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DWA



Department of Water Affairs
Republic of Botswana

MOTLOUTSE DAM
FEASIBILITY/PRELIMINARY DESIGN STUDY.

DRAFT ANNEX K

ENVIRONMENTAL IMPACT STUDIES

October 1989

627.8
MOT

SIR M. MACDONALD & PARTNERS
Demeter House, Station Road, Cambridge CB1 2RS, England

MOTLOUTSE DAM FEASIBILITY/PRELIMINARY DESIGN STUDY

This report consists of a

MAIN REPORT
ALBUM OF DRAWINGS

Accompanied by twelve Annexes:

Annex A:	Hydrology
Annex B:	Water Resources
Annex C:	Geology and Site Investigations
Annex D:	Dam Studies
Annex E:	Water Supply
Annex F:	Soils and Land Suitability
Annex G:	Agriculture
Annex H:	Markets and Prices
Annex I:	Irrigation Engineering
Annex J:	Economic and Financial Analysis of Irrigation Development
Annex K:	Environmental Impact Studies
Annex L:	Development Economics

Note: The pollution studies, formerly referred to as Annex L, will now be submitted as a separate report, independent of the Study.

The final version of the Album of Drawings will include an additional drawing, number 9, Letsibogo Dam Geological Cross – Section – Sheet 3. Consequently all subsequent drawing numbers are increased by 1. The revised numbers have been used in the Draft Annex.

MOTLOUTSE DAM FEASIBILITY STUDY

ANNEX K

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K.2	1:10 000 Vegetation Communities in the Reservoir Area
K.3	1:10 000 Reservoir Management and Development Possibilities
K.4	1:10 000 Reservoir Timber and Bush Clearing Programme

ABBREVIATIONS

ADC	Agricultural Development Company
AGC	Australian Groundwater Consultants Limited
API	Air photo interpretation
ARAP	Accelerated Rainfed Arable Programme
BCL	Bamangwato Concessions Limited
BDC	Botswana Development Corporation
BDF	Botswana Defence Force
BGS	British Geological Survey
BPC	Botswana Power Corporation
CDC	Commonwealth Development Corporation
CP	Crude Protein
CSO	Central Statistics Office
DLUPU	District Land Use Planning Unit
DMS	Department of Meteorological Services
DWA	Department of Water Affairs
DSL	Department of Surveys and Lands
EEC	European Economic Community
EIS	Environmental Impact Study
Eo	Open water evaporation
ETo	Potential reference crop evapotranspiration
FAO	Food and Agriculture Organisation of the United Nations
FSL	Full supply level
FWDS	Francistown Water Development Pre-investment Study (Gibb,1987)
IVDMD	In vitro dry matter digestibility
LWUS	Limpopo Water Utilization Study (MacDonald,1987)
MAP	Mean annual precipitation
MAR	Mean annual runoff
MFDP	Ministry of Finance and Development Planning
MLGL	Ministry of Local Government and Lands
MMP	Sir M. MacDonald and Partners
MMRWA	Ministry of Mineral Resources and Water Affairs
MOA	Ministry of Agriculture
MTS	Metsemotlhaba Transfer Scheme
NTU	Nephelometric Turbidity Units, an empirical measure of the amount of light scattering at right angles to the incident light
PMF	Probable maximum flood
RSA	Republic of South Africa
SADACC	Southern African Development and Coordination Committee
SEBWDS	South East Botswana Water Development Study (MacDonald,1986)
SIR	Scheme Identification Report
SMEC	Snowy Mountain Engineering Corporation
SPRDP	Selebi-Phikwe Regional Development Project
TGLP	Tribal Grazing Land Policy
TOR	Terms of Reference
USBR	United States Bureau of Reclamation
WHO	World Health Organisation
WLPU	Watermeyer, Legge, Piesold and Uhlmann
WUC	Water Utilities Corporation

UNITS

ha	Hectare
kg	Kilogram
km	Kilometre
kW/h	Kilowatt hour
l/s/ha	Litres per second per hectare
m^3/s	Cumecs
$m^3 10^6$	Million cubic metres
m	Metres
masl	Metres above sea level
mm	Millimetre
MW	Megawatt
P	Pula
t	Tonne (metric)
v	Volt

CHAPTER K1

INTRODUCTION AND APPROACH

K1.1 Background

The Motloutse Dam Feasibility/Preliminary Design Study is one of several water resource studies recently commissioned or planned by the Department of Water Affairs (DWA) as part of an accelerated programme for the development of Botswana's water resources. Earlier studies have identified a number of possible dam sites and irrigation potential in the Motloutse catchment. The major purpose of the accelerated programme is aimed at improved water supplies, but a further emphasis for a dam on the Motloutse is its potential to supply irrigation water.

The Terms of Reference (TOR) require that a range of options be examined for the use of the dam including those of solely supplying domestic and industrial water to Selebi Phikwe and larger neighbouring villages, or transfers south to supplement the water supplies to South East Botswana, or a combination of these with or without irrigation. This broad range of alternative requirements has involved a study that is both wide ranging and which embraces many disciplines.

K1.2 Development Objectives

The Government's National Development Plan VI covering the period 1985 – 1991 (MFDP 1985) states four main objectives: economic growth, social justice, economic independence and sustained development. The National Food Strategy places high priority on increasing local food production, improving nutrition and creating employment. In addition to seeing water resource development as part of achieving these objectives, Government is also keen to promote a diversification of economic activity and employment possibilities in the Motloutse valley. This is primarily to protect the future development of Selebi – Phikwe and its rapidly growing population, as and when mining operations begin to decline. At present the town is heavily dependent on the Bamangwato Concessions Ltd (BCL) copper/nickel mine which was previously forecast to have a limited future life. With this in mind the Government, with international funding support, has set up the Selebi – Phikwe Continuation Project (World Bank, 1986) which was later redesignated as the Selebi – Phikwe Regional Development Programme (SPRDP). The aim of this project was to identify and help generate interest in new agricultural and industrial potential. Enquiries during the course of this study indicate that there are now assured ore reserves for the next 25 years and that the smelter is expected to operate for another 40 years. This is however very much dependent upon world prices for copper and nickel.

The Government now has strict requirements in its planning of water resources to see that sound environmental criteria are adopted. Specific criteria relating to compensation issues are contained in the Ministry of Local Government and Lands (MLGL) "Compensation Guidelines for Land Boards and Assessment Committees in Tribal Lands", now recently adopted and attached as Appendix K – A. The overall policy is to ensure that major environmental impacts are identified and ameliorated and also that resources are sustained for use by future generations. The value placed on resources by conventional project economic analysis does not always reflect these needs. The completion of environmental impact studies helps to ensure that long term environmental interests and qualitative factors are not ignored in Government's decision making on major resource and policy issues.

K1.3 Terms of Reference

The primary objectives of the environmental impact assessment as required in the TOR are summarised below:

- to assist in the assessment of the resources and property, both present and future, which will be lost to the reservoir area, its associated infrastructure and in the development of irrigation areas downstream,

- to identify, study, recommend and cost possible ameliorative and compensation measures for resources lost to both individuals and the community,

- to act as a link between the project and district bodies such as the Land Use Planning Unit, District Council, Land Boards and the Selebi-Phikwe Continuation Project.

The environmental impact study (EIS) required a wide range of multi-disciplinary inputs covering inter alia, the following:

General Studies:

- agricultural development planning in the catchment
- agricultural impact of water resource development
- water resource planning for the catchment
- hydrological impact of water resource development
- groundwater response to water resource development
- public health impact of water resource development
- archaeological and other sites of national importance
- ecological impact analysis of reservoir and irrigation areas
- relocation of resources and resettlement needs
- social management needs of water resource development
- compensation costs and procedures
- quantification of environmental costs and benefits

Reservoir Related Studies:

- erosion hazards and reservoir siltation
- pollution hazards and remedial action
- reservoir hydrological modelling
- social and environmental impact of construction activities
- reservoir forestry surveys and bush clearance planning
- restoration planning for construction areas
- aquatic weeds and biology
- fisheries potential
- amenity and recreational use of water resources

Irrigation Related Studies:

- socio-economic impacts of irrigation development
- environmental risks of agro-chemical use

Figure K1.1

Study Area Location Map

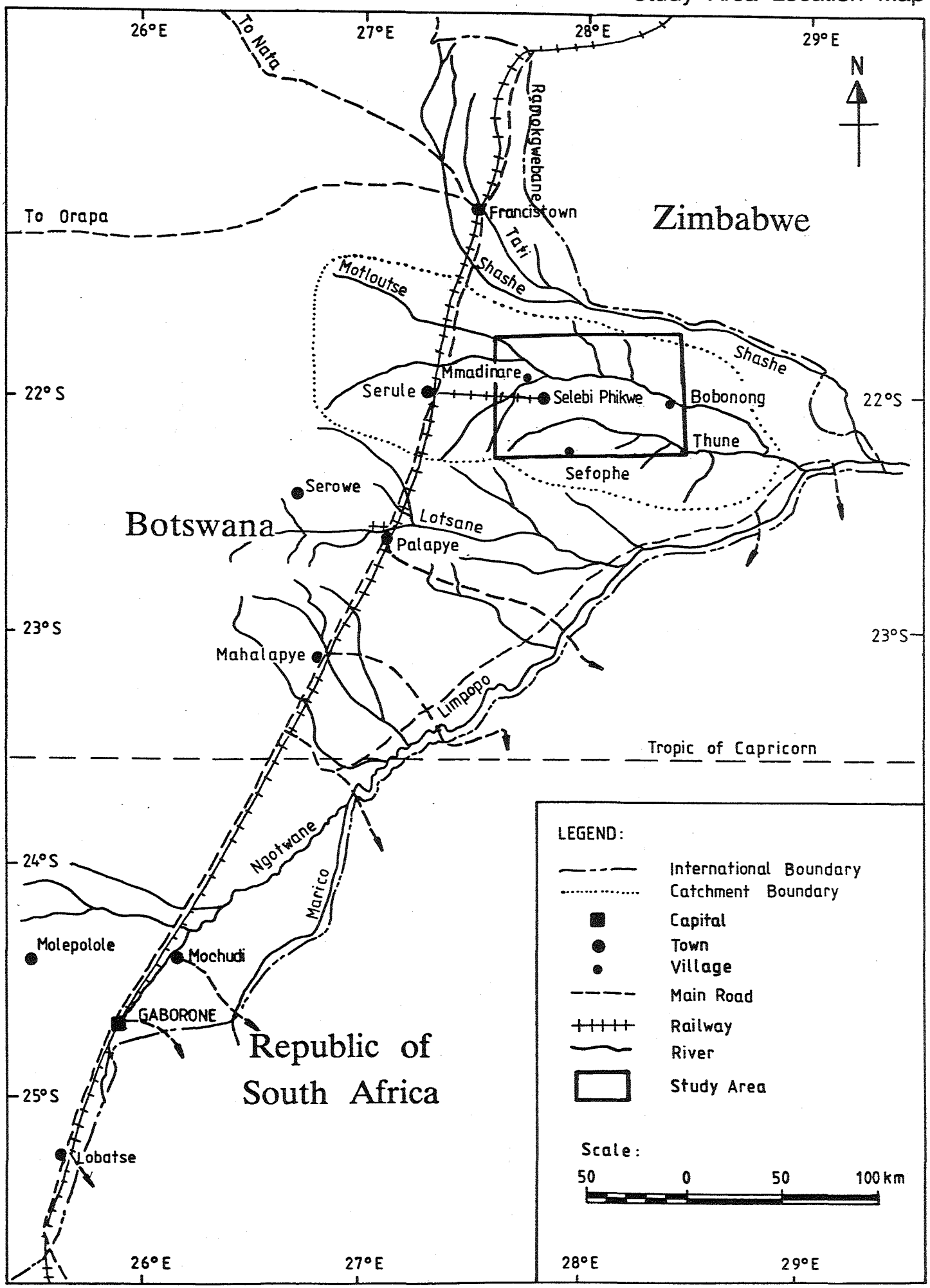


Figure K1.2

Catchment Area Map

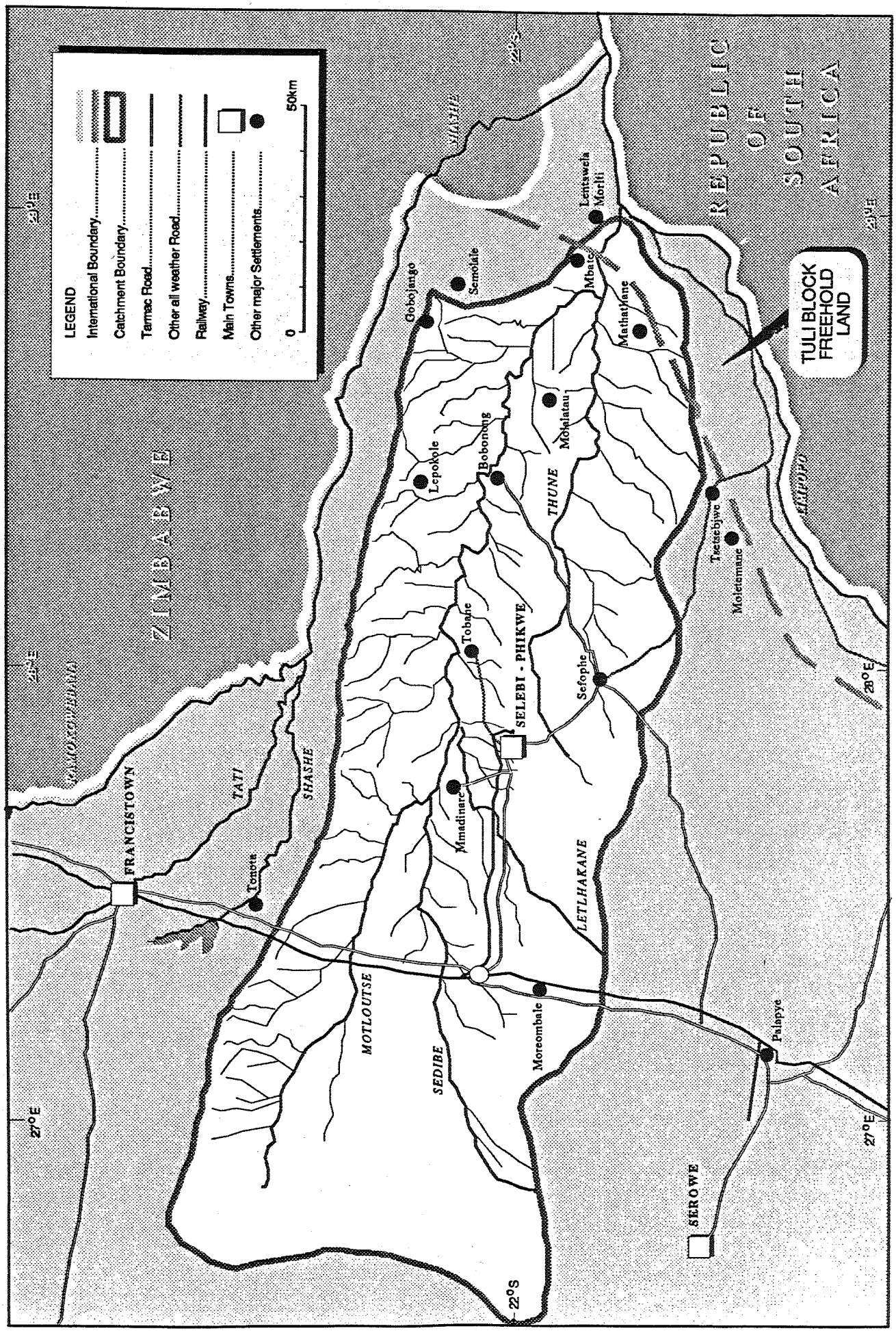


Figure K1.3

Letsibogo Reservoir and irrigation Areas IR1-IR5 and IR14

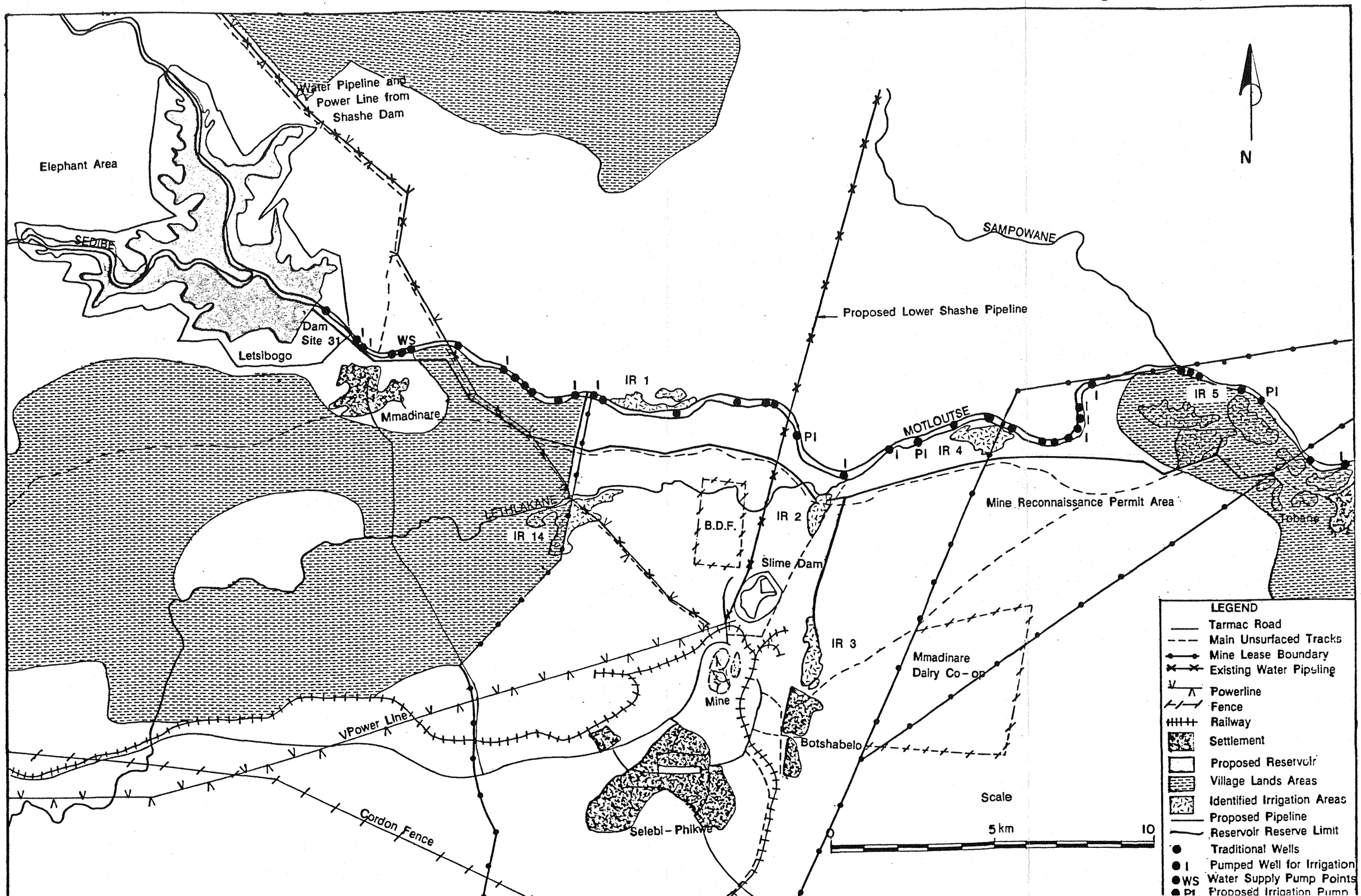


Figure K1.4

Irrigation Areas IR6-IR13

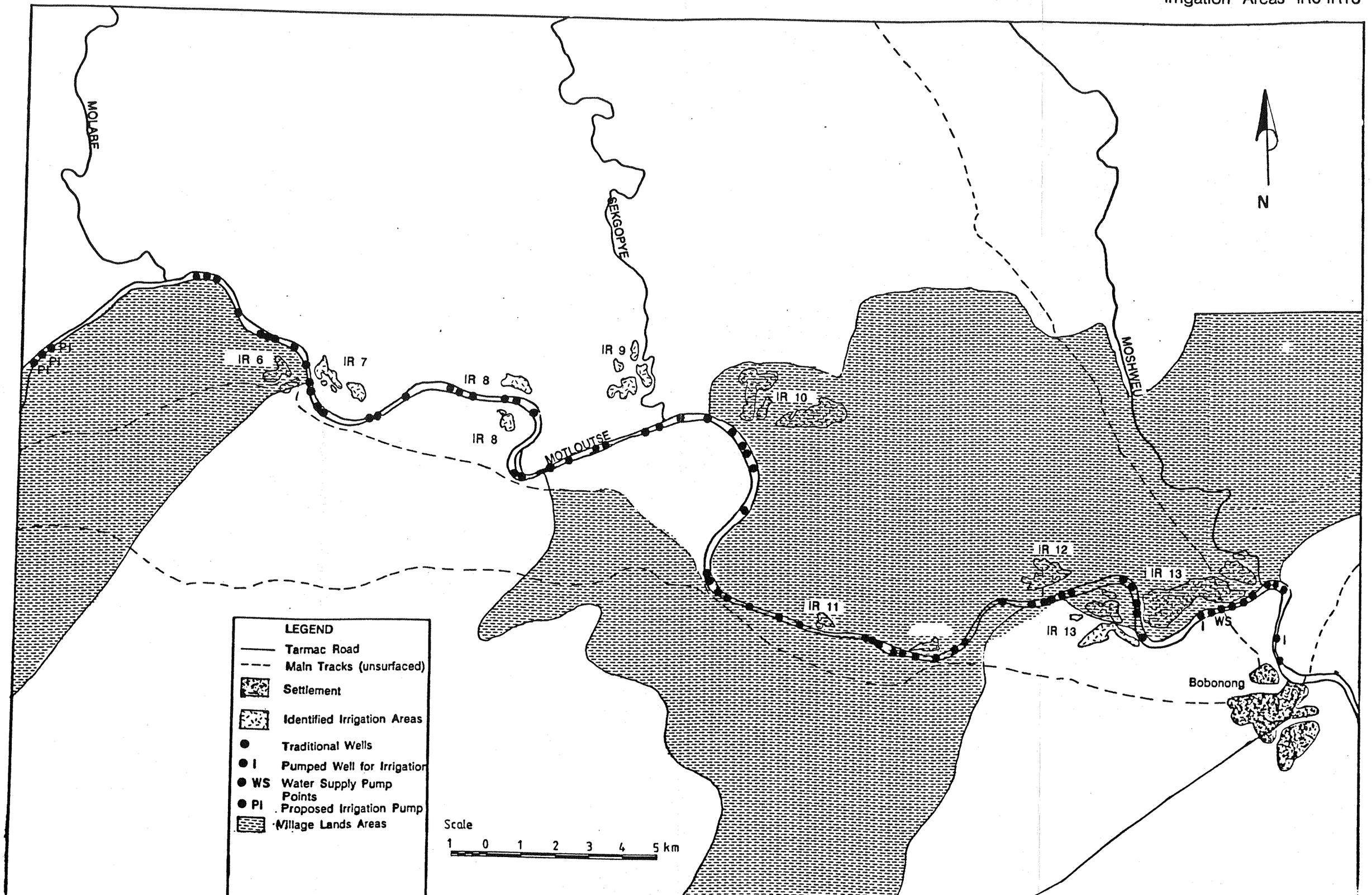


Figure K1.5

Air Photo Index 1:35 000 October 1988

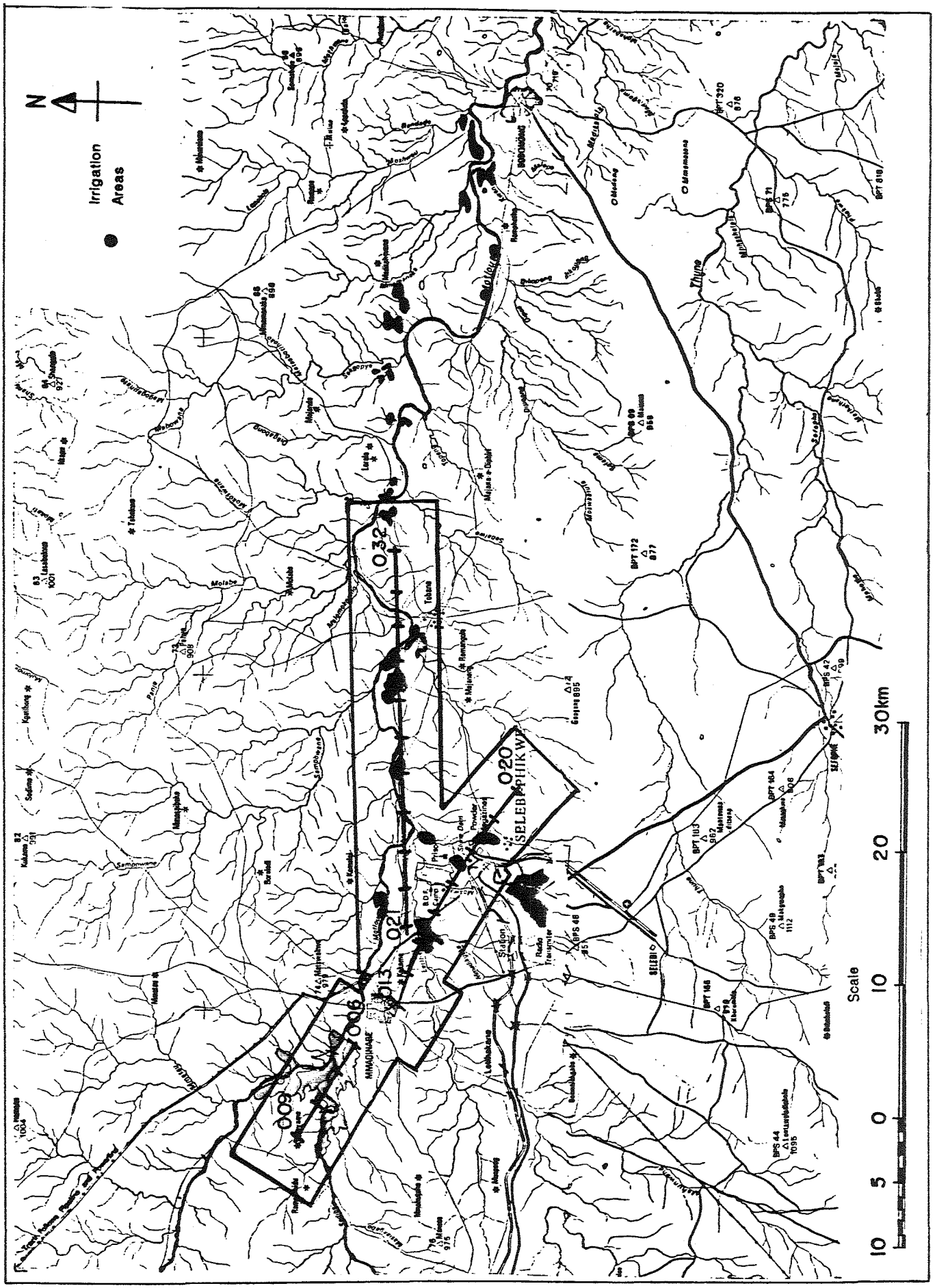


Figure K1.6

1:10 000 Aerial Photography

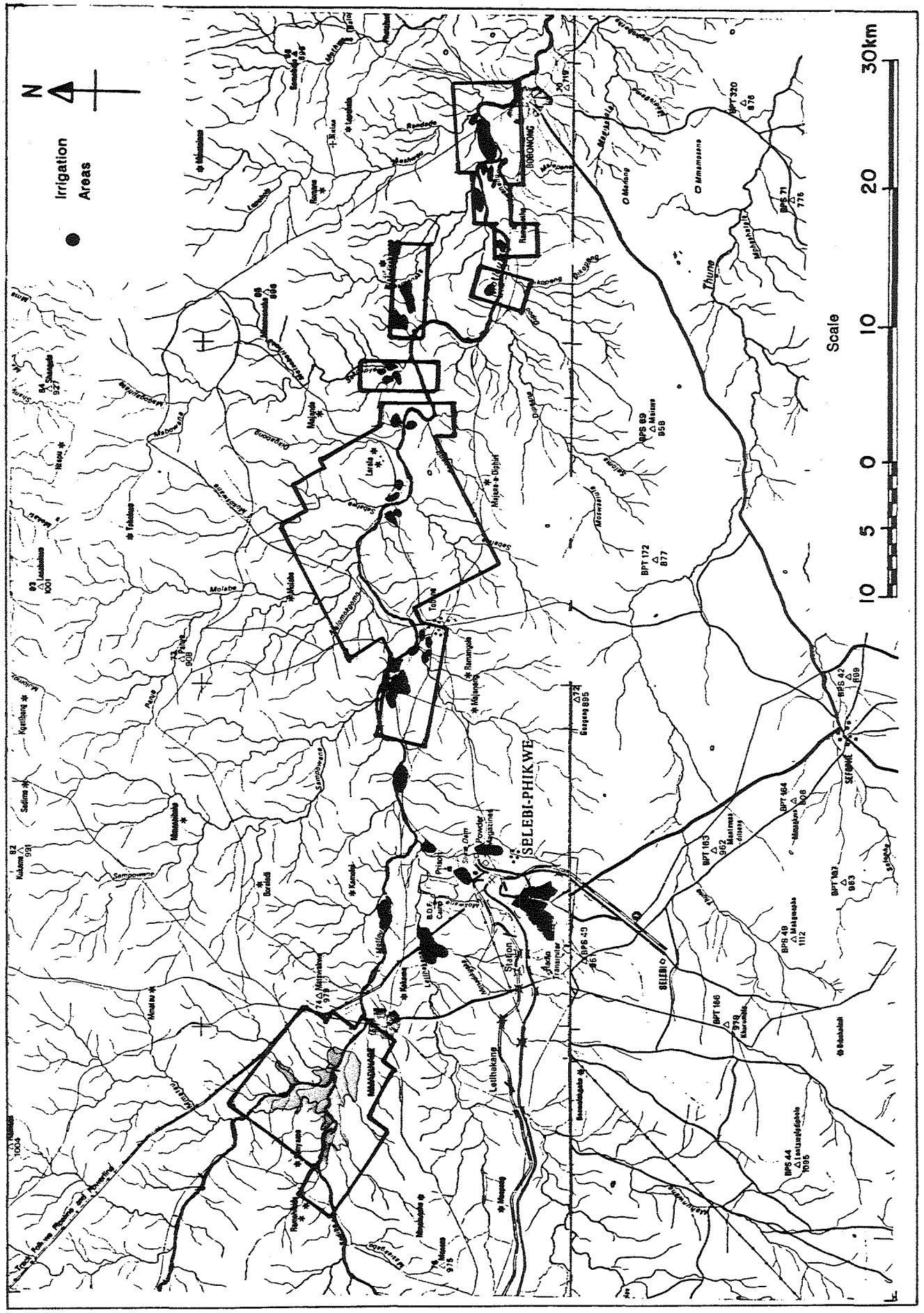
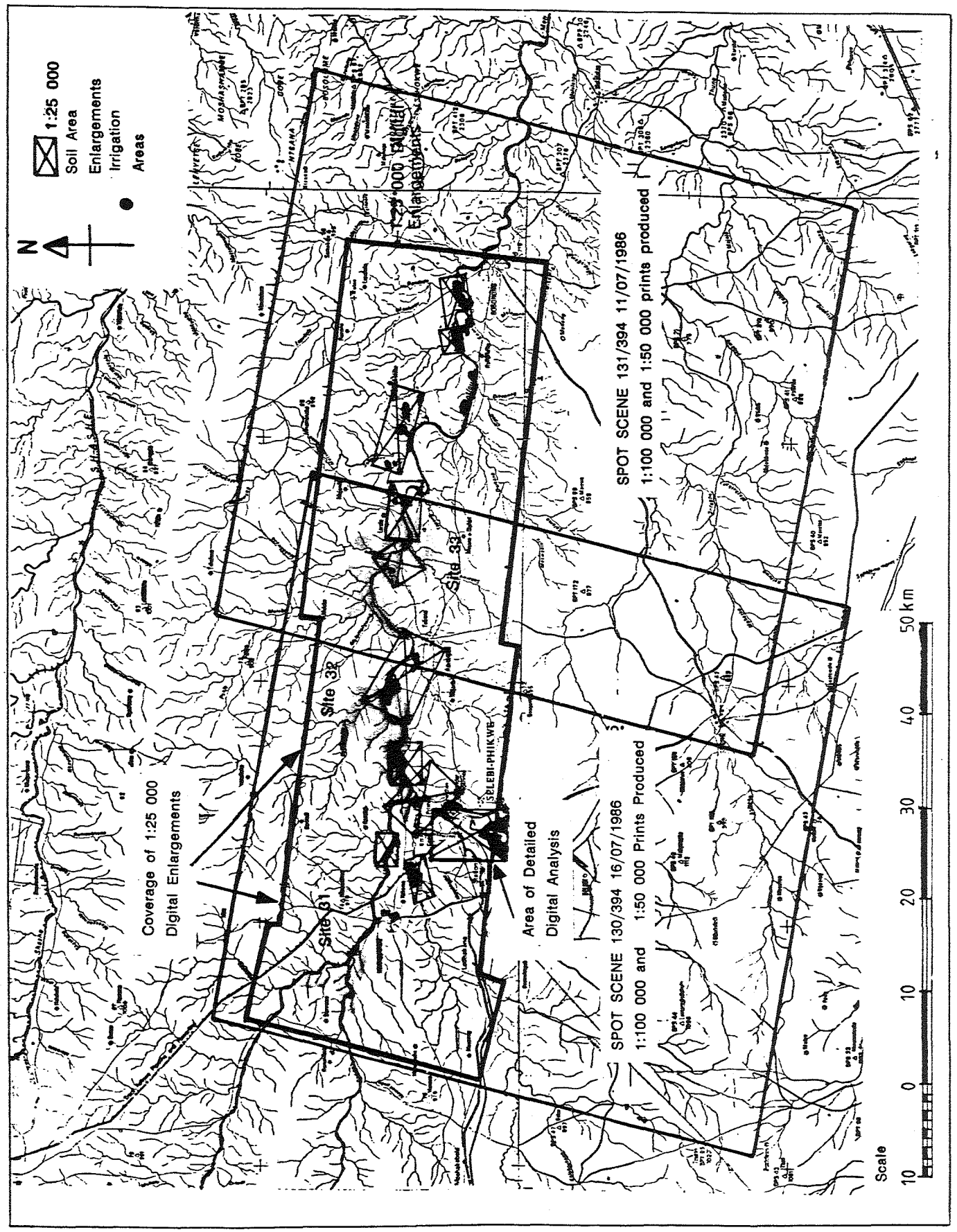


Figure K1.7

SPOT Satellite Imagery Index



K1.4 The Study Area

The location of the study area within Botswana is shown in Figure K1.1. The complete catchment is shown with its basic infrastructure, towns and principal villages in Figure K1.2. Specific surveys have concentrated upon the areas surrounding the proposed Letsibogo reservoir and the downstream riverain and irrigation areas as indicated in Figures K1.3 and K1.4.

K1.5 Phasing of Studies

The overall technical and economic studies have been divided into three phases:

Phase 1 – scheme identification stage: primarily to identify the best dam location

Phase 2 – detailed feasibility study: to examine the viability of the proposed developments

Phase 3 – preliminary design stage: where the designs and costs would be refined to the level required by the major funding agencies

The environmental and social impact study has been carried out in two phases. During the Phase 1 scheme identification phase, between June and August 1988, reconnaissance surveys and assessments were completed by the environmental and social impact team coordinator for four alternative dam sites on the Motloutse river and for one dam site on the Letlhakane river. In the second phase, overlapping with Phases 2 and 3 of the study, a range of specialist inputs concentrated their studies on the dam site at Letsibogo and possible irrigation areas downstream which were selected as a result of the Scheme Identification Report (see Section K1.7 below). In December 1988 an initial review and identification of archaeological sites was carried out. Between January and March 1989 other inputs covered the fields of ecology, aquatic biology, land tenure, resettlement and compensation issues, socio-economics, reservoir development and management, forestry, mine pollution, agriculture and hydrology. Once the final results of reservoir and hydrological modelling were completed, advice was sought from specialist support staff in the UK on health issues and fisheries potential.

K1.6 Data Availability

A number of similar studies, including published and unpublished material, concerned with the design, planning, management and evaluation of resettlement projects caused by the creation of man made lakes, were examined. Information was obtained on the following projects in Africa;

- Bokaa Dam, Botswana. (MacDonald, 1987b; MLGL, 1987; WLPU, 1987)
- Kariba Dam, Zambia/Zimbabwe. (Colson, 1971)
- Volta Dam, Ghana. (Hart, 1980 and Volta River Authority, 1965)
- Aswan High Dam, Egypt. (Hafez and Shenouda, 1978)
- Kainji, Nigeria. (Mabogunje, 1973)
- Bakolori, Nigeria (Bird, 1984)
- Dadin Kowa, Nigeria (MacDonald, 1982)
- Tiga Dam, Nigeria (WRECA, 1978)

General references for the effects of dams include Goldsmith and Hildyard (1984) and Stanley and Alpers (1975). The most relevant publication on EIS principles is Biswas (1987), as it deals specifically with less developed countries and the examples are primarily water

resources developments. The book by Lee (1985) is useful for its check list approach, which was found to be more relevant and useful than the matrix system outlined in Biswas.

In addition, reference was made to the many irrigation projects which the consultant's staff have experience of, including both large and small scale water resource schemes, as well as formal and informal irrigation developments.

The whole of the Motloutse catchment is well covered by geological and topographic mapping, the latter at a scale of 1:50 000 and produced using 1981 aerial photography at the same scale. The District's Land Use Planning Unit have recently had new aerial photography flown at 1:50 000 scale, but this was not available in time for use in this study. For the detailed work in the reservoir and irrigation areas the following were used:

Uncontrolled air photography

- 1:10 000 enlargements of 1964 1:40 000 air photography
- 1:10 000 enlargements of 1981 1:50 000 air photography
- 1:35 000 contact prints of air photography flown for the Study in October 1988
- 1:10 000 enlargements of the October 1988 1:35 000 air photography as shown on the index Figure K1.5
- 1:10 000 air photography of the reservoir area and selected irrigation areas flown for the study as shown in Figure K1.6

Controlled Air Photography

- 1:10 000 Orthophotos with 1m contours of the reservoir area and irrigation areas IR6 and IR7. These are produced in both bromide and screen dia-positive forms.

Mapping

- 1:50 000 Department of Surveys and Lands map sheets with 25 ft contours
- 1:10 000 contour plot of the reservoir area with 4m contours and 2m form lines.

Satellite Imagery

- 1:250 000 Landsat multispectral colour composite print of Path 171 Row 75 dated 3rd August 1985.
- SPOT digitally derived multispectral imagery of scenes 130/394 and 131/394 dated 16th July 1986 and 11th July 1986 respectively.

The SPOT imagery was laser film written and printed to 1:100 000, 1:50 000 and 1:25 000 scales and covers the areas indicated in Figure K1.7. In addition, digital image analysis was carried out on the imagery covering the identified soil areas and the pollution from mine. This was of little advantage in the soil areas but a density slice and classification of the tailings dam area was able to discriminate different responses from the water within the tailings dam and detect the discharge of polluted water into the river. The extent of deposition of airborne pollution can also be seen on the imagery. Colour ink-jet plots of the classifications were made and a colour photocopy of the enhanced imagery of the mine area is shown in Figure K2.14. Similar copies covering the areas of detailed study along with annotated overlays are shown in the separate album of drawings.

Reviews of the available literature and previous studies were made at the University of Botswana, the National Institute for Research and Development, the National Museum, the Botswana Society, the Government Printer and other private sources. These revealed little or no previous detailed research specifically of the study area that could assist the social,

economic, archaeological and ecological inputs. Those that were found are included in the references and include:

For social systems	Cooper (1986), Lawry (1983), Mahoney (1977), MFDP 1982, Schapera (1953).
For economic and planning data	MOA/MFDP 1988, MFDP 1981, MFDP 1982, MFDP 1985, MFDP 1987.
For archaeology	Campbell (1986), Denbow (1986), Fletemayer (1976), Parsons (1986), Tapela (1986).
For ecology	Arntzen and Veenendaal (1986), Cook and Silitshena (1988).

General ecology principles are covered in Dasmann, Milton and Freeman (1979). Applied manuals by Bryson (1986), and for Botswana rangeland by Field (1978) and soils by Rhebergen (1988) were consulted and the standard work on trees is Palgrave (1988).

Some agricultural survey data collected by the Ministry of Agriculture is published in the National Agricultural Statistics; the most recent volume available being from 1986. Veterinary statistics are collected annually from the crush censuses and data for most of the catchment was compiled for analysis covering the years 1987 and 1988. These record the largest livestock population figures ever documented (1987) prior to the major cattle mortalities caused by the extended years of recent drought and the very late rains in November 1987.

K1.7 Scheme Identification Conclusions

K1.7.1 Dam Site Investigations

The Scheme Identification Report (SIR) (MacDonald, 1988) was submitted to DWA in October 1988. This included the comparative technical, economic and environmental impact analysis of a number of different dam sites. Previous studies and opinion had led to a preference for a dam site close to the village of Tobane. On both environmental and economic grounds the Scheme Identification Report recommended the adoption of an upstream site at Letsibogo, close to the town of Mmadinare. The Letsibogo dam site was found to be most economically attractive of the alternative sites although with a lower yield. In addition it has the major advantage of being upstream of future pollution risk from the BCL mine and processing unit at Selebi-Phikwe. These recommendations were discussed and accepted by an Inter-Ministerial Reference Group. The detailed feasibility studies have proceeded on the Letsibogo site.

The potential for mine related pollution was considered an important constraint, not just on downstream dam and reservoir development potential, but also as a source of contamination which might enter the river system and food chain during a water resource and irrigation development programme. A full pollution sampling programme was therefore recommended to be carried out as part of the Phase 2 studies. This pollution study will form a separate report.

In view of the smaller capacity of the Letsibogo dam consideration was also given in the SIR to a dam on the Letlhakane which could be combined with the Letsibogo dam. In Phase 2 further hydrological and engineering studies have been carried out to improve the knowledge of the site since there may be significant advantages of a dam on the Letlhakane to be operated jointly with the dam at Letsibogo.
Although preliminary environmental impact assessments for a dam on the Letlhakane were

included in the SIR detailed studies have not been carried out since this work would have exceeded the study resources as originally planned.

K1.7.2 Irrigation Development

Reconnaissance soil surveys identified 14 areas within which there were potentially irrigable soils. These are widely scattered between Mmadinare and Bobonong and are generally within 4 km of the river (as shown in Figures K1.3 and K1.4). Semi-detailed surveys in Phase 2 within these areas found that most contiguous blocks range in area between 10-120 ha. However two blocks of 150 and 170 ha exist to the west of Tobane and to the north-west of Bobonong respectively.

Analysis of the main options for irrigation eliminated the possibility of canal conveyance from the dam on the basis of cost and poor efficiency. Options for pipeline or river conveyance were brought forward for feasibility study.

It was foreseen that the small size and land tenure arrangements of these irrigation areas could create constraints on the formal and commercial development of irrigation. A range of options for the institutional and technical framework of irrigation development have been considered, including centre pivots and sprinklers and commercial and smallholder schemes. A further option of supporting the existing spontaneous development of small pump schemes along the riverain strip has also been considered.

K1.8 Mapping and Survey Methodology

Data collection techniques centered upon the use of loosely structured interviews which covered the following items.

- settlement history including the location and tenure of lands, homesteads, cattle posts and main residential location;
- household size and structure;
- household assets including livestock, means of transport and non farm sources of income;
- an assessment of assets that would be lost in both the irrigation areas and reservoir along with indications of the use of other resources;
- attitudes to the adoption of irrigation and willingness to participate in it along with the location of possible resettlement sites.

More than 100 households were interviewed including all those in the reservoir area and samples selected as representative from the air photography in the formal irrigation areas and along the riverain strip. The returns of these are recorded on a computer database and are mapped as indicated below.

K1.8.1 Reservoir Studies

Limited time restricted the archaeological, ecological and forestry studies to reconnaissance or semi-detailed surveying. The surveys of existing infrastructure, resource use, land tenure and settlements were exhaustive. The pattern of both private and communal assets within the reservoir is likely to change with time and would need a detailed resurvey for actual compensation assessments once a decision to construct the Letsibogo dam were taken. The results of the current surveys are considered adequate for feasibility analysis and planning. Maps of the reservoir area were prepared at a scale of 1:10 000 using the aerial and ortho-

photos of the same scale taken in November 1988 and showing 1 m contour intervals. These maps (K.1, K.2, K.3 and K.4) are attached in pockets to the back of this annex. Inventories of the main resources to be affected by flooding were compiled during field surveys by vehicle and on foot using interviews as well as from air photo interpretation.

The specific sites of archaeological finds, valuable infrastructure and settlements and cattle posts in current use were pinpointed for use in future surveys and compensation assessments. The locations of abandoned settlements and old cultivated areas were also noted and their significance investigated. Socio-economic interviews with people within and surrounding the reservoir identified the agro-pastoral systems, resource use and economy which the reservoir would affect. The main zones of associated vegetation and their sub-associations were mapped and surveyed to assess tree value, biomass, nutrient status and bush clearance policy. The reservoir simulation models produced simulated data on the frequency and degree of flooding in the reservoir which, together with the results of the other surveys, allowed a preliminary assessment to be made of the development potential of the future terrestrial and aquatic ecology of the reservoir area, based on its dynamic operations.

K1.8.2 Irrigation Development and Downstream Studies

Ecology, soil, land tenure and socio-economic surveys were completed in the irrigation areas and riverain strip downstream. Inventories were taken of existing downstream water users. Reviews were made of the general agro-pastoral and urban economies to assess the future impact of the dam and irrigation development options. Particular attention was given to the likely impact on the riparian vegetation which plays a crucial role in stabilizing the river bank against erosion. Without this protection the pockets of good soil, which are already being developed for irrigation, as well as the main source of riverain grazing and browsing, could be lost. The most extensive damage to this zone is currently being caused by the BCL sand extraction operations. The importance of this operation and the effects of dam development on it were also given careful analysis to assess potential compensation demands.

Mapping of land tenure and other assets in the identified irrigation areas was carried out using uncontrolled 1:10 000 air photography which was re-plotted when the orthophotos were delivered. This mapping is shown on Album Drawing Nrs 35 to 51.

K1.9 Liaison and Public Participation

On going dialogue has been maintained throughout the study with key officials in the DWA and the MLGL in Gaborone. Similar contact has been maintained with the District and Local Government officials and, in particular, the local chiefs and Land Boards. Liaison with BCL proved vital and fruitful on the potential pollution, land tenure and sand resource problems. Discussions were also held with the Selebi-Phikwe Town Council, the Selebi-Phikwe Continuation Project, commercial irrigation farmers, farmers and agro-pastoralists. During the field interviews, which covered over 100 households, full explanations of the studies were given and discussions held on the various scenarios for development. One public kgotla meeting was held in Tobane in view of the more extensive irrigable lands identified there.

Much information on development potential and planning has now circulated orally amongst the local population who have maintained a keen interest in the progress of the study. It will be important to maintain their confidence. The conclusions which Government reach on the water resource development proposals should be transmitted to the local population as soon as this is politic through their representatives and by coverage in the media.

K1.10 Acknowledgements

During the course of the study close liaison has been maintained with the DWA and MLGL and the study team was supported by a DWA counterpart, Baredi Jay. In addition, a large number of people have assisted, either directly or indirectly, with the study and the consultants are grateful for their time and effort.

Particular thanks are recorded to the following:

- staff of the Department of Water Affairs;
- staff of the District Offices in Serowe and Selebi-Phikwe;
- staff of the Sub-Land Boards at Mmadinare and Bobonong;
- the Chiefs and Tribal Administration at Mmadinare, Selebi-Phikwe, Botshabelo, Tobane and Bobonong;
- members of the Traditional Doctors Association in Botshabelo and, in particular, the Secretary, Mrs Pudiephatshwa, without whose assistance little could have been learnt on the use of local plants for medicinal purposes;
- the Biology Department of the University of Botswana particularly Dr Christine Sydes, Lilian Turton and Moffat Setshogo whose assistance in the field collection and identification of vegetation has been much appreciated;
- residents of all the areas where the field surveys took place and the patience with which people have suffered soil trial pits, drilling rigs, extraction of vegetation and a stream of continuous questions on issues ranging far and wide on their future existence and environment;
- our interpreters and field assistants Rixs Monyadzwe, Guardians Bogosing and Fraser Mokgadi.

CHAPTER K2

RESOURCE AND DEVELOPMENT PROFILE

K2.1 Infrastructure and Administration

The study area is located totally within Central District with its headquarters at Serowe. The principal sub-districts within which the study area falls are the designated Town Council area of Selebi-Phikwe and parts of Tutume, Serowe/Palapye and Bobirwa sub-districts as shown in Figure K2.1. Additionally there are 13 subordinate Land Boards and an associated tier of administration, the boundaries of which do not necessarily fit within the boundaries of the sub-districts. These have a high degree of autonomy which has led to an unclear and often contradictory pattern of development. The institutional organisation of Central District is at present undergoing a major review by the MLGL. The majority of the land falls within the Bamangwato Tribal Area with a small part of the catchment in the freehold Tuli Block. Main sub-district centres are situated at Selebi-Phikwe and Bobonong with a lesser one at Mmadinare. The main centres for Tribal Administration are located at Mmadinare and Bobonong. Sub-Land Board offices are staffed at Mmadinare and Bobonong with staff visiting Tobane on a regular basis.

Historically the area has been a remote enclave enclosed to the north by the Zimbabwe border and to the east and south by the Tuli Block and South African border. The development of the mining town of Selebi-Phikwe in the 1970s had a major impact on the enhancement of infrastructure, employment potential and social services. Today the region is served by a railway to Selebi-Phikwe, which spurs from the main Gaborone to Francistown line. There are good surfaced roads linking Selebi Phikwe to the national network and to Sefophe and Bobonong. Main unsurfaced roads infill this network. One links Bobonong to the north east border at Gubajango. Another links Sefophe to the South African border at Zanzibar, and another from Mmadinare travels along the Selebi-Phikwe water supply pipeline to Tonota. Implementation of plans to surface these roads and to construct bridges across the Motloutse at Bobonong and Mmadinare would increase the access of these remoter areas to the rest of the country.

There is a reasonably well-developed system of social, financial, health, educational and communications infrastructure and services as shown in Figure K2.1. These are centered on Selebi-Phikwe town and the principal villages of Mmadinare and Bobonong. Selebi-Phikwe has two hospitals; one run by government and the other run by BCL. Most villages have primary schooling and basic health clinics.

K2.2 Natural Resource Systems

K2.2.1 Landforms

A detailed description of the regional geology is given in Annex C. The following summary covers some salient features which affect the natural environment and human resource use.

Southern Africa comprises a series of mobile belts and relatively stable crustal blocks around a cratonic nucleus. The study area is located within the Limpopo Mobile Belt. This is a 300 km wide zone of igneous and metamorphic rocks subjected to several phases of tectonic and metamorphic deformations during the Late Cambrian Age (500 million years ago). It remained geologically active until Carboniferous times (300 million years ago), but is believed to have now become a stable part of the cratonic block.

There are three minor sources of seismic activity in the region which have been considered for dam planning purposes. Seismic events occur from the deep shafted mines of the Johannesburg area 500 km away. These events are of low magnitude and are attributed to subsidence and explosions. There is also an inactive earthquake zone running through the Okavango Delta which is thought to be a southern subsidiary of the East African Rift Valley. Seismic analysis of these two sources give readings so low that no threat is perceived to the proposed dam. A further source of seismic activity is the operations at the BCL mine at Selebi-Phikwe. This is also thought to be minor. It is undergoing more detailed survey by the BCL mine and has yet to be reported on.

The catchment's altitude ranges between 1004 m on the northern watershed to 550 m at the Motloutse-Limpopo Confluence. The erosion surface was formed during the Quaternary period (1-2 million years ago) with local topography and vegetation generally reflecting the underlying rock types. On granites the topography is flat with sand-covered, undulating pediments that slope gently eastward. The more resistant rock types, generally structurally controlled ridges, form kopjes and inselbergs.

Figure K2.2 outlines the geology of the catchment which, in general terms, can be divided into four zones:-

1. The upper zone, west of the Francistown-Gaborone road is underlain by Karoo deposits and shows gentle relief with a few broad valleys forming a Late-Tertiary pediplain. Between the Motloutse and Letlhakane rivers the drainage is ill-defined on the mature flat landform which, in places, is pre-Karoo. The Karoo sediments overlie the metamorphic rocks. These consist of a succession of grits, siltstones, sandstones and mudstones.

2. The middle zone, between the Francistown road and Bobonong, is underlain by archaean basement rocks and shows moderate relief. The area's oldest rocks are exposed mainly on the south bank of Motloutse river. The drainage is dominated by structurally controlled dividing ridges and is generally dendritic.

3. The lower zone, downstream of Bobonong to the Limpopo confluence, is characterised by dissected basalt and castellated, flat-topped hills around Molalatau. At the Thune confluence aeolian sandstone butte-type kopjes dominate the landscape. The drainage pattern is also dendritic and may be superimposed from an earlier erosional surface.

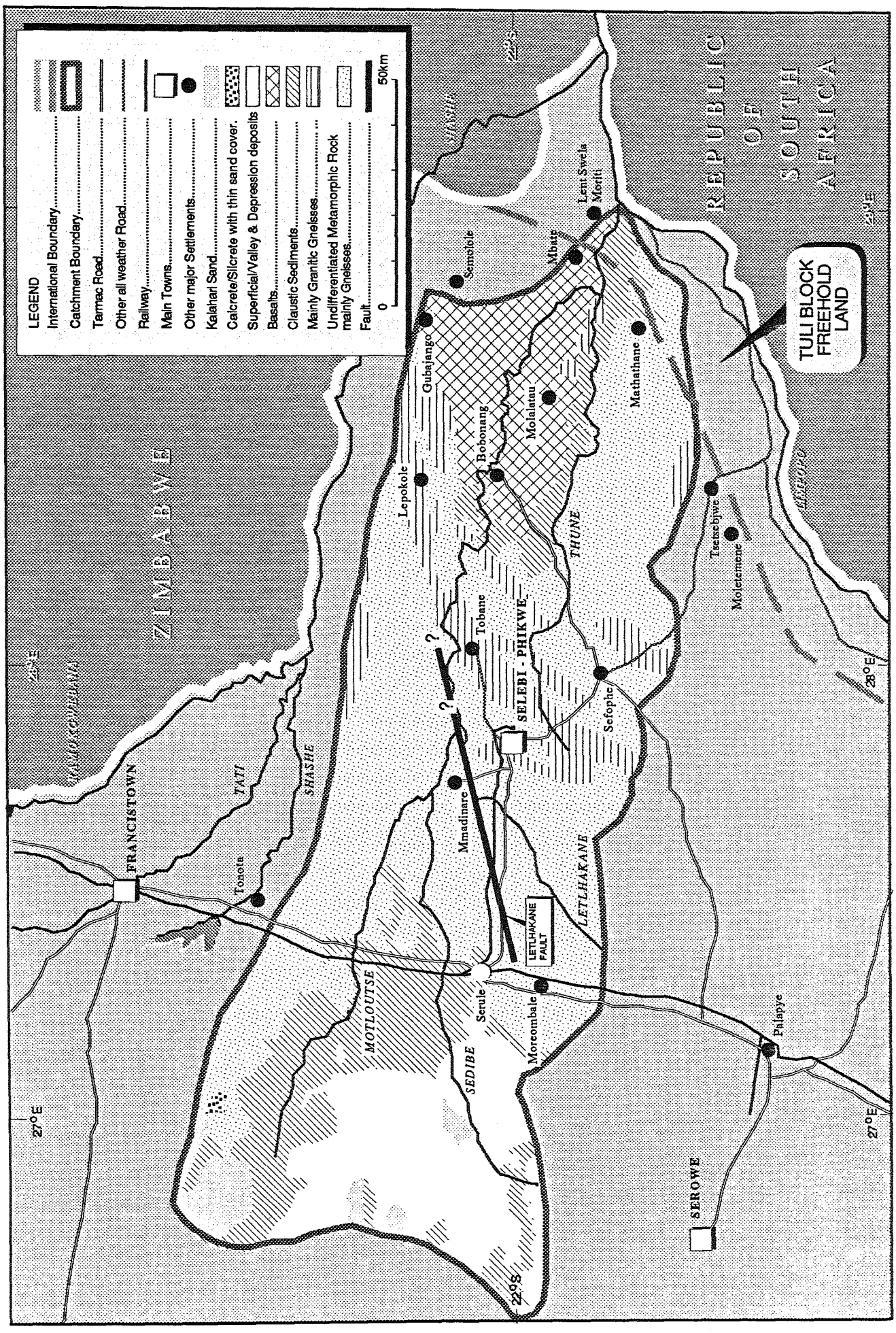
4. The recent alluvial deposits are generally confined to the main river courses in the form of quartz-rich, medium to coarse angular sand with some silt lenses. Silty sand alluvial soils outside the river channel are found along the Letlhakane River to the north-west of Selebi-Phikwe and just upstream of the Motloutse-Limpopo confluence. In some shallow areas along the secondary river tributaries, thin deposits of silcrete, calcrete and ferricrete occur within colluvial, sandy topsoils underlain by gravel and cobbles.

The Letlhakane Fault is a major structural feature which controls the alignment of the Letlhakane river and a part of the Motloutse river east of the Motloutse-Letlhakane confluence. It crosses the regionally important Tuli-Sabi Straightening Zone which runs NE-SW between Mmadinare and Tobane. This zone is about 15 km wide and contains numerous shear zones and cataclastic rocks. Between the late-Cambrian and Carboniferous Age tectonic activity moved the fault line northward creating a wide fracture/shear zone (0.5-5.0 km wide) running 20 km upstream of the Motloutse-Letlhakane confluence. Its influence on riverain soils, vegetation and the groundwater aquifer is significant.

Figure K2.1 Catchment Infrastructure

Figure K2.2

Simplified Geology



Upstream of Tobane the Fault separates two geological zones. To the north, within the Tuli–Sabi Straightening Zone, the rigid rock types, such as granite gneiss, have been converted into coarse crystalline gneisses with a cataclastic fabric. To the south the rocks are generally homogeneous granitoid types of the Basement Complex with some highly folded intrusives, such as amphibolites. Water bearing landforms and soils to the north are poor and have limited potential for settlement, while to the south a higher proportion of better soils and the major settlements are found.

K2.2.2 Soils

The greater proportion of soils studied (see Annex F) are shallow and stony, most reaching rock and/or gravels at a depth of less than 40 cm. Some are marginal, with depths ranging from 40–55 cm and a loamy sand to sandy loam texture. Very few are moderately deep to deep, free draining, generally yellowish red to red, to dark brown and greyish brown sandy loams to clays. Most soils are extremely deficient in organic matter and often have a coarse sandy surface layer.

Where underlain by gneisses the majority of soils are shallow, reddish brown and yellowish red loamy sands to sandy loams. Where mafic gneiss occur, or on amphibolite, schist or dolerite intrusions, the soil is often slightly deeper, redder and with a sandy clay loam texture. Deeper soils occur on old alluvial terraces, the more recent alluvial levees and in areas underlain by fine–grained Karoo sandstone and siltstones. However, stony areas are also prevalent here. Soils derived from basalt tend to be shallow and very poorly developed, if at all, and are often calcareous. The irrigation potential of soils along the rivers of Eastern Botswana was studied by Mitchell (1976).

K2.2.3 Climate and Water

In winter, when the sun is at its furthest north, Botswana lies within a subtropical high pressure zone giving calm settled weather with negligible rainfall. In summer the high pressure zone is displaced southward, low pressure develops over southern and central Africa drawing in moist air from the Indian Ocean and Atlantic. The main rainfall season is from November to March with transitional periods in October and April. Around 90% of the mean annual precipitation (MAP) in the Motloutse area falls between November and March. The MAP falls from around 450 mm in the upper catchment to below 350 mm near the confluence with the Limpopo. Spells of wet days occur throughout the wet season but most rainfall is contributed by localised convective storms of short duration and high intensity. Thus, the catchment typically averages 30 rain days a year, but only half of these days generate more than 10 mm of rainfall. Inter–annual variation is considerable and there is a tendency for wet and dry years to occur in groups. Severe droughts are a frequent occurrence, the most recent covering the period 1981 to 1986. The variability in annual rainfall is typified by the 66 year record at Francistown (just north of the Motloutse) the minimum recorded total was 114 mm and the maximum 938 mm. Reflecting this variability the 1 in 5 year rainfall in the Motloutse catchment ranges from 275 mm at Selebi–Phikwe to 230 mm at Bobonong. A summary of climatic norms are shown in Figure K2.3.

Water flow in the rivers and streams is ephemeral. The Motloutse River flows with a gentle gradient in a wide valley but has flashy flood characteristics. The banks are shallow and lack any significant flood plain. The river course is structurally controlled in places and generally runs across the regional fabric. The Sedibe River forms the most significant tributary upstream of Mmadinare. It has a wide, well–defined channel with high alluvial banks and little bank erosion. The Letlhakane River conversely has a relatively steep gradient and shows active bank erosion. Downstream of the Letlhakane confluence the Motloutse river widens out and

meanders, although structural control is still evident. Broad alluvial terraces and their associated riverain vegetation become more pronounced. Table K2.1 provides an analysis of riverain vegetation and river width of section down the Motloutse and on some of the key tributaries.

Table K2.1

Riverain Vegetation Analysis

	River length (km)	Riverine vegetation (ha)	(%)	Vegetation density (ha/km)	Average river width (m)
Motloutse					
Madibeng rapids – Letsibogo	14.2	160	3.7	11.3	80.0
Letsibogo – Letlhakane	18.9	213	4.9	11.3	92.0
Letlhakane – Site 32	13.5	600	13.7	44.4	100.0
Site 32 – Lerala	21.7	890	20.4	41.0	138.0
Lerala – Basalt	27.2	941	21.5	34.6	159.0
Basalt – Bobonong	16.5	239	5.5	14.5	123.0
Bobonong – Molalatau	32	566	13.0	17.7	na
Molalatau – Setombo	12.5	106	2.4	8.5	na
Setombo – Thune	21	343	7.8	16.3	na
Thune – Limpopo	24	312	7.1	13.0	na
	201.5	4370	100.0	21.7	na
Major tributaries					
Sedibe in Letsibogo Reservoir	12.5	170	52	13.6	50
Letlhakane proposed reservoir	20	281	29.0	14.1	25
Letlhakane (d/s of dam)	23.3	682	71.0	29.3	30

Source: 1981 1:50 000 aerial photography and 1986 1:25 000 Spot satellite imagery

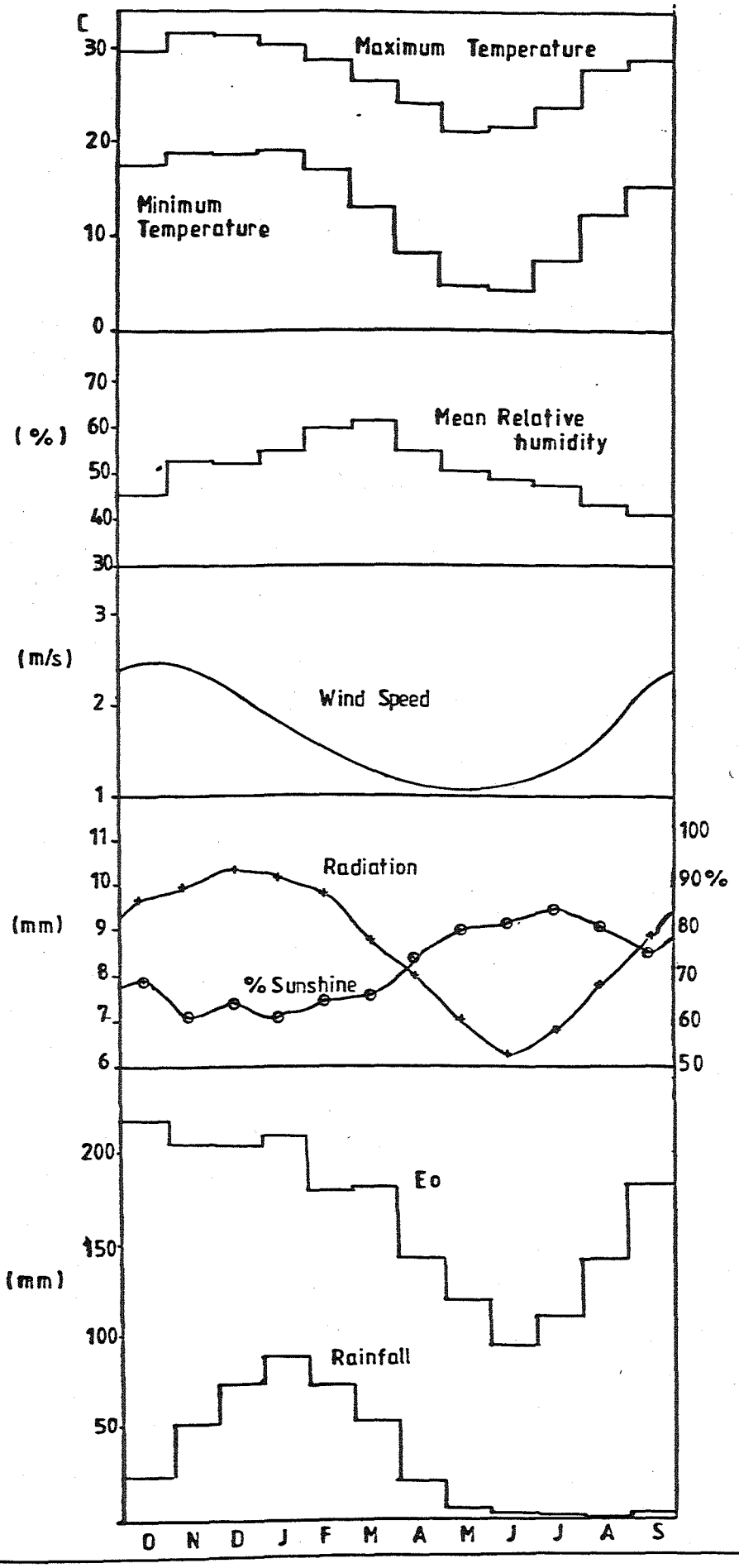
Mean annual runoff (MAR) is estimated at 94 $m^3 10^6$ at the Tobane gauging station (see Annex A). This represents about 12 mm or 2.5% of MAP. The Motloutse is a sand river and although surface flow ceases in April or May subsurface flow through the sand bed continues throughout the year.

Numerous rock bars form an important feature of these sand rivers. They are extensions of ridges which follow the regional structural trend and provide natural shallow rock foundation and weirs across the river channel. The resulting perennial sand aquifers have underpinned the historical basis of settlement and the access to resources prior to the establishment of Selebi-Phikwe and the BCL mine.

The Letlhakane Fault Zone is the only aquifer that appears to have significant storage and transmittal properties along with good recharge potential. It may contain a groundwater resource of considerable magnitude which may be significant in contributing to the existing riverain vegetation and might also be effectively exploited in conjunction with surface sources.

The Letlhakane Fault Zone has not as yet been adequately evaluated. Present estimates indicate a total recoverable resource of some 18 $m^3 10^6$ over a potentially exploitable reach some 20 km upstream of the confluence with the Motloutse. Estimates of recharge over its entire length indicate an annual renewable volume of approximately 5 $m^3 10^6$. If this value

Climatic Norms for the Motloutse Catchment



is reduced pro-rata, to apply to the same potentially exploitable area indicated above, then the annual renewable resources (recharge) available is 1.5 $m^3 10^6$.
Karoo sediments and volcanics comprising basalts and interbedded sandstones occur widely within the Motloutse catchment from about 20 km upstream of Bobonong down to the junction with the Limpopo. The sandstone formation of this group is known to form a significant primary aquifer possessing high storage and medium to high transmissivity. However the potential for recharge may be limited or non-existent due to depth beneath the basalts. In the Bobonong area, recharge potential is greatly enhanced by the active drainage system which traverses both the sandstone and basalt outcrops, and by the presence of a number of major structural features, several of which coincide with the river system itself. Thus, where sandstones outcrop adjacent to the river system, there may be potential for individual borehole supplies of up to 20-30 m^3/hr, at specific locations, with good prospects of continued recharge, to supply small irrigation plots.

K2.2.4 Flora and Fauna

Associations between floral and faunal species can be defined at a variety of spatial and temporal scales. At the continental level the catchment falls within the Zambezian regional centre which covers about 3.8 million square kilometres. This contains at least 8 500 plant species of which about 4 700 (54%) are endemic and are classified as Zambezian dry deciduous mopane woodland and shrub woodland. Within Botswana the area has been classified as mixed mopane/acacia tree savanna which is a formation that covers much of Eastern Botswana from Ramokgwebana to the Tuli Block (Timberlake, 1980).

Regionally, the vegetation shows great structural uniformity reflecting the overwhelming dominance of Colophospermum Mopane. Locally, there is more subtle variation in species composition and structure which reflects the complex interplay between the physical environmental features and the historical impact of human and animal land use practices. The plant collections associated with this study have identified over 366 dicotyledons and 91 monocotyledons (see data lists in Appendix K-E). These plant species can be broadly divided into five main classes:

1. Communities on granite-gneiss hills and rocky ridges

2. Communities on river and stream banks

3. Communities on bottomlands dominated by Acacia sp.

4. Communities on uplands dominated by Colophospermum mopane

5. Communities on occupied or abandoned lands

No detailed faunal survey has been carried out in the study area. However, in addition to using a variety of reference sources (see Appendix K-E) to determine which species are likely to occur in the project area, records were kept during the survey of all fauna or signs of their activity.

The resulting faunal list indicated that up to 77 mammal species potentially occur in the project area. Almost half of the species are small mammals weighing less than 1 kg and most of these are nocturnal. The larger mammals are generally uncommon.

A total of 120 species of birds were recorded in the study area. The actual number of species present is likely to be considerably higher than this. The majority of bird species are small insectivores (53%), with seed-eaters (11%), mixed feeders (8%), water birds (11%)

and raptors, including owls (9%), comprising most of the remainder. The relatively large number of species of water birds in this semi-arid region is due to the presence of permanent pools of water on the Motloutse River downstream from its confluence with the Letlhakane River.

Most of the species recorded are typical of the region as a whole, though there were some interesting records such as Saddlebill Storks *Ephippiorhynchus senegalensis*, Boulder Chats *Pinarornis plumosus* and Tropical Boubou *Laniarius aethiopicus*. Numerous small flocks of Redbilled Quelea *Quelea quelea* were seen in the proposed reservoir area and in the irrigation areas downstream. This species is a serious pest of agricultural grain crops in southern Africa, including Botswana, and is a factor that must be taken into account in any planning for the development of irrigation areas downstream.

No information was obtained on the composition or numbers of the reptile, amphibian, insect fauna or the microfauna of the project area. General observations indicate that there is a high diversity of reptiles, including some species which are probably rare elsewhere in Botswana. Honeybees *Apis mellifera* are common and probably depend heavily on nectar and pollen from *Acacia* tree species. *Acacia tortilis* and *A. mellifera*, are considered to be major food sources for honeybees.

A proper assessment of the impact of the dam, and to interpret clearly the presence and status of the faunal species, would require a more detailed survey than was possible in the time allowed for this study.

K2.3 Human Environment

K2.3.1 Socio-Economic and Settlement History

The Motloutse catchment is known to be rich in archaeological sites. These are plotted for the whole catchment on Figure K2.4 and within the reservoir on Map K.1. The report of the reconnaissance level archaeological survey of the reservoir area is given in Appendix K-D. The distribution of these indicates human settlement and resource use dating back for over 100 000 years. The fact that so many sites were found in the reservoir but so few are noted by the National Museum elsewhere in the catchment reflects the lack of knowledge of the area rather than a significant difference in distribution.

Historical and contemporary settlement patterns are intimately bound up with certain key dynamic influences. Changing conditions of climate, water availability, food acquisition, social stratification and conflict, political organisation, trading patterns and routes, resource value systems, disease and ecology are amongst the most important factors. A description of the available material and an analysis is given in Appendix K-B.

The Stone Age peoples of Botswana are thought to be the forebears of the present day San Bush People. They were probably the sole inhabitants until the arrival of the Bantu between A.D.200-400. They introduced cultivated agriculture, iron smelting, pottery making and radical new forms of social and political organisation.

Between A.D.850-1300 hill top settlements and agro-pastoralism were common. In the early 12th Century gold mining occurred north of the Shashe river and would have influenced life in the Motloutse catchment. Late in this period the population seemingly declined, possibly due to the intensive use of resources and extended drought. The area also then came under the control of the Great Zimbabwe Empire and later that of Khami, near Bulawayo in Zimbabwe. By the 15th century, settled and stable communities seemed to have existed across these regions integrated through a network of trade and regional specialisation,

Known Archaeological Sites in the Catchment

Figure K2.4

involving mining (for gold, copper and iron), metal working and salt production. The era of mining is thought to have declined around A.D. 1600. Little is known of the settlement pattern and resource use in the catchment from then until the 19th century. Riverine tsetse fly infestation may have been important in limiting settlement.

During the 19th century attempts at stable settlement were disrupted by wars along with the Boer and western commercial expansion northwards. The whole of southern Africa witnessed the chaos of refugee movements to escape the troubles. The Motloutse and Shashe catchments stood at the interface of the local conflicts and were disputed frontiers which remained unresolved until the early part of this century.

In 1896 the first known African epidemic of rinderpest swept down through east and central Africa into the south. The impact of this and the associated famine between 1896 – 1898 was dramatic. It decimated the cattle and wildlife populations in its path and laid waste to vast tracts of land and societies once under the control of pastoral and agro – pastoral peoples. This was also the culminating factor to the demise of the tsetse in the Limpopo and other riverine areas. The economic depression which followed led to an outflow of labour into the mines. The arrival of missionaries, western education and commerce all contributed to an erosion of indigenous cultural systems. The traditional strategies of pastoralism and agro – pastoralism, already disrupted by the chaos of the preceding decades, were moving through and into a period of major transformation.

The beginning of modern settlement patterns were established at the turn of the century with the resettlement of refugees from Serowe and other points of refuge. Four major historical settlement areas can be noted, the Tuli Block, where the local Babirwa were displaced by white settlers, the area known as Bobirwa which includes Bobonong and five villages associated with it, the villages of Mmadinare, Tobane and Sefophe which form a zone representing mixed settler groups and finally, there are the settlements located along the railway. The Basarwa (Bushmen) have increasingly come under pressure to adopt a settled village lifestyle so that social services can be better provided. In many cases this transition has been completed.

With the shift in the focus of conflicts to the theatre of World Wars, consolidation of local villages and resource use now began but still faced the social and economic implications of labour migration. With the arrival of trading stores, missionaries and new social services the population grew, commercialism established itself and the roots of a consumer society began to develop. The most important influence on settlement and the economy came with the development of the BCL mine and the planned town at Selebi – Phikwe in the early 1970s. Associated with this came the spontaneous growth of the labour township of Botshabelo and the major migration of labour from across the region in search of work. The distribution of the 1981 population is shown in Figure K2.5. This indicates a fairly even distribution of the rural population with the possible exception of the upper third of the catchment and to a lesser extent the barren basalt country downstream of Bobonong. This reflects the availability and use of resources.

It is important for planners to recognise that the overall settlement pattern involves a transhumant system (see Appendix K – B). Virtually all families have more than one residence site where well – constructed dwellings are erected for seasonal or permanent use. These can be located in the village, at the Lands, at the cattle posts and in the labour township of Botshabelo. Every family maintains dwellings in their village of affiliation to serve as a base from which to access modern social services, particularly for the term – time schooling of children. These sites are also important valuable urban assets. As population grows and commercialism and urban development increases, pressure on land induces increased economic value to be attached to urban sites.

The pressure on resources and the growing importance of irrigation potential are leading to the commercialisation and rising economic asset value of rural land. The start of land enclosure is evident both for riverside plots for irrigation development and in rainfed lands. This is to gain private control over grazing rather than be bound by the management constraints of the communal grazing areas. The increasing shortage of available farming land close to the villages and the reduced rural labour force has motivated some to establish cultivation at the cattle posts.

The transhumant settlement system clearly works to the best advantage of local families in the organisation of their resources and achieves their social and economic objectives at household level. This fact creates significant constraints that need to be considered during the planning and design of any formal irrigation scheme. To introduce another economic resource will add a further layer of opportunities and constraints onto those which already exist. It cannot be assumed that there will be unrestricted time and capacity for the society to rapidly absorb these apparent improvements. Irrigation development should be seen as being incorporated into an existing decision – making framework already full of responsibilities, demands on resources and constraints.

K2.3.2 Population Statistics

Table K2.2 provides population statistics and projections for the catchment based on the 1981 Census and CSO growth rates. This shows a current catchment population estimated at around 100 000 and growing at an average annual rate of 3.8% between 1981 – 2011. The implications of this would be for a doubling of population in the catchment over the next 20 years. The potential implications of this rate of increase on the demand for resources, the risk of major environmental degradation and the undermining of the capacity for sustainable development cannot be over – emphasised.

