGE

A preliminary annual water budget for the Save river is presented in Table 2.3.

Table 2.3 *Preliminary annual water budget above Save Gorge*

Precipitation	740 mm
Evaporation - Potential - Actual	1550 mm 669 mm
Runoff	71 mm
Soil moisture } Groundwater }	Estimates of groundwater recharge in this region of South Africa are estimated to typically range between 10-20% of rainfall (75-150 mm), of which up to 40 mm may contribute to runoff from the Save catchment.

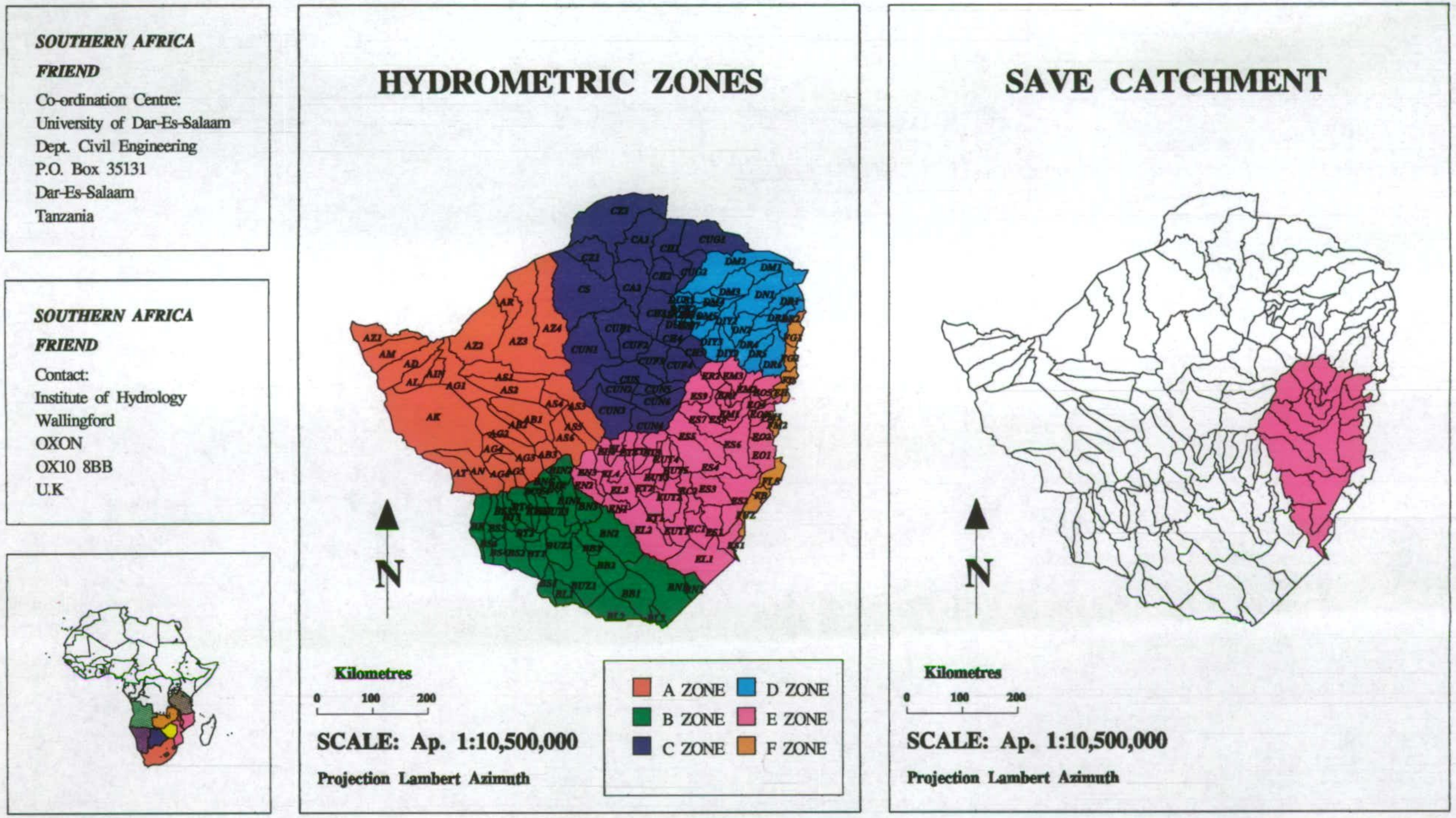

Figure 2.1 Hydrometric zones of Zimbabwe and location of Save River catchment

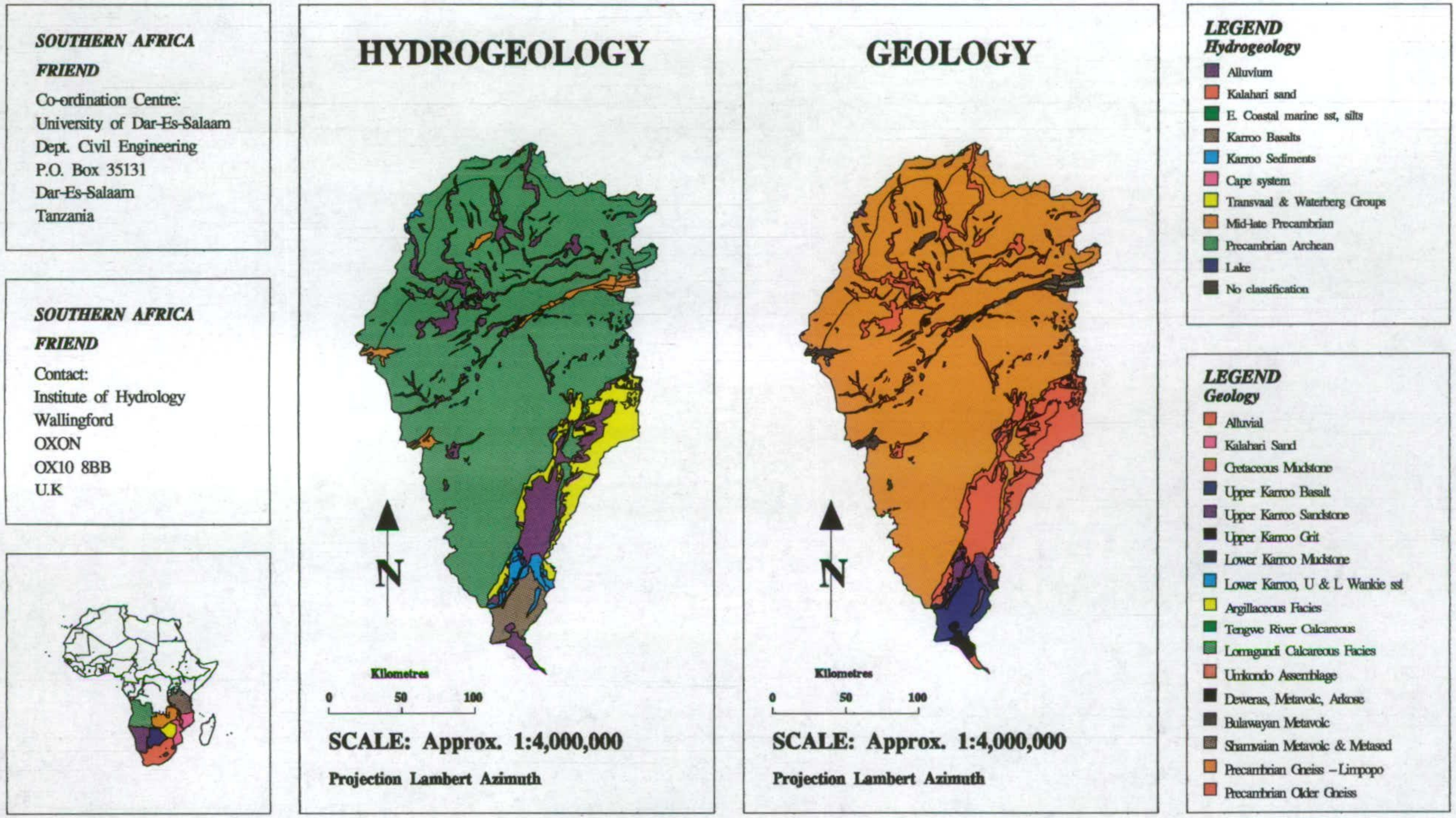

Figure 2.2 Geology and hydrogeology of the Save catchment, Zimbabwe

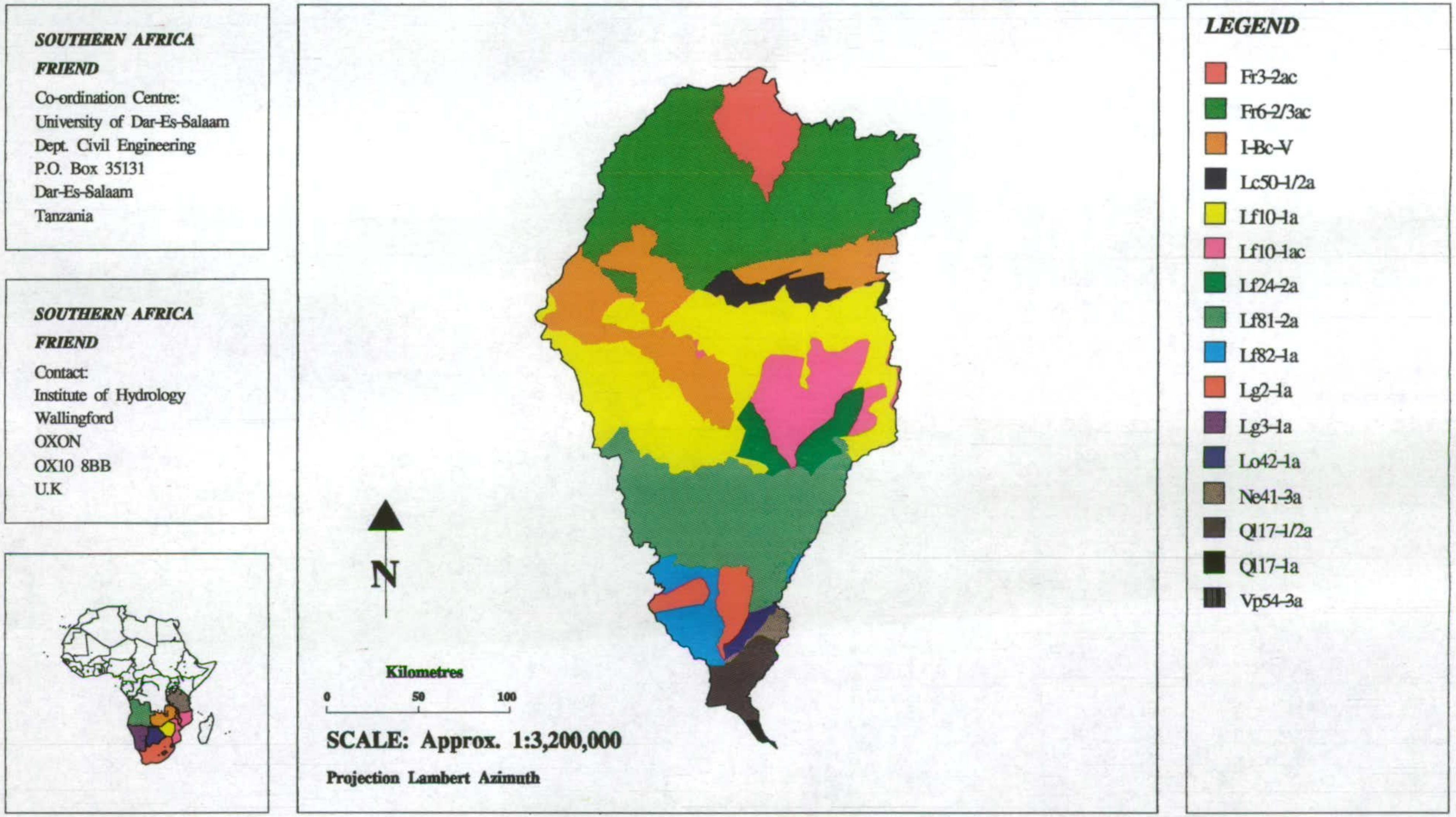

Figure 2.3 Soils of the Save River catchment, Zimbabwe

2.3 WATER CONVERSATION WITHIN THE SAVE CATCHMENT

2.3.1 Introduction

The Save catchment experiences seasonal rainfall that occurs from about mid-November to March. As a result river flows occur mostly during this period, while the rest of the year there are practically no flows on most major rivers. Furthermore the catchment is underlain by rocks of the basement complex which only form localised aquifers. Thus baseflows are very limited. Past and present water conservation policies and programmes have been targeted at addressing this imbalance between supply and demand. The other impetus for developing the water resources of the Save catchment is the existence of fertile, basaltic soils that are irrigable within the lower part of the catchment. It is estimated that up to 40,000 ha can be developed for irrigation. The population of the Save catchment was 1.5 million people in 1992, of which 11% lived in urban areas (Central Statistical Office 1993).

2.3.2 Past and current water conservation measures

Water conservation measures have been aimed at improving the supply of water for both urban and agricultural purposes. There has not been any effort made to control the demand. The Odzani Dams on the Odzani River were constructed to supply water to the City of Mutare (Fig. 1). These two dams have a combined capacity of 21 x $10^6 m^3$ and a yield of 23 x 10^6 m^3 which has a 96% reliability. This urban settlement had in 1992 a population of 139 000, and an annual water demand of 20 x 10^6 m^3 or 390 litres/head/day. It is anticipated that these two reservoirs will not be able to supply water with a 96% reliability by 1995.

There are several irrigation schemes within the Save catchment, and the major ones are given below (Table 2.4).

Table 2.4 Major irrigation schemes within the Save catchment

Scheme	Hectarage (ha)	Annual water demand (10^6 m^3)
Middle Save	6864	96
Chisumbanje	2400	25
Small scale	800	unknown
- Nyanyadzi		
- Devure		
- Mutema		