Table K2.2

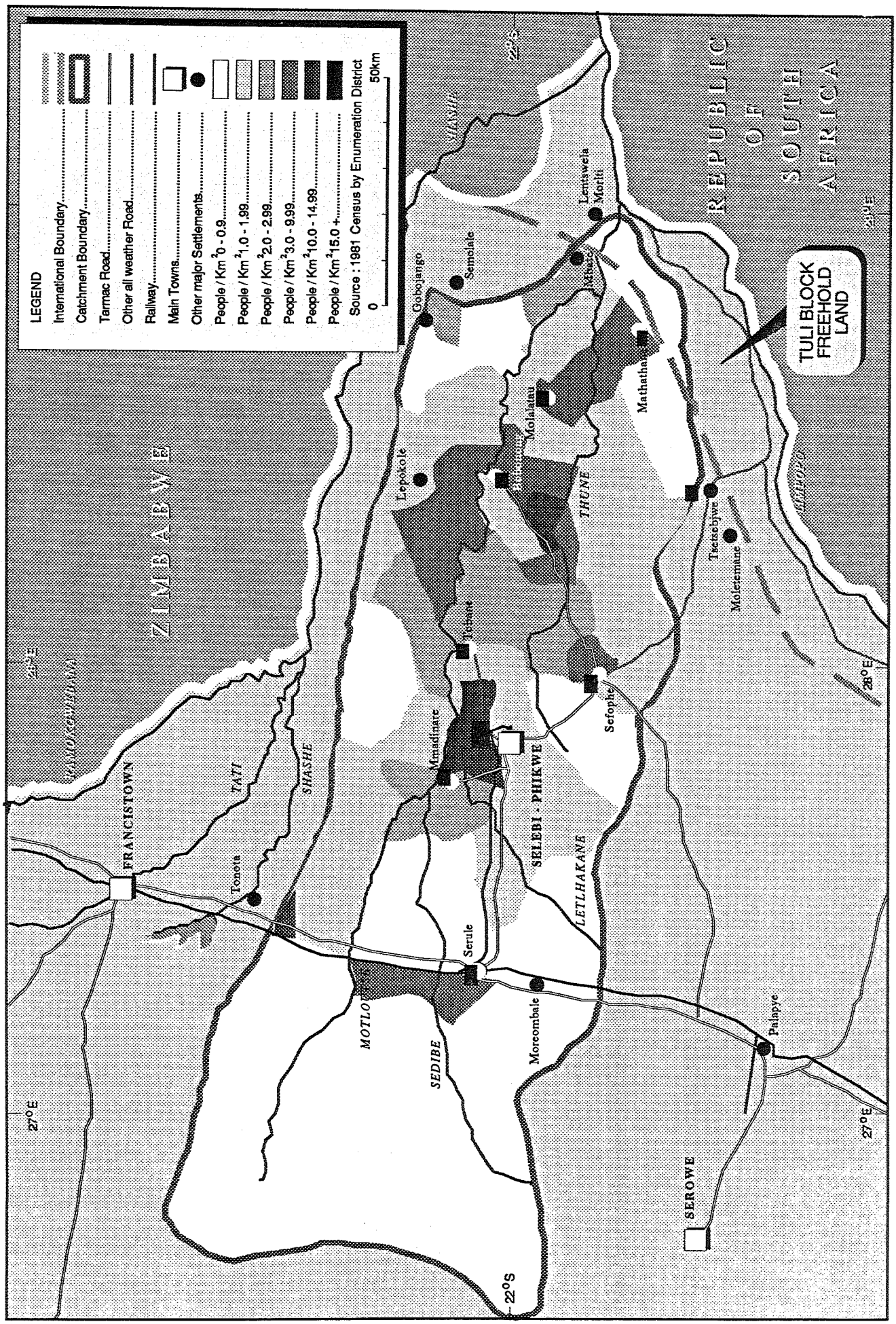
Motloutse catchment de facto population projections (medium variant)

	1981	1986	1991	2001	2011
Selebi – Phikwe	29 469	41 183	55 095	89 582	136 813
Mmadinare	5 234	6 373	7 683	10 877	14 882
Bobonong	4 711	6 093	7 683	11 692	16 851
Sefophe	1 980	2 872	3 899	6 565	10 076
Tsetsejwe	1 570	1 691	1 955	2 227	2 477
Serule	1 465	1 578	1 824	2 078	2 311
Mathathane	1 098	1 183	1 368	1 558	1 733
Semolale	1 018	1 097	1 268	1 444	1 606
Kobojango	855	921	1 065	1 213	1 349
Molalatau	722	778	899	1 024	1 139
Tobane	696	750	867	988	1 099
Mabolwe	519	559	646	736	819
Other Villages	957	1 031	1 192	1 358	1 511
Localities	25 621	27 601	31 906	36 341	40 422
Total	75 915	93 710	117 350	167 683	233 088

Source: C.S.O. Population Projections 1981 – 2011

Figure K2.5

1981 Population Density



The urban area of Selebi-Phikwe has a growing population which totals about 45% of the catchment's population at present. This is forecast to increase to almost 60% of the catchment's population by the year 2011. This concentration of population will create major demands for productive economic activities and will raise many questions as to the capacity of the economy to minimise the differentials between rich and poor.

Within the catchment there are 11 major villages with more than 500 persons. The most significant are the villages of Mmadinare and Bobonong whose real population utilising village resources probably exceeds 10 000 in both locations once due allowance is made for seasonal fluctuations, see Appendix K-C, Table K-C1.1.

It should be appreciated that not all the people living in the catchment will necessarily be affected by the water resource development programme covered by this study. The population figures have been adjusted downward to reflect this and are shown in Appendix K-C, Table K-C1.3. This shows that currently about 25 000 people or 25 percent of the catchment's population make direct use of the sand river aquifer between Letsibogo dam site and Bobonong. By the year 2011 this figure could be approaching 50 000 people which would then represent about 20 percent of the total catchment population.

People living in close vicinity to the proposed reservoir would mainly comprise the residents of Mmadinare, together with their settlements at both the Lands and cattle posts. Those people in these outlying localities who would be directly affected by the reservoir are estimated at present to number about 1 300 and by the year 2011 could have increased to 1 800.

K2.4 Land Tenure and Resource Rights

K2.4.1 Land Tenure Systems in Botswana

There are three major types of land tenure in Botswana depending upon its designation:

Tribal Land, which covers some 70% of the country, was up until the Tribal Land Act of 1968 administered under traditional tenure by local chiefs and village heads. The Act set up Land Boards which have now taken over these duties including the allocation of all new lands, the registration of existing customary rights and the issue of Tribal Leases. There is also a system of land use designation around villages which has evolved through historical development. Most households have a permanent main house in a nucleated settlement. In addition most also have homesteads that are seasonally occupied in designated lands areas and some have others at cattle posts. There are also plots specifically designated as gardens.

Freehold Land which covers some 6% of the country, is the remnants of land granted to white settlers during the time of the protectorate. These are generally large fenced farm blocks and many remain in the hands of descendants, some of whom have taken citizenship.

State Land which covers the remaining 24% of the country are those areas taken over by the state. They include designated wildlife, forest and game reserves as well as national parks and urban areas. The urban areas include Gaborone, Francistown and Selebi-Phikwe and the administration and allocation of plot leases (generally for periods of between 40 and 99 years) are the responsibility of the Department of Surveys and Lands.

K2.4.2 Land Tenure in the Study Area

Figure K2.6 shows the nature of land tenure in the catchment. The majority of the catchment falls within the Bamangwato Tribal Area which is administered by Bamangwato Land Board, the main base of which is in Serowe. There are subordinate Land Board offices operating from Tonota, Mmadinare and Bobonong and the Mmadinare officers regularly visit Tobane. Most of their work is concerned with the administration of arable lands, gardens, village plots and to a lesser extent the issue of tribal leases in conjunction with the main Land Board. There is a small portion of the catchment which falls in the freehold Tuli Block farms. These are fenced and due to lower livestock densities, do not suffer the over grazing of the Tribal Lands. More significantly there is the designated State land of the Selebi – Phikwe urban area which is surrounded by the BCL mine lease. The details of the mine lease area are shown in Figure K2.7. There are other areas covered by mine leases, prospecting licenses and reconnaissance permits within the catchment which are shown in Figure K2.6.

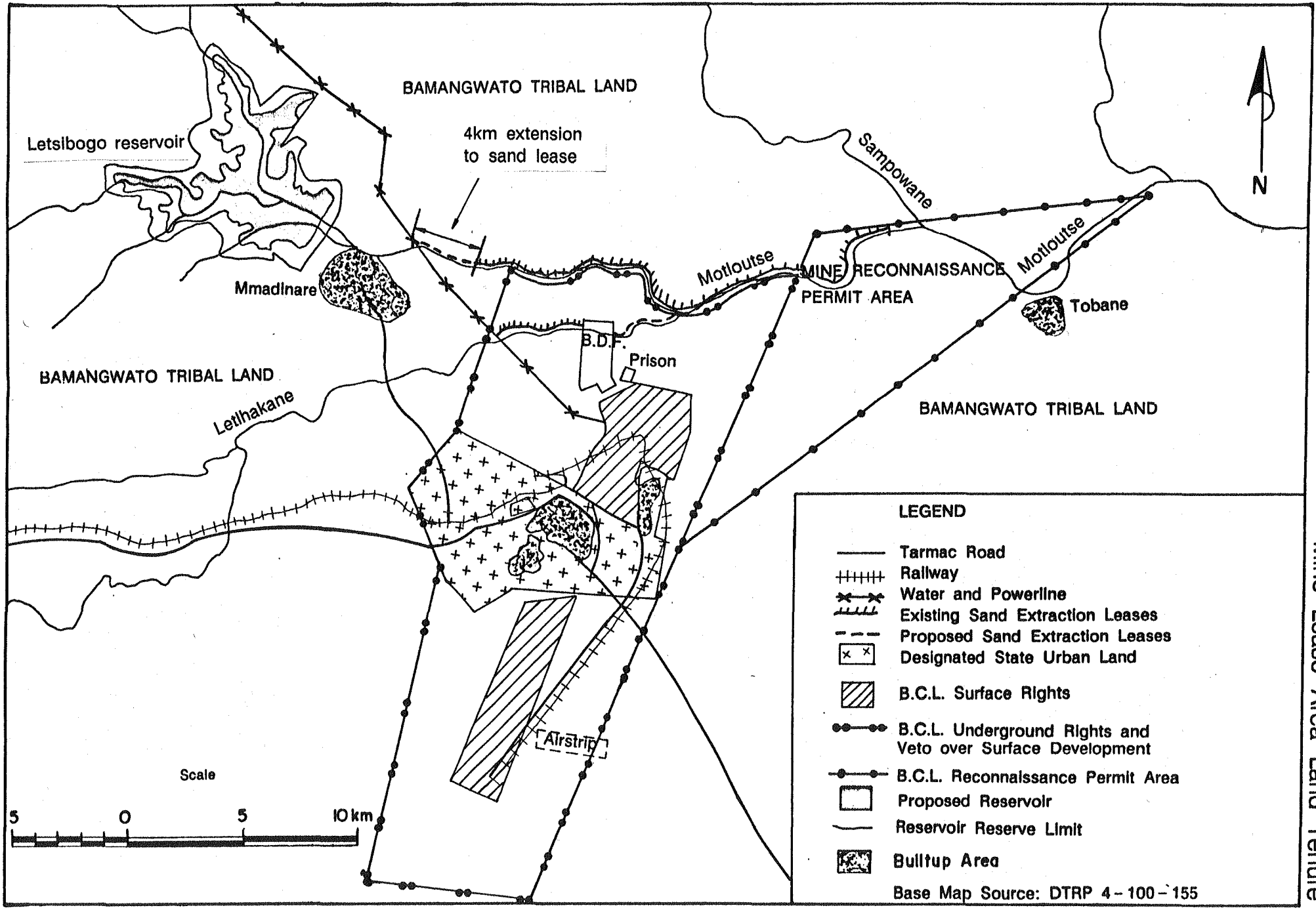
Arable land within the study area was traditionally designated in blocks by ward (see Figure K4.1 for the ward allocation of Mmadinare lands) with individual plots being allocated by the chief. Since the establishment of the Land Boards under the Tribal Land Act, many plot holders in the area have registered their former customary held plots. Security of tenure is perceived to be of unusually great importance in the area, perhaps a result of recent land expropriations and reallocations associated with the development of the mine. New land allocations are dealt with by the Land Board and are generally in blocks 350m by 350m except in the case of garden plots where the maximum size is reported to be 4ha. Inheritance is another common way of gaining land with no uniform pattern being recorded. Some plot holders stated that eldest sons would take over the land as a discrete unit, whereas others said that which ever of their children were interested in farming would have it. It was however commonly noted that the youngest daughter was often the person remaining behind to care for elderly parents and by default took over the land. Under the Act any land which remains uncultivated for more than five years is in theory available to be reallocated by the Land Board. However this is not enforced and is to all purposes politically unenforceable as cultivation of land goes in family life cycle phases. The sale of land is occurring in the area, although this is contrary to the Tribal Land Act and systems of renting, loan and share cropping were recorded.

The Land Board also issues Tribal Leases on land, mainly to non tribe members and to groups or organised bodies of people. Land is being developed by government agencies, cooperative groups and private companies and individuals; some of these under sub – arrangements from local title holders. This is particularly the case within the mine lease area and is a significant factor in the conflicting land management policies there. There has been a recent upsurge in the issue of rights on the south bank of the Motloutse river with many outsiders who have access to capital coming in, perhaps induced by developing markets for irrigated fruit and vegetables. This would seem to be reinforced by the SPRDP proposals for assisting such development and the expectation of a dam being built on the river which is expected to give all year water. At the time of survey some 28% of the left and 35% of the right riverbank adjacent land between the Letsibogo dam and Tobane had already shown evidence of being allocated.

The situation within the mine lease area is very complicated indeed and this is shown in Figure K2.7. BCL have a 25 year lease which is due to expire in 1997 but there is a facility to extend this. The lease allows BCL subsurface rights in the whole area and an annual royalty is paid both to central government and to the main Land Board in Serowe although the amounts are relatively small at P12 500 and 19 000 per annum. In addition they have exclusive surface rights on two large blocks of land plus a veto on all surface development within the lease area. An annual lease rental of P3 200 is paid to the Land Board for these surface rights which cover the mine shaft and smelter area as well as a block south of the

Catchment Land Tenure

Figure K2.6



Mine Lease Area Land Tenure

Figure K2.7

State Land. All existing surface rights were extinguished and compensated for when BCL were granted the lease and of prime consideration to the mine is the requirement that no new development should be allowed that would require compensation to be paid if in future the mine require surface rights over an area. Within the lease area is the designated State Land area under the control of the Selebi-Phikwe Town council. Development planning for the area is contained in the Selebi-Phikwe Development Plan (MLGL, 1985) and any new developments would have to be consistent with present policies and land use zoning which covers the whole mine lease area, not just the designated urban area. Land allocation within the lease area but outside the state land is the responsibility of the Mmadinare Sub Land Board but subject to a veto by BCL. This is further complicated by the fact that the designated planning area for the Town covers the whole mine lease area and that since 1984 there have been representations to the MLGL for the State Land area to be extended to the full mine lease area. No decision has yet been taken on this matter and all lands allocations have been suspended pending decisions and legal advice.

Of prime concern to the mine is that they are able to have the flexibility to develop surface rights anywhere within the lease area, particularly to sink shafts. The likelihood of this can not normally be determined until detailed deep drilling is completed. This is a time consuming and expensive task. Such drilling is at present taking place under the town, an area where previously it was considered to be a low priority for extraction. Conversely areas which were thought to have good potential, such as that under Botshabelo, have now been given low priority. This illustrates the uncertainties associated with this development.

Some people farm within the mine lease area, both in a subsistence manner and commercially. In general the subsistence farmers have not been permitted to register their land and have expressed fears as to the security of their future. Many reported their unwillingness to develop their plots any further without the security of registration. Those farming commercially have generally secured Tribal Leases or have their plots registered by the Land Board.

This conflicting situation needs resolving as a matter of urgency and may be a major constraint to the development of formal irrigated agriculture. A possible way around the problem would be for the mine to indicate those areas where they are now not likely to require surface rights and the present planning blight could be lifted. Alternatively the mine could be requested to evaluate the areas with irrigation potential as matter of priority.

Another significant development is that the mine have a reconnaissance permit on a large area to the east of the mine lease which overlays the largest identified area of irrigable soils. Indications are that the mine is likely to apply for a full prospecting licence over this area and would require the flexibility to drill where necessary within it and perhaps at a later stage consider the possibility of sinking shafts which would require both underground and surface rights to be granted to them. It must be recognised that the continuation of the mine and smelter is of paramount importance to the economy of the area. Indications have been given by the mine that there are already proven ore reserves to last for the next 25 years from within the existing lease area. The life of the smelter is thought assured for the next 40 years as ore can be brought into the area for smelting from outside Selebi-Phikwe. However the whole operation is very vulnerable to fluctuations in the world prices for the metals produced.

Another factor to be considered is the restriction on the development of any permanent works within two kilometers of the fence surrounding the BDF camp north of Selebi-Phikwe. This may prohibit the routing of any pipeline between the river and the BDF.

In conclusion, land development policy is a matter of priorities with the continuation of the mine being the first. However the possible future land requirements of the mine need to be

balanced against the present restrictive conditions within the mine lease area which are causing uncertainty and planning blight. Also of concern is the past inconsistency in implementation of registration between subsistence and commercial farmers within the mine lease area. A major effort is required to provide an overall land development policy that takes into consideration all users. It would be unwise to proceed with formal irrigation development in both the mine lease and reconnaissance permit areas until this has been resolved.

K2.4.3 Resource Rights in Botswana

The existing framework governing rights to water is covered in the Water Act (CAP 34:01) of 1967 along with the Boreholes Act (CAP 34:02) of 1956 and the Waterworks Act (CAP 34:03) of 1962. Of these the Water Act is the most relevant to this study. The Act contains eight parts and covers the setting up and operation of the Water Apportionment Board, the identification of water uses which do not require a permit and the procedures required in order to obtain such a permit when necessary.

The present situation is that there is no right of property of public water which is defined as "all water flowing over the surface of the ground or contained in or flowing from any natural lake or pan or swamp or in or beneath a watercourse and all underground water made available by means of works". Anybody is permitted to extract water for domestic, stock watering, mining and forestry purposes up to a stated maximum limit. Over and above that and for non domestic uses a permit is required from the Water Apportionment Board. The granting of a Water Right is conditional depending upon other users and can be subject to abstraction restrictions. Those people who had existing non domestic water rights (be they statutory or customary) prior to the implementation of the Act were required to apply to the Board for a permit. The Board also has the power to vary a water right on account of drought and to reduce proportionally the permitted abstraction rates in a reach of a watercourse.

Associated with the legislation that controls water use are the "Guidelines for Water Pollution Control" reproduced from their original sources (WLPU, 1985 and 1987) as Appendix K-I. The legal standing of these is unknown but all work for the Bokaa project was governed by them and there would seem no reason why this study should be any different.

The other major formalized resource abstractions in the project area include the extraction of river sand and the quarrying and mining of stone and minerals. These are covered by stipulations in the Mines and Minerals Act (CAP 66:01) and in Tribal Areas are subject to Tribal Leases with the District Land Board. They are normally drawn up with the assistance of the relevant Ministry and the Department of Surveys and Lands.

Rights for the extraction of firewood and other woodland resources along with grazing rights are communal and not exclusive. However there may be grazing areas which are designated by the Land Board and gazetted by the MLGL in which no arable or garden plots are allowed to be registered. The registration of an arable farm plot by the Land Board confers exclusive rights to grazing and woodland although in reality these are only enforceable by fencing.

K2.4.4 Resource Rights in the Study Area

The Motloutse river provides, by boreholes in the sand river bed, the primary source of water for domestic supply to Mmadinare, Bobonong and shortly to Tobane. In addition local homesteads at both the lands and cattle posts rely on digging seasonal wells in the sand river bed or using the natural pools upstream and downstream of rock bars for both domestic

and livestock watering. There is increasing use of small pumps for irrigating riverside farm plots particularly between Mmadinare and Tobane. Few if any of these irrigators appear to have approached the Water Apportionment Board for a permit. It would appear that there is insufficient knowledge of the workings of the Water Apportionment Board at the local level. The establishment of an effective local organisation to quickly issue permits and enforce restrictions would seem highly desirable. The ease of water abstraction from the sand aquifer has resulted in little perception of individual ownership of rights to water. There are however specific places where hand dug wells are constructed every year by individuals and it is also apparent that some locations e.g. the outside of bends, are known to be more favourable than others. In locations away from the river bed there are permanent hand-dug wells which can have both individual and group rights of use generally based on the labour input required to develop and maintain the wells.

Apart from the mine lease there is a major lease for abstraction of sand from the beds of both the Motloutse and Letlhakane for use as flux in the smelter at Selebi-Phikwe. This is a very major compensation issue and is covered in detail in Sections K3.3.5 and Appendix K-H. A significant factor is the need to allow frequent access points to the river bank in order to allow efficient extraction of the sand. There has already been conflict between commercial farmers and the sand extractors over this and any riverside development would have to be laid out to permit adequate access to the bank.

The use of communal grazing land is prevalent throughout the catchment with cattle posts being long established in them. There are a significant number of cases where arable lands have been cleared at cattle post locations and these have subsequently developed into mixed arable-livestock farms with significant fenced off areas. Stock owners may graze any number of animals but are limited, in practice, to the land within easy reach of water and grazing resources. Another controlling factor is the availability of herding labour. Shortages are apparent, with herders and owners almost without exception now leaving their animals unattended to graze by themselves while other tasks are being seen to. Other problems occur when herd sizes start to exceed the capacities of the herders particularly when hand watering from shallow river wells becomes necessary. There is also a programme of fencing designated lands areas to prevent the movement of unsupervised livestock into them. The extraction of timber for firewood is also widespread in communal areas and is covered in Appendix K-F.

The development of any proposed water resources programme will require that land be taken over for any permanent works. The procedures for doing this are laid down in the Tribal Land Act and are further detailed in the recently adopted "Revised Guidelines for Land Boards and Assessment Committees in Tribal Lands" which are attached as Appendix K-A. The Tribal Land Act is at present being redrafted to incorporate these. Details of the options and procedures that are relevant to the project proposals are given and discussed in Section K7.7. Previous projects in Botswana involving the expropriation of resources have provided valuable experience on how to go about such matters using the revised guidelines. Of particular relevance is the work done for the Bokaa reservoir (MacDonald, 1987b).

K2.5 Resource Use and Depletion

K2.5.1 General

Spatially the major resource users in the catchment are livestock. These are organised into a mixed economy which could be loosely described as agro-pastoral. In practice there are other management strategies which might be as important in terms of quantity and quality of resources owned, whether livestock or land. These include the urban salaried workers, traders, general dealers and wage labourers who re-invest in stock. While a system does

exist to separate the stock from the cultivation areas, in practice the boundaries are not always clear, and there are an increasing proportion of the rural population who do not have the means to own large numbers of animals. This group, therefore, do not run cattle posts, preferring to manage their few resources as a mixed farm often solely within the lands areas. Figure K2.8 provides information on the land use and designation through the catchment and Table K – C1.4 in Appendix K – C indicates the extent of livestock rearing and cultivation amongst the population in 1981.

Urban development arrived suddenly with the establishment in the early 1970s of the mining town of Selebi – Phikwe and its associated services and economic opportunities. Most of the unskilled labour came from within the catchment while amongst the skilled and salaried sectors there was movements from much further afield. Studies in the late 1970s of the use of the economic wealth being generated found that Selebi – Phikwe, and the labour township of Botshabelo particularly, were transit areas for short – term employment, rather than the location of permanent settlement. Income generated was generally being reinvested back into rural activities, particularly livestock, transport and agricultural equipment.

An appreciation of the interrelationships between the fields of livestock, cultivation, transport, petty income and wage labouring is crucial to a complete understanding of the nature of resource use and pressures in the catchment. So to is an understanding of the grazing systems and their dependence on the riverain vegetation and water supplies.

K2.5.2 Water

The importance of the natural sand river aquifers is discussed in Section K2.4.4. Alternative water supplies are generally very limited. Many are only seasonal, are scarcely distributed and often of poor quality. On the Lands settlements, local water is either carted from the nearest village supply or caught from run – off in shallow hand dug wells. Only a few of these wells supply water throughout the year. Some minor aquifers are tapped by shallow wells alongside tributary streams and in fracture zones of the weathered rock. These sources are also scarce. Significant groundwater potential from major fracture zones is only likely in the Letlhakane Fault and in the Karoo sandstones surrounding the basalt downstream of Bobonong. Details of water resources are given in Annex B. Figure K2.9 maps the main type of water abstraction in the catchment. Specific studies have been carried out by AquaTech (1983) and Varley with regard to the situation on the Motloutse/Limpopo confluence. Both Thomas and Hyde and also Wikner (1980) have studied the Motloutse particularly in the context of it being a sand river.

The sand river is the main source of domestic water supply for the villages of Mmadinare, Tobane and Bobonong. There is also increasing non – domestic use of river water particularly for brick and block making. It is also the main supply for the Lands areas and for livestock including ploughing animals who have to be daily watered. Additionally there is at present some 26 ha of informal irrigation along the riverbanks which is a major user of water. Under the SPRDPP this is planned to increase to 67 ha in the next two or three years. Table K2.3 lists the predicted increase in population dependent upon the river for water supply at peak demand time in the villages. It also gives the animal population dependant upon the river and informally irrigated areas. The animal population is the peak 1987 figure before the drought and this has been used as a realistic maximum figure where the constraint is availability of grazing.

Figure K2.8

Catchment Land Designation and Use

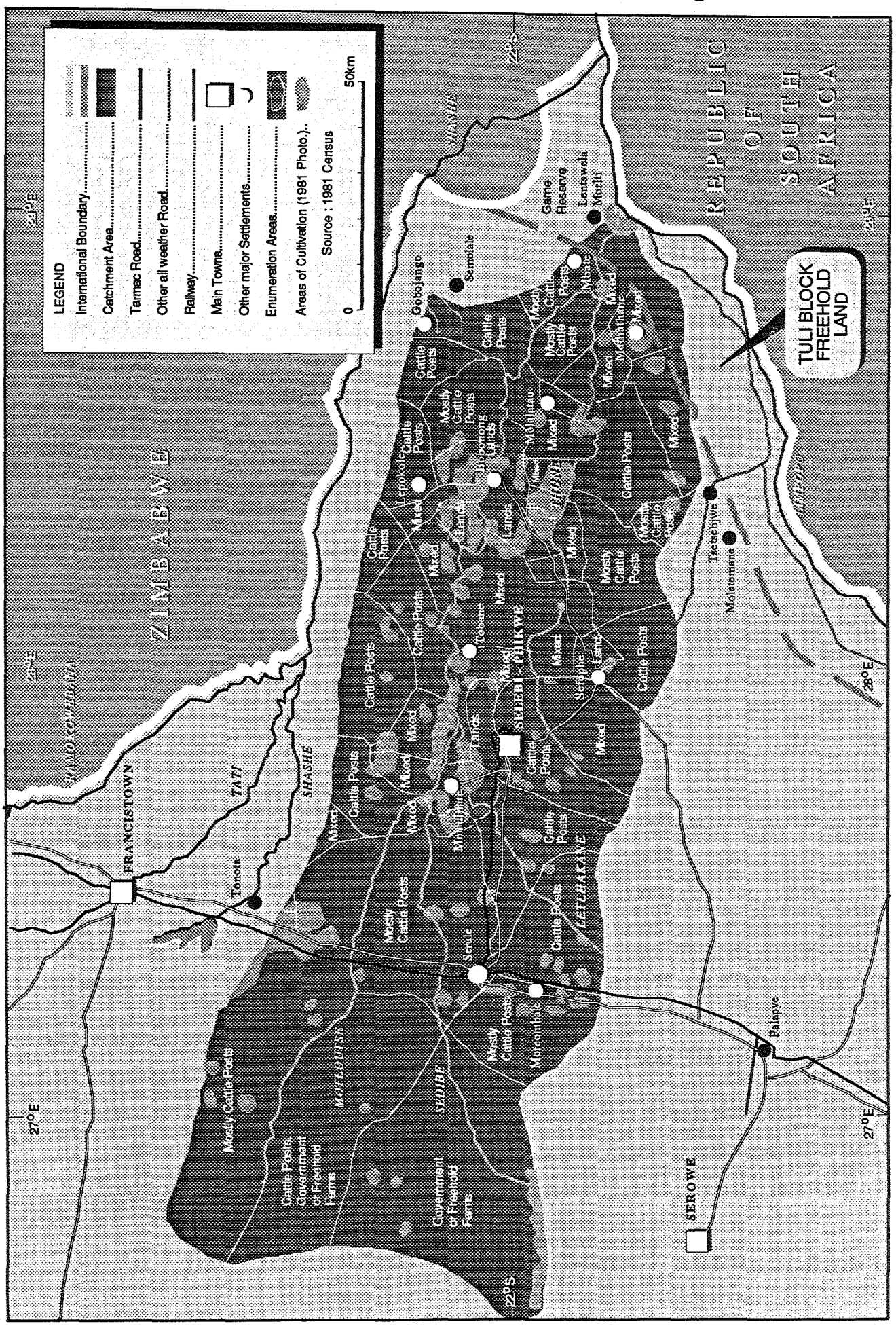


Figure K2.9

Catchment Water Supplies

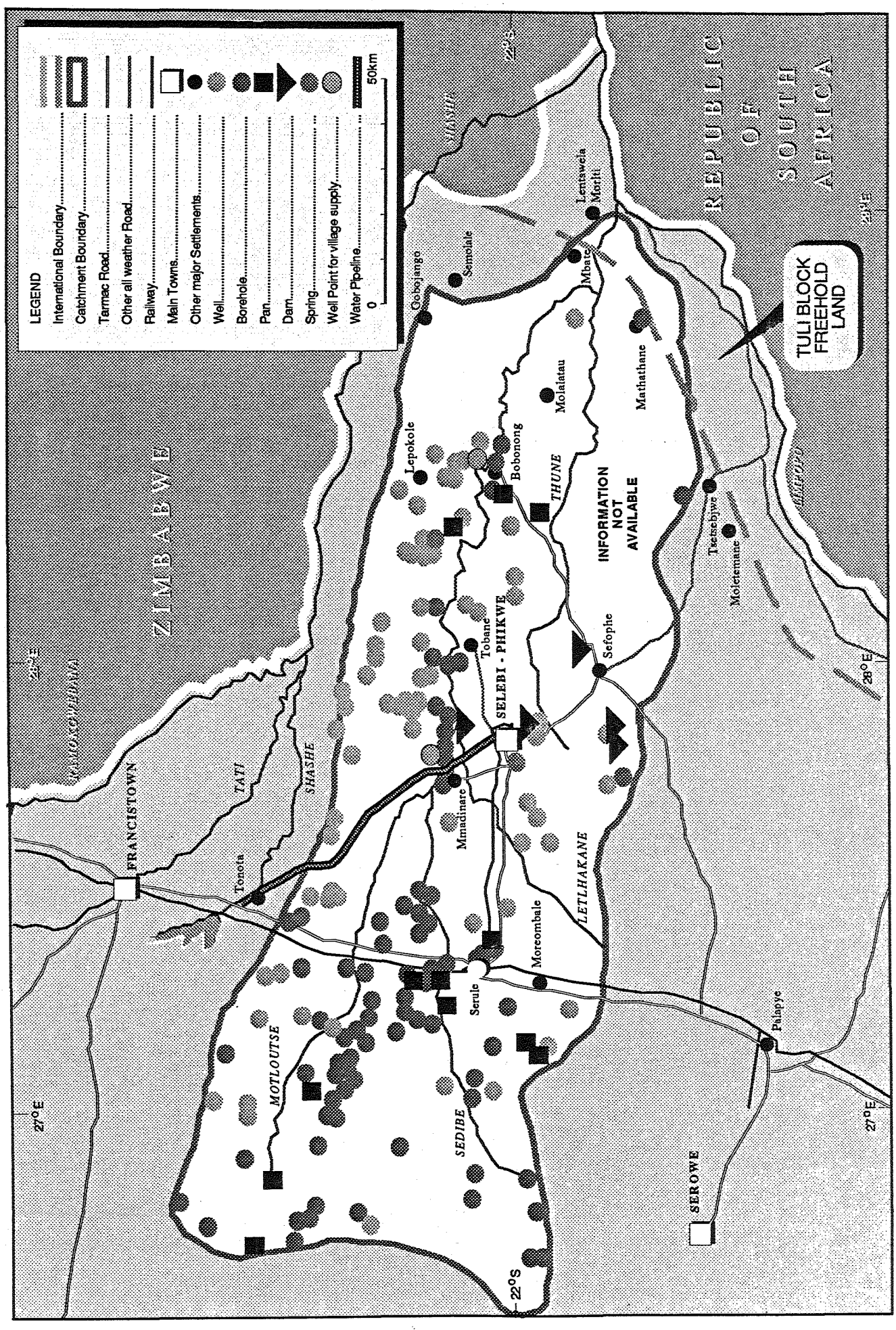


Table K2.3

Number of Water Users on the River 1981 – 1995

	1981	1987	1989	1991	1995
Rural Pop	370		411		444
Mmadinare	11 175		14 862		17 768
Tobane	2 942		3 266		3 530
Cattle		10 700		10 700	10 700
Sheep/Goats		11 500		11 500	11 500
Donkeys/Horses		2 400		2 400	2 400
Irrigation			26 ha	67 ha	

Notes : Human population figures are estimates for the height of the dry season based on CSO projections from the 1981 census adjusted as for Table K – C1.1. Livestock figures are from 1987 Vet. Dept records which are known to be the highest attainable figures prior to the November 1987 drought losses.

These figures have been converted into water demands using established criteria for consumption and are shown in Table K2.4 for 1989 and 1995, the likely date that the Letsibogo dam will commence impoundment.

Table K2.4

Estimates of Water Demands by Users

Item	l/head/day	1989 No	1989 Use m^3/day	1995 No	1995 Use m^3/day
Rural Pop	20	411	8.2	444	8.9
Mmadinare	20	14 862	297.2	17 768	355.4
Tobane	20	3 266	65.3	3 530	70.6
Cattle	45	10 700	481.5	10 700	481.5
Sheep/Goats	10	11 500	115.0	11 500	115.0
Donkeys/Horses	15	2 400	36.0	2 400	36.0
Irrigation		26 ha	1 482	67 ha	3 819

The spatial distribution of the supply is critical with certain areas being likely to become constrained as rival demands compete with each other. As can be seen from Table K2.4 the use of water for informal irrigation and its planned development between now and when the dam is due to impound is by far the major user of water. This is a process that is expected to happen irrespective of the development of a dam on the Motloutse.

The whole issue of water demands from the sand river has been studied using a computer model of the sand river and is dealt with in Annex B. From the environmental impact standpoint the key objective of this study to ensure that this vital riverain resource is not adversely affected by either the dam or by any present or future irrigation pumping. Should this policy not be implemented strictly then the downstream economy may be at risk. Not only does a significant proportion of the population depend on the sand river aquifers for

domestic water, but also the livestock economy and the cultivators whose ploughing stock (donkeys and cattle) water at the river. The flora and fauna, depending on the same aquifers could also be affected. The repercussions of not meeting these demands could have far-reaching adverse consequences on a potentially sustainable resource base for future generations. The real value placed on water stored for urban and industrial consumers must be balanced against the needs of the local environment and rural economy.

K2.5.3 Ecological Dynamics

The key ecological features of the system involve the relationships between soil type, soil moisture availability, plant growth, plant nutritional quality, and herbivory. Some processes such as rainwater runoff, sediment transport by overland flow, and herbivory, link spatially discrete areas and so act to transfer impacts across the catchment. The productivity and dynamics of the herbaceous vegetation needs emphasis because this resource is the base of most of the agricultural economy of the region. Changes in the timing and spatial location of grazing by domestic livestock caused by the loss of bottomland grazing areas would be among the most important and long lasting of the impacts of the reservoir.

Taken as a whole the following discussion highlights areas which are not just contributors to the degradation of the soil resources, but potentially to the absolute degradation of life itself. If the top soil continues to degrade, the region's capacity to support human settlement will decline. The implications for local people, the vast majority of which depend directly on the land, will be the very real prospects of increasing risks of starvation and deprivation. It is not believed unrealistic to suggest that, unless urgent attention is given to some of these issues, major environmental change and human disasters could occur by the turn of the century. If the situation were to occur no amount of investment in rehabilitation could recover the quality of environment which the Motloutse catchment still has to offer it's people. There is increasing evidence that the process of climatic and environmental change and potential desertification is already well advanced. Striking examples can be observed in the catchment of situations where poor management has led to the rapid removal of surface soil and the exposure of the underlying bedrock. These are mentioned later in this section.

The structure and dynamics of the vegetation in semi-arid ecosystems is determined primarily by moisture availability and secondarily by nutrients, herbivory and, occasionally, fire. The amount of moisture available to plants depends on the amount of rainfall; the duration of the rainy season; soil depth; soil texture; and position in the landscape. Rainfall in eastern Botswana is generally low, highly seasonal, and variable both between and within years. Most of the rain falls in short duration, high intensity storms in which the amount of rain falling often exceeds the short term infiltration capacity of the soil. The rate of infiltration depends on soil texture, soil surface conditions (particularly the amount of litter cover and soil capping), and the amount of antecedent soil moisture.

In general, sandy soils have higher infiltration rates than finer texture soils but they also hold less water at saturation. Infiltration in sandy soils is restricted if the soils are compacted or have a well developed surface crust formed by the displacement of finer soil particles under raindrop impact. Infiltration is also affected by the extent of herbaceous plant and litter cover. Much of the rain falling on sandy soils (other than shallow, rapidly saturated profiles) is absorbed and becomes available for plant growth. The annual yield of grasses on sandy soils therefore varies little between years and is poorly correlated with concurrent rainfall. The limited supply of nutrients may be the main factor limiting grass productivity in sandy soils.

In contrast, on clayey soils, infiltration rates are slower, more rainwater runs off, and more water is generally needed to wet the soil before the plants can begin growing. The effects

of variations in rainfall amount are therefore more marked on clayey than on sandy soils. The annual yield of grasses, for example, is closely correlated with the amount of rainfall. In a region with highly variable rainfall, such as eastern Botswana, wide fluctuations in grass yield also occur. Production in wet years can be very high (because of the generally higher fertility of clayey soils), but during dry years production can be almost nil.

Variations in soil texture, depth, and topographic position alter these relationships at the level of the landscape. Many of the upland soils are shallow and sandy, and therefore have a low water holding capacity. Consequently, during rainstorms the soil profiles rapidly become saturated, and the excess water runs off, transporting with it topsoil and nutrients. These are deposited in upland drainage lines and depressions, or in bottomland sites. As a result, some sites receive water and nutrients from surrounding areas and are able to remain productive, even in relatively dry years. These key resource areas include bottomland sites on alluvium, the deeper soils on pediments, and upland drainage lines. Conditions for plant growth on these sites is better, the plants are generally more productive, often more nutritious, provided that the site is not too wet, and relatively resilient to grazing.

Soil nutrient status also affects plant distribution, growth and quality, although nutrients are probably less limiting than water in this region because of the low rate of weathering and leaching. Nevertheless, there is a broad association between Acacia – dominated communities and the more eutrophic soils found in the bottomlands, and mopane and mixed broad leaf woodlands and mesotrophic to dystrophic upland soils. Figure K2.10 shows the general vegetation zones within the catchment.

Interactions between vegetation, herbivores, and fire parallel these vegetation – soil relationships. Fire is an uncommon event in semi – arid savannas because there is usually insufficient herbaceous production to support a dry season fire of any significant intensity. A reduction in the dry season standing crop of grass by grazing further reduces the probability of fire. Sufficient grass to fuel a fire usually only accumulates after one or more seasons of above – average rainfall, particularly if these coincide with low cattle numbers, for example, after a severe drought.

The generally sandy and loose – grained nature of the surface soils means that the quantity and quality of vegetation cover and rooting density are important in reducing the rate of surface run – off and limiting the removal of surface materials by wind or water erosion.

At the Mmadinare river crossing point, and at certain major watering and settlement points found on the Sedibe and Motloutse (often associated with permanent pools behind major rock bars and rapids), recent removal of the riverine vegetation has led to the degradation of the river bank and the consequent stripping of the alluvial sediments. Similar processes are operating where riverine vegetation is being bulldozed indiscriminately to create access to the river for sand extraction to supply the BCL mine. While less dramatic, the removal of riverain vegetation by hand and the enclosure of riverain farm plots also requires control if this erosion hazard is to be avoided. This could be achieved most effectively through conditions in the lease arrangements and a clearly stated land use policy for the riverain zones and the main drainage lines. This is discussed in Section K7.2.

In the upland area, poorly designed roads, clearance of woodland for expanding cultivation on sensitive soils, and overgrazing/browsing are contributing significantly to the rate and extent of erosion induced by human activity. A major cutline linking Tsetsejwa to Mathathane and on to the Thune/Motloutse confluence has removed the mopane cover across a 50 m swath. Where this enters into the clastic Karoo sediments the cutline is now a well eroded stream bed while no erosion is evident at the side of the track where the vegetation remains. The Tobane river bridge crossing provides a good example of downstream erosion caused by the speed of water and sediment transmission. The structure impedes the flow of water

which promotes sediment deposition upstream. The water flowing over the structure is then carrying less sediment than it's carrying capacity. Sediment is picked up again immediately downstream causing erosion. Major bridges, like that crossing the Letlhakane to Mmadinare, tend to confine river flow. This increases the water velocity which enhances the river's capacity to pick up sediment and thus to erode susceptible banks and sediments downstream. Deposition of major driftwood in the river channel produces a similar result.

Although a long history of cultivation in the catchment is evident in the archaeological remains, current pressures of population growth, ARAP subsidies and the support of rural activities by urban wage earnings are promoting vegetation clearance into woodlands probably untouched for arable use before. With little vegetation cover available during the early rains, which is before any field crops have become established, rates of surface run-off and erosion will increase the more that the woodland cover is cleared. On the lands preferred for rainfed cultivation, sandy topsoils allow rapid penetration of water into the soil profile. Once sheet erosion starts the removal of the surface cover limits infiltration and promotes more run-off and erosion. As the demand for the less erodible plateaus and ridges becomes over-subscribed and these spaces fully occupied, farm clearance is expanding onto slopes and steeper gradients far more susceptible to erosion. Similarly, if the pressures to adopt "modern farming" methods continue, real risks of increasing the pace of erosion do exist. The evidence now accumulating from studies in many developing countries suggest that an immediate and unreserved re-evaluation of farming systems is required since the political and commercial framework within which the "modern farming" systems have developed are often not appropriate to the specific environments in which they are being promoted nor do they pay enough attention to their future consequences and sustainability.

This speeding up of the degradation process will also be enhanced as demands for fuelwood and timber exceed the regenerative capacity of the surrounding woodland. To date the collection of wood has generally focused on clearing dead wood or the regrowth of suitable species. The removal of the dead wood is in itself preventing the on-site recycling of valuable nutrients and debris. The growth and concentration of population demands in the major villages of Mmadinare and Bobonong and the urban areas of Selebi-Phikwe are each creating zones of increasing influence. These zones are visible in the aerial photography around villages, around Lands settlements and around cattle post sites.

Although the commercialism of pastoral activities for trade exports dates back a century (see Appendix K-B) it has only really advanced with the price incentives and marketing developments associated with the EEC export markets and the modern abattoirs. Overlain onto the traditional socio-economic importance of stock to local people, and the exploitation of range and water resources by the large stock owners, over grazing has denuded or degraded much of the grass and browse ecology within easy access to watering points. This has particularly affected the cattle post rangelands within 1 km of the main rivers which is also the zone where developing gulley erosion is most evident. The presence of this gulley erosion may also reflect the removal of vegetative cover higher up in the side catchments. An analysis of erosion hazards was carried out by the University of Botswana on Landsat Imagery and the assessment overlay for the catchment is shown in Figure K2.11. However, it should be stated that not all the areas identified as being highly degraded are due to human or livestock activity, but can reflect natural features which inhibit vegetation cover, such as shallow rock outcrops and sodic soils.

K2.5.4 Grazing Systems

The organisation and management of grazing within the catchment has to be viewed against an historical backdrop of social and political development. The management of cattle posts (see Appendix K-B) and the organisation of livestock resources is a highly dynamic process

Figure K2.10

Catchment Principal Vegetation Zones

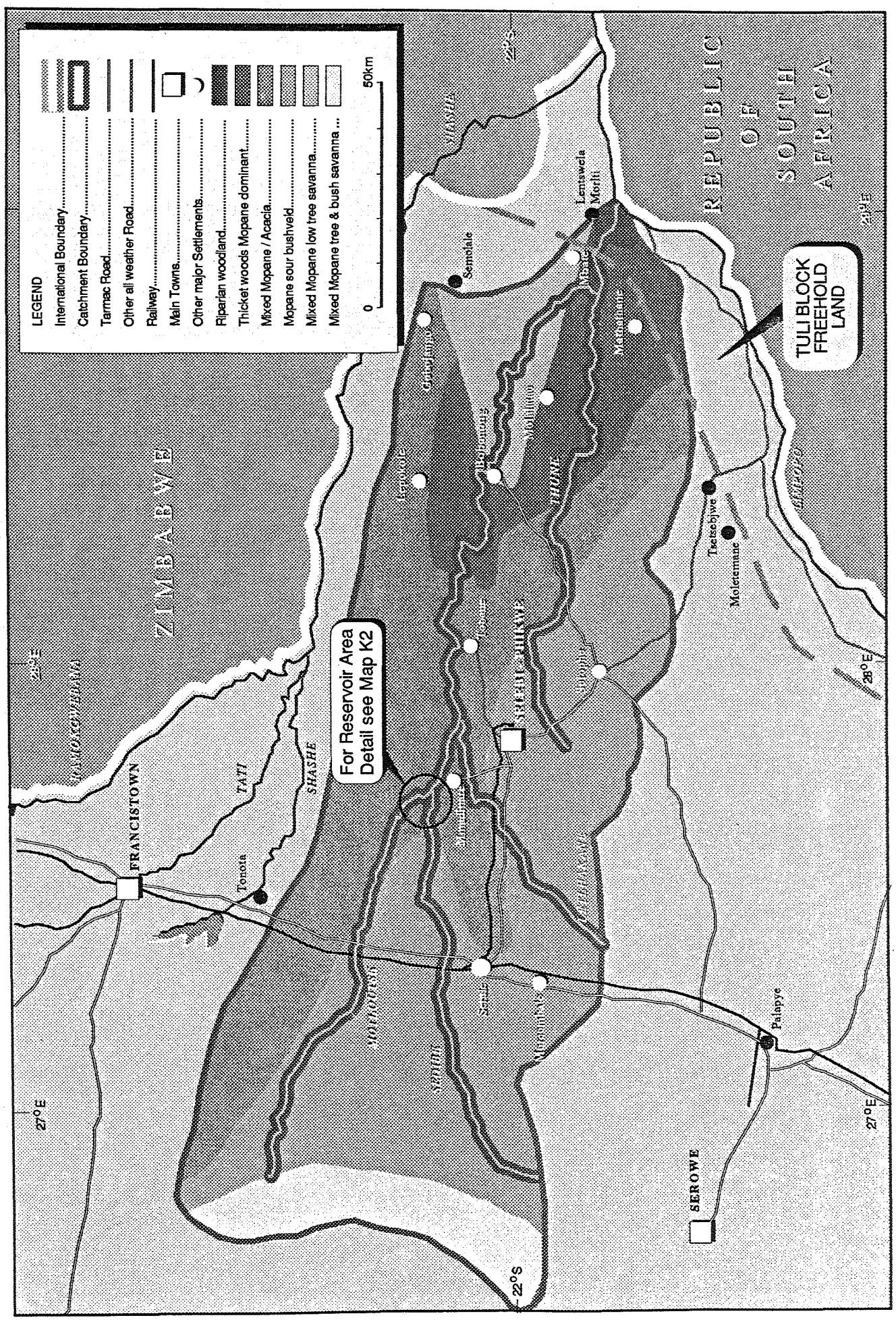
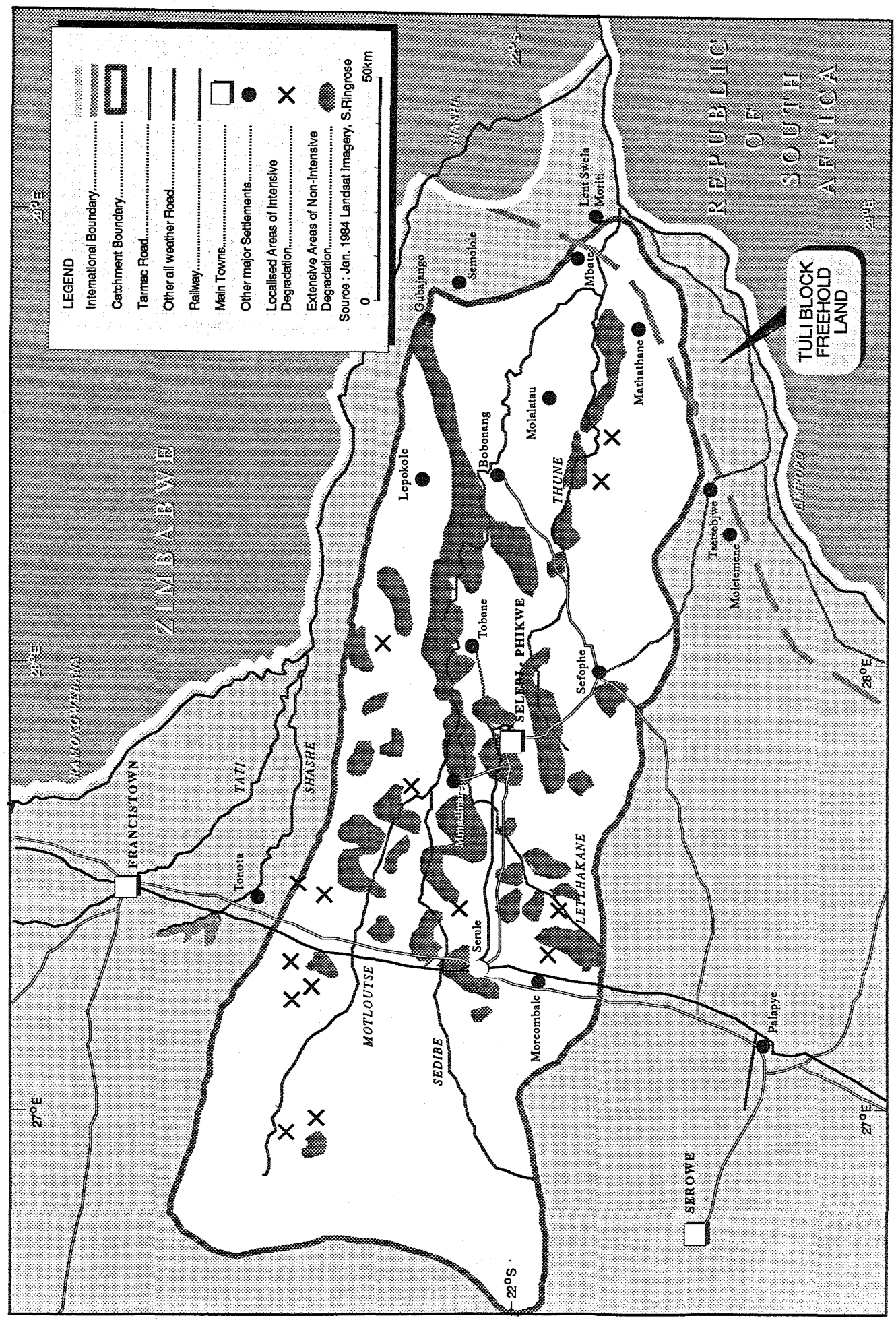


Figure K2.11

Catchment Erosion Hazards



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that responds constantly to changing economic, social, climatic and vegetation factors Concepts, such as carrying capacity and planned livestock grazing management, have little value, given the scope and dimensions of the real world in which the local livestock exist. A full analysis of the context within which Botswana's livestock sector has developed, and the problems of distribution of ownership, grazing management, veterinary policy and marketing controls, is beyond the scope of this report, but certain key features of the system are highlighted in this study.

The social and economic organisation of pastoral and agro-pastoral system across Africa have undergone profound changes in recent decades. Some of the most important forces of change include the weakening of traditional political control, the encroachment of agricultural settlement, the shift from subsistence to commercially orientated systems and the increasing dependence of pastoralist communities on the market values of the stock. In drought years, as the prices of cereal crops rise and livestock fall, it has become increasingly difficult for small scale producers to remain viable. Many are forced into clientship arrangement or are reduced to labouring as hired herders. Others are forced to move out of the livestock sector altogether and migrate to the fringes of the urban economy.

Absentee and commercial ownership have become increasingly common features as urban based entrepreneurs and civil servants, major rural livestock producers and even sedentary farmers seize upon the opportunities of buying stock when prices are low. This shift in ownership patterns has important ramifications. Absentee ownership and hired herding can result in less respect for the maintenance of the natural environment. Absentee owners are removed from direct contact and appreciation of the state of the environment. Ex-herders, now looking after stock that are not their own, care less about the maintenance of this property and its productive environment than if they were their own.

Given the ecological dynamics and variability of soils, moisture and vegetation discussed above, livestock browsing and grazing pressures are not spread uniformly across all the landscape and vegetation types. Some sites are heavily impacted, others hardly at all. Bottomland sites and drainage lines are favoured more than upland sites on shallow or stony soils because of the higher plant production and better quality. The grazing systems also reflect a dependence on the distribution of watering points associated with the main rivers/streams and the few groundwater wells. This places special pressure on the grazing resources within walking distance of them. Flooding of the bottomlands would therefore result in the loss of a significant area of these key resources. Moreover, because of the differences in grazing capacity, the loss of bottomland sites cannot be compensated for by access to an equivalent area of upland. Neither are the bottomland and upland sites two independent production systems which can be substituted for each other (with appropriate adjustments in the size of the grazing areas to accommodate the differences in productivity). The systems are part of a single livestock production system, linked through the seasonal movement of cattle and, to a lesser extent, other livestock.

Most livestock are concentrated in the bottomlands during the summer months where, as plant quality and production is higher and the grasses are generally resilient to grazing (since most of them are able to grow despite being eaten), animals are able to gain weight. In general the small stock and equines continue grazing and browsing around the river and its immediate terraces all the year round.

With the onset of winter, plant growth ceases and the standing crop of forage gradually declines. Cattle in particular start to range more widely in search of food and are moved by their owners into the upland plateaus and ridges where there is still grass largely ungrazed as few domesticated animals feed in the uplands during summer. Although the nutrient quality of the upland grasses is below maintenance levels the animals supplement their diet with protein obtained from tree leaf litter, particularly that of Colophospermum

mopane. The distance that the animals can range into the uplands is constrained by the lack of surface water. Consequently the animals do not usually move further than about one or sometimes two days walk from watering points located along the rivers. They will remain there through to the end of the flush of upland grazing brought on by the first rains. Late in the dry season, as the upland grazing becomes scarce, the cattle rely increasingly on browse, and particularly mopane, which is amongst the last of the trees and shrubs to loose its leaves.

Because the uplands are mostly grazed when their grasses are dormant, there is no direct feedback between grazing pressure and grass growth as the grasses are still able to recover in summer. The generally unfavourable environment for growth in the uplands means that grasses are therefore less resilient to grazing and particularly if grazed all the year round. The lack of regrowth during winter means that there is a gradual decline in grass standing crop with time. The earlier that the animals move up into the uplands in winter, the sooner they begin to reduce the grass standing crop and the quicker food shortages emerge.

The differences in forage production and quality between different land units, and the seasonal movements of livestock, among the patches of this mosaic, enables the animals to offset partly the seasonal and inter-annual fluctuations in forage availability and quality. It is doubtful if, in the long run, either the uplands or the bottomlands could support the same numbers of livestock alone as a system in which both are used alternately.

A major delay in the first rains can have disastrous consequences on the survival of cattle, as was witnessed in late 1987 when the available grazing and browse could not sustain the grazing pressure. Since the winter grazing areas are already distant from the watering points the cattle became exhausted and high mortalities resulted. In the catchment as a whole the deaths amongst cattle averaged 54%, but in some locations 100% losses were experienced with devastating economic implications for the families concerned.

This scenario also sets up a new dynamic, with grazing pressure falling in the following season and a major restructuring of the cattle post distribution and of livestock using mafisa arrangements. The mafisa system is used by large stock owners to spread the animals and risks as widely as possible, and by small stock owners who borrow animals to maintain their stakes in agro-pastoralism, dairy production and as a means of starting new herds. In 1988/89 many cattle posts were seen to have been abandoned as a result of the losses. But it important to recognise that as herds begin to be re-established these abandoned units may come back into operation. Figure K2.12 shows the cattle density throughout the catchment as it prevailed before and after this event.

A second grazing system does exist in the catchment where alternative water supplies exist. Where shallow wells can be established away from the riverain strip it allows owners to avoid the heavy grazing pressure exerted on the riverain resources. To an extent it also allows them individual control over the grazing resources that are in walking distance of the water supply points. However, most of these wells are not perennial and movement to the riverain strip for water again becomes overriding. The owners of perennial well points face the problem of overuse of the surrounding grazing if it is being grazed throughout the year. This again encourages them to move their stock to the riverain strip during the rains, thereby allowing them to exercise some degree of rotational grazing.

With the encroachment of farms and development leases (mining, sand extraction, reservoirs, villages) into these bottomlands there is a change in the communal access of stock to their best grazing and browsing areas and also an absolute decline in the total seasonal grazing area available. As a result, often unresolvable disputes over land and conflict between customary rights and land development pressure are likely to become more commonplace.

Figure K2.12

Cattle Densities 1987 / 1988

The breakdown of the traditional agro-pastoral system over the last century (see Appendix K-B) has had major repercussions on the potential for either individuals, or the community, to coherently manage their livestock and grazing resources. Political changes aside, which directly affect the role which the community and its own institutions can exert in management, one fundamental constraint relates to the level of herding skills and capacity now available. The advent of schooling and modern lifestyles has left the cattle post system denuded of children once brought up in an apprenticeship environment. Many herds and flocks are now left to graze unsupervised and only at watering times, and during times that the animals are rounded up to count or administer veterinary treatment, will labour be brought in. The animals often take themselves to and from the kraals, and dogs are trained from births to stay with the stock. The lack of supervision raises many management problems. Controlled grazing becomes impossible, losses from predators or from animals getting trapped in mud (as occurs at Shashe reservoir) can occur undetected, thefts are more prevalent, searching for strays becomes difficult and time consuming, and an intimate and evolving relationship between man, beast and the environment is lacking. The values system, once directed towards the maintenance of the quality of the natural and livestock resources, are not being re-kindled in the new forms of education and youth training in the society. It is in the schools dealing with children in their formative years that there is an immediate need to instill these value systems. If this is not confronted it is difficult to see how there can be a sufficiently widespread level of public concern and commitment to redressing the environmental balance in favour of methods of resource use and management which can be sustained and enable a healthy environment to be handed over intact to future generations.

A number of social issues were also apparent in the field surveys. Many amongst the modern generation, while interested in the asset value of livestock and the need to amass stock to pass onto children, appear to regard life on the cattle posts as less socially desirable as a lifestyle and survival orientated around urban based activities. Those who remain reflect a number of different minority groups in society. There are the poorer livestock owning families who have no choice as to their economic and employment strategies. There are those who are dedicated and skilled agro-pastoralists and dairy producers. There are the mentally ill and those who become physically disabled at the cattle posts and cannot return to the villages where, in addition, they would face social barriers. There are also the individualists in society who prefer the relative isolation and life free from human pressure and who derive pleasure from the quieter life with their animals.

The historical links with the Basarwa as clients continues in their positions today as hired herders paid with stock or in cash and kind. With the increasing pressure on the Basarwa to settle in sedentary communities they are regaining status as independent agro-pastoralists in certain areas.

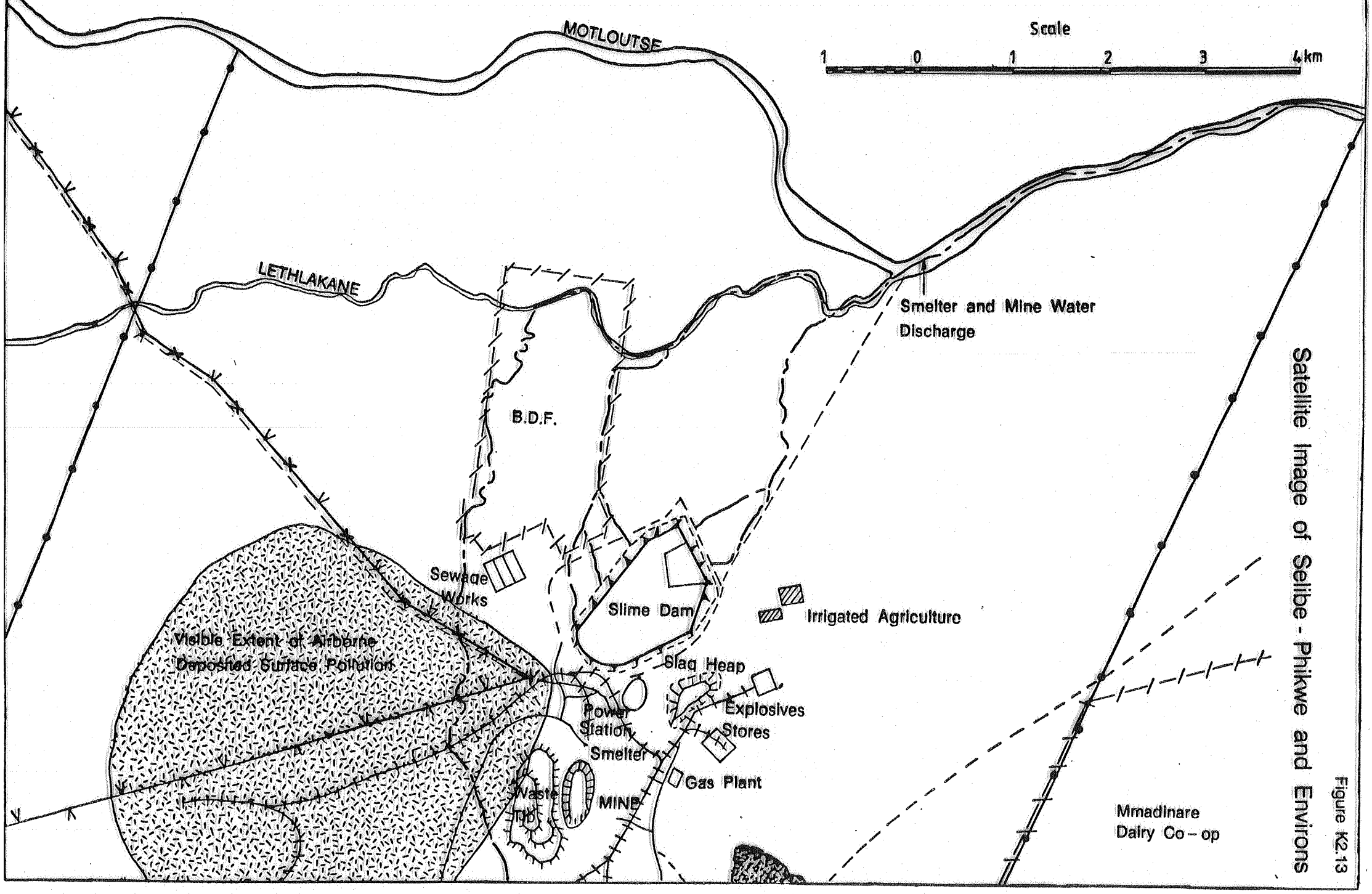
K2.5.5 Urban and Industrial Resources

The primary industrial development in the area is mining and processing of copper and nickel at the BCL works in Selebi-Phikwe. However, other mining and prospecting leases exist and are shown in Figure K2.6. Until the recent increase in the world prices for nickel the BCL operation was running at a significant financial loss. The extent of the available ore body was also uncertain and the life of the mine was projected to be only 20 years i.e. until 1997. However, recent assessments suggest that local ore bodies may be more extensive and new nearby prospecting areas are now also being investigated. It is also clear that the ore processing facilities would continue to operate on contract taking in ore from other mines. The decline of activities at Selebi-Phikwe are now being considered over a much wider time horizon of perhaps 40 years. The development strategies employed in setting up the mine have already had major impacts from both the expropriation of land resources,

aerial pollution from the smelter and power station and from the contamination of both river and groundwater. These effects can be clearly seen in Figure K2.13.

In attempts to diversify the economic base of Selebi – Phikwe considerable efforts are being made to encourage new industrial investment in alternative industries. Many of these are service industries stimulated by the mine activities, but new units are developing, such as fish and vegetable processing and paint and carpet manufacture.

The growth of building, both in Selebi – Phikwe and the major villages, is stimulating demands for building skills, materials and brick works. Building clay and sand are extracted from selected locations along the Motloutse and Letlhakane. By far the largest use of river sand is by the BCL mine for use as a flux in the smelter. This is extracted under lease by a single sub – contractor. Dam development will have a major impact on the resource and is discussed further in Section K3.3.5 and Appendix K – H.


MOTLOUTSE
Scale
1 0 1 2 3 4km
LETHLAKANE
Smelter and Mine Water Discharge
B.D.F.
Sewage Works
Slime Dam
Irrigated Agriculture
Visible Extent of Airborne Deposited Surface Pollution
Slag Heap
Explosives Stores
Power Station
Smelter
Gas Plant
Waste Tip
MINE
Mmadinare Dairy Co-op
Satellite Image of Selibe-Phikwe and Environs
Figure K2.13



Photocopy of Satellite Image
(originals will be included in Final Report)

CHAPTER K3

UPSTREAM AND DOWNSTREAM IMPACTS

K3.1 General

The following chapter looks at the main upstream and downstream impacts following on from the studies originally carried out during the scheme identification phase.

K3.2 Upstream Impacts

K3.2.1 Erosion Hazards and Sedimentation

The erosion hazards identified vary with location and reflect changing land use practices, vegetation cover, livestock grazing and watering point distribution, climatic factors (such as storm intensity and frequency) plus local relief and geology. The natural conditions which prevail are conducive to active erosion. This is mostly sheet wash, but gulleys occur close to the main river channels and watercourses. Progressive removal of both tree cover by cultivation and groundcover by overgrazing, particularly towards the end of cycles of drought, is an important factor contributing to soil erosion in recent decades. The widespread distribution of shallow and rocky soils indicates the fragility of the available topsoil in many areas. Further aspects are discussed in Appendix K-E.

The impact of erosion and sedimentation on the Letsibogo reservoir is likely to be moderate in the short-term. About 95 percent of the reservoir catchment is still vegetated and only about 4 percent appears degraded, this being related to outcropping of the Karoo sandstone. The susceptibility to erosion of the upstream catchment is moderated by the flat terrain on the southern hinterland, where part of the catchment is often ineffective in providing direct run-off to the river. The northern section is more incised and with a drainage pattern that is well developed. Around the main road from Serule to Francistown the influence of the Tonota Lands begins. If these cleared and cultivated areas were to expand further into the Motloutse catchment and were farmed with poor land management techniques, enhanced erosion could increase the rate of sedimentation. To assist in the monitoring of the erosion hazards a survey programme is recommended which is discussed further in Section K9.9.

K3.2.2 Agricultural Development

The most significant users of land upstream are livestock and some wildlife. There is a veterinary quarantine area at Sese on the main Francistown road. The Tonota Lands have few fully commercialised farms and farmers make little use of fertilisers or agro-chemicals. There were no plans identified for major agricultural development in the upstream catchment. Irrigation development in the Tonota Lands is being considered as part of the planning for the future use of the water from existing Shashe Dam. Land use changes and future agro-chemical use related to this would not affect the Letsibogo reservoir as these irrigation areas lie in the Shashe catchment.

Immediately upstream of the reservoir area is a dairy which was abandoned in the early 1970s after exports of cream to Mafeking were discontinued. This was a modern cement and block building supplied with hand operated separators which collected milk from a wide area between the railway and Mmadinare. Further dairies operated downstream near Tobane and Bobonong. No contamination source from the upstream site was noted.

The upland zone between the two rivers has very few cattle posts located within it. The major cattle post concentrations are along the river at Madibeng, Sedibe and Butetela, where reliable and often perennial supplies of water are available from the river. The hinterland forms the main winter grazing reserves for these cattle posts, and is a zone in which the remaining wildlife are to be found. The impact of the reservoir will be to intensify the use of the vegetation resources of this area. This changing use of resources on upland slopes and ridges will enhance the capacity for erosion and could create peripheral stream sedimentation problems for the reservoir. Methods to minimise these risks are discussed in Section K8.7.

K3.2.3 Small Dams

The present distribution of small dams in the Motloutse catchment is shown in Figure K2.9. This indicates that there are no existing small dams in the catchment upstream of the proposed Letsibogo reservoir. The only potential dam sites which have been identified are those studied by Gibb (1977). These are both small dams on tributaries of the Motloutse and major sites on the main river numbered 20 and 24 which are shown in Figure K3.1. There is no known programme to develop these. Restrictions on the development of upstream water supplies would not appear to be an issue.

K3.2.4 River Profiles and Sand Resources

Detailed data from which to model reservoir operations, river dynamics and upstream sedimentation characteristics after dam development, are not yet available. Over the life of the reservoir the natural river channel will receive increased deposition of gravel, sand and silt. This will affect the river profiles immediately upstream. Since the annual silt load will no longer be carried downstream with the floods, the quality of sand downstream, which might otherwise be taken out for economic uses, will also be affected. Some deposition in certain areas will create mud banks which will make access to water more difficult for livestock. Immediately upstream of the reservoir the perennial pools associated with the Madibeng rapids should be unaffected by these processes due to the protection afforded by the major rock bar.

K3.2.5 Urban and Industrial Development

There are no known plans for urban or industrial development upstream of the dam site. As there are no villages the need for urban planning or pollution restrictions will not arise.

K3.2.6 Livestock and Wildlife

The pivotal role which the sand river aquifer plays in providing for the watering of livestock and wildlife means that deposition and run-off of faecal material can be expected to wash into the reservoir. These regular flushes of biological material will provide a source of nutrition from which the reservoir's aquatic biology can develop. This will have implications as to the potential for fisheries, algal blooms and eutrophication. Letsibogo would receive run-off from up to 5 480 km^2 and directly from over 70 km of the Motloutse river bed where livestock and wildlife water. The proportion of animals which currently use the reservoir area for watering is small compared to the total numbers upstream.

The major upstream impact of the reservoir depends upon the policy adopted to allow livestock to water from the reservoir. If livestock were excluded from the reservoir area and

Figure K3.1

Location of Possible Dam Sites



no alternative provisions are made then stock are likely to relocate upstream of it on the Motloutse and Sedibe. This will concentrate additional animals in areas already exposed to over-stocking. Relocation downstream is restricted by the proximity of the residential areas of Mmadinare and the extent of its Lands. The provision of alternative water supplies around the fringes of the reservoir or outside any fence would not ameliorate the loss of the riverain grazing areas which at present is the major constraint. If stock continued to graze in the immediate vicinity of these watering points throughout the year then rapid degradation of the surrounding upland range would occur. Thus, even in this situation, there will be pressure for these stock to move into the upstream riverain areas.

There is considerable influence by elephant in the hinterlands of the Motloutse and the Sedibe. While seasonal movements of elephant occur into the Motloutse river from Shashe, Zimbabwe and Mashatu, a number of small herds, perhaps totalling 60 head, entered the area between the two rivers in 1982. One small irrigation unit has recently been abandoned and a number of cattle posts have been relocated as a result of damage caused by these elephant. At the time of the study Wildlife Officers were understood to be investigating the means by which these elephant could be moved out of the district. These, and other wildlife within the zone between the two rivers (see Appendix K-E), could form an important amenity resource to consider as part of the overall reservoir developments. However, if a policy to fence the reservoir is adopted then considerable damage and high maintenance budgets will likely result unless electrified fencing is used. These issues are discussed further in Chapter K8.

K3.3 Downstream Impacts

K3.3.1 Water Supplies

Surveys along the river bed confirm that the river is used for water supplies throughout its length. The users include villages, Lands and cattle post settlers, large and small stock (including ploughing animals) and wildlife. The main villages are Mmadinare directly downstream of Letsibogo dam site and Tobane and Bobonong respectively. The present and future water supplies to these villages is discussed in Annex E. In the case of Mmadinare its water supply will be directly effected by construction of the dam and it is being proposed that a new treated supply is provided from the reservoir with a branch off the raw water main to Selebi-Phikwe to a storage bank on the high ground directly south of the dam site, from where the water will gravitate to the village. Irrigation users, though few in number presently, are increasing and are concentrated between Mmadinare and Bobonong. Album Drawing Nrs 2 and 3 show the distribution of the major infrastructure involved.

The sand river gives a permanently reliable water supply for all these users providing demand does not exceed the storage of each confined section of river aquifer. The major concentrations of demand exist around the villages of Mmadinare, Tobane and Bobonong and over-use could occur eventually in sections where irrigation and village water supply pumping is being developed. The proposed regulation of use of downstream water is discussed in Chapter K7 and monitoring requirements discussed in Chapter K9.

Livestock, wildlife and rural settlers along the main river do not appear to face shortages, even in the face of severe drought in the catchment. The extraction points for water are usually where the depth of sand is minimised and where rock bars provide back-up. Wells are dug by hand and the sides supported by sinking a barrel into the sand and sometimes with additional timber shoring. Animals continue to drink from exposed pools into the dry season and then, either dig into the sand themselves, or are provided with water bucketed from the wells into drinking troughs.

Downstream of the Letlhakane confluence the continual discharge of waste water from the sewage works and mine provides a small base flow and recharge to the river aquifer. This flow extends over a variable distance downstream. Surface flow through to Tobane is observed at times. Minor flow visible in the winter at Bobonong would appear to rise from springs located in the Lepekole hills to the north.

The ease of access to the river water, and its reliability, is the foundation of the rural settlement patterns and economy. Although upland watercourses and boreholes are used, many of these are liable to dry up, particularly to the north and on the watershed between the Motloutse and the Shashe. Further dependence on the Motloutse is caused by the shortages of grazing which occur elsewhere. Government boreholes developed on the Shashe river when the veterinary cordon fence was erected provide adequate water but, when grazing is depleted around these water points, stock can be moved across to the Motloutse to be grazed and watered.

It is clearly important that dam development on the Motloutse should not disrupt the access of animals to water supplies or grazing resources. Not only is the pastoral economy directly dependent on the sand river aquifer, but also the cultivators who water and graze their ploughing animals at the river.

To obtain a clearer indication of the effect of Letsibogo dam on the sand river aquifer, a computer model of the sand river has been developed. This is described in Annex B. With the present level of extraction and assuming that the outflow from the sewage works and BCL Mine will in future be stopped, the model has shown that, if Mmadinare's present water supply from the river sands plus small irrigation plots for 3 km downstream are supplied from Letsibogo, there will be no reduction in the water levels in the sand river. This is primarily due to rainfall on the catchment downstream and the contribution of the Letlhakane in replenishing the aquifer. However if unregulated irrigation development continues as occurring at present along the river, a rapid seasonal depletion of the available water stored in each confined aquifer in the river bed could occur. This can be avoided by an integrated programme of resource management which provides a database for the Water Apportionment Board linked with conditional leases on the issue of irrigation plots by the Land Board. This is dealt with in more detail in Section K7.2.

K3.3.2 Agricultural Development

The only major downstream development project identified is the BDC Talana Farm which is expanding its irrigation area for cotton, maize, wheat and potatoes in the Tuli Block. The main source of this water is from the sand river, with a drainage gallery, and from boreholes. The effect of any upstream dam on this supply was investigated during the Phase 1 studies and discussed in the Scheme Identification Report (MacDonald, 1988). It was established that the volumes of water abstracted at Talana far exceed the supposed recharge from throughflow through the shallow Motloutse sand aquifer by a factor at least 10 times, indicating that the aquifer is much larger than previously supposed and possibly supplied from regional groundwater. It should also be noted that the catchment area to Talana Farm is nearly 3 times the Letsibogo catchment.

Smaller irrigation units are to be found between Mmadinare and Bobonong and other units were seen operating near to the Motloutse - Thune confluence. Between the Letsibogo dam site and two kilometers downstream of Tobane, there is a gross fenced area of 366 ha, of which 88 ha are cleared and 26 ha are currently irrigated. This irrigated area looks set to rise to 67 ha within the near future. In addition, there are further irrigators located on the Letlhakane and Mathathane tributaries. Those on the Matatane and lower Letlhakane are

dependant on the discharges from the mine and the Selebi-Phikwe sewage works for their water source.

Between Tobane and Bobonong there appear to be four private units and one horticultural station of the MOA. Further details on this section of the river cannot be quantified due to a lack of up to date suitable scale air photography. At least two other units pumping from groundwater away from the river in the sandstone aquifer are known to operate.

Most farmers in the Motloutse catchment, and particularly the Bobonong area, now plough with donkeys in preference to their traditional oxen. The main reasons for this change in management strategies include the increased commercial value of cattle, the better prospects of drought survival with donkeys, the ease of training and operating donkeys for ploughing and their suitability for ploughing in these lighter sandier soils. Although preliminary surveys in Phase 1 did not identify any dependence of farmer's ploughing stock on riverain grazing, the more detailed research in Phase 2 did. The particular conditions under which farmers are dependant on the riverain grazing and browsing for ploughing capacity vary from location to location. The factors which influence this are the proximity of the Lands to the riverain areas, access to alternative water supplies, the size and composition of the herds and flocks owned, and entrepreneurial capacity. This re-emphasies the importance of preserving downstream water supplies as discussed in Section K3.3.1 and the riverain grazing, which is examined in more detail below.

K3.3.3 Vegetation and Ecology

The downstream vegetation and ecology is based on communities found in the kopje, upland and riverain areas. The more isolated kopje communities are unlikely to be affected, except in the direct area to be excised for dam construction. The upland communities are predominantly associations of mopane and acacia species. These areas could be affected by secondary pressures resulting from the changing status and condition of the riverain zone under the influence of dam and irrigation development. In the long-term, as clearing for arable lands occurs and as population demands for wood products increase, over-exploitation of these important woodlands could occur.

The riverain system could be more at risk from dam development, since it is primarily controlled by river flows and alluvial depositions. This system itself is not static and has evolved with the ageing of the river system, changing climate and the influence of human settlement and resource use. To intervene in the annual river flows, periodic floods and alluvial deposition could have repercussions, particularly in the long term. These particularly relate to loss of grazing and the risks of greater erosion due to vegetation changes at the river banks.

A survey of the river profiles indicates a free draining, contained river channel which also encloses the alluvial deposits. Seepage to the main groundwater body through the river bed is minor. Meandering, set up by alluvial deposition, appears minor, the course of the river channel being controlled frequently by geological structure. This pattern means that there has been no development of wetlands or an extensive floodplain. Areas of alluvial deposition and riverain vegetation at any distance from the river channel are limited and occur mainly between the Letlhakane confluence and where the river enters the Karoo sandstones and basalt. There is little evidence to suggest that these areas receive regular floodwater by bank overtopping and, in most years, are probably saturated more by lateral outflow or surface or sub-surface runoff from the side catchments.

The ecological dynamics and the possible effect on the riparian vegetation due to reduced flows is discussed in Appendix K-E. Unless a dam is later built on the Letlhakane, the

length of the river likely to be most affected is the 19 km length between Letsibogo and the Letlhakane confluence. However, as shown in Table K2.1, this length only has 210 ha of riverine vegetation compared with 2 400 ha over the next 35 km down to Lerala.

Irrespective of this there is the need, in view of the importance of the riverine vegetation for grazing and erosion protection, to establish to what degree the vegetation is dependent on the sand river.

Predicting the response to variation in water levels of the main different species of riverain tree, shrub and undercover is impossible as there is no previous research available on precedents. Species which are wholly or largely confined to the riparian fringe in this area, e.g *Combretum erythrophyllum, C. hereroense, C. imberbe, Acacia erioloba, and A. galpinii,* are mostly the taller trees and probably have deep enough roots to reach water well down in the river bed.

However more detailed fieldwork, most specifically the installation of piezometers at selected locations in the riverain areas, will establish if there is a hydraulic connection with the sand river. This will require monitoring of the water level responses over at least one wet season.

The computer model of the sand river described in Section K3.3.1, which was based on actual flow measurements indicated that, during the dry season, losses into the riverain areas are probably minimal. If this is the case, possibly the regional groundwater table, as an inflow situation, is a greater influence. Alternatively a critical element of the ecological dynamics is the soil type and depth and possibly this is the major influence.