The supply of irrigation water is the responsibility of the Regional Water Authority which formerly was called the Sabi-Limpopo Authority. It was established as a statutory body in 1964. During the rainy season, irrigation water is abstracted from flows within the Save River since the above irrigation schemes are located along it. During the dry season or mid-summer droughts, these flows are not sufficient to satisfy the water requirements. Three dams were therefore constructed in the upper parts of the Save River. These are:

Ruti Dam on Nyanyadzi River	128 x 10^6 m^3
Rusape Dam on Rusape River	67 x 10^6 m^3
Osborne Dam on Odzi River	420 x 10^6 m^3

2.3.3 Groundwater

The lower Save Valley contains an alluvial plain that is about 20 km wide and 60 km long. This alluvium comprise interbedded silt, clay and sand intercalcated with gravel and scree near the escarpments in the east. It is of the Pliocene age and has a maximum depth of 70 m. The Save River runs straight through this alluvial plain as a braided channel, and sand deposits within it are arkosic with a depth of about 15 m (Dennis & Hindson 1960).

Investigations undertaken over the last 35 years have revealed the occurrence of groundwater within this formation. It is regarded as one of the largest aquifers in Zimbabwe. Although the yield of boreholes in this formation are highly variable, yields greater than 7 000 m^3/day have been realised. The Regional Water Authority has drilled 29 boreholes at Middle Save Irrigation Scheme. Fourteen of these boreholes are operational with yields in the 60 to 70 litres/second range, and a depth of about 60 m. These boreholes are used to supply irrigation water during drought periods.

The rest of the catchment is underlain mostly by granitic formations. Aquifers in these formations are found within the weathered regolith and have limited yields in the 10 to 50 m^3/day range. Borehole yields can be as high as 50 to 100 m^3/day in those few areas with a great depth of weathering. Due to these limited yields, groundwater development has mostly been for domestic water supply in both large scale commercial farming areas and communal areas. The rural water supply and sanitation programme in communal areas is based on the development of hand-pump boreholes and large diameter wells. Table 2.5 below shows the main sources of water within Manicaland Province based on the results of the 1992 Population Census. Most of this province is within the Save catchment and the figures given below are representative of groundwater usage within this catchment.

Table 2.5 Sources of water for cooking and drinking within the Manicaland Province

Source of water	Percentage of the population
Piped water	32.35
Boreholes and protected wells	37.66
Unprotected wells	19.35
Rivers and dams	10.64

Source: Central Statistical Office (1993), Census 1992; Provincial Profile Manicaland.

The above figures show that 57% of the population within the Save catchment rely on groundwater for domestic purposes. This shows that although the groundwater resources of the greater part of the catchment are limited and localised, they are however important as the main source of water for the rural population.