Surveys of the economic importance of the upland and riverain systems indicate that both areas are significant seasonally. The role of mopane as a major upland species contributes significantly to the balance of use between upland and riverain areas. Its value comes both as a multi-purpose timber resource and as a source of browse late in the dry season. The primary economic role of the riverain area is for both its grazing and as the main source of water.

The use of thatching grasses in the catchment is still extensive. A gradual change in modern roofing materials in the rural areas is evident. The riverain species are not important as a supply for these requirements and most preferred species are taken from hilltops and upland areas. Good quality thatching materials are only available from sources upstream of the main road to Francistown and from reeds growing around the Motloutse-Thune confluence.

K3.3.4 Pollution

Pollution is of concern mainly as an upstream impact. However, the Letsibogo dam site, depending on how BCL reacts to the conservation of water in its operations, could reduce river flows which, in the past, have diluted the releases of toxic waste which have occurred under heavy rainfall. A programme of field investigations to determine the future risk of pollution is being carried out as an extension to the study. This work includes :-

- an assessment of groundwater pollution on the area between the mine and the Motloutse river, emanating from the tailings dam and the surrounding marshing areas.

- investigation of any latent pollution in the Motloutse river sands between the letlhakane confluence and Tobane due to historic dumping.

- the effects on the water resource of aerial pollution deposition, washing into the river course, concentrating on the area 9 km x 14 km mainly to the north and west of Selebi – Phikwe.

Irrespective of the above studies, it is important that the pollution from the river complex is effectively stopped by good management by the BCL mine. Recommendations in this respect are given in a short study of the mine carried out by WLPU (1988), which it is hoped will be implemented by the mine authorities.

K3.3.5 Sand Resources

The prime user of the sand resources of the Motloutse is the BCL mine. They use sand as a flux in the smelter process. Further downstream, contractors remove sand for building purposes at Bobonong. BCL's mining lease extends for a 20 km length of the Motloutse river, 10 km upstream and downstream of the Letlhakane confluence and for 4.5 km up the Letlhakane upstream of the army camp. The locations of these leases has been shown in Figure K2.7. The lease permits the annual extraction of 200 000 tonnes of sand, although recently the mine has only been extracting 160 000 tonnes annually. Extraction has generally concentrated in the Motloutse river for the first 4 km upstream of the Letlhakane confluence, with little extraction downstream. Construction of a dam at Letsibogo will prevent natural recharge of sand along the Motloutse downstream of the dam site into the sand lease area. The impact of this is examined in detail in Appendix K – H and included in the costs given in Chapter K7.

K3.3.6 Communications

Existing cross river communications are limited only in times of river flows and by flood damage to existing bridges and stream culverts. All the major village settlements are located on the southern side of the Motloutse. The main need to cross the river is for access to cattle posts and the few lands on the northern side and to travel to the Shashe river, and across country to Tonota and Francistown along the main water pipeline route from the Shashe Dam. Future development of the rights to mine the marble and other mineral deposits north of Selebi – Phikwe in the Monatsane Hills, or the mining possibilities north of the Lepokole Hills, would probably dictate the need for bridges across the Motloutse at Bobonong and Mmadinare. Similarly the later construction of lower Shashe dam would also dictate a bridge at Mmadinare.

The creation of a reservoir at Letsibogo for urban water would assist the seasonal access for communities downstream but prevent it permanently for upstream communities wishing to access across the reservoir flood zone covering a 12 km length of the river. However, the introduction of downstream irrigation and the need for compensatory flows could impact on downstream cross river access depending on the policy adopted for the timing, frequency and volume of regulated releases. Infrequent major releases modelling the existing flood system would have the least impact. The provision of a culverted crossing designed to be overtopped at or downstream of the dam at the present Mmadinare crossing may be required to maintain access to its present level.

K3.3.7 Other Impacts

(a) Catastrophic Failure

In the extremely unlikely event of a failure of the dam from acts of god or man, major downstream flood damage and compensation claims would result. The impact on Mmadinare would be catastrophic and the water pipeline and power lines to Selebi Phikwe would also be at risk. The extent of damage would depend on the dam storage level at the time. If full and the failure rapid, the flood wave would likely carry through to, and leave a trail of timber and other debris, as far as the Limpopo confluence. It would probably take out all infrastructure along the river, including resources at Tobane, Bobonong and Talana Farm. Depending on the time of year, considerable numbers of livestock, watering in the river or grazing in the riverain strip, could also be affected. The height and speed of the flood wave would probably remove significant riverain vegetation and alluvial soils for a considerable distance downstream.

The advance warning of such an event might involve days or possibly only hours. The former would allow an organised evacuation of downstream villages. The latter would make any meaningful ameliorative action impossible. The infrastructure and services available locally at the current time would be quite inadequate to deal with such a disaster. Mobilisation of national and international resources and coordination would probably be necessary.

(b) Planning Restrictions

The close proximity to Mmadinare of the reservoir, particularly the spillway and operations buildings, will mean that no expansion of the town to the west will be possible.

(c) Reservoir Operations and Design

Water for the urban supply will usually be drawn off from the highest 7 m in the reservoir. However, if water for release downstream is drawn from the bottom of the reservoir without provisions for mixing this would release hypolimnetic water with a fine silt content, rich in nutrients and decaying particulate matter, deficient in oxygen, and cooler than the water which normally would flow down the river. Such water would have a number of adverse effects on organisms downstream. This is discussed in Appendix K – E.

Although too little is known about the biota of permanently saturated sand rivers to make firm predictions, the release of anoxic water would be likely to kill aquatic organisms downstream near the dam. The discharge of any silt – laden water would smother aquatic invertebrates and the river sediments, and seal the spaces between sand grains. Eutrophication of the water downstream would occur, because of the hypertrophic nature of the discharge, and this would adversely affect water quality. If the discharge were to be continuous, or frequent, suitable conditions would be created for species such as bloodsucking blackfly *Simulium* plagues which transmits various viral diseases of livestock.

In this context it is strongly recommended that, unless unavoidable, releases downstream should not be made from the bottom of the reservoir.

CHAPTER K4

RESERVOIR IMPACTS

K4.1 Reservoir Profile

The location of the proposed Letsibogo dam and reservoir are shown in Figure K4.1 and some of its main characteristics are listed in Table K4.1 below.

Table K4.1

Summary of Reservoir Characteristics

Full supply level (FSL)	850	m
Dead storage level	833.5	m
Reservoir volume at FSL	125	$m^3 10^6$
Reservoir area at FSL	2 166	ha
Downstream permanent works area	344	ha
Total reserve area	3 736	ha
Reservoir as proportion of reserve area	58	%
Reserve perimeter length	43	km
Uplands woodland lost	2 052	ha
Riparian woodland lost	223	ha
Cleared land lost	50	ha
Cultivated land lost (1989)	40	ha
Interval between spillway overtopping		
– Mean	5	years
– Maximum	17	years

Note: The true Full Supply Level is 850.15 m but for all planning work a level of 850 m has been used due to the constraints of topographic data.

The dam will comprise a rock fill embankment, about 1 300 m long with a maximum height of 27 m above adjacent ground level. The 250 m long gravity spillway will be located on the northern flank. A pumping station, immediately downstream of the dam on the north abutment, will have a rated capacity of around 1250 l/s to supply a 18.3 km long, 1200 mm diameter pipeline to join to the proposed new Selebi-Phikwe treatment works. The data given in Table K4.1 assumes a reserve area for the reservoir located 2 m or 100 m above full supply level whichever proved the greater distance. For a zone in which settlements would be excluded a height of 4 m above FSL has been adopted.

Reservoir simulation modelling has been carried out based on the full supply level at 850.15 m which provides a capacity of 125 $m^3 10^6$. The main operating demands include requirements for urban water demand and downstream irrigation, and possible compensatory flows to maintain downstream supplies for existing users and riverain ecology. The pattern of flooding in the reservoir will vary considerably depending on the operational policy. One typical pattern indicative for planning purposes is shown in Figures K4.2 and K4.3. This simulation indicates that the upper 25 % of the reservoir area would have remained unflooded for 67 % of the time with one continuous unflooded period of nine years. Table K4.2 indicates the areal extent of the reservoir based on the reservoir simulation analysis.

Table K4.2.

Areal Extent of Reservoir

Surface Area (km^2)	% of time exceeded
0.00	100
2.50	97
5.00	92
7.50	84
10.00	72
12.50	57
15.00	40
17.50	21
20.00	8
21.00 (FSL)	4
33.34 (Resettlement Limit)	0

During the early years of operation the levels in the reservoir are likely to be higher than those indicated in Figure K4.2 as this represents a steady state situation once the scheme is fully operational and linked as part of an overall network to other water resources developments. During the first seven years of operation the water demand in south east Botswana will be less than the design operational capacity of the reservoir and there will be less need to pump and draw down water levels; however the major control on levels will be inflow to the reservoir. The differences between a 'with' and 'without' formal irrigation option are thought to be minimal.

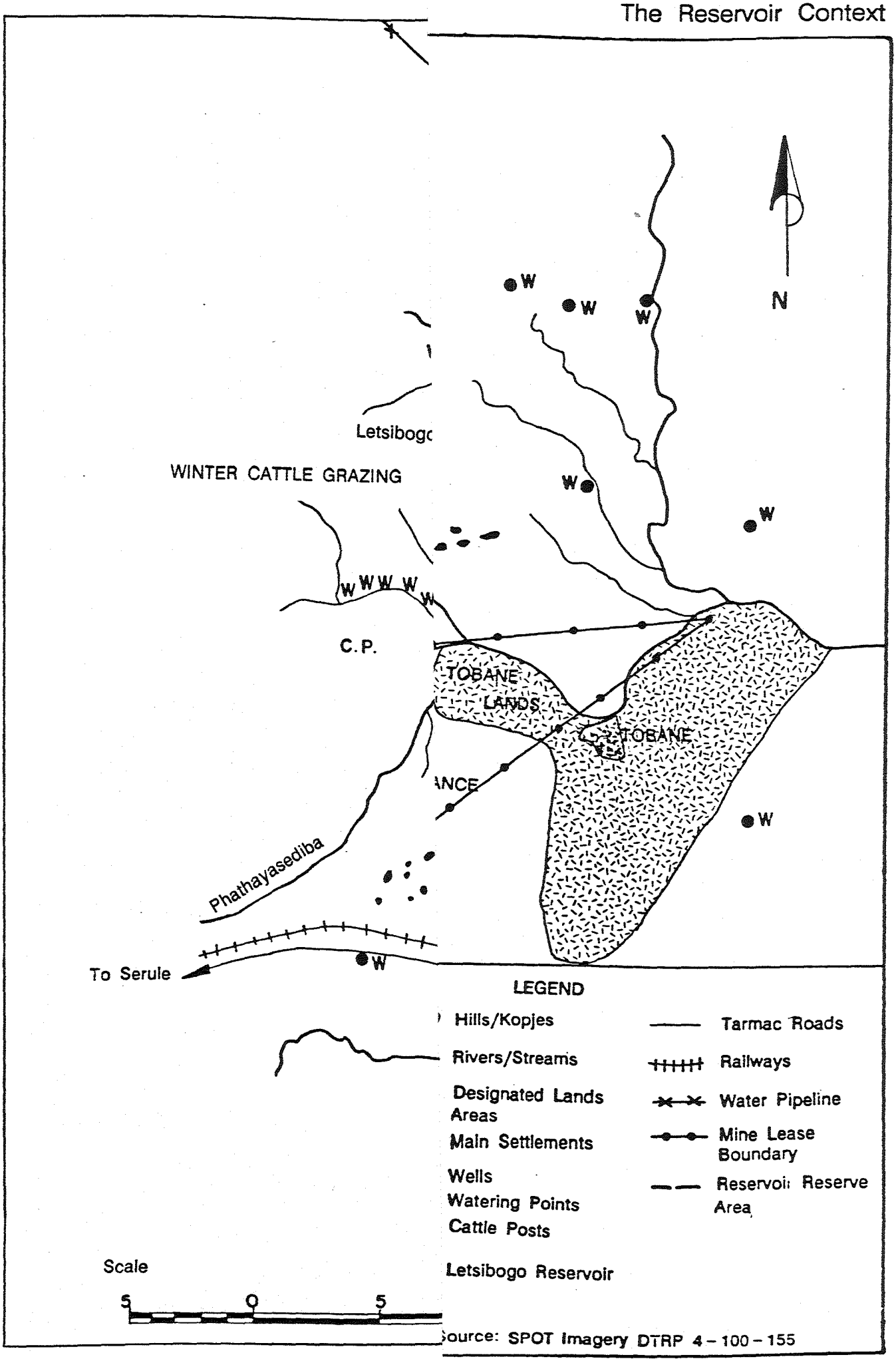
11.7 km of the 18 km long raw water pipeline will be located within the existing servitude from the Shashe pipeline. The first 7 km from the dam will be partly in the land requisitioned for the dam and the remainder will be open land, some possibly cultivated, to the west and north of Mmadinare. Permanent requisition of land along the pipeline route will not be necessary, but application will have to be made for a servitude to allow access for maintenance and repairs. No direct asset losses caused by the construction and operation of the pipeline are envisaged if it is located with these factors in mind and construction appropriately fitted around the agricultural calendar. Some temporary disturbance could occur and notional compensation provisions have been allowed for in the assessment of costs.

K4.2 The Reservoir Context

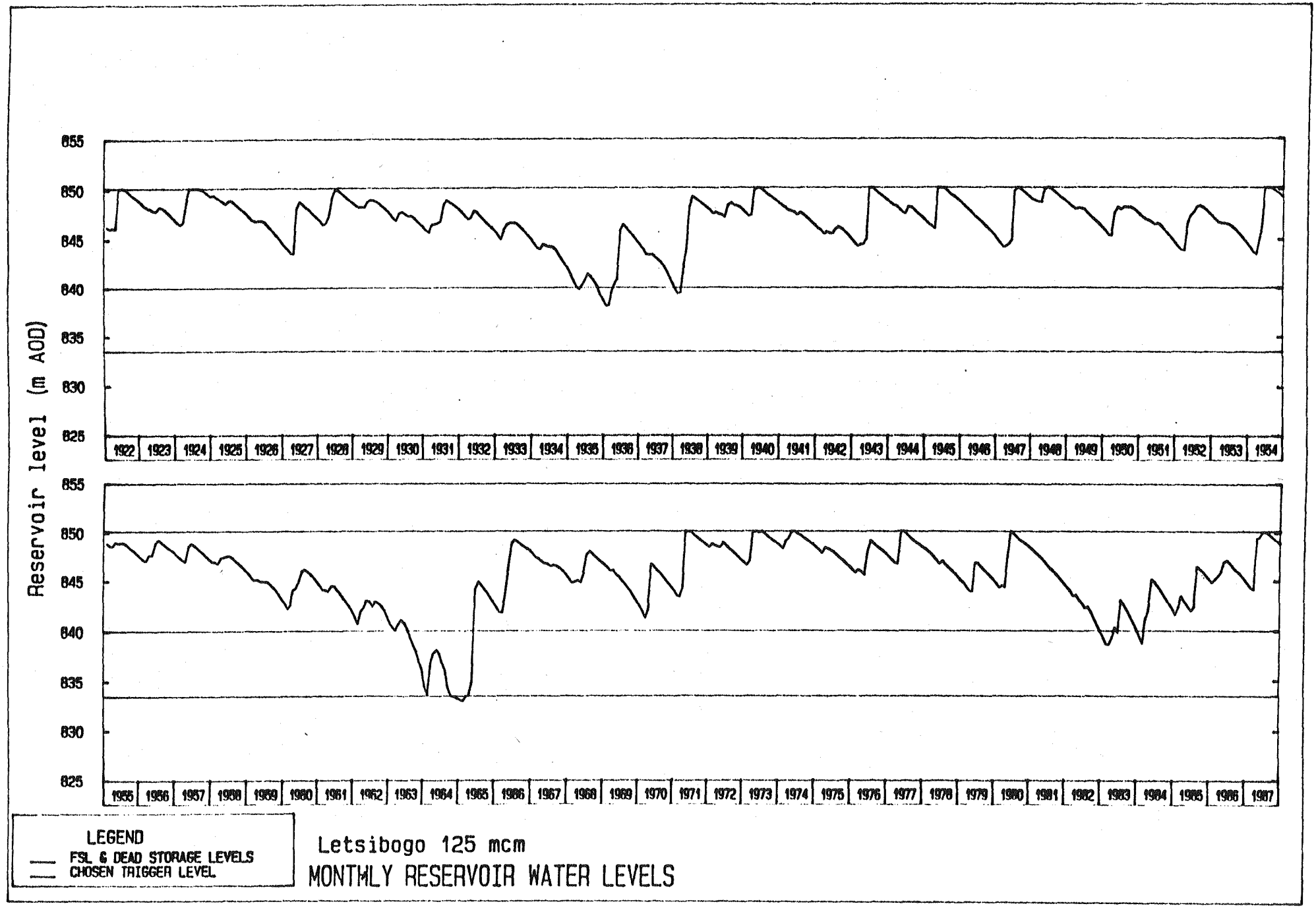
The archaeological surveys described in Appendix K – D confirm a long history of use of the reservoir area. Over 100 sites in, and immediately around, the reservoir provide evidence of country important to Stone Age man and both pastoral, cultivation and trade activities going back over many centuries. Important village sites are found on ridges and plateaus which straddle the old trek route, which is still referred to as the old Ndebele road, linking Zimbabwe and central Botswana. This crosses the river just upstream of the Sedibe confluence. The dam wall abuts onto a range of kopjes that contain many important sites, including one of the sites of old Mmadinare. This area also encompasses some mature woodlands that would be worthy of conservation as discussed in Chapter K8. Today the emphasis of settlement and crossing points has shifted downstream to the present location of Mmadinare and along the pipeline route through to Tonota and Francistown. Major settlements are no longer to be seen in the study area. Cultivation has been severely curtailed, both from erosion, and from when the Land Boards started to restrict cultivation rights in the cattle post areas.

Figure K4.1

The Reservoir Context

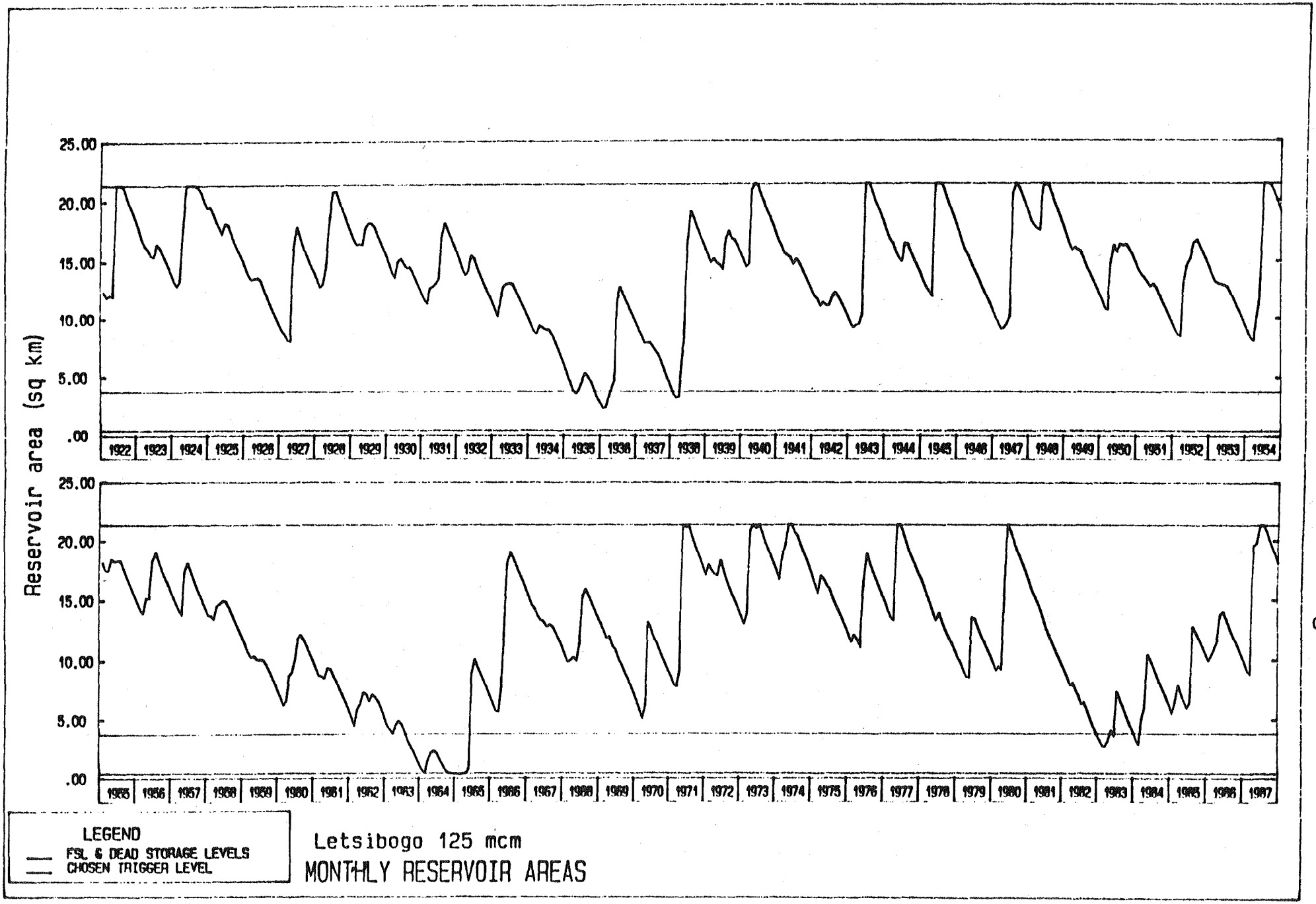


Source: SPOT Imagery DTRP 4 – 100 – 155



Letsibogo Fluctuations in Levels

Figure K4.2



Letsibogo Fluctuations in Area

Figure K4.3

The proposed reservoir is to be implanted into an on-going agro-pastoral system. The transformation of the resources will be fundamental and will demand a major adjustment by the people who currently use the resources. Secondary impacts will be created by the displacement of people and animals into other areas and thereby intensifying the pressure on resources over a much wider area. Figures K1.3 and K4.1 show the context of the areas surrounding the reservoir.

Approximately two kilometres to the north of the Motloutse, on the water pipeline route from Shashe dam to Selebi-Phikwe, lies one of the major Lands areas for people from Mmadinare. Only a small part of these Lands at Monatjane actually abut the reservoir area but as water supplies are so poor the farming operation is totally dependant upon the river. Settlers at Monatjane and their stock collect water at the Motloutse, irrespective of whether they maintain cattle posts there. Some families own so few stock that these remain with them at the Lands.

Two kilometres downstream lies the town of Mmadinare having a possible affiliated population today of around 12 000 persons. While not supporting any significant industrial development, it is has political, economic and social influence over a considerable area. Its economic significance has been over-shadowed and substituted for by the arrival of the BCL mine and Selebi-Phikwe in the early 1970s. Historically, the village formed the centre of tribal administration which was supervised from Serowe.

Four kilometres to the south lie the second major Lands area for Mmadinare. These settlements are better endowed with domestic water but depend on moving their livestock, including their ploughing animals, to the Sedibe river for daily watering. There are also sections of these Lands where water is not adequate and people become reliant on supplies from the Sedibe.

Immediately upstream of the Sedibe/Motloutse confluence on the Sedibe are two major cattle post and river watering areas used by people affiliated with Mmadinare; one at Sedibe itself and the other upstream of the rock pools at Butetela. Cattle posts displaced from the Sedibe section of the reservoir would probably relocate into these zones. It is also here that the veterinary department have located a cattle crush which will have to be relocated upstream.

In the land between the two rivers, which will become cut off from Mmadinare once the reservoir fills, there were very few cattle posts at the time of the survey. This section hosts the Senyame hills and the plateau woodlands set aside for the winter dry season grazing of cattle. For the cattle which winter in the areas between the Motloutse and Sedibe these grazing areas are also at the greatest distance from water, and thus come under more dry season stress. Due to the lack of water and settlement in this area it has become something of a refuge for the few wildlife which remain in the vicinity. Since 1982 a group of up to 60 elephant have moved permanently into the area and caused the few remaining cattle posts to relocate across the Sedibe. There has been a similar disruption to cattle post settlements on the Motloutse, but to a lesser extent. If wildlife officers succeed in driving these elephants out of the area then this, and the influence of the reservoir, would likely lead to an expansion of cattle posts back into this zone.

Less than ten kilometres upstream of the reservoir the Mmadinare cattle posts area starts to overlap with that from Tonota. The primary focus of activity here is around the permanent pools and well points enhanced by the Madibeng rapids. This provides a resource that has stimulated settlement probably over many centuries. It has also led to intensive grazing pressure which periodically would have led to decline in settlement intensity. This appears to be the case today where the surveys identified some eight sites in use and over thirty abandoned.

To the north of the upper end of the reservoir is the major tributary of the Itsokwane river. There are a number of important cattle post locations in this sub-catchment which have access to three well sites distant from the Motloutse. Despite their distance from the river these can remain wet throughout the year. This provides an advantage for these stock owners, since it allows the use of the grazing areas up into the watershed with the Shashe river. During times when these wells do dry up and during the rains cattle are brought down to the Madibeng rapids for water, while the small stock remain watering from the wells in the sub-catchment.

K4.3 Ecology

K4.3.1 Species Distribution and Conservation Status

The vegetation of the reservoir area can be divided broadly into four main classes. Within each of these there are a number of sub-classes based on differences in species composition in response to changes in local edaphic conditions affecting plant rooting depth and soil moisture availability. In addition, there is a fifth class consisting of highly disturbed vegetation resulting from past and present activities of people and livestock, and a sixth class of minor communities on localised sites with special edaphic conditions. Map K.2 shows the distribution of these communities in the reservoir area. These plant associations and their respective sub-associations as well as the fauna of the reservoir area are described in detail in Appendix K-E.

The apparent absence in the reservoir area of any endangered, vulnerable, or rare taxa as identified in the field surveys does not imply that the conservation status of the plants occurring there is necessarily secure. First, the project area is little known or collected botanically. Second, by definition, rare plants are unlikely to be found easily, particularly in a two-week survey. One species, *Rhinacanthus gracilis,* was collected for only the second time in Botswana (the first specimen having been collected during the Lower Shashe Dam survey). Third, the threats posed to a species' survival, is also not simply an inverse function of its population size. The extent of a species' geographic range and its degree of habitat specialisation also influence its vulnerability to disturbance or habitat destruction. Thus, species confined to the banks of the larger rivers, are vulnerable to changes in river flow regime irrespective of their abundance.

Under present land use, the prospects for wildlife in the project area are limited. The general trend over the past decades or longer has been one of a gradual decline in the numbers and diversity of the larger mammals as human and livestock populations have increased. The trend seems likely to continue. The causes for this are complex and include competition with livestock for food, water and space; habitat modifications; and hunting and disturbance by people.

Some of the bird species recorded during the survey are considered to be vulnerable or rare in South Africa. These include *Ephippiorhynchus senegalensis*, *Marabou Leptoptilos crumeniferus*, Lappetfaced Vulture *Torgos tracheliotus,* and Bataleur *Terathopius ecaudatus.*

The population size of the Saddlebill Stork is estimated to be less than 50 pairs in South Africa, and the species is probably rare in southern and eastern Botswana (it occurs more commonly in Chobe and the Okavango). The species is reported to have bred in riverine woodland along the Motloutse River in recent years. The sighting of a young bird there during the survey supports this, although it is not known whether the birds breed regularly here. The species requires reasonably large stands of mature, undisturbed riverine woodland for successful nesting. The impact of building a dam at Letsibogo would depend on whether there was a die-back of the riverine woodlands caused by a reduction in downstream river

flow. On the positive side, the formation of a large reservoir could benefit the species by providing more foraging habitat for the storks.

Another species, the Boulder Chat *Pinarornis plumosus* endemic to the granitic shield of Zimbabwe and Botswana, is confined to rocky hills and outcrops and was found on a number of these within the proposed reservoir. Construction of a dam would result in a loss of habitat for a number of pairs occupying the outcrops which lie on the proposed line of the dam wall. Nevertheless, the species occurs on other outcrops in the area and the construction of the dam would not appear to threaten seriously the conservation status of this species.

K4.3.2 Economic Usefulness

Many of the medicinal plants commonly used by traditional doctors which are found in the project area are common and widespread. These are detailed in Appendix K-E. Consultations with local traditional doctors revealed that the site of the proposed dam at Letsibogo is not unique in any way. The construction of a dam would therefore not result in the irreparable loss of any medicinally important plants, nor would it threaten the livelihoods or status of the traditional doctors.

Food obtained from wild plants are particularly important to rural people during drought years. A number of plant species occurring in the reservoir area are used by local inhabitants as supplementary food sources. These are listed in Appendix K-E Data List K-E.5. Beverages, including alcoholic drinks, are made from the fleshy fruits of a number of species. Although construction of a dam at Letsibogo would flood the habitat in which many of these species occur, no populations would be at risk overall since the species all occur relatively widely throughout the region.

A number of the Acacia species, particularly *A. tortilis* and *A.* mellifera, are important sources of nectar for honeybees *Apis mellifera.* The loss of large areas of Acacia woodland through flooding could adversely affect the local honeybee population, honey production, and the pollination of other plants. The impact of the construction of a dam would depend on what other nectar sources and pollinators there are nearby that are unaffected by the reservoir. No information is available on these.

A wide range of plant species are used for firewood, building homes, constructing fences, or making tools. Colophospermum mopane is the most favoured and widely used firewood species. The economic impact of dam construction on this resource would probably be minimal because most of the C. mopane woodland lies above the FSL of the proposed dam and there are other sources available within a reasonable distance.

A number of species are used to construct barrier fencing to keep livestock and wildlife out of fields during the growing season. The branches of Acacia species are favoured, where they are available, although in upland areas where acacias are generally uncommon branches of C. mopane and other broadleaf species are used. In general, farmers with fields on alluvial soils alongside the rivers have access to abundant fencing material in the form of regenerating acacias, but farmers in the upland areas appear to have difficulty finding sufficient suitable material because of the general lack of thorn trees. There is thus the need for greater amounts of non-spinescent species, such as C. mopane, to be used in order to construct an animal-proof fence. Moreover, the upland species appear to regrow more slowly than Acacia species so that the effect of harvesting material for fencing is more severe.

The demand for fencing material is high and there is often a marked reduction in woody plant cover in the vicinity of well-established fields and cattle posts. The shortage of fencing material in the uplands would be one of the main constraints faced by farmers displaced from the bottomlands to the uplands by construction of the dam. The rates of woodland clearance in the uplands would likely accelerate.

There is a shortage of suitable thatching grass in the region. Wealthier individuals purchase or collect thatching grass from as far away as Serule. The poorer members of the community have to make do with local grass species, mainly *Eragrostis spp.* and *Aristid rhiniochloa*, which lack bulk and are insufficiently fibrous to last for more than a year or two. Construction of the dam would not threaten this already depleted resource, and may even enhance it by encouraging the growth of reeds, sedges, and tall grasses on the reservoir margins which can be used for thatching.

K4.3.3 Livestock Forage

Livestock are the main source of wealth and security for most of the inhabitants of the proposed reservoir area and also for many of the people living in Mmadinare and surrounding areas. The availability and quality of forage is therefore of crucial importance in determining the dynamics of the livestock populations and, thereby, the wealth of their owners. The forage resources are best divided into grazeable matter and browse, since the plants in these categories exhibit somewhat different dynamics. Although it is conventional to classify livestock into grazers (cattle, donkeys, and sheep) and browsers (goats), the reality is that in this environment cattle and goats are mixed feeders.

Much of the area surveyed has been heavily grazed by livestock and the perennial grass cover is very low. Most of the herbaceous cover is made up of forbs and annual grasses. Many of the forbs are not eaten and are either unpalatable or toxic. Annual grasses lack bulk and are thus not generally ideal fodder for grazers, though some, such as *Urochloa trichopus*, are productive and do provide good quality grazing.

The production and quality of grazing is higher in the bottomlands alongside the rivers than in the uplands. Cattle in the tropics require a minimum of 6.3% crude protein per day to maintain body mass. Higher levels are needed for the animals to gain mass. The results discussed in Appendix K-E clearly indicate that only the bottomlands have grasses of sufficient quality for cattle to grow, and then only during summer. The loss of the bottomland grazing areas through the formation of the reservoir would put local livestock and their owners under pressure.

In contrast to the grasses, shrubs and small trees have higher crude protein contents but the presence of lignins, secondary chemicals such as tannins, and refractory carbohydrates interferes with the digestion of woody plant leaves. Nevertheless, some species are heavily browsed and are clearly an important resource for livestock (Table K-E5.1 in Appendix K-E). Browsing pressure is particularly high among those shrubs and small trees growing on the alluvial terraces and pediments which, unlike cattle, small stock feed on throughout the year. Many of the favoured browse species occur throughout the area, but they are most abundant and grow best in the bottomlands. Inundation of these areas during the formation of the reservoir would represent a significant loss of key resources to the livestock owners of the area.

K4.4 Loss of Private Assets

Private assets in the reservoir area include all those improvements on land occupied by individuals holding customary or statutory rights on Tribal Land. The location of these assets in give in Map K.1 and listed in Table K4.3 as recorded at the time of the survey. The extent of the area affected comprises the reservoir and dam including an area downstream sufficient for construction and operation facilities and these areas at risk from the proposed spillway. All settlements up to 854 m have been included and this gives a better than 1:10 000 year security when wind action is excluded. The longest reach of open water relative to the prevailing wind is from the dam to upstream on the Sedibe arm of the reservoir and there are no settlements at risk. All improvements to land up to 852 m have also been included for the case of a fenced reservoir. If the reservoir were to be fenced then all improvements below the reserve limit would need to be compensated for. Unlike the situation with communal assets, there would be very few significant additional losses of private assets if a fenced reservoir were adopted rather than an unfenced one.

Table K4.3

Estimates of Private Assets Lost to a
fenced and unfenced reservoir with a FSL of 850 m

Item	Unfenced	Fenced
Private Assets		
Fully cleared land	44.15 ha	47.65 ha
(1st Phase Area is 33.35 ha)		
Partially cleared land	4.62 ha	4.62 ha
Trees:		
Mature	51 nr	53 nr
Average	43 nr	43 nr
Young	0	0
Fencing (including fields and kraals):		
Thorn fence	5 215 m	5 365 m
Wood paling fence	1 450 m	1 530 m
Post and wire fence	6 467 m	6 817 m
Mud walls	64 m	
Homesteads (14 nr individually assessed)		
Huts	39 nr	39 nr
Threshing floor	386 m^2	386 m^2
Granaries	1 nr	1 nr
Infield Tank	1 nr	1 nr
Wells in river bed	16 nr	16 nr
Displacement/removal	10% of total	10% of total
Access Replacement	4.5 km	4.5 km

The above estimates are based on the information recorded in the 1989 field surveys. Since new dwellings and kraals can be set up at any time, and since temporarily abandoned cattle

posts may be re-established if conditions improve, the current figures do not reflect the position which may prevail at the time a decision is taken to reserve the land.

Only 14 families would have to be relocated and a maximum of 12 need replacement lands. There are six cattle posts and a further seven that also have lands at the cattle post. There is only one homestead which has lands only and no livestock kraals. Although only these 13 currently used cattle posts have been noted, it is very likely that there will be a return to some of the recently abandoned cattle posts once the effects of drought stock losses and overgrazing are lessened in time. It is conceivable that the number could double in the next four years. This emphasizes the need to come to a clear decision on the development of the dam and to communicate it to the affected population as soon as possible and to place a moritorium on new settlement in the reservoir area as soon as is practical. One irrigated garden, close to the confluence of the Sedibe and Motloutse rivers, would be affected. This was abandoned recently due to the damage caused by elephant. One operating irrigation farm with an overhead water storage tank immediately downstream of the dam wall would need relocation. In addition 16 seasonally constructed hand dug wells would be flooded.

K4.5 Loss of Communal Assets

K4.5.1 General

Communal assets are defined as those which occur in Tribal Land but have no recognised individual rights attached to them. The main communal assets considered for compensation and/or amelioration include the natural grazing and browse, thatching grass and medicinal herbs; the range of woodland products (see Appendix K-E); access to surface water resources; loss of cross river access; access to river sands; loss of community structures (dams, boreholes, cattle crushes, development projects); loss of future development potential; health and social impacts; and disruption factors. The direct losses are listed below in Table K4.4 with a direct comparison between a fenced and an unfenced reservoir. The unfenced reservoir takes into consideration all resources up to 850 m where as the fenced reservoir includes all resources up to the reserve limit. It can be seen that fencing the reservoir removes a considerably larger amount of resources from use by the local community and will inevitably increase still further the pressure on surrounding unfenced resources and lead to even greater environmental degradation. It will also considerably increase the amount of compensation that will have to be paid. The valuation of this is given in Section K7.7.4.

Table K4.4

Communal Assets Lost to a Fenced and an Unfenced Reservoir with FSL 850m

	Unfenced	Fenced
Tribal Land (not individually occupied or replaced)	2 510 ha	3736 ha
Grazing and browse resources	223 ha riverain	269 ha riverain
	2 052 ha upland	3194 ha upland
Standing Timber	15 000 t	23 000 t
Sand Resources	not significant	not significant
Veterinary Crush	1 nr	1 nr
Council Kraal	1 nr	1 nr
River Crossing	1 nr	1 nr
Communal Water Rights	1 600 families	1 600 families
	Amelioration at no cost	Amelioration Expensive

The impact of the loss of communal assets will be to intensify the pressure on resources outside the reservoir area. This pressure will compound the already evident gradual decline in the grazing and forestry resources caused by increasing demands from people and livestock. To ameliorate for this effectively would require a much wider framework of institutional and social reorganisation in the management of the communal range resources. To address this would be beyond the scope and capacity of this study. Nevertheless, in order to sustain the long-term productivity of the resource base, management of the complete resource system is required. In practice, the institutional capacity and socio-economic motivations to achieve this are not present. It may be possible to ameliorate, to some degree, the impact of the loss of communal assets by managing areas of the reservoir as an environmental resource. The possibilities for this are covered in Chapter K8.

K4.5.2 Loss of Woodland Resources

The natural woodlands and shrublands provide a range of important resources. These include seasonal grazing and browse for livestock. This loss could affect ploughing capacity, milk production and grazing quality in the area. A range of wild flora and fauna provide other useful food, medicinal and economic products. Almost 300 species of flora have been identified so far in the vegetation surveys.

The socio-economic survey found that the main source of locally available thatching grass were not taken from the riverain lands, but from the uplands and kopjes. These would not be directly affected by flooding but some areas would come within the reserve area.

The survey team were fortunate to receive the assistance of the Traditional Doctors Association. A number of practitioners who accompanied the field surveys confirmed that the area is an important source of medicinal materials, although it could not be regarded as unique in this respect. Over 80 species of vegetation were identified which are used. Amelioration measures overall can include a number of investment possibilities in grassland management around the draw down zone to promote additional grazing, the introduction of suitable species of moisture-loving grasses and reeds for thatching grasses, and to allow access to the reservoir area for the use and removal of these resources. These possibilities are discussed further in Chapter K8. Fencing the reservoir and preventing access would require compensation to be increased by some 53% for this item.

K4.5.3 Loss of Water Resources

Within the reservoir area 17 major watering points were identified in the bed of the Motloutse and Sedibe rivers. This includes sites where hand dug wells are located and where seasonal or perennial pools exist. These form the water supply point for both livestock, wildlife and domestic water. The users of this resource comprise more than those found within or immediately around the reservoir area. People and stock from the Monatjane Lands to the north and from the Manga lands to the south are involved. It is also significant that these water supplies are also used for stock involved in the ploughing of the Lands.

It is estimated that by 1991 around 1 600 families might be affected. An adverse impact will result only if restrictions are imposed on access to the reservoir area. Discussion of this policy and the problems of amelioration is discussed in Chapter K8.

K4.5.4 Loss of Access

The main losses of access are related to the absolute losses due to flooding and others which would be exacerbated by a decision to fence all or selected areas of the reservoir reserve area. The impact would include restrictions of access to:

- the cattle posts and lands on the reservoir periphery;
- the watering points as discussed above;
- the cattle crush located on the Sedibe;
- the cattle posts within the reserve area;
- the riverain grazing areas;
- the woodland resources;
- the direct access tracks to homes and services in Mmadinare from the cattle posts between the two river and upstream on the Motloutse;
- communications between friends and relatives located on different sides of the reserve area;

There are four households (nos R14/15, R24, R25 and R27) who still have significant resources above full supply level but whose access to them would be seriously impaired by the flooding of the reservoir. This would be made a little worse if the reservoir were fenced. In the case of household R27 it is impossible to ameliorate the situation and there is no alternative but to relocate it even though neither the homestead or the significant cattle post facilities are within the reserve limit. Amelioration for R14/15 and R24 would involve the bulldozing of a replacement access track above the reserve limit or FSL, a total distance of 4.5 km. This would also improve access for reservoir management and dam operational activities to the left abutment.

Surveys at Shashe Dam indicated that damage to the fenceline was as much caused by domestic and trade travel routes as it was to allowing entry of livestock to the water and grazing resources provided by the reservoir. This need for access will apply particularly to the cattle posts settlements located around and upstream of the Madibeng rapids on the Motloutse. This is approaching the edge of the area used by stock owners from Mmadinare, before the border with the Tonota cattle posts begins. In times when the reservoir levels are low, direct access to Mmadinare would be available along the right bank of the Motloutse and through the reservoir reserve area.

Riverain grazing resources would be transformed to variable areas of regrowth of grass and weedy species in the drawdown zone. This will provide an attractive alternative grazing resource. Existing local stock owners will perceive this as a resource which they have the customary rights to graze. Whether through deliberate damage to a fence, or through the unsupervised roaming of the stock through fence entry points, stock and wildlife can be expected to enter. In times of severe drought it might also become politic for government to guarantee access to alleviate unnecessary livestock mortality and losses.

Ameliorative measures for loss of use of resources and issues relating to a fencing policy are discussed further in Chapter K8.

K4.5.5 Loss of Sand Resource

No users of sand from within the reservoir area were identified. The primary impact will be on downstream users which has been outlined in Section K3.3.5 and costed in Appendix K – H. The likely build up of sand deltas at the upstream ends of the reservoir could provide a valuable alternative source of material for BCL. However it is likely that the natural grading which presently occurs in the river bed will not occur when the river meets a large body of

standing water. It is also likely that contamination of the sand with mud and other foreign matter will be more of a problem than it is at present. Haulage costs and difficulty of access to the upstream end of the reservoir would be high and it is likely that there are more cost effective alternative sources of sand. The possibility of recovering the sand resource that will be flooded when the reservoir impounds is also discussed in Appendix K-H.

K4.6 Loss of National Assets

K4.6.1 Sites of Historic Value

The results of the initial archaeological surveys are given in Appendix K-D. Over 100 previously unrecorded archaeological sites were identified within or close to the proposed reservoir area. Not all these sites would be flooded but many lie within the proposed reserve area. A major group of sites is on the terrace and kopjes adjacent to the right abutment of the dam axis. This area had been considered as a potential quarry site but has now been discounted due to a left bank spillway now being favoured. Fencing of this site and careful design of access roads and blasting to avoid any disturbance to the national monument would be proposed. More detailed surveys will need to be completed before construction work commences. Proposals for this are given in Chapter K9.

K4.6.2 Sites of Scientific Value

At the level of detail employed, the ecological surveys (see Appendix K-E) have not identified any unique species or associations which would affect any decision to go ahead with the dam. The most direct effect will be the loss of plant and animal habitat, and perhaps some species through flooding. Riverine woodland, Acacia-dominated woodland, communities on rocky outcrops and ridges, and communities of old lands and settlements would be the ones most directly affected. None of these are unique to the area; similar communities occur upstream and downstream of the dam site. Nevertheless, attempts should be made to preserve some of the Commiphora mollis - Kirkia acuminata woodlands in the vicinity of the proposed dam site. The woodland at grid reference 2127D3 5743/75830 is a fine example of this vegetation type. It also has a number of sites of archeological importance and should be protected from damage if possible.

K4.7 Public Health

K4.7.1 General

The new water regimes introduced with a reservoir or irrigation will create environmental conditions that can be conducive to water-borne disease and to certain vector-borne diseases and parasites. Similarly, soil chemistry and micro-biology can be effected.

The primary health risks to be considered, given the catchment's geographical location, latitude and altitude, are malaria, schistosomiasis, typhoid and hepatitis. To limit any impact of water resource development on the spread of these diseases requires adequate basic primary health care and education and the correct long-term management of the water resources and their associated infrastructure.

K4.7.2 Malaria

Malaria is endemic in Ngamiland, Chobe and the Francistown areas. Dependence on rainfall makes its movement south unstable and usually sporadic. Infection is often transported from one region to another by migrants and travellers. During the recent periods of extended drought, and under the influence of extensive control programmes, the impact of malaria has been limited. With the onset of the heavy rains in 1987/88 widespread transmission of the disease was witnessed. Significant outbreaks and deaths within the catchment area were recorded. The Regional Medical officials noted that outbreaks were associated with both upland and riverain areas, and particularly amongst the Basarwa community of Chokwe, north of Tobane.

The primary species involved is *Plasmodium falciparum*, which is carried by the vectors *Anopheles gambiae* and *Anopheles funestus*. Although the mosquito vectors in Botswana are believed to find their optimal habitat in rain-water pools and not in or near major water reservoirs, the chances of increased malarial risks under the influence of reservoir and irrigation development cannot be discounted. Considerable mosquito breeding does occur around Shashe Dam but again endemic problems of malaria for the local communities are not reported, possibly because breeding involves non-malarial culicine mosquitoes.

Local control measures employ oils and not DDT to kill the mosquito larvae. Oils are not of such environmental concern as DDT, which accumulates in the food chain. Some spraying with DDT is reported to take place in the Tuli Block. Chloroquine is the most widely used anti-malarial drug, and health units should hold stocks of the drug sufficient to deal with unexpected outbreaks of malaria. Malarial parasites in Botswana have not yet become resistant to chloroquine, nor indeed, to any of the alternative antimalarials. However, with known foci of chloroquine resistance present in Namibia, Swaziland, Mozambique, Zimbabwe and the Republic of South Africa, it is highly likely that Botswana will be affected in the near future. International health advisory bodies for travellers already make recommendations for personal malaria prophylaxis as though resistance were present.

4.7.3 Schistosomiasis

Urinary schistosomiasis *S.haematobium* is potentially present in many parts of Botswana, while intestinal schistosomiasis *S.mansoni* has been found only in the Okavango and Chobe areas. The latter is of greater importance epidemiologically and of higher priority for control. The Regional Medical officers report no cases of schistosomiasis arising from local infections. The only known cases have been associated with migrants returning with the disease. The presence of schistosomiasis was first confirmed in Shashe Dam in 1985 but a serious infestation amongst the local population is not reported.

The snail vectors of the Bulinus genus are to be found in the catchment in pans, watercourses, floodplains and sand river beds. They can be expected to inhabit the immediate vicinity of any dam and irrigation areas. The degree of mobility of people in and out of infected regions of the country means that increased transmission of the disease has to be considered. It is also significant that considerable amenity use of the river has developed around the urban lifestyles of those in Selebi-Phikwe. This will place people close to areas of potential infection.

The main methods of control, if it were to be introduced, would include the surveying and monitoring of snail vectors, transmission points and the local populations. Special attention would have to be given in the local primary health programmes and public education, with controls on access to infected sites, the draining and restoration of borrow areas and the provision and advertising of safe alternative water sources for drinking, washing and

recreation. Schistosomiasis is not an acute disease, and there is a time interval of months between infection and the appearance of morbidity. Uncommon cases of death from schistosomiasis usually occur years after infection, in contrast to malaria, where severe illness and death can occur within two weeks of an infected mosquito bite. Praziquantel is a highly effective and well tolerated single oral dose treatment for both forms of schistosomiasis in the early years of infection, and the local primary health care service should become familiar with it's use.

K4.7.4 Water-borne Diseases

The other main water-associated diseases, including cholera, typhoid and hepatitis, were not considered to be of major importance by the Regional Medical authorities. Only viral hepatitis 'A' occurs to any significant extent. A potential hazard which has been considered is that of the breeding of the blackflies of the genus Simulium on the dam spillway, thus creating a risk of onchocerciasis transmission. This risk can be discounted for the species *S. damnosum* which in Southern Africa is zoophilic and the nearest focus of onchocerciasis is in the Thyolo Highlands of Southern Malawi. The simulation models available of the reservoir indicate that, in any case, the periods of use of the spillway would not allow a complete breeding cycle of the blackfly to occur.

K4.8 Animal Health

Discussions with the local Veterinary Department on the impact of a new ecology related to reservoir and irrigation development provided little evidence to suggest animal health, whether livestock or wildlife, might be affected. The only possible risk might be in the creation of conditions suitable for liver fluke, which can be easily controlled and managed.

CHAPTER K5

CONSTRUCTION IMPACTS

K5.1 Introduction

On a construction scheme of the scale proposed, involving dam construction, pipe laying and possibly major land development for irrigation, significant impacts on local people and the environment are inevitable during the construction stage. The following comments apply particularly to the construction of the dam but the more general points are also relevant for the irrigation areas. As a generalisation, the construction impacts for the dam will be more concentrated in terms of area but the irrigation impacts will be extensive. The use of sprinkler system irrigation avoids the need for land levelling which can be very disruptive. However the use of centre pivots will necessitate the felling of all trees within the area of pivot rotation.

Environmental amelioration during the construction phase is often given insufficient consideration. It is often seen as costly and difficult to arrange and constrains the efficient operation of the contractor's working. Sensitive and well planned incorporation of these elements into the construction contract, along with sufficient powers of enforcement and variation being given to the supervising engineer, should result in far better relations with those local people affected. Coupled with sensitive implementation this should improve the situation in the longer term and help gain the goodwill of local people. In the past some construction contracts have been characterised by crisis management in the handling of these sorts of issues. In view of the fact that there is a large settlement close by and the area is traditional Tribal Land, it is considered important to plan the construction programme for the dam with these considerations as an intrinsic part of it. In order to provide continuity and a consistent approach it would seem advisable that one individual is given the responsibility for overseeing the implementation of these measures. Too often the responsibility for these falls between different parties with the result that many are missed or thought of too late. Sensitive management of this nature is not necessarily costly: if handled well it can actually save money by avoiding conflicts and potential disruptions to the work which could result in claims by contractors.

To provide the best safeguards for local people, carefully produced specifications covering the contractor's responsibilities, beyond the specific construction activities, should be included in the tender documents. Items that are specifically required to ameliorate impacts (e.g. special fencing types) should be included under specific headings in the bill of quantities so that this category of real costs can be priced and budgeted for. In addition the contract documents should draw the bidding contractors attention to the need to conform to current national legislation, in particular the relevant health and safety legislation and the labour laws. Specifically the procedures for working through the local labour office need to be spelt out together with the restrictions on employing non citizens on the contract, particularly when local people with the required skills are available. Controls on the practice of Sunday and night work also need to be incorporated into the contract along with conformation to noise, dust and nuisance legislation and procedures. The operation of the quarry and borrow areas will need to conform to current safety legislation, particularly with regard to the storage, handling, transport and use of explosives. Of particular importance is the consideration of environmental matters in the siting of both temporary and permanent structures. Recommended locations for such items are given on Map K.3 and these have been incorporated into various other programmes such as bush clearance and the provision of an access road which skirts the built up area of Mmadinare.

If adequately planned and supervised, in conjunction with the District Council and people at the local level, the construction phase could provide much that is positive. The construction

operations will be carried out in very close proximity to Mmadinare. It will give birth overnight to a new, unique and mostly temporary industrial complex and neighbourhood to the town. Improved short-term economic activity will bring a minor boom which the commercial, trading and labouring communities will take advantage of. Investment finance will be encouraged and may help generate a new plane of economic activity once the construction phase comes to an end. Experience elsewhere in Africa shows that the longer term impacts of such temporary employment can often be damaging to the overall local economy. However, Mmadinare is already integrated into the wage economy and this is likely to be less of a problem. The high levels of local under-employment, and the attractions of local wage paid employment, may entice younger people from the village to remain or return from where they are working or seeking work elsewhere.

However, there are a number of important issues which need to be addressed. A significant relocation of labour could take place in the region. While the labour force may average 200 and peak at 300 at any one time, in practice, many more people are likely to be induced to migrate to Mmadinare. Labourers queuing for vacancies, the arrival of families of workers, the immigrants drawn in by the improved peripheral support and service activities, and the growth in entertainment activities associated with construction camps and earnings will all impose new demands on services and administration in Mmadinare. The development of the informal settlement at Botshabelo in response to the development of the mine at Selebi-Phikwe is a pointed reminder of what can happen if these things are not planned and regulated from an early stage.

If the contractor were to use access roads from Serule, Francistown and Selebi-Phikwe that were to pass through the Lands area this would result in dangerous, noisy and dusty conditions to those residents living along or using the route. People walking, herding animals, travelling by donkey cart or driving by vehicle will all be at some risk. These can be lessened if construction traffic were confined to the new recommended route avoiding the built up part of Mmadinare, as shown in Map K.3.

Recognition of these impacts could be accommodated by increased compensation payments made to the individuals most affected by the project. Other proposals made as part of the detailed environmental impact study of Bokaa dam (MacDonald, 1988a) suggested possible contributions to a village welfare fund to be administrated on behalf of needy groups, such as the disabled and the disadvantaged. Unlike the situation at Bokaa, improved access, installation of power lines and telephone facilities are unlikely to have such great beneficial spill over affects to the town due to the existing level of provision of these services. There is a strong likelihood that demands on these existing services will increase as a result of the stimulation of the local economy and the increase in the circulation of capital. This must be borne in mind when planning for the future development of such infrastructure. There is also the option of providing increased infrastructural provision as part of the compensation and amelioration programme as occurring at Bokaa. A further construction impact will be the effect on the existing water supply for Mmadinare, which draws water from the river sands 2 km downstream of the dam site. Apart from any reduction in the through flow in the sands due to the dam construction, there is the considerable risk of contamination. Following the construction of the dam Mmadinare will need a new source for its water supply and in Annex E it is proposed that this be provided from the reservoir, via a storage tank on high ground directly south of the dam site. This is referred to in Chapter K3 of this Annex in the context of downstream impacts. In view of the contamination risks during construction it is being proposed that this storage tank and pipeline are constructed directly at the start of the dam construction with a temporary supply provided by the contractor from the sand river upstream of the site.

K5.2 Contractor's Site Installations

The major temporary site installations will include offices, workshops, stores, batching plant, stone crusher, contractor's camp and the services and access for these facilities. In view of the proximity of Mmadinare village, the location of installations should be discussed and planned in conjunction with the Mmadinare District Council, Sub-Land Board and MLGL. An appropriate site for the location of the permanent housing complex for the dam operating authority has been identified downstream of the dam on the right bank. This conforms to the pollution guidelines and is shown on Map K.3.

For convenience of access, and to prevent contamination of the reservoir area, the site yards should also be located downstream of the dam, the most favourable location being on the right bank just to the west of the town and closer to the river than the permanent housing complex.

The sand extraction areas, rock quarries and earth borrow sites, along with temporary access roads to them, will all be contained within the reservoir area. Since the prevailing wind makes this area lie downwind of the village it should minimise any direct disturbance by noise and dust to the main village area (Map K.3). At the end of construction these will need to be graded off and made self draining to avoid the development of isolated pools when the reservoir level is drawn down as these would constitute a serious health hazard. Any spoil is to be dumped and spread in the borrow areas as part of the process.

A construction camp is possibly not justified for the number of workers expected and the length of construction involved. The 200-300 workers that are estimated to be required, would be transported daily from Mmadinare and the Selebi-Phikwe area. Senior staff would likely live in Selebi-Phikwe. If it were decided that it was necessary to build a housing compound then a range of options exists:

- temporary housing could be located slightly away from the built up area of the village a little towards the river from the permanent housing. At the completion of the project the housing would be removed and the area reinstated.

- consideration could be given to the construction of permanent housing, perhaps in partnership with the Botswana Housing Corporation or the District Council with the aim of this reverting to them once the construction contract were finished. This would perhaps be an economic way of providing much needed public sector housing. The location of these, perhaps as an estate, would have to be considered in terms of the longer term development of Mmadinare set against an appropriate position for the dam.

- the possibility of constructing quality permanent housing that could then be used as a recreational chalet complex, although successful elsewhere in Africa, would be difficult as the best location for these facilities (see Map K.3) is too far and inaccessible from the dam site.

In addition it may be worth considering the operation of a site and service provision programme for self-help housing in an appropriate part of Mmadinare. This would include the laying out of roads, surface water drainage, urban housing plots, pit latrine sites, water supply points and if thought appropriate, an electricity distribution system. This would be particularly appropriate for returning residents of the area drawn back by the expectation of jobs. The aim is to avoid the development of an unplanned informal or squatter settlement like that at Botshabelo.

The proposed pipeline route would create temporary disturbance to those farmers currently cultivating land along the route and to residents in Mmadinare. Preliminary assessments indicate that few families would be affected as the alignment has been deliberately chosen to minimise this. It will be necessary that during construction any pipeline trenches left open will have to be guarded or temporarily fenced so as to prevent livestock and particularly children from falling into them. It is also likely that any power line for supplying electricity to the irrigation areas IR4 and IR14 will follow the route of the pipeline. A maintenance track as well as a servitude will be required for this. Where possible the proposed alignment follows existing tracks in order to minimise these problems and hence reduce compensation costs, which if the work is well planned (particularly by construction in the dry season when there are no standing crops) could be minimal. It will be important to ensure that prior consultation and advance warning of work is given and that procedures for compensation assessment and payment are arranged well in advance. It is highly preferable to prevent farmers from planting on any required alignment by paying compensation in advance for lost potential crops rather than be forced into the very emotive position of having to destroy standing crops.

K5.3 Services and Pollution Control

Assuming that a construction camp will not be required, the extent of services and pollution control measures would be limited principally to the immediate construction activities, covering water, sewage and refuse disposal.

With water supplies at Mmadinare already limited, water requirements for construction may have to be obtained from new sources. A combination of sources is likely to include pumped well extractions from the sand aquifer and surface water ponds excavated during the first wet season for general water needs.

Sewage disposal would be by approved, regularly emptied, sealed septic tanks to be organised by the contractor. General refuse would be disposed of in approved pits which would be backfilled. Disposal should not be located within 200 m of the FSL of the dam, a borehole or a water course. Oil and chemical spillage and disposal would likewise be controlled. Some downstream pollution due to surface runoff is probably unavoidable but can be reduced by regular tidying up of the yards, for which an item could be included in the Bill of Quantities.

K5.4 Operations and Disturbance

The proposed quarries are not in the immediate vicinity of habitations which could be affected by debris or dust. However, blasting would be heard in Mmadinare and should be restricted to specified times of the day. Controls on site would be required to safeguard workers when blasting is being carried out.

Nighttime working at the quarry or haulage of materials should be avoided if possible. Night construction work on the dam may be unavoidable for some operations, such as concrete placement on the spillways, particularly when daytime temperatures are high. This will inevitably cause some noise disturbance to parts of Mmadinare village but this is unavoidable and in any case will be minimised as far as possible in relation to the prevailing wind direction.

K5.5 Restoration Works and Landscaping

The design of the dam, spillway and pumping station should take into consideration the landscape context in which it is being placed. This is particularly important when viewed from the east to the west across the reservoir. The contract should specify the final landscaping and appearance of the permanent works. If carried out in a sympathetic manner this can actually enhance the landscape. Final tidying up of the contractor's temporary works must be thorough and specified in detail in the contract documents, with a financial penalty if this is not carried out. Since all borrow areas are available within the reservoir area restoration measures will be limited to trimming back excavated slopes and the provision of natural drainage to avoid ponding when the reservoir is drawn down.

Depending upon the level to which the amenity and recreation proposals are to be taken, considerably more work on landscaping around the reservoir may be required. This is discussed further in Chapter K8.

K5.6 Employment Potential

One amelioration measure to offset the environmental impact of construction will be the creation of short-term employment opportunities on the construction site. Specifications to the contractor could help encourage this. Demand for unskilled jobs for construction of the dam could vary considerable depending on the level of capital intensity decided on by the contractor. If fully mechanised the employment generated could be as little as 200-300 jobs. A fair proportion of these jobs would be skilled.

Contractors generally do not appreciate being told where to obtain labour but, to discourage unnecessary influx of workers from elsewhere, and if handled sensibly by all parties, this need not constitute a problem. Unskilled workers should be available in Mmadinare and the remainder will be operators, artisans, clerks and some semi-skilled labour, many of which could be found in Selebi-Phikwe and Botshabelo, or if necessary further afield in Francistown or Gaborone.

K5.7 Social and Health Problems

The contractor will be required to follow all the standard safety procedures laid down by the government with respect to construction sites, including provision of an adequately equipped accident and First Aid post staffed with qualified attendants. The Ministry of Health should be notified to provide an Occupational Health Unit to assist and supervise with this.

The influx of workers from outside and the construction tasks will introduce new health risks. If the proposed pipeline is to be built using asbestos cement pipes it will be important to protect workers from inhaling asbestos dust. Similarly on the quarry areas and construction site workers should be given full facilities to protect them from the adverse effects of inhaling dust.

The arrival of a major construction project will lead to a number of social problems for which action may be required. Problems of alcoholism and prostitution are likely to be dominant amongst these problems with all the associated issues which these raise. Early liaison with the Ministry of Health and joint planning with the local authorities will be crucial to ensure that timely and effective advance provisions are made. Particular attention should be given to the provisions needed to combat the spread of AIDS and other sexually transmitted diseases, serious outbreaks of which have recently been recorded amongst migrant unskilled farm labourers at Pandamatenga.

K5.8 Consultation with Local Authorities

Prior to formulating the contract documents for the construction works, consultation should be made with the relevant local authorities to ensure that specification clauses relating to environmental and land use planning issues satisfy, where possible, specific local requirements. The dam location and pipeline alignment falls solely within the Bobirwa Sub-District of Central District thereby minimising the number of different institutions to be involved. The headquarters is at Bobonong.

In addition to the consultations with the District Council, frequent meetings should also be held during the construction period, possibly using a liaison officer delegated from both the District Council and the contractor. This will ensure that problems will be resolved before developing into major issues that will then be more difficult to deal with.

CHAPTER K6

IRRIGATION IMPACTS

K6.1 Irrigation Potential and Constraints to its Development.

K6.1.1 General

Irrigation development options are discussed fully in Annex I and J. The TOR for the study place the socio-economic feasibility of irrigation development within the framework of the Environmental Impact Study, which is primarily related to the impacts of the proposed dam, considering these to be derived impacts of development that could perhaps be ameliorated for. Experience from other projects in Africa has indicated that these factors can be the most important, over all others, in determining if a project is capable of achieving its objectives. It is more appropriate to see the existing socio-economic and political conditions as major constraints on the nature and scope of any proposed development and these should form a major consideration in approaching any decisions as to possible development options. As such, Annex I and J are best viewed in the context of this chapter.

K6.1.2 Small-scale Irrigation Development

In the section of river under study, between Mmadinare and Bobonong, there are two distinct components for potential irrigation development, differing in location, scale and market orientation. Larger contiguous blocks of land (although by general formal irrigation development standards they are quite small and fragmented) have been identified by the soil surveys for this study: in general they lie behind the heavy riverain vegetation. In addition there are smaller riverside plots (typically about 4 ha in area) which have in the past been only rainfed. Some plots, that are owned by people with access to capital, have recently been equipped with small pumps and others are currently being, or soon to be, developed. Many of these lie within the riverain strip and stretch back away from the river. The development of this spontaneous irrigation is now being assisted by the SPRDP, who have prepared detailed farm plans for over 20 plots (see Minster, 1989). There is at present no major problem over water allocation, save for the fact that few if any of the irrigators appear to have a permit from the Water Apportionment Board. However, even within the planned framework of the SPRDP assistance programme there is potential for both a water shortage and a saturation of the market for vegetables.

The construction of Letsibogo dam will have the effect of substantially reducing the number of days each year when there is surface flow in the river, particularly upstream of the Letlhakane confluence. However, with an average of only 86 flow days per year (see Annex A, Table A3.5) it is clear that all of these small-scale irrigation schemes must rely on stored water in the sand river aquifer. Results from the sand river model (see Annex B, Chapter B5) have indicated that the construction of Letsibogo dam will have a minimal impact on water levels in the sand river at the most crucial period, the end of the dry season. The only plots to be directly affected by dam are two immediately downstream (see Table K6.1), with about 3 ha of irrigation. Consideration should be given to supplying these areas directly from the dam.

Quantifying the constraints imposed by water resources on the area of small-scale irrigation that can be supported is essentially one of assessing the volume of water that may be obtained from the sand river local to the extraction point. This, in turn, is dependent on

the volume stored in any particular reach. In this respect the sand extraction process of the BCL Mine can be seen as reducing the available storage in the aquifer.

As there appears to be no requirement for releases from the dam to maintain existing small-scale irrigation the level of this development is set by existing water resource and marketing constraints. With regard to large-scale irrigation development the basic alternatives being considered relate to conveyance method. Pipeline conveyance effectively leaves the river downstream of the dam unaffected. River conveyance for large-scale irrigation would also remove the water resource constraint on small-scale development for any extraction point between the dam and the most easterly irrigation block. Market constraints would not be significantly effected, however, as vegetables would still be regarded as the main cash crop. The construction of a cotton ginnery could provide the opportunity for a further cash crop, but returns are not likely to be very attractive.

Brief details of current and projected areas of small-scale development are given in Table K6.1.

Table K6.1

Existing and Proposed Informal Irrigation Development in the Motloutse Valley from Letsibogo Dam Site to 3 Km Downstream of Tobane

Chainage[1] (km)	SPRDP nr	Name	Fenced area (ha)	Cleared area (ha)	Present irrigation	Proposed irrigation
2.0S		Unknown	2	2	2	2+
1.7N	1	Mbulawa	1.3	1.3	1	1.3+
6.2S	2	Malesele	4	4	2	4
9.2S		Unknown	4	4	1	2
9.0S	4	Pelser	196	8.25	0	10+
11.7N		Unknown	4.5	4.5	0.3	?
16.9S	6	Rice	88	20	7	20+
20.3S		Nata	5	2	2	2
24.0N		Unknown	12	4	2	4
27.4S	9	Ntshipi	2	2	1	2
27.5S	10	Gouws	8	8	4	8
27.7S	11	Harris	4	0.5	0.25	0.5+
28.4S	12	Coop	11	11	2	2+
34.0S	13	Dintwe	6	6	0	3
38.0S	14	Rakwadi	14	10	1.5	1.5+
39.4S	15	Motlhasedi	1.5	1	0	1.5
39.5S	16	Rakwadi	1.5	0	0	1.5
39.6S	17	Othusitse	1.5	0	0	1.5
Totals	18		366+	88	26	67

Notes: N and S refer to North and South bank chainage from Letsibogo
Source: Consultants Field Surveys and 1988 Air Photography plus SPRDP (Minster, 1989)

It is considered unlikely that all of the 'proposed' irrigation areas will actually come to fruition, with the marketing constraints as the most serious. Even so the total area is comparatively small, and as such is not considered to have a significant bearing on two major study objectives of assessing the potential for meeting urban demand and large-scale

irrigation development. A case could, perhaps, be made to improve the existing water resources of the sand river, to support some areas of small-scale development. However, sand river conveyance would be the only practical method for supplying such small areas and this would be very inefficient. It is, therefore, recommended that small-scale development should be limited to that which can be sustained by the stretch of river in the locality of each scheme, which will not be affected by the construction of the dam.

Small-scale development using the sand river will draw down water levels in the dry season, which may have an effect on other users, cattle, local population etc, and riverine vegetation. However, the present level of study would suggest that a natural limit will be set by the difficulty of extraction with the techniques available to small-holders, and other users should still be able to locate sufficient water. Work with the sand river model has suggested that the riverine strip does not draw significantly from the sand river, although it is still possible that lower water levels in the sand river could draw some water out of bank storage.

There is a need to regulate the development of small-scale irrigation, primarily to ensure that proposals are practical and the schemes are sustainable. Mutual interference between adjacent schemes will result from uncontrolled development. It is also important to monitor the effects of new extraction points. This regulation requires that the Water Apportionment Board be operational and effective in enforcement. It also requires the Land Board to work within guidelines in respect to the allocation of garden plots, specifically their maximum size and location relative to other similar plots and water availability in the sand river, plus restrictions on the cutting of riverside vegetation to prevent bank erosion. These issues are covered in the Terms of Reference for a land use planning and management study shown in Appendix K-K.

K6.1.3 Large-scale Irrigation Development

With regard to the development of formal irrigation, a range of options for its institutional and technical framework are considered in Annexes I and J. These include water distribution systems such as center pivots and sprinklers, and the scale and management of units. Options included both commercial and smallholder schemes on the larger blocks of land. However the use of capital intensive, high technology, delivery systems to maximise water distribution efficiencies has resulted in the recommendation that a highly managed commercial operation is required, to run the system in an efficient manner. This then precludes the option of smallholder operation of the formal irrigation areas, with the result that the only possible way of incorporating displaced land holders is by the opportunity for them to work as wage paid labourers. Enquiries as to if the existing land occupiers would be prepared to do this indicated that it was not an attractive proposition and so, generally, providing replacement land is the preferred option.

The areas identified with potential for formal irrigation were originally delineated by reconnaissance soil surveys in the Phase 1 studies. Fourteen areas with potentially irrigable soils have been identified, totalling about 2 000 ha. These blocks are widely scattered between Mmadinare and Bobonong and, although greatly fragmented, generally lie within 4 km of the river as shown in Album Drawings 33 and 34. Subsequent semi-detailed surveys within these areas found that blocks range in area between 30-620 ha. In view of the constraints of water availability and the economics of conveyance, it was decided to limit irrigation development to those blocks between the dam site and Tobane i.e. irrigation areas IR1-IR5 and IR14. The environmental and socio-economic studies initially covered all 14 areas but later concentrated on the selected areas with a total irrigated area of about 1000 ha.

Existing informal irrigation is all limited to very small blocks of land immediately adjacent to the river. At the level of detail which the soil surveys were conducted it was not possible to delineate any such areas for future development. In any case it should be recognised that the process by which informal irrigation plots are developed firstly relies upon the holding of an existing land right.

Early in the studies the option of canal conveyance was discounted on the basis of cost and poor efficiency. Delivery system options considered include river conveyance feeding to river pump schemes, and a pipeline from the dam. On-farm irrigation options analysed include both sprinkler and centre pivot systems.

Of the gross land area, 35% is fenced and shows signs of having been cultivated in the last two or three years. This should be considered as the lowest figure for the land on which there are existing individual land rights. The other major factor is that the lease area upon which BCL have a veto over surface land rights, covers 30% of the identified irrigable soil area. There is also a complication in that there are recently registered rights within the mine lease area that have been granted since the area was expropriated from existing customary right holders. There are also a significant number of local people living and carrying out small-scale dry land foodcrop farming within the irrigation areas that occur in the mine lease area. They have been refused registration of their plots on the grounds that they are within the mine lease and are thus technically squatters. However, this argument has not stopped the allocation within the mine lease area of very large (in one case an area of 200 ha) registered plots to certain people. In addition the Reconnaissance Permit area covers an additional 43% of the irrigable soils and this must be viewed in the light of the likelihood of a full exploratory lease being applied for this area. In all there are thus existing surface rights or actual and potential controls for 90% of the identified irrigation areas. A summary of the overall occupancy levels as a proportion of the total irrigation areas is given in Table K6.2.

Table K6.2

Proportion of Existing Land Occupancy in Proposed Irrigation Areas

Irrigation Area	Occupancy (%)	In Mine Lease Area (%)	In Reconnaissance Permit Area(%)
IR 1	47	0	0
IR 2	80	100	0
IR 3	2	100	0
IR 4	10	68	32
IR 5	40	0	72
IR 14	30	62	0
Weighted average	35	30	43

Source: Consultants field studies and air photography, October 1988

The unfenced land within the identified irrigation areas (about 750 ha) is used for grazing and some is also likely to have historical customary cultivation land claims on it. The utilisation of these remaining uncultivated areas would excise less than 0.5% of the grazing areas within about 12 km of the Motloutse. The total irrigation area combined with the reservoir would still represent less than 3% of the available grazing area in this region. While these areas are proportionally small, their loss to grazing would not be insignificant.

The irrigable lands mostly lie adjacent to the riverine zone and comprise the better soils. They are also the better grazing lands and thus, in terms of productivity, the proportional losses may be greater. This zone is also more densely stocked than the hinterland uplands, as it lies close to the major river watering points, and to the riverain Lands where other homestead stock are also kept. Irrigated farming systems may help to ameliorate this loss of land. The productivity of forage from irrigated crop residues and fodder crops should exceed that of the existing grasslands and browse. However, it is unlikely that this output could benefit the same stock owners who were displaced from the irrigated lands. Forage from irrigation units would not be produced directly for local stock or other owners and hence is not comparable to the free resources available from the communal grazing land.

Experience from other countries indicates that the success of irrigation development and the achievement of social and economic policy objectives rests, to a significant extent, upon achieving a sound foundation in terms of security of tenure, its links to financial support strategies and a thorough approach in land tenure planning.

The promotion of commercially-run units under modern management raises problems of social acceptability. This option would have to draw on imported management skills and would demand the expropriation of land from existing users, with their likely exclusion from the management of the resources and receiving few direct benefits from the development.

K6.1.4 River Conveyance

During the first phase of the study three options were considered for conveying water from the dam site to the irrigation areas, (MacDonald, 1988). The initial assessment was sufficient to reject canal conveyance: a pipeline and river conveyance have been considered in the subsequent analyses. The impact of a pipeline would be minimal. However, using the river as a means of conveying water would significantly alter the regime downstream of the dam.

Due to lack of data, the optimum programme of releases into the sand river has not yet been established (see Annex I). However, a release of 300 000 m^3 has been assessed, indicating that 50 such releases would be required to meet the requirements of 1 000 ha. Releasing this amount over 24 hours results in a discharge of 3.5 m^3/s, which is well within the capacity of the channel. It is likely that surface flow would cease by the day following the release, but water would be a near-permanent feature behind the proposed weir at Tobane. The chief impact of this release pattern is in restricting vehicle access across the river. Pedestrian and livestock movements could commence soon after the surface flow has ceased.

A crossing point has been incorporated into the weir at Tobane. Flow over the weir would be limited to periods of high runoff in the river, which is the traditional time for access to be impeded. The requirement for further crossing points would have to be assessed once firm details of areas to be irrigated and a pattern of releases had been established. In particular, the construction of further weirs may be justified by savings in the cost of riverside extraction facilities. Should this be so, there would be further opportunities for incorporating permanent crossing points.

The programme of releases into the river will probably enhance the general role of the sand river as a water resource. Transmission of water through the sand aquifer is relatively slow, which means that the draw-down produced by the river extraction points will be limited in extent. A further release will be triggered by depletion of the aquifer in the

vicinity of the extraction point, well before the draw-down extends very far along the river.

Finally, it is important to consider the effect of river conveyance on the sand extraction process for the BCL Mine. This is difficult without final details of the irrigated area and further work on optimum release patterns. At worst, the greater periods of saturation could necessitate double-handling of the sand, with initial excavation carried out by dragline. The sand could then be allowed to drain before re-excavation into dumper trucks for transporting. Alternatively, it may prove possible to excavate a channel in the sand over the reach being worked, to reduce the volume entering into storage.

K6.2 Resources at Risk

The majority of the irrigable soils used for the preliminary designs do not extend into the riverine strip, as the alluvial soils of the river banks tend to be too coarse and variable. However, IR1 does have a significant river frontage. In order to limit the risk of erosion from cleared land adjacent to the river bank it is necessary to maintain a minimum strip of riverine vegetation. Whilst this must be site-specific a general minimum of 30 m has been adopted. This process must be followed in detailed design. It is recommended that this important vegetation zone be protected by clauses in the Leases issued for any riverain farm (whether irrigated or not). Its primary objective would be to maintain dense tree rooting and the protection this affords for the river banks against erosion and the possible loss of irrigable soils and the important riverain livestock grazing areas. It also would have the effect of conserving the specialised ecological habitats for valuable species of flora and fauna.

The development of the spontaneous smallholder pump schemes is still in its infancy and some growth may be expected. If this occurs then rates of pumping for irrigation may soon compete with the demands of existing users within each section of the sand aquifer. The surveys suggest that the socio-economic conditions do not exist locally for a positive and self-regulating set of agreements between local users. This competitive situation may also persist after the construction of the dam, depending upon the operating criteria for providing the irrigation water. The interests of all existing users must be served if other sectors of the economy and society are not to suffer as a result of irrigation development.

The 1981 census data and further data from agricultural surveys (see Table K-C1.4) show that over 80% of families are involved in cultivation. The land distribution patterns are not so well understood. Experience worldwide indicates that when a major new farming system becomes available patterns of resource ownership can shift. Land enclosure of riverain and communal land are common developments when pressure on land and suitable economic conditions exist. This can make land enclosure both a new farm management system, as well as an effective economic strategy. This is achieved by using durable fencing to fix land boundaries when land (particularly riverain land) begins to attain a real if not growing asset and market value. The enclosure of land can become the main pressure on a dwindling resource of communal riverain grazing and browse. Those mixed farmers within fences find it increasingly difficult to find adequate grazing outside their fenced areas and so start to erect more to allow the conditions for individual management of their own fodder resources to develop.

The attraction of irrigation, to both politicians and aid financiers, can also induce land enclosure by relieving institutional and credit constraints. Various scenarios of conflict between competing interests can soon arise, depending upon the distribution of resource ownership and the state of social and economic relations. Large stock owners may be dominant amongst the irrigators. Land owners might also control marketing chains and

trading interests which can be serviced by direct involvement in irrigated production. Similarly, these same traders or other urban based or foreign investors, might perceive benefit in land investment for speculative or strategic purposes.

Common outcomes, whoever the players, can include the widening gap between rich and poor, the creation of a new middle class of wealthy rural landowners and the increase in landless families. Issues of equity and the distribution of development benefits should therefore be central to the decision-making on the planning of irrigation development. However, the proposed methods of sprinkler irrigation, based on the demand for efficient, and economic use of water, combined with the lack of local experience of large-scale irrigation, mean that the majority, if not all, of the existing land owners are unable to take a direct benefit from irrigation development, although there will be opportunities for employment.

K6.3 Land Tenure and Relocation

The development of formal irrigation along the lines proposed would require a major programme of land expropriation from those people having existing land rights in the identified areas. The degree of existing rights is indicated in Table K6.2, with preliminary estimates of the losses being given in Table K6.3. These are valued according to the MLGL Compensation Guidelines, reproduced in Appendix K-A, and are given in Table K7.3. Gross area is based on the nett irrigated area in each block (see Annex I), with an additional allowance of 10%, for tracks, building, etc.