2.3.4 Water conservation problems

The major problem faced in conserving the water resources of the Save catchment is land degradation due to both deforestation and soil erosion. According to studies undertaken by Whitlow (1988), the middle part of this catchment experiences some of the highest soil erosion rates within Zimbabwe. Soil erosion rates have been estimated for arable lands within communal lands as being about 50 to 70 tonnes/ha/year. This has adversely affected the productivity of arable lands. A survey of siltation rates within small to medium sized dams in communal lands did also reveal that sediment yields were about 400 to 700 tonnes/km^2/year (Interconsult 1986). In contrast sediment yields in the better conserved large scale commercial farming areas were about 50 to 90 tonnes/km^2/year. In the case of Ruti Dam which drains land under both tenure systems, the sediment yield was estimated to be 333 tonnes/km^2/year. Although these sediment yields are small by world standards, they are of great concern due to the reduction of the channel capacity which causes decreases in dry season flows particularly along the Save River. Such adverse effects become much more severe due to the seasonality of river flows. HRS (1983) estimated that for the planned large dams on the Save River, the prevailing sediment yields would result in a 5 to 10% loss in live storage over a 72 to 115 year period.

The main factors responsible for land degradation are both physical and human. The sandy soils derived from granites that are found on the greater part of the catchment are easily eroded. Granites do often result in a rugged terrain characterised by inselbergs. Runoff generated from these steep slopes causes high soil erosion rates. High rainfall intensities which range from 25 to 50 mm/hour due to convectional storms, cause high soil erosion rates particularly in areas where vegetal cover is minimal.

The Save catchment has an average population density of about 42 persons/km^2 (CSO 1993). In some parts of the catchment the population density can be as high as 60 persons/km^2. Such high human population densities in conjunction with high livestock population density means that resources such as soils and vegetation are under pressure. Poor land management practices and the extension of cultivation to marginal lands do inevitably lead to high soil erosion rates within communal lands. Due to the extreme shortage of land in communal lands, communal grazing areas are confined to river valleys and dambos. Overgrazing in these parts has led in some parts to severe gully erosion and desiccation of some of the dambos. The inhabitants of communal lands have no alternative source of energy besides woodfuel and timber. Consequently trees are cut for such purposes and deforestation within parts of the Save catchment is now a major problem. The lack of alternative sources of energy is mainly due to poverty which is partly a result of a poor resource base. The combination of the above factors has therefore led to both severe soil erosion and deforestation in parts of the Save catchment. Obviously these have major adverse effects on the water resources of this basin.

2.3.5 Water losses within the distribution system

The major water losses that are of concern within the Save catchment are those that occur when the water is released from upstream reservoirs, and then delivered to downstream irrigation schemes using the natural channels. These losses are high and variable depending on the season or wetness of the channel, amount of water released, and the composition of the river bed. There are still some uncertainties on the magnitudes of the losses. The figures presented in Table 2.6 were obtained from observations made by both the Regional Water Authority and the Department of Water Development.

Table 2.6 River losses within the Save catchment

River bed composition	Losses (litres/sec/km)
Rocky	4 - 6
Rock and sandy	10 - 20
Sandy	40 - 50

Source: Regional Water Authority (1994).

The greatest losses occur between Middle Save and Chisumbanje Irrigation Schemes that are 75 km apart. The braided Save River passes through the Save alluvium. If the river is initially dry and water is being passed through this section where the travel time is about 5 days, losses can amount to 2 to 4 x $10^6 m^3$. The Regional water Authority minimizes losses by continuously releasing some water so that the river does no dry up. Water is released in bulk since losses are small for large releases.

2.3.6 Future water conservation strategies

Both the Department of Water Development and Regional Water Authority are modifying their approach to water resources management. Unlike in the past when supply-oriented solutions were only considered, the new approach depends on both supply and demand management solutions. It is increasingly becoming evident that the water resources of the Save catchment and Zimbabwe in general are finite. The Save catchment has a population growth rate of about 2.3%. Although water demand will increase due to the growth in population, improvement in the living standards, and expansion of irrigation schemes, the water demand will have to be controlled by pricing water so that consumers pay the true value of water. Previous droughts during the eighties and nineties have also incalculated a water conservation consciousness with the general population.

In order to satisfy the water demand for the City of Mutare it is planned to transfer water from Osborne Dam. This will be sufficient up to year 2000. Thereafter water will be diverted from the Pungwe River through a tunnel, and this should be adequate up to about year 2011. There are however contrasting opinions on whether the Pungwe River Diversion should commence earlier than the Osborne Dam diversion. Recycling of water is also an option that is gradually becoming popular in urban areas in Zimbabwe after noting the benefits that have accrued to the City of Harare. During drought years Harare did not face major difficulties like other urban centres since 25% of the water consumed is recycled.

Studies that have been undertaken show that the Chisumbanje Irrigation Scheme can be expanded from the present 2400 ha to 41 000 ha. Some 30 000 ha can be developed on the west bank of Save River. In order to meet these water demands the following dams on the Save River have been identified for future construction:

Condo Dam	3 530 x $10^6 m^3$
Chitowe	2 320 x $10^6 m^3$

Various canals will also be required to distribute the water to the irrigation schemes.

Further development of the Save alluvial aquifer is also a possible option. The recharge rates to this aquifer are not completely known. A comparison of the tritium content of water in both the Save River and the alluvial aquifer did suggest that the Save River does recharge this aquifer. The rate of recharge could be as high as 580 l/s. However this recharge may not be occurring along the whole length of the Save River due to the presence of clays in some parts. Recharge from the eastern mountain range is estimated to be about 60 l/s. It has also been suggested that by decreasing the water table by about 1.5 m through pumping from boreholes located 300 to 400 m from the Save River, recharge rates could increase. While there are still uncertainties regarding the water resources available in this aquifer, it is clear that this is a major source of water that could be developed, and conjunctively utilized with surface water.

Future water conservation strategies will have to consider soil conservation as part of water conservation. Without soil conservation water resources projects will not be sustainable. This will require the reduction in population growth rates and densities through educational programmes and resettlement, and improvement in the land management. The current efforts aimed at improving grazing schemes, and establishment of woodlots need to be expanded. Poverty alleviation measures will also play a central role. Thus future water conservation strategies should be part of the overall development thrust. Water conservation alone is not tenable amidst poverty.

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2.4 PROPOSAL FOR A SCOPING WORKSHOP ON THE SAVE CATCHMENT CONSERVATION, REHABILITATION AND SUSTAINABLE DEVELOPMENT PROGRAMME

by IUCN
(Note that this workshop has taken place but proceedings are not yet available.)

2.4.1 Introduction

The Save catchment, located in Eastern and South Eastern Zimbabwe, constitutes the most important inland basin for Zimbabwe. The catchment which consist of the Save and Runde rivers, covers a total area of 84 500 km^2. The predicament of the Save catchment has far reaching effects on the survival of 3 million lives in Zimbabwe. The catchment spreads over four administrative provinces of *Manicaland, Masvingo, Midlands* and *Mashonaland East*. Major river systems within the catchment are *Odzi, Rusape, Macheke, Ruzawi, Mwerihari, Dewure, Mtirikwi* and *Runde*.

Environmental degradation in the Save catchment have been topical since the 1950s. Despite various conservation efforts, environmental degradation in form of soil degradation and erosion, siltation of rivers and reservoirs, deforestation and desiccation of wetlands have continued unabated. Various scenarios of the nature and causes of environmental problems of the Save catchment have been put forward. Both human and livestock population pressure on resources in communal lands have been identified as the main cause of environmental degradation in the Save catchment. However, other scenarios have considered the type of land tenure, poverty, lack of alternative economic activities leading to unsustainable resource utilisation, haphazard settlements, uncontrolled cultivation and lack of community involvement in the catchment's conservation and land-use plans as major contributors to the environmental problems of the catchment.

Despite the pre-independence conservation efforts and failures, new efforts gained momentum after independence in 1980. Since then, various initiatives to address the environmental problems of the Save catchment have been launched. These initiatives include a national initiative, the Save Catchment Area Rehabilitation and Monitoring Programme (SCARMP) and various other small initiatives by government sector departments and non-governmental organisations. The SCARMP was formulated in 1990 and has wider objectives to contribute to the overall national objectives of developing the agricultural sector and increase standard of living of the rural people while at the same time conserving and rehabilitating the natural resources of the catchment. The programme aims to contribute towards sustainable self-sufficiency and food security for the rural communities through sustainable utilisation of natural resources. The specific programme objective is the development of a master plan to ensure orderly rural development and rehabilitation of the catchment. The programme is planned to focus on; the inventory and assessment of the present status and potential of the catchment's natural resources, identification of short and medium term private and public investment projects within the context of the National Conservation Strategy and sustainable development, identification of institutional arrangements for the orderly development and management of the catchment's natural resources, development of an appropriate environmental framework for the catchment and assessment of the effects of the present land tenure system in the communal lands on the natural resources of the catchment. Although the programme was formulated in 1990, its implementation have not yet started due to various reasons such as lack of funding, technical capacity, etc.

2.4.2 Present status

The Save catchment is still beset with the environmental problems it had before independence. In fact, the environmental problems are worsening as evidenced by increasing deforestation, soil erosion and siltation, desiccation and poverty.

Today, numerous government departments and parastatals, and NGOs are implementing various projects in the catchment. Some of the government institutions and NGOs actively involved are; Agricultural and Technical Extension Services (AGRITEX), Department of Natural Resources, Department of Water Development, Department of Research and Specialist Services, Ministries of Local Government, Health, Employment Creation and Cooperatives, Forestry Commission, ADA, Africa 2000 Network, Lutheran World Federation, Zimbabwe Environment Research Organisation (ZERO), Save Rehabilitation Action Committee (SARAC), Manicaland Development Association (MDA), ENDA-Zimbabwe and Christian Care. Conservancies, parastatals, commercial farmers and private companies operating in the catchment are also concerned and interested in the conservation and rehabilitation of the catchment. Much of the conservation, rehabilitation and development work carried out in the catchment is done on a sectoral basis with very little collaboration and coordination. As a result, most of the environmental problems of the catchment remain unresolved. It is against this background that the Ministry of Environment and Tourism, through its Department of Natural Resources approached IUCN for both technical and financial assistance to implement the SCARMP.

In light of the current situation in the catchment, the national land reform and Land Tenure commission, and new ideas such as conservancies and ecotourism, the orientation of and recommendations made in the SCARMP document may not fully address the environmental problems of the Save catchment. Integrated resource conservation and management, sectoral coordination and collaboration, and ecological sustainable development may be the answer to most of the environmental problems of the Save catchment. It is against this background that IUCN Regional Office for Southern Africa and the Ministry of Environment and Tourism (Department of Natural Resources) are proposing the convening of a scoping workshop to investigate the most appropriate strategy to address the environmental problems of the Save catchment.

2.4.3 Proposed scoping workshop

In view of continued environmental degradation, food shortages, widespread poverty, national land reform and changes in landuse in the Save catchment, a scoping workshop has been planned for the 13th to 15th of April 1994. The main objective of the scoping workshop is to review the current SCARMP documents, examine and recommend the best strategy of conservation, management and rehabilitation of natural resources, and sustainable rural development in the Save catchment. In addition, the scoping workshop aims to:

- initiate and instill dialogue and spirit of coordination among the various institutions working in the catchment;
- bring together all the stakeholders in the Save Catchment to discuss the current environmental problems and encourage them to exchange information and experiences in conservation and development;
- review the current SCARMP documents in light of the changing political, economic, social and physical environments in the catchment;
- discuss and establish the status of natural resources in the catchment and recommend methodologies for natural resources inventory and relevant institutions to be involved;
- highlight and examine current conservation and rehabilitation initiatives, and institutions involved in the catchment;
- based on the discussions and review of current initiatives, formulate and recommend a programme of action on how a strategy for the Save Catchment Resource Inventory, Conservation, Rehabilitation, Sustainable Development and Environmental Monitoring Programme should be developed.

It is suggested that a three day workshop be held in Mutare and participants drawn form the key institutions mentioned above, the Save catchment stakeholder and international network.

The following outputs are expected from the scoping workshop:

- dialogue, information exchange and a network initiated and established among the Save Catchment stakeholder;
- priority issues and areas in the catchment identified, debated and established;

- an action plan for the Save catchment Conservation, Rehabilitation and sustainable resource utilisation formulated and endorsed by the stakeholder;

- an inter-ministerial/sectoral/disciplinary task force established to promote and monitor the rehabilitation, conservation and development initiatives in the catchment.

3 Groot River Basin, Eastern Cape Province, Republic of South Africa

3.1 INTRODUCTION

Substantial proportions of the Cape and Orange Free State provinces of South Africa experience a semi-arid to arid climate with vegetation characterised by drought resistant plant species covering a diverse range from minute succulents to large thorn trees. The vegetation cover for these areas has been classified by Ackocks (1975) as Karoo and False Karoo veld types. Although sparsely populated, there are numerous irrigation schemes in the river valleys of the Karoo. In the recent past there has been growing concern about the hydrological and ecological equilibrium of the Karoo drainage basins, with reports of decreases in runoff due to land use changes (Commission of Enquiry into Water Matters, 1970; Whitmore and Reid, 1975; Alexander, 1978; Braune and Wessels, 1980). Much of the concern is related to the replacement of the natural herbivore population with selective feeders in the form of sheep, goats and cattle (Downing, 1978). Daniel (1980) refers to severe overstocking in parts of the Karoo, while Rooseboom and Harmse (1979) provide evidence of increases in sediment production related to over-exploitation of the land resources during the first half of this century. Hall and Gorgens (1978 and 1979) report increased mineralisation of runoff from both point (irrigation return flows) and natural diffuse sources leading to constraints on the utilization of the regions water resources.

The Groot River (figure 3.1) is the main tributary of the Gamtoos River which flows into the western Indian Ocean just to the west of Port Elizabeth. The catchment has a total area of some 30 000 km^2, of which all but the very lower parts fall within the Karoo region. There are eight catchments with gauged streamflow records over 15 years in length within the total basin area, as well as over 25 rainfall and several evaporation pan gauging stations with reasonably long records. The Groot River basin therefore represents an excellent example of the Karoo region and there is sufficient available information to describe its characteristics.

The recognition of the contribution that the Karoo region makes to the gross domestic product of South Africa, the dependence of this on the veld and the general deterioration of the veld resource led to the establishment of a major research effort during the early 1980's. The Karoo Biome Project was initiated by the Foundation for Research Development (FRD) as a cooperative programme and led to three main publications on the characteristics of this region (Cowling, 1986, Cowling, Roux and Pieterse, 1986 and Cowling and Roux, 1987). These reports cover all the major concerns within the region as well as providing extensive lists of previous studies and reports. Consequently, much of the background for this review has been taken from these reports.

3.1.1 Geology, topography and drainage

The Groot River rises as two main tributaries (Salt and Kariega or Buffalo Rivers) draining the mountainous and hilly area of the northern parts of the Great Karoo. The underlying geology consists of mainly flat bedded sandstones of the Balfour formation of the Beaufort Group which are intensively intruded by dolerite sills and dykes. These tributaries then pass into the flatter areas of the central Karoo where the underlying rock consists of more easily weathered mudstones with some interbedded sandstones. These are less affected by dolerite intrusions but have been affected by the Cape folding resulting in minor folds and a relatively high degree of fracturing. The low topography is evidenced on the Salt River tributary by the existence of a major endoreic area (pan or vlei area) covering some 750 km^2. Where the dolerite intrusions are present they give rise to an uneven topography due their greater resistance to weathering than the surrounding formations.

Further south the Groot River passes over rocks of the Dwyka Formation and the Ecca Group (part of the Karoo Sequence) which have been intensely affected by the Cape folding. The topography consists of some mountain ridges, heavily dissected by tributary streams with a relatively broad and flat main valley floor. As the Groot River moves further south and east the Karoo Sequence gives way to the older rocks of the Cape Supergroup. The main systems underlying the south eastern part of the basin are the Bokkeveld (shales and sandstones) and Witteberg (quartzites, sandstones and shales) Groups. The Cape rocks occur closer to the coast in areas of mountain topography, again with some broad flat valley floors.

While the majority of the Groot River basin falls within an area of low rainfall, some of the topographic highs (particularly in the southern area) do experience significantly more rainfall.

Groundwater exists as secondary aquifers in the joints and fracture zones of the otherwise impermeable rocks. Fracture zones are however fairly abundant, particularly close to dolerite dykes and in the southern areas affected by the Cape folding. The aquifers have very low storages but short term borehole yields are highly variable. The value of the groundwater as a resource is therefore highly dependent upon the temporal patterns of recharge.

3.1.2 Soils and vegetation

The soils of the Karoo are predominantly shallow, structureless to weakly structured and mainly developed from in-situ weathering. The textures of the surface soils vary from sandy-clay-loams to loamy-fine-sands with finer textures in the lower horizons. The surface soils can be subject to a high degree of crusting and sealing.

The Karoo vegetation can be characterised as dwarf open scrubland, consisting of a mixture of succulents, deciduous scrubs, thorn trees and grasses. The persistence of the various growth forms is determined largely by their physiological and demographic responses to stochastic moisture inputs. Both prolonged droughts and a series of high rainfall events can have an impact on the composition of the vegetation years after the meteorological occurrences. The impression is one of high population instability, even in the relatively short term, as species respond differentially to particular sources and combinations of climatic conditions. These factors have important implications for land use and particularly grazing management.