Table K6.3

Estimates of Loss of Assets in the Proposed Irrigation Areas

Irrigation area	Gross area (ha)	Existing cultivated area (ha)	Homesteads (nr)	Other plots (nr)
IR1	76	36	8	1
IR2	65	52	3	6
IR3	80	2	0	1
IR4	110	11	2	0
IR5	616	246	17	16
IR14	173	52	5	6

Source: Field Surveys and October 1988 Air Photography

In preparing the irrigation layouts for area IR5B (see Album Drawing 58) account was taken of the urban homes associated with Tobane village. Even though this resulted in a reduction in irrigated area it also significantly reduced the level of compensation. At detailed design stage the policy of assessing the merits of each field on an individual basis should be extended to all potential irrigation areas.

This expropriation of land from the Tribal Areas will have to address a number of major policy issues. There would seem to be difficulty in identifying who the implementation body for this sort of development could be. The only precedent so far would seem to be the issuing of commercial farming leases at Pandamatenga. In this case they were issued by the Land Board to commercial operators on a 15 year lease. This would get around the necessity to justify taking land in the national interest, which would be the case if it were

developed by a central government department or ministry. It would also retain ultimate control of the land by the Tribe and perhaps generate income from rents. This is further discussed in Section K7.4. The issuing of leases to commercial operators in Tribal Lands has major political implications, which are compounded by the limited availability of replacement land nearby to compensate existing land holders. It is also the case that the benefits of commercial irrigation development are unlikely to accrue to existing farmers. The result will be that commercial cash and foodcrop production for sale to the urban population will be produced at the expense of existing rural subsistence foodcrop farming. Surveys in the proposed irrigation areas indicated that typical sorghum yields are of the order of 150 kg/ha. With 415 ha of the irrigation areas between the dam site and Tobane being farmed then this would represent a loss of 60 tonnes of sorghum to the local population, being replaced by an average of 1 450 tonnes of maize, 1 050 tonnes of wheat and 700 tonnes of cotton. It is also the case that amongst these families there are many who have already been the subject of displacement when the BCL mine lease was taken up in the early 1970s.

The availability of alternative equivalent replacement land nearby is not easy to assess without very detailed enquiries which would be likely to cause anxiety in an area where security of tenure is already an emotive issue. Detailed study of the air photography indicates that there are areas outside those identified for irrigation development which appear to have no current cleared and farmed plots. It must be pointed out that the soil quality of the areas identified for irrigation is, by definition, superior to that outside the areas and under the Compensation Guidelines any replacement land must be able to give the same total amount of crop as the land lost. In the case of IR 5, which lies in the heart of a main Lands area of Tobane village, this will not be at all easy to find. Previous experience at Bokaa (MacDonald, June 1988) has indicated that it is only by very detailed questioning at household level can these issues be tackled. It would seem inadvisable to embark on this level of detail at this stage of the project. The conclusions that can be reached from the present study are that there will be a real problem in finding replacement land in IR5 but of the eight sub-areas within it, one has a considerably higher proportion of losses than the others. Under the revised Compensation Guidelines (Appendix K-A) there is provision to pay cash for the asset value of land if no equivalent land can be found. Whilst this is, in general, highly undesirable in social terms there may well be individual cases where this policy could be justified and would actually be favoured by some households.

The existence of current and possible future mining leases within the irrigation area also raises national policy issues. As shown in Table K6.2 some 30% of the irrigable areas lie within the existing BCL mine lease area. An additional 43% fall within the current reconnaissance permit area, which is at present being surveyed in detail and it seems likely that a full exploration lease will be applied for it. In the context of the region's economic development, the continuation of mining activities is likely to receive far higher priority than irrigation, given its existing level of capital and infrastructural investments. However, recent discussions with the mine authorities have indicated a willingness to consider the possibility of irrigated agriculture within the lease area. Careful planning would be necessary to ensure that none of the mine operations were adversely affected by such developments, most specifically the mine would require direct access between the mine shaft and the processing operations in Selebi-Phikwe.

In conclusion, it must be recognised that the present land tenure situation is a significant constraint on the development of formal irrigated agriculture. Procedures are available to government to expropriate Tribal Land and pay compensation to displaced persons. Whether this is the justifiable approach to follow depends on a judgement as to the value, in the national context, of the benefits of improved agricultural production and modest employment generation, against the disruption, and possible long-term disadvantage to those

displaced. A significant factor in making such a judgement is the poor economic returns from such a development, see Annex J. Nevertheless, it is difficult to see an alternative to irrigation in meeting Government objectives of increased food production and creating employment in the agricultural sector. If Government were interested in encouraging formal irrigated agriculture in the Motloutse valley, then a detailed assessment of land reallocation needs would have to be undertaken for each household effected, followed by further soil surveys to identify suitably located replacement land.

K6.4 Agro-chemical Use

The increased levels of capital mobilisation required for irrigation usually demands a proportion of high value crops in the cropping pattern to ensure economic feasibility and debt repayment capacity. To achieve and maintain high yields requires good control of pests and diseases. The use of modern agro-chemicals usually provides the simple answer when such farming systems lack the research and institutional support for alternative pest control management systems. There is no reason why Government could not institute this alternative approach, for the future protection of the environment, as agricultural techniques become more intensive. This shift in emphasis is already being adopted in countries with major irrigation schemes (the Sudan provides a good example) where there has been a legacy of financial and economic problems caused by the irrational use of agro-chemicals.

It appears unlikely that the total irrigable area available could be developed due to the competitiveness of the urban water demand. The hydrological and economic models indicate that a maximum of 1 000 ha could be supported by the proposed Letsibogo dam. If all this were developed using agro-chemicals the risks to the local ecology and water quality would be small, but strategically no less important.

By definition, most agro-chemicals are poisons, often derived from naturally occurring chemicals originally discovered in plant materials. Some are highly selective in their action, others indiscriminate. Some are bio-degradable, others gradually dissipate or are fixed in the soil or water medium. Some can enter and accumulate in the food chain, and many are hazardous to the health of workers unless strict precautions are taken. All are part of an industrial trade network which actively promotes the expansion of their markets and sale. Commercial interests should not be allowed to interfere with good farming practices and the preservation of a healthy environment for future resource users.

A number of international organisations and pressure groups monitor and release information on dangerous and banned chemicals which have a tendency to dumped in Third World countries. These include, amongst others, the Pesticide Action Network, the United Nation's Consolidated List and the FAO's International Code of Conduct. Amongst the most hazardous agro-chemicals banned, or severely restricted, for use in developed countries are DDT, EDB, Alrin/Endrin, Chlordane/Heptaclor, Parathion, 2,4,5-T, Paraquat, DBCP, Lindane/HCH, Toxaphene and PCP.

Care will be needed in the selection and management of chemicals because of the location of the irrigable areas. Virtually all the blocks identified are close to the riverain area, and thus a specialised ecological zone. Spray drift will be of particular importance. Their location will mean that drainage and leaching from these farms will be directly into the river, or closely associated groundwater. While the annual quantities of agro-chemical used may be small, the effects of long-term use on soil chemistry, micro-biology and local insect ecology are poorly researched and should not be ignored. The evidence accumulated worldwide indicates that proper planning and guidance to farmers should be initiated from

the outset. To do otherwise may disturb important local ecological features and without prior knowledge of the implications.

A further factor to be considered is the possible adverse chemical reactions which might occur when agro-chemicals are mixed in the environment with the aerial and aqueous pollutants emanating from the BCL mine. The ecological impact on water and food quality of water would require specialised research.

The enterprise models used for planning purposes could have little bearing on the type of agro-chemicals and dosages which farmers may actually adopt. Individual assessment of the agro-chemicals assumed in the models has not been carried out.

K6.5 Socio-Economic Aspects of Irrigation Development

K6.5.1 General

The development of irrigation, from a base where no previous experience exists, faces a number of socio-economic problems. The issues will vary with the organisation and management systems selected. Of the wide variety of options to choose from only a few have been considered as potentially viable and carried through for analysis (see Annexes G I and J). Formal public sector development of smallholder schemes, cooperative schemes and nucleus estates have all been rejected.

The types of farms still being considered include:

1. Large scale commercial farms (a farm size of 375 ha has been assumed in the technical and economic analysis)

2. Medium scale commercial farms (a farm size of 60 ha has been assumed in the technical and economic analysis)

In addition these will not preclude the strengthening of the present development of small-scale informal riverside irrigation plots.

K6.5.2 Management Adaptations

Since these options do not involve either public sector or smallholder management, cropping decisions will be left to large-scale farmers or farm managers. Commercial farm managers will tend to select cropping patterns reflecting the crops of best economic advantage. However, it may be necessary to have controls over cropping patterns and this could perhaps be best achieved by stipulations in the lease agreement and/or price support mechanisms for selected crops. As part of the socio-economic surveys the attitude of existing farmers to irrigation was investigated. Although the option of smallholder irrigation has since been ruled out it is worth recording the results of this, given the insights it provides into the priorities of those farmers who are likely to be displaced by formal irrigation. Local smallholder farmers expressed a major objective for crop selection as being a priority for food security. Although irrigation of food crops may appear uneconomic at the macro level, at the household level it is a very rational strategy as it helps to reduce the very real risks which have to be faced by farming families. This risk is deemed sufficient for them to forego some cash income. Irrigated surpluses can be sold to rainfed farmers in both drought years and dry seasons and since prices late in the season are usually higher than the annual averages then good cash returns are sometimes possible.

The surveys also confirmed the importance attached to the mixed enterprise strategy involving livestock, both for the asset value but, more importantly, as sources of regular cash income through sales of dairy products and meat animals. Some farmers were also found who strived to improve fodder supplies from the rainfed Lands to achieve an improvement in the condition of the ploughing stock early in the season. Other equally important social and economic objectives were confirmed in the field surveys. These include the need to maintain a breeding capacity to cover drought losses and the desire of parents to accumulate sufficient stock to pass on to children as inheritance assets. Livestock breeding also provides an effective strategy of inflation protected savings by producing a stock of saleable assets for future cash flow requirements. This seems preferred to that available from the banking services and perhaps implies that livestock operations of the larger existing farmers are considered by them to be of far greater importance than cropped farming. This reflects the overall perception that returns from livestock are considerably higher than those from food cropping. These livestock priorities may also affect the strategies for the reinvestment of any returns generated from small-scale irrigation. Re-stocking after drought losses or purchases of breeding stock may take priority over irrigation reinvestment.

The limits of the local markets for vegetables has been covered in Annex H. The main period of profits will occur for the first irrigation farmers who can take advantage of under-exploited vegetable markets. Once the relatively small areas required to over-supply seasonal markets have been developed, prices and profitability will decline.

Over and above the technical, maintenance and economic problems of keeping the smallholder pump schemes operational, many of the existing farmers face damage to infrastructure and crops caused by wildlife. This has, in some cases, led to irrigation operations being discontinued. The main problems includes elephants, monkeys and birds (the Motloutse riverine area is a major roosting site for quelea-quelea birds). The elephant populations have free access to the Motloutse, both from Zimbabwe, and from the lower Motloutse and Shashe catchments. Simple wire and post fencing is unlikely to deter elephants and electric fencing may be necessary.

K6.5.3 Irrigation Skills and Attitudes

As part of the socio-economic surveys, attempts were made to ascertain the existing level of experience and attitudes to the development of irrigated agriculture under a wide variety of scenarios. Whilst the range of scenarios has now been greatly reduced it is still felt worthwhile recording peoples perceptions to other possibilities. There is no traditional base of irrigation skills available amongst farmers in the Motloutse valley. A few older ex-migrant workers have brought back skills after working for irrigation enterprises in Zimbabwe or South Africa. Those who have these skills, and the means of raising capital, are amongst those who have already tried setting up irrigation units on the Motloutse. The level of irrigation skill shown is not sophisticated and most suffer from a lack of support services to maintain their pumps and pipelines, or they suffer from a lack of capital to purchase the appropriate or full range of equipment. In all cases the area under irrigation is very small and only sometimes does this involve the need for hired labour.

A few cases of expatriate irrigation farmers exist where they have been able to organise leasing arrangements. This group includes both new and professional irrigators who are developing both sprinkler and centre pivot systems on small to medium scale units. This group could induce a demonstration effect on other local irrigators. They might also be prepared to participate in an organised promotion of these modern and more efficient irrigation methods and the training of other farmers.

The socio-economic surveys identified a range of different attitudes to irrigation prevailing in the study area. A high profile has already been given to water resource development along the Motloutse by national and local politicians. Most people were therefore aware of impending change and new opportunities. However, the interviews revealed a keen sense of awareness of the real problems which were likely to occur.
First amongst people's concerns were issues of land tenure, as discussed above, and the implications of any re-organisation of land made necessary by the technical method of irrigation to be introduced. People expressed their fears of being dispossessed of their Lands to make way for immigrant or commercial farmers.

They also highlighted the financial problems which they would face if asked to take part in this more capitally intensive form of land use. They particularly asked about the type and level of investments which would be asked of them, the interest rates which they would be charged if they had to borrow money, and the types of collateral and security which would suffice for them to be accepted for a loan.

The existing pattern of social organisation, on and between farms, shows a strong regard for individual freedoms and self-reliance. In part, frictions caused by social attitudes, social status and the distribution of wealth in the society are the cause of this. But, at the same time, reciprocal and charitable arrangements do exist amongst neighbours, to minimise the stresses of incapacity or lack of resources. The advantages which these confer, in most circumstances, do not interfere with the capacity of individual farm units to make their own independent farm management decisions.

When asked about the likely reactions to a re-organisation of land and farm management to make the best use of irrigation opportunities, there was a general consensus amongst the people interviewed that problems would be faced. First, there would be many who would be unlikely to show strong or long-term commitment to the new levels of management required to operate irrigation units profitably. This would mean a shifting pattern of involvement with regard to members of any association of irrigators or their labour force. Second, due to the tensions which can so easily develop between neighbours, joint agreement on management of assets, which may have been amalgamated to rationalise irrigation, would be difficult to maintain. Thus, the organisation of irrigation management, and the forms of leadership required to direct schemes in a coherent and economic fashion, would also face difficulties.

Their reaction to the possible expropriation of their land to allow skilled commercial interests to make the best of the irrigation resources reflected a resigned attitude. This was a decision for Government and one which they did not regard themselves a party to. They seemed to accept, from the precedents set by the arrival of the BCL mine, that their voice would not be significant in this process. Their main concern centered on how the compensation and relocation issues would be dealt with and how their interests and resources would be protected.

K6.5.4 Labour, Employment and Income Possibilities

A major Government objective, associated with water development on the Motloutse, is to promote diversification of the regional economy, away from the dependence on the mining in Selebi-Phikwe. To this end, any irrigation development should act to maximise the amount of employment generated, not only for field labour and farm management, but also in the agro-servicing and agro-processing support industries.

In practice, the over-riding priorities set by the economic and technical analysis of scarce stored national water, the competitive demands between the urban and rural consumer, and

the need to maximise the efficiency of use of irrigation water with the available soils, have all concluded that labour saving technologies would be most appropriate for commercial irrigation development, using water from the Motloutse. Even if the commercial options are adopted, this need not preclude support to developing the existing riverain spontaneous pump schemes. However there would appear to be little scope to generate on-farm employment and returns for existing farmers through the use of these less sophisticated irrigation technologies as it is only the broad area crops, such as maize/wheat/cotton, that can justify large areas of irrigation and these are not well suited to smallholder development.

Agro-processing capabilities already exist in Selebi-Phikwe for fruit and vegetables, and tomato processing, as part of a fish canning enterprise. These units have expressed interest to take locally grown irrigated produce. Fresh fish would also be taken if produced as part of a fisheries scheme within the Letsibogo reservoir. Proposals are also being considered by BDC and CDC for the construction of a cotton ginnery in the region, which would improve the opportunities for cotton as a major irrigated crop with significant employment generation.

Irrigation development superimposed on, and displacing a traditional rainfed and livestock farming economy, will have an impact on the income distribution pattern. The degree to which income redistribution can occur as a result of irrigation will depend on who will own and control the resources, how much new employment is created and for whom, along with the competitiveness of irrigated labour opportunities and wage levels when compared with the alternative of urban and mining wage employment. Evidence from Pandamatenga and Talana Farms indicates that many of the opportunities will be taken up by outsiders, both in terms of management of the irrigated farms and the provision of labour.

The commitment of local people to existing family farming occupations, the close proximity of urban wage markets and the low rate of agricultural wage labour may create disincentives to wage labouring on commercial irrigation units. Changing social attitudes and the drift to the towns amongst the younger generation will restrict the availability of labour from amongst the urban unemployed, even though the level of existing urban unemployment is high. The reluctance for a return of this labour pool, to assist in rural labouring, is best exemplified by the shortages of herding labour.

If the irrigation areas were to expand significantly, increasing demands for daily paid seasonal labour could lead to competition for labour between farmers and push wage levels upward. However, rural wages would only rise to a level which maintained profitability on the farm. This may still not compete sufficiently with the urban wage alternative, to induce a shift of the urban unemployed. However, the demands for labour from the relatively small area, which is likely to prove viable for irrigation, should not exceed the supply of available labour prepared to take on this work. While some labour would come from amongst the urban unemployed, a greater contribution would probably be found from amongst rural women.

The BDC Talana farm has had considerable difficulty in recruiting labour for its cotton picking operations. This seems to be due to a number of related factors, including unattractive rural labour wages, the need for family farms to be tended when the seasonal cotton labour is required, and the changing attitudes of workers to rural work, which is partly associated with the local urbanisation of the labour market in Selebi-Phikwe.

K6.6 Sites of Special Interest

In view of the greater uncertainty as to the likelihood of developing formal irrigated agriculture, archaeological studies were not started in the irrigation areas. The reservoir area was considered a higher priority, however if a decision is taken to consider irrigation development further, then these studies should be completed. Preliminary reviews of the ecology of these areas found that the major part of the area is covered with regenerating species on lands previously cleared and cultivated. The findings are discussed further in Appendix K – E.

K6.7 Access and Communications

In general the existing spontaneous irrigation only takes up small, separated plots of land along the river bank. This should not raise problems for communications and access of local people or livestock to the river, nor for access to the river bed for the extraction of sand. However, in view of the fact that there is already a considerable frontage of cleared land within 200 m of the river, and that permanent fencing is increasingly being erected, this situation should not go unmonitored. Where a riverside plot coincides with the point of access to a major river watering point, provisions for the maintenance of this access should be incorporated. This is an issue which should be addressed by the Land Board and could again be dealt with as conditions contained within the granting of leases for any irrigated gardens and dealt with in the TOR for the study in Appendix K – K.

If commercial irrigation development area is to go ahead then specific provision for through access will be necessary as part of each project layout and design. This will need to consider access to the major human and livestock watering routes as well as road access for sand extraction. It will be necessary to heavily fence all the irrigation areas to prevent access by livestock and wild animals. This could be expensive and the possibilities for solar powered electric fencing are outlined in Appendix K – E.

The implications of river conveyance with regard to cross – river access are discussed in section K6.1.4.

K6.8 Risk of Failure

If formal irrigation were developed then a guarantee of water availability would have to be given to those commercial operators taking up leases. This would probably best be covered as a condition of lease. Due to the marginal economic nature of irrigation the risk of water shortage for irrigation must be minimised. There is of course a cost attached to this in terms of having sufficient installed water storage capacity to do this. The point my well be reached where it is more cost effective to pay a subsidy to farmers not to irrigate in exceptionally dry years, rather than use a scarce resource which has greater economic opportunity for supplying urban and industrial consumers.

In terms of riverside spontaneous irrigation, the requirement is that the situation that exists before the dam starts impounding will not be jeopardised. The aim, of the land and water use planning and management study (Annex K – K) is to regulate this development prior to the construction of the dam. In terms of rational water use the best situation is for informal development to take place well downstream of the dam and the extraction points for formal irrigation, so that in dry years there is less likely to be such a great problem of scarce water resources.

K6.9 Public Health

With the use of buried pipeline and sprinkler delivery systems the risk to public health as a result of the development of formal irrigation will be minimal. Even the existing informal irrigators generally use hosepipes and the risk of waterborne diseases is low. Some countries, notably Israel, have reported droplet transmission of hepatitis A, salmonellosis and shigella dysentery as a result of wind drift from sprinkler irrigation when polluted water was used. Other authorities hotly contest this possibility and, at the moment, this situation must still be regarded as controversial.

However the use of the sand river for irrigation conveyance will, inevitably, increase the number of pools of water to be found in the bed of the sand river. This will have some impact on the health risks in the area, as discussed in Section K6.7. However, the nature of the proposed sand river extraction is to deplete significant proportions of the subsurface storage before replenishment by releases from the dam. This should have the effect of periodically drying out most of the surface pools, a cycle that is not well suited to the breeding patterns of the various disease vectors. The tendency for pools to persist in certain areas is difficult to predict. The situation would require periodic monitoring by local health authorities to ensure that any necessary action is taken.

The most likely negative health impact is the possible influx of disease that may be brought onto the area by migrant farm labourers. There have been serious increases in both bilharzia and sexually transmitted diseases, including AIDS, at Pandamatenga as a result of a such a similar influx. The numbers likely to be employed in formal irrigation are not great; however monitoring of their health condition and their living conditions should be carried out as part of the routine work of the Ministry of Health and Social Welfare.

There are two outstanding risks which cannot be ignored which relate to the transmission of mine pollutants into the food chain via irrigation, and the risks to workers from using agro – chemicals. However, other than the on – going pollution studies and the additional work recommended in Section K9.6, the responsibilities for this will lie with the local agricultural demonstrators and the development of proper educational programmes to advise farmers on pest control strategies and safety precautions.

CHAPTER K7

DEVELOPMENT STRATEGY

K7.1 Sustaining Development Potential

This chapter sets out a socio-economic and environmental framework for the detailed planning and implementation of the water resource developments identified. As foreseen in the TOR, this programme cannot proceed in isolation from events and activities elsewhere. Technical progress and economic solutions for rationalising Botswana's water supplies will interact with an existing social and environmental context where water remains an elemental influence. The perception of this is often lost to the urban consumer, unaware of the hidden, often unquantifiable, price which is paid in environmental terms by the rural community. The impact of new and fundamental changes to the catchment's aquatic system will require appreciation in policy formation if the long term interests of the country and people are to be well served. The policies and action required for many of the issues discussed below go beyond the requirements of this study. They have been raised to demonstrate their importance in the government's current land use planning exercise and the lead which government services can offer.

Both Botswana and the Motloutse valley are entering a crucial development period. Population growth rates are amongst the highest in Africa and the available resources of water and fertile land are limited. While there is increasing concentration of people in urban areas, close links are still being maintained with the land and livestock. In the countryside population is also growing, but at a slower rate. The doubling of population in the next two decades, together with rapidly changing values and life styles, is already creating major impacts on the demand for and use of natural resources. The need for long-term objectives in their planning and utilisation is vital if these resources are to be sustained for use by future generations.

Land use plans for the Central District are in the process of being drawn up by the MLGL in Serowe. The Motloutse dam study has highlighted various problems relating to both existing and planned developments. The primary long-term constraint concerns the erosion hazards resulting from the sustained clearing of the woodlands for cultivation, establishment of cattle posts and the extraction of timber. This impact will be felt across the whole catchment, but immediate attention is required in certain key zones, notably the more fertile riverain lands and selected areas on the terraces and uplands.

Development within the riverain strip is gathering pace as irrigation potential begins to be exploited. It is recommended that both soil and vegetation surveys be carried out to assess the conditions for its development when issuing leases for these lands (see Appendix K-K). The criteria should primarily reflect erosion hazard and suitability for irrigation. It is not possible to specify globally any zone of restriction on the removal of vegetation, as each section of the river is unique. In general, limits on the removal of riverain vegetation should start 40 m from the river bank and, in some cases, could extend up to 100 m. For land adjoining tributary watercourse similar restrictions should be considered. This process would require a more integrated approach between the sub-Land Board staff and the MOA.

The catchment's colonisation and economy depend on the river system. To dam this water and transfer it to other catchments to supply others requires that any existing users are not jeopardised. The development of the sand river model has addressed this problem with the aim of determining the amount, if any, and timing of compensatory releases which would be required from the dam. In addition to artificial storage upstream, the timing of any compensatory releases may have to be scheduled to fit in with irrigation demands and periods which minimise the evaporative losses. This implies a basic change to the river flow

system and one which existing vegetation and fauna will adapt to. The extent to which all species could be successful in this, and maintain their regenerative capacity is also not well understood, due to a lack of basic knowledge on these ecological systems and their dynamics. The work of this study has begun this research, but has essentially concluded with more questions than it started with. It could well be the case that downstream releases are unable, due to their attenuated nature, to maintain the present situation. If this is the case there would seem little that can be done about it except to monitor the situation and ensure that any lost usable resources are compensated for.

This deficiency exists not only for the riverain ecology, but also for the upland mopane woodlands. Without basic knowledge to which the prevailing conditions of its social and economic use can be related, confident evaluation of their true importance, potential and regenerative and adaptive capacities are difficult. A full programme of grant aided research is recommended to alleviate this constraint.

Even after the assessment of the results of this research, the real power lies in the hands of local people who have the resources directly under their influence. To change attitudes and local resource use practices effectively, demands an educational input from an early age to impress new values and install these for life. It also implies a political will, leadership, institutional commitment and capability to mould and restructure resource use in practical and economic ways.

Since the primary use of land will remain for some time with livestock, their management systems and land use implications should be the focus of attention. To achieve improvements would require renewed vitality and interest in herding and management skills, and a framework in which different groups could cooperate for their joint interest. The example of the Mmadinare Cooperative ranch, which is fenced off to the east of Selebi Phikwe, is striking, both from its potential grasping of the solution, but also by highlighting the inherent social and economic problems which would be caused if this management option became widespread.

Through the use of a much reduced stocking rate, the level of vegetation recovery within the fenced area is plainly visible on the SPOT satellite imagery (see Figure K2.13). By comparison to the communal grazing land around it, this affords the land better soil protection and infiltration of moisture. This in turn provides a higher plane of productivity for the particular animals being managed there. However, to translate this system across the grazing lands of the catchment would be to reduce dramatically the numbers of families who could have access to stock resources. Only if the larger stock owners were prepared to reduce their herd sizes significantly, in the interests of an environmentally conscious and egalitarian society, could the existing widespread pattern of resource ownership be maintained.

Unless a concerted attempt is made to coordinate new grazing management techniques, then both large and small stock owners will continue to lose. They will suffer widespread animal mortalities in times of severe drought, and risk handing onto future generations a resource base whose quantity and quality has been seriously impaired.

While livestock may dominate the current spatial use of land, the fastest growing pressures derive from the expansion of the cultivated lands. With the inevitable uptake of marginal land as population demands for land increase, the need for sound land management practices will become paramount to minimise the erosion hazard. Historically, this need seems to have been serviced by a continual abandonment and resting of lands as a result of social mechanisms involving the family cycle and marital arrangements. As pressure on resources intensifies, and as land gains real economic asset value, the freedom to abandon family lands will decline. There will also be more pressure to maintain land in continuous cultivation.

Unless this trend is accompanied by measures to prevent erosion and loss of soil fertility, serious long-term threats to the viability of some areas may result.

K7.2 Resource Conservation

The specific areas of resource conservation related to this water development programme include the zoning of the archaeological sites and mature kopje woodland near to the right abutment of the dam as shown in Map K.3. An area of mature uncut Acacia woodland worthy of conservation was also identified on the right bank of the Motloutse, immediately upstream of the confluence of the Tobane river in IR 5. The proposed continuation of archaeological surveys may recommend further sites of national interest which should be zoned for the future.

The results of the resource analysis propose many aspects of development strategy which go beyond the scope of work of the dam and irrigation programme. Primary amongst this is the need for erosion and land use controls and improved land management practices. The identification of specific areas along the riverain strip where alluvial soils and vegetation are to be protected and the access of local people and stock to the river maintained, should be dealt with through on-site surveys and the development regulated by conditions of the issue of land leases.

It is recommended that the Water Apportionment Board enforce the existing legal requirement to obtain permission before irrigation water is extracted. However, over and above this registration procedure, there is a need to regulate irrigation pumping from the Motloutse. This is to conserve dry season water storage in the sand aquifers and to protect the interests of other downstream water users. The conflict of demands has not yet become an issue along the valley but is likely to appear if encouragement to irrigators continues and a rapid growth in the uptake of pumping results. To ensure that mediation is fair and effective will require that the storage characteristics and demands for water from various sections of the river are analysed and a water balance established. This balance can only be representative, but should be sufficiently well researched to determine the peak seasonal demands when conflict of interests are most likely. This could necessitate the installation of additional gauging stations to provide a more detailed knowledge of the contributions of the sub-catchments. In practice, the administration and enforcement of this from Gaborone is unlikely to be effective. It is recommended that urgent attention be given to devolving these responsibilities to a local DWA office which would have more detailed on-site knowledge than that available to a central facility in Gaborone. The operation of this is covered for in the TOR for a special study given in Appendix K-K.

The conclusions of the first stage of pollution studies investigating the water borne contamination emanating from the BCL mine should allow the risks to irrigation development to be assessed. However, these studies will not be able to assess the need for restrictions and exclusion zones around the areas where aerial pollution may be contaminating soil and vegetation and where animals have free access to graze.

K7.3 Regional Employment Strategy

The creation of employment and a diversification of the economy to lessen the dependance upon the BCL mine is a major objective of this study. One expectation of the TOR would seem to have been the possible contribution to this by exploiting irrigation potential. The main conclusion of this study in this respect is that the contribution which irrigation can make is likely to be minor. As such, the focus of attention must be shifted to other sectors of the economy which may have more to offer in achieving government's strategic objectives.

While there are other mining possibilities in the catchment, the remaining natural resources and the current systems of use offer little scope for major employment generation. The livestock and arable sectors are unlikely to be converted into fully commercialised systems in the near future, since these are still mainly family enterprises in Tribal Lands. Even if such opportunities were to arise the employment generated by commercial units is usually less than that which prevails with smallholder and family agro-pastoral systems. In order to promote employment in the water resource development programme labour intensive methods would need to be specified for dam construction and less capital intensive forms of irrigation encouraged in the support to this sector. In practical and economic terms these options are probably not available.

Alternative industrial developments are being considered and developed within the framework of the SPRDP and existing commercial interests. These developments are likely to be more significant in their contribution if the investment climate remains healthy.

Strong possibilities exist for the development of amenity, tourism and recreation, particularly if Selebi-Phikwe were to be considered as a major growth centre for the redeployment of national service functions. This could allow revaluation of the need to transfer large quantities of water from the north and east of Botswana to Gaborone and is consistent with government objectives of decentralisation. Associated with this could be the development of services to attract international development, finance and research operations. This may offer better chances of maximising the diversification of the economy and creating employment and income opportunities. This would also enhance the role which the Letsibogo reservoir could provide as a major amenity resource.

A strategy on these lines might involve a major reconsideration of regional development plans and policy depending on the scale of development considered appropriate. If linked to existing rates of expansion of Selebi Phikwe and the future presence of a reservoir, amenity and recreational facilities could be designed solely to cater for local needs and would not require significant planning, resource and financial inputs.

The plans could go further with a deliberate policy to stimulate tourist trade from other Southern African States and from within Botswana. This could involve some minor accommodation and catering facilities and the provision of transport facilities to and from the dam site and linking with the airport and hotel facilities of Selebi-Phikwe. This option raises the possibilities of employment generation from transport, handicraft industries, food processing and catering, as well as the travel and financial sectors.

The most ambitious strategy would consider establishing Selebi-Phikwe as a major centre in Southern Africa. The sorts of possibilities which might be investigated could include establishing a major international environmental research center, links and facilities for SADACC, conference facilities, lease arrangements offered to international and multi-national organisations, hotel and tourist facilities tied to international charter deals and international sports stadiums and facilities to mention a few. To stand any chances of success this scale of development would require in-depth market research and very tightly planned and managed commercial arrangements.

The potential of these options could be considerable in terms of employment, income and political spin-offs. However, the initial capital investment and risks will also be high, but could be worthy of initial consideration and further investigation. The scope of this strategy is clearly within the framework of the SPRDP but would appear to go beyond the level of the strategies so far developed.

K7.4 Irrigation Development

As outlined in Chapter K6 the possibilities for irrigation have been narrowed down to the development of formal irrigation of up to 1000 ha, between the dam site and Tobane village. In terms of sustainability, the overall framework that was being worked to was that all capital costs of irrigation development could be written off but the running costs should be covered and sufficient profit made from the operation to make it attractive to commercial operators. However, this goal has not been achieved, and some form of annual subsidy would also prove necessary, see Annex J. Due to the requirements of water efficiency it is necessary to use buried pipeline and sprinkler techniques with the available soils. These irrigation methods are unlikely to provide significant alternative employment opportunities to the mine. In addition the existing farmers in the identified areas will be displaced and are unlikely to be absorbed into the irrigation development.

At the present time it is difficult to see the institutional arrangements for developing such proposals. One possibility is for the land to be expropriated from the Tribe, detribalised and then developed by a central government department or ministry. This would require the expropriation to be justified in the National Interest and would need to be sanctioned by the President. The fully developed irrigated units could then be leased out as going concerns at some fixed rents, with suitable long leases to give the operator sufficient security of tenure. The sizes of the units and possible conditions of operation in relation to water use/demand and scheduling, along with the selection of crop types, could be controlled by conditions of the lease. It is difficult to see how this could be easily justified to the tribe unless the rents obtained were significant. An alternative would be for the land to be developed on behalf of the Tribe by a development agency, possibly BDC or perhaps as part of the remit of the SPRDP. If a system operating within the framework of the Tribal Lease arrangement were used then this would allow control to be retained by the Land Board and hence the Tribe. It may be less complicated for the irrigated blocks that fall within the mine lease area, as is the case in IR2 and IR3 plus half of IR4 and IR14. In these areas negotiations would have to be held with the mine, though fortunately none of the areas actually fall within the designated State Land area.

In order to take these proposals further it will require responses from Government as to the favoured policy before the details of institutional arrangements could be studied. If a decision is taken to promote formal irrigation then detailed surveys for very specific options and designs would need to be carried out, in the next phase of the project. This would have to incorporate a major programme of liaison and consultation with those people directly affected and would require commitment from Government to see that the difficult issues of land tenure, relocation and compensation are fully addressed, so that such a project could start off from a position of favourable support. It is the experience of many such projects in Africa that the initial negative impacts can be quite severe and that there is a significant time lag before any benefits can be felt. This can be mitigated against to some extent by careful planning and sensitive implementation, with a commitment to ensuring that those people adversely affected do not suffer serious livelihood loss.

K7.5 Social Infrastructure

If the option of developing the commercial irrigation were followed some degree of social infrastructural provision will be required, including all weather road access. However the nature of the discrete farm units which would be proposed suggests that individual investors would set up their own on-farm infrastructure in tune with their own requirements. The recruitment of labour would draw on local sources and for permanent workers particularly for those in-migrants from outside the area, facilities would have to be provided, probably by the commercial investors as part of their overheads, or perhaps as part of the overall

construction programme. It is evident that much of the on-farm housing provided by such commercial farmers in similar situations is of a poor standard with resulting health risks and poor standards of living. Since the level of employment likely to be generated is small and the dispersed nature of the irrigation units will not concentrate workers into particular areas, there is again probably little justification for considering major new investments in social infrastructure, such as schools and health centres. It would be advisable to insist that any commercial farms provide secure buildings and operating procedures for the storage and use of dangerous agro-chemicals and to liaise with the local health authorities to see that adequate facilities are on hand in the event of any accidents.

The existing and proposed informal irrigation alongside the riverain strip would seem to require little in the way of major infrastructural provision, over and above that already being considered in the District plans. The only assistance which might be considered would be better access roads, to allow smallholder irrigators and transporters to move more readily between farms, service centres and market outlets. This could involve the upgrading of the existing road parallel to the river linking Mmadinare, Tobane and Bobonong. This may also create an opportunity to zone off certain sensitive riverine vegetation areas and to undertake remedial measures in locations of developing gulley erosion.

The health and social implications of a major construction project raises questions about the adequacy of existing facilities and social services in Mmadinare. However, the period of impact is only short term and the scale of immigrant employment cannot be predicted. It would be preferable to make temporary arrangements for the specific period of dam construction, rather than to install a new level of expensive infrastructure, which perhaps would not be fully utilised and maintained once construction activities were completed. The main requirements will be for an Occupational Health Unit to be supplied by the Ministry of Health, which should include capacities for counselling and education to offset some of the adverse social, psychological and disease risks, which may accompany the construction activities.

K7.6 Consultation with Local and National Authorities and Public Participation

It is of prime importance that detailed planning for the project incorporates a major element of public participation and liaison at all levels. Once some policy outlines have been indicated, as a result of the final report of the study, then it is imperative that all affected parties are drawn into the planning framework. This includes the District administration in Serowe, particularly the District Officer (Lands) and the Secretary of the main Land Board. Maintenance of liaison with the District Council in Central District is nothing like as easy as in other Districts, due to its vast size. As a result the five sub-regions are very autonomous and there is poor coordination between them. In addition there are over ten Sub-Land Boards, the boundaries of which do not nest with the sub-districts. The situation is now a little simplified, in that the irrigation areas that could be developed fall within the same Sub-Land Board as the reservoir. The Land Board are the major body to be dealt with in regard to land expropriation and compensation/resettlement, whereas the land use planning function is handled by the Sub- District Officer (Lands), newly appointed in Bobonong. The exception is the mine lease area, where the Selebi-Phikwe Town Council have jurisdiction. The Sub-Land Board in Mmadinare is at present under a lot of pressure and is badly understaffed, especially if it were to be required to carry out the necessary work for the reservoir and irrigation areas unassisted. Experience from the Bokaa project indicates that if a consultant is to be used for the detailed enumeration work there would be great benefits in having formal attachments and on the job training with Land Board and District officers. In addition to the technical officers there are the elected representatives. So far little contact has been made with these people but, as part of the next stage of the project, a major effort will need

to be made to draw in both the elected councillors, the village heads and members of the Tribal Administration.

In addition, depending upon the institutional arrangements decided upon for the implementation of the project, close ties will need to be maintained with the SPRDP and BDC. If the water resources development were to fall to the Water Utilities Corporation (WUC) then their present operation at Selebi – Phikwe would seem the logical administration location. Close liaison would also be continued with DWA and MLGL. It would seem pertinent to form closer links with the MOA and, as at Bokaa, the involvement of the Ministry of Health and Social Welfare will be required for the health monitoring programme. Future studies and monitoring will draw in a wide range of bodies including academic researchers.

K7.7 Land Acquisition and Compensation

As outlined in Section K2.4, land allocation in Tribal Areas is governed by the Tribal Land Act of 1968. With regard to the acquisition of land for reservoirs there are a range of three options available; however a major consideration will be the authority responsible for construction and operation of the dam and also if this will be the same body who will be responsible for any irrigation development. At present the WUC are responsible for the two largest existing dams in Botswana, as well as the dam at Bokaa which has just commenced construction. The land to each of these is held in different ways, due to historical reasons, and also the fact that WUC is not a government organisation.

The land under Upper Shashe dam and reservoir is directly vested in WUC, whereas that of Gaborone dam and reservoir is vested in Central Government, who then have a management agreement with WUC. The new dam under construction at Bokaa is to be held on a 99 year renewable Common Law Lease from the local Land Board. There would seem to be little difference as far as the day to day operations of WUC are concerned; the only foreseeable relevant factor being how WUC have their assets and liabilities valued and depreciated. The reasons for Shashe and Gaborone being so different are historical. The land at Shashe was split between two districts and a lease agreement would have been difficult to arrange. For the heightening of Gaborone dam the area was formally freehold land and the level of compensation payment allowed for by the funding agency was limited and, as Central Government met the shortfall, the land was vested in Government. Bokaa was the first project in Botswana to be carried out within the framework of the revised MLGL compensation guidelines. These include the requirement for an environmental impact study and wider provisions for compensation payments, especially for secondary impacts. Due the very tight time schedule for the Bokaa project and the fact that it lay entirely in one district, plus the incorporation of all compensation costs into the project analysis, a Common Law Lease seemed the most appropriate method of land acquisition. In addition the MLGL are now trying to standardise on this procedure for such projects that fall directly in Tribal Land. In the Selebi – Phikwe area the BCL mine lease area and the Voice of America transmitter are examples of this type of agreement.

There are thus three major options for acquiring the land for the reservoir and dam permanent works:

- under Section 32 of the Tribal Land Act the implementing authority could request the MLGL to have the land vested in Government. This is more appropriate if the implementing agency is a Government Ministry or department. This would then require that the land be detribalised and the consent of the President would have to be sought along with a justification that it were needed in the National Interest.

There would then be the option of the operating authority having a management agreement as is the case with Gaborone dam. This would require the DSL to be directly involved in detribalising the land and drawing up the agreement.

- The same procedure could be followed but instead of a management agreement the operating authority could take over the land directly.

- Under Section 24 of the Tribal Land Act the operating authority could apply for a Common Law Lease from the Land Board. This requires the consent of the Minister of the MLGL and would be conditional. This negates the need for the land to be detribalised.

The factors influencing the choice are thus:

- is all of the land Tribal Land?
- is the whole of the required area located within one Land Board area?
- is the operating Authority a government organisation or not?
- is the compensation for all lost assets going to be met directly by the developer?
- how quickly is the land needed?
- is the land acquisition easily justified in the National Interest?

K7.7.1 Planning and Procedures

The procedures required for land acquisition in the case of large projects are contained in the Tribal Land Act of 1968, amended in 1969. These are further detailed, along with the items and rates for compensation payment, in guidelines prepared by MLGL. These guidelines were recently redrafted and have been circulated and approved by the Land Boards. The Tribal Land Act is now being redrafted to incorporate these. A copy of these is guidelines is attached as Appendix K-A.

In broad terms the procedures for land acquisition are indicated below but this will vary according to the chosen option and factors outlined above. Assuming that a Common Law Lease is applied for, which seems the most likely option, then the stages of the application are as follows:

- notification to the Land Board;
- moratorium on new development within the required area;
- formal application to the Land Board for a lease;
- agreement in principle to the application;
- commissioning of a detailed environmental impact study;
- inspection and demarkation of the site;
- detailed enumeration and assessment;
- payment of compensation for private assets;
- negotiation of Lease with conditions;
- payment of communal compensation;
- monitoring for secondary impacts and likely claims.

These procedures need to be phased to fit the planned construction programme (see Chapter K10). In the past many projects in Africa have suffered from lack of adequate advance planning of such issues and have been characterised by crisis management. Commendably there is plenty of time to plan this element of the project and perhaps the converse situation may occur and care must be taken to ensure that there is sufficient flexibility for changes in approach to the project and possible options are not pre-empted.

K7.7.2 Compensation Policy

The basis of compensation policy for private assets, as laid out in the Guidelines (See Appendix K-A) is that all improvements to land are to be compensated in cash, sufficient to allow replacements to be constructed. Policy with regard to land has in the past been to allocate replacement equivalent land to that lost, although the revised guidelines have provision for paying cash for land if there is insufficient equivalent replacement land available for allocation. Enquiries during the socio-economic surveys confirmed, contrary to the Land Act, cases of land changing hands for money with a rate of around Pula 50 per ha for undeveloped land being quoted. This is similar to the figure found at Bokaa for equivalent undeveloped plots. There is also now provision for those people who suffer secondary impacts of a project to lodge claims up to three years after the commissioning of a project. There is a problem with some of the rates, particularly those for housing, which are in general low, particularly if the losers are unable to build replacements themselves and have to pay others.

With regard to communal items there is provision for compensating the Tribe for losses of such assets, generally in the form of cash payments or replacement infrastructure or facilities. A problem with this can be that the compensation provision may not necessarily reach the sections, be they in a specific location or social group of the Tribe, who were most effected by the lost access to the communal assets. In such cases the sensitivity of the local political system has to be relied upon to ensure that an overall notion of fairness is satisfied.

It is very difficult to replace self-sustaining and productive assets where they provide a livelihood, and even in cases where it is possible there is a time lag during which some effected households may be particularly vulnerable. In this context the payment of cash compensation by itself is normally unlikely to provide a replacement sustainable livelihood. It is not until detailed enumeration and socio-economic studies that policies and strategies can be formulated. Experience from Bokaa indicates that priorities for each household can be very different. It is vital that these issues are handled with sensitivity and in an open fashion. It is in the interest of all parties that compensation procedures are seen to be fair and are followed by all, so that the political system retains credibility. Continuity of approach and participation of the effected population are crucial to this process.

In conclusion it must be appreciated that the loss of private assets in the reservoir area is small and certainly smaller than any other site in the valley. The situation with the irrigation areas is different and of particular concern must be area IR5. The detailed study phase will need a mechanism whereby the findings of outline enumeration are able to feed back into the design to minimise losses. It is also apparent that there is scope to treat each of the irrigation units separately and decide upon the feasibility and nature of compensation policy for each unit.

K7.7.3 Compensation For Private Assets in the Reservoir Area

Table K7.1 lists and values the private assets which may be lost to the reservoir, based upon a detailed enumeration carried out in the field during March 1989 and using the rates in the MLGL guidelines. Details of these estimates are given in Chapter K10. The table obviously reflects the situation which pertained at that date. This was at a time when the number of occupied cattle posts was low, due to the recent stock losses, overgrazing and the problem of elephants, all causing people to leave the area. As such these should be treated as minimum values. However, once a decision is reached on developing the dam then a moratorium on all new development should be enforced to prevent new development, although there will undoubtedly be historical claims which only detailed final enumeration, combined with a consultation process, will resolve.

Table K7.1

Estimates of Private and Communal Assets Lost to an unfenced Reservoir with FSL 850 m

Item		Valuation Pula
Private Assets		
Fully cleared land	44.15 ha @ P200/ha	8 830
(1st Phase Area is 33.35 ha)		
Partially cleared land	4.62 ha @ P100/ha	462
Trees:		
Mature	51 nr @ P75 each	3 825
Average	43 nr @ P50 each	2 150
Young	0 nr @ P25 each	–
Fencing (including fields and kraals)		
Thorn fence	5 215 m @ P0.60/m	3 129
Wood pailing fence	1 450 m @ P1/m	1 450
Post and wire fence	6 467 m @ P0.40/m	2 587
Mud walls	64 m @ P5/m	320
Homesteads (14 nr individually assessed)		
Huts	39 nr @ P315/hut	12 285
Threshing floor	386 m^2 @ P2/m^2	772
Granaries	1 nr @ P200 each	200
Infield tank	1 nr @ approx P1 000	1 000
Wells in river bed	16 nr @ P200 each	3 200
Displacement/removal	Assumed to be 10% of private assets	4 021
Sub total		44 231
Communal assets		
Tribal land (not individually occupied and not replaced)	2 510 ha @ P50/ha	125 500
Grazing and Browse resources:	223 ha riverain @ P50/ha	11 150
	2 052 ha upland @ P50/ha	102 600
Valuation of standing timber	Between P2 046 000 – P382 000	382 000
Sub total		621 250
Replacement Provision		
Veterinary Crush	1 nr @ P4 000	4 000
Council Kraal	1 nr @ P4 000	4 000
Sub total		8 000
Amelioration Measures		
Cleared replacement land for those plots partially affected	5.38 ha @ P200/ha	1 076
Total		674 557

Note: Loss of the downstream sand resource to the BCL Mine has been assessed separately as an annual payment of P364 000 from the year 2010. This assessment is described in Appendix K–H.

There are only 14 cattle posts or homesteads that were still in use (although not necessarily occupied) at the time of survey but careful study of the air photography indicates that there are a further 45 presently abandoned. Study of the 1964 air photography also shows some of these as abandoned but it also shows others both abandoned and then occupied of which there is no evidence on the 1988 photography.

There are 44.15 ha of cleared land that are lost to the reservoir limit of 2 m above nominal FSL. Only 14 homesteads comprising 39 huts would be lost and most of these are cattle posts without adjacent cleared lands. In no case will a household lose its only residence as all have main homes in their village of affiliation. There are three households who lose a small proportion of their cleared and cultivated land. It would seem to be a viable option to clear equivalent replacement land for them, adjacent to the unflooded portion of their developed land if this were agreed to by the occupiers. If for some reason this were not possible then all their unflooded immovable assets would have to be compensated for.

If it were decided to fence the reservoir area then there would be few additional private assets to be compensated for but the amount additional communal assets lost would be considerable. This alone would seem to make fencing the reservoir unjustifiable. These additional losses are listed in Table K7.2 below.

Table K7.2

Estimates of Additional Private and Communal Assets lost to a Fenced Reservoir

Item		Valuation Pula
Private assets		
Fully cleared land	7.0 ha @ P200/ha	1 400
Partially cleared land	10.0 ha @ P100/ha	1 000
Tree	None	–
Fencing (including fields and kraals):		
Thorn fence	Est 300 m @ P 0.60/m	180
Wood pailing fence	Est 300 m @ P 1.00/m	300
Post and wire fence	Est 300 m @ P 0.40/m	120
Homesteads	None	–
Displacement/removal	Assumed to be 10% of private assets	300
Sub – total		3 300
Communal assets		
Tribal land (not individually occupied and not replaced)	1 226 ha @ P 50/ha	61 300
Grazing and browse resources:	46 ha riverain @ P 50/ha	2 300
	1 142 ha upland @ P 50/ha	57 100
Valuation of standing timber	Between P 941 275 – P 176 000	176 000
Sand resources	None	–
Sub – total		296 700
Total		300 000

K7.7.4 Compensation For Communal Assets Lost to the Reservoir

Communal assets are defined as those which occur in tribal land but have no individual rights attached to them. The main communal assets considered for compensation and/or amelioration include the natural grazing and browse, thatching grass and medicinal herbs; the range of woodland products; access to surface water resources; loss of cross river access; access to river sands; loss of community structures (dams, boreholes, cattle crushes, development projects); loss of future development potential; health and social impacts; and disruption factors.

The level of future exclusion of the local people to the communal resources of the reservoir will depend on the fencing policy adopted. The proposed reserve area totals 3 736 ha. Of this 2 166 ha (58%) will be within the FSL and 223 ha (6%) will be valued riverain woodland.

Table K7.1 includes the quantities and values of the losses to an unfenced reservoir and Table K7.2 gives the additional losses to a fenced reservoir.

The valuation of many of these communal assets is difficult in either commercial or economic terms since these methods cannot reflect the long term value to society of processes and contributions which the local ecology make and for which there is no market. An example is the role which woodlands play in preventing loss of soil. The detailed discussion of the valuation procedures used and the problems faced is given in Appendix K-H.

The impact of the loss of communal assets will be to intensify the pressure on resources outside the reservoir area. This pressure will compound the already evident gradual decline in the grazing and forestry resources caused by increasing demands from people and livestock. To ameliorate for this effectively would require a much wider framework of institutional and social reorganisation in the management of the communal range resources. To address this would be beyond the scope and capacity of this project. Nevertheless, in order to sustain the long-term productivity of the resource base, management of the complete resource system is required. In practice, the institutional capacity and socio-economic motivations to achieve this are not present. It may be possible to ameliorate, to some degree, the impact of the loss of communal assets by managing areas of the reservoir as an environmental resource.

The payment of communal compensation does provide a means by which communal resource management practices can be given impetus and financial capability. A strategy of recycled compensation funding, similar to that put forward for Bokaa dam, is proposed as a means of ensuring a replacement of like by like, and as an approach to serve the long-term interests of both nation and local community. The strategy to enable this would expect a reservoir management unit to work towards a multi-purpose contribution to development. This should be based on multi-disciplinary research designed to allow an integrated management capability. The objectives would be maintain and improve water quality and seek to enhance wider development potential. Secondly, if the proposals to establish a full research station facility are accepted, then contributions would be expected to initiate a much needed land and resource use management system which relates to the catchment as a whole.

K7.7.5 Compensation for Loss of Private Assets in the Irrigation Areas

The techniques used for the estimation of average compensation rates per household in the irrigation areas are described in Section K-H1.4. The enumeration of land area losses, both individual and private, as well as estimates of the number of homesteads destroyed, and a maximum figure for those effected are given in Table K7.3. The maximum number of

homestead figures include all those people who lose land, whereas the minimum figures are those who would lose their homestead. It could well be the case that those who lose some land but not their homestead will still need to be compensated in full for all their unaffected plots and homesteads if the land loss is severe enough to render their remaining land unviable and there is no adjacent replacement land available. The value of these homesteads is included in the assessment but no estimation can be made of the area, and hence value, of any unaffected plots or part plots that may still need to be compensated for, although this land may be available for reallocation to other people who lose land and will not figure in the overall compensation bill. This will however depend upon its specific location. The gross irrigated area is based on the net area (see Annex I) with an additional 10% to cover tracks, buildings, etc.

Table K 7.3

Estimates of the Number of Private and Communal Assets lost in each Irrigation Area

Irrigation Area	IR1	IR2	IR3	IR4	IR5	IR14	Total
Developed land (ha)	36	52	2	11	246	52	399
Undeveloped land (ha)	40	13	78	99	370	121	721
Homesteads displaced	8	3	0	2	17	5	35
Other homesteads	1	6	1	0	16	6	30

Table K7.4 lists the valuation of both private and communal assets lost by each irrigation area. The totals are a minimum figure and a possible higher figure would result if all the homesteads of every affected plot holder would need to be compensated for. The totals could also be higher if any of the unaffected plots of effected households have to be compensated for. Average minimum compensation figures per ha of irrigated land are given for each block with an overall mean of P 502 per ha. This includes the paying of the asset value of the developed land. The area of replacement land corresponds with that lost on the assumption that land with the equivalent potential yield for rainfed cropping can be located. The cost of replacement land has been based on the rate for mechnical bush clearing (see Annex I) at P400/ha, although employing traditional techniques could well reduce this cost.

Table K 7.4

Valuation in Pula of Lost Assets by each Irrigation Area

Item	Rate	IR1	IR2	IR3	IR4	IR5	IR14	Total
Asset value:								
Developed land	P 50/ha	1 780	2 600	80	550	12 320	2 590	19 920
Undeveloped land	P 50/ha	2 010	650	3 940	4 950	18 480	6 040	36 070
Homesteads	P 4 000	32 000	12 000	0	8 000	68 000	20 000	140 000
Grazing	P 50/ha	2 010	650	3 940	4 950	18 480	6 040	36 070
Sub-total		37 800	15 900	7 960	18 450	117 280	34 670	232 060
Replacement land	P 400/ha	14 270	20 770	640	4 400	98 560	20 720	159 360
Other homesteads	P 4000	4 000	24 000	4 000	0	64 000	24 000	120 000
Total		56 070	60 670	12 600	22 850	279 840	79 390	511 420
Nett irrigable area (ha)		69	59	73	100	560	157	1 018
Unit cost (P/ha)		813	1 028	172	229	500	506	502

K7.7.6 Compensation for Loss of Communal Assets in the Irrigation Areas

Compensation valuation for communal assets are included in Table K7.4. The communal land lost has been taken to be that which is not fenced and lies within the defined irrigation areas i.e. the residual of the gross irrigation area minus the fenced land. It is valued with the figure for the asset value of land of P 50 per ha. This communal land area has also been valued at an additional P 50 per ha for grazing resources. No allowance has been made for forestry resources as the style of scattered irrigation development will still leave adequate resources in the vicinity to meet local needs. Detailed surveys of each irrigation block would be necessary to confirm that this is the case throughout. In particular a careful assessment will be necessary for block IR3. This is the closest unit to Selebi-Phikwe and, hence, a reduction in the amount of firewood available may be difficult to replace if surrounding resources are inadequate.

There should be no additional adverse effect on the extraction of sand resources above those of the Letsibogo dam provided that access to the river is not impeded. However if a weir were built across the river at a rock bar location for a pump offtake then this factor would need to be considered at detailed enumeration time.

K7.7.7 Impact of Compensation Payments to Individuals

Past experience with the payment of cash compensation for similar projects in other parts of Africa (see MacDonald 1982, Hart 1980 and Volta River Authority 1965) would seem to indicate that it is often not invested wisely and very often not used for replacement of those items which are lost. This is particularly the case where compensation is paid as one lump sum and not as a phased programme, linked to the agricultural calendar or assigned for specific items such as land or buildings.

For the above reasons it must be realized that the direct provision of replacement items, such as cleared land for the cultivated land lost, is far more likely to preserve economic livelihoods. There is a very strong risk that compensation money will be spent on consumer goods, with little potential of preserving the present level of economic livelihood. This is particularly the case in the irrigation areas, where there are far more serious problems of land loss than the reservoir. Trying to convince people who are displaced by man made reservoirs of the inevitability of their homes being flooded is difficult, especially if they have never had even secondhand experience of this. They have little perception of what is going to happen and the best way to overcome this is, perhaps, to arrange a visit to a nearby existing dam and let them meet people who were displaced. It is fortunate that Shashe Dam is close by and could be used in this way. Similarly, in the irrigation areas, the idea that the Government is proposing to displace existing right holders to develop the land, and lease it to outsiders, may be treated with incredulity and be beyond the perception or belief of local people. For these reasons, it is recommended that the replacement land allocation and bush clearance programme for both the reservoir and any irrigation development, is carried out (be it as part of the direct compensation programme or as an amelioration measure) well within the required time frame, otherwise there is a very strong likelihood of discontent and perhaps destitution, in specific households with no other forms of livelihood.

It should also be pointed out that many of the affected people are probably at the lower end of the socio-economic scale. Unlike many other parts of Africa, agriculture in this part of Botswana is, to a large extent, practiced by the poor and vulnerable; the better placed people having strong inputs to the wage paid cash economy and/or assets held in the form of cattle. It would be worth alerting the relevant District welfare department of those who may be vulnerable and to instigate appropriate discrete monitoring of the situation.

CHAPTER K8

RESERVOIR PLANNING AND MANAGEMENT

K8.1 Planning Framework

The main criteria adopted to plan the reservoir management strategy seek to minimise the disruption to the existing agro-pastoral, settlement and environmental systems, to make the maximum use of the development potential of the resources left, or made available, by the reservoir, and to coordinate research and management activities in such a way that the contribution of the reservoir to development can be sustained and, where feasible, improved. The sudden appearance of a reservoir in a region previously devoid of permanent surface water brings with it many consequences and problems which have to be anticipated. New health hazards will have to faced as the habitats for aquatic disease vectors become more extensive. These hazards could be more significant if there is a major thrust towards exploiting the amenity and recreational value of the reservoir. The reservoir will inevitably receive nutrient run-off from a catchment densely stocked with livestock and lead to seasonal nutrient levels in the reservoir which could pose a pollution problem for the drinking water supplies intended for urban consumers.

If reservoir authorities are to realistically address ways of enhancing water quality, public health and development opportunities, it demands that attention be properly focused and coordinated across a broad range of subject and management areas. Any such strategy goes beyond the scope of specialised water authorities with restricted skills, objectives and responsibilities. This suggests the lack of foresight in the historical approach to the selection of the criteria by which such institutions have been set up, and the lack of appreciation of the direct linkages between the supply of urban water, the rural economy and the environmental resource base. It is unrealistic to expect that the reservoir authorities or the urban consumer should have to cover all the costs of establishing such a wider and more integrated reservoir management strategy. This is mainly because a number of the potential benefits of such a strategy will accrue directly to the local economy and to the protection of the local environment. But, by the same reasoning, the urban consumer should not expect to be able to extract resources from the rural areas without being accountable and responsible for providing the best means of amelioration for the adverse impacts caused.

A major thrust of the analysis of this study concerns the dynamic ecological framework into which the water resource development programme is to be set. As a direct result, a main management objective will be to ensure that the nature of these processes are properly understood and the potential contribution of planned interventions for the protection of water quality, public health and development developed in an integrated way.

The study of the biological properties of man-made reservoirs in Africa is a relatively new science. However, certain criteria have been observed which would appear to apply to all impounded waters and have been used as a guiding principle in the analysis and recommendations of this study. However, biological controls and ecological management alone cannot be regarded as being sufficient or wholely effective. Only coordinated action involving a number of authorities and strategies will ensure an effective approach to the opportunities and problems.

The following chapter covers a range of policy areas where problems and opportunities have been anticipated based on the current state of knowledge. Also discussed are the possible mechanisms and strategies by which these can be most effectively addressed.

K8.2 Construction Policy

Early decisions on certain of the proposed future studies and reservoir management activities will be required to enable timely preparations prior to the arrival of the contractor on site. In particular, the specific areas proposed for conservation should have been demarcated and fenced to limit any damage to these sites by continuing site surveys or construction activities. The forestry programme needs to be started as early as possible to ensure that all the valuable timber can be removed well in advance of construction. Similarly, decisions on the scale and feasibility of the amenity, recreation and tourist developments proposed for the reservoir should have been taken. This option will affect plans for how the contractor will deal with construction and restoration items peripheral to the dam and spillway. Amenity and recreational facilities could form additional items in the overall contract or a separate sub-contract. If a separate contract is to be issued, after the completion of the main dam construction construct, then the main contractor should be provided with clearly defined requirements on how the site should be left, ready for the contract for the amenity facilities to proceed. Early decisions will also assist the Ministry of Health in planning a timely programme of advance baseline health and disease vector surveys and to prepare a programme for an occupational health unit for the construction phase and a public health educational campaign.

K8.3 Fencing Policy and Pollution Controls

The first management decision to be taken concerns the fencing of the reservoir. Three main options have been considered:

a. Unfenced Reservoir

The reservoir could be left unfenced and unrestricted access allowed to the reservoir area, as is common for most reservoirs elsewhere in Africa. This would provide existing livestock with the necessary access to drink and graze around the reservoir and remove the need for any amelioration programme for water supplies. This policy is unlikely to induce an increase in herds and flocks coming in from outside the area as there is already a severe shortage of grazing and the local resources would not be able to sustain their numbers. The loss of the riverain grazing could not be directly ameliorated and movement to alternative riverain grazing upstream would probably be promoted.

b. Totally Fenced Reservoir (No Access Permitted)

The reservoir area could be fenced and managed solely as a protected water supply source. No access would be permitted to utilize its resources. This option would result in the least financial cost and the simplest management. Experience at the existing Shashe dam indicates that maintenance of fencing could require considerable manpower and without considerable policing could still prove ineffective in denying access. Of the three options, it would create the greatest resource cost to the nation and would preclude a number of development opportunities and productive ways to enhance the protection of water quality.

c. Zoned Reservoir Fencing (Controlled Access Permitted)

Investigation of the soils, topography and possible flood regimes indicate that, unlike the Bokaa reservoir and any potential reservoir on the Letlhakane, there is unlikely to be any major potential to exploit the upper part of the reservoir through productive draw down activities. Nevertheless, small areas of land can be considered for fodder and thatching reed production. Access to these areas could be permitted on a zoned basis.

Depending upon the amenity and community health educational policies to be adopted, and the fact that the area is currently utilised for cattle posts, the reservoir need not pose a major health risk to local people or amenity visitors as long as planning and management address the problem from the outset. Evidence from Shashe dam, which has a very similar surrounding situation, also suggests that these risks can be minimised. Since, unlike Bokaa dam, there is no village or Lands policy operational in the area, there should be little problem establishing (through the Land Board and within the terms of the reservoir lease) legal restrictions on any settlement or undesirable cultivation of land within the reserved area.

The risks to water quality, by livestock depositing manure when watering and grazing around the reservoir, are not to be ignored. However, initial studies undertaken at Shashe dam indicate that the assumption of a causal relationship linked mainly to local stock is possibly mistaken or overemphasised. The initial survey found no evidence of new stock owners successfully emigrating into the area to take advantage of the reservoir. Furthermore, cattle watering was not the only reason given as to why local people had resorted to cutting the fencelines. Other motives included the need for direct access to villages, and the exploitation of the fenceline to create a paddock and prevent stock from gaining entry to local lands and damaging crops. This latter motive will be removed as the policy of cordon fences around village lands throughout the country is fully enacted. The fenceline around the Mmadinare lands is already almost complete.

It was further established that a primary factor in determining the distribution of stock in the catchment are the limits on seasonal grazing resources and not solely access to water. This means that stock owners collectively prefer to spread their stock across watering points, rather than to concentrate them around one major watering point, such as the Shashe dam.

Investigations of the spatial distribution of cattle posts, water points and grazing systems in the Shashe catchment indicated that the major contribution of nutrients from animal manure is most likely to emanate from animals other than those found directly around the reservoir. These stock, utilising riverain grazing and watering points upstream, are likely to outnumber local stock considerably. The concentration of these other stock upstream, in the river and stream beds upstream, would result in the deposition of manure which would be washed directly into the reservoir with the rains. This likely major source of nutrients to the reservoir and run off of other nutrients originating from soil and vegetation could never be prevented. It may also be significant that the manure deposited by livestock around the reservoir margins could be derived substantially from vegetation in the draw down zone which otherwise would still have entered the aquatic system as decomposing material once this zone again becomes inundated.

During the peak of drought, when alternative water supplies and grazing are depleted in other parts of the catchment, stock owners, who normally keep their stock in the uplands away from the reservoir, are left with little choice but to come to the Shashe reservoir for their grazing and water resources. This pattern and direction of movement seems to have been employed before the Shashe dam was constructed. To deny this customary response to drought implies a strategy which increases the chances of stock mortality. In practice, an important precedent have been set already at Shashe whereby stock have been allowed access to the reservoir as a drought contingency reserve. Many of the national water supply dams being planned or considered for the future will be implanted into an agro-pastoral economy. National interests should also urge that these dams have a duty to protect livestock assets, particularly in times of drought.

There are risks associated with this strategy as cattle, particularly, are susceptible to getting trapped and dying from drought induced exhaustion in mud banks. As so many of the stock graze and water unsupervised results in the responsibility for detecting and removing these

animals falling to those who manage the reservoir. This problem could be most effectively overcome through a planned programme of drought contingency reserves of fodder, selective electric fencing around the areas of mud banks, and, if necessary, the enhancement of watering points with hard standing at selected locations along the fringes of the reservoir.

In the case of Motloutse dam, the presence of elephant and other wildlife will also affect the approach to fencing and amenity policy. If the elephant are to remain and be exploited then only electric fence lines are likely to be effective. Solar powered fencing has been tested in Zimbabwe and was successful against elephant and proved to be the most cost effective method.

The concerns over pollution caused by livestock at the existing Shashe reservoir seem to emanate from an assumption that the location of the fenceline, which demarcates a legal boundary, is also the limit within which the exclusion of cattle would prevent the degradation of water quality. In practice, only beacons and agreement with the Land Board are required to establish the legal boundary. The initial review concludes that the contributions of stock manure in the catchment cannot be prevented from washing into the reservoir.

The issue of enhancing water quality seems to be contingent more on how nutrients can be extracted from the system. This would imply that the focus of attention should shift to an closer examination of the nutrient cycle as a whole and how this could be more effectively managed and used productively to enhance water quality. The experiences at Shashe dam also show that, even if a policy for prevention of access of stock is adopted, enforcement proves unmanageable and a costly maintenance and manpower exercise.

Based on the experiences of Shashe dam and applying to the Letsibogo dam site, the option of an unfenced reservoir, with a full management plan to exploit its potential, would appear to offer the best prospect of meeting government's objectives for economic and social development of water resources and for enhancing water quality. The possibilities for development within the reservoir reserve area are illustrated in Map K.3 and the needs for integrated management discussed at the end of this Chapter.

K8.4 Aquatic Weeds and Biology

K8.4.1 General

None of the common aquatic weeds, eg. *Eichornia crassipes, Pistea stratiotes* or *Salvinia molesta*, have been recorded at Shashe Dam. Their absence does not necessarily imply unsuitable conditions for their establishment and spread. None of the species have so far not been recorded from the seasonal river systems of Eastern Botswana and WUC check and spray all boats brought to the reservoir to prevent the accidental introductions. The only potential weed species found at Shashe Dam was *Ludwigia stolonifera*, a species which has been implicated in the closure of waterways in the Okavango Swamps and is said to be troublesome in irrigated crops. It was found only at the top of one of the side-arms of the reservoir and is unlikely to spread uncontrollably.

Stands of *Phragmites mauritianus* occur along the shoreline of Shashe Dam, particularly along the sheltered eastern shores and protected bays along the reservoir. It also occurs in all of the main rivers of the region. It can close up bays and inlets and, in the long-term, contribute to the encroachment of the shoreline into the water body, thereby reducing the storage capacity and amenity value of the reservoir. On the positive side, stands of *Phragmites* serve as nesting habitat for a number of water birds, which can be an attraction, as well as protecting the shoreline from erosion by waves. WUC personnel at Shashe Dam do not consider the growth of *Phragmites* to pose any significant problems.

The establishment of *Phragmites* is probably limited by a combination of excessive wave action on exposed shores, silting and too frequent desiccation. There is little growth near the head of the reservoir where the reservoir basin is covered with relatively deep deposits of silt. These are regularly exposed during the annual drawdown of water during which time they dry out and crack. Some individual *Phragmites* plants which are established close to FSL, and are currently 1.5 – 2 m above water level, appeared more stressed than those closer to water.

The enrichment of a water body with excessive quantities of plant nutrients, such as phosphates and nitrates, leads to the uncontrolled growth of phytoplankton and aquatic macrophytes. This can adversely affect water quality and increase the cost of providing water for domestic consumption. The amenity value of the reservoir can also be reduced. Eutrophication results from a imbalance between nutrient loading and nutrient withdrawal. Nutrient inputs can come from both internal and external sources, mainly the decomposition of organic matter in the reservoir and the mobilisation of nutrients trapped in older alluvium and organic sediments (both internal); and the input of nutrients from the catchment and directly in rainfall (both external). Nutrients can be withdrawn by plants, fixed in lake sediments, or removed in water taken from the reservoir or released downstream. The effect of the additional nutrients on phytoplankton or aquatic macrophyte productivity will depend on whether plant production is constrained primarily by nutrients, temperature, light, or the hydrological regimes of the reservoir.

K8.4.2 Nutrient Cycling

The contribution of decomposing organic matter to eutrophication depends on the plant biomass present in the area to be flooded, the extent of clearing of this vegetation before flooding, the nutrient content of the remaining plant material, and its rate of decomposition. Continual run – off from the catchment will also bring in an annual contribution of nutrients to the reservoir. The estimated nutrient content of the plant communities in the area which if not removed would be flooded by the reservoir is given in Table K – E8.1.

In the case of Letsibogo dam a considerable percentage of the timber volume is durable hardwood. Not all of these nutrients would be released immediately since the rate of decay of wood in freshwater impoundments is relatively slow. Most of the nutrient input from decaying vegetation will come from the decomposition of current growth (leaves and twigs). Some timber could be removed for commercial purposes. Both factors reduce the potential for any short – term nutrient flush soon after the dam is commissioned. Surveys at Shashe dam found similar hardwoods there which, uncleared at the time of construction, are still standing 16 years later. It is also likely that the remaining tree trunks provided a more varied environment for the evolution of fish and other aquatic life which can assist in the processing of the nutrients being washed into the reservoir every year. If well researched and managed these may provide useful harvestable resources which can remove the nutrients at the top end of the food chain.

When parts of the reservoir have been inundated for periods of up to six months most naturally occurring vegetation will die and decomposing organic matter will be taken into suspension. Subsequent lowering of water levels will lead to colonisation by weed species which may grow vigorously. These weeds will then die when the next sustained rise in levels takes place and decomposing organic matter will again be taken into suspension. This suspended organic matter will increase the chlorine demand in the water and can result in an unpleasant taste in the treated water. This sequence of events has occurred to some extent in Shashe dam but it has not been quantified. Decomposing vegetation can be expected to lower the pH as has occurred in both Shashe and Gaborone dams.

The release of nutrients from decaying organic matter has the potential to contribute to the eutrophication of the reservoir. Inputs from other sources, however, may be 4 – 5 times greater. While extensive clearing of the vegetation from the reservoir basin prior to flooding would reduce the input of nutrients from plant material, in the long-term, it will be less significant than inputs brought in during annual floods. The solubilisation of nutrients already present in alluvium in the reservoir basin cannot be prevented. Since of the soils are derived from granite-gneisses, the input may not be significant. There is also a dynamic equilibrium between the sorption and release of nutrients, such as phosphorus, from bottom sediments. This is controlled partly by the nature of the sediments and partly by the physical-chemical conditions in the water body. For example, phosphorus is released under anoxic conditions or at low concentrations in the water body, and is adsorbed when concentrations are high or under oxidising conditions. These contrasting conditions can vary seasonally resulting in net fixation at one time of the year and net release at another.

No measurements are available on the concentration of nutrients in the rivers at different times of the year. The rivers in eastern Botswana are subject to flash flooding. Because sediment transport (and therefore nutrient load) rises non-linearly with river flow velocity, the input of nutrients is likely to be pulsed and coincident with these periods of high flood. Spot measurements or average values of the nutrient load in the river water have little relevance under these circumstances.

The amount of nutrients carried into the reservoir depends not only on the amount of runoff and the mass of sediments, but also on the degree of plant cover in the catchment, the amount of erosion, the nutrient status of the eroding substrate, and the land use practices upstream. Cultivation, irrigation and the associated use of fertilisers can add significantly to the nutrient load of a river. To safeguard water quality, and limit the occurrence of those biological problems associated with eutrophication, management of land use within the catchment would be needed.

There is no information on the average number of livestock present daily throughout the year in the reservoir protection zone at Shashe Dam, nor any measurements of the quantity of faeces and urine deposited on the shoreline. Cattle dung and urine can produce the equivalent of 71 kg N and 16 kg P per head annually. A herd of 400 cattle would therefore deposit approximately 28.3 t N and 6.4 t P annually, slightly less N than has been estimated to be released from the decomposing woody vegetation but considerably more P. If all of this was deposited on the lake shore then it would add significantly to the nutrient content of the reservoir. But some of the nutrient would have come from vegetation growing in the drawdown zone which would be released anyway when the reservoir filled. Moreover, not all of the excreta deposited would be in the drawdown zone; the nutrients in excreta deposited outside this zone would probably be taken up by plants before they could be washed into the reservoir.

Although livestock may be responsible for some nutrient input, the sediments and organic matter brought in by flood waters is likely to be the major source of nutrients. There are, however, no time-series data on the volume and composition of the inputs from these various sources which can be used to assess their relative importance. This information is needed before the impact of livestock on the nutrient dynamics of reservoirs such as Shashe Dam can be fully evaluated.

K8.4.3 Algal Blooms

Growth of algal blooms has caused problems in particular in Shashe Reservoir but also to a lesser extent at Gaborone. The problem usually occurs during late winter and early spring

when there is no inflow and the turbidity is low. A similar problem must be expected for the Letsibogo reservoir although its extent cannot be defined at this stage.

The main species involved are the cyanobacteria, *Microcystis* sp (called *Anacystis* in WUC reports) and Anabaena *flos-aquae*, and they impart an bad odour and taste to the water. Both species can be toxic, even lethal at high concentrations, to people and animals drinking untreated or poorly treated water. In most cases the effects are sublethal and cause intestinal and dermatological disorders. Excessive phytoplankton growth can add significantly to the operating costs of the water treatment plants.

The excessive growth of phytoplankton and aquatic macrophytes in impoundments is usually a symptom of eutrophication. WUC suggest that cattle excreta deposited along the shoreline is the main cause of enrichment at Shashe Dam. The highly seasonal occurrence of these blooms, however, suggests that other factors are probably involved, at least in determining the timing of the blooms. Livestock are present around the reservoir throughout the year despite the efforts of WUC personnel to prevent this. The phytoplankton blooms, on the other hand, occur in late winter and early spring (July - September), well before any significant amount of nutrients from livestock excreta would have been washed into the reservoir by the annual rains.

The blooms at Shashe Dam are associated with the annual, winter overturn of reservoir water that follows the disappearance of the summer thermocline separating the warm, nutrient-poor surface waters from the colder, nutrient-rich bottom waters. High turbidity contributes to the formation of the thermocline by restricting the depth of penetration of solar radiation, and therefore heating, to a shallow surface layer.

Turbulence induced by wind can cause some mixing, especially in shallower waters, but generally mixing will not occur so long as the temperature differential between the surface and bottom waters persists. As a result, nutrients in the surface waters are gradually depleted as the phytoplankton populations grow, and the bottom waters are correspondingly enriched as organic matter originating in the surface waters sinks and decays. The bottom waters gradually become anoxic as microbial decomposers use up the available oxygen, leading to further enrichment as phosphorus is released from the lake sediments under anaerobic conditions.

Phytoplankton production is eventually limited by a combination of the depletion of nutrients in the surface waters, and the lower solar radiation levels and ambient temperatures in autumn. Renewed production follows the winter overturn when nutrient rich water rises to the surface. The rise in ambient temperatures in late winter re-creates suitable conditions for the growth of phytoplankton. This is when the water quality problems caused by phytoplankton blooms are experienced at Shashe Dam.

The scale of the problem posed by the excessive growth of aquatic organisms depends largely on the degree of eutrophication of the reservoir and on whether plant growth is limited by factors other than nutrients. The problems of excessive phytoplankton growth experienced at Shashe Dam seem to be relatively minor compared to those experienced at some other southern African impoundments. Light, rather than nutrients, may be the major limiting factor. The water in the reservoir is turbid for much of the year, and turbidity has been shown to limit phytoplankton production (eg. *Microcystis aeruginosus*: Robarts and Zohary, 1984).

K8.5 Water Quality and Treatment

The limited data available suggest that the water is almost neutral to slightly alkaline (pH 6.8 – 7.8), and mesotrophic with respect to nitrogen (1.0 – 1.3 mg/l) but eutrophic with respect to phosphorus (0.2 mg/l). Both N and P are implicated in the eutrophication of freshwater systems, though P is generally considered to be most limiting in southern African impoundments.

Normally raw water would have a pH in the range from 7.5 to 8.2 but pH as low as 6.2 has been recorded in the Gaborone dam. This is thought to occur after rapid rises in lake levels which results in suspended, rotting organic matter. The likely hydrobiological characteristics of the proposed Letsibogo Reservoir and the probable aquatic weed problems discussed in Appendix K – E with reference to the situation at Shashe Dam. However, the hydrological and biological characteristics of each reservoir are somewhat unique since no two reservoirs are identical in terms of climate, geology, soils, and vegetation of the catchment; the position of the impoundment along the river system; the biota present in the impoundment and upstream; and the management regime. These will all affect the chemical and physical characteristics of water coming into the reservoir and its characteristics afterwards. Extrapolations from one reservoir to another should therefore be viewed cautiously, especially when there is almost no hydrobiological data available from either site.

Shashe Dam is turbid. The coincidence of high turbidity and peak inflow indicates that most of the suspended material originates from material brought down during floods, although wind induced turbulence may be responsible for slowing down the rate of sedimentation of this material. Some settled material may also be re – suspended during the late dry season when strong easterly winds blow. The data presented in Appendix K – E, if representative, suggest that nitrogen is more likely to be limiting and that the trophic status of Shashe Dam and possibly also other reservoirs constructed in the region would be determined by nitrate levels and their dynamics.

The water quality problems which may be encountered, and should be planned for, at the Letsibogo reservoir could include variable turbidity, intermittent occurrences of suspended decomposing vegetation, algal blooms during the winter and pollution from bacteria, pathogens and schistosomiasis cercariae. It is unlikely that the problems of excessive phytoplankton growth currently experienced at Shashe Dam would be any greater in the proposed Letsibogo Reservoir. The problems can be expected to increase in drought years when water levels are continuously low because of the absence of inflow and the concentration of nutrients by evaporation is greatest. Reduced flow also means a decline in turbidity, allowing greater depth of penetration of solar radiation and a possible stimulation of algal production.