3.1.3 Land use

The Karoo vegetation is characterised by a high seasonal and annual variation in forage quality and quality. In pre-settlement times the migratory behaviour of indigenous herbivores and aboriginal herdsmen would have resulted in a patchy distribution of animals. Following a severe drought, it is likely that some time would elapse between the rains signalling the end of the drought and the build up of herbivore numbers to pre-drought levels. This period of low grazing pressure and optimum growth conditions would have been crucial for seed production and seedling establishment. It is difficult to imagine how managed grazing using fencing and concentrated livestock can simulate similar conditions and therefore it is easy to understand why there has been a deterioration in the vegetation during the period over which this area has been settled and farmed.

Vegetation deterioration and accelerated erosion started as early as the start of the 19th century, the chief cause being the pressure of an expanding extensive small stock (mainly sheep) industry. Sheep numbers reached a peak in South Africa in about 1930 at 48 million and this number reduced to 34 million in 1980. According to estimates of grazing capacities in the Karoo, a safe stocking rate is considered to be no more than 7.5 million small stock units. The current (mid 1980's) figure is about 10 million, an overstocking of 30%.

During the early development of the livestock industry, vulnerable grazing lands such as valley bottoms, spring areas and vlei (natural shallow seasonal lakes) areas were made more grazeable by burning the vegetation and draining, followed by ploughing and the establishment of cultivated lands. These areas were also denuded by selective grazing and trampling. During droughts the ground cover reaches a minimal level, the soil dries out and is easily eroded by wind.

3.2 WATER BALANCE COMPONENTS

The available information on the water resources of any area within South Africa includes the streamflow and pan evaporation records of the Department of Water Affairs and Forestry (DWAF), the rainfall and pan evaporation records of the Weather Bureau and the information contained within the publications on the Surface Water Resources of South Africa (Pitman, et al., 1981). The latter includes regional information on monthly streamflow, rainfall and potential evaporation rates for a large number of zones within the country and is currently being updated to include data for the 1980's and early 90's. The regional zones are referred to as tertiary sub-catchment areas and sub-divided further into quaternary areas. Within the Groot River basin there are 14 tertiary sub-catchments and 100 quaternary areas. Table 3.1 provides a summary of the basic tertiary area information. Some of these are indicated on Figure 3.1.

There are some 15 gauged sub-catchments within the total basin (Figure 3.1), although as Table 3.2 illustrates many have short records and are now closed for various reasons. There are also patches of missing data within the overall data period and the quoted figures for data completeness (given as a % in Table 3.2) are not always a true indication of the real amount of data available. A further factor is that prior to and even after 1960, many of the records are based on stage-discharge rating curves with limited ranges. High flows were frequently not measured and as a consequence the records do not always provide a true indication of the real amounts of streamflow volume, particularly in these rivers which have infrequent, but high, flow events.

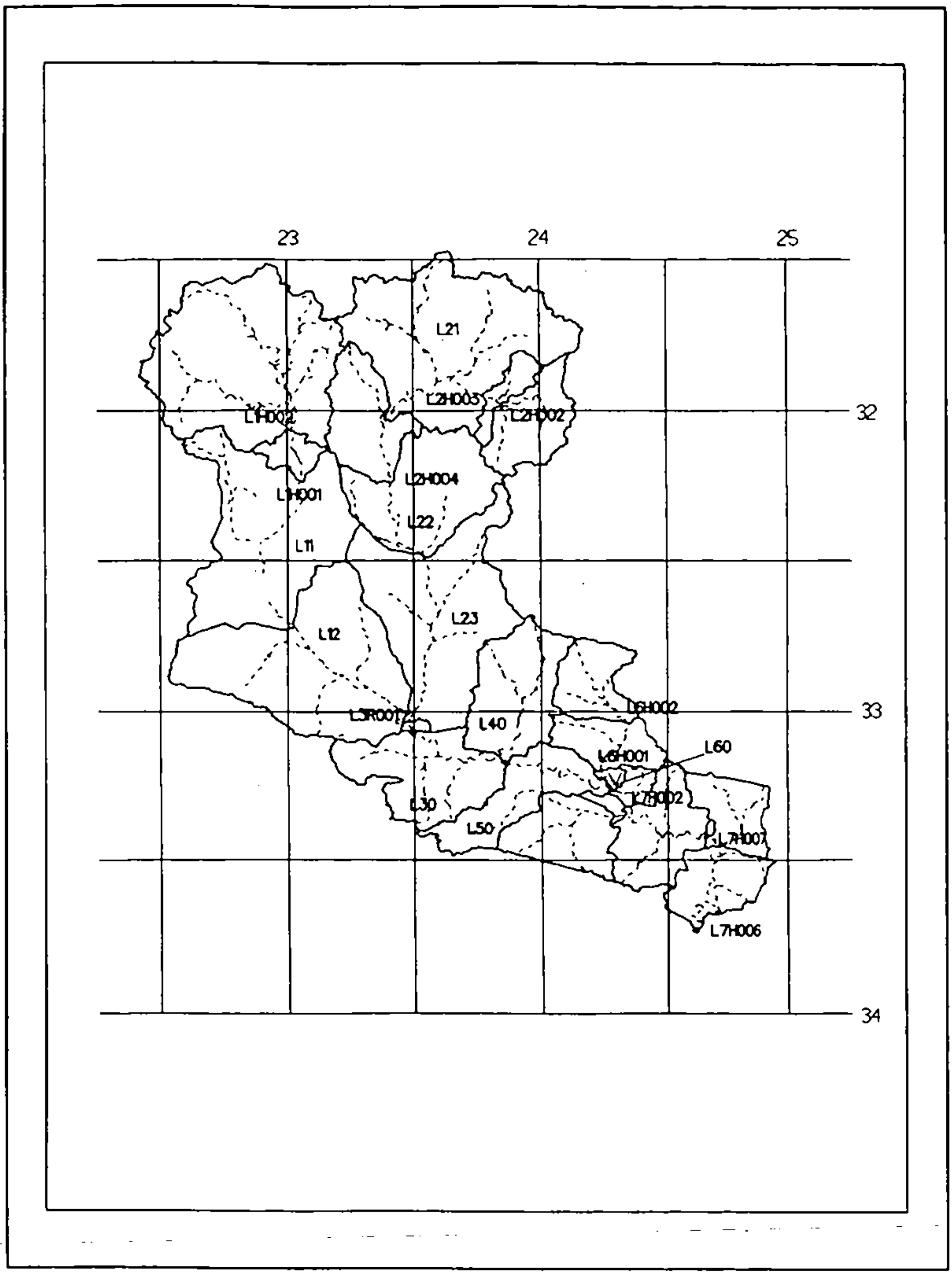

Figure 3.1 Map of the Groot River catchment showing the main drainage network, the location of some of the streamflow gauging stations (L?H00?) and some of the ungauged portions of the tertiary sub-catchments (L??)

Rainfall input to the basin can be estimated from the records available from more than 25 daily recording raingauges scattered throughout the basin (but rarely representing the less accessible mountain areas). The records are frequently quite long (over 60 years) but many have been discontinued within the last few decades. Mean annual rainfall varies from less than 180 mm in parts of the central basin, through a more general average of about 250 mm for the basin as a whole, to extremes of over 400 mm in the higher lying areas of the south. There may even be higher unrecorded rainfalls on some of the south facing slopes of the southern mountain ridges. Figure 3.2 provides an impression of the seasonal distribution of the rainfall based on three raingauges located in three parts of the basin. It can be seen that the area falls within the summer rainfall region with the main rainfall period being late summer/early spring with a secondary peak in early summer. Also plotted is a curve representing the coefficient of variation (standard deviation/mean) of the monthly rainfall at the gauges. The high variability of the rainfall is clearly evident with CV's in excess of 100% for most months.