Regular monitoring of selected hydrological and biological variables would provide some warning of impending problems. This monitoring should be an integral part of the operating procedures of the proposed reservoir. A number of possible treatment methods are available and include both water management, chemical and biological strategies.

Detention in the reservoir will remove many bacteria, pathogens and schistosomiasis cercariae. Attempts to remove them completely normally require pre – chlorination and the maintenance of an appropriate chlorine residual. At 20°C and a pH of 7.5 a chlorine residual of 0.6 mg/l will eliminate cercariae. Without chlorination a detention time of more than 48 hours at 20°C is required to ensure the elimination of cercariae, and at lower temperatures the required detention time increases, such that at 10°C over 90 hours is required.

Chlorination on raw water pipelines can be carried out to avoid the build up of slime and loss of capacity in the pipeline, to kill and oxidise algae and rotting vegetation, to sterilise

the water when there is a pollution hazard and reduce the possible transfer of water quality problems. If the pipeline is designed to allow for swabbing, the build up of slime can be achieved without chlorination. If chlorination were carried out, the chlorine demand could be broadly similar to the 2 to 3 mg/l normally found in the water at Gaborone dam. However, demand can rise substantially whenever significant quantities of algae or vegetation are present. To allow for this a maximum chlorine dose of 10 mg/l might be required.

Chlorination of raw water is not a certain cure for all such problems. It is not effective on very turbid waters when high dose rates are called for. Under certain conditions, pre-chlorination can cause an interaction with industrial pollutants which produces carcinogenic trihalomethanes. As a result, modern practice uses pre-chlorination only where necessary. Nevertheless, the cost of the installation is relatively low and pre-chlorination has itself proved cost effective in controlling water quality problems. Water samples would have to be tested to determine the chlorine demand and any need for pre-chlorination. While this may be a risk in the future for the dams on the Shashe river, there is no industrial development foreseen in the Motloutse catchment upstream of the Letsibogo reservoir.

Control of algal bloom at Shashe reservoir has been tried using copper sulphate applied in a grid fashion from a boat in the vicinity of the intake tower. This method is too imprecise to be of recommended value. This is only a short-term solution and addresses the symptoms, not the causes, of the problem. Dosage rates cannot be adequately controlled, given the tendency for current and temperature variations to concentrate the applications. Also, there is risk of polluting the aquatic environment, which is counter-productive if it removes indiscriminantly flora and fauna which themselves assist in controlling the outbreaks. This can destabilise the food chains in the reservoir, with unknown consequences. Moreover, the decay of the dead organisms merely releases nutrients which become available to support the next bloom.

Alternative methods of treatment would seek to have an integrated contribution of different methods to minimise the conditions which can lead to poor water quality. This would concentrate on biological and management techniques to counteract or remove the causes of poor water quality in situ. This would include the stocking of the reservoir with selected species of fish to encourage nutrients and disease vectors to be taken up in the food chain (as discussed in Section K8.9), and the development of systems of harvesting both fish and useful vegetation to remove biomass from the reservoir system. Further research into the dynamic interactions of the reservoir with climate, seasons, flora and fauna could also establish other biological control and management mechanisms which could enhance these affects. This would form a major part of the research work of the proposed ecologist and the Management Unit discussed in Section K8.12.

K8.6 Grazing and Livestock Watering

The most difficult loss to ameliorate will be that of riverain grazing and browse. If a fenced reservoir policy is selected this would aggravate the situation further by denying access to areas of grazing exposed in the draw down zone, and by taking out a significant area of upland grazing and browse. The only possibility to offset this might be to allow access in times of severe drought. The practical management of this would be difficult with staff having to deal with definition, bureaucratic decision-making and negotiation and the rationalising of precedents set in earlier years.

To be successful, a livestock owner must have access to a range of grazing lands, from the more productive bottomland sites, to the upland sites where there is a dry season grazing reserve. Policies such as fixed land allocation, restrictions on distant or short range movements, or on the types of grazing areas to which the stock owner is allowed access,

will adversely the ecological and economic sustainability of the system. It is essential therefore that any planned resettlement of people from the bottomlands should take into account and seek to maintain this dynamic interaction between these spatially separate, but temporally linked, grazing resources.

The upper reservoir and the drawdown areas will produce some sites of valuable grazing. These could be used to ameliorate for the loss of the main riverain zone to reservoir development. If there were a managed approach to the removal of vegetative growth, this would help minimise nutrient contribution to the reservoir. Some areas of the drawdown zone will be recolonised by unpalatable and noxious weeds. These may also affect water quality as decay sets in from the re-flooding of the draw down zone. The ecology of regrowth in the draw down zone should be monitored as the reservoir begins operation. Its purpose should be to establish a management system for using economically useful species to compete with undesirable regrowth vegetation likely to affect water quality.

Broadcast reseeding with useful grass species might be investigated to provide thatching grasses and fodder resources as a drought contingency strategy. Due to the micro-topography, annual flood status and soil characteristics of the draw down areas, reseeding and cutting operations could not easily employ mechanised equipment. Reseeding techniques might include hand broadcasting or aerial seeding, with either pure or, possibly, soil encapsulated seed to aid rapid germination at the onset of the rains. If a successful system were developed a seed multiplication facility to maintain a store of selected seed would be required.

The possibilities for fodder production on the draw down zone using a cut and cart operation cannot be adequately assessed at the present time until more precise details on the scheme configuration, dam inter-relationships and operations are derived. The reservoir reserve area includes some small areas of already cultivated land along the full supply level where flood risks are minimal. Soil surveys of these lands would be needed to confirm their suitability for cultivation. Conditions may be amenable for fodder production based on a cut and cart operation. Possibilities for this are discussed further in Appendix K-E (Section K-E7.2.3).

In addition to providing drought reserves of fodder a further objective of such a unit could be to provide fodder for local dairy producers. A number already market dairy products to Mmadinare and were also involved with the old dairy industry which exported cream to Mafeking but ceased operating in the 1970s. If detailed research found this system to be economically viable, a single local commercial farmer, or small syndicate of dairy producers, might be identified to manage the area under a controlled lease. If the local demand for purchased fodder proved inadequate a guaranteed buyer can be found in the Livestock Advisory Centre.

If the reservoir were fenced the provision of alternative livestock water supplies will be necessary. To locate these in close proximity to the fence line would lead to a major erosion hazard on the upland terraces and slopes. This could then exacerbate the rate of sedimentation into the reservoir via peripheral streams. Due to the demands of the people and stock coming from the Lands at Monatjane and Manga, these alternative supplies would probably have to go close to the Lands cordon fences. This could also encourage overgrazing, through the concentration of stock in areas which are mainly used for winter grazing. If this overgrazing intensified, stock would have to be moved further afield, and probably upstream of the reservoir arms, thus transferring the problem to other cattle post areas. Neither of these solutions is satisfactory and emphasises the need to not fence the reservoir.

K8.7 Erosion Controls

In view of the need for soil stabilization, many selected areas, particularly on the western side of the Motloutse and on the southern side of the Sedibe, should be given special planning consideration. These areas already exhibit sheet and gulley erosion. Any woodcutting or intensive grazing of stock in these areas would increase the erosion hazard. Restrictions on access to selected areas should be considered to allow regeneration of vegetation in these areas.

Bush clearance will also be required for areas, such as the housing and office compound and other working areas outside the reservoir. This clearance should be carried out by hand and every effort made to maintain the larger trees in order to minimize soil loss, to maintain its landscaping value and to give the best chance for the recovery of vegetation in these areas.

Possible changes in the management of livestock arising out of the relocation of people and animals also has implications for soil conservation in the catchment and thus for reservoir functioning. If, as suggested, the upland grazing areas are less resilient to continuous grazing than the bottomlands and drainage lines, then plant and litter cover will decline. This will adversely affect rainwater infiltration rates. Reduced infiltration rates mean lower soil moisture levels in the soil, a shorter growing season, and a harsher environment for plant growth. Plants that are already being stressed by grazing now have to contend with a stressful growth environment as well. Recovery is slower (or not at all), forage availability declines, and the animals graze the remaining plants more heavily. Runoff increases and with it, potentially, soil erosion. The overall reduction in forage availability means greater pressure is placed on the remaining plants. Because the soil surface is exposed, compaction by animal hoof pressure and raindrop impact seals the soil and reduces infiltration rates even further.

Under these conditions only annual herbaceous plants and short-lived perennials survive. The abundance of annual forbs and grasses (relative to the paucity of perennials) in all the plots surveyed in the reservoir area and downstream, indicated that vegetation is already heavily stressed by grazing and browsing. A number of degraded sites were seen in both the uplands and bottomlands. Despite a more than 50 % reduction in livestock numbers in the past two years as a result of drought, the vegetation looks heavily overgrazed. The potential for further reductions in plant cover and soil erosion to become more widespread is considerable, particularly if the current pressure on the lowlands is transferred to the uplands without detailed land-use planning.

If construction of a dam at Letsibogo is to go ahead, then a detailed land use and management plan for the catchment needs to be worked out and implemented. This process is being undertaken, as yet without reference to the potential impact of the dam, by the MLGL at Serowe. Such a plan should take into account the spatial and temporal variability in rainfall, soil moisture, plant production and quality, herbivory and animal movements are closely related. Events occurring in one part of the system (such as the construction of a reservoir, the provision of water points, or the settlement of people) will have direct and indirect consequences for the functioning of other parts of the system, and for their stability.

K8.8 Forestry Planning

K8.8.1 General Approach

It is usually considered necessary to remove all vegetation within the FSL of a dam site to permit construction and reduce the amount of organic matter which could later decay and

create a water quality hazard. However, the many hardwoods present are also the most valuable and useful timbers. It would be desirable to plan the clearance of the reservoir area in such a way as to allow utilization of these timber resources.

A number of factors were considered in drawing up a plan for vegetation clearance for the reservoir area. The details of this are dealt with in Appendix K – F and include:

(a) the distribution of vegetation types, their economic value and ease of access for removal by hand;

(b) the potential to maintain, separately manage and monitor woodland in the upper reservoir area and above the FSL;

(c) the need to maintain woodland and screening around the reservoir perimeter and above the full supply level for soil and wildlife conservation purposes. These areas are where the chances of flooding will be remote and where natural reseeding and coppice regrowth would in any case occur. Savings on the bush clearing contract would also be made by preserving these woodland and shrublands. They also assist soil stabilization;

(d) the need to reduce sedimentation and maintain water quality;

(e) the market potential for both traditionally used firewood, construction and carving materials, and for commercially sawn timber;

(f) the potential for leaving selected hardwoods stumps to provide suitable breeding habitats for fish.

K8.8.2 Forestry Characteristics

The vegetation communities within the reserve area are shown in Map K.2 and are discussed in Appendices K – E and K – F. Table K8.1 shows their area, volume and other characteristics. The reservoir area includes significant timber resources in the riverain and mopane woodlands. The riverain woodland, which comprises 47 % of the timber volume, contains good quality firewood and a small but valuable volume suitable as commercially sawn timber. The mopane woodland, which comprises 22 % of the timber volume, contains high quality timber for use as firewood, carving materials and traditional construction materials.

K8.8.3 Reservoir Margins

It is unnecessary and undesirable to clear the vegetation from the area above the full supply level of 850 m. This area will serve to conserve soil stability, maintain the existing ecology and provide screening around the reservoir fringes. However there are vegetation species that are unable to withstand even a few days of waterlogging and where these lie within the area that will be flooded when the spillway is overtopping then they will need to be cut off just above ground level and burnt as they are of little economic use. It would be highly desirable to replant these areas with species that are able to withstand occasional inundation. The present simulation indicates that the reservoir will be above FSL and spilling some 4% of the time. The areas of existing riparian woodland at the confluence of side tributaries provide a resource which will serve to trap silt. This has been noted in the planning for soil conservation zones.

Table K8.1

Forestry Characteristics of the Areas to be Cleared

Ref No.	Vegetation community	Area ha	Area %	Volume m^3	Volume %	Weight t	Weight %	Access conditions	Commercial value
1.1	Commiphora/croton Kopje Woodland	17	1	202	1	126	1	poor	poor
1.2	Commiphora/kirkia Kopje Woodland	21	1	1083	5	607	3	poor	average
2.1	Combretum/acacia Riverine Woodland	81	4	6298	32	5126	28	average	good
2.2	Combretum/peltophorum Riparian Woodland	87	4	2977	15	2989	16	good	good
3.1	Acacia/boscia Woodland	33	2	401	2	378	2	good	average
3.2	Mixed Acacia Woodland	266	14	3216	16	3101	17	good	average
3.3	Acacia/combretum Woodland	152	8	830	4	839	5	good	good
4.1	Colophospermum/acacia Woodland	28	1	381	2	427	2	good	good
4.1.1	Colophospermum/combretum Woodland	473	24	3073	15	3478	19	good	good
4.1.2	Colophospermum Woodland	38	2	490	2	583	3	good	good
4.2	Colophospermum/commiphora Woodland	191	10	356	2	427	2	good	average
5.1	Acacia Scrubland	549	28	527	3	501	3	good	poor
6	Catophractes/rhigozum Shrubland	4	0	0	0	0	0	good	nil
	Totals	1 940		19 834		18 581			

Source: Consultant's field surveys

The possibility of managing the upper reservoir area for forestry was considered. The Letsibogo dam will not have the operational characteristics of a transfer dam, like that at Bokaa. Particularly in the early years, the flood levels at Letsibogo are likely to remain consistently high, as discussed in Section K4.1. The reservoir also does not have a floodplain

or topographic profile with extensive alluvial deposits which could create a suitable environment for the sort of extensive multipurpose developments considered for the Bokaa dam. Tree survival in the upper zones of the flooded area is considered to be highly unlikely. Thus, it has been concluded that there will be no potential to utilise this upper drawdown area of the reservoir for forestry purposes.

K8.8.4 Vegetation Clearance

It is estimated that there are some 15 000 tonnes of potentially usable timber could be extracted. Three options for removal of the total useable timber have been examined (see Appendix K-F).

- bulldozing and on-site burning or removal for charcoal/firewood
- labour intensive hand clearance under professional supervision
- unsupervised removal by local people

The analysis concludes a policy of indiscriminate bulldozing and on-site burning is undesirable as it would result in a considerable natural energy resource going to waste and deposit a considerable mineral nutrient balance into the reservoir. The available wood would be sufficient to supply the annual fuel wood needs of 40 000 people. The potential for charcoal production may exist but is limited by no previous experience or market in Botswana and would require more detailed research to establish its viability. With up to four years in which the clearing programme could be completed this provides an opportunity where local people could benefit from the clearance programme. However, as the calculations in Appendix K-F show to attempt the complete removal of the useable timber by hand would not be an economic operation as long as the total timber resources is valued as general firewood. It would require a government subsidy estimated at P 154 000. Furthermore, there is no way that the local people could possibly handle or consume the quantity of timber involved within the likely time constraints.

This analysis did not consider the higher value of selected hardwoods as carving materials, high quality firewood and commercial sawlogs. The analysis of only extracting these species indicates an economically viable operation which may also generate a profit if marketed in Gaborone. This selective programme would significantly reduce the total scale of operations for a forestry programme and simplify its management. Budgetary provisions would be required to pre-financing the programme until sales returns were received.

The implications of this selective programme would be to reduce the extraction volume from 15 000 tonnes to 6 700 tonnes and to require the remaining timber to be cleared by bulldozer. In this context local people should be given advanced warning and allowed to remove independently as much wood as they wish prior to a burning exercise. To reduce the risks of nutrient build up in the reservoir, it is recommended that the larger part of the bulldozer clearing operation is carried out in the early part of the dam construction contract, allowing one whole rainy season to wash the ash and remains downstream of the dam site.

The proposed bush clearance programme is, therefore, as follows:

1. Supervised commercial operation to hand cut selected species in designated areas prior to bush clearance by a sub-contractor;
2. Hand Clearance by the sub-contractor of designated soil conservation areas

3. Bulldozing of the remaining timber for burning in the river beds

The proposed bush clearance programme is summarized in Table K8.2 and Map K.4. Further details of bush clearance are given in Appendix K-F.

K8.8.5 Forestry Programme

As the experience at Bokaa has shown, early decisions are required if these proposals are to proceed in a timely and effective manner. It could take up to four years to actually clear and process the timber from the area. The decision on the clearance method will be necessary before 1990 if selective commercial clearance is to be viable.

Although there is no potential for forestry developments within the flooded area of the reservoir the work load involved in the timber extraction programme is still considerable. There are also other areas of important forestry inputs. It is proposed that a forestry coordinator be brought in as soon as is possible to start on the management of the timber removal and bush clearing programme. This post would be seen as having an on-going role as part of the management unit for the research and development aspects surrounding the effective use of the reservoir. The other main activities in the brief could include

- collect seeds during clearing;
- assess soil conservation needs and demarcation of areas of erosion risk, both within and adjacent to the designated reservoir area; these to be managed in association with the Land Board, the District Forester, the community and other relevant institutions;
- manage perimeter woodland as a natural resource if a fenceline is adopted
- design and complete the survey of reservoir and downstream vegetation to assess long-term impacts;
- feed research results back into policy development for land use planning and soil and resource conservation and management.

K8.9 Fisheries

Details on the potential for fisheries are discussed in Appendix K-G. The preliminary assessment indicates that a modest fishery potential exists with a possible production target of 20 tonnes per year and full time employment opportunities for about 20 people. A fishery development however has much to offer in assisting the enhancement of water quality and public health, which is seen as a more important objective than any economic use, for which the returns will be relatively low.

The simulated pattern of reservoir drawdown and flooding (with the accompanying growth and subsequent decay of marginal vegetation) and catchment run-off (where seasonal rains will wash nutrients into the reservoir) will provide an environment which, if the physical and chemical fluctuations remain within acceptable limits, will support fish populations on a continuing basis.

Table K8.2

Bush Clearing Programme and Timber Potential by Vegetation Type

Ref	Vegetation community	PHASE 1 AREA				PHASE 2 AREA				PROGRAMME TOTAL			
		Area ha	%	Clearing method	Reduced timber volume m^3	Area ha	%	Clearing method	Reduced timber volume m^3	Area ha	%	Volume m^3	%
1.1	Commiphora/croton, Kopje woodland	17	1	Hand	0	0	0	n/a	0	17	1	0	0
1.2	Commiphora/kirkia, Kopje woodland	21	2	Hand	305	0	0	n/a	0	21	1	305	4
2.1	Combretum/acacia, Riverine woodland	35	3	Hand/Dozer	844	46	6	Hand/Dozer	1108	81	4	1952	28
2.2	Combretum/peltophorum, Riparian woodland	61	5	Hand/Dozer	1128	26	3	Hand/Dozer	480	87	4	1608	23
3.1	Acacia/boscia, Woodland	32	3	Hand/Dozer	51	1	0	Hand/Dozer	2	33	2	53	1
3.2	Mixed acacia, Woodland	82	7	Hand/Dozer	179	184	24	Hand/Dozer	400	266	14	579	8
3.3	Acacia/combretum, Woodland	130	11	Hand/Dozer	369	22	3	Hand/Dozer	63	152	8	432	6
4.1	Colophospermum/acacia, Woodland	14	1	hand	164	14	2	hand	253	28	1	417	6
4.1.1	Colophospermum/combretum, Woodland	245	21	hand/dozer	531	228	30	hand/dozer	403	473	24	934	13
4.1.2	Colophospermum, Woodland	38	3	hand	489	0	0	hand	0	38	2	489	7
4.2	Colophospermum/commiphora, Woodland	148	13	dozer	0	43	6	dozer	0	191	10	0	0
5.1	Acacia, Scrubland	355	30	hand/dozer	102	194	26	hand/dozer	56	549	28	158	2
6	Catophractes/rhigozum, Shrubland	4	0	dozer	0	0	0	dozer	0	4	0	0	0
	Total	1 182			4 162	758			2 765	1 940		6 927	

The actual fishing patterns to be evolved and techniques to be used will depend upon the final management strategy selected for the reservoir itself. In the long term it will also be affected by the system of integrated operations resulting from the conjunctive use of the network of water supply reservoirs already existing or being planned.

To achieve a balanced and productive reservoir ecology where fish can contribute the greatest overall benefit an integrated approach is recommended. This would require close collaboration between the Fisheries Department, the proposed reservoir management unit and the Ministry of Health to establish a programme of applied research well in advance of impoundment.

Planning will be needed for the habitats suitable for food fish and other species beneficial in the control of nutrient in-flow and removal, eutrophication and aquatic weeds and disease vectors even though some of these species have little or no appeal as food fish. Planning will also be required for the establishment of a small artisanal and subsistence fishery. A re-stocking programme will very likely be required to augment natural replenishment of fish stocks after the infrequent occasions when the reservoir will dry up. As the facilities required are relatively considerable and permanent the establishment of commercial fish farming should be considered to assist with these re-stocking requirements. Such a unit could also be used to supply the needs of the other reservoirs existing or being considered elsewhere in Eastern Botswana.

The organisation required to develop this type of fishery strategy will involve experimentation and adequate preparation on the part of the Fisheries Section of the MOA if it is to guide the operatives authoritatively and ensure the rational utilisation of the resource. New fishing techniques and management strategies will be introduced and raise the need for training. As it is common for fishermen to have limited financial means, provisions will have to be made for loans to be made readily available on easy terms to allow equipment to be brought in the first instance. Certain facilities will also be required ashore to assist in the preservation and disposal of the catch, to maintain and administrate the fishery and to manage the commercial licenses issued by the reservoir operating authority.

There is likely to be a demand for recreational angling over and above any decision by government to encourage such activities. Therefore, it will be prudent for the Fisheries section to take the initiative and supply a economic service to sports people which should be self-financing through the sale of fishing rights and the hire of boats and tackle. This intervention should also be planned as a valuable source of practical scientific information and feedback on the resource and the fishery development strategy.

As the production potential of the Letsibogo reservoir will be limited, the fishery programme being recommended could be regarded as excessive and unjustifiably expensive if taken in isolation. However, it is likely that some of the expenses and activities should fall into the on-going activities and budgets of the existing Fisheries Section. Also the consultant stresses that the proposals should be seen as part of the wider context of other reservoir and water resource developments. The work proposed is thus seen as having direct application to the existing Gaborone, Bokaa and Shashe dams and the other reservoirs now being planned for Eastern Botswana. With the pace of water resource development as they are now developing it is considered of some urgency that reservoir fishery activities and strategies are incorporated into the overall reservoir planning and operational activities as soon as possible. This necessitates the delegation of the responsibility and appointment of an experienced officer within the authority to develop the themes outlined above. Within the specific strategy for the Letsibogo reservoir this officer is required on the proposed Management Unit and if stationed permanently at Selebi Phikwe could take on the responsibility for the other existing or planned water developments in the region.

A limited local market demand for fish does exist but the level and taste requirements require further elaboration. There is a fish canning unit in the industrial estate in Selebi Phikwe which produces a canned pilchard from raw fish imported from South Africa. Another company produces quality frozen packs of marine fish and could become important as an outlet if local aquaculture were to develop in the region. These outlets are unlikely to be suitable unless catches are sizeable and the landed price for fish is low. Neither of these occurrences could be anticipated at the present time. However, as other reservoirs come on line, and if integrated reservoir management or commercial fish farming evolve successfully, this situation may change in the future.

K8.10 Shoreline Irrigation

Within the context of the integrated management of the reservoir proposed it may be necessary to investigate the possibilities for shoreline irrigation further. This system may be required on the small scale to establish a seed multiplication unit for species to be encouraged as shoreline colonisers. Irrigation facilities may also be required to manage the production of contingency reserves of fodder.

The initial surveys indicate only very small areas along the shoreline where suitable conditions may exist for irrigation and a detailed soil survey would be required to confirm this. If any irrigation were to be introduced the risks of pollution from fuel powered motors would demand that electric or solar powered systems were used. Such schemes could be limited to those which came under the direct control of the proposed Management Unit or research programmes. Alternatively, if other areas with suitable soils were identified, limited lease arrangements might be negotiated with commercial dairy producers who would be allowed to produce fodder on a cut and cart basis with no use of agro-chemicals or potential pollutants.

K8.11 Amenity and Recreation

The new landscape which will come into existence once the reservoir has impounded could offer a considerable potential for income generation from amenity, recreation and tourism. The level to which this can be taken will be determined by the reaction to the proposals on developing Selebi Phikwe as a major regional center as is discussed in Section K7.3. The three main options raised include minor facilities for local residents in the surrounding towns, major facilities to attract tourism from within the Southern African circuit, and a major programme of development aimed at a range of international activities.

If a full programme of amenity development were taken up and planned commercially it could minimise the need for public funds. The issue of controlled sub-leases or consideration of joint venture developments could also ensure that any developments had to self-financing and could create the potential to generate income for the dam operating authority to maintain the non-commercial infrastructure and facilities within the reserve area.

There will be a series of kopjes which could be left intact by the contractor close to the dam wall and others scattered on the FSL shoreline which will provide attractive features and viewing points overlooking the reservoir, dam wall and surrounding woodland countryside. In times of full flood some of these will be islands which will be transformed into attractive, accessible, rocky promontories projecting out close to the dam wall as the reservoir levels fall. If these potential features are borne in mind during the supervision of the construction phase some of these assets could be protected from unnecessary damage and be enhanced by suitable landscaping and access designs. The location of a viewing platform at the

southern end of the dam axis along with a car park and visitors informational display board would seem a minimum requirement and would fulfill a much needed public relations opportunity.

Attractive landscapes surrounding water will not be adequate facilities in themselves to encourage the use of the reservoir area, particularly for local people. With care and attention major attractions with considerable educational value could be developed out of the archaeological, wildlife and woodland resources. If well planned around organised tours with well laid out and displayed sites this may not only derive income from tourists, but could also be used by local schools to educate children in the own history, culture and environmental assets.

The development of the wildlife resource would require particular attention. The land enclosed by the reservoir between the Sedibe and Motloutse rivers up to the Senyame hills is used solely by cattle for their winter grazing area. Since 1982 small herds of elephant, possibly totalling as many as 60 head, have taken up residence in this zone. A few ostrich are also present, as well as smaller game and buck. It may be possible to consider this zone as an open wildlife reserve where all settlement would be prohibited, but access for grazing still allowed. Possibilities for farming game through culling programmes may also exist. Coordination with the Wildlife Department will be required at an early stage to assess possibilities.

These ideas could be developed further if a full conservation programme were deemed desireable. Under suitable financing arrangements and management, it may provide an environment where breeding of endangered species could be organised which, in itself, could become a major tourist and research attraction. If commercial links were sought this operation could be financially attractive.

Taken at its smallest development level the reservoir could be zoned into areas where camp sites, pony trekking and boating facilities would be available. Stables and riding stables already exist in Selebi Phikwe and there is a tradition of horse riding amongst local people. Special provisions for jetties and sand beaches would be desireable and require planning as part of the construction programme. A boat club and boat house could also form part of the construction programme. This would lead to a minor employment and income generation for the local people.

If commercial developments, based around chalet or hotel accommodation and catering facilities, were planned, this could provide another outlet for the produce of the irrigation areas and start to open up other trading opportunities for local people. Bus and taxi services, ice cream makers and sellers and local handicrafts could be encouraged and, with semi-precious stones still available in relative abundance in the downstream catchment, this could provide a new industry in jewellery trade and skills. Sales of these products could be allowed through stalls leased and organised around a planned small market in the main access area to the reservoir and its accommodation facilities. Further outlets could be developed in Selebi Phikwe and Mmadinare.

It will be important to minimise the health and pollution risks involved. To prevent swimming in the reservoir swimming pool facilities available to both tourists and local residents should be considered and the risks of swimming in the reservoir clearly displayed around the reservoir and explained to local school children as part of their education.

K8.12 Research and Management Coordination

It is important that all amelioration and development activities within and adjacent to the reservoir area are coordinated and integrated. None of the existing or planned dams in this part of Botswana are in close enough proximity to Gaborone to consider the involvement of the specialist institutions working out of Gaborone, as was the case for the Bokaa reservoir. This reinforces the need for an on-site capability. It is therefore proposed that a Management Unit be established to take responsibility for the environmental research and management.

The objectives of this unit would be twofold. The primary task will be to work to improve the development contributions of the three dams likely to exist in this region of the country, namely the existing Shashe dam and the proposed Letsibogo and Lower Shashe dams. In addition, it would initiate field studies to address the gaps in knowledge on a policy for adequate compensatory flows from a future dam to ensure continuing regeneration of the riverain woodland. They would also address the resource status of the catchment as a whole and the needs for a land use planning programme and Land Board policy which appreciates the role, importance and potential of the upland woodlands and particularly the ecology of the mopane woodlands.

Initially, the Unit should comprise a forester and an ecologist. At a later stage, and nearer construction, involvement of fishery and socio-economic experts would be required. The secondment of these staff from existing government institutions would be a preferable strategy to maintain long term continuity. Alternatively a temporary planning and implementation unit could be established to coordinate the works up to the commissioning of the dam. By this stage full discussion and a decision on the regional strategy for economic, amenity and research development could have been taken. Decisions on the structure of the unit and its integration into on-going activities could be taken then. A third alternative would involve letting this research work to international tender or by negotiation with an interested international research body.

A number of possible research strategies are available. Part-time research contracts and grants could be set up for existing personnel within the University, or provisions could be made for full-time contracts to be administered and directed by the management unit in advance of any full environmental research station facility being set up. This could be set up as part of an ongoing studies course or as a commercial or institutional research operation. Funds could be drawn, either directly from the dam development budgets, or from other Government sources or international finance and research sources.

Selected personnel should commence work immediately after a decision to proceed with the dam. The management unit would design and instigate the initial baseline studies along with the monitoring and research programmes as well as coordinate and manage the proposed forestry programme. It could also assist in the planning and establishment of a full environmental research programme under the future auspices of an international research centre, should this be agreed upon. It is unlikely that sufficient time exists to allow the proposed research center facilities to be provided in advance of dam construction.

In carrying out its work the Management Unit should refer to the experiences of the Bokaa dam and call on the experiences of other specialist institutions, such as MLGL (Land Use Planning and Pollution Departments), DWA (Ecologist and Pollution Sections), University of Botswana (National Institute for Research and Documentation, and the Biology and Environmental Sciences Departments), the Forestry Association of Botswana, the Morwa Forestry Unit, and the MOA (Department of Agricultural Research, Animal Production Research Unit, Farming Systems Research Group and the Fisheries Section).

CHAPTER K9

FUTURE STUDIES AND MONITORING

K9.1 Aims and Objectives

This study has assessed the likely scope of impacts which a water resources development programme may induce. There is insufficient data and understanding of a number of key parts of the environment and socio-economic system. Further research and analysis will be needed to confidently predict how irrigation and the reservoir should be operated and managed and how to most effectively ameliorate some of their more adverse consequences.

The primary aim of this stage of the research strategy should be to ensure that adequate basic studies are carried out during the final phase of detailed planning and before full implementation of the programme. The monitoring programme should establish sufficient baseline data to catalogue and model the "before project" situation and then to develop a capacity to detect and monitor change and to assess the implications of this change and thereby be in a position to advise on ameliorative action to offset any, as yet, unforeseen adverse consequences arising from the project. The monitoring programme should also serve to refine the proposed strategies of amelioration which have already been identified based on current knowledge.

K9.2 Resettlement and Compensation

The effects of the drought have left many cattle posts abandoned in the reservoir area. Added to this is the significant time period between the feasibility study and the planned start to construction. Unless an immediate moratorium on all new development in the reservoir is introduced, new cattle posts and lands are likely to be re-established. A similar position will apply to the potential irrigation areas where new lands can be established or old claims, not visibly apparent at the present time, can be renewed. The inventory of resources eligible for compensation and the people to be relocated will have to be reviewed in a timely fashion once a decision to proceed with the dam and irrigation is taken. The survey should follow the format used on the Bokaa detailed study (MacDonald, 1988b) combining as it did the enumeration of lost resources for compensation assessment and valuation with relevant socio-economic enquiries to ascertain the degree of livelihood loss and offer a range of resettlement options for each household to consider. Draft enumeration forms are given in Appendix K-H. It is highly likely that new air photography of the reservoir will need to be flown due to the changes that are likely to occur in the next four years. If formal irrigation were to go ahead then consideration would also have to be given to doing the same for these areas. The identification and order of importance of amelioration measures will also need to be made at this stage so that these can be considered as conditional clauses during the negotiation for any lease agreement.

K9.3 Water Resources

The current model of the downstream riverain systems lacks the sophistication needed to fully assess future impacts. More data is required on the effective run off and contributions of the sub-catchments. Data is also required to assess the losses through evapotranspiration from the riverain vegetation. Further discussion is given in Appendix K-E. The need for a regulation of the take up of river side plots for irrigation has been previously mentioned and this will be covered by the recommended Land and Water Management Study. This is

outlined in Section K9.13 item 4. The Terms of Reference for this study are attached as Appendix K – K.

K9.4 Grazing Systems

The general pattern of grazing and livestock management has been identified in this study. It would be sensible to arrange a more in – depth study to reveal particular characteristics which may help in the final designs of the relocation and amelioration programme. This could be done most effectively through a research grant for a university graduate specifically commissioned for the Letsibogo and Shashe dam projects.

K9.5 Ecology and Wildlife

K9.5.1 General

The survey carried out during this study shows that the flora and fauna of the area are poorly known. Prior to this survey very few plant specimens had been collected, and although this survey has provided a more comprehensive collection of species, including a species recorded only once previously from Botswana, significant gaps undoubtedly remain. Among the faunal groups, the herpetofauna appears to be quite diverse. No collecting was done and very few species were positively identified. This group too would be worth surveying in detail. In view of these and other gaps in the knowledge of the area, it is suggested that more detailed surveys be carried out prior to construction of the dam.

The importance of the downstream riverain vegetation has been stressed but little is really known of how this system operates and maintains itself and how the fluctuations in the water levels in the sand river and extreme climatic events influence the system. It will also be necessary to continue with basic ecological research to allow further understanding on the dynamics and regenerative processes which control the development and survival of the riverain woodlands.

Again the need for in – depth, time consuming research presents itself. This can be done most effectively and economically through research grants. The basis of this work should preferably involve multi – disciplinary inputs which implies the need for a strong institutional support service. While this might be possible through the negotiated involvement of the University of Botswana, the significance of the findings of such research may have considerably wider application and provide an opportunity to consider an international involvement.

Many of the ecological problems associated with the management of reservoirs stem from processes operating in the catchment. Proper management of the catchment is therefore essential if problems within the reservoir are to be minimised. There is a need for a more comprehensive survey of the catchment, the land use options available for different areas, and the current land use practices. The functional links between different land units and areas need to be identified and an integrated land use plan prepared in consultation with local people. Reservoirs cannot continue to be seen in isolation from their sources.

K9.5.2 Flora and Fauna

Considerable advances have been made by this study in stimulating the first real collections of plant material from the Motloutse valley. These riverain and mopane ecologies are poorly understood. It would be in the interests of proper land use planning that the foothold gained

is not lost to future development planners and implementors. The full set of plant collections are being deposited with the National Herbarium and this also includes that made by the University Biology Department. The University and Herbarium should be given the means to report to government on this collection and their findings and to make proposals on future research. A further research grant to allow a proper ecological and economic assessment of the mopane and riverain woodlands would add invaluable understanding to future planning in the catchment.

The immediate focus of this water resource development study has been to concentrate attention on the vegetation of the study area. While fauna may be less visible they, nevertheless, have no less an important role to play. Some of their interactions may be vital to the stability and vitality of the environment as it now occurs. They may also have significant economic value as has been proved with the development of exports of the mopane worm. These aspects would be best dealt with in the framework of the research studies discussed above.

In view of these and other gaps in the knowledge of the area, it is suggested that more detailed surveys be carried out prior to construction of the dam. The surveys should span a number of months (though not necessarily continuously), in order to take differences in seasonal activity of the species into account. The botanical survey could be carried out by the National Herbarium at Gaborone, with the assistance of the University of Botswana, or it could be contracted out. Likewise, the faunal survey could be carried out by the National Museum, Gaborone. The estimated costs of such surveys would be about P 200/day. Approximately 10 – 15 days of field work, spread over some months, would be needed to cover the area adequately. The priority areas to survey are the rocky outcrops and the riverine woodlands.

As and when a decision is taken to proceed with the Letsibogo dam the possibilities for the amenity and economic use of wildlife should be studied further. The preparations necessary for any implementation along this line could take years to complete and could involve many institutions in both public and private sectors, depending upon the extent of the amenity and tourist development that was decided upon.

K9.5.3 Monitoring Downstream Vegetation

The analysis of the vegetation reveals that there are a number of species that are confined to the banks of the rivers and which are possibly dependant on the movement of water laterally into the alluvium from the river. Construction of a dam at Letsibogo would alter the flood regime of the river downstream, the length affected primarily being from the dam to the Letlhakane confluence. The sand river model described in Annex B indicated that, if Mmadinare obtains a new supply direct from the dam, there should be no significant lowering of the water table in the sand river during the dry season as a result of the river closure. The need to refine the model based on a monitoring programme is outlined in Appendix K – K.

Nevertheless the change in the flood regime and a significant drop in the water table due to any future increased extraction of water from the sand aquifers for irrigation purposes could result in the death of some of riverine species, the failure of seedlings to establish themselves, or both.

Die – back of the riverine vegetation would destabilise the riverbanks and cause further disruption to the river system. A die – back, if one occurs, would be gradual. Provided that the signs were identified and interpreted in time, controlled releases from the dam flow from the dam could be made to prevent further deterioration of the riverine woodland. This requires

a monitoring programme to determine the rates of change, if any; their causes; and where the changes are taking place. It is therefore suggested that consideration be given to monitoring the species' composition, size structure, and recruitment of the riverine woodland at a number of sites downstream from the dam.

K9.5.4 Biological Functioning of Sand Rivers

Almost nothing is known about the biological functioning of the sand rivers of southern Africa. Most limnological and hydrological research has been carried out on perennial rivers and impoundments. Basic information on the chemistry, microbiology, and productivity of the water in these sand rivers is lacking. Consideration should be given to establishing a monitoring unit prior to the construction of the dam, to provide some background information on water in these rivers and how its features change seasonally, and to follow through with these studies during and after dam construction to determine the effects. The information obtained would make future impact assessments on the effects of damming sand river systems more accurate.

Information is also needed on the functional relationships between the riverine vegetation and the sand river aquifers. How much water moves laterally into the sediments, and how far? How dependant is the riverine woodland on water levels in the riverbed? What sorts of feedbacks exist between the riverine vegetation and the sand river system? For example, how much organic matter from the riverine woodland enters the sand river system? What is its fate? How important is it in affecting the quality of the river water, and how does it do this? None of this information is available. Research aimed at answering some of these questions should be encouraged and would form a major research objective of a research station in the area.

K9.5.5 Monitoring Hydrological and Biological Variables

Water destined for domestic consumption must be of sufficiently high quality. Therefore the processes which lower water quality and introduce health-related problems need to be identified, understood and, where possible, managed. Current management of water quality problems at Shashe Dam is reactive rather than preemptive (ie. actions taken to maintain or enhance water quality are generally implemented in response to declines in water quality to unacceptable levels). Moreover, the actions taken tend to treat the problems as physical and chemical ones rather than as ecological or land use management issues. Regular monitoring is needed to establish the direction, rates and magnitude of any changes in the levels of nutrients and other biologically active substances in the reservoir. Monitoring of selected biological variables is also necessary in order to provide some index of response to any physical-chemical changes.

Since most water quality problems arise from high inputs of sediments and nutrients from the catchment, monitoring of these inputs is essential to detect any changes and thereby provide advance warning of potential problems. Potential sources of these substances upstream of the reservoir need to be identified, evaluated and, where possible, controlled. The main sources of input to a reservoir upstream of Mmadinare are likely to be diffuse and therefore difficult to manage. Effective management of inputs from organic matter from riverine vegetation, animal excreta, and natural erosion of the topsoil requires first, that the kinds, amounts and timing of the inputs are known (the object of monitoring) and secondly, that there is a realistic plan for the management of the catchment, which is able to affect the inputs.

K9.6 Pollution

Following upon the pollution studies investigations already instigated there will need to be a continuing programme of monitoring water quality downstream of Selebi-Phikwe and as far as Bobonong. this would fall within DWA's overall pollution monitoring programme.

There are a few key outstanding areas requiring study, which, although not specifically related to the study, are of importance in the context of the overall environment. The first unknown concerns the possible need to impose zones of restricted grazing in the areas surrounding the mine and in the downwind areas of aerial deposition of pollutants from the smoke stacks. Monitoring and health inspections of animals known to graze in these areas would assist in an understanding of the transmission of these pollutants into the food chain via the meat or dairy products of the animals concerned. The veterinary department should be approached to assist in this study.

In view of the typical results of the water analysis taken from points downstream of the BCL mine, a particular focus of this study should be the copper concentrations in the tissues, particularly muscle and liver, of cattle, sheep, goats and donkeys grazing in the area; sheep and goats have a very marked concentrating power for copper ingested whilst feeding.

The second issue relates to the future planning and specialist budgetary, personnel, equipment and service needs of the Ministry of Health to deal with any long-term adverse health problems which may have been caused by the pollution of water and other resources over the last 15 years. The long-term implications of exposure to heavy metals are poorly understood and may require specialised medical and social service inputs in the future.

Some idea of the wide range of effects produced by air-or food-borne heavy metal contamination over long periods of time can be gained from comparative studies in other mining areas of the world. Acknowledged effects include cancer of the lung and nasal sinus from nickel; cancer of the prostrate from cadmium; osteomalacia with amino-aciduria from cadmium; acute poisoning, liver cirrhosis and encephalopathy from copper; manic-depressive psychosis from vanadium; and tremors and paralysis from manganese.

K9.7 Archaeology

Discussions with the National Museum and their associated researcher's indicate that, in view of the pressure on their scarce skilled resources, it would be preferable to integrate the research into the history and remains in the Letsibogo and Shashe reservoir areas. This would also widen the scope and understanding of the history and significance of this whole part of Botswana. Proposals have been made to start on this work immediately in order to finish a full assessment by the early 1990s when construction of the first dam is likely to start. Further discussion is given in Appendix K-D.

K9.8 Fisheries

To achieve a small productive fishery which also assists in the enhancement of water quality, public health, amenity and recreational potential is to be regarded as a desirable bonus to the main objective of a reservoir for urban water supply. While there will be a need for continuing dialogue between government and the project planners on the strategies for reservoir management, the main responsibility for the role and establishment of the fishery potential will rest with the officers of the Fisheries Section of the MOA. The needs for further study and monitoring before, during and after impoundment are elaborated upon in Appendix K-G. The principal areas are as follows:

1. Regular analysis of water samples before, during and after impoundment is necessary to assess, with increasing sophistication, the possible production potential of the reservoir.

2. A long term review of the ecological requirements of the principal food fishes must be carried out to determine which species can establish and maintain themselves naturally and those which would require periodic re-stocking.

3. The dam will obstruct the natural migration of certain species during breeding periods and it will be necessary to determine which of these have importance and the manner in which they can be moved satisfactorily over the dam.

4. The principal spawning grounds should be surveyed and plans prepared for their protection or, if necessary, for their re-location.

5. Early definition of fishing grounds and arrangements for the adequate clearance are essential. Similarly, provision must be made for suitable shore facilities to handle the catch hygienically and for the welfare of a small fishing community.

6. Experimental fishing trials using improved techniques should be carried out and technical and administrative arrangements made to ensure that fishing people can purchase, use and maintain the new equipment.

7. Once conclusions have been drawn on the re-stocking programmes, the reservoir regimes and the habitats of the preferred species, the possibility of developing fish farming, incorporating re-stocking requirements, should be explored.

The Fisheries Section would have a responsibility together with the proposed Reservoir Management Unit to monitor constantly the environment of the reservoir and protect its productive capacities. The nature of the reservoir will inherently be one that is changing and sufficient understanding should develop over the years to allow adverse changes to be corrected and for the role of fisheries in this to be established. There will also be a responsibility for the Fisheries Section to monitor and safeguard the interests and status of the artisan, subsistence and sports fishing people at the Letsibogo and other reservoirs.

To ensure that there will be adequate capacity and skills available in the Fisheries Section in future years to deal with these issues, a review of the existing and future staffing and programme of the section should be considered. Since the work proposed for the Letsibogo reservoir links directly to other water resource developments in the country, and the Fisheries Section has the responsibility for the management of their fishery potential, the cost of an improved service spread across the various potential projects makes good sense in the long term. It is also significant that, if it were well organised, the national potential for production from capture fisheries could add substantially to the availability of animal protein. The existence of an operational canning factory at Selebi-Phikwe is a very strong reason to vigorously pursue this.

K9.9 Sand Recharge and Reservoir Sedimentation

In view of the effect of Letsibogo dam on the recharge of sand in BCL's sand extraction lease downstream, an indication of the present natural recharge would be most useful. This can be achieved by a series of survey transacts across the river at, say, 250 m intervals extending over the area of the present lease. These would be surveyed at the start and end

of each rainy season. Due to the probable variability in recharge from year to year, this should preferably be initiated as soon as possible.

To ensure that a full set of data on reservoir sedimentation can be amassed in the future it is necessary that a baseline survey of appropriately selected transacts of the reservoir be made before impoundment. This survey could be completed during the detailed design phase and after a decision to proceed is taken. It is crucial that the locations of these lines are recorded in a way that will allow their very accurate resurvey on exactly the same locations once the reservoir has impounded and for many years after.

K9.10 Letlhakane Dam Studies

The water resources studies in Annex B have identified the potential of a dam on the Letlhakane to supplement the yield of Letsibogo. The impacts of such a dam have not been studied at this stage. An environmental impact study will need to be carried out once sufficient survey and mapping data are available and some ideas of possible scheme configurations are proposed for study.

K9.11 Socio-economic Studies

It would be advisable to ensure that socio-economic studies are carried out to monitor the impact of the construction activities on Mmadinare and the surrounding economy. If the Letsibogo dam is the next to be constructed then monitoring of the construction impacts of Bokaa dam, presently under construction, will help in the proper protection of the local population when it comes to the construction of the other dams now under study.

The impact of the reservoir on agro-pastoralism will be fundamentally linked to a decision on whether to allow unrestricted access and whether a proper integrated reservoir management programme is to be initiated. Again to assist in the rational development of future reservoirs, detailed monitoring and study of the social and economic implications of the selected strategies will be required.

The impact of irrigation development is already being felt in the valley, even though to date it is very minor. Any major developments decided upon will extend and intensify these impacts, particularly if this involves the transfer of Tribal Land into the hands of commercial farmers. Irrigation development will affect many central features and linkages in the operations and structure of the local social and economic systems. Some of these will have important political and social ramifications which it would be wise for government to be aware of. This is particularly the case as there is a growing pressure from some quarters of government for the development of formal irrigated agriculture.

K9.12 Health Surveys

The major risks to public health from the proposed water resource development programme are likely to arise from the reservoir. In the case of irrigation if the proposed irrigation water delivery system is by buried pipelines and sprinklers rather than open channels, the risks will be minimal. However if river conveyance is adopted, ponded water at the proposed weir at Tobane and at other locations due to the sand extraction activities could increase the health risk. It will be necessary for the Ministry of Health to conduct baseline surveys of the schistosomiasis snail vectors in the reservoir area and to establish the prevalence of the disease amongst the local population who may have contracted the disease whilst working away in infected areas elsewhere. There are recently discovered serious infections of migrant

farm labourers working on the commercial farms at Pandamatenga and this will require a review to ascertain the likely risk of diffusion. It would be wise to integrate the limnology study with the requirements of the Fisheries studies as discussed in Appendix K-G. These surveys will establish the basis for future monitoring of the problem. It must be stressed that once a definite decision is taken to proceed with the construction of the dam, DWA must send official confirmation of the fact to the Ministry of Health immediately, in order that the necessary baseline studies may be initiated.

Second only in importance to schistosomiasis is malaria. Baseline surveys and follow up monitoring studies of mosquito breeding after impoundment of the reservoir will be required. These are needed in order to give a background for the future planning and monitoring of malarial control operations (if and when they become necessary) but also to identify the controls which would be appropriate for culicine mosquitoes if these prove to be a major nuisance hazard and limiting factor for the amenity and recreational value of the reservoir. Perhaps the most important factor in promoting a healthy environment during and after dam construction is the on-going programme of health education. This must be directed towards two distinct target groups - health professionals and the general public.

Health professionals require specific in-service up-dating in the new potential health hazards, their epidemiology, prevention and treatment. The general public requires a less technical and less formal programme of health education designed to explain in the most appropriate ways the possible health hazards, the means of recognizing them, the ways of avoiding them when they do occur, and the availability and (when appropriate) the urgency of treatment.

In relation to the water resources development programme three specific area of education and target groups in the population can be identified:

- the problems arising from the construction period and the related health risks of construction employment/activities. This will involve the migrant workers and the local towns people of Mmadinare;

- the new hazards induced by standing body of water at the reservoir and the new activities which will develop around it. This will involve the reservoir workers, the fishing communities, the livestock herders and the tourists plus other people making use of the amenity and recreational resources;

- the irrigation areas where some new risks of water-borne diseases may exist and more likely the very real risks attached to the use of agro-chemicals particularly by unskilled and semi-literate people.

K9.13 Studies During Detailed Design Stage

In summary, the range of topics identified and discussed throughout this report will need the following more detailed studies:

1. Final enumeration of the resources and compensation values for the reservoir and irrigation areas once a moratorium on development is decided upon. Standard forms for this are attached in Appendix K-H. This work will also need to be widened to cover the amelioration items for consideration as conditions in the negotiation of any lease agreement for the taking over of the rights of the land.

2 Soil surveys of the reservoir fringes to identify development potential and erosion control measures.

3. Detailed soil surveys on a plot by plot basis to identify replacement land for any resettlement programme related to the selected reservoir and irrigation development.

4. Land and water management survey of the Motloutse riverain zone to assist the Land Boards, Water Apportionment Board and MOA in the proper regulation and control of resource development in this sensitive ecological zone. Draft Terms of Reference for this are shown in Appendix K-K.

5. Monitoring of subsurface water levels in the sand river and improved evapotranspiration measurements to allow an improved hydrological model of the sand river, leading to a more systematic approach to the use of this resource.

6. Grant-aided research to look at the future of grazing systems and management in the catchment which could also assist in the final designs of the re-location and amelioration programme.

7. Establishment of a research station approach to the study of the ecology and management of the riverine, bottomland and upland woodlands, for the future protection and conservation of the resource base of the catchment. Baseline studies for monitoring of future downstream impact would also be encompassed by this facility.

8. The completion of the pollution studies with regard to the land use zoning and restrictions on livestock grazing and the identification of the long term health risks and needs.

9. Continuation of the archaeological studies of the reservoir area and in the irrigation areas if a decision to proceed with formal commercial irrigation is taken.

10. Water quality sampling and monitoring to serve a wide range of purposes.

11. Fisheries studies and surveys as highlighted in Section K9.8 and in Appendix K-G.

12. A sedimentation survey to establish the monitoring base for assessing the future rate of sedimentation of the reservoir, the development of mud banks and different fishery and other ecological habitats. Also included in this movement survey could be the determination of sediment movement off lateral streams downstream of the dam site with the construction of interception weirs to measure this natural replenishment of downstream sand resources.

13. Detailed environmental and social impact studies for the Letlhakane dam site if a decision to proceed with the study of this option is taken.

14. Socio-economic studies to assist in the monitoring of the impact of the construction activities on Mmadinare and the surrounding economy. In addition a study of the impact of the reservoir on agro-pastoralism and the impact of irrigation upon the development of the many social and economic features in the operations and structure of the local social and economic systems will need to be carried out. It is important that these are of a problem solving nature rather than pure data collection, so that practical implementation policies can be considered.

15. Limnology surveys to assist the health and fisheries programme

16. Health baseline and monitoring studies of the malarial, schistosomiasis and mosquito hazards.

17. If a decision to proceed with a major development of amenity and recreation investments this will require detailed planning studies and commercial assessments involving a wide range of factors as discussed in Section K8.11.

18. River cross section surveys to monitor sand movement and the impact of sand extraction to the BCL mine.

19. Monitoring of groundwater pollution boreholes and of the water quality downstream of the mine.

CHAPTER K10

COST AND BENEFIT ESTIMATES AND PROGRAMMING

K10.1 General

This Chapter provides an attempt to quantify of the impacts and components of the development programme as requested in the TOR. It also lays out a phased schedule of programme operations as seen if the main recommendations of this study are adopted.

In general, quantification is difficult, as appraisal often has to address qualitative features or complex interactions for which satisfactory modeling and valuation techniques are not yet available. In these circumstances valuation often becomes a process of subjective judgement based on a knowledge and experience of the local conditions and, inevitably, the final figures produced will be open for discussion. However, such discussions would quite likely conclude that to try and make value judgments which assume a financial market place for these features is actually to misunderstand the true nature of the subject in question and to accept that, in terms of the contemporary market place and financial world, they can have no recognisable price. This would not suggest that these features have no value, but that the basis of the value judgments in common use in financial and economic planning cannot yet encompass the contribution which long term environmental and social factors make in sustaining our resource base and human society.

Environmental economic theory is still developing but starts by making a distinction between renewable and non-renewable resources. This can help establish whether the stocks of the resource in question are being withdrawn from future use by an absolute depletion of the available reserves. If the resource in question is renewable, through inherent regenerative capacities or through technological resource transformations, it then has to be established as to whether the rate of use of the resource exceeds the regenerative capacity. Over use of resources in this category will often come up against environmental limits inherent within the system which make these resource non-renewable if the capacity for regeneration is undermined.

Typical examples of this would include the over-exploitation of natural woodland and tropical forest resources whose whole existence is based on the sum of its components being more than the whole. An analogy in chemistry for this is a synergist effect and, in practical terms, means that simply re-planting trees may be insufficient to provide the full range of needs for a healthy, sustainable woodland having adequate regenerative potential. This will be influenced by a variety of interactions between soil, chemical, floral and faunal features which evolve in the woodland bio-system.

Major problems of valuation also arise when trying to rationalise the basic discounting assumptions of economic theory to these circumstances. While the resource and financial markets of the modern world depend upon the values and concepts of future values being worth less than todays, the value, to society as a whole, of the resource base, and the complex interactions which sustain it, cannot be viewed in the same light. These features cannot be bought and sold in the market place, and thus do not have a financial value per se. The long term degradation of the resource base may take a long time reaching the point where supply shortages raise market prices for some of the marketable output of the resource base. However, by this time it may already be too late to recover the full regenerative capacities of the resource system in question, and only in hindsight will the shortcomings of placing too much value on the short term output for the market place become apparent. Thus, logically there can be no reason why this generation should regard the value of the resource base any more or less precious than the next or previous

generations. Each generation takes on from the last the responsibility of being caretaker. This becomes increasingly the case as each generation becomes more adept at transforming natural resources into consumable and useful products for human gain.

K10.2 Upstream Impact

The major long term impact upstream will be the more intensive use of riverain and upland grazing and browse, particularly if the reservoir is fenced and future access denied. If access is already and a fodder amelioration programme organised this may provide some compensation. This will lead to some increase in the rate of erosion. Appendix K–H discusses one approach to the valuation of this and concludes that the minimum cost to society might be in excess of P 2.0 million if a full replanting programme were attempted.

Against this would be offset the upstream benefits of the reservoir. At this stage it has not been possible to identify any such benefits although an integrated management plan to exploit the full development potential of the reservoir may create income and employment effects for upstream livestock owners.

K10.3 Downstream Impact

It has been a requirement of the study that no existing downstream users (people, livestock, wildlife and vegetation) would find themselves deficient of water as a result of the proposed water development programme and transfers of water to south east Botswana. Thus at this stage no cost is allocated, while the economic analysis provides the derivation of the urban and rural benefits of a successful programme.

The main known downstream impact with financial implications will be to the economics of the extraction of the sand resources discussed in Appendix K–H. This concludes that compensation of P 364 200 per annum after the year 2010 will have to be budgeted for to cover the adverse impact of the water development programme.

The level of benefits downstream will be dependant on the irrigation programme. These benefits are discussed in Chapter K6. Further benefits may derive to Mmadinare as a result of the construction activities and the multiplier effects if a programme of amenity development were to proceed. This would include small business, lodging facilities, artisans, and transport services. Sub–contractors in Selebi Phikwe would probably receive a temporary boost from the issue of local sub–contracts. Increased economic activity in both Mmadinare and Selebi Phikwe would perhaps create a more healthy investment climate for outside commercial investors. However, these trends would be offset by the widening in income differentials in the community and inflationary effects may also be of influence.

K10.4 Reservoir Management

The cost of a managed programme for removal of selected valuable timber in the reservoir has been estimated at P352 220. This is listed in Table K–F2.5, Appendix K–F. This has been shown to be economic and the cost of the removal programme would be recovered from the sale of the timber.

It is not possible to provide detailed budgets on a future managed forestry and soil conservation programme at this stage. This would require some soils mapping and analysis and decisions by government on the fencing policy.

Similarly it is not possible at this stage to make estimates for budgetary provisions for the proposed Management Unit and the research facilities which they will require. The needs of the long term research programme will have to await further decisions on their desirability and the exact nature of the detailed environmental studies which would follow a decision to proceed with the dam.

Table K10.1 lists items for which budget estimates will need to be made for possible reservoir development and management.

Table K10.1

List of Reservoir Development Possibilities and Management Items for Which Funding Would be Required

Research and Management Unit – Placement and running costs
Downstream Monitoring and Research
Reservoir Monitoring and Research
Amenity and Recreation
Forestry
Erosion Control
Fisheries
Health Monitoring
Socio-economic Monitoring
Shoreline Irrigation

K10.5 Compensation

Table K10.2 summarises the costs associated with the compensation and amelioration of the reservoir area. As far as the compensation amounts are concerned these are of course estimates subject to detailed enumeration and assessment by the Land Board, checking by the DSL and negotiation between MLGL and the implementing agency. The costs in Table K10.2 are the direct compensation costs for lost improvements and assets in the reservoir area, including the additional costs incurred by fencing it. There can be little question that these will have to be found by the implementing agency. At P674 557 they represent a small proportion of construction costs. They include the land reallocation and bush clearance programme as the most important amelioration measure which at the cost of P1 076 is minimal but would go a long way to helping those people displaced to create sustainable replacement livelihoods. Possible long term compensation claims which can not as yet be envisaged are listed in Table K10.3.

K10.6 Added Costs of Reservoir Fencing

In the event that a full fencing programme is preferred an amelioration programme for water supplies will be required for people at nearby cattle posts, lands, their livestock and wildlife. A figure of P350 000 for survey, design and implementation has been allowed for in the budgets. This includes drilling and installation of boreholes supplemented by a reticulation system from the dam. Additionally private and communal assets will need to be compensated for. These total a further P 300 000.

Table K10.2

Compensation and Amelioration Cost Summary for the Reservoir

Private Assets	P 44 231
Communal Assets	P 621 250
Replacement Provision	P 8 000
Minimum Amelioration	P 1 076
Total	P 674 557

Additional Costs of a Fenced Reservoir

Private Assets	P 3 300
Communal Assets	P 296 700
Replacement Water Supplies	P 350 000
Total	P 650 000
Overall Total For a Fenced Reservoir	P 1 324 557

Note: See Tables K7.1 and K7.2 for more details
In addition for both an unfenced and fenced reservoir there will be an annual payment of P364 200 from year 2010 for sand extraction involving greater haul distances.

Table K10.3

Items for Which There Could be Long Term Compensation Claims

Downstream Impacts – up to 3 years after impoundment, including vegetation, wells, irrigation and water supplies
Upstream Impacts – up to 3 years after impoundment date
Development Restrictions in the Mmadinare Western Urban Area

K10.7 Programme Planning

The principal activities are the detailed environmental studies, the compensation payment programme and the monitoring programme.

The monitoring programme covering the activities outlined in Chapter K9 should ideally commence prior to the 1989–90 rainy season to enable a comprehensive database of the existing situation to be established. Particularly of relevance for this start date is the study of the response of the water table in the riverain areas to variation in river levels and transects across the river over several kilometers upstream and downstream of the Letlhakane confluence to determine the extent of sand recharge over the rainy season. The establishment of these monitoring programmes would form part of the Land and Water Management Study, draft TOR for which are given in Appendix K–K.

The detailed environmental studies of the reservoir impact are outlined in Chapter K9. The studies would include a detailed enumeration of lost resources for compensation assessment

and valuation combined with relevant socio-economic enquiries to enable a range of resettlement options to be identified for each household. Included within the study would be soil surveys both of the existing plots and replacement areas.

In the case of the Letsibogo dam and reservoir, the number of affected households is small and hence the enumeration of resources would be expected to be relatively straightforward. However, if a fenced reservoir option is adopted, more detailed socio-economic studies will be required.

In the case of irrigation considerably more detailed studies will be required to enumerate lost resources and identify replacement land, combined with the need to possibly exclude specific areas of certain irrigation blocks where resources lost are high.

The detailed environmental studies for the dam will also include the study of alternative reservoir management options and ecological studies of the downstream riverain areas.

The programming of the detailed environmental studies and compensation payment will be dependant on the timing of the required land acquisition in relation to the specific components of the project.

For the dam there is a two phase approach, with the dam site and downstream reservoir area covering the proposed borrow areas expropriated as a first stage. Based on the recommended implementation programme of construction commencing in late 1992, this first stage expropriation needs to be completed at the end of that year's harvesting. The second stage expropriation will be required to be completed in 1994. The detailed environmental studies should be carried out during the enumeration exercise in late 1991/early 1992. These two distinct phases should be communicated to land users whilst the detailed enumeration surveys are being carried out in order to prevent planting of crops in areas that will need to be expropriated before harvesting can be carried out. This should negate the need for compensation payments for destroyed crops.

It is extremely important that overall responsibility for the implementation of the programme is clearly allocated with this as their sole function. For this reason the appointment of a management unit has been recommended to provide continuity.

The programming of the irrigation studies can only be determined once a decision is made by Government on the scale and site specific nature of any irrigation development.

REFERENCES

AquaTech	1983	AquaTech Groundwater Consultants (Pty) Ltd, Water Resources Evaluation for Talana Farm. For Botswana Development Corporation.
Arntzen, J.W.and Veenendaal	1986	A Profile of Environment and Development in Botswana. Institute for Environmental Studies, Free University, Netherlands, National Institute of Research and Documentation.
Bird, A.C.	1984	The Land Issue in Large Scale Irrigation Projects, Some Problems From Northern Nigeria. In Adams and Grove, "Irrigation in Tropical Africa: Problems and Problem Solving", African Studies Centre, University of Cambridge, U.K.
Biswas, A.K.	1987	Environmental Impact Assessment for Developing Countries, Tycooly International, London.
Bryson, T.	1986	Farm Wildlife Conservation Manual. TVS/ICI, U.K.
Campbell, A.C.	1986	Notes on the Prehistoric Background to 1840. In Settlement in Botswana, Symposium papers for the Botswana Society. P186.pp.13 – 22. Gaborone, Botswana.
Cooke, H.J. and Silitshena, R.M.	1988	Botswana – An Environmental Profile. UNEP Desertification Branch,
Cooper, D.	1986	An Overview of the Botswana Urban Class Struggle and its Articulation with the Rural Structure: Insights from Selebi – Phikwe. In Settlement in Botswana, Symposium papers for the Botswana Society, 1986, pp.245 – 255.
Colson, E.	1971	The Social Consequencies of Resettlement: The Impact of the Kariba Resettlement upon the Gwembe Tonga. Manchester University Press, U.K.
CSO	1981	Guide to the Villages and Towns of Botswana : Population and Housing Census Analytical Report, Central Statistics Office, Ministry of Finance and Development Planning
Dasmann, R.T, Milton J.P. and Freeman, P.H.	1979	Ecological Principles for Economic Development. J.Wiley & Sons.
Denbow, J.	1986	A New Look at the Later Prehistory of the Kalahari. Journal of Africa History.No. 27, pp. 3 – 28, 1986
FAO	1971	An Operational Manual for Resettlement. FAO, Rome, Italy.
Field, D.I.	1978	A Handbook of Range Ecology for Range Management in Botswana. Land Utilisation Division, Ministry of Agriculture.

Mitchell A.J.	1976	The Irrigation Potential of Soils Along the Main Rivers of Eastern Botswana – a Reconnaissance Assessment. Land Resources Study No 7. LRDC, Ministry of Overseas Development, London.
MFDP	1982	Migration in Botswana, Patterns Causes and Consequences Central Statistics Office, Ministry of Finance and Development Planning.
MFDP	1982	Summary Statistics on Small Areas. Central Statistical Office, Ministry of Finance and Development Planning.
MFDP	1985	National Development Planning, 1985 – 91. Ministry of Finance and Development Planning.
MFDP	1987	Population Projection 1981 – 2011. Central Statistical Office, Ministry of Finance and Development Planning.
MLGL	1985	Selebi Phikwe Development Plan Final Report. Department of Town and Regional Planning/Selebi Phikwe Town Council, Ministry of Local Government and Lands.
Minster	1989	Selebi – Phikwe Regional Development Project. Small Scale Irrigation in the Selebi – Phikwe Region, Botswana. Thame, U.K.
Palgrave, K.C.	1988	Trees of Southern Africa. Struik Publishers, Cape Town, RSA. 5th Impression.
Parsons, N.	1986	Settlement in East – Central Botswana area 1800 – 1920 In Settlement in Botswana, Symposium Papers for the Botswana Society, 1986, pp.115 – 128. Gaborone, Botswana.
Rhebergen, A.J.	1988	A System of Land Evaluation for Arable Farming in Botswana. FAO/UNDP Soil Mapping and Advisory Services Project, Government of Botswana. BOT/85/011, Field Document. Gaborone Botswana. March 1988
Schapera, I.	1953	The Tswana. International African Institute, reprint, London, U.K. 1984
Stanley and Alpers, (eds)	1975	Man – Made Lakes and Human Health. Academic Press, London.
Tapela. H.M.	1986	Movement and Settlement in the Tati Region. A Historical Survey in Settlement in Botswana. Symposium Papers for the Botswana Society, 1986, pp.174 – 188. Gaborone, Botswana.
Thomas, E.G. & Hyde L.W	1972	Water Storages in the Sand Rivers of Eastern Botswana Surveys and Training for the Development of Water Resources and Agricultural Production in Botswana. Technical Note 33 UNDP/FAO

Timberlake, J.	1980	Vegetation Map of South East Botswana. Division of Land Utilisation, Ministry of Agriculture.
Varley J.B.	19??	Report on a visit to Talana Farms (Pty) Ltd Botswana (Soil and Water Appraisal) C.D.C. London.
Volta River Authority	1965	Volta Resettlement Symposium Papers, Kumasi, Ghana.
WRECA	1978	Resettlement of People Displaced by Dam Construction Projects in Kano State, Nigeria. Water Resources Engineering and Construction Agency, Kano, Kano State, Nigeria.
Wikner T.	1980	Sand Rivers of Botswana. Department of Water Affairs/SIDA, Gaborone, Botswana.
WLPU	1985	Surface Water Pollution with Particular Reference to the Gaborone Dam Catchment Area, WLPU Consultants for the Department of Water Affairs.
WLPU	1987	Environmental Impact Assessment of Kolobeng and Metsemotlhaba Dams and Bokaa Dam, WLPU Consultants with the Ministry of Local Government and Lands.
WLPU	1988	Study of BCL Selebi Phikwe Mine, Tailings Dam, Water Useage, Water Quality and Pollution, WLPU Consultants for Department of Water Affairs.
World Bank	1986	Selebi – Pikwe Technical Assistance Project. Washington DC, USA.

APPENDIX K – A

APPENDIX K-A

MINISTRY OF LOCAL GOVERNMENT AND LANDS
REVISED COMPENSATION GUIDELINES FOR LAND BOARDS AND ASSESSMENT COMMITTEES IN TRIBAL LANDS

K-A1.1 Introduction

1 When Government or a non Government body wants to construct a project which is of national importance or for the public good and the only land that can be found suitable for the project is already occupied and owned privately then there are legal provisions for assigning the land to that project. When such land is taken, compensation will be necessary for loss of rights, etc. The Government or non Government body will be responsible for provision of the compensation money but physical payment is the job of Land Board. National projects include new airports, power stations, extensions of villages, new roads etc.

2 The first action is for the body wishing to take over the land to inform the Ministry of Local Government and Lands in writing who will then inform the relevant Land Board. As an intrinsic part of the planning phase of any major project and at the expense of the body wanting the land, the Land Board may commission an Environmental Impact Study to assess the projects implications. The results of the study are to be utilized as a factor in deciding the nature of the development and allow the Land Board to state the appropriate conditions under which the application can be granted. The relevant Land Board should be approached in the early stage of the project so that any major constraints with regard to land acquisition and rights can be incorporated into the decision making process. The identification of amelioration measures to overcome the identified impacts should be included in the Impact Study along with an overall framework and programme for compensation provision.

3 In the Tribal Areas the Land Boards are the responsible authorities for administration of the land on behalf of the tribes. The granting or re-taking of tribal land will be carried out through the Land Boards. As such an application shall take the form prescribed in the Tribal Land Act (1968) and its regulations. No action undertaken in 2 above shall be construed to be a formal application.

4 District land Use Planning Unit

The Land Board Secretary will ensure that the District Land Use Planning Unit (DLUPU), through the District Commissioner's office, is informed of all proposed major projects. It will assist in environmental impact studies.

5 Procedures for Dealing with the Application

The procedures for dealing with applications are given in the Tribal Land Act of 1968, amended in 1969. Part IV specifically deals with Common Law Leases and Part V with land required for Public Purposes.

Under Part IV Section 24, a Land Board may grant a lease to an applicant but only with the consent of the Minister. Under Section 24.1 this can be given under such terms and conditions as the Land Board may determine. In order that a lease can be registered, a plan approved by the Director of Surveys and Lands (DSL) defining the boundaries of the area must accompany the lease.

Under Part V Section 32, land can be granted to the State for Public Purposes only if the President determines that it is in the national interest. In this case the Minister has to serve notice on the relevant Land Board. The procedures then followed are as for Section 24, with the Land Board able to impose conditions of grant. In cases of non agreement provision is made in Section 35 for a Commission of Enquiry reporting to the Minister to be set up.

On receipt of the application the Land Board should:

(a) refer the application to the relevant DLUPU.

(b) using the Environmental Impact Study, the DLUPU should endeavour to give an early recommendation, in principle, to the Land Board whether to accept or reject the application. The conditions under which the application would be accepted will form the basis of a subsequent more detailed recommendation. The purpose of the recommendation, given in principle, is to allow the Land Board to mobilize the Compensation Assessment committee as quickly as possible.

K–A1.2 The Framework for Land Compensation

Tribal Land can be considered in two categories for compensation purposes.

(a) Customary Land Rights
(b) Common Law Rights which include TLGP and Arable Farming Leases

In the case of Customary Rights (under the Tribal Land Act of 1968) the Land Board has been required to make available alternative land of equivalent value to the land which has been taken from any people holding such rights over that land.

The Government, or non Government organisation which takes over the land, is required to pay compensation to all people who are forced to move. The amount of compensation to be paid includes :

(a) the value of any standing crops taken.
(b) the value of any improvements on the land.

In addition there will be cases where the following apply:

Where there is no suitable alternative land available to be allocated as replacement land, or where the alternative land is clearly inferior to the land being expropriated then additional cash compensation will be paid to cover for the asset and unimproved utility value of that land or the difference between the original and the replacement land.

Where fixed assets are to be compensated for but they can in fact be salvaged and transported to the replacement site, (eg. building materials etc) then displacement compensation shall be paid.

Where Tribal Land with no individual rights is acquired then communal compensation is payable to the Land Board for its usable resources that can not be replaced, e.g. woodlands, water sources, grazing, usable veld products etc. This will not form part of any individual assessment but will be a claim by the Land Board. There may be cases where evidence of loss is not immediately apparent,

in which case an appropriate time must be allowed for monitoring and assessment of losses after the commissioning of the project.

Where any land is not itself required to be expropriated for a project but the project impacts are apparent (eg restrictions on use or externalities) then compensation for loss of existing and potential benefits is payable. There is a three year period from the commencement of the commissioning of a project in which claims can be lodged. These are to be individually assessed by the Land Board in conjunction with the DSL.

The following situations are covered;

- loss of goodwill previously built up by an enterprise
- dislocation and severance costs where access or other conditions are changed
- loss of potential returns due to restrictions being placed on any new or existing activity or development, be they temporary or permanent. This includes temporary disruption and disturbance.

These also apply to cases were a reallocated plot is inferior to the original plot for the above reasons.

K-A1.3 Procedures for Compensating Customary Right Holders

1 Notification

The Ministry of Local Government and Lands will advise the Land Board of the details of any proposed project on tribal land in their area and involve the Land Board in discussions concerning the carrying out of the project. The Land Board is responsible for arranging the Environmental Impact Study which should include identification of alternative replacement land and measures to maintain economic livelihoods.

2 Inspection and Demarcation

Once it has been decided to proceed with the project but without prejudice to the Land Boards final decision in regard to the application then government officers and Land Board officials will make a physical inspection of the land required. Where necessary the boundaries of the land will be marked out in the field according to prepared plans.

3 Assessment Committee

The Secretary of the Land Board will set up an Assessment Committee to include the following :

- a member of the Land Board, other than the Chairman, who shall chair any meetings
- the Land Board Secretary who will record all minutes
- a Representative of the Tribal Administration
- the District Officer (Lands)
- a representative of the Department of Surveys and Lands
- an Agriculture Officer
- the relevant Sub-Land Board Chairman or Clerk
- a District Council Technical Officer
- a Land Board Technician

A minimum of 5 members must be present at any one time. In addition a representative of the organisation wishing to take over the land has observer status at all meetings.

4 Notification of Enumeration

The Land Board will make every effort to identify and contact all occupiers within the demarcated land and in the case of major development request for a Kgotla meeting to advise the people of the scheme and of their rights. The occupiers are to be advised not to carry out any additional improvements to their land as these new improvements will not be compensated.

The occupiers must be advised of the day when the Enumeration Team will be making its enumeration of the properties affected and that they should be present.

5 Enumeration Procedures

Implementation of the enumeration of lost and affected assets will be the responsibility of the DLUPU. The enumeration team will comprise the following people :

- a Land Board technician
- a representative of the Village Office, Headman or Development Committee
- a representative of the District Council (eg a Councillor or Council official)
- a representative of the organisation applying to expropriate the land.

The team will record the details of all improvements to the land and any other fixed assets affected within the demarcated area. These are written onto a standard enumeration form which also has a section for assessment. An example is attached in this Appendix.

A schedule of current rates of compensation to be applied during 1987/88, to be reviewed every two years, is also included in this Appendix.

6 Assessment

The Assessment Committee will meet, discuss and agree on the appropriate rates of compensation to be entered on the enumeration forms based upon actual knowledge of the improvements. Its assessments will be recorded on the forms.

The rates of compensation are a guide to the most common types of improvement to be found and the committee must add its own descriptions and comments in each case.

Each report description must be related to a plan and/or aerial photography of the area by proper referencing. Where only part of someone's land has been demarcated and the part remaining cannot be used by itself (e.g because it is too small, or the land will be affected by the Government project or the land has no reasonable access), the assessment report should give full details as Government may be required to take the remaining land and pay compensation for any improvements.

The enumeration and resulting report are the basis upon which compensation is assessed. This should be read out to the claimant, who then adds their views and signs the form to indicate that they were present.

7 Appeals and Claims by Occupiers

The Assessment Committee will invite the various affected occupiers to submit any additional claims for compensation for their improvements if they so wish. This should be in the form of a simple (even verbal) request. The committee should note any claim put forward by any occupier and include this information in the report but remind the claimant that it is still subject to checking by the DSL. The Committee shall also publicly request that any other person who feels they have a justifiable claim, which has not been enumerated, to come forward and present it. These should be recorded on assessment sheets. The Committee then meets to discuss compensation after all enumeration and assessments have been completed.

8 Checking

The committee agrees on the appropriate compensation for each occupier and in the case of major projects submits its recommendations to the Land Board. The Land Board then submits these to the DSL for checking. The Department of Surveys and Lands will then advise the Ministry of Local Government and Lands who will then inform the appropriate government department or non government body. Payment will be made to the Land Board for distribution to occupiers. In the event of the applicant being dissatisfied about the compensation assessment then they can appeal to the MLGL who may then appoint an arbitrator.

9 Compensation Payment

Compensation for all lost assets, displacement and relocation is to be paid before occupiers are required to vacate their land. In the case of occupiers being allowed to remain on the land for any length of time after compensation payment, then a written agreement shall be signed at compensation payment time indicating the date by which the occupier must vacate the land.

In the case of emergencies an order may be issued to the effect that people should vacate their land before compensation is paid. In such cases a written undertaking must be given by the body wanting the land, to the occupier guaranteeing payment along with details of the enumeration and assessment. Delayed payment will attract interest. The final compensation is to be agreed by the occupiers. Any occupier may refuse to agree to the assessment and may appeal to the Permanent Secretary of the MLGL who may appoint an arbitrator. But it must be recognised that the occupier also has the right to take their appeal to court if they so wish. This is to be avoided if possible and any complaint by occupiers after the payment of the approved compensation should be resolved locally and only in the final instance should appeals be forwarded to the MLGL.

K–A1.4 Procedures for Dealing with Common Law Leases including TGLP and Arable Farming Leases

Many complications can arise in dealing with these types of leases and all such cases should be referred to the DSL with copies of the relevant leases documents and a report on all improvements on the land.

Three situations may arise:

(a) The Land Board negotiates with the occupier to move to an alternative site and to grant a new "Lease" on similar terms. Where the occupier agrees to this, compensation will follow as for customary rights.

Compensation will be paid only for direct damage to improvements or nuisance, i.e. not for any land taken. The payment can be made under the heading "nuisance" without need to amend the lease.

(c) The Land Board may exercise its right to terminate the lease by giving six months notice in writing. Termination is permitted usually for public purposes and compensation is based on "adequate compensation", which is not defined. However, under standard Tribal Leases using TLB5 the Land Board may only terminate if there has been no development or where the land is being used for a different purpose than that granted.

Difficulties may arise due to :

(i) The lease being registered.
(ii) The lease being mortgaged i.e. a loan secured against registered lease.
(iii) The sub-letting of one or more parts of the leased property.
(iv) The disruption or closure of operational businesses and Industries.

In view of the above the DSL should be involved at an early stage.

COMPENSATION ENUMERATION AND ASSESSMENT REPORT

CLAIMANT

LOCATION/VILLAGE

LAND BOARD

GENERAL PLAN REF.