Table 3.1 *Main water balance components for the tertiary sub-catchments in the Groot River (Source - Pitman, et al., 1981)*

Tertiary sub-area	Approx. location	Gross Area (km^2)	MAP (mm)	Mean Ann. S Pan Evap (mm)	Mean Ann. Runoff (MCM)	Mean Ann. Runoff (mm)
L11	Salt River - Upper North West	2060	216	2200	8.9	4.0
L12		2230	233	2200	12.2	5.5
L13	Salt River - Central West	2340	213	2300	8.7	3.7
L14		3355	200	2250	10.3	3.1
L21	Kariega & Buffalo Rivers - Upper North East	2640	319	2050	26.0	9.8
L22		1920	251	2200	15.0	7.8
L23		2935	259	2100	32.0	10.9
L24	Kariega R & Others - Central East	2740	221	2100	16.0	5.8
L40		1110	233	2000	8.5	7.6
L50	Lower Groot and southern tributaries (some draining the wetter parts of the Southern Mtns.)	2255	258	2000	18.5	8.2
L60		1580	259	1900	13.0	8.2
L71		2300	293	1800	19.9	8.6
L72A		875	260	1800	5.3	6.1
L72B		805	495	1700	23.0	28.5

There are also several pan evaporation stations within, or close to the boundaries of, the basin with which to evaluate potential evaporation rates. These stations indicate that annual Symons pan evaporation rates vary from about 1200 - 1500 mm in the extreme south, through 1800 - 2100 mm in the central parts of the basin, to over 2200 mm in the upper part. Figure 3.3 illustrates the seasonal distribution of potential evaporation and the difference between PE and rainfall.

Table 3.2 provides some details of the available streamflow gauges that are (or have been in the past) operated within the basin (their locations are indicated on Figure 3.1).

There are no observed figures for soil moisture status, groundwater recharge or actual evapotranspiration. Consequently a simplified simulation approach has been employed to obtain some representative figures for these components of the water balance. The model that

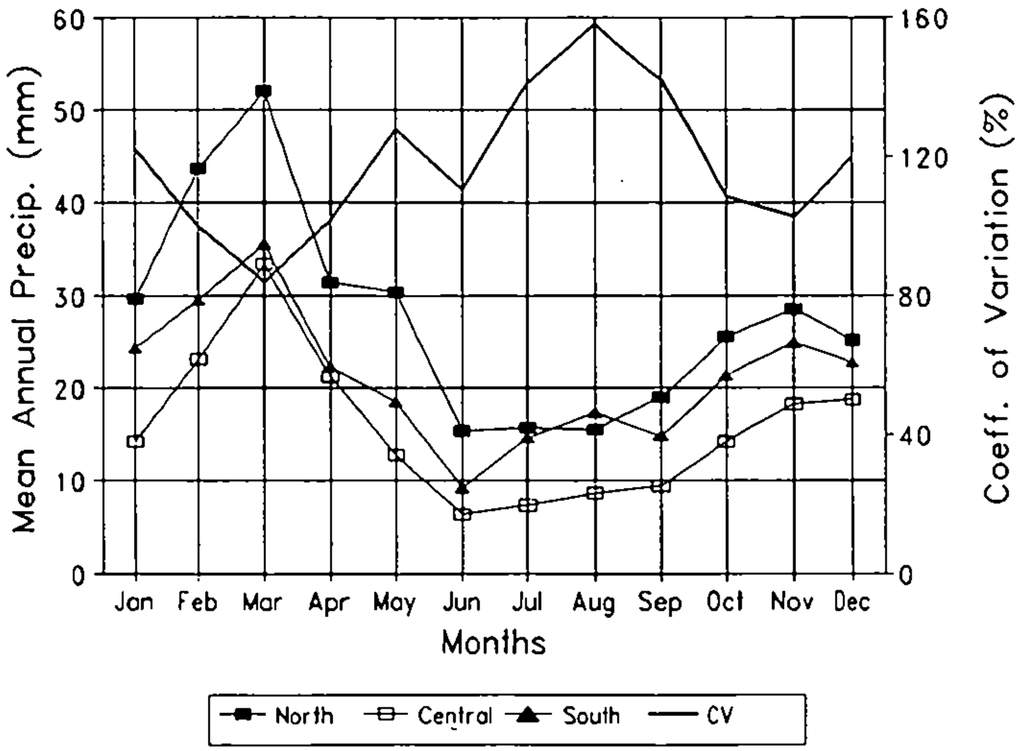

Figure 3.2 Monthly distribution of rainfall for three representative stations and a representative distribution of coefficients of variation

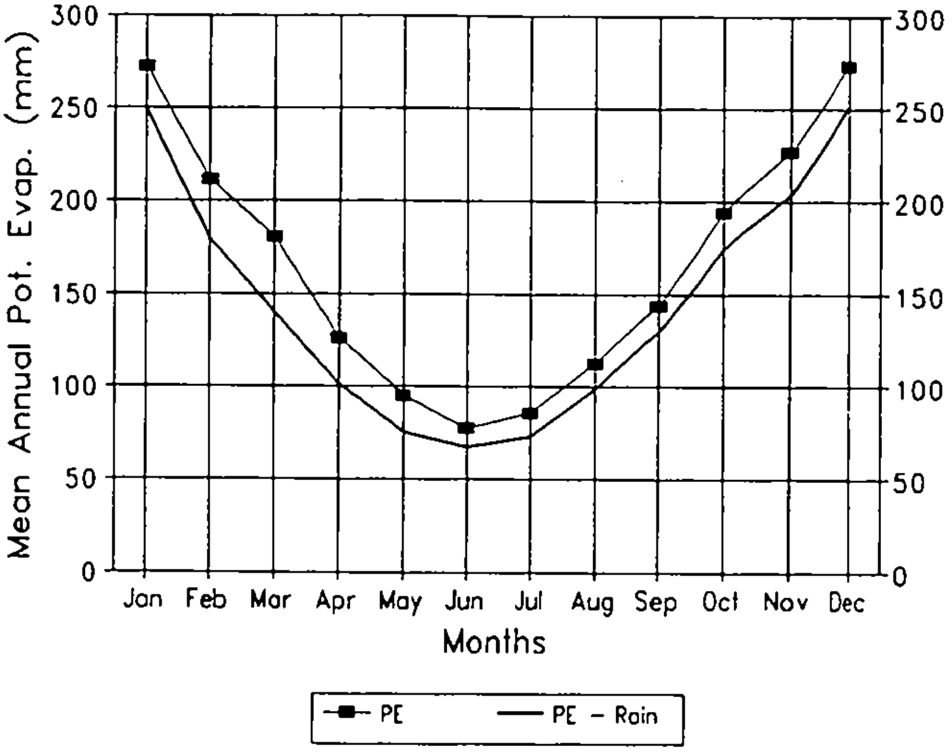

Figure 3.3 Monthly distribution of Potential Evaporation

has been used is the daily time-step version of the VTI model (Hughes and Sami, 1994) which has already been employed successfully in semi-arid regions of South Africa with similar soils, vegetation and geology (Sami and Hughes, 1993; Hughes, 1994). It is essentially a semi-distributed model with functions to simulate most of the components of the hydrological cycle including surface/groundwater interactions. The model has been applied in this instance to an hypothetical catchment using a 60 year time series from a single raingauge with an MAP of 210 mm. Mean annual potential evaporation has been set at about 2100 mm and distributed over the year as in Figure 3.3. The vegetation has been assumed to be sparse grassland and scrub bush, while the soil characteristics have been set similar to sandy-clay-loams (but finer textures in the lower soil horizons) of relatively shallow depth (335 mm). This results in a profile water holding capacity of 128 mm, field capacity of 87 mm and wilting point of 49 mm. The soil surface is assumed to be subject to quite severe crusting with final infiltration rates (after 120 min) of 7 mm h^{-1} and hydraulic conductivities in the region of 5 mm h^{-1}. The important groundwater parameters are storativities of about 0.002, transmissivities of about 15 m^2 day^{-1} and hydraulic conductivities of 0.025 mm h^{-1}. The time series of simulated streamflows are difficult to compare with any observed flow sequences, because the observed are subject to routing influences and spatial variability of rainfall. However, comparison of Table 3.1 and the basic water balance results of the simulations given in Table 3.3 suggest that, in general terms, the simulated depths can be considered to be reasonably representative of the higher runoff sub-catchments. In addition the recharge figure appears to be acceptable given the experience in similar areas of South Africa (Sami, 1992; Sami and Hughes, 1993). Figure 3.4 illustrates the mean monthly distribution of the three major output components of the water balance.