DATE OF INSPECTION

ENUMERATION		ASSESSMENT	
DESCRIPTION	AREA OR LENGTH	RATE	COMPENSATION
		TOTAL	

CLAIMANTS VIEWS

CLAIMANTS SIGNATURE _____ DATE _____

CHAIRMAN,
ASSESSMENT COMMITTEE _____ DATE _____

SECRETARY,
LAND BOARD _____ DATE _____

DRAFT SCHEDULE OF RATES OF COMPENSATION 1987/88

		Pula per hectare Maximum	Minimum
Improved land			
a)	Partially debushed but not destumped	30	20
b)	Fully debushed but not destumped	70	40
c)	Partially debushed and partially destumped	100	70
d)	Fully debushed and fully destumped	200	100

Consideration must be given to the density of vegetation that has been removed, the number of shade trees remaining and the degree of rock, stone and debris removal.

Land where no or inferior replacement land is allocated

All improvements are to be paid for according to the above rates. In addition a local assessment of the utility and asset value of each plot is to be made considering the following factors.

a) Soil quality, workability and crop yield potential
b) Firewood resources
c) Grazing resources

The fixing of per hectare rates for these will have to be carried out on a claim by claim basis.

Standing crops

a) The occupier should normally be allowed to harvest their crops and no additional compensation will be paid over and above the improved land compensation.

b) Where the occupier is required to vacate their land and leave the crops then additional compensation will be paid for the estimated value of the harvest. The Agricultural Officer will make an estimate of value based on the type of crop and the anticipated yield. This will form part of the Compensation Assessment.

Planted and utilized trees

All trees are to be valued on the following rates per tree (Pula):

	Fruit Trees	Shade Tree
Mature trees	75	25
Average trees	50	15
Young trees	25	5

Orchards and Plantations are to be separately assessed. The age of trees is to be recorded at the time of enumeration.

BUILDING AND STRUCTURES

The basis for the rates is replacement value. Market values are assumed to reflect land values.

			Pula per Square Metre
1	(a)	House of mud walls, corrugated iron roof, mud floor, no foundations or ceiling	15
	(b)	Round or straight sided hut with mud block walls, rough thatched, mud floor, no foundations or ceiling	10 – 25
	(c)	Round or straight sided hut with mud block walls, smooth thatched, no foundations or ceiling	30 – 40
	(d)	House of concrete block walls, concrete floor and tin roof	30 – 40
	(e)	House of concrete block walls, concrete foundation and floor, tin roof, with walls rendered with cement	50 – 60
	(f)	House of concrete block walls, concrete foundation and floor, tin roof, ceilings, rendered and painted	70 – 90

The above costs allow for salvage of materials by occupiers. Where a cost range is given the assessment committee will determine the appropriate rate having regard to the quality of construction and materials and the general condition of the building.

The assessment committee should also determine the appropriate rate for buildings having different combinations of the materials listed in 1 (a) – (f) or having similar materials e.g. bricks instead of blocks.

2 Buildings of permanent materials which are connected to main services of water, electricity, etc should be detailed on assessment reports and referred to the Department of Surveys and Lands for valuation.

3 A Pit Latrine of permanent materials : Pula 150 – 200

4 Threshing Floors P 2 per m^2

5 Mud Brick walls P 5 per m^2

Fencing

Salvage is permitted in all cases. Where not the rates should be increased.

			Pula per metre length
1.		Post and Wire Fence	
	a)	Metal Poles, chain link, by height	–
	b)	Treated gum poles, anchored with droppers	0.80
	c)	Mopane poles, anchor wired with droppers	0.40
	d)	Simple fencing, untreated poles, no droppers	0.20 – 0.40

In cases of substantial fencing (eg around large, developed ranches where contractors have been used and would again be needed for fencing of any alternative land, then details should be referred to the Department of Surveys and Lands).

		Pula per metre length
2.	Local Fencing	
	Thorn bushes	0.60
	Wooden paling fence	1.00
	Wooden posts with wood horizontal bars	–

Cattle kraals and crushes should be individually assessed breaking them down to their components and using the rates above. Consideration has to be given as to if the materials were available locally or had to be brought in a long distance.

Wells

There are two factors to consider when assessing wells :

a) The physical work required to build the well. This will include its depth, diameter and the resulting volume of material that had to be excavated. In addition the hardness of the material excavated plus the placement of an immovable improvement to it (eg a lining of same sort) will also have to be assessed.

b) The yield of the well due to its size and location. This can be expressed as both the volume of water that can be taken out at a constant rate without the well going dry and also the average number of months a year in which the well has water. Each well has to be individually assessed and should fall within the following limits: –

a)	Shallow, hand – dug, open wells (MOSINYAA/SEDIBA)	100 – 200
b)	Deep, open drinking wells in rock or lined (PETSE)	2000 – 3000

Boreholes

Each borehole is to be individually assessed according to its replacement costs of construction.

No standard cost can be given as drilling and transport costs are too variable throughout the country. All cases should be referred to the Department of Surveys and Lands with details of depth of borehole, diameter and yield together with any fixed equipment.

Additionally extra compensation will be payable if there is no underground water on the alternative land given to the displaced occupier, or if it is found at a greater depth than at the original site.

Displacement and relocation

In cases where recoverable items (such as building materials) have to be relocated onto a new plot, disruption compensation should be paid at a rate of an additional 10% of the whole compensation sum per affected household. It may also be necessary to take into consideration the distance involved in the relocation.

Disruption and disturbance

In cases where people are temporarily prevented from utilising their land then they are to be compensated in cash for the production that they could reasonably have expected from the land. This will be individually assessed and in the case of lost potential crops the same procedures for standing crops will be followed.

APPENDIX K-B

APPENDIX K-B

SOCIO ECONOMIC AND SETTLEMENT HISTORY

K-B1.1 General

There is a dearth of professional archaeological and historical studies for the Motloutse catchment. The region is known to be rich in archaeological sites and those that are known in the catchment are shown in Figure K2.4 and in detail for the reservoir area on Map K.1. This bears witness to a considerable period of human settlement and resource use dating back for over 100 000 years. Historical, as well as contemporary settlement patterns are closely linked to some key dynamic influences. Changing conditions of climate, water availability, food acquisition, social conflict, political organisation, trade routes, resource value systems, disease and ecology are amongst the most important factors.

K-B1.2 Pre-history

Most Early Stone Age relics have been found in eroded gullies close to the river, while Middle Stone Age remains have been discovered in areas of sheet erosion, sometimes at some distance from the river. Late Stone Age sites have mostly been identified to the east of Bobonong but are also to be expected elsewhere in the catchment.

Long and short-term cycles of climatic change produce major impacts. Between 16 000-7 500 years ago temperatures in southern Africa are believed to have risen considerably, with rainfall falling to about half its current levels. At least one other major peak and trough has occurred since. Shorter term fluctuations over decades or centuries can be equally as dramatic. One such cycle is thought to have occurred between the 7th and 8th centuries. When linked to the other key factors mentioned above the response of human settlement and organisation can be dramatic.

K-B1.3 Recent History

The Stone Age peoples of Botswana are thought to be the forebears of the present day San Bush People. They probably would have been the sole inhabitants until the arrival of the Bantu speaking peoples which has been dated to between 200-400 AD, based on finds in Chobe, Francistown, the Transvaal and on the Lotsane and Shashe rivers. This influx of new peoples brought with it major influences on settlement and resource use. They introduced cultivated agriculture, iron smelting, pottery making and radical new forms of social and political organisation. The Khoi, who are believed to be closely related to the San, were amongst the first who are thought to have been influenced. They had long been pastoralists, but subsisted through hunting and gathering rather than by agriculture.

Iron Age settlements are usually to be found on higher ground and are particularly associated with the tops and slopes of ridges. The period from 850-1300 AD saw the development of many sites close to, or on top of, hilltops and appears to have been a time when agro-pastoralism was common. At the end of this period the population apparently declined, possibly due to the intensive use of resources and extended drought. Concurrent with this in the early 12th Century, gold mining started just to the north across the Shashe river. The exploitation and trade in this newly valued resource would have influenced peoples in the Motloutse catchment and some evidence suggests that mining sites were investigated in the catchment. It is possible that political organisation at this time was based around small local chiefdoms.

In the following four centuries the area came under the influence and peripheral control of the Great Zimbabwe Empire and later that of Khami, near Bulawayo in Zimbabwe. Important Zimbabwe and Khami sites have been located in the catchment and in the proposed reservoir area at Letsibogo. These sites are found associated with kopjes but also off the rugged country and on ridges. The local settlers may have been incorporated into these Empires through overlords, clientship or peripheral strategic dependency. By the 15th Century settled and stable communities seemed to have existed across these regions integrated through a network of trade and regional specialisation involving mining organisation and labouring for gold, copper and iron, metal working and salt production. Stone walling in villages became more common and highly skilled craftsmen developed. The era of mining went into decline around 1600 AD and iron working ceased in the 19th Century as competition from European imports began to take hold.

As pressure of people on resources began to increase in southern Africa, movement of different groups again started to become widespread in response to the changing natural, social, ecological and political forces. This brought new settlers into central and eastern Botswana and witnessed the movement north of the Bangwato to Shoshong in the 1770s, the Khurutshe moved to Shashe, while about 1700 AD the Babirwa are believed to have first come to their present day region around Bobonong.

Little is known of the settlement pattern and resource use in the catchment in these times. Riverine tsetse fly infestation along the main rivers may have been important in limiting settlement. Continuity of resource users would seem likely to have existed amongst the Basarwa communities who today live in both village and isolated settlements throughout the catchment. Their oral traditions record this and suggest much greater numbers than those present today. Their independence of lifestyle and social status in the wider society indicate that absorption by the Bantu population was not a significant factor, but also indicate that close social and economic contact has been maintained over the last 1 500 years.

Any attempts at stable settlement were significantly disrupted by the territorial expansion and wars which started with the Difaqane in the 1820s and the Boer and western commercial expansion northwards. The whole of southern Africa witnessed the chaos of refugee movements to escape the troubles. The Motloutse and Shashe catchments stood at the interface of the conflicts between the Ndebele from the north and east, the Ngwato from the south and the Boer and British pressure from the east and south. The attempts to control these disputed frontiers were exercised first with military tactics and later by colonisation and negotiated political and commercial advances. The final shape of today's social landscape was not resolved until the early part of this Century.

The independent Ngwato state was re-established in 1849. This unleashed a period of intensive exploitation of wildlife based on tribute and trading motives. Local Basarwa hunters were extensively recruited and by the 1870s much of the major game population had been exterminated or driven out. As some of these animals are hosts for tsetse fly this decline in population may have created some of the conditions which led to the disappearance of the tsetse. Concurrently with this the Ngwato Chief, Sekgoma, moved his cattle posts during the 1860s up to the Motloutse river, allying with Kalanga speakers who then were living north of the Ramokgwebane river, which is a tributary to the Shashe.

In 1868-1870 the Tati gold rush just across the Shashe river and the development of the Kimberley mines opened up new markets for meat. Sekgoma's successor, Kharma III, exploited these opportunities to bring in state revenues and in an effort to consolidate the northern borders against the Ndebele, sent out refugee settlers to the Mmadinare and Bobonong areas. These outlying cattle posts were regularly supervised and the new villages became a base for local political control and the redevelopment of grain cultivation. Relatives of the Khama family were installed as local overlords and a royal blood line established which

exists to the present day. In the study area two main villages were then occupied. Batalaote families were settled at the base of the Makome Hills at a village called Kelele. This is intersected today by the water pipeline route from Shashe as it cuts through the Makome Hills. Ngwato families were settled at Manga which lies adjacent and just upstream of the proposed right bank abutment of the dam wall. This area will mostly lie within the conservation area proposed. These two villages were amalgamated in about 1910 and moved to form the present day village of Mmadinare.

As trade in ivory, furs and feathers declined, new routes were established to service the transit and communications lines for white settlers moving up to Rhodesia. Use of ox wagons and their associated need for skilled drivers and craftsmen became common. Negotiations with the British arbitrators between 1886 – 1895 tried to resolve the competing claims for mining concessions in the Shashe and Motloutse catchments. The Ndebele used commercial fronts to give rights up to the Motloutse while the Ngwato claimed up to the Shashe.

The 1890s again saw significant changes in the settlement and territorial arrangements. Refugees were flooding in from the Transvaal in the face of Boer expansion. In 1895 Khama was induced by the British to give up a 10 – 12 km wide strip for railway development along the Limpopo. In 1896 a new strip was negotiated along the present railway route, but rights to the old strip were not re – instated and the BSA Company soon began selling off land to white settlers from South Africa and expelling the local Babirwa. This process continued up to the 1920s.

In 1896 the first known African epidemic of rinderpest swept down through east and central Africa into the south. It decimated cattle and wildlife populations in its path and laid waste to vast tracts of land and societies once under the control of pastoral and agro – pastoral peoples. This was also the culminating factor to the demise of the tsetse in the Limpopo and other riverain areas. This was followed by a famine between 1896 – 1898. The impact of the rinderpest and famine on the cattle post systems was dramatic. The economic depression which followed also saw the outflow of labour into the mines and the introduction of missionary schools for children. In the face of these influences the traditional strategies of pastoralism and agro – pastoralism, already disrupted by the chaos of the preceding decades, went though a considerable pattern of change.

In 1897 the railway track reached Mahalape and later in that year, Bulawayo. The wood burning locomotives soon created a strip of denuded woodland alongside the railway line and around the station watering posts. Ngwato age regiments were also employed to cut wood for export. The tenure arrangements in the railway strip allowed squatters within it to escape the jurisdiction of the Ngwato laws. This provided opportunities for illegal beer sales, prostitution, missionaries and commercial units.

In 1898 over 2 000 recent refugees were moved from Serowe and Palapye to join the earlier settlements on the Motloutse. This strategy was both to prevent their permanent settlement in Serowe and to promote the occupation of the outlying areas. These were mainly Babirwa moving to Bobonong, but included other groups sent into Mmadinare. In 1899 the final boundaries between the nation states of today were fixed. Serowe's control of the main villages in the Motloutse continued under direct Ngwato governors, while in the outlying settlements subject chiefs took responsibility for the scattered Batalaote and other minor settler groups.

K – B1.4 Contemporary Patterns

The context of modern settlement patterns thus really only began at the turn of the century with the refugee resettlement from Serowe and other points of refuge. Four major historical settlement areas can be noted. The Tuli Block, where the local Babirwa were displaced and where white farmers were allowed to settle with freehold titles. These evacuees left to join other Babirwa settlers in the area known as Bobirwa. This includes Bobonong and five villages associated with it; Kobojango, Semolale, Molalatau, Mathathane and Tsetsejwa. The villages of Mmadinare, Tobane and Sefophe form a zone representing mixed settler groups. In Sefophe the people are predominantly of Batalaote origin. In Tobane the two main groups are Batalaote and Batlokwa. In Mmadinare the main groups are Batalaote and Bangwato. Finally, there are the settlements strung out along the final route chosen for the building of the railway. This is mainly associated with the people of Buhuratse origin.

Consolidation of village sites and resource use could now begin in earnest. With the arrival of trading stores, missionaries and new social services the population grew. The area continued to receive settlers from amongst refugee groups scattered elsewhere in Botswana. As late as the 1970s refugees caught up in the conflicts in Zimbabwe were settling in the catchment; particularly groups of Basarwa from the Shashe borderlands. They have been provided with resettlement sites at Tshokwe (to the north of Tobane), Tobane and Sefophe. Others settled spontaneously to the west of Mmadinare and also at other scattered points throughout the catchment. The Basarwa groups have increasingly come under pressure to adopt a settled village lifestyle so that social services can be better organised. In many cases this transition has been completed and one new village at Damochongina is about to be established along the main road from Serule to Selebi Phikwe.

By far the most important influence on settlement and the economy of the area was the development of the BCL mine and the planned town at Selebi Phikwe in the early 1970s. Associated with this came the spontaneous growth of the labour township of Botshabelo and the major migration of labour from all over the region in search of work.

The influence of climate, ecology and resource use pressures are still having an impact on settlement. The considerable mortality amongst cattle in late 1987 has led to many cattle posts being abandoned as was clearly apparent in the reservoir area surveys. Similarly, the previous years of continued growth in livestock numbers increased the pressure on rangeland which was already over-grazed in certain areas prior to the drought of the 1980s. The relocation of many cattle posts in response to this was also traced in the reservoir surveys. The distribution of the 1981 population is shown in Figure K2.5. This indicates a fairly even distribution of the rural population with the possible exception of the barren basalt country downstream of Bobonong and the remoter upstream parts of the catchment west of the main north-south road. The spread of population reflects the availability and use of resources.

It is important for planners to recognise that the overall settlement pattern involves a transhumant system. Virtually all families have more than one residence site where well-constructed dwellings are erected. Some may have up to four sites that remain in seasonal or permanent use. Every family maintains a compound (lolwapa) in their village of affiliation. These are used as a base from which to access modern social services, particularly for the term-time schooling of children. Family members will travel in from the lands and cattle posts to use these compounds during weekends and during the periods of slack operations in the countryside. These sites are also important valuable urban assets. As population growth, commercialism and urban development increase, pressure on land induces increased economic value to be attached to urban sites.

These pressures, together with the shortage of good grazing resources and the growing importance of irrigation potential, are also leading to the commercialisation and rising

economic asset value of rural land. An enclosure process is already evident by investments in wire fences. Individuals are gaining access to riverside plots for irrigation development to exploit the growing urban markets and evolving consumer tastes. Rainfed lands are also being enclosed with wire fencing to allow individuals private control over grazing and allow them to be free of the management constraints of the communal grazing areas. This is primarily to preserve grazing capacity for the ploughing and dairy animals and to a more limited extent for the fattening of beef stock.

The majority of families also farm land and the lands settlements are in constant use during the main agricultural season. Depending on the family circumstances and their access to local water supplies, these may also be the primary site of family residence in preference to the site maintained in the village. The increasing shortage of available farming land close to the villages and the reduced rural labour force has motivated some to establish cultivation at the cattle posts. Thus, in country which is recognised as a cattle post and grazing area, it is not uncommon to find the transformation of cattle posts into a mixed farming unit which incorporates both Lands and cattle post. Again permanent housing is usually erected and may provide the primary settlement site, particularly for the older retiring generation. Some redefinition of cattle post and lands area has already occurred through the Sub-Land Boards although the boundaries are not always clear.

A smaller proportion of families own sufficient stock to warrant one or more cattle posts. Cattle post structures are commonly, but not always, well-built dwellings that are used throughout the year, either by family members or by hired herders. Some of the wealthier families owning very large herds have extensive cattleposts at great distance from their village of affiliation.

The arrival of the BCL mine created one further economic option to be exploited by rural families. The rapid growth of the labour township of Botshabelo reflects the motives of rural families with migrant labour to position additional dwellings close to the mine in order to maximise their employment potential. Many of these township dwelling units are believed to operate as transit shelters for the period that people remain employed or seek work in Selebi-Phikwe. Having spent some time on a regular wage many migrants leave the township to reinvest these earnings in alternative enterprises. This is primarily livestock but can also include cultivation and in many cases has included expenditure for transport in the form of donkey carts.

The transhumant settlement system that is employed, even with its demands for mobility and time spent travelling, clearly works to the best advantage of local families in the organisation of their resources and in the achievement of their social and economic objectives. This fact has important implications when considering planning and design requirements of any formal irrigation scheme. To install another economic resource will add a further layer of opportunities and constraints onto those which already exist. It cannot be assumed that there will be unrestricted time and capacity for the society to rapidly absorb these apparent improvements. Irrigation development should be seen as being incorporated into an existing decision-making framework already full of responsibilities, demands on resources and constraints.

APPENDIX K-C

APPENDIX K-C

POPULATION PROJECTIONS

K-C1.1 Catchment Projections

The following data provides basic population figures drawn from the 1981 Population and Housing Census. Table K2.2 in Chapter K2 gives the population projections from 1981 to 2011 for the whole Motloutse catchment. The data is segregated into the urban area of Selebi-Phikwe, the major villages of over 500 people, other minor villages and the localities associated with all these villages. The administrative layout and the location of the enumeration area boundaries are shown in Figures K2.1 and K-C1. respectively.

The population growth rates used are those given by the CSO in their Population Projections for the period 1981-2011. Where a particular village was not separately dealt with by the CSO the figure given for Central Bobonong or the Central District as a whole has been adopted.

While a distinction between urban areas, major villages, minor villages and localities is widely used, some reservations with this approach must be stated. The timing of the Census (August 1981), although arranged to minimise problems of location, found many families still residing at the Lands or on their cattle posts due to unusually late rains and hence late harvesting times. The net result is that the winter time main settlement populations have been under enumerated and the impression given is that there are a lot of families who have homesteads and no main houses in the large settlements. It is believed that the Census village population figures do not accurately record the number of people regularly using village services. This error is important for estimating peak winter demands for service provisions in the main villages, particularly water supply.

Table K-C1.1 provides analytical data to assess how this situation may affect the different village population. It first shows the number of people who associate themselves with the village but were away abroad at the time of the census. It also shows the number of residences visited recorded as being empty, in both settlements and the localities associated with each settlement. These could reflect either abandoned dwellings or a second house of a family who were enumerated in their alternative location.

In Bobonong for instance, there were only 4 711 people enumerated as being resident in the village in 1981. The number of empty dwellings covered some 45 percent of the total number in the settlement. Conversly the census recorded over 8 100 people resident on the Lands where a further 37 percent of the dwellings were empty. If the village and locality people are taken together the maximum number of people associated in one way or another with Bobonong could total over 12 800. Clearly not all the people in the localities are living for even part of the time in the village. It might be reasonable to assume that perhaps 50-60% do. This would imply a village population for Bobonong closer to 10,000 people as being appropriate as a planning statistic for project design purposes. A similar situation exists in the other villages and Table K-C1.2 provides what is considered to be a more realistic estimate of village population. This Table has been used to estimate the future water demands in the main villages, Mmadinare, Tobane, Sefophe and Bobonong (see Annex E).

Table K – C1.1

Motloutse Catchment Population and Housing Profile

Area	Enumerated population	Number H.H. (1)	Absent abroad	% Dwellings empty	Population in locality	% Dwellings empty in locality	Maximum village size (2)
Selebi – Phikwe	29 469	5 878	271	10	n/a	n/a	n/a
Mmmadinare	5 234	908	77	32	5 941	35	11 175
Bobonong	4 711	967	110	45	8 150	37	12 861
Sefophe	1 980	354	54	35	2 402	40	4 382
Tsetsejwe	1 570	242	58	33	1 285	36	2 855
Serule	1 465	253	40	29	1 813	40	3 278
Mathathane	1 098	181	72	34	929	30	2 027
Semolale	1 018	165	45	27	383	61	1 401
Kobojango	855	142	25	27	492	53	1 347
Molalatau	722	140	33	39	1 729	34	2 451
Tobane	696	118	9	38	2 246	28	2 942
Mabolwe	519	86	28	10	74	44	593
Other Villages	957	168	16	28	177	52	1 134
Localities	25 621	4 495	429	n/a	see below	see above	see above
TOTAL	75 915	14 097	1 267				25 621
De jure population	77 182						
% Population urban	39						

(1) These figures assume that families registered on the lands are independent from any relatives who make have been in the village residences at the time of the census.
(2) If it were assumed that all people from the localities have a second house in the village and might use its services

Source: C.S.O. Population and Housing Census 1981

Table K – C1.2

Population Estimates for Demands on Village Services

	1981 census data			2011 projections			
	De facto population	Population in localities	Max size of village (1)	Village population	Population in localities	Max size of village	Nos using services
Selebi – Phikwe	29 469	n/a	n/a	136 813	n/a	136 813	136 813
Mmmadinare	5 234	5 941	11 175	14 882	9 369	24 251	20 503
Bobonong	4 711	8 150	12 861	16 851	12 853	29 704	24 563
Sefophe	1 980	2 402	4 382	10 076	3 788	13 864	12 349
Tsetsejwe	1 570	1 285	2 855	2 477	2 026	4 503	3 693
Serule	1 465	1 813	3 278	2 311	2 859	5 170	4 026
Mathathane	1 098	929	2 027	1 733	1 465	3 198	2 612
Semolale	1 018	383	1 401	1 606	604	2 210	1 968
Kobojango	855	492	1 347	1 349	776	2 125	1 815
Molalatau	722	1 729	2 451	1 139	2 727	3 866	2 775
Tobane	696	2 246	2 942	1 099	3 542	4 641	3 224
Mabolwe	519	74	593	819	117	936	889
Other Villages	957	177	1 134	1 511	279	1 790	1 678
Localities	25 621	see below	see above	see next	see below		
TOTAL	75 915	25 621	192 666	40 405	233 071	216 909	

(1) If it were assumed that all people from the localities have a second house in the village and might use its service

K – C1.2 Impact Assessment Projections

To assess the upstream and downstream populations who may be affected by the building of a dam on the Motloutse required some adjustments to the catchment wide population

Census Enumeration Area Boundaries 1981

Figure K-C.1

figures. The field surveys indicated that many of the people living or utilising resources within the sub-catchment of the Thune river would not necessarily be directly affected by any dam development on the Motloutse. Similarly, there are some people from Tonata living or utilising resources in the upper catchment and others on the catchment watershed with the Shashe river who would not be directly affected. Some of these areas have an independent water supply, even during periods of drought. Only those enumeration areas lying adjacent to the Motloutse river have been included in this analysis. These figures are thought likely to best represent those who might be affected by the dam development.

Table K-C.3 separates the upstream and downstream populations and also provides an estimate of the numbers of people who may be directly associated with resource use in the reservoir area. Table K4.3 in Chapter K4 provides figures on the numbers of families who would be directly affected by the expropriation of land for the reservoir.

Table K-C1.3

Letsibogo damsite population impact statistics 1981-2011

Year	Location	Upstream	Downstream	Adjacent
1981	Villages	1562	11797	5234
	Localities	4220	9285	1239
	Total	5782	21082	6473
1986	Villages	1683	14461	6373
	Localities	4546	10003	1335
	Total	6229	24464	7708
1991	Villages	1810	17511	7683
	Localities	4888	10755	1435
	Total	6698	28266	9118
2001	Villages	2062	25012	10877
	Localities	5567	12250	1634
	Total	7629	37262	12511
2011	Villages	2294	34450	14882
	Localities	6192	13626	1818
	Total	8486	48076	16700

Note: The numbers living adjacent to the reservoir include the Mmadinare residents who also appear in the downstream population figures

Source: Consultants estimates based on 1981 Census Data and CSO projections.

Table K-C1.4 provides a socio-economic profile of activites in the various villages of the catchment as recorded in the 1981 census.

Table K – C1.4

Motloutse Catchment Socio – Economic Profile

Area	H.H. size (de facto)	Dwellings per capita	Dwellings per H.H. (1)	% H.H. managing only Cattle	% H.H. managing only shoats	% H.H. managing only equines	% H.H. with mixture of livestock	% who have cultivated last 5 years
Selebi – Phikwe	4.9	0.21	1.0	14	3	2	32	48
Mmmadinare	5.7	0.25	1.4	19	5	1	56	86
Bobonong	4.8	0.30	1.4	8	3	3	77	91
Sefophe	5.4	0.27	1.5	25	3	1	48	84
Tsetsejwe	6.3	0.23	1.4	7	5	8	61	89
Serule	5.6	0.23	1.3	21	9	1	36	59
Mathathane	5.7	0.24	1.4	4	1	13	54	77
Semolale	5.9	0.29	1.7	12	1	5	72	94
Kobojango	5.9	0.27	1.6	6	2	1	87	98
Molalatau	4.9	0.26	1.3	6	2	3	86	94
Tobane	5.8	0.23	1.3	12	3	1	74	75
Mabolwe	5.7	0.22	1.3	13	0	7	70	93
Other Villages	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Localities	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Summary	5.7	1.50	1.4	12	4	3	67	87

n/a = data not available

(1) Figures are estimated using the total population and total dwellings in the village and its localities. The per capita figure was then multiplied by the average household size in the enumerated village population. As this figure ignores the other members of the family resident in the localities at the time of the census real household size is likely to be under – estimated. Therefore dwellings per household are also likely to be low.

Source: C.S.O. Population and Housing Census 1981

APPENDIX K – D

APPENDIX K-D

ARCHAEOLOGY SURVEY

K-D1.1 Introduction and Methodology

The only archaeological surveys conducted previously in this area of eastern Botswana were by Ellenberger and Weyland. Ellenberger recorded a number of rock paintings and stone walled settlements. None of these fall within the proposed reservoir area. Weyland, who made collections of stone artifacts all over Botswana, noted the presence of Middle and Late Stone Age materials along the Motloutse river. Thus, although the presence of archaeological sites in the catchment has been known since the 1930s, no systematic surveys have been carried out and little is actually known of the history of the area.

A preliminary field review of archaeological sites in and around the proposed Letsibogo reservoir area was carried out in a nine day period during December 1988 by Mr Alec Campbell of the National Museum, Gaborone. The purpose of this survey was to identify the general nature and importance of archaeological remains in the area and to make recommendations with respect to their future should the Letsibogo dam be built. It was not possible to visit the potential irrigation areas between Mmadinare and Bobonong and this work has been held pending a decision as to the likelihood of formal irrigation being developed.

The 1:10 000 aerial photography was not available for use during the study which had to be conducted using the 1:50 000 DSL map sheets. A level equivalent of 853.5 m was indicated as the maximum likely FSL at that stage in the study. This is 3.5 m higher than the FSL later selected for detailed planning in February 1989. However this was fortunate as there are inconsistent discrepancies between the contour mapping of the 1:50 000 series and the 1:10 000 ortho-photographs which became available in mid-February 1989 with the result that the preliminary survey managed to encompass all the land falling within the proposed reserve area. It must be appreciated that a nine day rapid survey cannot be regarded as exhaustive in identifying all sites of importance but was sufficient to give an initial overview in order that a detailed programme could be drawn up.

The survey was impeded by a spell of rains which made travelling, crossing the river and the collection of samples for carbon-14 dating difficult. Most of the survey was carried out on foot. The ability to undertake an effective rapid survey was complicated by the variety of terrains and the number of archaeological sites found which exceeded original expectations. As a result, those sites which were investigated could not be given the attention they deserved and it is likely that many sites have been missed altogether. Thick vegetation and canopy cover and similarity of environments made it difficult to locate the exact positions of sites, except where major landmarks were clearly visible. Many of the sites were extremely small and easily missed. As Stone Age remains cover the whole area, sometimes being scattered over square kilometres, the identification of specific human activity areas (settlements and tool-making sites) would have been impossible without considerably more time and care.

Wherever settlement sites were noted these were marked up on the 1:50 000 map. Collections of worked stone, pottery shards, bone, hutclay and beads when these were were made when visible at sites which appeared representative of the general area. Some of this material has been illustrated and is reproduced as Figures K-D.2 to K-D.6. Where collections were made a brief site description was prepared and these sites have been given a number. The sites are marked on the detailed reservoir map (Map K.1) and the site descriptions and illustrations given at the end of this Appendix.

One village site (No. 16) was sketch mapped (Figure K – D.1). This site, although above the FSL, will fall within the reserve area and appears to be important. Charcoal was collected from three sites (Nos. 10, 15 and 19) representative of many of the Iron Age settlements.

K – D1.2 Initial Survey

The initial survey commenced with an examination of the variety of habitats proceeding from the riverbed to large kopjes along the general alignment of the dam wall. Local residents were questioned about their knowledge of previous occupation and archaeological remains. As a result of this survey the area was divided into three parts:

- the area around the Moremogolo Hills and the Sedibe – Motloutse confluence
- the Motloutse river and the higher country westward to Setimela Hill
- the area around the Sedibe and Sedibanyane rivers

The results of the initial survey indicated that stone artifacts occur in abundance scattered over wide areas of the country. These scatters were dense along the north bank of the Motloutse particularly where there is sheet or gulley erosion. Much of the area lying close to the south bank is covered with sediment, but as the ground begins to rise similar scatters of stone artifacts appear. These are generally made of flaked quartz and to a lesser extent sandstone retouched to form points, scrapers and choppers. These appear to date from the Middle Stone Age. Other artifacts were made from chert and agate. These often occurred in sites which also contained pottery and granary stands which may or may not be associated with them.

Actual settlements are characterised by remains of granary stands, burnt clay flooring and collapsed walling, and by low stone walling and terracing. Pottery was found at the majority of these sites. For ease of description the sites are referred to as Iron Age sites. These occur in fairly specialised locations as follows:

- on hilltops (rarely)
- at the base of hills, often small in size and tucked into folds in the hill, or between two adjoining hills on slightly raised ground
- on the brow or along the spine of ridges. Those on the brow (nearest the river) are usually fairly large, while those on the spine (away from the river) are smaller, sometimes consisting of only one granary stand

As a result of the initial survey it was decided to concentrate the survey on the Iron Age remains which were easiest to identify at the above mentioned habitats.

K – D1.3 Main Survey Conclusions

As a result of the vehicle and foot traverse over 100 sites identified and marked up on the map. The evidence indicates that the area has been occupied by people for a considerable period. One fairly early Middle Stone Age discoid was found which suggested a date of around 100 000 years ago. Most stone artifacts appear to belong to the later Middle Stone Age (50 000 – 20 000 years before the present). The chert and agate microliths belong to the Late Stone Age and probably date to within the last 10 000 years. The nearest rock

Figure K-D.1

Sketch Map of Site 16

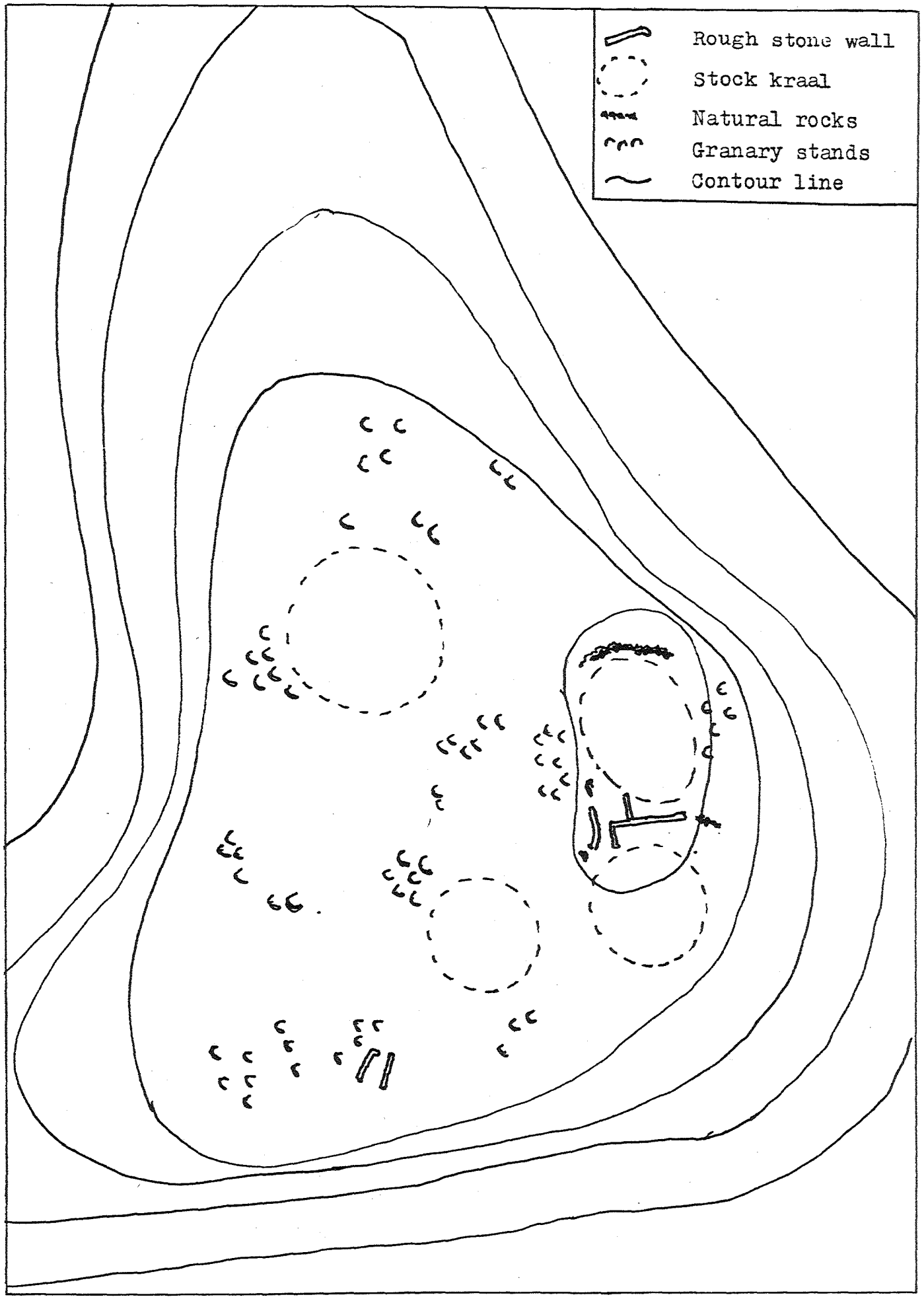


Figure K-D.2

Stone Artifacts from Various Sites

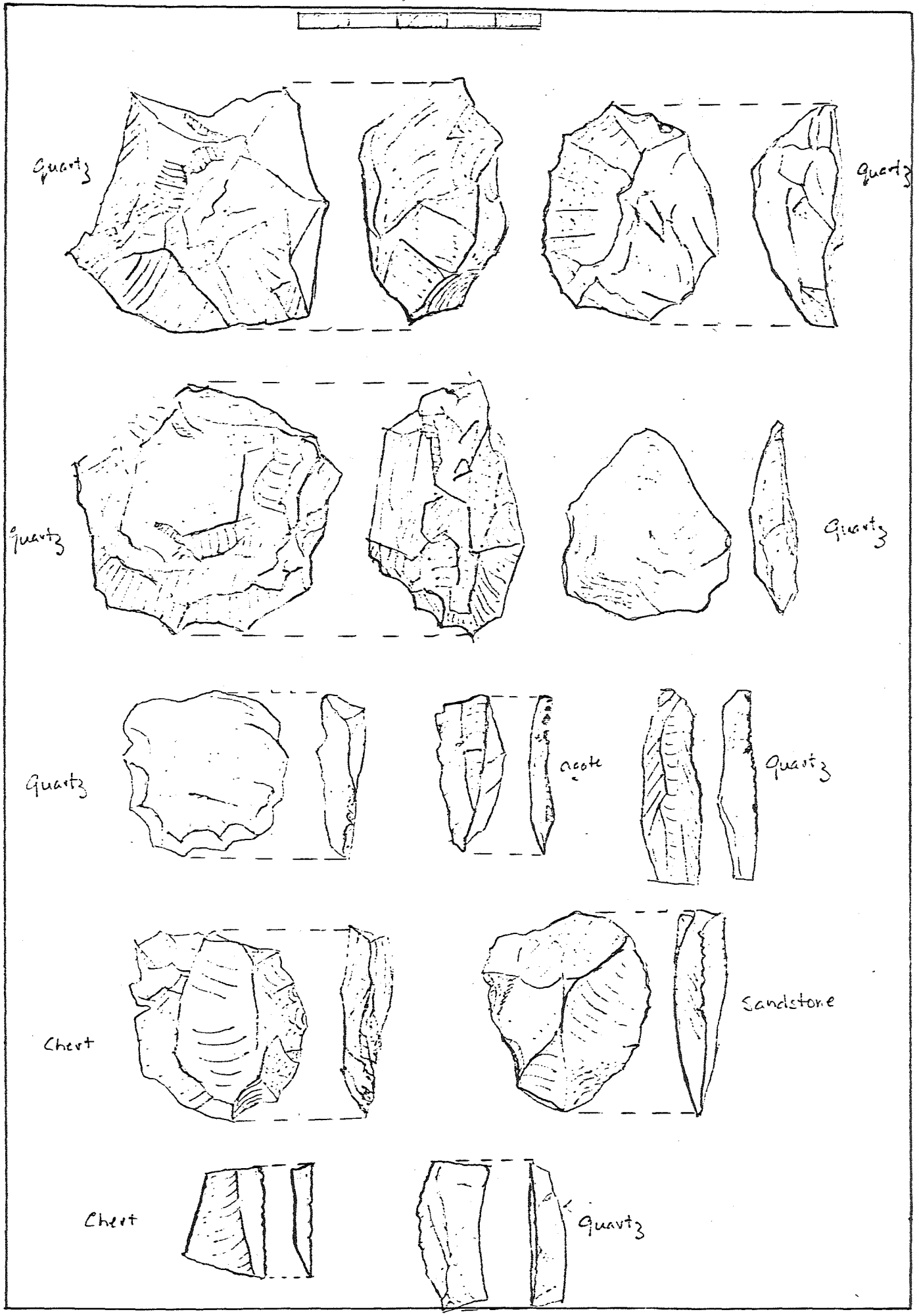
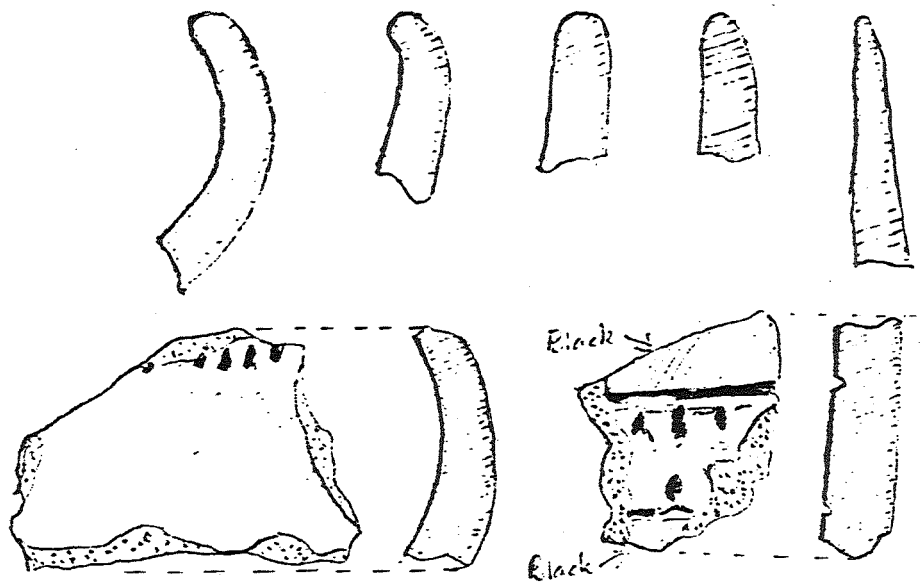
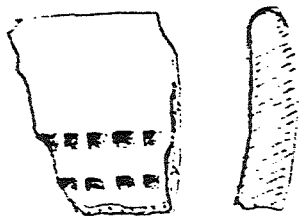


Figure K-D.3

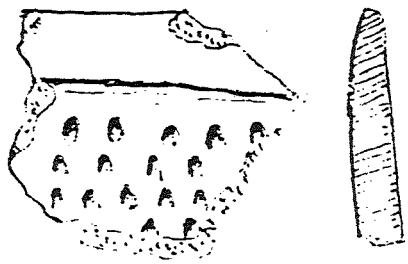
Artifacts from Sites 2, 3, 9 and 12



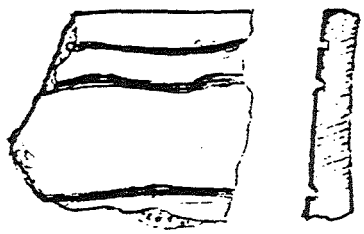
Site 2
Letibogo



Site 3



Site 12



Site 9

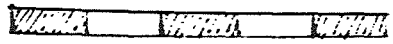


Figure K-D.4

Pottery from Site 10

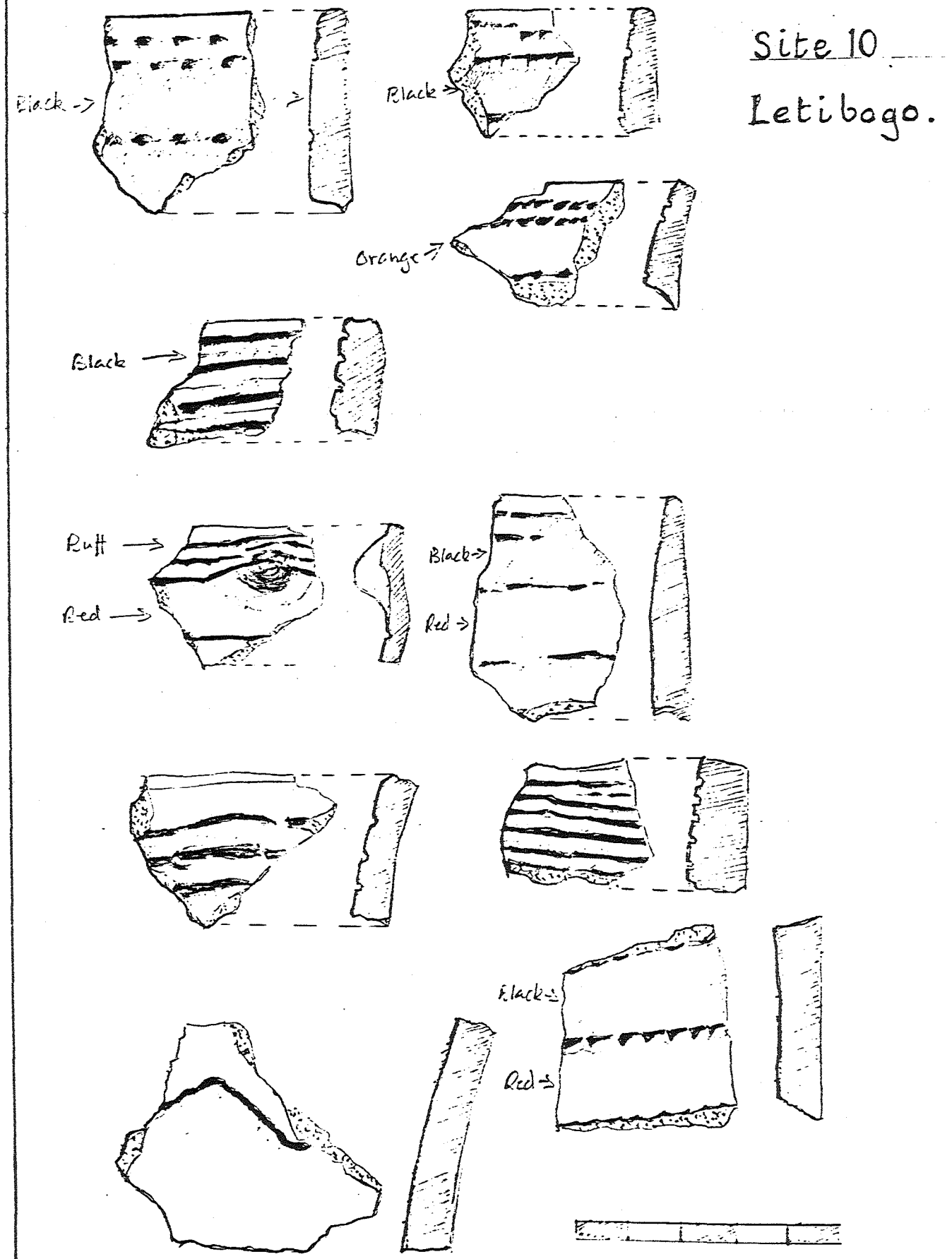


Figure K-D.5

Pottery from Site 15

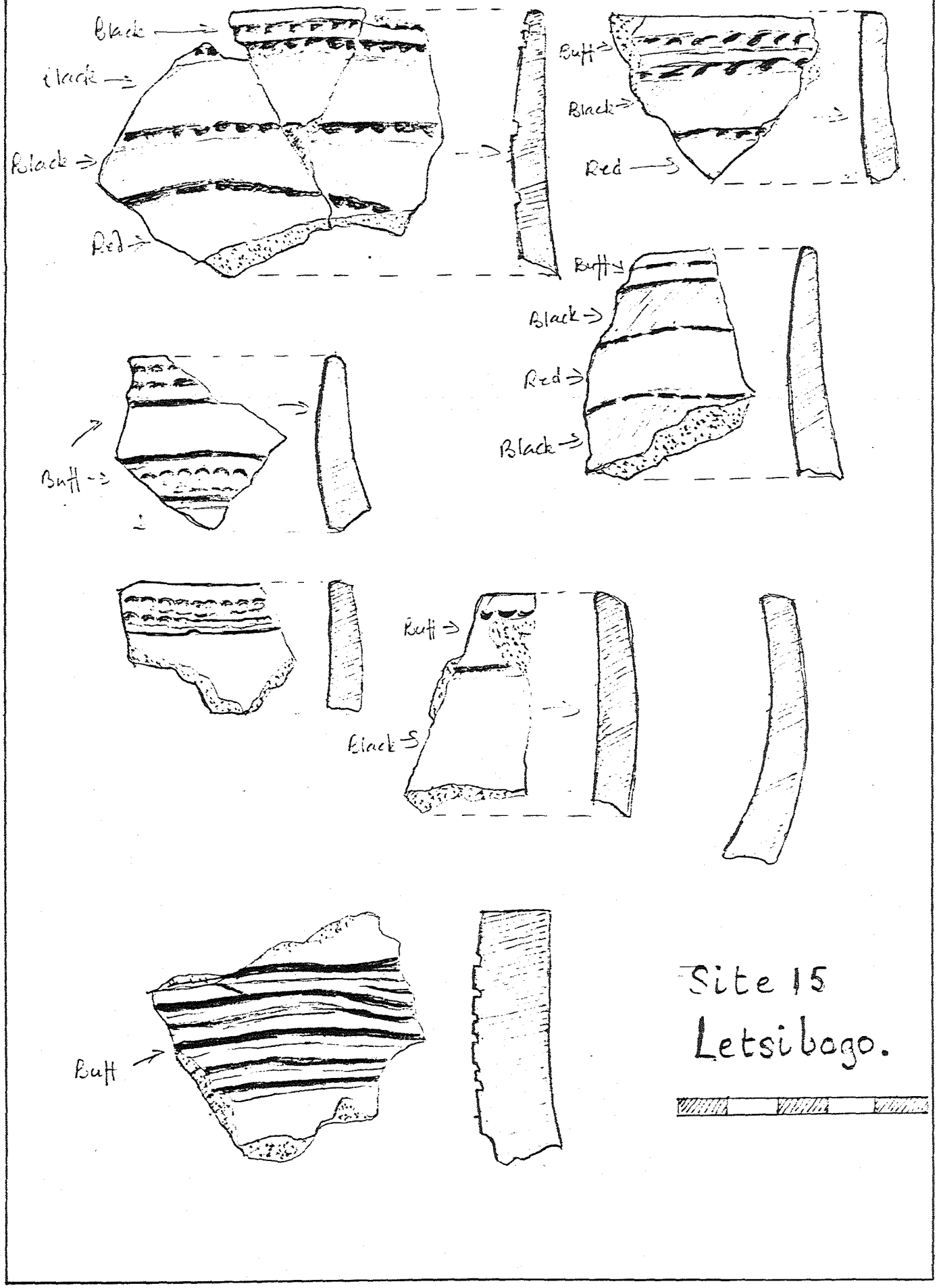
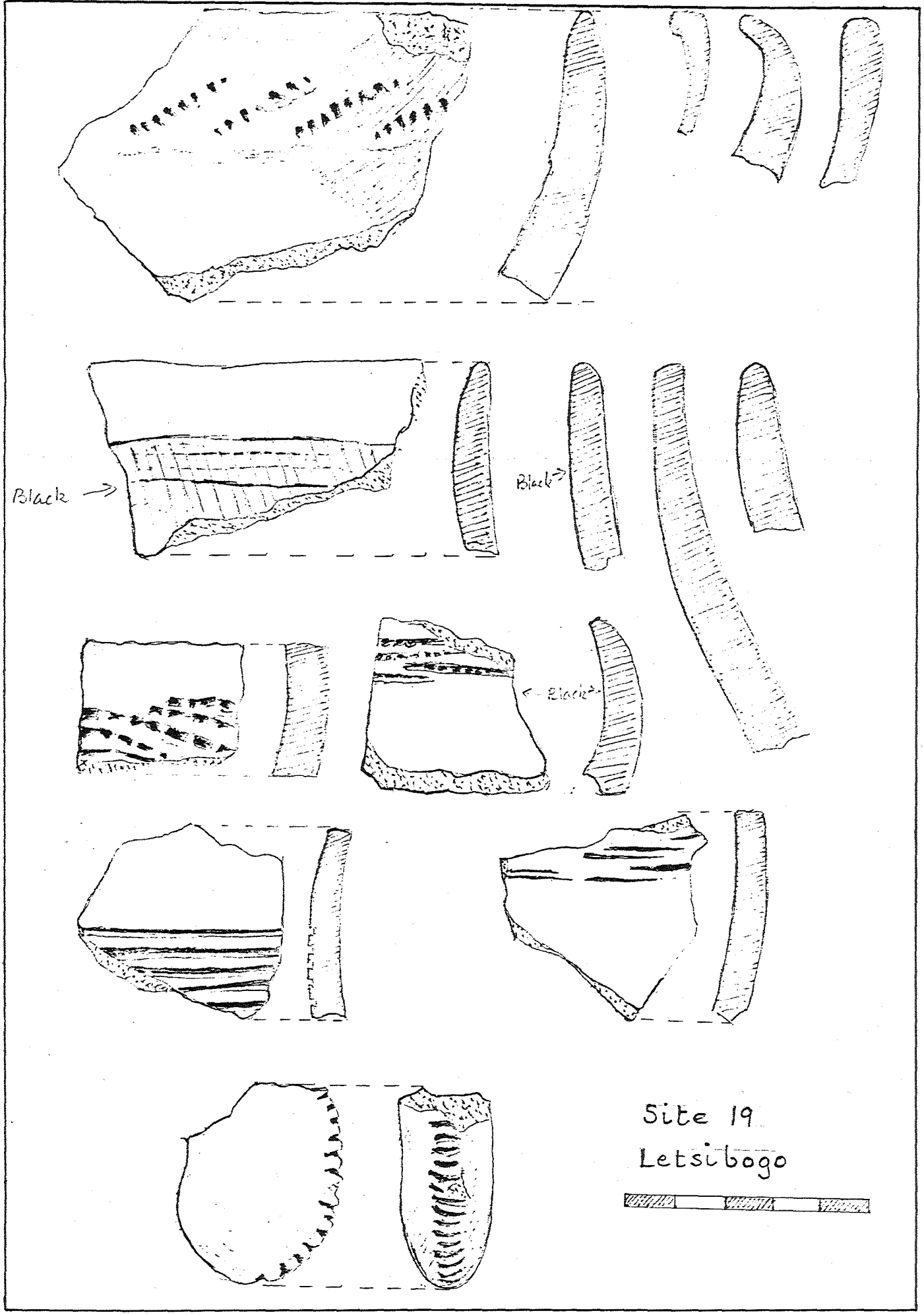


Figure K-D.6

Pottery from Site 19



paintings mentioned by local residents were in the Makone Hills between Mmadinare and Selebi Phikwe. These were not seen.

The small quantities of decorated pottery recovered made diagnosis of age difficult. Carbon-14 dating suggests that some sites were occupied between AD 500 and 1000. Somewhat similar sites, but with different ceramics, have been found to the south at Maunatlala (AD 390) and to the north near Polometse (± AD 900).

The earliest Iron Age materials found came from site 19 which has been radio-metrically dated at about AD 530. Site 10, which is similar, but occurs in a ploughed field, yielded similar pottery although one shard is of obvious Leopard's Kopje origin suggesting either a generally later date, or that it has more than one component.

A similar survey for the proposed Shashe reservoir in the neighbouring catchment found a large number of village sites now marked by granary stands and stock kraal remains. Two of these sites have been dated approximately to AD 1350 and AD 1750 suggesting that they fall within the Zimbabwe (AD 1250-1450) and Kharmi (AD 1450-1800) Empires. Many of the sites found at Letsibogo show marked similarities to the Shashe sites suggesting a similar time frame. Local people spoke of one hilltop walled site in the Matswake Hills which may belong to the elite of the Zimbabwe, but more likely the Kharmi Empire.

It would therefore appear that there are very likely Iron Age villages in the proposed reservoir area which span an enormous time depth, from AD 500 possibly to as late as AD 1 750. The earlier sites probably belonged to local chiefdoms which evolved into larger units and became incorporated into the Zimbabwe and later Kharmi Empires. Although no sites similar to those found at Maunatlala (AD 390) and Polometse (± AD 900) were found, it is probable that they exist.

Later Stone Age artifacts suggest contact between the Stone Age and Iron Age peoples. Local people stated that the Basarwa (San or Bushpeople) still live in the area in small numbers. All those questioned agreed that most of their descendants now lived along the Shashe river. The Shashe dam study found that up to half the people living in Polometse and Dikgathong at the Shashe river were of San origin. This suggests that the San have not been significantly absorbed into the Bantu-speaking population and that contact between the two distinct peoples has continued throughout the period AD 1100-1800.

K-D1.4 Significance of the Survey Findings

The level of survey possible to date was far too brief to provide sufficient information on what transpired to be an extremely important archaeological area. The survey has been adequate to identify the future action now required and recommendations are given in the final section of this appendix.

The area is important for a number of reasons:

(a) Modern people are believed to have evolved during the last 200 000 years, possibly in Southern Africa, but certainly in Eastern/Southern Africa. The finding of considerable quantities of Middle Stone Age materials in the reservoir area suggests a fairly large human population, particularly during the last 50 000 years. Thus, Eastern Botswana may be an important area for gaining an understanding of recent human evolution.

(b) The presence of Later Stone Age materials in Iron Age settlements, and the fact that the San in the area still identify themselves ethnically as such, may

mean that important information exists for gaining an understanding of how these two peoples have lived side-by-side and assimilated during the last thousand years.

(c) There is an almost certain evolution of settlements (and thus peoples) over a period of some 1 200 years which will provide important information on the development of modern population.

(d) There has been practically no work done on either the early Iron Age in Botswana or the commoner sites falling within the Zimbabwe and Khami Empires. These sites found within the reservoir area will provide valuable information about this major gap in historical knowledge.

(e) The patterns of settlement appear to differ from those found in the Shashe reservoir studies in the next catchment. At Shashe there is a distinct hierarchical system of settlements with a large central village with up to 300 granaries and a major central stock kraal, surrounded by smaller villages which appear to have been entirely agriculturally based. At the Letsibogo reservoir area the villages appear more open (as the granaries are more widely spaced) and more even in size with no central village site. The reasons for these differences are not immediately apparent, but probably result from differences in topography (given the many kopjes which are present at Letsibogo, but not at Shashe), the slightly different soil types which may have favoured the settlements at Shashe, the presence or not of tsetse fly, or most likely that the bulk of sites at Shashe may fall into a shorter time period than those at Letsibogo.

(f) Finally, some of the sites are extremely well preserved, particularly sites 5, 15, 16 and 19, as well as many of those which are marked but not numbered on the reservoir map. Such sites contain a wealth of information and, although similar to each other and to sites outside the reservoir area, are unique in themselves and capable of imparting important knowledge about the lifestyles and significance of past populations.

K-D1.5 Recommendations

The results of this survey have been discussed with the Senior Curator at the National Museum. As a result the following recommendations can be made:

1. A more thorough survey of the reservoir area should be conducted in the winter of 1989 to:

   a. locate Stone Age sites
   b. ensure that no Early Iron Age sites have been missed
   c. locate accurately all settlement sites within and immediately adjacent to the reservoir area

2. Charcoal samples should be collected from all the different types of sites to attempt chronological dating of settlements and to provide a time scale comparison with the Shashe.

3. A number of different types of site should be mapped. This should include at least six smaller sites, a cluster of small sites around a kopje, two medium

sized sites, such as Nos. 4, 8 or 10, and all sites with over 200 granary stands which could involve a further four sites.

4. Systematic collections of stone artifacts should be made based on a grid and habitat types. For example, a surface collection covering six square metres should be made along transects from the river to hilltop.

5. Test excavations should be made at a minimum of three Stone Age sites (if located), two of which should belong to the Middle Stone Age and one to the Later Stone Age.

6. Test excavations should be made at sites 4, 5, 8, 10, 15, 16 and 19 to determine their actual importance and relationship, if any, to the sites found in the Shashe reservoir area.

7. Rock paintings, if they occur, will probably remain undamaged by the reservoir flooding as they are likely to be well above the FSL. Even so, at some stage, a careful examination should be carried out to determine if these do occur.

The recommended work should provide a fairly detailed picture of the actual archaeological remains in the reservoir area and act as the basis for determining whether future work is required and what nature this should be.

Excavation of archaeological sites is governed by the Monuments and Relics Act, Chapter 59:03. This falls within the portfolio of the Minister of Labour and Home Affairs and is administered by the National Museum, Monuments and Art Gallery Department through the Senior Curator of Archaeology. All correspondence and information relating to the archaeological programme should be channeled through him.

SITE DESCRIPTIONS AND ILLUSTRATIONS

The 20 sites numbered on the reservoir map (Map K.1) are described in the following.

Site 1. :- This comprises an area of about 10 ha in extent lying on the north bank of the Motloutse river immediately downstream of the proposed dam wall. It would be directly affected by the left bank spillway. it is littered with broken quartz, particularly visible where erosion is occurring. There are numerous pieces of worked stone, mostly quartz, but also sandstone and chert. Most material belongs to the Middle Stone Age, although a few Later Stone Age artifacts were also found. At some places, concentrations of worked material seemed to be greater than at others, but no definite activity site was located. The type of collection made here can be made at almost any point on the river in the area, and at many places away from the river.

Site 2. :- A small area on the east side and at the base of a line of kopjes lying just to the east of Moremogolo Hill. The area is eroding exposing burnt hut floors, midden and pottery. It also contains a number of stone granary stands. A small collection of pottery was made. On the west side of the kopjes are a number of similar sites, some larger and one with two stone platforms.

Site 3. :- At the base of Moremogolo Hill and within the cut line which demarcates one of the alternative dam wall alignments. There is one large hut floor clearly exposed and a little pottery. A few shards were collected. No granary stands were noted.

Site 4. :- On the brow of a gentle ridge which lies just east of the proposed dam wall. There are 55 stone granary stands and pottery shards. A small collection of pottery was made. This site appears very similar to many sites found in the Shashe reservoir area.

Site 5. :- Situated at the base of Moremogolo Hill and probably just above the FSL. Three daga floors and a number of granary stands were noted. A small collection of pottery and lithics was made. A Later Stone Age chert scraper was found on one of the hut floors.

Site 6. :- Situated in the saddle of Moremogolo Hill. There were two stone circles, a granary stand or cairn and a semi-circular wall about seven metres long and built against some flat rocks, probably to provide a house stand. No pottery was seen and no collection made.

Site 7. :- On raised ground at the base of a small hill just to the northwest of Moremogolo Hill. There are a number of granary stands and a stone wall about seven metres long. It is made of rough stones and is partially collapsed. A small collection of material was made.

Site 8. :- A gently sloping area backed with rocks and containing some large trees. There are a considerable number of large granary stands and some hut circles of between three and five metres diameter. One of the circles contains a granary stand. No pottery was seen and the area is extremely well preserved with little erosion. It lies just above the FSL but could be flooded if the reservoir is a few metres higher than this.

Site 9. :- An area at the base of a small hill standing within the reservoir area. An eroded midden was noted and a few pottery shards collected. There is also a concentration of Middle Stone Age artifacts which may be in situ. A number of these were also collected.

Site 10. :- An area at the base of some rocky outcrops and stretching down a long slope through a ploughed field. There are a large number of granary stands and a lot of exposed pottery. A collection of pottery was made and two carbon samples collected.

Unfortunately the ground was very wet making the collection of the sample very difficult. One sample was collected, from what appears to have been a midden at the south end of the site, and the other from a midden containing shards and bone at the north end of the site. There appears to be more than one component of this site as a piece of Leopard's Kopje pottery was collected amongst the earlier pottery. Unfortunately, the carbon sample proved "modern", probably as a result of being collected in a ploughed field.

Sites 11, 12 and 13. :- These three sites were situated at the northeast end of a low ridge and divided by kopjes. They all included stone granary stands and decorated pottery. Site 12 also included a small stone terrace against the hill. A collection of pottery and some stone artifacts was made.

Site 14. :- An area at the base of an isolated cluster of low kopjes just above the FSL. There are at least five sites in the hills where granary stands and a little terracing occurs. It was difficult to determine whether these formed one settlement divided by streams and kopjes or a number of separate settlements. A badly broken, but almost complete, undecorated pot was found eroding from a cattle path and collected.

Site 15. :- A hummock situated against the road which runs along the west bank of the Motloutse river. The hummock's summit supported a large village with numerous granary stands which surrounded a stock kraal. Large quantities of pottery were noted. A small collection was made and also included microliths and iron beads. This is an important site and deserves attention. Charcoal was collected from a hearth on the north side and proved to date to AD 530.

Site 16. :- The top of a ridge which supports numerous rocky areas. This is another important site with stone walls, granary stands and four distinct stock kraals. It has not eroded and no pottery was visible. Attempts to collect charcoal were unsuccessful. A map was prepared.

Site 17. :- The surround at the base of Gaboruthwe Hill. At both this and the adjacent Setimela Hill large villages containing some 250 granary stands were noted. At Gaborothwe there is also terracing at the base of the hill and three stone circles which possibly supported house platforms. No domestic stock kraals could be seen, but both villages are not eroded and practically no artifacts were found. Attempts to obtain charcoal were unsuccessful. Because of their size and position far from permanent water, these villages must have held important positions in the hierarchy of settlements; however, their general layout appears to be quite different to the central important villages found in the proposed Shashe reservoir area.

Site 18. :- An eroded slope at the junction of the Ditsokwane and Motloutse rivers. Large quantities of worked stone were noted and a small collection made for purposes of comparison with that made at Site 1. at the other end of the reservoir area.,

Site 19. :- A raised area between two kopjes in the Kurumela Hills. The site includes three eroding hut floors, stone granary stands and large middens. Pottery, ostrich egg shell beads and bone were collected from the surface of the midden. Charcoal was collected from one hut floor and dated to AD 850.

Site 20. :- The base of a hill in the middle of the Kurumela Hills and lying just above the FSL. Quantities of Middle and Later Stone Age artifacts were seen to be eroding from a slope at the very base of the hill. These artifacts may also be in situ. A small collection was made.

APPENDIX K-E

CHAPTER K-E1

INTRODUCTION

K-E1 Introduction

K-E1.1 Background and Objectives

Rivers are linear ecosystems whose inputs are largely derived from material brought in from the catchment. The features of a river system are therefore determined largely by the nature of the catchment, in terms of geology, landform, soil and vegetation, and the processes which link them. There are also feedbacks between the river system and the surrounding catchment, mediated largely through the biota. Wildlife and livestock localise their activity close to surface water sources, and through their feeding activities and trampling they affect the vegetation and soils in the catchment, and thereby the processes regulating the inputs to the river system.

Impounding a river system alters these relationships in a variety of ways. The transport of material along the system is slowed and even halted, giving rise to impacts both upstream and downstream. Animal distributions and behaviour are altered. Some constraints are relieved; new ones emerge. The interactive nature of the system needs to be emphasised.

The ecological studies, including the risk of aquatic weeds, were carried out by Peter Frost from the University of Zimbabwe.

Fieldwork was carried out during a two-week period in January 1989. Ten days were spent surveying the vegetation and fauna of the reservoir area of the proposed Letsibogo Dam (Damsite 31); the riverine woodlands downstream from the damsite as far east as Bobonong; and of some of the proposed irrigation areas alongside the Motloutse River. Because of the limited time available, it was not possible to survey all these areas in the same detail. One day was spent at Shashe Dam, near Francistown, reviewing the problems of aquatic weeds with Water Utilities Corporation personnel. Two days were spent with local traditional doctors in the field identifying medicinally important plants.

The aims of the ecological survey were:

a) To identify and describe the main ecological communities within and downstream of the proposed reservoir development area;

b) To assess the impacts of dam construction on these communities;

c) To determine whether any known rare plant species, unique plant associations, or plants of medicinal or other value will be affected by the construction of a dam.

d) To assess possible ecological changes in the functioning of riverine communities downstream of the proposed dam;

e) To evaluate the ecological impact of proposed irrigation schemes;

f) To assess potential problems arising from the unrestricted growth of aquatic weeds and algae;

g) To suggest what actions are needed to ameliorate any adverse effects of reservoir construction and irrigation operations; and,

h) To suggest what measures could be taken to enhance the conservation and amenity values of the reservoir.

K – E1.2 Report Structure

The report is in six parts: the physical environment; a description of composition and functioning of the vegetation of the areas surveyed; a brief review of the fauna of the area; the economic, ecological and scientific values of the systems and species in the reservoir area; a discussion of the direct and indirect effects of dam construction, including a review of potential aquatic weed problems; and suggestions for future investigation and monitoring which have been incorporated into Section K9.5, Chapter K9.

K – E1.3 Acknowledgements

The consultant acknowledges, with thanks, all those people who assisted with the ecological survey. Discussions were held with personnel of the Water Utilities Corporation on the problems of aquatic weeds and phytoplankton blooms at Shashe Dam and the likelihood of similar problems being experienced in the proposed Letsibogo Dam, and with members of the Botshabelo Traditional Doctors Association on the impact of the proposed dam on sources of supply of traditional medicines. Plants collected during the survey were identified by staff of the National Herbarium of Zimbabwe in Harare.

CHAPTER K-E2

LOCATION AND PHYSICAL ENVIRONMENT

K-E2.1 Climate

The proposed dam site at Letsibogo is situated on the Motloutse River, 2.5 km upstream from the town of Mmadinare. The region is semi-arid with a strongly seasonal climate. The key climatic feature, as it affects plant growth, is the relatively low rainfall concentrated into a short 5 month wet season (November - March) which alternates with a 7 month dry season. Mean annual precipitation varies from about 450 mm in the west, at the head of the catchment, to 350 mm in the east, in the Limpopo River valley. Much of the rain falls during short duration, high intensity convection storms (MacDonald, 1988). The rivers and streams are therefore subject to flash flooding during the summer months.

Annual evaporation potential is approximately 2250 mm or about 5 times mean annual rainfall. Daily temperatures are high in summer (mean maximum for January at Francistown, 31.3 C; mean minimum, 19.3 C) and moderate in winter (mean maximum in July, 23.4 C; mean minimum, 5.1 C). Mean annual temperature is 20.9 C (Key, 1976). Frosts occur occasionally in winter, particularly in low lying areas and hollows.

Long-term rainfall records (>50 years) are available from only a very few stations in Eastern Botswana. The rainfall records for Francistown (61 years between 1922/23-1984/85), approximately 100 km NNW of Letsibogo, and Mahalapye (70 years records between 1911/12-1984/85), 175 km SW show marked year-to-year variation. Mean annual rainfall at these localities is 461 mm (coefficient of variation: 38%) and 471 mm (CV: 33%) respectively. Less than 300 mm annual rainfall is recorded during drought years (20% of years at Francistown, 14% at Mahalapye), while in wet years rainfall can exceed 600 mm (18% of the years at Francistown, 24% at Mahalapye). Exceptional rains fell in the year preceding this study, following five years of drought.

The summer rainfall region of southern Africa, including eastern Botswana, is subject to a quasi 18-year oscillation in rainfall, with about 9 years of generally below-average rainfall alternating with 9 years of above- average rainfall (Tyson 1986). Rainfall in the region was generally above-average during the early-mid 1920s and again in the early 1930s, mid 1950s, and 1970s. Below-average rainfall was recorded during the late 1920s, mid-late 1930s and late 1950s to late 1960s. Rainfall during the 1940s was also generally low but highly variable from year to year.

K-E2.2 Landforms

The landscape is flat to gently undulating and forms part of the late Miocene (Post African I) pediplain. Remnants of the older, late-Tertiary (African) erosion surface occur as isolated inselbergs, the heights of which are broadly concordant. The younger Pliocene (Post African II) erosion surface is evident only along the main rivers.

The drainage of the Motloutse River is superimposed on the underlying rock formations and generally cuts across the predominantly NE trend of the regional geological structure, providing further evidence for the existence of a previous erosion surface. Local structural

control is provided by ridges of metasediments of the Monatsane formation north of Mmadinare, and by the Letlhakane Fault, downstream of the proposed dam site. The drainage of the subsidiary streams and rivers is dendritic.

K – E2.3 Geology, Soils, and Land Use

Geology, landform, soils and the vegetation are closely associated. The rocks of the region form part of the North West Marginal Zone of the Shashe – Limpopo Mobile Belt. Most of the project area is underlain by Precambrian porphyroblastic and migmatitic granitoid gneisses derived from regional metamorphism of the Tati Schist Group of basement complex rocks. Metaquartzites, amphibolites, calc – silicate rocks and undifferentiated gneisses of the Monatsane Formation, one of the basal formations of the Tati Schist Group, occur immediately to the north east of the dam site and at a number of sites within it. A number of minor dykes of Karroo age intrude (Key, 1976).

The soils derived from the gneisses are generally shallow, reddish – brown to yellowish – red loamy sands or sandy loams. Over amphibolite, mafic schists, or dolerite the soils tend to be deeper, redder, and more clayey. Organic matter contents are low and the surface soils often friable (MacDonald, 1988). Some bottomland soils appear to be sodic.

CHAPTER K – E3

VEGETATION

K – E3.1 Introduction

At a continental scale the vegetation of the study area forms part of the Zambezian regional centre of endemism, an area covering about 3.8 million square kilometres containing at least 8500 plant species (White, 1983). It is classified as Zambezian dry deciduous mopane woodland and scrub woodland (Wild & Barbosa, 1967; White, 1983). In the vegetation map of Botswana, the vegetation of the project area is termed Mixed Mopane/Acacia Tree Savanna (Weare and Yalala, 1971). This formation covers much of eastern Botswana from Ramokgwebana south to the Motloutse/Lotsane watershed.

The dominant tree species of this regional vegetation formation is *Colophospermum mopane*, but there is much subtle variation in both species composition and structure at a local scale which reflects complex interactions between physical environmental features such as soil type and depth, and biotic factors such as past and present land use practices and the impact of wild and domestic herbivores.

During this survey, plant associations were distinguished mainly on the composition and growth form of the woody plant component of the communities. Herbaceous species composition in arid and semi – arid regions is a less reliable indicator of site conditions since composition varies greatly in response to the amount and timing of rainfall, and land use.

K – E3.2 Species Diversity

A total of 256 species of plants were identified during the ecologist's survey, 126 of which were collected and prepared as herbarium specimens to be deposited with the National Herbarium in Gaborone. These are recorded in Datalist K – E.1 at the end of this appendix, which also incorporates the collections made by the University of Botswana team and brings the total number of species collected throughout to almost 460. The ecologist recorded over 200 species from the proposed reservoir area, and 134 from areas downstream. The most diverse communities are those on rocky outcrops, riverbanks, and alluvial terraces. Further collecting would undoubtedly reveal additional species.

K – E3.3 Species Associations within the Proposed Reservoir Area

The vegetation of the reservoir area can be divided broadly into four main classes. Within each of these there are a number of sub – classes based on differences in species composition in response to changes in local edaphic conditions affecting plant rooting depth and soil moisture availability. In addition, there is a fifth class consisting of highly disturbed vegetation resulting from past and present activities of people and livestock, and a sixth class of minor communities on localised sites with special edaphic conditions.

These plant associations and their respective sub – associations are:

1. Communities of granite – gneiss hills and rocky ridges
   - 1.a *Commiphora marlothii – Croton gratissimus* Open Woodland
   - 1.b *Commiphora mollis – Kirkia acuminata* Closed Woodland

2. River and stream bank communities
   - 2.a *Combretum erythrophyllum – Acacia karroo* Dense Riverine Woodland
   - 2.b *Combretum hereroense – Peltophorum africanum* Riparian Woodland

3. *Acacia* – dominated communities of bottomlands
   - 3.a *Acacia tortilis – Boscia albitrunca* Woodland
   - 3.b *Acacia mellifera – Acacia tortilis* Open Woodland
   - 3.c *Acacia erubescens – Combretum apiculatum* Woodland

4. *Colophospermum mopane* – dominated communities of the uplands
   - 4.a *Colophospermum mopane – Acacia nigrescens* Woodland
   - 4.b *Colophospermum mopane – Combretum apiculatum* Woodland
   - 4.c *Colophospermum mopane* Woodland
   - 4.d *Colophospermum mopane – Commiphora pyracanthoides* Scrubland

5. Communities of occupied and abandoned lands
   - 5.a *Regenerating Acacia tortilis* Thicket
   - 5.b *Grewia spp* Scrub

6. Minor communities
   - 6.a *Catophractes alexandri – Rhigozum brevispinosum* Shrubland
   - 6.b Communities of seasonally waterlogged depressions and drainage lines.

The structure and composition of these communities is described in more detail below.

1. Communities of Granite Hills and Rocky Ridges

1.a *Commiphora marlothii – Croton gratissimus* Open Woodland

This community is confined to the granite gneiss hills and boulder outcrops within and around the proposed reservoir development area. The soils are very shallow, excessively drained, and relatively infertile. Nevertheless, there is considerable tree cover due to the presence of fractures and joints in the rocks in which trees are able to root and exploit the moisture stored within.

Characteristic tree species are *Commiphora marlothii*, *Croton gratissimus*, *Ficus tettensis*, *Commiphora mollis*, *Steganotaenia araliacea*, *Kirkia acuminata*, *Sterculia rogersii* and *Pappea capensis*; common shrubs include *Antherothamnus pearsonii*, *Barleria holubi*, *Cissus cornifolia*, *Elephantorrhiza goetzei* and *Euphorbia griseola*.

These species show some zonation up the hill slopes. *Combretum apiculatum*, *Acacia erubescens*, *Colophospermum mopane*, *Grewia flava*, *G. subspathulata* and *Commiphora africana* form a characteristic subassociation on the shallow pediments of the hills. Species such as *P. capensis*, *S. rogersii*, and *A. pearsonii* occur most commonly on the lower and mid slopes, whereas *F. tettensis*, *C. marlothii* and *S. araliacea* are usually confined to the mid and upper slopes. *Combretum molle*, *K. acuminata*, *C. gratissimus* and *C. cornifolia* do not occur on the pediments but are widely distributed on the hills. Because of the shallow soils, herbaceous cover is generally low. The commonest grasses are *Enneapogon cenchroides*, *Aristida congesta*, *A. adscensionis* and *Oropetium capense*, which is confined to shallow soils on the upper slopes of the hills. The more common forb species include low growing annuals such as *Acalypha indica*, *Abutilon*

matopense and *Hibiscus mutatus*; scandent herbs such as *Adenia digitata*, *Cyphostemma puberulum* and *Tinospora caffra*; and bulbous perennials such as *Scadoxus puniceus*. The community is diverse and includes a number of species not found in other communities. A total of 34 tree species (14 of which were found only on the hills), 14 species of shrubs and climbers (including 6 species confined to the hills), 25 species of forbs (7 of which are restricted in distribution), and 9 species of grass (all of which are widespread) were recorded on the hills. Construction of the dam would destroy this community on a number of hills due to be incorporated into the abutments and walls of the proposed dam.