Table 3.2 *Streamflow gauges operated by DWAF (currently or in the past)*

River Name	DWAF No.	Area (km^2)	Data availability period (% complete)	Position in Basin
Groot	L7H006	29232	1964 - 1994 (98%)	All located close to the basin outlet into the Gamtoos River.
Groot	L7H007	28451	1982 - 1994 (93%)	
Groot	L7H005	27774	1963 - 1984 (91%)	
Groot	L7H004	27746	1939 - 1948 (99%)	
Groot	L7H002	25730	1928 - 1984 (47%)	
Groot	L3H001	20339	1917 - 1960 (99%)	Junction of Kariega and Salt Rivers in the central basin. Beervlei Dam - 93 MCM.
Groot (Beervlei Dam)	L3R001	20336	1958 - 1993 (99%)	
Heuningklip	L6H001	1290	1926 - 1994 (99%)	A south-western trib. joining the Groot close to outlet.
Heuningklip	L6H002	675	1963 - 1987 (99%)	
Buffalo	L2H004	5584	1951 - 1984 (93%)	Middle reach of the major NE tributary of the Groot.
Buffalo	L2H001	5582	1923 - 1948 (99%)	
Buffalo	L2H003	1145	1954 - 1993 (95%)	Upper reaches of the major NE tributary of the Groot.
Buffalo	L2H002	851	1925 - 1952 (98%)	
Salt	L1H001	3938	1917 - 1977 (70%)	Upper reaches of the major NW tributary (major pan or endoreic area downstream)
Salt	L1H002	3675	1973 - 1988 (99%)	

Figure 3.5 illustrates the distribution of soil moisture levels during the year. The diagram is based on the mean of the simulated daily moisture levels (as mm of water) and shows the range between the upper and lower 50 percentiles (heavy lines) as well as the upper and lower

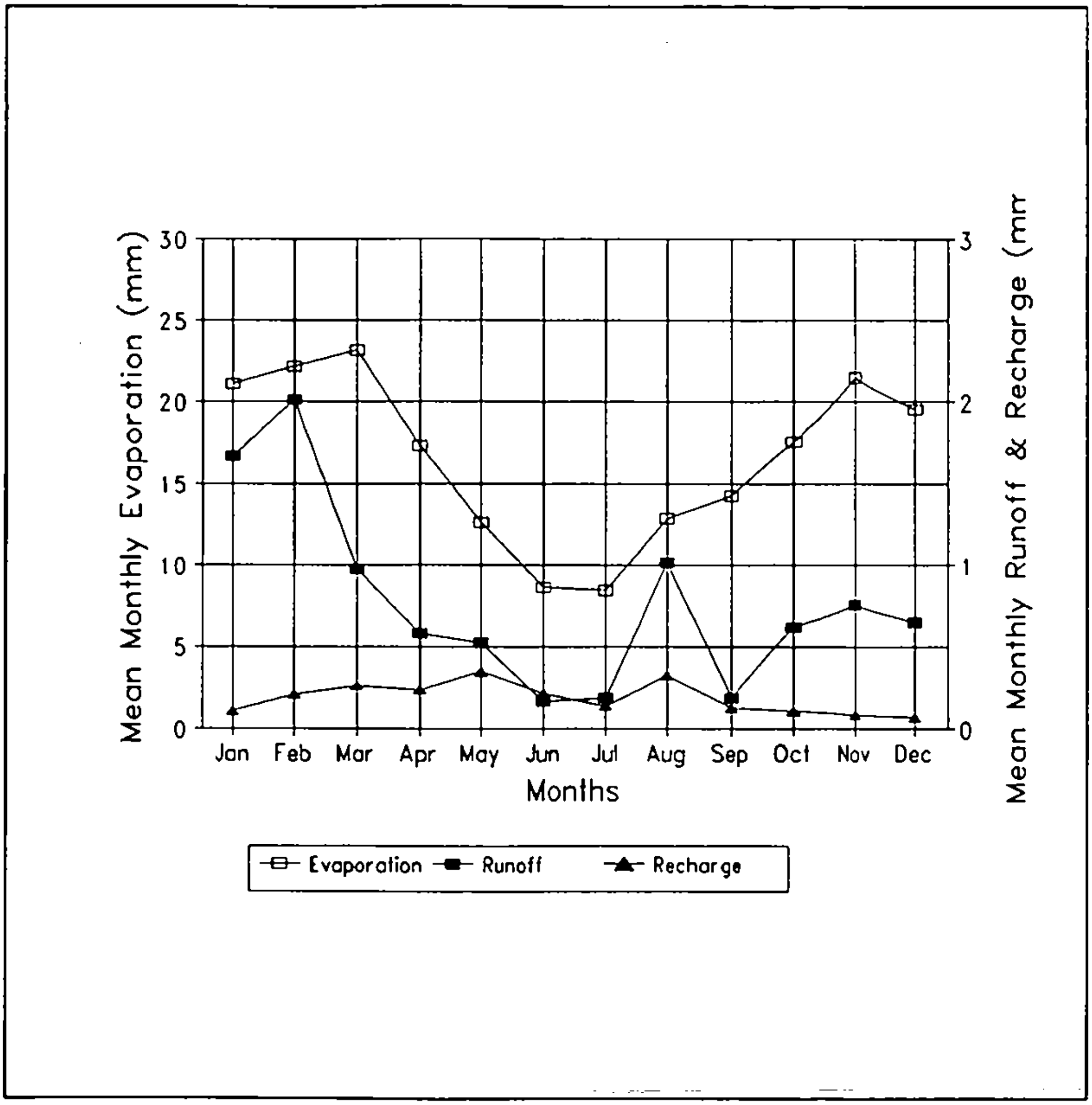

Figure 3.4 *Monthly distribution of the means of the major output components of the water balance equation*

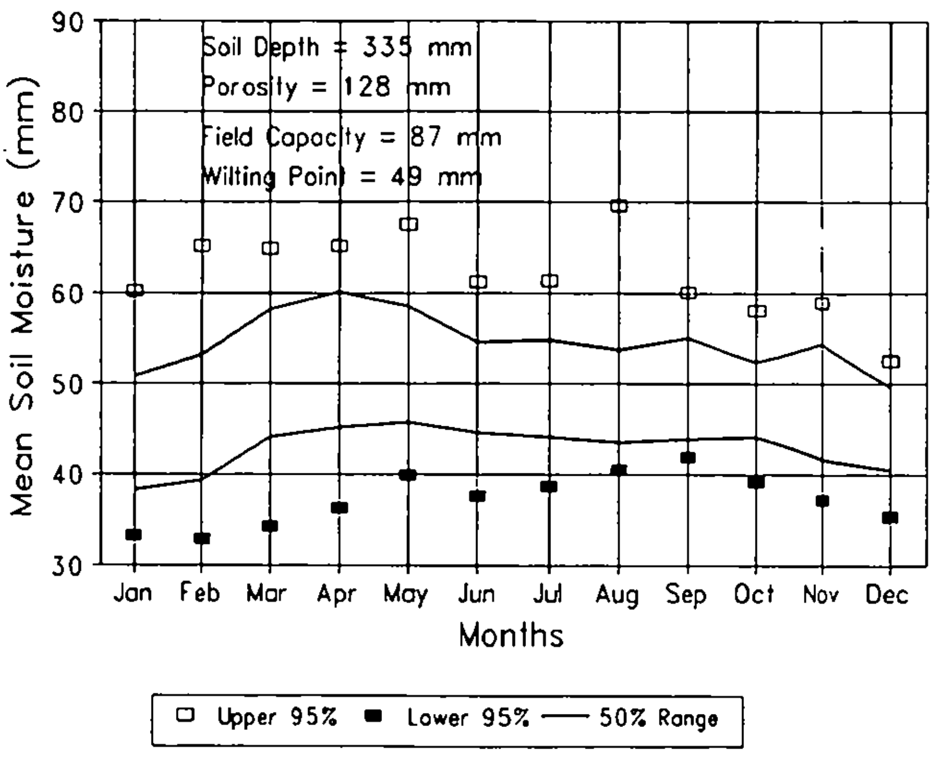

Figure 3.5 Monthly distribution of soil moisture (using the means of the simulated daily values)

95 percentiles for each month of the year. Clearly the mean monthly soil moisture levels remain low during most of the year and are frequently lower than the wilting point value estimated for the defined soil texture.

Table 3.3 *Simulated water balance components (annual means based on a 59 year period 1930 to 1988)*

Water balance component	Depth (mm) and percent of rainfall
Rainfall	210.0
Potential evaporation	2068.5
Actual evapotranspiration	198.5 (94.5)
Runoff	9.3 (4.4)
Recharge	2.2 (1.0)

The observed streamflow records for some of the gauged catchments have also been analysed in various ways and these results are presented below. Figure 3.6 illustrates duration curves for the total basin (Groot River at L7H006), one of the central tributaries (Heuningklip River at L6H001) and one of the upper tributaries (Salt River above the endoreic area at L1H001). It is clear that the main river receives some baseflow inputs form the central and lower parts of the basin. Undoubtably some of this contribution is made up of releases from Beervlei Dam situated at the confluence of the Salt and Kariega Rivers, some may be due to return flows from irrigated areas (supported with water from Beervlei Dam) along the Lower Groot River and some may be due to natural baseflow inputs from the somewhat wetter mountain catchments in the south of the basin.