1.b *Commiphora mollis – Kirkia acuminata* Closed Woodland

This community occurs on ridges where fractured and jointed bedrock lies close to the surface. The soils are generally shallow (occasionally moderately deep) sands, often with a marked gravel component. The surface soil is moderately well to somewhat excessively drained and generally infertile. Most of the trees are deeply rooted in fissures and joints in the underlying bedrock. The groundwater table lies about 20 m below the surface on these ridges, which is potentially within the root depth of the larger trees but probably beyond the reach of smaller trees, saplings, and shrubs. It is therefore likely that most of the plants in this community use water stored in the fissures and joints in the bedrock.

The importance of jointed and fractured bedrock in facilitating the establishment of woody plants on otherwise shallow soil profiles is well illustrated by strongly linear patterns in the vegetation visible on SPOT and LANDSAT imagery. These lineations are most apparent in the vegetation overlying the gneisses and metaquartzites of the Monatsane Formation immediately north of the proposed reservoir, and on the gneisses of the Tuli – Sabi Straightening Zone east of Mmadinare. These lineations in woody plant cover parallel the predominant NE – SW trend in the joints of the underlying rocks. Vigorous tree growth also clearly demarcates the main faults and fractures which cut across the regional geological fabric.

The most common trees and shrubs in these woodlands include *Commiphora mollis*, *C. glandulosa*, *C. africana*, *Kirkia acuminata*, *Colophospermum mopane*, *Lannea schweinfurthii*, *Acacia nigrescens*, *Cassia abbreviata*, *Combretum apiculatum*, *Terminalia prunioides* (especially where there is basic parent rock such as amphibolite or mafic schists) and *Markhamia zanzibarica*. Tree canopy cover is high, 60 – 80%, over half of which is due to *Commiphora mollis*. There is also a relatively dense shrub layer comprising mainly *Grewia subspathulata*, *G. flavescens*, *Commiphora africana* and *Ochna inermis*. Herbaceous cover is low, 5 – 10%, but relatively diverse; 24 species of forbs and 5 grass species were recorded in three 0.02 ha plots. The most common of these species are the forbs *Crabbea velutina*, *Evolvulus alsinoides*, *Stomatostemma monteiroae*, the sedge *Kyllinga alba*, and the grass *Enneapogon cenchroides*.

Stands of this woodland community occur on the upper slopes above both the left and right abutments of the proposed dam wall. Although some timber is being removed from the stands north of the Motloutse River, these woodlands overall are relatively undisturbed and should be given some protection both for their aesthetic and their conservation value.

2. River and Streambank Communities

2.a *Combretum erythrophyllum – Acacia karroo* Dense Riverine Woodland

This woodland is confined to the banks of the Motloutse and Sedibe rivers, and to the confluences with the larger tributaries. The soils are mostly deep, well drained, loamy sands to sandy clay loams. Along most of the length of the project area the Motloutse and Sedibe rivers are bounded by 2 – 3 m high banks of old alluvium. The vegetation is generally tall and dense and probably maintained by the seepage of water laterally from the saturated river sands into the finer textured sediments of the riverbanks.

The main tree species include *Combretum erythrophyllum* (confined to the immediate river bank on sandy and sandy loam soils), *C. imberbe* and *C. hereroense*; *Acacia karroo*, *A. galpinii*, *A. tortilis* and *A. grandicornuta* (possibly including *A. robusta*); *Ziziphus mucronata*, *Rhus pyroides* and *Peltophorum africanum*. *Faidherbia albida* (better known as *Acacia albida*), a characteristic species of the larger seasonal rivers of southern tropical Africa, was not recorded in the proposed reservoir area but was found further downstream below the confluence of the Motloutse and Letlhakane rivers. It is one of the dominant species of the riverbank vegetation on the Motloutse R downstream from Lerala.

The understory of the riverine woodland varies from dense thickets of *Diospyros lycioides*, *Maytenus senegalensis*, *M. heterophylla* and *Fluggea virosa*, to more open patches dominated by the grasses *Setaria sagittifolia*, *S. verticellata*, *Brachiaria deflexa*, *Digitaria nuda* and, where it escapes grazing, *Panicum maximum*. Where heavy grazing pressure has removed the grass cover the herbaceous layer becomes dominated by forbs including *Plumbago zeylanica*, *Pupalia lappacea*, *Justicia flava*, *Hibiscus ovalifolius* and *Ocimum canum*.

2.b *Combretum hereroense – Peltophorum africanum* Riparian Woodland

This community occurs as a narrow fringe of usually tall woodland along the seasonal streams draining into the Motloutse and Sedibe rivers. Many of the streams cut deeply into the landscape so that there is seldom any accumulation of sediments. Some of the streams are fault – guided and in these the trees may take root in fractures along the fault. In contrast to the year – round availability of water in the sediments of the Motloutse and Sedibe rivers, these small tributaries are dry for much of the year and the tree species growing along them are therefore likely to be better adapted to withstanding seasonal aridity than those species which occur only along the main rivers.

Characteristic species include *Peltophorum africanum*, *Combretum hereroense*, *C. imberbe*. *Colophospermum mopane* (usually towards the head of the drainage lines), *Acacia nigrescens*, *A. erubescens* (on stony, shallow, excessively drained banks), *A. fleckii* (on sandy banks), *Ziziphus mucronata* and *Lonchocarpus capassa*. The main understory shrubs are *Fluggea virosa* and, less commonly, *Diospyros lycioides*.

The herbaceous layer is patchy: *Brachiaria deflexa*, *Eragrostis trichophora* and *Digitaria nuda* are the most common grasses; *Sida hoepfneri*, *Justicia flava*, *Pupalia lappacea*, *Plumbago zeylanica*, *Ocimum urticifolium* and *Kalanchoe brachyloba* are the most common herbs. Less common species include *Gomphrena celosioides*, *Sericorema remotiflora*, *Commicarpus helenae*, *Mollugo nudicaulis* and *Portulaca kermesina*.

The riparian community is often fringed by an open shrubland of *Grewia flava*, *G. subspathulata*, *G. bicolor* and, in more densely vegetated areas, *G. flavescens*. This *Grewia* – dominated shrubland is established on flat terraces flanking the larger streams. Herbaceous cover is generally low because of heavy grazing. *Urochloa trichopus*, *Tragus berteronianus*, *Schmidtia pappophoroides* and *Aristida congesta* are the common grasses; *Evolvulus alsinoides*, *Indigofera vicioides*, *Tephrosia purpurea* and *Geigeria acaulis* are the common forbs.

3. *Acacia* – dominated Communities of Bottomlands

3.a *Acacia tortilis* – *Boscia albitrunca* Woodland

This woodland occurs on the deeper colluvium on the fringes of the bottomlands, and on consolidated loamy sand terraces. The soils are generally well drained. The trees appear to be relatively deep rooted and to have access to deep lying moisture. The characteristic species include *Acacia tortilis* (usually overwhelmingly dominant), *A. grandicornuta*, *A. mellifera*, *A. karroo* (close to riverbanks), *A. erioloba* (on very deep, sandy soils), and *Boscia albitrunca*. Associated species include *Grewia flava*, *G. flavescens*, *G. subspathulata*, *Z. mucronata* and *Diospyros lycioides*. Much of this woodland has been cleared in the past for cultivation and settlement. *Boscia albitrunca*, a valuable fodder species, is usually left standing. When the fields are abandoned, *Acacia tortilis* rapidly recolonises them.

The herbaceous layer is diverse but cover is sparse, primarily because of heavy grazing. *Eragrostis trichophora*, *E. biflora*, *Chloris virgata*, *Aristida congesta*, *A. adscensionis* and *Tragus berteronianus* are the main grasses. Most of them are annuals or shortlived perennials. *Evolvulus alsinoides*, *Endostemon tereticaulis*, *Commelina africana*, *Abutilon grandiflorum* and *Solanum tomentosum* are the main forbs species. They are more common in more heavily grazed areas.

3.b *Acacia mellifera* – *Acacia tortilis* Open Woodland

This community occurs on generally flat upper alluvial terraces with compacted clayey or clay loam subsoils. The soils appear to be slightly sodic with a shallow, loose, sandy A – horizon contrasting sharply with a very compacted clayey B – horizon. Drainage into the subsoil is impeded and water tends to pond in low lying areas and depressions on the terraces. Rainwater runoff from slopes is high. The A – horizon is gradually stripped through sheetwash and gullies may form along animal tracks. The marked pedestalling of the plants is an indicator of this topsoil erosion.

The dominant tree species is *Acacia mellifera* with *A. tortilis* as the main subdominant. Other frequently encountered species include *Colophospermum mopane*, *A. grandicornuta*, *Boscia albitrunca*, *Grewia bicolor* and *Cadaba termitaria*. The herbaceous component is relatively diverse (9 grass species and 11 forb species were recorded at one site) but the total canopy cover of these species is low because of heavy grazing. Most of the grasses, however, are perennial. *Aristida congesta* is the dominant grass; *Evolvulus alsinoides* the most common forb. *Ocimum canum*, *Urochloa trichopus* and *Sporobolus ioclados* are common in and around depressions. *Sansevieria aethiopica* is frequently found under trees. *Sporobolus ioclados* is an indicator of alkaline or saline soils in seasonally moist areas.

Possibly related to this community is a scrubby community of *C. mopane* on highly eroded, sodic, bottomland soils. *Grewia bicolor*, *A. grandicornuta*, and *Cadaba termitaria* are the main associated species. This may be a community which has lost the *Acacia* species component through erosion, leaving *C. mopane*, *Grewia* spp. and others as remnants.

3.c *Acacia erubescens – Combretum apiculatum* Woodland

Acacia erubescens and *Combretum apiculatum* are co-dominant on shallow, broken soils overlying irregularly weathered bedrock and colluvial gravels. The relative abundance of the two species varies with the degree of weathering of the bedrock. *Acacia erubescens* is dominant on coarse gravelly soils produced by a more uniform pattern of bedrock weathering, whereas *C. apiculatum* becomes dominant on stony soils produced by a highly irregular pattern of weathering. In addition to these two species, other tree and shrub species which occur commonly in this community are *C. mopane*, *Boscia albitrunca*, *Acacia tortilis*, *A. nigrescens*, *Commiphora pyracanthoides*, *Grewia subspathulata* and *G. bicolor*. Most of these species appear to root in fissures in the weathering bedrock.

The skeletal soils do not provide an adequate rooting environment for shallow rooted grasses and forbs. Consequently, herbaceous cover is very sparse and clumped in pockets of deeper soil. *Enneapogon cenchroides* is the most widespread grass species. Others include *Aristida barbicollis*, *A. congesta*, *Brachiaria deflexa*, *Eragrostis trichophora* and *Schmidtia pappophoroides*. Common forbs include *Abutilon matopense*, *Acalypha indica*, *Evolvulus alsinoides* and *Indigofera vicioides*.

4. *Colophospermum – dominated* Communities

Colophospermum mopane is the dominant species over most of the upland sites of the reservoir area other than on very shallow or rocky soils. Vegetation height and density appear to be determined largely by soil depth and soil moisture availability. Because of the apparent unevenness of the bedrock underlying much of the uplands, the various mopane-dominated communities show much subtle variation in composition and structure and the boundaries between the communities are not sharp.

4.a *Colophospermum mopane – Acacia nigrescens* Woodland

The *C. mopane – A. nigrescens* community occurs mainly on the deeper soils of the gently undulating to flat upper slopes of the reservoir area, and on adjacent midslopes where the gradient is shallow. Most of the plant cover comprises *C. mopane*, with emergent *A. nigrescens*, particularly on soils derived from mafic gneisses and amphibolites. *Commiphora glandulosa*, *C. mollis*, *Terminalia prunioides* (also more common on basic soils), *Acacia erubescens*, *Combretum apiculatum*, *C. imberbe* and *Boscia albitrunca* also commonly occur, though they are seldom abundant. In the shrub layer, *Grewia flava*, *G. subspathulata*, and *Ximenia americana* are the main species. Herbaceous cover is relatively sparse, comprising mainly the grasses *Aristida congesta*, *A. barbicollis* (both annuals), *Enneapogon cenchroides* and *Eragrostis porosa*.

4.b *Colophospermum mopane – Combretum apiculatum* Low Woodland

This woodland occurs widely on shallow, gravelly soils of the upper slopes of upland ridges. It forms one end of the continuum of communities on shallow soils (the other is C.3 *Acacia erubescens – Combretum apiculatum* Woodland) but differs in having slightly deeper soils than these other communities; that is, the soils are lithic rather than being lithosols in the strict sense). *Colophospermum mopane* is dominant on the deeper soils; *C. apiculatum* is more common in shallower soil profiles.

Associated tree and shrub species include *Acacia erubsecens*, *A. nigrescens*, *Commiphora pyracanthoides*, *Fluggea virosa*, *Grewia bicolor*, *G. subspathulata* and *G. flavescens*. Grass cover is moderate, with *Enneapogon cenchroides* being the commonest species. *Aristida congesta*, *A. barbicollis*, *Eragrostis trichophora* and *Rhynchelytrum repens* also occur regularly. *Evolvulus alsinoides*, *Indigofera vicioides* and *Hibiscus micranthus* are among the more common forbs.

4.c *Colophospermum mopane* Woodland

This woodland comprises almost pure stands of mature *C. mopane* growing on moderately deep, compacted loamy sands of upland areas, where it grows moderately tall and is usually single – stemmed. Dense stands of mopane also occur in both upland and lowland areas on compacted clay loams. Here the plants are low – growing and multistemmed. The factor determining vegetation structure in both cases is apparently the restricted subsurface drainage. The communities are overwhelmingly dominated by *C. mopane*, with a few scattered *Grewia bicolor*, *Combretum apiculatum*, *Acacia erubescens*, *Boscia albitrunca*, *Cadaba termitaria* and *Commiphora pyracanthoides*.

4.d *Colophospermum mopane – Commiphora pyracanthoides* Scrub

Where the upland soils are gravelly or compacted and sometimes eroded, the vegetation tends to be lower in stature. *Colophospermum mopane* is dominant as a relatively low – growing, often multistemmed shrub, usually in association with *Commiphora pyracanthoides* as the main subdominant. Associated species include *Ximenia americana*, *Grewia subspathulata*, *G. bicolor*, *Cadaba termitaria* and, occasionally, *Euclea undulata*. Because of the shallowness and the compacted nature of the soil, much of the incoming rainfall runs off, causing sheetwash and channelling, and leaving behind the coarser components as a gravel lag. The herbaceous component of this community is very sparse. *Bulbostylis hispidula* and *Oropetium capense* occur; both are species which favour shallow soils.

5. Communities of Occupied and Abandoned Lands

5.a Regenerating *Acacia tortilis* Thicket

Old and recently abandoned lands in the bottomlands can be identified by the presence of dense thickets of similar sized, 1 – 2 m tall *Acacia tortilis* with some emergent *Boscia albitrunca*, which appears to be a remnant of the original vegetation cover. Other occasional species include *Dichrostachys cinerea*, *Grewia flava*, and *G. subspathulata*. Herbaceous cover is often quite high, mainly because of the protection against grazing that the grasses receive when growing under the dense thorn scrub. Forbs and grasses

growing under the trees average 40 cm whereas in the open the same species are seldom more than 5 cm high.

The dominant grasses in this community are the perennial *Eragrostis trichophora*, and the annuals *E. biflora*, *Aristida congesta*, *Aristida adscensionis*, *Tragus berteronianus* and *Chloris virgata*. Most of the common forbs are also annuals: *Evolvulus alsinoides*, *Abutilon grandiflorum*, *Solanum tomentosum*, *Commelina africana* and *Endostemon tereticaulis*.

5.b *Grewia* species Scrub

Around existing settlements there is a zone of heavily disturbed vegetation dominated by *G. bicolor* and *G. subspathulata*, both of which are unpalatable and therefore not browsed. Most of the taller trees of the original vegetation have been cut, except occasional *Boscia albitrunca*. There is a gradual invasion of *Acacia tortilis* and, less commonly, *A. mellifera*. Palatable species such as *Acacia* spp., *B. albitrunca*, *Grewia flava*, *Cadaba termitaria*, *Rhigozum brevispinosum* and *Combretum apiculatum* are all heavily browsed.

The herbaceous layer is heavily disturbed and herbaceous canopy cover is very low. Most of the few species which occur are annuals, *Aristida barbicollis*, *A. congesta* and *Tragus berteronianus*. The common forbs are mostly weeds of disturbed sites and include *Alternanthera pungens*, *Portulaca kermesina*, *Ocimum canum*, *Evolvulus alsinoides* and *Endostemon tereticaulis*.

6. Minor Communities

In addition to the above communities, which are widespread even if confined to specific habitats such as granite gneiss hills, there are two other very localised communities.

6.a *Catophractes alexandri* – *Rhigozum brevispinosum* Scrub

Catophractes alexandri and *R. brevispinosum* occur as minor elements in a number of the main plant communities, but they form a distinct localised community on patches of calcareous soils derived from calc – silicate rocks of the Monatsane Formation. The soils are greyish and very friable. Associated species include *Acacia tortilis*, *Dichrostachys cinerea*, *Grewia subspathulata* and *Grewia flava*. *Enneapogon cenchroides* is the dominant grass, but *Cenchrus ciliaris* also occurs where the grazing pressure is not too high. The most extensive stand of this vegetation is situated near the left abutment of the proposed dam (grid reference 2127D3 5761/75853).

6.b Communities of Seasonally Waterlogged Depressions and Drainage Lines

These communities occur on deep brown clay loams within broad, flat, seasonally waterlogged depressions. The main example occurs east of the Motloutse River (grid reference 2127D3 5730/75875). The vegetation comprises dense thickets of tall *Acacia tortilis*, *A. grandicornuta*, *A. mellifera*, *Ziziphus mucronata*, and *Combretum imberbe*. Understory shrubs include *Diospyros lycioides*, *Grewia flavescens*, *G. flava*, *G. subspathulata* and *Fluggea virosa*.

Although the area is extensively grazed, the herbaceous cover is high with tall, rank grasses and forbs indicative of fertile, well watered soils. The grasses and forbs each account for about half the total herbaceous cover. Common grass species include *Eragrostis trichophora*, *Tricholaena monachne* and *Urochloa trichopus*. Less common species are *Brachiaria deflexa*, *Eragrostis superba*, *Setaria pumila*, *Digitaria milanjiana* and *Echinochloa colona*. The dominant forbs are *Sida hoepfneri*, *Ocimum urticifolium*, *Justicia flava*, *Indigofera cryptantha*, *Hibiscus dongolensis*, *Tragia okanyua* and *Nidorella auriculata*.

K – E3.4 Plant Associations of the Irrigation Areas

The vegetation types of the proposed irrigation areas were surveyed to determine if any unique plant associations or rare species would be adversely affected by the development of these areas under irrigation. Brief surveys of the vegetation were carried out in proposed irrigation areas IR 2, IR 3, IR 4, IR 5 and IR 14. A lack of time prevented the survey of the other 9 areas. In each area, the species composition and structure of the vegetation on each of the main soil types was recorded, together with information on the nature and scale of disturbance, herbivory, erosion, and any other salient feature. Forty – seven vegetation stands were surveyed on 13 soil types (including variations). All of the most widespread soil types present in the irrigation areas were included.

The soils of the irrigation areas are derived from six main parent materials: alluvial deposits (mapped as soil unit A: see Annex F); basic igneous and metamorphic rocks (B); highly calcareous rocks and materials (C); fine – grained sedimentary rocks (D); acid igneous and metamorphic rocks (G); and coarse grained sedimentary rocks (S). Soil units A and G are the most widespread and the ones on which the vegetation survey concentrated. A few sites with soil units C were also surveyed, but none on soil units B, D, and S. In the following descriptions, the association between particular vegetation types and given soil types is highlighted, although some vegetation types occur across a number of soil types.

Acacia nebrownii – Eragrostis cilianensis Thicket and Grassland

This vegetation type is confined to deep to very deep, poorly to imperfectly drained, dark grey brown to very dark grey vertisols (soil type A1). The soils are characteristic of low – lying seasonally inundated depressions situated on the back slopes of the alluvial terraces of the Motloutse River. Because of their limited extent, seasonal waterlogging, clayey texture, and self – churning characteristics, these soils are not considered suitable for irrigation. Examples of this soil type were examined in IR 4 and IR 14.

The plant community on these soils comprises two main components: the woodland situated on slightly higher and better drained sites, usually surrounding the pan; and the forbs and grasses growing in wetter areas along the edge. *Acacia nebrownii*, *A. karroo* and *Ziziphus mucronata* are the common trees found on these soils; other species include *A. tortilis*, *A. mellifera* and shrub *Colophospermum mopane*. The forbs *Cullen obtusifolia* and *Alternanthera pungens* grow along the edge of the pan in association with the grasses *Eragrostis cilianensis* (an indicator of heavy textured soils), *Echinochloa colona* (an indicator of moist conditions) and *Urochloa trichopus*, and the sedge *Bulbostylis hispidula*. The centre of the pans are largely devoid of vegetation other than the water fern *Marsilea farinosa*.

Acacia karroo Riverine Woodland

This woodland is confined to deep, fine textured soils overlying coarse-textured alluvial sands and river gravels forming some of the river levees (soil type A4). The soils have a high water retention capacity and sluggish drainage. One stand of vegetation was surveyed, on IR 14, where this soil type covers a considerable area.

The vegetation is a dense, 5-6 m high woodland of *Acacia tortilis*, *Ziziphus mucronata* and *Acacia karroo*. The understory is relatively open with few shrubs: *Grewia flava*, *G. flavescens*, *G. subspathulata*, *Maytenus heterophylla* and *Diospyros lycioides* were the main species. In contrast to the paucity of shrubs, the cover of the herbaceous layer is high (60%) and comprised mainly of the forb, *Justicia flava*, and the grasses, *Panicum maximum* and *Brachiaria deflexa*. Although the herbaceous layer is heavily grazed, the grasses and forbs grow vigorously, indicating the favourable environment for growth resulting from the high fertility and good moisture status of the soils.

Acacia tortilis-*Acacia grandicornuta* Woodland

This woodland is found in IR 3 and IR 5 on moderately deep, imperfectly drained, saline-sodic duplex soils in upland drainage lines (soil type A5). Tree cover is sparse, mainly *Acacia tortilis* and *A. grandicornuta*, but the shrub layer is dense and composed of shrubby *Colophospermum mopane*, *Dichrostachys cinerea*, *Grewia bicolor* and regenerating *Acacia* species, mostly *A. tortilis*. The herbaceous layer is sparse and consists mainly of the forb *Solanum tomentosum* and the annual grass *Eragrostis biflora*.

Woodland dominated by *Acacia tortilis* and *A. grandicornuta* also occurs on moderately deep lower slope soils characterised by a loamy coarse sand topsoil overlying a very coarse sandy clay loam subsoil (G10). Drainage is imperfect to moderately good. Periodic, short-term waterlogging seems to be the common feature linking these two soil types and influencing the composition of this woodland. In addition to the two dominant species, *A. erioloba*, *Boscia albitrunca*, *Colophospermum mopane*, *Combretum imberbe*, *C. hereroense* and *Ziziphus mucronata* also occur regularly. Mopane tends to be more common up the slope.

The density of the shrub layer is variable, ranging from 15-40%, and comprised primarily of *Grewia flava*, *G. subspathulata*, *G. flavescens* and *Fluggea virosa*. The dominant forbs are *Acalypha indica* and *Hibiscus ovalifolius*; the main grasses are *Urochloa trichopus*, *Eragrostis trichophora*, *E. biflora* and *Brachiaria deflexa*.

Acacia galpinii-*Acacia karroo* Riverine Woodland

Riverine woodland occurs on low natural levees, often on the inner, prograding banks of river meanders. The soils of these levees are deep to very deep, well drained to excessively drained, yellow-brown sands and loamy sands (soil type A22). They form sections of the levees of the Motloutse, Letlhakane and Tobane rivers (IR 2, IR 4, IR 5 and IR 14). The trees are tall (up to 18 m) with densely packed crowns (canopy cover 80-90%). The dominant species are *Acacia galpinii*, *A. karroo*, *Ziziphus mucronata*, *Combretum imberbe* and *C. hereroense*. *Combretum erythrophyllum* and *Rhus pyroides* are confined to the edges of the river banks and are presumably dependant on having constant access to moisture in the adjacent riverbed.

The shrub layer of the woodland is relatively sparse (5 – 15% canopy cover) and short (1 – 2 m average height). *Fluggea virosa*, *Diospyros lycioides* and *Grewia flavescens* var. *olukondae* are the dominant species, with *Maytenus heterophylla*, *M. senegalensis*, *Lycium shawii*, *Grewia flava* and *Tarchonanthus camphoratus* as associates. Herbaceous cover varies (10 – 60% cover) depending on the amount of disturbance and grazing pressure from livestock. The main grass species, *Brachiaria deflexa*, *Setaria verticellata*, *S. sagittifolia* and *Panicum maximum*, are characteristic of shaded habitats on better quality soils. *Sida hoepfneri*, *Hibiscus ovalifolius*, *Alternanthera pungens* and *Pupalia lappacea* are the common forbs, particularly where the understory has been opened up by livestock.

Acacia tortilis – Combretum imberbe Riverine Woodland

In contrast to the woodland growing on the low lying river levees, the woodland on raised alluvial terraces is shorter (4 – 5 m) but more dense (canopy cover 70 – 95%). The soils are deep to very deep, well drained, red coarse sandy clay loams with a loamy coarse sand topsoil (A36). The dominant tree species are *Acacia tortilis* and *Combretum imberbe* with *A. mellifera*, *A. erioloba*, *C. hereroense* and *Ziziphus mucronata* as common associates. *Acacia galpinii* is present but not dominant as it is on the sandy A 22 soils. Shrub cover is relatively dense: *Grewia flava* and *Diospyros lycioides* are the dominant species; *G. bicolor*, *G. flavescens* and *Maytenus heterophylla* also occur commonly. Herbaceous cover is high and the plants grow relatively tall where they are protected from grazing. *Hibiscus ovalifolius*, *Blumea decurrens*, *Plumbago zeylanica*, *Ocimum canum*, *Justicia flava*, *Pupalia lappacea* and *Protasparagus suaveolens* are the common forbs, and *Brachiaria deflexa*, *Digitaria nuda*, *Panicum maximum* and *Urochloa trichopus*, the common grasses.

Acacia tortilis – Acacia mellifera Woodland

Woodlands dominated by *Acacia tortilis* and *A. mellifera* occur on a variety of deep to very deep, well drained alluvial soils. The best developed stands occur on raised alluvial terraces with deep to very deep, red – brown to dark brown, fine sandy clay loams with a loamy fine sand topsoil. The subsoil is firm and the soils are imperfectly to moderately well drained. The woodland is relatively tall (5 m) and dense (50 – 60% cover). *Acacia* species are dominant, particularly *Acacia tortilis*, *A. mellifera*, *A. karroo* (close to the rivers) and *A. erioloba*. *Combretum imberbe*, *C. hereroense* and *Lonchocarpus capassa* are the main subdominants. The understory is relatively open; *Diospyros lycioides* and regenerating *A. mellifera* are the usual dominants with *Lycium shawii*, *L. cinereum*, *Grewia flava*, *G. flavescens* var. *olukondae*, and *Ziziphus mucronata* as frequent associates.

The herbaceous layer is relatively diverse; the species composition suggests that it is subject to heavy grazing pressure. Common forbs include *Acalypha indica*, *Achyranthes aspera*, *Corchorus asplenifolius*, *Endostemon tereticaulis*, *Hibiscus ovalifolius*, *Leucas glabrata*, *Limeum sulcatum*, *Ocimum canum*, *Protasparagus suaveolens*, *Sida cordifolia*, *S. hoepfneri*, and *Tephrosia purpurea*. Most of the grasses are annuals: *Brachiaria deflexa*, *Digitaria nuda*, *Eragrostis biflora* and *Tragus berteronianus* were the main species recorded.

In most cases, despite their suitability for cultivation, these tall woodlands have not yet been cleared, presumably because of the size and density of the trees. A particularly mature stand occurs in IR 5, just north of the Tobane River. It has been identified as a prime site for the development of a small – scale irrigation plot. The stand is one of the few apparently natural mature stands of *Acacia* woodland still remaining on the alluvial soils upstream from Tobane. Any decision to clear it for cultivation should first take into account its relatively undisturbed

state. Some representative examples of the natural vegetation of these areas should be retained.

Where the woodland has been cleared, for example, in IR 3 alongside the Matatane River, it has been replaced by dense *Acacia* thicket on compacted soils. Much of the topsoil appears to have been stripped by erosion. Tree cover comprises *Acacia tortilis, A. mellifera, Colophospermum mopane* and *Boscia albitrunca*, with a dense thicket of regenerating *Acacia mellifera, Grewia flava, G. subspathulata, G. flavescens* and *Cadaba termitaria*. Herbaceous cover is low and made up mostly of the forbs *Ocimum canum, Evolvulus alsinoides, Tephrosia purpurea*, and the grasses *Aristida barbicollis, A. congesta, Schmidtia pappophoroides* and *Urochloa trichopus*.

Acacia species, mainly *A. tortilis* and *A. mellifera*, are also dominant on older consolidated levees set back from the river. Associated species include *Combretum imberbe, C. hereroense, Lonchocarpus capassa* and *Acacia galpinii*. The soils are deep, well drained yellow-brown sands and loamy sands (A22). Species which are characteristic of the riverbanks, such as *Combretum erythrophyllum* and *Rhus pyroides*, are absent, suggesting that these soils are drier than equivalent soils closer to the rivers. The shrub and herb layers are similar to those of *Acacia galpinii - Acacia tortilis* riverine woodland but are more heavily browsed and grazed by livestock. Some additional forb species were recorded: *Waltheria indica, Peristrophe paniculata, Otoptera burchellii* and *Pergularia daemia*.

Mixed *Acacia* species Woodland

Mixed *Acacia* species woodland occurs under a number of different edaphic conditions ranging from very deep, freely drained soils to shallow, excessively drained ones. The most diverse community was recorded from very deep, freely drained, yellow red to dark red loamy coarse sands with a coarse sandy clay subsoil (G14). The woodland is moderately tall (4-6 m) and dense (40% tree canopy cover). *Acacia tortilis, A. fleckii* and *A. karroo* are dominant; *A. nilotica, A. erioloba, A. mellifera, Combretum hereroense, C. imberbe, Ziziphus mucronata* and *Gardenia volkensii* are common associates.

The canopy cover of shrubs is less than that of the trees. *Grewia subspathulata* and *Maytenus senegalensis* are the most common species; others include *G. flavescens, G. flava, G. bicolor, Dichrostachys cinerea, Maytenusheterophylla, Diospyros lycioides* and *Ehretia rigida*. Herbaceous cover is sparse and generally heavily grazed. The common grasses are *Eragrostis trichophora* and *Aristida congesta*; common forbs include *Gossypium herbaceum* (wild cotton), *Sida hoepfneri, Evolvulus alsinoides* and *Endostemon tereticaulis*.

Mixed *Acacia* woodland about 3-4 m high also occurs on shallow to very shallow, moderately well to somewhat excessively drained, yellow-red to reddish brown loamy coarse sands, in some areas with significant amounts of gravel and loose rock (G1). *Acacia tortilis* and *A. mellifera* are the dominants with *A. grandicornuta, A. erubescens* (particularly on gravelly or rocky soils), *Boscia albitrunca, Colophospermum mopane, Grewia flava, G. subspathulata* and *Maytenus senegalensis* the associated tree and shrub species. The herbaceous layer is sparse and comprised mainly of low growing annuals: *Endostemon tereticaulis* and *Evolvulus alsinoides* are the common forbs; *Eragrostis trichophora, Enneapogon cenchroides, Tragus berteronianus, Aristida rhiniochloa* and *Urochloa trichopus* are the common grasses.

A similar community occurs on shallow, moderately well to well drained, yellow red to red brown soils with a loamy coarse sand topsoil overlying a compacted coarse sandy loam/sandy clay loam subsoil (G2e). These soils are found mainly on slight rises in the pediplain cut by the Motloutse and Letlhakane rivers. Tree cover is generally sparse (5–15%) and comprised mainly of scattered *Acacia tortilis*, *A. grandicornuta*, *A. erubescens* and *Boscia albitrunca*. The shrub layer is dense and consists of either regenerating *Acacia* species or shrub *C. mopane*. Associated shrub species include *Grewia flava*, *G. bicolor*, *G. subspathulata*, *Fluggea virosa*, *Ximenia americana* and *Cadaba termitaria*.

The herbaceous layer is heavy grazed and very sparse. *Ocimum canum*, *Evolvulus alsinoides* and *Protasparagus africanus* are the dominant forbs; *Urochloa trichopus*, *Aristida congesta*, *A. barbicollis*, *Eragrostis trichophora* and *Tricholaena monachne* are the common grasses.

Acacia tortilis*–*Colophospermum mopane Shrubland

Colophospermum mopane occurs alongside *Acacia* species (mainly *A. tortilis* and *A. grandicornuta*) in IR 4 and IR5. The soils are either deep, well drained, reddish brown sandy clay loams with loamy coarse sand topsoils of the high level alluvium set back from the rivers (A36), or deep, moderately well to well drained residual soils with a coarse sandy loam topsoil overlying a sandy clay loam subsoil (G9). Much of the vegetation is secondary, the plants regenerating following disturbance, possibly clearance and cultivation. The acacias form dense thickets of mostly small to medium–sized plants with occasional taller individuals of *Combretum imberbe*, *Acacia erioloba*, *Boscia albitrunca* and *Terminalia prunioides*.

Colophospermum mopane occurs both as an emergent and as a multistemmed regenerating shrub. The main shrub species are *Grewia flava*, *G. flavescens*, *Cadaba termitaria*, *Ziziphus mucronata* and *Acacia mellifera*, all of which have been heavily browsed by goats. The herbaceous layer is very sparse and heavily grazed: *Aristida barbicollis*, *A. congesta*, *Tragus berteronianus* and *Urochloa trichopus* were the only grasses identified; *Aptosimum lineare*, *Evolvulus alsinoides*, *Acalypha indica* and *Mormodica repens* were the main forbs recorded.

Colophospermum mopane Woodland

Mopane woodland is the dominant vegetation type on the soils of the middle and upper slopes of the landscape. There is a wide variety in composition and structure, both within and between soil types, but the constant feature is the presence of *Colophospermum mopane*. The soils of these communities are usually shallow to moderately deep coarse sandy loams overlying coarse sandy clay loam subsoils (G6, G9). Drainage is moderate to good. Associated species include *Acacia grandicornuta*, *A. fleckii*, *A. mellifera*, *Terminalia prunioides* and *Combretum apiculatum*.

Grewia flava dominates the shrub layer. Associated species include *G. subspathulata*, *G. bicolor*, *Dichrostachys cinerea*, *Jasminum stenolobum*, *Ximenia americana*, *Aloe littoralis* and shrubby forms of *Boscia albitrunca* and *C. mopane*. The herbaceous cover is sparse, primarily because of heavy grazing pressure. Common forbs include *Evolvulus alsinoides*, *Tragia okanyua*, *Sida hoepfneri*, *Commelina africana* and *Mormodica repens*. The common grasses are *Schmidtia pappophoroides*, *Aristida barbicollis*, *Panicum maximum* and *Oropetium capense*.

Mopane woodland is also the dominant woodland on soils derived from calcareous materials (C5a). These soils are shallow to moderately deep and moderately to well drained. Most of the areas visited have been cultivated and are now being encroached by *Acacia tortilis*. Apart

from being lower and more open, the species composition of these communities is similar to other mopane communities, except that species such as *Terminalia prunioides*, which is characteristic of more basic soils, is more common. Additional species of forbs recorded from these soils include *Ocimum canum*, *Blumea decurrens*, *Corchorus asplenifolius* and *Aptosimum lineare*.

K – E3.5 Riverine Vegetation Downstream from the Dam

The banks of the Motloutse River and its major tributaries are fringed by strips of tall riverine woodland. The density, composition and structure of this vegetation varies considerably depending on soil type and depth, position on the river banks and along the river system. There is a set of common species that occurs throughout but the detailed composition and species dominance varies along the length of the river.

The size and density of the riverine woodland strips is apparently determined by the availability of moisture during the dry season derived mainly from lateral flow of moisture from the saturated river sands into the finer sediments of the river levees and alluvial terraces. The width of the riverine fringe varies from less than 10 m in places where high outer riverbanks on meanders are being actively eroded, to more than 200 m on the inner prograding bends of the river. Mature stands of woodland also occur at the confluences of the Motloutse River and its major tributaries. Table K – E3.1 below gives a schedule of the riverain vegetation.

The riverine fringe is least well developed upstream from the confluence of the Motloutse and Letlhakane rivers, where the density of woodland per unit river length averages 11.3 ha/km, see Table K – E3.1. This includes the woodland upstream of the proposed damsite which would be flooded after dam construction. In this section the river is relatively narrow and incised, cutting through older alluvium and leaving the riverine fringe exposed on relatively high river banks.

The woodland is most dense downstream from the Motloutse/Letlhakane river confluence to Lerala (Table K – E3.1), a section which coincides with inflow from Selebi – Phikwe waterworks and the BCL mine. This inflow fills the sand river aquifer and results in minor surface flow along the river for about 7 km below the point of inflow (MacDonald, 1988). While some of the increase in riverine woodland density may be attributable to this enhanced flow, the size and apparent age of the trees in the woodland indicate that this woodland has been established for longer than the return flow from Selebi – Phikwe, which started only in the early 1970's.

This suggests an additional source of moisture allowing the woodland to develop downstream from the Letlhakane River confluence. At this point the Motloutse River cuts across, and for a short distance even runs along, the Letlhakane Fault. Whether the fault feeds water into the river system needs investigation but it is noticeable that there is a high density of riverine woodland along the Letlhakane River upstream from the Motloutse River confluence, suggesting that the trees there are benefitting from water present in this major aquifer.

Table K – E3.1.

Riverain Vegetation Analysis

River Section	River Length	Riverain Vegetation		Vegetation Density	Av. River Width
	km	ha	%	ha/km	m
Motloutse					
Madibeng rapids – Letsibogo	14.2	160	3.7	11.3	80
Letsibogo – Lethlakane	18.9	213	4.9	11.3	92
Lethlakane – Site 32	13.5	600	13.7	44.4	100
Site 32 – Lerara	21.7	890	20.4	41.0	138
Lerala – Basalt	27.2	941	21.5	34.6	159
Basalt – Bobonong	16.5	239	5.5	14.5	123
Bobonong – Molalatau	32	566	13.0	17.7	na
Molalatau – Setombo	12.5	106	2.4	8.5	na
Setombo – Thune	21	343	7.8	16.3	na
Thune – Limpopo	24	312	7.1	13.0	na
	201.5	4370	100.0	21.7	na
Major Tributaries					
Sedibe in Letsibogo Reservoir	12.5	170	52	13.6	50
Lethlakane proposed reservoir	20	281	29.0	14.1	25
Lethlakane (d/s of dam)	23.3	682	71.0	29.3	30

Source: 1981 1:50 000 aerial photography and 1986 1:25 000 Spot satellite imagery

If this hypothesis is correct, then it has important implications for the construction of a dam at Letsibogo. It suggests that only the river section from the damsite to the confluence of the Motloutse and Letlhakane rivers would be adversely affected by the cut in river flow, and that downstream sections of woodland would be maintained by seepage from the Letlhakane Fault. The input from this aquifer to the sand river still needs to be determined, and the impact of a proposed dam on the Letlhakane River itself thoroughly evaluated.
The density of riverine woodland declines sharply downstream from Lerala. At this point the river widens and the underlying geology changes from mainly granitic gneiss, through fine-grained sandstones of the Karroo Supergroup, to Karroo basalt at Mosalakwane, upstream from Bobonong, at which point the river narrows again. This change is accompanied also by a change in riverine vegetation, with *Faidherbia albida* (=*Acacia albida*) becoming dominant.

The vegetation over much of the length of the river is characterised by a set of common species including *Acacia karroo*, *A. galpinii*, *A. erioloba*, *A. tortilis*, *Combretum erythrophyllum*, *C. imberbe*, *C. hereroense Ziziphus mucronata*, *Rhus pyroides* and *Peltophorum africanum*. Common shrubs associated with the riverbanks are *Diospyros lycioides*, *Maytenus heterophylla*, *M. senegalensis*, *Grewia flavescens* var. *olukondae*, *Euclea undulata* and *Fluggea virosa*.

The dominant species in the riverine woodland change along the length of the river. The upper sections, above the proposed dam site, are dominated by *Acacia karroo*, *Combretum*

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The dominant species in the riverine woodland change along the length of the river. The upper sections, above the proposed dam site, are dominated by *Acacia karroo*, *Combretum erythrophyllum* and *Rhus pyroides*. Further downstream, below the confluence of the Motloutse and the Letlhakane river, both *C. erythrophyllum* and *A. karroo* become more localised, and *Acacia galpinii* becomes common, particularly on low sandy levees. Further downstream again, below Lerala, *Faidherbia albida* becomes dominant, forming almost monospecific stands on point bar deposits and on islands in the riverbed. Only a few, scattered individuals of this species were recorded upstream from the confluence of the Motloutse and Sempowane rivers.

Other species only recorded from the downstream sections of the Motloutse River include *Hyphaene petersiana*, *Salvadora australis*, *Lycium cinereum*, *L. shawii* and *Pluchea leubnitziae*. A more detailed survey would undoubtedly reveal more such species, as well as clarifying the reasons for these restricted distributions.

Much of the pattern in the vegetation is associated with changes in the underlying soils. The complexity of these alluvial soils has been commented on (see Annex F) and some of the associations between the vegetation and these soils have been described in Section K-E3.3 above. There is some zonation of the vegetation away from the river. *Combretum erythrophyllum*, *Rhus pyroides* and, to a lesser extent, *Acacia galpinii*, are confined to the immediate riverbank where they are presumably dependant on access to water in the riverbed. *Faidherbia albida*, where it occurs, is also confined to sandy riverbanks.

Ziziphus mucronata, *Acacia karroo*, *Combretum imberbe* and *C. hereroense* extend from the riverbank back into the alluvial terraces and backslopes where they are gradually replaced by a zone of *Acacia* species, mainly *A. tortilis*, *A. mellifera* and, occasionally, *A. grandicornuta*. *Acacia erioloba* is confined largely to deeper sands on the upper alluvial terraces. *Acacia nebrownii* forms almost monospecific stands in heavy clay soils filling seasonally waterlogged depressions on the fringe of the lower alluvial terraces.

There is relatively little permanent vegetation in the riverbed. *Phragmites mauritianus* occurs widely along the length of the river but is confined to the shelter of the riverbanks or to sections of the riverbed upstream from where rock bars form a barrier impeding the flow of water through the sand aquifer. Its distribution therefore probably indicates perennially moist sites. Small stands of *Typha capensis* occur on the edges of perennial pools in the river downstream from the Motloutse/Letlhakane confluence. A number of weedy species occur in the dry riverbed. These include *Argemone subfusiformis* (Mexican poppy), which forms

dense, low growing stands, *Ricinus communis* (castor oil plant) and *Nicotiana glauca* (wild tobacco). For all these species, regular flooding of the river is probably an important means of dispersal.

CHAPTER K-E4

FAUNA

K-E4.1 Mammals

No detailed faunal survey has been carried out in the project area. The distribution of the mammals of Botswana was surveyed in the 1960s (Smithers, 1971), while the distribution of mammals generally in the southern African sub-region is given by Smithers (1983). De Graaff (1981) gives detailed information on the distribution of rodents in southern Africa. In addition to using these sources to determine which species are likely to occur in the project area, records were kept during the survey of all mammals or signs of their activity.

A faunal list compiled from all these sources is given in Datalist K-E.2. Up to 77 mammal species potentially occur in the project area. Almost half of the species are small mammals weighing less than 1 kg and most of these are nocturnal. The larger mammals are generally uncommon. The presence these species and their status, if they occur, would require a much more detailed survey than was possible in the time allowed.

K-E4.1.1 Large Mammals

Up to 28 large mammal species may have occurred in the area in the recent past. Some of these (eg. lion *Panthera leo*, wild dog *Lycaon pictus*, hippopotamus *Hippopotamus amphibicus*) are almost certainly now locally extinct. Villagers reported the presence of spotted hyaena *Crocuta crocuta*, but these must now be very rare in the region. Very few ungulates were seen; steenbok *Raphicerus campestris* was seen on a number of occasions but is not common. Impala *Aepyceros melampus* and kudu *Tragelaphus strepsiceros* (identified only from droppings) were only recorded well away from settlements, mainly in the hinterland between the Motloutse and Sedibe rivers. Two klipspringer *Oreotragus oreotragus* were seen on Senyame Hill, and may occur sparsely on some of the other rocky outcrops in the area. Most of the larger game mammals have undoubtedly declined in recent years as people and livestock populations have increased. Hunting pressure, habitat modification, disturbance, and competition with livestock for food and water are likely to have been the main causal factors.

A small herd of elephants *Loxodonta africana*lives in the area between the Sedibe and the Motloutse rivers. Estimates of their numbers vary from 35 to 60. During this survey, the elephants were reported from the vicinity of the Madibeng Rapids on the Motloutse River, while day-old footprints and droppings of a small number of animals were found along the Sedibe River opposite Senyame Hill. Senyame Hill appears to be a centre of activity for this herd where much of the vegetation has been browsed.

Crop raiding and the threats posed by elephants to peoples' safety have apparently caused the abandonment of a number of small settlements and cattle posts in the area between the Sedibe and Motloutse rivers east of Senyame Hill. Persistent crop raiding also caused one farmer to abandon a small irrigation plot at the junction of the Sedibe and Motloutse rivers. Elephants could become a problem for small-scale irrigation farmers in the vicinity of the proposed reservoir, and although they could be deterred by the use of solar-powered electric fencing, this would add significantly to the cost of the establishing such schemes.

K-E4.1.2 Medium-sized and Small Mammals

Nearly 70% of the medium-sized and small mammals potentially occurring in the area are nocturnal and so are difficult to survey. The most commonly recorded diurnal mammals were the vervet monkey *Cercopithecus pygerythrus* and the bushveld tree squirrel *Paraxerus cepapi*. Vervet monkeys occur widely along the rivers and the more densely wooded tributaries, while the bushveld tree squirrels are widespread in relatively mature woodland. The scrub hare *Lepus saxatilis* is also reasonably common. There were surprisingly few rock dassies *Procavia capensis* or *Heterohyrax brucei* in the rocky outcrops adjacent to the dam site.

Among the rodents and small insectivores, *Tatera* species are common in the bottomlands and in certain upland areas where the soils are deeper. Many occupied burrows were seen. Stick nests of the tree mouse *Thallomys paedulcus* were seen in the some of the riparian woodlands. Rock Elephant-shrews, *Elephantulus myurus* were recorded on every rocky outcrop visited.

K-E4.2 Birds

A total of 120 species of birds were recorded in the project area in late January 1989 (Datalist K-E.3). The actual number of species present is likely to be considerably higher than this. The majority of species are small insectivores (53%), with seed eaters (11%), mixed feeders (8%), water birds (11%) and raptors, including owls (9%), comprising most of the remainder. The relatively large number of species of water birds in this semi-arid region is due to the presence of permanent pools of water on the Motloutse River downstream from its confluence with the Lethlakane River.

Most of the species recorded are typical of the region as a whole, though there were some interesting records. A juvenile Saddlebill Stork *Ephippiorhynchus senegalensis* was seen on the Motloutse River near Lerala and there are reports of the species having bred in riverine woodland downstream from the Motloutse/Letlhakane confluence. Boulder Chats *Pinarornis plumosus* were recorded on a number of the rocky outcrops in the proposed reservoir area. These records are on the extreme western end of this species' limited distribution. It is endemic to the granite shield country of Zimbabwe and only just enters Botswana along the Shashe/Motloutse watershed and neighbouring catchments. The records for Tropical Boubou *Laniarius aethiopicus*, while not unexpected, extend the recorded range of the species as given by Maclean (1984).

Numerous small flocks of Redbilled Quelea *Quelea quelea* were seen in the proposed reservoir area and in the irrigation areas downstream. This species is a serious pest of agricultural grain crops in southern Africa, including Botswana, and is a factor that must be taken into account in any planning for the development of irrigation areas downstream. Quelea populations are controlled by late dry season food supply, and they tend to rise in areas where this constraint is alleviated by year-round cultivation of small grains.

K-E4.3 Reptiles and Amphibians

No information was obtained on the composition or numbers of the reptile and amphibian fauna of the project area. General observations indicate that there is a high diversity of reptiles, including some species which are probably rare elsewhere in Botswana. The Giant

Plated Lizard *Gerrhosaurus validus* was common on the rocky outcrops of the project area. Like the Boulder Chat, it is a species confined to large granitic hills which only just occurs Botswana along the Shashe/Motloutse watershed. A more detailed survey of the herpetofauna is needed before the full impacts of the proposed dam can be determined.

K – E4.4 Insects and Microfauna

No information is available on this component of the fauna. Honeybees *Apis mellifera* are common and probably depend heavily on nectar and pollen from *Acacia* tree species. *Acacia tortilis* and *A. mellifera*, are considered to be major food sources for honeybees (Crane, 1985).

CHAPTER K-E5

ECOLOGICAL, ECONOMIC AND SCIENTIFIC IMPORTANCE OF THE BIOTA

K-E5.1 Rare Species of Plants

There has been no detailed assessment of the conservation status of plants in Botswana. Hall et al (1980) have reviewed the threatened plants of southern Africa, including Botswana. The review was based principally on herbarium records, published literature and the advice of specialists. For a country such as Botswana, in which relatively little collecting has been done, the assessment must be considered to be incomplete.

Fifteen plant taxa are listed as threatened. Of these, one is considered to be vulnerable, six as rare and eight uncertain (Datalist K-E.4). Only one of the taxa listed, *Albizia amara* sp. *sericocephala*, has been recorded from degree square 2127. It was not recorded in the project area.

The apparent absence of any endangered, vulnerable, or rare taxa in the project area should not be taken to imply that the conservation status of the plants occurring there is necessarily secure. First, the project area is little known botanically. Not much collecting has been done in the past (Figure K-E1). Secondly, by definition, rare plants are unlikely to be found easily, particularly in a two-week survey, although one species, *Rhinacanthus gracilis*, was collected for only the second time in Botswana (the first specimen having been collected during the Lower Shashe Dam Survey).

The rarity of a species, and therefore the threats posed to its survival, is also not simply an inverse function of its population size. The size of a species' geographic range and its degree of habitat specialisation also influence the species' vulnerability to disturbance or habitat destruction. For example, species such as *Combretum erythrophyllum* or *Faidherbia albida*, which are confined to the banks of the larger rivers, are vulnerable to changes in river flow regime irrespective of their abundance.

Because of the lack of collecting, neither the occurrence nor the status of potentially rare species can be assessed. The collections made during the environmental impact survey are not complete, though they are a start. It is suggested, therefore, that provision be made in the final proposal for a more thorough survey of the flora by the National Herbarium in Gaborone, the University of Botswana, or some other party, prior to construction of the Letsibogo Dam.

K-E5.2 Rare Species of Animals

As with the plants, there has been no overall assessment of the conservation status of any of the animal groups in Botswana. Moreover, unlike the plants, the reviews of the conservation status of southern African mammals and birds occurring in South Africa have not been extended to cover Botswana as well (Brooke, 1984; Smithers, 1986).

Figure K – E1

Number of Plant Specimens Collected from Different Quarter – Degree Grid Squares in North – Eastern Botswana

The data are derived from specimens recorded in the PRECIS data base (see Gibbs – Russell, Retief and Smook, 1984, for details; information provided by Moss, personal communication, 1989). The squares containing the reservoir and main irrigation areas are asterisked.

	27°E			28°E				29°E
21°S	2	0	71	0				
	0	1	0	0	0			
	0	4	1	1	0	0	0	0
	4	2	* 0	*34	* 0	* 0	0	0
22°S	4	3	0	60	0	0	0	0
	1	1	0	1	0	0	1	0
	14	1	6	0	2	5	51	13
23°S	1	0	1	15	5			

K – E5.2.1 Conservation Status of the Mammals

A number of the species which may occur in the project area are conserved species in terms of the Fauna Conservation Act (1982). These are indicated in Datalist K – E.2. Smithers (1986) has reviewed the conservation status of terrestrial mammals in neighbouring South Africa and some of the species included in that review may occur also in the project area. Their conservation status as given by Smithers (1986) is also indicated in Datalist K – E.2. Other than elephant, none of the species observed during the ecological survey are listed. Smithers (1986) lists elephant as "Out of Danger", implying a species which was once considered threatened but is now thought to be secure, at least in the immediate future.

Under present land use, the prospects for wildlife in the project area are limited. The general trend over the past decades or longer has been one of a gradual decline in the numbers and diversity of the larger mammals as human and livestock populations have increased (Campbell, 1983). The trend seems likely to continue. The causes of complex and include competition with livestock for food, water and space; habitat modifications; and hunting and disturbance by people.

Although game reserves and national parks cover over 1 million sq km (17%) of Botswana, and the proposed Wildlife Management Areas cover an additional 20% of the country, it should be noted that none of these are situated in the savanna ecosystems in the eastern part of the country (although the game ranches of the Tuli Block function as non – statutory

proposed reservoir, specifically the area between the Motloutse and Sedibe basins, as a wildlife conservation area with a potential to serve local tourism. The drawback is that proclamation of the area might alienate local cattlemen from a valuable dry season grazing area and, even if the area were restocked with game, the carrying capacity is likely to be low and the animals difficult to see, thereby diminishing the area's appeal to tourists.

K – E5.2.2 Conservation Status of the Birds

A wide variety of the larger bird species, including storks, vultures, birds of prey, and water birds other than duck and geese, are protected in Botswana under the 1982 Fauna Conservation Act. There is, however, no assessment of the conservation status of individual species in the country. Some of the species recorded during the survey are considered to be vulnerable or rare in South Africa (Brooke, 1986). These include *Ephippiorhynchus senegalensis*, Marabou *Leptoptilos crumeniferus*, Lappetfaced Vulture *Torgos tracheliotus*, and Bataleur *Terathopius ecaudatus*.

The population size of the Saddlebill Stork is estimated to be less than 50 pairs in South Africa (Brooke, 1986), and the species is probably rare in southern and eastern Botswana (it occurs more commonly in Chobe and the Okavango). The species is reported to have bred in riverine woodland along the Motloutse River in recent years. The sighting of a young bird there during the survey supports this, though it is not known whether the birds breed regularly here. The species requires reasonably large stands of mature, undisturbed riverine woodland for successful nesting. The impact of building a dam at Letsibogo would depend on whether there was a die-back of the riverine woodlands caused by a reduction in downstream river flow. On the positive side, the formation of a large reservoir could benefit the species by providing more foraging habitat for the storks.

One species not covered by Brooke (1986) is the Boulder Chat *Pinarornis plumosus*, a species endemic to the granitic shield of Zimbabwe and neighbouring Botswana. The species is confined to rocky hills and outcrops and is found on a number of these within the proposed reservoir. Construction of a dam would result in a loss of habitat for a number of pairs occupying the outcrops which lie on the proposed line of the dam wall. Nevertheless, the species occurs on other outcrops in the area and the construction of the dam would not appear to threaten seriously the conservation status of this species.

K – E5.3 Socially and Economically Important Species

K – E5.3.1 Medicinal Plants

Some of the medicinal plants commonly used by traditional doctors in Botswana and which are found in the project area are given in Datalist K – E.5. The majority of plants listed are common and widespread. Alternative sources of supply are available outside the reservoir development area. Consultations with local traditional doctors revealed that the site of the proposed dam at Letsibogo is not unique in any way. The construction of a dam would therefore not result in the irreparable loss of any medicinally important plants, nor would it threaten the livelihoods or status of the traditional doctors.

K – E5.3.2 Food Plants

Food obtained from wild plants are particularly important to rural people during drought years. A number of plant species occurring in the reservoir area are used by local inhabitants as supplementary food sources (Datalist K – E.5). The most important of these are the fruit trees *Azanza garckeana* (Setswana name: Morojwe), *Cissus cornifolia* (Mogogo), *Diospyros lycioides* (Motlhajwa), *Ficus* sp. (Motlhatsa), *Fluggea virosa* (Monwana), *Grewia* species (Mogwana/Moretlwa), *Sclerocarya birrea* (Morula), *Rhus pyroides* (Mogodiri), *Vangueria infausta* (Mmilo), and *Ximenia mucronata* (Morotologa). The leaves of some species are cooked as a relish, including *Cleome gynandra* (Rotho), *Corchorus asplenifolius* (Ledelele), and *Pergularia daemia* (Letlalagadi). Roots are also used, mainly *Boscia albitrunca* (Motlope), *Commiphora pyracanthoides* (Seroka and possibly other species), and various asclepiads including *Caralluma rogersii* and *Fockea angustifolia*.

Beverages, including alcoholic drinks, are made from the fleshy fruits of *Sclerocarya birrea*, the dried fruits of *Combretum hereroense* (Mokabe), the seeds and bark of *Boscia albitrunca*, the sap of *Hyphaene petersiana* (Mokolwane) and the leaves of *Terminalia prunioides* (Motsiara). The fleshy fruits of *Ximenia americana*, in addition to being eaten raw, are used to sour milk.

Although construction of a dam at Letsibogo would flood habitat in which many of these species occur, no populations would be at risk overall since the species all occur relatively widely throughout the region.

K – E5.3.3 Honey

A number of the *Acacia* species, particularly *A. tortilis* and *A. mellifera*, are important sources of nectar for honeybees *Apis mellifera* (Crane, 1985). The honeybees in turn are exploited by people. The loss of large areas of *Acacia* woodland through flooding could adversely affect the local honeybee population, honey production, and the pollination of other plants. The impact of the construction of a dam on nectiferous plants and their pollinators would depend on what other nectar sources and pollinators there are nearby that are unaffected by the reservoir. No information is available on these.

K – E5.3.4 Construction Materials

Plant species used for building homes, constructing fences, or making tools are listed in Datalist K – E.5. The most important general purposes woods are *Colophospermum mopane*, various *Acacia* and *Combretum* species, *Terminalia prunioides* and *T. sericea*, and *Ziziphus mucronata*. Axe and hoe handles are made from *Combretum hereroense*, while *Kirkia acuminata* is used for making sledges. Bark fibres and thin roots of *Acacia grandicornuta*, *A. galpinii*, *Sterculia rogersii*, and *Dregea macrantha* are used for making ropes.

A number of species are used to construct barrier fencing to keep goats, other livestock, and wildlife out of fields during the growing season. The branches of *Acacia* species are favoured, where they are available, although in upland areas where acacias are generally uncommon branches of *C. mopane* and other broad leaf species are used. The demand for fencing material is high and there is often a marked reduction in woody plant cover in the vicinity of well established fields.

In general, farmers with fields on alluvial soils alongside the rivers have access to abundant fencing material in the form of regenerating acacias, but farmers in the upland areas appear to have difficulty finding sufficient suitable material because of the general lack of thorn trees and therefore the need for greater amounts of non-spinescent species, such as *C. mopane* to construct an animal-proof fence. Moreover, the upland species appear to regrow more slowly than *Acacia* species so that the effect of harvesting material for fencing is more severe. The shortage of fencing material in the uplands would be one of the main constraints faced by farmers displaced from the bottomlands to the uplands by construction of the dam. The rates of woodland clearance in the uplands would likely accelerate.

There is a shortage of suitable thatching grass in the region. Wealthier individuals purchase or go and collect thatching grass from as far away as Serule. The poorer members of the community have to make do with local grass species, mainly *Eragrostis* sp. and *Aristida rhiniochloa*, which lack bulk and are insufficiently fibrous to last for more than a year or two. Construction of the dam would not threaten this already depleted resource and may even enhance it by encouraging the growth of reeds, sedges, and tall grasses which can be used for thatching.

K-E5.3.5 Fuelwoods

The quantities and value of timber used for firewood in the reservoir area are discussed in Appendix K-F. Tree species which are commonly used for fire wood in the project area are given in Datalist K-E.5. *Colophospermum mopane* is the most favoured and widely used species. The economic impact of dam construction on this resource would probably be minimal because most of the *C. mopane* woodland lies above the FSL of the proposed dam and there are other sources available within a reasonable distance.

K-E5.3.6 Livestock Forage

Livestock are the main source of wealth and security for most of the inhabitants of the proposed reservoir area and for many of the people living in Mmadinare and surrounding areas. The availability and quality of forage is therefore of crucial importance in determining the dynamics of the livestock populations and, thereby, the wealth of their owners. The forage resource can be divided into grazeable matter and browse since the plants in these categories exhibit somewhat different dynamics. Although it is conventional to classify livestock into grazers (cattle, donkeys, and sheep) and browsers (goats), the reality is that in this environment cattle and goats are mixed feeders.

Much of the area surveyed has been heavily grazed by livestock. Mean herbaceous canopy cover in 33 plots was 12% (range 1-60%). The highest cover was in riverine woodland on alluvial soils; the lowest in mopane woodland on eroded upland soils derived from granite-gneiss, though some compacted saline-sodic alluvial clays were also virtually devoid of herbaceous plants. The perennial grass cover is very low. Most of the herbaceous cover is made up of forbs and annual grasses. Many of the forbs are not eaten and are either unpalatable or toxic. Annual grasses lack bulk and so are generally not ideal fodder for grazers, thought some, such as *Urochloa trichopus*, are productive and do provide good quality grazing.

The production and quality of grazing is higher in the bottomlands alongside the rivers than in the uplands. The average crude protein content (CP) and *in vitro* dry matter digestibility (IVDMD) of seven grass species which grow primarily in the bottomlands is 8.1% CP and 58% IVDMD in summer and 5.4% CP and 36% IVDMD in winter. Corresponding values for seven predominantly upland grasses which occur in the project area are: summer – 6.3% CP, 52% IVDMD; winter – 3.9% CP, 31% IVDMD (data from Pratchett, in Field, 1976; DHV, 1980). Cattle in the tropics require a minimum of 6.3% crude protein to maintain body mass. Higher levels are needed for the animals to gain mass. Clearly, only the bottomlands have grasses of sufficient quality for cattle to grow, and then only during summer. The loss of the bottomland grazing areas through the formation of the reservoir would put local livestock and their owners under pressure. This issue is dealt with further in the following section.

In contrast to the grasses, shrubs and small trees have higher crude protein contents (see Table K–E5.1) but the presence of lignins, secondary chemicals such as tannins, and refractory carbohydrates interferes with the digestion of woody plant leaves. Nevertheless, some species are heavily browsed and are clearly an important resource for livestock (Table K–E5.1).

Browsing pressure is particularly high among those shrubs and small trees growing on the alluvial terraces and pediments. Unlike cattle, which forage in the uplands during winter, most small stock feed in the bottomlands throughout the year. Many of the favoured browse species occur throughout the area, but they are most abundant and grow best in the bottomlands. Inundation of these areas during the formation of the reservoir would represent a significant loss of key resources to the livestock owners of the area.

Table K–E5.1

Common Shrub Species Occurring in the Project Area.

Species	Mean Index of Browsing Pressure	Crude Protein (%) Summer	Winter
Rhigozum brevispinosum	3.7	–	–
Cadaba termitaria	3.0	–	–
Combretum apiculatum	2.3	15.1	12.2
Boscia albitrunca	2.1	15.8	14.8
Diospyros lycioides	2.0	–	–
Fluggea virosa	1.8	–	–
Dichrostachys cinerea	1.5	16.2	–
Acacia tortilis	1.2	19.4	15.0
Grewia flavescens	1.2	18.8	12.5
Grewia flava	1.1	15.2	12.6
Acacia erubescens (fleckii)	1.0	(22.6)	(13.2)
Acacia mellifera	1.0	27.1	14.1
Ziziphus mucronata	1.0	25.2	13.5
Commiphorapyracanthoides	0.8	–	–
Colophospermum mopane	0.6	14.7	12.3
Grewia bicolor	0.3	–	11.7
Grewia subspathulata	0.2	–	–

Notes:

a) The index of intensity of browsing pressure shows the degree of preference for different species (0 = not browsed, 1 = 1 – 20% of shoots browsed, 2 = 21 – 40%, 3 = 41 – 60%, 4 = 61 – 80%, 5 = 81 – 100%). Based on observations made in the project area January 1989.

b) Data on crude protein contents mainly from DHV (1980).

CHAPTER K-E6

ECOLOGICAL DYNAMICS

K-E6.1 Introduction

In order to assess the impacts that constructing a reservoir on the Motloutse River will have it is first necessary to establish the key ecological features of the system, in particular the relationships between soil type, soil moisture availability, plant growth, plant nutritional quality, and herbivory, and the ways in which these would be affected by the reservoir. Some processes such as rainwater runoff, sediment transport by overland flow, and herbivory, link spatially discrete areas and so act to transfer impacts across the catchment and, potentially, to feedback onto the functioning of the reservoir itself.

In the following discussion the productivity and dynamics of the herbaceous vegetation is emphasised because this resource is the base of most of the agricultural economy of the region. Changes in the timing and spatial location of grazing by domestic livestock caused by the loss of bottomland grazing areas would be among the most important and long lasting of the impacts of the reservoir.

K-E6.2 Determinants of Vegetation Structure and Productivity

K-E6.2.1 Soil Moisture Availability

The structure and dynamics of the vegetation in semi-arid ecosystems is determined primarily by moisture availability and secondarily by nutrients, herbivory and, occasionally, fire. The amount of moisture available to plants depends on the amount of rainfall; the duration of the rainy season; soil depth; soil texture; and position in the landscape.

Rainfall in Eastern Botswana is generally low, highly seasonal, and variable both between and within years. Most of the rain falls in short-duration, high-intensity storms in which the amount of rain falling often exceeds the short term infiltration capacity of the soil. The rate of infiltration depends on soil texture, soil surface conditions (particularly the amount of litter cover and soil capping), and the amount of antecedent soil moisture.

In general, sandy soils have higher infiltration rates than finer texture soils (see Annex F), but they also hold less water at saturation. Infiltration in sandy soils is restricted if the soils are compacted or have a well developed surface crust formed by the displacement of finer soil particles under raindrop impact. Infiltration is also affected by the extent of herbaceous plant and litter cover. Infiltration in soils under mopane woodland is positively correlated with litter cover (Kelly and Walker, 1976).

Much of the rain falling on sandy soils (other than shallow, rapidly saturated profiles) is absorbed and becomes available for plant growth. The annual yield of grasses on sandy soils therefore varies little between years and is poorly correlated with concurrent rainfall (Dye and Spear, 1982). The limited supply of nutrients may be the main factor limiting grass productivity in sandy soils.

In contrast, on clayey soils, infiltration rates are slower, more rainwater runs off, and more water is generally needed to wet the soil before the plants can begin growing. The effects of variations in rainfall amount are therefore more marked on clayey than on sandy soils. The annual yield of grasses, for example, is closely correlated with the amount of rainfall (Dye and Spear, 1982). In a region with highly variable rainfall, such as Eastern Botswana, wide fluctuations in grass yield also occur. Production in wet years can be very high (because of the generally higher fertility of clayey soils), but during dry years production can be almost nil.

Variations in soil texture, depth, and topographic position alter these relationships at the level of the landscape. Many of the upland soils are shallow and sandy, and therefore have a low water holding capacity. Consequently, during rainstorms the soil profiles rapidly become saturated, and the excess water runs off, transporting with it topsoil and nutrients. These are deposited in upland drainage lines and depressions, or in bottomland sites. As a result, some sites receive water and nutrients from surrounding areas and are able to remain productive even in relatively dry years. These key resource areas include bottomland sites on alluvium, the deeper soils on pediments, and upland drainage lines. Conditions for plant growth on these sites is better, the plants are generally more productive, often more nutritious, provided that the site is not too wet, and relatively resilient to grazing.

K – E6.2.2 Soil Nutrients, Herbivory and Fire

Soil nutrient status also affects plant distribution, growth and quality, although nutrients are probably less limiting than water in this region because of the low rate of weathering and leaching. Nevertheless, there is a broad association between *Acacia* – dominated communities and the more eutrophic soils found in the bottomlands, and mopane and mixed broad leaf woodlands and mesotrophic to dystrophic upland soils.

Interactions between vegetation, herbivores, and fire parallel these vegetation – soil relationships. Fire is an uncommon event in semi – arid savannas because there is usually insufficient herbaceous production to support a dry season fire of any significant intensity. A reduction in the dry season standing crop of grass by grazing further reduces the probability of fire. Sufficient grass to fuel a fire usually only accumulates after one or more seasons of above – average rainfall, particularly if these coincide with low cattle numbers, for example, after a severe drought.

Livestock browsing and grazing pressures are not spread uniformly across all the vegetation types. Some sites are heavily impacted, others hardly at all. Bottomland sites and drainage lines are favoured more than upland sites on shallow or stony soils because of the higher plant production and better quality. Flooding of the bottomlands would therefore result in the loss of a significant area of these key resources. Moreover, because of the differences in grazing capacity, the loss of bottomland sites cannot be compensated for by access to an equivalent area of upland.

K – E6.3 Livestock Movements

Despite the differences in plant production and quality between the bottomland and upland sites, they are not two independent production systems which can be substituted for each other (with appropriate adjustments in the size of the grazing areas to accommodate the

differences in productivity). The systems are part of a single livestock production system, linked through the seasonal movement of cattle and, to a lesser extent, other livestock.

Most livestock are concentrated in the bottomlands during the summer months. Plant quality and production is higher there (see Section K-E5.3 (6) and Tables K-E5.1 and K-E8.1), and the animals are able to gain weight. The grasses are generally resilient to grazing since most of them are able to grow despite being eaten.

With the onset of winter, plant growth ceases and the standing crop of forage gradually declines. Cattle in particular start to range more widely in search of food (or are moved by their owners for the same reason), and move into the uplands where there is still grass largely ungrazed (few animals feed in the uplands during summer). Although the nutrient quality of the upland grasses is below maintenance levels the animals supplement their diet with protein obtained from tree leaf litter, particularly that of *Colophospermum mopane*. The distance that the animals can range into the uplands is constrained by the lack of surface water. Consequently the animals do not usually move further than about a day's walk from water located along the rivers.

K-E6.4 Grass Stability

Because the grasses in the uplands are grazed when they are dormant, there is no direct feedback between grazing pressure and grass growth. The grasses can be heavily grazed and still be able to recover in summer, provided that they are not heavily grazed then as well. Continuous grazing of these grasses would add an additional stress to that already imposed by a generally unfavourable environment for growth. The upland grasses are therefore less resilient to grazing, if grazed all year round. The lack of regrowth during winter means that there is a gradual decline in grass standing crop with time. The earlier that the animals move up into the uplands in winter, the sooner they begin to reduce the grass standing crop and the quicker food shortages emerge.

The differences in forage production and quality between different land units, and the seasonal movements of livestock, among the patches of this mosaic enables the animals to offset partly the seasonal and inter-annual fluctuations in forage availability and quality. It is doubtful if, in the long run, either the uplands or the bottomlands could support the same numbers of livestock alone as a system in which both are used alternately.

K-E6.5 Implications for Livestock Management

To be successful, a livestock owner must have access to a range of grazing lands, from the more productive bottomland sites, to the upland sites where there is a dry season grazing reserve. Policies such as fixed land allocation, restrictions on distant or short range movements, or on the types of grazing areas to which the stock owner is allowed access, will adversely the ecological and economic sustainability of the system. It is essential therefore that any planned resettlement of people from the bottomlands should take into account and seek to maintain this dynamic interaction between these spatially separate but temporally linked grazing resources.

Possible changes in the management of livestock arising out of the relocation of people and animals also has implications for soil conservation in the catchment and thus for reservoir

functioning. If, as suggested, the upland grazing areas are less resilient to continuous grazing than the bottomlands and drainage lines, then plant and litter cover will decline. This will adversely affect rainwater infiltration rates. Reduced infiltration rates mean lower soil moisture levels in the soil, a shorter growing season, and a harsher environment for plant growth. Plants that are already being stressed by grazing now have to contend with a stressful growth environment as well. Recovery is slower (or not at all), forage availability declines, and the animals graze the remaining plants more heavily. Runoff increases and with it, potentially, soil erosion. The overall reduction in forage availability means greater pressure is placed on the remaining plants. Because the soil surface is exposed, compaction by animal hoof pressure and raindrop impact seals the soil and reduces infiltration rates even further.

Under these conditions only annual herbaceous plants and short-lived perennials survive. The abundance of annual forbs and grasses (relative to the paucity of perennials) in all the plots surveyed in the reservoir area and downstream, indicated that vegetation is already heavily stressed by grazing (and browsing). A number of degraded sites were seen in both the uplands and bottomlands. Despite a more than 50 % reduction in livestock numbers in the past two years as a result of drought, the vegetation looks heavily overgrazed. The potential for further reductions in plant cover and soil erosion to become more widespread is considerable, particularly if the current pressure on the lowlands is transferred to the uplands without detailed land-use planning.

If construction of a dam at Letsibogo is to go ahead, then a detailed land use and management plan for the catchment needs to be worked out and implemented. Such a plan should take into account the spatial and temporal variability in rainfall, soil moisture, plant production and quality, herbivory and animal movements are closely related. Events occurring in one part of the system (such as the construction of a reservoir, the provision of water points, or the settlement of people) will have direct and indirect consequences for the functioning of other parts of the system, and for their stability.

CHAPTER K-E7

ECOLOGICAL IMPACTS OF RESERVOIR DEVELOPMENT

K-E7.1 Direct Impacts

The construction of a dam on the Motloutse River will have both direct and indirect effects on the structure and functioning of the ecosystems in its vicinity, in the catchment, and downstream. Some of these may feedback to affect the functioning of the dam itself.

K-E7.1.1 Loss of Habitat in the Proposed Reservoir Basin

The most direct effect will be the loss of plant and animal habitat, and perhaps some species, through flooding. Riverine woodland, *Acacia*- dominated woodland, communities on rocky outcrops and ridges, and communities of old lands and settlements would be the ones most directly affected. None of these are unique to the area; similar communities occur upstream and downstream of the dam site. Nevertheless, attempts should be made to preserve some of the *Commiphora mollis-Kirkia acuminata* woodlands in the vicinity of the proposed damsite. The woodland at grid reference 2127D3 5743/75830 is a fine example of this vegetation type. It also has a number of sites of archeological importance and should be protected from damage if possible.

K-E7.1.2 Potential Loss of Species

No known threatened species of plant or animal occurs in the proposed reservoir area. One plant species, *Rhinacanthus gracilis* was collected from the base of one of the rocky outcrops near the damsite. This specimen is only the second one collected for Botswana. Subsequently, however, other specimens were collected near to and at Senyame Hill, above FSL. It is therefore felt that no special efforts need to be made to locate and secure any remaining specimens in the proposed reservoir basin. The plant is a small cryptic forb that has probably been overlooked before.

K-E7.1.3 Reduction in Downstream River Flow

The construction of the Letsibogo Dam will cut the amount of water flowing downstream during the wet season and will limit the recharge of the sand aquifers filling the river bed. This may affect the survival of riparian vegetation, depending on the amount by which river flow and aquifer recharge are reduced. Although the overall effect of the dam on the downstream riparian vegetation can only be fully assessed once the reduction in river flow and recharge have been estimated by hydrologists, present evidence suggests that the effect will not be severe. Tributaries such as the Lethlakane R will continue to feed water into the Motloutse (unless it too is dammed at a later stage). Species which are wholly or largely confined to the riparian fringe in this area, eg. *Combretum erythrophyllum*, *C. hereroense*, *C. imberbe*, *Acacia erioloba*, and *A. galpinii*, are mostly the taller trees and probably have deep enough roots to reach water well down in the riverbed.

In the longer term, the establishment and recruitment of subsequent generations of trees, including those listed above, may be adversely affected if there is a significant drop in the watertable in the alluvium. Given the importance of riparian vegetation in protecting the banks from excessive erosion, the longterm implications of this effect for river bank stability must be considered. Monitoring the vegetation at selected points along the Motloutse River downstream from the dam is recommended.

K-E7.1.4 Increased Erosion Downstream of the Dam

The Letsibogo dam would act as a sediment trap. The reduction in velocity as floodwaters enter the reservoir causes unloading of sediments at the head of the reservoir. Floodwaters spilling over the dam during peak flood, and gaining speed during the descent of the spillway would, be carrying less sediment than capacity. The floodwaters would therefore scour sediment from the riverbed and banks until the equilibrium between sediment load and transport capacity was re-established. This erosion may destabilise the riparian vegetation, both by reducing the amount of sediment in the riverbed, which holds water that is extracted during the dry season, and by undercutting the banks on which the plants are established. Scouring of the riverbed below the dam will also lower the local base levels of streams flowing into the main river. Increased erosion along the lower sections of these streams would be expected. It should be noted that the spillway retaining wall at Shashe Dam had to be extended at a cost of more than P 600 000 less than 10 years after construction because of the erosion and undercutting of the bank immediately below the dam.

The functioning of the riparian communities downstream of the dam would be affected by the attenuation of the flood peaks and by the release of sediment free waters. Instead of depositing sands and silts on the riverbanks and in the riverbed, the river would be likely to erode. The eroded material would be deposited downstream wherever rock bars form barriers across the river bed and reduce flood velocities. Perennials pools upstream of these rock bars would become silted up.

In order to minimise the adverse impact of the release of sediment free water on the ecology of the river downstream, it is important for the spillway to be designed in such a way that water flowing down it gathers as little velocity as possible. This can be done by building a wide rather than a narrow spillway. It is suggested that the spillway be built as wide, and with as shallow a gradient, as is technically and economically feasible.

K-E7.1.5 Provision of Compensation Flow

In order to maintain a supply of water for users downstream, it is proposed to release water periodically from the dam. The actually pattern of the proposed release has not yet been finalised but if water were drawn off from the bottom of the reservoir it would result in hypolimnetic water laden with silt, rich in nutrients and decaying particulate matter, deficient in oxygen, and cooler than the water which normally would flow down the river. Such water would have a number of adverse effects on organisms downstream.

Although too little is know about the biota of permanently saturated sand rivers to make firm predictions, the release of anoxic water would be likely to kill aquatic organism downstream near the dam. The discharge of silt-laden water would smother aquatic invertebrates and the river sediments, and seal the spaces between sand grains.

Eutrophication of the water downstream would occur, because of the hypertrophic nature of the discharge, and this would adversely affect water quality. If the discharge is to be continuous, or frequent, suitable conditions would be created for blackfly *Simulium* plagues. These are bloodsucking flies which transmit various viral diseases of livestock.

Insufficient information is currently available to discuss in any more detail the possible effects of the release of compensation water. It is suggested, however, that the proposals be discussed with limnologists and public health officials before a final decision is reached on this matter.

K-E7.2 Indirect Effects

The main indirect effects come from the resettlement of people and livestock and the attraction of people, livestock and wildlife to the reservoir area. The resettlement of people and the movement of livestock has been referred to above (Chapter K-E6).

K-E7.2.1 Attraction of People, Livestock, and Wildlife to the Reservoir

A large reservoir on the Motloutse River will attract people, livestock and wildlife, and will place pressure on the soils and vegetation around the dam. This may cause erosion of the surrounding catchment and increase sediment input to the dam, a process which could shorten its effective life-span and possibly threaten its long-term economic viability. This problem may already exist at Shashe Dam situated near Tonota, south of Francistown. It is examined below in the context of the potential for a similar problem to arise at the proposed Letsibogo Dam, and the kinds of responses that would be most appropriate.