Table 3.4 provides some further information on the low flow and flood characteristics of a sample of the gauged rivers. The fact that some of the figures seem to be a little odd (compare the flood figures for the total basin with those for the smaller tributary rivers) is partly an indication of the problems of trying to obtain representative figures for several rivers with different length records. This is particularly exacerbated in the highly variable flow regime of a semi-arid climate. The mean daily flows also tend to be somewhat meaningless and very much a reflection of the number and magnitude of flood peaks within the period for which data are available.

Table 3.4 *Low flow and flood statistics for some gauged rivers (the flow data are all given in $m^3 s^{-1}$)*

Basin Name and Code	Catchment Area (km²)	Data Period	Average Daily Flow	Base Flow Index	180 day, 20yr RP low flow	Mean Annual Flood	20yr RP flood peak.
Groot @ L7H006	29232	1965 - 1992	2.46	0.23	0.07	213	685
Heuningklip @ L6H001	1290	1926 - 1956	0.71	0.0	0.0	279	851
Heuningklip @ L6HOO1	1290	1980 - 1992	0.10	0.02	0.0		
Salt @ L1HOO1	3938	1918 - 1931	0.46	0.0	0.0	163	428
Salt @ L1H002	3675	1973 - 1987	2.70	0.20	0.0	105	264

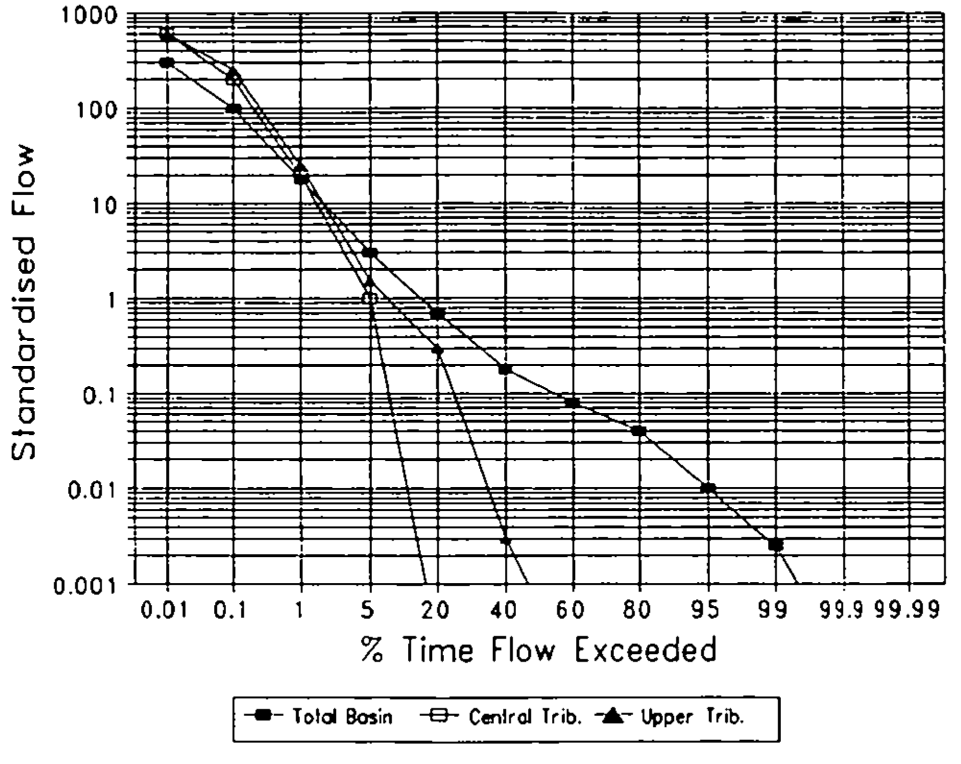

Figure 3.6 Duration curves for three rivers within the Groot River basin (the vertical axis represents daily flow values divided by average daily flow)

Görgens and Hughes (1982 and 1986) report on some additional statistical properties of some Karoo rivers and suggest that the coefficient of variation of annual flows lies between 70% and 200%, the minimum annual flows being between 0.5% and 1.5% of the mean annual flow and the maximum annual flows being between 300% and 900%. Once again these figures illustrate the extreme variability in the hydrology of these regions. The monthly coefficients of variation are even higher at between 1300% and 2200%, the number of zero flow months being about 50% to 65% of the total number of months and the maximum continuous period of less than the mean monthly runoff of between 20 and 55 months.

These publications also provide some limited information on the sediment yields and water quality characteristics of the streamflow. The estimated sediment yield into Beervlei Dam at the junction of the Salt and Kariega Rivers is 235 t km^{-2} y^{-1}, while the 90% exceeded TDS (Total Dissolved Solids) values are between 600 and 960 mg l^{-1}, with medians in the range of 1400 to 2700 mg l^{-1}.

3.3 WATER USE

There are three main forms of water use within the basin. The first two are for domestic use and stock watering purposes and the majority of this is taken from groundwater using a large number of scattered wind driven pumps. The second is for irrigation purposes and the water is derived from a large number of small to medium sized farm dams as well as a small number of larger dams (mostly 0.1 to 1.8 MCM capacities), of which Beervlei Dam (L3R001 in Figure 3.1 - capacity 92.8 MCM) is the largest.

The amount of water used for stock watering purposes can be estimated on the basis of average stocking densities and the stock unit daily water consumption (approximately 12 l $ssu^{-1}d^{-1}$). The total annual water consumption figure for the basin amounts to a maximum of some 2 MCM, or about 0.06 mm. If this figure is compared with the mean annual recharge value given in Table 3.3, it is clear that the long term availability of groundwater for this purpose is not a limiting factor. Most of the population situated on the widely dispersed farms rely upon a combination of groundwater and roof runoff (collected in raintanks) for their domestic supply and this may contribute a further 1 MCM to the demand from groundwater. Similarly, the few small towns and villages within the basin will also largely rely upon groundwater, although some in the lower basin may be utilising flow released from Beervlei Dam. The total domestic water consumption for this area is quoted as about 3 MCM (DWA, 1986). If all the domestic and stock water is abstracted from groundwater it still does not come close to the estimated recharge figure. The limiting factor is then more likely to be the ability to locate a suitable borehole site with an adequate yield and the quality of the groundwater.

It is difficult to estimate the amount of water usage for irrigation purposes. Pitman, et al. (1981) indicate that a total of 163 km^2 of irrigated land exists within the basin which, assuming an annual irrigation depth requirement of 1200 mm (probably a low estimate), amounts to an annual volume of some 195 MCM. The average amount of water released from Beervlei Dam during the period 1969 to 1980 was 46.3 MCM (Pitman, et al., 1981), sufficient to irrigate only 38 km^2 using the same requirement figure. The implication is that the remaining area is supplied from the lower storage and therefore less reliable smaller dams and that irrigation over the total quoted area is unlikely to be a continuous activity, but one that can be practised only during the years when sufficient water is available.

3.4 WATER CONSERVATION AND AUGMENTATION MEASURES

The main conservation measures are more directly related to the status of the vegetation rather than water and have taken the form of defining more realistic and acceptable stocking densities to avoid further deterioration of the Karoo veld. There are clearly some implications with respect to hydrology and particularly to sediment yield, but they are somewhat difficult to estimate in the absence of any detailed studies.

Conjunctive use of groundwater and surface water has long been a feature of this region, where the more distributed demands (stock watering and farm domestic use) are generally met by groundwater and the more concentrated ones (irrigation) by localised development of surface water.

There are unlikely to be any major water supply schemes developed in this area in the foreseeable future as the population is small and the priorities within South Africa are to supply the major urban centres of the country as well as the more densely populated rural areas in the eastern parts of the Republic. Any problems that may arise could be related to uncontrolled further exploitation of the land caused by population pressures and the current, post-apartheid, South African Governments objective of achieving a more even distribution of land amongst the population. It seems to have taken a long time for previous Governments and farmers to realise the limitations of the extent to which the Karoo region can be exploited for agriculture. It would be very unfortunate if this hard learnt lesson were now ignored as the priorities for land utilization shift.

Any proposals for comprehensive evaluations should then be related to assessing the best use that these areas can be put to without causing further progressive deterioration of the vegetation and without affecting the clearly delicate balance that exists in such arid areas.

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