K-E7.2.2 Livestock Incursions into the Reservoir Protection Zone

In order to stop pollution of the water by livestock, safeguard public health, and prevent erosion of the shorelines, the current policy of WUC is to exclude livestock from around the reservoirs under its control (WUC, 1975). A reservoir protection zone has been established around Shashe Dam and fenced, and water is provided by WUC at source to be pumped to watering troughs outside the perimeter fence. Any livestock found within the area are impounded. A team of six men on horseback are deployed fulltime to patrol the perimeter fence, report breakages, and impound livestock.

In practice, this scheme to compensate local livestock owners for the loss of traditional watering points has never worked satisfactorily. The water points were not established at the outset, although they were planned to be built at the same time as the dam. Consequently, livestock owners had to be granted access to the reservoir initially. This set a precedent. Even when the pumps and watertroughs were installed, livestock owners regularly had to be allowed to water their stock at the reservoir because of frequent breakdowns of the pumps.

Only one of the pumps is currently working and some of the water tanks and drinking troughs are in poor condition. Large numbers of livestock forage along the reservoir margins. For example, in February 1989, there were at least 485 head of cattle, 347 goats and sheep,

and 55 donkeys present on the shoreline. The actual numbers of animals using the reservoir daily is generally considered to be higher than this (Hopkins personal communication, 1989).

The failure of the water compensation scheme and the enforcement of the policy to keep livestock out of the reservoir protection zone by impounding livestock has created tensions between the water authority and the local communities. Local people cut the fence regularly and drive their livestock into the reservoir area. WUC spend considerable amounts of money patrolling, repairing and strengthening the fence.

The uncontrolled access of animals to the reservoir became a particular problem during the recent drought when large numbers of weakened animals were driven into the reservoir area to find grazing and water and subsequently died. In 1987 alone, WUC personnel had to remove about 400 carcasses of animals which had died after getting stuck in muds of the reservoir, thereby creating a serious health hazard to domestic water supplies drawn from the reservoir (Stafford personal communication, 1989).

Even if the water point scheme were to work satisfactorily it is doubtful if this would stop the incursion of livestock into the reservoir protection zone. This is because one of the principle reasons livestock owners cut the fence and drive their animals into the reservoir protection zone is not the need for drinking water but the need for access to better grazing areas, particularly during droughts.

K–E7.2.3 Controlled Grazing of the Reservoir Protection Zone

It is probably impractical to try to keep livestock out of the reservoir area in any way other than at great cost. Instead, it would be more appropriate to allow livestock owners, possibly under a leasing scheme, to graze their animals in selected areas along the shoreline provided that they were under control. Such a scheme could be enhanced by the establishment of suitable forage grasses in the drawdown zone, and the development of means to control the movement of the animals.

K–E7.2.4 Establishment of Forage Grasses in the Drawdown Zone

One species which should be investigated is *Panicum repens*, a cosmopolitan species that is adapted to growing in moist sites. It is widely distributed in suitable habitat in central and parts of southern Africa, including northern and eastern Botswana. It is palatable and highly productive, and is able to withstand heavy grazing and trampling by virtue of its extensive, dense rhizomatous root system. The species has colonised the shores of Lake Kariba on the Zambezi River, where it supports large numbers of wildlife grazers, and it has been planted on some commercial cattle ranches in Zimbabwe. It is a potential weed in cultivated lands, however, a factor which should be carefully evaluated before any decision is made to introduce it anywhere.

K–E7.2.5 Use of Solar–Powered Electric Fencing to Control Grazing

To confine livestock to selected areas requires herding or the erection of fences. Conventional cattle fences do not allow much flexibility in the allocation of grazing areas, as would be

needed for example in the drawdown zone of reservoirs where the area accessible to livestock varies unpredictably. Temporary fencing is more appropriate in these circumstances.

Recent developments in livestock management using portable, solar powered electric fencing, provide a solution to this problem. Two or three reel systems attached to high powered energisers are now commercially available in southern Africa (see Datalist K-E.6 for references to suppliers). Costs range from about P 2 000-P 3 000/km depending on the system used.

Power fencing has additional advantages. It is much more effective than conventional fencing at controlling small stock and has been used effectively against elephants in Zimbabwe. It can also be used to keep animals out of ecologically sensitive areas such as creeks or eroded shores. Because of its flexibility it can be deployed to control animal movements temporarily.

CHAPTER K-E8

EUTROPHICATION OF THE RESERVOIR AND THE GROWTH OF AQUATIC WEEDS

K-E8.1 Introduction

The enrichment of a waterbody with excessive quantities of plant nutrients such as phosphates and nitrates leads to the uncontrolled growth of phytoplankton and aquatic macrophytes. This can adversely affect water quality and increase the cost of providing water for domestic consumption. The amenity value of the reservoir can also be reduced.

Eutrophication results from a imbalance between nutrient loading and nutrient withdrawal. Nutrient inputs can come from both internal and external sources, mainly the decomposition of organic matter in the reservoir and the mobilisation of nutrients trapped in older alluvium and organic sediments (both internal); and the input of nutrients from the catchment and directly in rainfall (both external). Nutrients can be withdrawn by plants, fixed in lake sediments, or removed in water taken from the reservoir or released downstream. The effect of the additional nutrients on phytoplankton or aquatic macrophyte productivity will depend on whether plant production is constrained primarily by nutrients, temperature, light, or the hydrological regimes of the reservoir.

K-E8.2 Sources of Nutrients

K-E8.2.1 Decaying Organic Matter

The contribution of decomposing organic matter to eutrophication depends on the plant biomass present in the area to be flooded, the extent of clearing of this vegetation before flooding, the nutrient content of the remaining plant material, and its rate of decomposition. The estimated nutrient content of the plant communities in the area which would be flooded by the reservoir is given in Table K-E8.1.

Not all of these nutrients would be released immediately, however, since the rate of decay of wood in freshwater impoundments is relatively slow. For example, large numbers of dead trees still occur in Shashe Dam, 15 years after it first filled, and in Lake Kariba more than 25 years after the lake was formed. Most of the nutrient input from decaying vegetation will come from the decomposition of current growth (leaves and twigs).

In a number of southern African savanna woodlands current growth constitutes 8-9% of the total biomass in mature woodlands and 29-39% of total biomass in some shrub communities (Rutherford, 1982). Assuming therefore that 20% of the total biomass decomposes soon after the dam fills, a total of about 35 t N, 3 t P, 25 t K, 67 t Ca and 9 t Mg would be released into the reservoir. For a reservoir with a capacity of 100 $m^{3}10^{6}$, this would amount to the addition of of 0.35 mg/l N, 0.03 mg/l P, 0.25 mg/l K, 0.67 mg/l Ca and 0.09 mg/l Mg. These amounts are probably less than the quantities brought in annually in river flow during the wet season, but they are sufficiently high to create a mesotrophic reservoir (defined as one with a total P content of 0.005-0.03 mg/l, and a total N content of 0.25-1.0 mg/l (Hart and Allanson, 1984).

In calculating this input, no allowance has been made for possible losses during or after decomposition of the organic matter. Some nitrogen may be lost through denitrification if conditions on the lake bottom become anoxic. Phosphorus may become fixed in bottom sediments, possibly irreversibly if there is significant siltation.

Nevertheless, the release of nutrients from decaying organic matter has the potential to contribute to the eutrophication of the reservoir. Inputs from other sources, however, may be 4 – 5 times greater. While extensive clearing of the vegetation from the reservoir basin prior to flooding would reduced the input of nutrients from plant material, in the long – term it will be less significant than inputs brought in during annual floods.

Table K – E8.1

Estimated Mass of Nutrients Present in the Plant Biomass of the Basin of the Proposed Letsibogo Dam

Plant Community	Biomass t	N kg	P kg	K kg	Ca kg	Mg kg
1.a *C.marlothii – C.gratissimus*	126	1 069	99	921	2 569	328
1.b *C.mollis – K.acuminata*	607	5 147	478	4 437	12 377	1 578
2.a *C.erythrophyllum – A.karroo*	5 126	47 005	4 029	35 216	94 780	13 020
2.b *C.hereroense – P.africanum*	2 989	27 409	2 349	20 534	55 267	7 592
3.a *A.tortilis – B.albitrunca*	378	4 143	297	2 166	5 130	903
3.b *A.mellifera – A.tortilis*	3 101	33 987	2 437	17 769	42 081	7 411
3.c *A.erubescens – C.apiculatum*	839	7 694	659	5 764	15 513	2 131
4.a *C.mopane – A.nigrescens*	427	3 916	336	2 934	7 896	1 085
4.b *C.mopane – C.apiculatum*	3 478	29 493	2 737	25 424	70 916	9 043
4.c *C.mopane*	583	4 944	459	4 262	11 887	1 516
4.d *C.mopane – C.pyracanthoides*	427	3 621	336	3 121	8 707	1 110
5.a *A.tortilis*	501	5 491	394	2 871	6 799	1 197
Total	18 581	173 919	14 610	125 419	333 922	45 717
Total in shoots, twigs and bark (estimated)	3 716	34 784	2 922	25 084	66 784	9 143

Note:
Calculations based on the following average values for the nutrient content of twigs and stem wood (units mg/100g dry mass of wood).

Sample	N	P	K	Ca	Mg
Acacia species (n = 5)	1096	78.6	573	1357	239
Broadleaf species (n = 13)	848	78.7	731	2039	260
Combined (n = 18)	917	78.6	687	1849	254

K – E8.2.2 Nutrient Inputs from the Catchment

No measurements are available on the concentration of nutrients in the rivers at different times of the year. The rivers in eastern Botswana are subject to flash flooding. Because sediment transport (and therefore nutrient load) rises non – linearly with river flow velocity, the input of nutrients is likely to be pulsed and coincident with these periods of high flood. Spot measurements or average values of the nutrient load in the river water have little relevance under these circumstances.

K – E8.2.3 Solubilisation of Nutrients in Alluvial Sediments

The solubilisation of nutrients already present in alluvium in the reservoir basin cannot be prevented. Since of the soils are derived from granite – gneisses, the input may not be significant. There is also a dynamic equilibrium between the sorption and release of nutrients such as phosphorus from bottom sediments. This is controlled partly by the nature of the sediments and partly by the physical – chemical conditions in the waterbody. For example, phosphorus is released under anoxic conditions or at low concentrations in the waterbody, and is adsorbed when concentrations are high or under oxidising conditions. These contrasting conditions can vary seasonally resulting in net fixation at one time of the year and net release at another.

The amount of nutrients carried into the reservoir depends not only on the amount of runoff and the mass of sediments, but also on the degree of plant cover in the catchment, the amount of erosion, the nutrient status of the eroding substrate, and the land use practices upstream. Cultivation, irrigation and the associated use of fertilisers can add significantly to the nutrient load of a river. To safeguard water quality, and limit the occurrence of those biological problems associated with eutrophication, a management plan for the catchment is needed in which the most appropriate land use practices for different sectors of the catchment are identified and applied.

There is no information on the average number of livestock present daily throughout the year in the reservoir protection zone at Shashe Dam, nor any measurements of the quantity of faeces and urine deposited on the shoreline. Cattle produce about 25 kg fresh weight of dung and 9 kg of urine daily, containing on average 194 g N and 45 g P, as well as other elements (Petersen, Woodhouse and Lucas, 1956). This is equivalent to 71 kg N and 16 kg P annually. A herd of 400 cattle would therefore deposit approximately 28.3 t N and 6.4 t P annually, slightly less N than has been estimated to be released from the decomposing woody vegetation but considerably more P.

If all of this was deposited on the lake shore then it would add significantly to the nutrient content of the reservoir. But some of the nutrient would have come from vegetation growing in the drawdown zone which would be released anyway when the reservoir filled. Moreover, not all of the excreta deposited would be in the drawdown zone; the nutrients in excreta deposited outside this zone would probably be taken up by plants before they could be washed into the reservoir.

Although livestock may be responsible for some nutrient input, the sediments and organic matter brought in by floodwaters is likely to be the major source of nutrients. There are, however, no time – series data on the volume and composition of the inputs from these various sources which can be used to assess their relative importance. This information is

needed before the impact of livestock on the nutrient dynamics of reservoirs such as Shashe Dam can be fully evaluated.

K – E8.3 Hydrobiology and Water Quality Aspects

The likely hydrobiological characteristics of the proposed Letsibogo Reservoir and the probable aquatic weed problems which would result can be best discussed by reference to the current situation in at Shashe Dam. There is one important qualification: the hydrological and biological characteristics of each reservoir are somewhat unique since no two reservoirs are identical in terms of climate, geology, soils, and vegetation of the catchment; the position of the impoundment along the river system; the biota present in the impoundment and upstream; and the management regime. These will all affect the chemical and physical characteristics of water coming into the reservoir and its characteristics afterwards. Extrapolations from one reservoir to another should therefore be viewed cautiously, especially when there is almost no hydrobiological data available from either site.

K – E8.3.1 Hydrobiological Characteristics of Shashe Dam

Shashe Dam is situated on the Shashe River, approximately 20 km southwest of Francistown. The dam was constructed in 1971/72 and was commissioned in 1973. It has a capacity of approximately 85 m^{3106} and a surface area of just over 18 km^2. The annual drawdown varies from about 1.3 to 2.1 m below FSL, equivalent to 21 to 31 $m^{310}6$. Mean annual runoff from the 4 126 km^2 catchment is about 90 $m^{310}6$, enough to fill the reservoir to overflowing annually. The reservoir has overflowed in 11 of the 14 years since it first filled in January 1974.

There is little information on the open water chemistry or hydrobiology of Shashe Dam. Only a few spot samples of the water have been taken (Table K – E8.2: Gilmore, 1978; WUC, unpublished). Isolated samples, however, contribute little to understanding the dynamics of the reservoir since most physical and chemical variables in impoundments fluctuate greatly over short periods of time. Nevertheless, the limited data suggest that the water is almost neutral to slightly alkaline (pH 6.8 – 7.5), and mesotrophic with respect to nitrogen (1.0 – 1.3 mg/l) but eutrophic with respect to phosphorus (0.2 mg/l). Both N and P are implicated in the eutrophication of freshwater systems, though P is generally considered to be most limiting in southern African impoundments. The data presented here, however, if representative, suggest that nitrogen is more likely to be limiting and that the trophic status of Shashe Dam and possibly also other reservoirs constructed in the region would be determined by nitrate levels and their dynamics.

Shashe Dam is turbid, with turbidity values ranging from 400 NTU in summer, after flooding, to less than 40 NTU at the end of the dry season (NTU = Nephelometric Turbidity Units, an empirical measure of the amount of light scattering at right angles to the incident light). Turbidity values as low as 2 have been recorded following a long period without any inflow to the reservoir (Stafford, personal communication, 1989). The coincidence of high turbidity and peak inflow indicates that most of the suspended material originates from material brought down during floods, although wind induced turbulence may be responsible for slowing down the rate of sedimentation of this material. Some settled material may also be re-suspended during the late dry season when strong easterly winds blow.

Table K – 8.2

Water Quality Data for Selected Variables for Shashe Dam

Variable	Units	Data source Gilmore (1978)	WUC (unpubl)
Conductivity	µmhos	118.0	92.0
pH	pH units	7.5	6.8
Total Dissolved Solids	mg/l	88.0	82.0
Nitrate	mg/l	1.0	1.3
Phosphate	mg/l	0.2	–
Potassium	mg/l	3.3	3.6
Calcium	mg/l	15.0	10.5
Sodium	mg/l	6.0	2.9

Note: WUC unpublished data collected 25.02.81.
Data collected by Gilmore in May 1978.

K – E8.3.2 Phytoplankton Blooms

Phytoplankton blooms occur annually during late winter and early spring. The main species involved are the cyanobacteria, *Microcystis* sp (called *Anacystis* in WUC reports) and Anabaena *flos – aquae*, and they impart an bad odour and taste to the water (WUC, 1987). Both species can be toxic, even lethal at high concentrations, to people and animals drinking untreated or poorly treated water. In most cases the effects are sublethal and cause intestinal and dermatological disorders. For example, the incidence of diahorrhea among children in Harare, Zimbabwe is positively correlation with the annual peaks in the concentrations of these algae in neighbouring Lake McIlwaine from where their drinking water comes (Marshall, unpublished).

Copper sulphate is used to control of the phytoplankton blooms in the vicinity of the intake tower at Shashe Dam. This is only a short – term solution and addresses the symptoms, not the causes, of the problem. In addition to killing the phytoplankton, copper sulphate also kills aquatic plants and animals, including fish. This can destabilise the foodchains in the reservoir, with unknown consequences. Moreover, the decay of the dead organisms merely releases nutrients which become available to support the next bloom.

Excessive phytoplankton growth can add significantly to the operating costs of the water treatment plants. During the phytoplankton blooms at Shashe, water passing through the treatment works at both Shashe and Selebi – Phikwe is pretreated with chlorine. Because of this, poly – electrolyte cannot be used as a flocculant and the more costly ferric chloride and lime treatment has to be used instead. Extensive pre – chlorination has another major disadvantage in that potentially carcinogenic trihalomethanes can form in the treated water (Hart and Allanson, 1984).

K – E8.3.3 Aquatic Macrophytes

None of the common aquatic weeds, eg. *Eichornia crassipes*, *Pistea stratiotes* or *Salvinia molesta*, have been recorded at Shashe Dam. Their absence does not necessarily imply unsuitable conditions for their establishment and spread. None of the species have so far not been recorded from the seasonal river systems of Eastern Botswana and WUC check and spray all boats brought to the reservoir to prevent the accidental introductions. The only potential weed species found at Shashe Dam was *Ludwigia stolonifera*, a species which has been implicated in the closure of waterways in the Okavango Swamps and is said to be troublesome in irrigated crops (Wild, 1961). It was found only at the top of one of the side-arms of the reservoir and is unlikely to spread uncontrollably.

Stands of *Phragmites mauritianus* occur along the shoreline of Shashe Dam, particularly along the sheltered eastern shores and protected bays along the reservoir. It also occurs in all of the main rivers of the region. It can close up bays and inlets, and in the long term contribute to the encroachment of the shoreline into the water body, thereby reducing the storage capacity and amenity value of the reservoir. On the positive side, stands of *Phragmites* serve as nesting habitat for a number of waterbirds, which can be an attraction, as well as protecting the shoreline from erosion by waves. WUC personnel at Shashe Dam do not consider the growth of *Phragmites* to pose any significant problems.

The establishment of *Phragmites* is probably limited by a combination of excessive wave action on exposed shores, silting and too frequent desiccation. There is little growth near the head of the reservoir where the reservoir basin is covered with relatively deep deposits of silt. These are regularly exposed during the annual drawdown of water during which time they dry out and crack. Some individual *Phragmites* plants which are established close to FSL, and are currently 1.5 – 2 m above waterlevel, appeared more stressed than those closer to water.

K – E8.3.4 Causes of Excessive Growth of Aquatic Plants

The excessive growth of phytoplankton and aquatic macrophytes in impoundments is usually a symptom of eutrophication. WUC suggest that excreta deposited by cattle feeding along the shoreline is the main cause of enrichment at Shashe Dam (WUC, 1987; Stafford, personal communication 1989). The highly seasonal occurrence of these blooms, however, suggests that other factors are probably involved, at least in determining the timing of the blooms. Livestock are present around the reservoir throughout the year despite the efforts of WUC personnel to prevent this. The phytoplankton blooms, on the other hand, occur in late winter and early spring (July – September), well before any significant amount of nutrients from livestock excreta would have been washed into the reservoir by the annual rains.

The blooms at Shashe Dam is associated with the annual, winter overturn of reservoir water that follows the disappearance of the summer thermocline separating the warm, nutrient-poor surface waters from the colder, nutrient-rich bottom waters. High turbidity contributes to the formation of the thermocline by restricting the depth of penetration of solar radiation, and therefore heating, to a shallow surface layer.

Turbulence induced by wind can cause some mixing, especially in shallower waters, but generally mixing will not occur so long as the temperature differential between the the surface and bottom waters persists. As a result, nutrients in the surface waters are gradually depleted

as the phytoplankton populations grow, and the bottom waters are correspondingly enriched as organic matter originating in the surface waters sinks and decays. The bottom waters gradually become anoxic as microbial decomposers use up the available oxygen, leading to further enrichment as phosphorus is released from the lake sediments under anaerobic conditions.

Phytoplankton production is eventually limited by a combination of the depletion of nutrients in the surface waters, and the lower solar radiation levels and ambient temperatures in autumn. Renewed production follows the winter overturn when nutrient rich water rises to the surface. The rise in ambient temperatures in late winter re-creates suitable conditions for the growth of phytoplankton. This is when the water quality problems caused by phytoplankton blooms are experienced at Shashe Dam.

The scale of the problem posed by the excessive growth of aquatic organisms depends largely on the degree of eutrophication of the reservoir and on whether plant growth is limited by factors other than nutrients. The problems of excessive phytoplankton growth experienced at Shashe Dam seem to be relatively minor compared to those expereienced at some other southern African impoundments. Light rather than nutrients may be the major limiting factor. The water in the reservoir is turbid for much of the year, and turbidity has been shown to limit phytoplankton production (eg. *Microcystis aeruginosus*: Robarts and Zohary, 1984).

K-E8.4 Potential Water Quality Problems in the Letsibogo Reservoir

A reservoir on the Motloutse River would probably have similar hydrological characteristics (relatively high turbidity; moderate nutrient status) to those of Shashe Dam. It is therefore unlikely that the problems of excessive phytoplankton growth currently experienced at Shashe Dam would be any greater in the proposed Letsibogo Reservoir. The problems can be expected to increase in drought years when water levels are continuously low because of the absence of inflow and the concentration of nutrients by evaporation is greatest. Reduced flow also means a decline in turbidity, allowing greater depth of penetration of PAR and a possible stimulation of algal production.

Regular monitoring of selected hydrological and biological variables would provide some warning of impending problems. This monitoring should be an integral part of the operating procedures of the proposed reservoir.

DATA LIST K-E1.1

LIST OF PLANT SPECIES COLLECTED IN THE MOTLOUTSE CATCHMENT

Introduction

Enquiries during the Scheme Identification Studies at the University of Botswana and the National Herbarium showed that there had been virtually no systematic collection of plant material from the Motloutse valley until its confluence with the Limpopo river. In the Tuli Block some specimens had been submitted by de Beer (1953-1959), Yalala (1962), van Rensburg (1970), Mott (1976), Woolard (1977-1978), Timberlake (1978), Moss (1981), Sydes (1985) and Kalake (1986).

Material collected during July and August 1988 by the socio-economist and the soil surveyor between Mmadinare and Bobonong was identified directly from existing texts and/or specimens submitted to the National Herbarium (Gaborone). In October and December 1988 and in February 1989 a team from the Biology Department of the University of Botswana (see Chapter 1) also collected specimens from the reservoir and downstream to Tobane. In February 1989 the consultant ecologist and his wife collected specimens from the reservoir area and in selected sites on the riverain strip and irrigation areas down to Tobane. These specimens were identified by R.B. Drummond and S. Kativu (Poaceae) of the National Herbarium of Harare.

The following list incorporates identified specimens from all the sources of floral collection in the Motloutse valley to date. Wherever the collector has recorded the main form and association of the specimens these have also been noted for future reference. There was not the time available in this study to complete the full details of some of these characteristics. Whilst there are readily observable differences in the tree species in the main vegetation associations discussed in Appendix K-E, the Forbes found in the understorey vary more in quantity than in the range of species, except on the kopjes, although a few species are only to be found close to the rivers. The differing relative numbers of individuals are probably a function of overgrazing of rangelands and of time since abandonment of old lands.

Wherever the collector indicated a location the notation has followed standard herbarium practice of map referencing, i.e. 2127D4 (=2127DD), 2128C3 (=2128CC), and 2128C4 (=2128CD). Dam site 31 (Letsibogo) occurs in quarter-degree square 2127DC. Species collected by any source and logged with the Herbarium are identified by an asterisk (*). No localities are given for species which are widespread and occurred throughout the area.

Scientific names and authorities for the plants follows those used currently by the compilers of the Flora Zambesiaca. Although most of the collected material was positively identified, some problematic identifications remain. All material identified in the field as *Grewia monticola* was identified as *G. subspathulata*, a species thought to be a natural hybrid between *G. monticola* and *G. bicolor*. All records of *G. monticola* are therefore incorporated into, and referred to, as *G. subspathulata*. It was not possible to distinguish unequivocally between *Acacia robusta* from *A. grandicornuta*, the species identified in the field. Consequently, all identifications are restricted to *A. grandicornuta* although the occurrence of *A. robusta* in the survey area is highly likely. *Commiphora pyracanthoides* var. *glandulosa* is now classified as a separate species *Commiphora glandulosa*, which is normally a medium-sized tree. *Commiphora pyracanthoides* is a normally low-growing shrub. Consequently, all tree-sized individuals have been classed as *C. glandulosa*. No distinctions, however, were made among shrub-sized individuals and they are accordingly all listed as *C. pyracanthoides*, though some plants may have been young *C. glandulosa*.

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT	LOCATION
	PTERIDOPHYTA				
	ADIANTHACEAE				
1	Actinopteris raddianum	Presl.			*
	MARSILEACEAE				
1	Marsilea farinosa	Launert			* 2127DD
2	Chielanthes viridis was Pellaea viridis	(Forssk.) Swartz			*
	OPHIOGLOSSACEAE				
1	Ophioglosum polyphyllum	A.Br. ex Seub.			*
	SPERMATOPHYTA				
	DICOTYLEDONS				
	ACANTHACEAE				
1	Asystasia schimperi	T.Anders		Acacia/mopane woodland	*
2	Barleria affinis	(L.) C.B.Cl.			* 2127DC
3	Barleria capitata	Klotszch		Hill	*
4	Barleria holubii	C.B.Cl.			* 2127DC
5	Barleria lugardii	C.B.Cl.			* 2127DC
6	Barleria senensis	Klotszch			*
7	Blepharis serrulata	(Nees) Fic & Hiern		Acacia/mopane woodland	* 2127DC
8	Blepharis transvaalensis	Schinz			*
9	Crabbea velutina	S.Moore			* 2127DC
10	Justicia flava	(Forssk.) Vahl			* 2127DC
11	Justicia metammensis	(Schweinf.) Oliv.		Hill	*
12	Monechma sp.				*
13	Nelsonia nova ?				*
14	Peristrophe kotschyana	Nees			* 2128CD
15	Peristrophe paniculata	(Forssk.) Brummitt			* 2127DD
16	Rhinacanthus gracilis	Klotzsch			* 2127DC
17	Ruellia patula	Jacq.			*
18	Thunbergia neglecta	Sond.		Riverine	*
	AIZOACEAE (See also Molluginaceae)				
1	Gisekia africana	(Louv.) Kuntze		Acacia woodland	*
2	Hypertelis bowkeriana	Sond.		Acacia woodland	*
3	Zaleya pentandra	(L.) Jeffrey			* 2127DD
	AMARANTHACEAE				
1	Achyranthes aspera	L.			Common
	- var. sicula	L.			*
2	Achyropsis leptostachya	(E.May.ex Meissn.) Hook.f.			* 2127DD
3	Alternanthera nodiflora	R.Br.			* 2127DC/2127DD
4	Alternanthera pungens	Kunth			

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT		LOCATION
	AMARANTHACEAE (contd)					
5	Amaranthus hybridus	L.	Sethababerike		*	2127DD
6	Gomphrena celosioides	Mart.			*	2127DC
7	Hermbstaedtia odorata	(Burch.)T.Cooke		Acacia woodland	*	
8	Pupalia lappacea	(L.) A.Juss.	Bogoma		*	
	- var. lappacea				*	2127DC/2128DC
9	Sericorema remotiflora	(Hook.f.) Lopr.			*	2127DC
	ANACARDIACEAE					
	Lannea schwienfurthii	(Engl.) Engl.			*	
1	- var. stuhlmanni	(Engl) Kokwaro		Kopje	*	
2	- var. tomentosa	(Dunkley) Kokwaro			*	2127DC
3	Ozoroa paniculosa	(Sond.) R & A Fern.	Monotane	Decid woodland/rocky	*	
4	Rhus leptodictya	Diels	Motshotlho	Open woodland/rocky	*	
5	Rhus pyroides	Burch.	Mogodiri	Open woodland/rocky	*	Common
6	Sclerocarya birrea	(A.Rich) Hochst.	Morula	Base of kopjes	*	Common
	- ssp. caffra	(Sond.)Kokwaro	Morula	Open woodland	*	2127DC
	ANNONACEAE					
1	Artabotrys brachypetalus	Benth.		Riverine fringe	*	
	APIACEAE (UMBELLIFEREAE)					
1	Heteromorpha trifoliata	(Wendl.) Eckl. & Zeyh.		Base of kopjes	*	2127DC/2128CC
2	Steganotaenia araliacea	Huchst.	Morobolo	Base of kopjes	*	
	APOCYNACEAE					
1	Strophanthus kombe	Oliv.			*	
	ASCLEPIADACEAE (including PERIPLOCACEAE)					
1	Caralluma rogersii	(L.Bolus)E.Bruce & R.Dyer			*	2127DC
2	Dregea macrantha	Klotzsch.		Acacia/mopane woodland	*	2127DC
3	Fockea angustifolia	K.Schum.			*	2127DC
4	Gomphocarpus tomentosus	Burch.			*	2128CC
5	Pergularia daemia	(Forssk.) Chiov.	Letlalagadi	General	*	2128CC
6	Raphionacme monteiroae ?	(Oliv.)N.E.Br.			*	2127DC
7	Sarcostemma viminale	(L.)R.Br.			*	
8	Stapelia gigantea	N.E.Br.			*	2127DC
9	Stomatostemma monteiroae	(Oliv.)N.E.Br.		Acacia/mopane woodland	*	2127DC
	ASTERACEAE (COMPOSITAE)					
1	Acanthospermum hispidum	DC.	Setlhebakolobe		*	
2	Bidens pilosa	L.				Common
3	Blumea decurrens	(Vahl) Merxm.			*	2127DD
4	Blumea gariepina	DC.	Motlalemetse	Disturbed sandy	*	2127DD
5	Conyza bonariensis	(L.) Cronq.			*	
6	Dicoma schinzii	O.Hoffm.			*	
7	Flaveria bidentis	(L.) Kuntze		Hill	*	

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT	LOCATION
	ASTERACEAE (COMPOSITAE) (contd)				
8	Geigeria acaulis	Benth,J.Hook ex Oliv/Hiern			* 2127DC
9	Geigeria burkei	Harv.			
	- ssp. burkei				* 2127DC/2127DD
10	Geigeria ornativa	O.Hoffm.		Acacia/mopane woodland	*
11	Helichrysum argyrosphaerum	DC.	Vaalbos		*
12	Helichrysum candolleanum	Buek	Vaalbos		* 2127DC
13	Kleinia longiflora	DC.			* 2127DC
14	Nidorella auriculata	DC.			* 2127DC
15	Nidorella resedifolia	DC.		Acacia/mopane woodland	*
16	Osteospermum muricatum	E.Mey ex DC.		General	*
17	Philyrophyllum schinzii	O.Hoffm.		Acacia/mopane woodland	*
18	Pluchea leubnitziae	(Kuntze) N.E.Br.			* 2128CD
19	Psiada arabica	Jaub. & Spach.	Mosikamabi	Watercourses	* 2128CC
20	Sphaeranthus peduncularis	DC.		River banks	
21	- ssp. peduncularis				* 2128CC
22	Senecio sp.				*
23	Sonchus sp.			General	*
24	Tarchonanthus camphoratus	L.	Mohatlha	General	* 2127DC
25	Verbesina enceloides	(Cav.) Benth. J.Hook		General	*
26	Vernonia cinerascens	Sch. Bip.		Dry woodland	*
27	Vernonia fastigiata	Oliv & Hiern		General	*
28	Vernonia glabra	(Steetz) Vatke			*
29	Xanthium spinosum	L.	Lepero	sandy	* 2127DD
30	Xanthium strumarium	L.		River banks	*
	BALANITACEAE				
1	Balanites pedicellaris	Mildbr. & Schlecht.			* 2128/2228
	BIGNONIACEAE				
1	Catophractes alexandri	D.Don		Limestone ridges	2127DC
2	Markhamia acuminata =	(Klotzsch.) K.Schum.		Riverine fringe	*
	Markhamia zanzibarica	(DC.) K.Schum			* 2127DC
3	Rhigozum brevispinosum	Kuntze		Rocky woodland	2127DC
	BOMBACACEAE				
1	Adansonia digitata	L.	Mowana	Dry woodland	* 2227BB
	BORAGINACEAE				
1	Ehretia amoena	Klotzsch	Morobe	Riparian	*
2	Ehretia rigida	(Thunb.) Druce	Morobe	Widespread	Common
3	Heliotropium steudneri	Vatke	Letlhogotshweu	Ac.woodland/riverine	*
	BRASSICACEAE (CRUCIFERAE)				
1	Rorippa fluviatilis	(Mey.ex Sond.) Thell.			*

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT		LOCATION
	BURSERACEAE					
1	Commiphora africana	(A.Rich.) Engl.	Mokomoto,Motapo	Dry woodland/rocky	*	
	- var. africana					2127DC
2	Commiphora marlothii	Engl.	Mokomoto,Mophaphama	Rocky	*	2127DC
3	Commiphora mollis	(Oliv.) Engl.	Mokomoto,Motapo	Dry woodland/rocky	*	2127DC
4	Commiphora pyracanthoides	Engl.	Moroka/Seroka	Dry woodland/rocky	*	2127DC
5	- ssp. glandulosa	(Schinz) Wild		Dry woodland/rocky		2127DC
6	Commiphora tenuipetiolata	Engl.			*	
	CACTACEAE					
1	Opuntia ficus-indica	Miller	Motoroko	Rocky introduced sp.		Escaped
	CAPPARACEAE					
1	Boscia albitrunca	(Burch.) Gilg. & Bened.	Motlhopi	Open woodland	*	2127DC
2	Boscia foetida	Schinz	Mopipi	Dry bushveld	*	
3	Cadaba aphylla	(Thunb.) Wild	Monnamontso	Dry bushveld/limestone	*	2127DC
4	Cadaba termitaria	N.E.Br.	Makgolela	Dry bushveld	*	2127DC
5	Cleome augustifolia	Forssk.		Woodland	*	
6	Cleome gynandra =	L.	Mhitswana,Rotho	Dry bushveld/limestone	*	2128CD
	Gynandropsis gynandra	(L.) Brig.				
7	Maerua angolensis	DC.	Moomane	Woodland/thicket	*	2127DC/2128CC
8	Maerua juncea	Pax	Modikaseolo	Woodland/thicket	*	2127DD
	- ssp. crustata	(Wild) Wild			*	2127DD
9	Maerua parvifolia	Pax		Woodland/thicket	*	2127DC
	CELASTRACEAE					
1	Maytenus heterophylla	(Eckl. & Zeyr.)N.K.Robson		Widespread		
	- ssp. heterophylla				*	2127DD
2	Maytenus senegalensis	(Lam.) Exell	Motlhono	Widespread		Common
	CHENOPODIACEAE					
1	Chenopodium ambrosioides	L.			*	2128CD
2	Chenopodium carinatum	R.Br.			*	2128CD
	COMBRETACEAE					
1	Combretum apiculatum	Sond.	Mohudiri	Woodland		Common
	- ssp. apiculatum					
2	Combretum erythrophyllum	(Burch.) Sond.	Modubanoka,Modubu	Riverine		2127DC/2127DD
						2128CC/2128CD
3	Combretum hereroense	Schinz	Mokabi	Wooded grassland	*	2127DC/2127DD
						2128CC/2128CD
4	Combretum imberbe	Wawra	Motswiri	Riverine/woodland		
5	Combretum molle	R.Br ex G.Don	Moduba	Woodland	*	
6	Combretum mossambicense	(Klotzsch) Engl.		Riverine fringe/kopje	*	2127DC
7	Terminalia brachystemma	Welw. ex Hiern		Sands	*	
8	Terminalia prunoides	G.Laws	Motsiara	Woodland/shrub	*	Common
9	Terminalia sericea	Burch. ex DC.	Mogonono,Mokubu	Sandy	*	2127DC

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT	LOCATION
	CONVOLVULACEAE				
1	Evolvulus alsinoides	(L.) L.		Common	* 2127DD
2	Ipomoea bolusiana	Schinz		Mopane woodland	*
3	Ipomoea magnusiana	Schinz			* 2127DC
4	Ipomoea obscura	(L.) Ker-Gawl.			* 2127DC
5	Merremia kentrocaulos	(C.B.Cl.) Rendle			*
	- var. pinnatifida	N.E.Br.			* 2127DC
6	Merremia palmata	Hall.f.			*
7	Merremia tridentata	(L.) Hallf.	Motantanyane	Rocky	* 2128CC
8	Seddera suffruticosa				*
9	Xenostegia tridentata = Merremia tridentata	(L.) Austin & Staples			
	CRASSULACEAE				
1	Kalanchoe brachyloba	Welw. ex Britten			* 2127DC/2128CC
2	Kalanchoe thyrsiflora (?)	R. Hamet			*
3	Kalanchoe rotundifolia	(Haw.) Haw.			* 2127DC
	CUCURBITACEAE				
1	Acanthosicyos naudinianus	(Sond.) C. Jeffrey			*
2	Coccinea sp.			Mopane woodland	*
3	Cucumis hirsutus	Sond.		Acacia/mopane woodland	* 2127DC
4	Cucumis metuliferus	E.Mey. ex Naud.		Acacia woodland	*
5	Cucumis tributus				*
6	Momordica balsamina	L.		Acacia/mopane woodland	*
7	Momordica repens	Bremek.		Acacia/mopane woodland	* 2127DC/2128CC
	EBENACEAE				
1	Diospyros lycioides	Desf.	Letlhaja,letlhawa	Widespread	* Common
	- ssp. lycioides				
2	Euclea divinorum	Hiern	Motlhakola	Widespread	*
3	Euclea undulata	Thunb.	Motlhakolwana	Widespread	Common
	ELATINACEAE				
1	Bergia sp.			Barren areas	*
	EUPHORBIACEAE				
1	Acalypha indica	L.		Rocky/Overgrazed woods	* 2127DD
2	Bridelia mollis	Hutch.		Rocky	2127DC
3	Chamaesyce eyelesii was Euphorbia eyelesii	(Rendle) Koutnik			*
4	Chamaesyce mossambicensis was Euph. mossambicensis	(Klotzch.& Garcke) Koutnik		Acacia woodland	*
5	Chamaesyce neopolycnmoides	(Pax & K.Hoffm.) Koutnik			* 2127DC
6	was Euph. neopolycnmoides				
7	Croton gratissimus - var. gratissimus	Burch.	Moologa	Woodland/rocky	2127DC
8	Euphorbia cooperi	N.E.Br. ex A.Berger		Rocky	*

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT		LOCATION
	EUPHORBIACEAE (Contd)					
9	Euphorbia griseola	Pax				
	- ssp. griseola				*	2127DC
10	Euphorbia guerichiana	Pax		Sand/rocks	*	
11	Euphorbia ingens	E.Meyer ex Boiss.	Mookoso	Decid woodland/rocky	*	
12	Euphorbia tirucalli	L.			*	
	Fluggea virosa = securinega virosa	(Willd.) Voigt	Monwana			2127DC
13	Jatropha sp.				*	
14	Phyllanthus maderaspatensis	L.		Acacia/mopane woodland		2127DC
15	Phyllanthus pentandrus	Schumach. & Thonn.		A. tortilis woodland	*	
16	Phyllanthus reticulatus	Poir.			*	
17	Pterococcus africanus	(Sond.) Pax & K.Hoffm.		Rocky	*	
18	Ricinus communis	L.				2127DC/2127DD
19	Securinega virosa	(Roxb. ex Willd.) Baillon	Monwana	Decid woodland/rocky	*	
20	Spirostachys africana	Sond.	Morukuru	Riverine	*	
21	Tragia okanyua	Pax		Rocky	*	2127DC
	FABACEAE (LEGUMINOSAE)					
	- sub-family CAESALPINIOIDEAE					
	Bauhinia esculenta = Tylosema		Morama	Woodland/thicket	*	
1	Bauhinia petersiana	Bolle	Mokoshi	Sandy woodland	*	
2	Burkea africana	Hook.	Monato	Woodland	*	
3	Cassia abbreviata	Oliv.	Monepenepe	Open woodland/rocky		
	- ssp. beareana	(Holmes) Brenan		Hill	*	Common
4	Colophospermum mopane	(Benth.) J.Leonard	Mopane	Woodland		Common
5	Peltophorum africanum	Sond.	Mosetlha	Wooded grassland		Common
6	Schotia brachypetala	Sond.		Woodland	*	Tuli Block
7	Tylosema esculenta	(Burch.) A.Schreib.				
	- sub-family MIMOSACEAE					
1	Acacia albida	(Del.) A.Chev.	Mokosho	Riverine/woodland		2127DD/2128CC 2128CD
2	Acacia arenaria	Schinz	Motsilaphala	Sandy woodland	*	
3	Acacia burkei	Benth.	Mokgwa	Riverine	*	
4	Acacia caffra	(Thunb.) Willd.	Morutlhare	Rocky	*	
5	Acacia erioloba	E.Mey.	Mogothlo	Sandy woodland		Common
6	Acacia erubescens	Welw. ex. Oliv.	Moloto	Mainly watercourses		Common
7	Acacia fleckii	Schinz	Mhahu	Sandy thicket	*	
8	Acacia galpinii	Burtt Davy	Mokala,Mophoka	Riparian	*	2127DD
9	Acacia gerrardii	Benth.	Moga,Moki,Motsha	Woodland,heavy soils	*	
10	Acacia grandicornuta	Gerstner	Moshauka	Mopane woodland	*	2127DD
11	Acacia karroo	Hayne, Darstell, Beschreib	Mooka,Mookana	Mostly riverine	*	
12	Acacia mellifera	(Vahl) Benth.	Mongana,Monyaka	Dryland		
	- ssp. detinens	(Burch.) Brenan				Common
13	Acacia nebrownii	Burtt Davy	Lerwana	Dryland thicket	*	2127DD
14	Acacia nigrescens	Oliv.	Mokoba	Woodland/grassland	*	Common
15	Acacia nilotica	(L.) Willd. ex Del.	Motlabokgosi	Woodland/grassland		

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT	LOCATION
	- sub-family MIMOSACEAE (contd)				
	- ssp. kraussiana	(Benth.) Brenan			* 2127DD
16	Acacia robusta	Burch.	Moshaoka,Moqa	Woodland/grassland	2127DD
	- ssp. clavigera	(E.May) Brenan			Common
17	Acacia schweinfurthii	Brenan & Exell		Riverine/dryland	*
18	Acacia senegal	(L.) Willd.		Basic rocky slopes	*
	- var. leiorhachis				
19	Acacia sieberana	DC.	Moremosetlha	Riverine/woodland	*
20	Acacia tenuispina	Verd.	Lerula	Vertisols	*
21	Acacia tortilis	(Forsk.) Hayne	Mosu	Widespread/old lands	Common
	- ssp. heteracantha	(Burch.) Brenan			Common
22	Albizia amara	(Roxb.) Boiv.	Mmola	Woodland	*
23	Albizia anthelmintica	(A.Rich.) Brongn.	Monoga	Woodland	2128CD
24	Albizia brevifolia	Schinz	Mmola	Woodland	*
25	Albizia harveyi	Fourn.	Minola	Woodland/hill	*
26	Dichrostachys cinerea	(L.) Wight & Arn.	Moselesele	Wooded grassland	Common
27	Elephantorrhiza goetzei	Benth.	Mositsane	Rocky slopes	* 2127DC
28	Elephantorrhiza burkei	(Harms) Harms	Mositsane	Rocky slopes	
	Faidherbia albida = Acacia albida				
	- sub-family PAPILIONACEAE				
1	Bolusanthus speciosus	(Bolus) Harms	Motsokophala	Wooded grassland	* Common
2	Cullen obtusifolia	(DC.) Stirton			* 2127DD
3	Dalbergia melanoxylon	Guill. & Perr.		Mixed woodland/rocky	* 2127DC
4	Decorsea schlechteri	(Harms) Verdc.			* 2127DC
5	Erythrina latissima	E.Mey		Woodland	2127DC
6	Indigofera circinnata	Benth. ex Harv.		Acacia/mopane woodland	*
7	Indigofera cryptantha	Harv.			* 2127DC/2127DD
	- var. cryptantha				*
8	Indigofera holubii	N.E.Br.		Acacia woodland	*
9	Indigofera trita	L.f.			* 2127DC
10	Indigofera vicioides	Jaub. & Spach			Common
	- var. rogersii	(R.E.Fr.) Gillett		Riverine/woodland	*
11	Lonchocarpus capassa	Rolfe	Mopororo	Dry woodland	2127DD
12	Lonchocarpus nelsii	(Schinz) Schinz	Mhata,Mhoto,Mhatu		Common
13	Otoptera burchellii	DC.		General	*
14	Rhynchosia totta	(Thunb.) DC.			
	- var. totta			Acacia woodland	* 2127DC
15	Stylosanthes fruticosa	(Retz.) Alston		Riverine/alluvium	* Tuli Block
16	Tephrosia purpurea	(L.) Pers.			
	- ssp. leptostachya	(DC.) Brummitt			
	- var. pubescens	(Bak.) Brummitt			
17	Xanthocercis zambesiaca	(Bak.) Dumaz-le Grand	Motha		
	GERANIACEAE				
1	Monsonia burkeana	DC.		Acacia woodland	* Common
2	Monsonia glauca	Knuth.		General	*

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	LAMIACEAE (LABIATAE)					
1	Becium filamentosum	(Forssk.) Chiov.			*	2127DC
2	Becium kirkii	Bak.		Acacia woodland	*	
3	Endostemon tereticaulis	(Poir.) Ashby			*	2127DD
4	Leonotis sp.					
5	Leucas glabrata	(Vahl.) Sm.			*	2127DC/2128CC
	- var. glabrata					2128CD
6	Leucas sexadentata	Skan			*	
7	Ocimum canum =	Sims			*	2127DC/2127DD
						2128CC
	Ocimum fructiculosum					
8	Ocimum urticifolium	Roth			*	2127DC
9	Plectranthus caninus	Roth			*	2127DC
	LOGANIACEAE					
1	Strychnos madagascariensis	Poir.	Mogorogorwane	Rocky/mopane woodland	*	2128CD
2	Strychnos pungens	Soler.	Mogwagwa	Rocky	*	
	LORANTHACEAE					
1	Erianthemum ngamicum	(Sprague) Danser		Acacia/mopane woodland	*	
2	Plicosepalus kalachariensis	(Schinz) Danser				2127DD
3	Tapinanthus oleifolius	(Wendl.) Danser			*	
4	Tapinanthus sambesiacus	(Engl. & Schinz) Danser			*	2127DC
	MALVACEAE					
1	Abutilon angulatum	(Guill. & Perr.) Mast.		Riverine/woodland	*	
2	Abutilon grandiflorum	(Willd.) Sweet			*	2127DC
3	Abutilon matopense	Gibbs				2127DD
4	Abutilon rehmannii	Bak f.			*	2127DC
5	Azanza garckeana	(F.Hoffm.)Exell & Hill.	Morojwe	Woodland/rocky	*	2127DC/2127DD
6	Gossypium herbaceum	L.		Acacia/mopane woodland	*	
	- var. africanum	(Watt) Hutch. & Ghose			*	2127DD
7	Hibiscus calyphyllus	Cav		General	*	
8	Hibiscus dongolensis	Del.			*	2127DC
9	Hibiscus engleri	K.Schum.			*	2127DC
10	Hibiscus micranthus	L.f.		Mopane woodland	*	2127DD
11	Hibiscus mutatus	N.E.Br.			*	2127DC
12	Hibiscus ovalifolius	(Forssk.) Vahl			*	2127DD/2128CC
13	Hibiscus praeteritus	R.A Dyer			*	
14	Hibiscus schinzii	Guerke		Acacia woodland	*	
15	Hibiscus sidiformis	Baill.		Acacia woodland	*	
16	Hibiscus subreniformis	Burtt Davy			*	2128CD
17	Hibiscus vitifolius	L.		General	*	
18	Pavonia burchellii =	(DC.) R.A.Dyer			*	2127DC
	Pavonia patens	(And.) Chiov.				
19	Pavonia senegalensis	(Cav.) Leistner			*	2128CD
20	Sida alba	L.	Motatshoana		*	2128CD
21	Sida chrysantha	Ulbr.	Motatshoana		*	

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT	LOCATION
	MALVACEAE (contd)				
22	Sida cordifolia	L.			* 2127DC
23	Sida hoepfneri	Goerke			* 2127DC
24	Wissadula rostrata	(Schumach.) Hook.f.		General	*
	MELIACEAE				
1	Melia azedarach	L.	Morulwana	Sandy	*
2	Turraea obtusifolia	Hochst.		General	*
	MENISPERMACEAE				
1	Cocculus hirsutus	(L.) Diels			* 2128CD
2	Tinospora caffra	(Miers) Troupin			* 2127DC
	MOLLUGINACEAE				
1	Corbichonia decunbens	(Forssk.) Exell		Mopane woodland	*
2	Glinus bainesii	(Oliv.) Pax			* 2128/2228
3	Glinus oppositifolius	(L.) DC.			* 2128CC
4	Limeum fenestratum	(Fenzi) Heimerl.		Acacia/mopane woodland	*
5	Limeum sulcatum	(Klotzsch) Hutch.			2127DC/2127DD
6	Mollugo cerviana	(L.) Ser. ex DC.		Acacia woodland	*
7	Mollugo nudicaulis	Lam.		Hill	* 2127DC
	MORACEAE				
1	Ficus abutilifolia = Ficus soldanella	Miq.	Motlhatsa	Rocky	* Common
2	Ficus cordata - ssp. salicifolia	Thunb. (Vahl) Berg	Motlhatsa	Rocky	* 2128CD
3	Ficus tettensis	Hutch.	Motlhatsa	Rocky	* 2127DC
	NYCTAGINACEAE				
1	Boerhavia erecta	L.		Acacia woodland	*
2	Boerhavia oppositifola	L.			* 2128CD
3	Commicarpus helenae	(J.A.Schultes) Meikle			* 2127DC/2127DD
4	Commicarpus pentandrus	(Burch.) Heimerl		Acacia woodland	*
5	Commicarpus squarrosus	(Heimmerl) Standl.			* 2128/2228
	OCHNACEAE				
1	Ochna inermis	(Forssk.) Schweinf.			* 2127DC
2	Ochna pulchra	Hook.	Monyelenyele	Sandstone woodland	*
	OLACACEAE				
1	Ximenia americana	L.	Morotologa wa pudi	Sandy open woodland	2127DC/2127DD
2	Ximenia caffra	Sond.	Morotologa		*
	OLEACEAE				
1	Jasminum stenolobum	Rolfe			* 2127DD/2128CD

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT		LOCATION
	PAPAVERACEAE					
1	Argemone mexicana = Argemone subfusiformis	L. G.B.Ownbey		Riverine	*	2127DC/2127DD 2128CC/2128CD
	PASSIFLORACEAE					
1	Adenia digitata	(Harv.) Engl.			*	2127DC
2	Adenia glauca	Schinz		Rocky	*	
	PEDALIACEAE					
1	Ceratotheca triloba	(Bernh.) Hook.f.			*	2127DC
2	Dicerocaryum eriocarpum was Diceroc. zanguebarium	(Decne) Abels			*	
3	Harpagophytum procumbens		Sengaparile/Makakare	Acacia shrubland	*	
4	Harpagophytum zeyheri - ssp. sublobatum	Decne (Engl.) Ihlenfeld			*	2127DC/2127DD
5	Holubia saccata	Oliv.				2127DD
6	Pterodiscus ngamicus	Stapf			*	2127DC
7	Pterodiscus speciosus	Hook.f.		General	*	
8	Sesamothamnus lugardii	N.E.Br.			*	2128/2228
	PLUMBAGINACEAE					
1	Plumbago zeylanica	L.	Bogoma	River banks	*	2127DC/2127DD 2128CD
	POLYGALACEAE					
1	Polygala sphenoptera	Fresen		Mopane woodland	*	
	POLYGONACEAE					
1	Oxygonum sinuatum	(Hochst.& Steud. ex Meisn.) Damm.		Acacia woodland	*	2127DC
2	Polygonum lapathifolium	L.			*	
	PORTULACACEAE					
1	Portulaca kermesina	N.E.Br.			*	2127DC
2	Portulaca quadrifida	L.			*	
3	Talinum tenuissimum	Dinter			*	2127DC
	RANUNCULACEAE					
1	Clematis brachiata	Thunb.			*	
	RHAMNACEAE					
1	Berchemia discolor	(Klotzsch) Hemsl.			*	2128CD
2	Ziziphus mucronata	Willd.	Mokgalo	Riverine		Common
	RUBIACEAE					
1	Gardenia spatulifolia = Gardenia volkensii	K.Schum.	Morala	Open woodland	*	
2	Gardenia thonningii				*	
3	Kohautia aspera	(Staff. & Hutch.) Verdc.		Mopane woodland	*	

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT	LOCATION
	RUBIACEAE (contd)				
4	Pavetta gardeniifolia	A.Rich.		Rocky/open woodland	*
	- var. subtomentosa	K.Schum.			* 2127DC
5	Psydrax livida	(Hiern) Bridson	Modumelantswe	Woodland/thicket/rocky	*
	was Canthium huillense				
6	Spermacoce senensis	(Klotzsch) Hiern		Very common	*
7	Vangueria infausta	Burch.	Mmilo	Wooded grassland/rocky	* 2127DC
	SALVADORACEAE				
1	Salvadora angustifolia	Turrill			*
2	- var. australis	Schweick.			* 2128CD
	SAPINDACEAE				
1	Cardiospermum corindum	L.		Rocky	*
2	Pappea capensis	Eckl. & Zeyh.	Mopenwaeng	Near dwellings	* 2127DC
	SCROPHULARIACEAE				
1	Antherothamnus pearsonii	N.E.Br.		Hill	* 2127DC
2	Aptosimum lineare	Marl. & Engl.		Acacia woodland	* 2127DC
3	Craterostigma plantagineum	Hochst.		Acacia/mopane woodland	*
	SIMAROUBACEAE				
1	Kirkia acuminata	Oliv.	Modumela	Woodland/rocky	* 2127DC
	SOLANACEAE				
1	Datura innoxia	Mill.			* 2128/2228
2	Datura stramonium	L.			2127DC
3	Lycium cinereum	Thunb.			* 2127DD
4	Lycium shawii	Roem. & Schult.			* 2128CC/2128CD
5	Nicotiania glauca	R.C.Grah.			2127DC
6	Solanum delagoense	Dun.		Acacia/mopane woodland	*
7	Solanum incanum	L.			* 2127DD
8	Solanum kwebense	N.E.Br.		Acacia/mopane woodland	*
9	Solanum nigrum	L.		Hill	*
10	Solanum panduriforme	E.Mey		Acacia/mopane woodland	*
11	Solanum supinum	Dun			Common
12	Solanum tomentosum	L.		General	* 2127DC
	STERCULIACEAE				
1	Dombeya rotundifolia	(Hochst.) Planch.	Motubana	Rocky/sandy	*
2	Hermannia kirkii	Mast			*
3	Hermannia quartiniana	A. Rich			*
4	Melhania acuminata	Mast			*
5	Melhania forbesii	Planch. ex Mast.		General	*
6	Sterculia africana	(Lour.) Fiori	Mokokobugu	Rocky	
7	Sterculia rogersii	N.E.Br.	Mokakata	Rocky	* 2127DC
8	Waltheria indica	L.	Seretlhwane,sesennye	Sandy/Acacia woodland	* 2127CC

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT		LOCATION
	TILIACEAE					
1	Corchorus asplenifolius	Burch.	Letelele	Kopje	*	2127DC/2127DD
2	Grewia bicolor	Juss.	Mogwana	Riverine/sandy/rocky	*	Common
3	Grewia flava	DC.	Moretlwa	Riverine/sandy	*	Common
4	Grewia flavescens	Juss.	Mokgompathe	Riverine/sandy/rocky	*	
	- var. flavescens					Common
	- var. olunkondae	(Schinz) Wild			*	2127DD
5	Grewia monticola	Sond.	Mogwana kgomo	Riverine/woodland		Common
6	Grewia retinervas	Burret	Motsotsojane	Deeper sands	*	
7	Grewia subspathulata	N.E.Br.		Acacia woodland	*	
8	Grewia villosa	Willd.			*	Common
	TURNERACEAE					
1	Piriqueta capensis	(Harv.) Urb.			*	2128CC
2	Streptopetalum serratum	Hochst.			*	2127DC
3	Tricliceras schinzii	Urb.		Acacia woodland	*	
	URTICACEAE					
1	Pouzolzia hypoleuca =	Wedd.		General	*	
	Pouzolzia mixta	Solms				2127DC
	VAHLIACEAE					
1	Vahlia capensis	(L.f.) Thunb.				
	- sub sp. vulgaris	Bridson		Hill	*	2127DC
	VERBENACEAE					
1	Clerodendrum myricoides	(Hochst.) Vatke		Rocky	*	2127DC
2	Clerodendrum ternatum			General	*	
3	Lantana camara				*	
4	Lippia javanica	(Burm.f.) Spreng	Mosukujani		*	
5	Plexipus pinnatifidus	(L.f.) R.Fernandes		General	*	
	was Chascanum pinnatifidus					
	VITACEAE					
1	Cissus cornifolia	(Bak.) Planch.	Mogogo		*	2127DC
2	Cissus quadrangularis	L.		Acacia/mopane woodland	*	2127DC
3	Cyphostemma puberulum	(C.A.Sm.) Wild & Drum.		Rocky	*	2127DC
	ZYGOPHYLLACEAE					
1	Tribulus terrestris	L.	Mosethlo	Ac.shrub/cleared land	*	Common
1	YET TO BE IDENTIFIED		Monyaku	woodland	*	2128CC

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT	LOCATION
	MONOCOTYLEDONS				
	AGAVACEAE				
1	Sansevieria aethiopica	Thunb.			2127DC
	ALOEACEAE (LILIACEAE)				
1	Aloe greatheadii	Schonl.			* 2127DC
2	Aloe littoralis	Bak	Mokgopha	Mopane woodland	
	AMARYLLIDACEAE				
1	Crinum sp.				* 2127DC
2	Scadoxus puniceus	(L.) Friis & Nordal			Common
	ARECACEAE (PALMAE)				
1	Hyphaene coriacea	Gaertn.	Mokolwane	Sandy	Tuli block
2	Hyphaene petersiana	Klotzch ex Mart.			2128CD
3	Phoenix reclinata	Jacq.			2228
	ASPARAGACEAE (LILIACEAE)				
1	Protasparagus africanus	(Lam.) Oberm.		General	* Common
2	Protasparagus exuvialis	Burch.		General	* Common
3	Protasparagus laricinus	Burch.			* Common
4	Protasparagus suaveolens	(Burch.) Oberm.		General	* 2127DC
	COMMELINACEAE				
1	Aneilema hookii	De Wild.		General	*
2	Commelina africana	L.	Mosigamabe		* 2128CC/2127DD
	- var. krebsiana	(Kunth) C.B.Cl.		Acacia woodland	* 2127DC
3	Commelina diffusa	Burm.f.		General	*
4	Commelina livingstonia	C.B.Cl.		General	*
	CYPERACEAE				
1	Bulbostylis hispidula	(Vahl) Haines			* Common
2	Cyperus dives	Del.			*
3	Cyperus fulgens	C.B.Cl.		Hill	*
4	Cyperus holostigma	Schweinf.			*
5	Cyperus involucratus	(Rottb.) Kuek.			* 2127DD
6	Fimbristylis hispidula	(Vahl) Kunth			*
7	Fuirena pubescens	(Poir.) Kunth			*
8	Kyllinga alba	Nees			* Common
9	Mariscus hamulosus	(M.Bieb) Hooper			*
10	Mariscus rehmannianus	C.B.Cl.			* Common
	HYACINTHACEAE (LILIACEAE)				
1	Eriospermum bakerianum	Schinz.		General	*
2	Eriospermum sphaerophyllum	Bak.		General	*
3	Eucomis cf. autumnalis	(Mill.) Chitt.			2127DC

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT	LOCATION
	HYACINTHACEAE (LILIACEAE) (contd)				
4	Ledebouria hyacinthina	Roth			* 2127DC
5	Ledebouria revoluta	(L.f.) Jessop		Mopane woodland	*
6	Urginea cf. altissima	(L.f.) Bak			* 2127DC
	ORCHIDACEAE				
1	Ansellia africana	Lindl.			2127DC
	POACEAE (GRAMINAE)				
1	Andropogon festuciformis	Rendle			*
2	Aristida adscensionis	L.			* 2128CD
3	Aristida barbicollis	Trin.& Rupr.			Common
4	Aristida canescens				*
5	Aristida congesta	Roem.& Schult.			* 2127DC
6	Aristida rhiniochloa	Hochst.			Common
7	Aristida scabrivalvis	Hack.			Common
	- ssp. contracta	(De Winter) Melderis			Common
8	Brachiaria deflexa	(Schum)C.Hubbard ex Robyns			* 2127DC
9	Brachiaria eruciformis	(J.E.S.M.) Griseb.			* Tuli Block
10	Brachiaria nigropedata	(Munro)Stapf			*
11	Cenchrus ciliaris	L.			*
12	Chloris virgata	Swartz			2128CD
13	Cymbosetaria sagittifolia	(A.Rich)Schweick			*
14	Cynodon dactylon	(L.) Pers.	Motlho		*
15	Dactyloctenium aegyptium	(L.)			Common
16	Digitaria milanjiana	(Rendle) Stapf			* 2127DC
17	Digitaria nuda	Schumach.			* 2127DD/2128CD
18	Digitaria perrottetii	(Kunth) Stapf			* 2128CD
19	Digitaria velutina	(Forsck.)Beauv.			*
20	Echinochloa colona	(L.) Link			* 2127DC/2127DD
21	Enneapogon cenchroides	(Licht) C.E. Hubbard			Common
22	Enteropogon macrostychyus	(A.Rich.) Benth.			* 2127DC
23	Eragrostis biflora	Hack.			Common
24	Eragrostis cilianensis	(All.) F.T. Hubbard			* 2127DD
25	Eragrostis cylindriflora	Hochst.			*
26	Eragrostis lehmanniana	Nees			* 2128CD
27	Eragrostis pallens	Hack.	Motsikiri		*
28	Eragrostis porosa	Nees			* 2127DC
29	Eragrostis racemosa				*
30	Eragrostis rigadior	Pilg.	Rathathe		Common
31	Eragrostis superba	Peyr.			* 2127DC
32	Eragrostis trichophora	Coss. & Dur.			* 2127DC
33	Microchlora caffra	Nees			*
34	Oropetium capense	Stapf			* 2127DD
35	Panicum deustum	Thunb.			* Tuli Block
36	Panicum maximum	Jacq.			Common
37	Phragmites mauritianus	Kunth	Lotlhaka		Common
38	Pogonarthria squarrosa	(Roem. & Schult.) Pilg.			2127DC

	BINOMIAL	AUTHORITY	LOCAL NAME	MAIN HABITAT		LOCATION
	POACEAE (GRAMINAE) (contd)					
39	Rhynchelytrum repens	(Willd.) C.E. Hubbard			*	2128CD
40	Schmidtia kalahariensis	Stent.			*	
41	Schmidtia pappophoroides	Steud.ex J.A.Schmidt			*	
42	Setaria pumila	(Poir.) Roem. & Schult.			*	2127DC
43	Setaria sagittifolia	A. Rich.				Common
44	Setaria ustilata	de Wit			*	
45	Setaria verticillata	(L.) Beauv.				Common
46	Sporobolus festivus				*	
47	Sporobolus ioclados	(Trin.) Nees				Common
48	Stipagrostis uniplumis - var. uniplum is	(Licht.) De Winter	Tsikhitshane		*	
49	Tragus berteronianus	Schult.				Common
50	Tricholaena monachne	(Trin.) Stapf & Hubbard			*	2128CD/2127DC
51	Urochloa mosambicensis	(Hack.) Dandy				2127DD
52	Urochloa panicoides	Beauv.			*	
53	Urochloa trichopus	(Hochst.) Stapf			*	2127DC/2128CD
54	?		Makgai a namane		*	
	VELLOZIACEAE					
1	Xerophyta humilis	(Bak.) Durand & Schinz		Rocky	*	
2	Xerophyta retinervis	Bak.		Rocky	*	
3	Xerophyta schlechteri	(Bak.) N. Menezes		Rocky	*	2228

DATA LIST K – E2.1

LIST OF MAMMALS POTENTIALLY OCCURRING IN PROJECT AREA

The following mammals are reported to occur, or to have occurred until recently, in the project area (Smithers, 1971, 1983; de Graaff 1981).

* = species recorded from the project area during this survey.
? = possible occurrence, based on reports from local inhabitants.
o = rodent species for which there are specimens from within quarter – degree squares 2127D or 2128C (from de Graaff, 1981)
m = species' distribution is marginal to project area.
\+ = species probably no longer occurs in the area.

The conservation status (see Data List K – E4.1) of the species is given after the scientific name: P = protected species in terms of the 1982 Fauna Conservation Act. There is no assessment of the conservation status of Botswanan mammals but species which are listed as threatened in South Africa (Smithers, 1986) and which occur also in Botswana are indicated: E = Endangered, V = Vulnerable; R = Rare; I = Indeterminate; O = Out of danger (a species which was formerly considered to be threatened).

Soricidae	
Tiny Musk Shrew	*Crocidura bicolor*
Reddish – grey Musk Shrew	*Crocidura cyanea*
Lesser Red Musk Shrew	*Crocidura hirta*
Erinaceidae	
South African Hedgehog	*Erinaceous frontalis* R
Macroscelidae	
Short – snouted Elephant – shrew	*Elephantulus brachyrhynchus*
Bushveld Elephant – shrew	*Elephantulus intufi*
* Rock Elephant – shrew	*Elephantulus myurus*
Emballonuridae	
Tomb Bat	*Taphozous mauritianus*
Molossidae	
Egyptian Free – tailed Bat	*Tadarida aegyptiaca*
Vespertilionidae	
Schreiber's Long – fingered Bat	*Miniopterus schreibersii*
Rusty Bat	*Pipistrellus rusticus* I
Cape Serotine Bat	*Eptesicus capensis*
Yellow House Bat	*Scotophilus dinganii*
Schlieffen's Bat	*Nycticeius schlieffenii*
Nycteridae	
Common Slit – faced Bat	*Nycteris thebaica*
Rhinolophidae	
Hildebrandt's Horseshoe Bat	*Rhinolophus hildebrandti*
Darling's Horseshoe Bat	*Rhinolophus darlingi*

Galagidae	
Lesser Bushbaby	*Galago senegalensis* P
Cercopithecidae	
Chacma Baboon	*Papio ursinus*
* Vervet Monkey	*Cercopithecus pygerythrus*
Manidae	
Pangolin	*Manis temminckii* PV
Leporidae	
* Scrub Hare	*Lepus saxatilis*
Jameson's Red Rock Rabbit	*Pronolagus randensis*
Bathyergidae	
Common Molerat	*Cryptomys hottentotus*
Hystricidae	
Porcupine	*Hystrix africae – australis*
Pedetidae	
o Springhare	*Pedetes capensis*
Gliridae	
Rock Dormouse	*Graphiurus platyops*
Woodland Dormouse	*Graphiurus murinus*
Sciuridae	
o* Bushveld Squirrel	*Paraxerus cepapi*
Muridae	
o Spiny Mouse	*Acomys spinosissimus*
Desert Pygmy Mouse	*Mus indutus*
Multimammate Mouse	*Praomys natalensis*
Tree Mouse	*Thallomys paedulcus*
o Namaqua Rock Mouse	*Aethomys namaquensis*
o Red Veld Rat	*Aethomys chrysophilus*
Cricetidae	
o Bushveld Gerbil	*Tatera leucogaster*
Highveld Gerbil	*Tatera brantsii*
Pouched Mouse	*Saccostomus campestris*
Grey Climbing Mouse	*Dendromus melanotis*
Hyaenidae	
Aardwolf	*Proteles cristatus* PR
Brown Hyaena	*Hyaena brunnea* PR
? Spotted Hyaena	*Crocuta crocuta*
Felidae	
+ Cheetah	*Acinonyx jubatus* PO
Leopard	*Panthera pardus* R
+ Lion	*Panthera leo*
Caracal	*Felis caracal*
African Wild Cat	*Felis lybica* V

Canidae

m	Bat-eared Fox	*Otocyon megalotis*
+	Wild Dog	*Lycaon pictus* E
	Black-backed Jackal	*Canis mesomelas*

Mustelidae

	Honey Badger	*Mellivora capensis* PV
	Striped Polecat	*Ictonyx striatus*

Viverridae

m	African Civet	*Civettictis civetta* PR
	Small-spotted Genet	*Genetta genetta*
	Large-spotted Genet	*Genetta tigrina*
m	Selous' Mongoose	*Paracynictis selousi* R
*	Slender Mongoose	*Galerella sanguinea*
	Banded Mongoose	*Mungos mungo*
	Dwarf Mongoose	*Helogale parvula*

Orycteropodidae

*	Antbear	*Orycteropus afer* PV

Elepantidae

*	African Elephant	*Loxodonta africana* O

Procaviidae

*	Rock Dassie	*Procavia capensis* P
m	Yellow-spotted Rock Dassie	*Heterohyrax brucei* P

Equidae

m+	Burchell's Zebra	*Equus burchelli*

Suidae

	Bushpig	*Potamochoerus porcus*
	Warthog	*Phacochoerus aethiopicus*

Hippopotamidae

+	Hippopotamus	*Hippopotamus amphibicus* PR

Bovidae

+	Blue Wildebeest	*Connochaetes taurinus*
+	Tsessebe	*Damaliscus lunatus* R
	Common Duiker	*Sylvicapra grimmia*
*	Klipspringer	*Oreotragus oreotragus* P
*	Steenbok	*Raphicerus campestris*
*	Impala	*Aepyceros melampus*
+	Sable	*Hippotragus niger* V
*	Kudu	*Tragelaphus strepsiceros*
	Bushbuck	*Tragelaphus scriptus*
m+	Eland	*Taurotragus oryx*
+	Waterbuck	*Kobus ellipsiprymnus* P

DATA LIST K – E3.1

LIST OF BIRD SPECIES RECORDED FROM THE PROJECT AREA

Three lists are given which cover the following areas:

2127D3 Letsibogo Damsite and Reservoir Area

2127D4 Motloutse River downstream from the Motloutse/Letlhakane River confluence

2128C4 Motloutse River upstream from Mosalakwane

BOTSWANA BIRD LIST

DATE	LOCATION	NAME, ADDRESS
January '89	Motloutse	MMP
TIME, WEATHER	**TYPE OF HABITAT**	**MAP REFERENCE /SQUARE NUMBER**
V. dry	Mixed Acacia/Mopane	2127 D3

001	OSTRICH	158	BLACK SPARROWHAWK	286	ETHIOPIAN SNIPE	436	GREY H KINGFISHER	583	SHORTTOED R THRUSH	740	PUFFBACK
006	GREAT CRESTED GREBE	159	LITTLE BANDED G HAWK	287	BLACKTAILED GODWIT	437	STRIPED KINGFISHER	584	MIOMBO ROCK THRUSH	741	BRUBRU
007	BLACKNECKED GREBE	160	AFRICAN GOSHAWK	288	BARTAILED GODWIT	438	EUROPEAN BEE-EATER	585	(EUROPEAN WHEATEAR)	743	3 STREAKED TCHAGRA
008	DABCHICK	161	GABAR GOSHAWK	289	CURLEW	439	OLIVE BEE-EATER	586	MOUNTAIN CHAT	744	BLACKCROWNED TCHAGR
049	WHITE PELICAN	162	PALE CHANTING G'HAWK	290	WHIMBREL	440	BLUE CH BEE-EATER	587	CAPPED WHEATEAR	746	BOKMAKIERIE
050	PINKBACKED PELICAN	163	DARK CHANTING G'HAWK	291	GREY PHALAROPE	441	CARMINE BEE-EATER	589	FAMILIAR CHAT	748	ORANGE B BUSH SHRIKE
055	WHITE BR CORMORANT	164	(EUR MARSH HARRIER)	294	AVOCET	443	WHITE FR BEE-EATER	590	(TRACTRAC CHAT)	751	GREYHEADED B SHRIKE
058	REED CORMORANT	165	AFR MARSH HARRIER	295	BLACKWINGED STILT	444	LITTLE BEE-EATER	591	SICKLEWINGED CHAT	753	WHITE HELMETSHRIKE
060	DARTER	166	MONTAGU'S HARRIER	297	SPOTTED DIKKOP	445	SWALLOW T BEE-EATER	592	(KAROO CHAT)	754	RED B HELMETSHRIKE
062	GREY HERON	167	PALLID HARRIER	298	WATER DIKKOP	446	EUROPEAN ROLLER	593	MOCKING CHAT	755	WHITECROWNED SHRIKE
063	BLACKHEADED HERON	168	BLACK HARRIER	299	BURCHELL'S COURSER	447	LILACBREASTED ROLLER	594	ARNOT'S CHAT	780	WATTLED STARLING
064	GOLIATH HERON	169	GYMNOGENE	300	TEMMINCK'S COURSER	448	RACKETTAILED ROLLER	595	ANTEATING CHAT	781	PLUMCOLOUR STARLING
065	PURPLE HERON	170	OSPREY	301	DOUBLEBANDED COURSER	449	PURPLE ROLLER	596	STONECHAT	782	BURCHELL'S STARLING
066	GREAT WHITE EGRET	171	PEREGRINE FALCON	302	THREEBANDED COURSER	450	BROADBILLED ROLLER	597	WHINCHAT	783	LONGTAILED STARLING
067	LITTLE EGRET	172	LANNER FALCON	303	BRONZEWINGED COURSER	451	HOOPOE	599	MEUGLIN'S ROBIN	784	GLOSSY STARLING
068	YELLOWBILLED EGRET	173	HOBBY FALCON	304	REDWINGED PRATINCOLE	452	REDBILLED WOODHOOPOE	602	WHITETHROATED ROBIN	785	G BL EARED STARLING
069	BLACK EGRET	174	(AFRICAN HOBBY FALCON)	305	BL WINGED PRATINCOLE	454	SCIM BILL WOODHOOPOE	608	THRUSH NIGHTINGALE	786	L BL EARED STARLING
070	SLATY EGRET	175	REDNECKED FALCON	306	ROCK PRATINCOLE	455	TRUMPETER HORNBILL	610	BOULDER CHAT	787	SHARPTAILED STARLING
071	CATTLE EGRET	178	W REDFOOTED KESTREL	313	L BLACKBACKED GULL	457	GREY HORNBILL	613	WHITEBROWED ROBIN	789	REDWINGED STARLING
072	SQUACCO HERON	180	E REDFOOTED KESTREL	315	GREYHEADED GULL	458	REDBILLED HORNBILL	615	KALAHARI ROBIN	770	PALEWINGED STARLING
074	GREENBACKED HERON	181	ROCK KESTREL	321	GULLBILLED TERN	459	YELLOW B HORNBILL	617	BEARDED ROBIN	771	YELLOW B OXPECKER
075	RUFOUSBELLIED HERON	182	GREATER KESTREL	322	CASPIAN TERN	461	BRADFIELD'S HORNBILL	619	GARDEN WARBLER	772	REDBILLED OXPECKER
076	BL CROWNED N HERON	183	LESSER KESTREL	328	WHISKERED TERN	463	GROUND HORNBILL	620	WHITETHROAT	778	(COPPERY SUNBIRD)
077	WHITEBACKED N HERON	185	DICKINSON'S KESTREL	330	WHITEWINGED TERN	464	BLACKCOLLARED BARBET	621	TITBABBLER	779	MARICO SUNBIRD
078	LITTLE BITTERN	186	PYGMY FALCON	343	AFRICAN SKIMMER	465	PIED BARBET	625	ICTERINE WARBLER	780	(PURPLE B SUNBIRD)
079	DWARF BITTERN	188	COQUI FRANCOLIN	344	MAMAQUA SANDGROUSE	470	YFRONT TINKER BARBET	626	OLIVETREE WARBLER	784	MIOMBO D COL SUNBIRD
080	BITTERN	189	CRESTED FRANCOLIN	345	BURCHELL'S SANDGROUSE	473	CRESTED BARBET	627	RIVER WARBLER	787	WHITEBELLIED SUNBIRD
081	HAMERKOP	193	ORANGE R FRANCOLIN	346	YELL THR SANDGROUSE	474	GREATER HONEYGUIDE	628	GREAT REED WARBLER	788	DUSKY SUNBIRD
082	(SHOEBILL)	194	REDBILLED FRANCOLIN	347	DOUBLE B SANDGROUSE	476	LESSER HONEYGUIDE	631	AFR MARSH WARBLER	791	SCARLET CH SUNBIRD
083	WHITE STORK	196	NATAL FRANCOLIN	348	FERAL PIGEON	478	SHARP B HONEYGUIDE	633	EUR MARSH WARBLER	792	BLACK SUNBIRD
084	BLACK STORK	199	SWAINSON'S FRANCOLIN	349	ROCK PIGEON	479	BLENDER B HONEYGUIDE	634	EUR SEDGE WARBLER	793	COLLARED SUNBIRD
085	ABDIM'S STORK	200	COMMON QUAIL	352	REDEYED DOVE	481	BENNETT'S WOODPECKER	635	CAPE REED WARBLER	796	CAPE WHITE-EYE
086	WOOLLYNECKED STORK	201	MARLEQUIN QUAIL	353	MOURNING DOVE	483	GOLDEN T WOODPECKER	636	GR SWAMP WARBLER	797	YELLOW WHITE-EYE
087	OPENBILLED STORK	202	(BLUE QUAIL)	354	CAPE TURTLE DOVE	488	CARDINAL WOODPECKER	638	AFR SEDGE WARBLER	798	RED B BUFFALO WEAVER
088	SADDLEBILLED STORK	203	HELMETED GUINEAFOWL	355	LAUGHING DOVE	487	BEARDED WOODPECKER	643	WILLOW WARBLER	799	WH BR SPARROWWEAVER
089	MARABOU STORK	205	KURRICHANE B'QUAIL	356	MAMAQUA DOVE	489	(RED THR WRYNECK)	645	BARTHROATED APALIS	800	SOCIABLE WEAVER
090	YELLOWBILLED STORK	206	BLACKRUMPED B'QUAIL	358	GREENSPOTTED DOVE	490	(AFRICAN BROADBILL)	648	YELLOW BR APALIS	801	HOUSE SPARROW
091	SACRED IBIS	207	WATTLED CRANE	361	GREEN PIGEON	492	MELODIOUS LARK	651	LONGBILLED CROMBEC	802	GREAT SPARROW
093	GLOSSY IBIS	208	BLUE CRANE	362	CAPE PARROT	493	MONOTONOUS LARK	653	YELLOW B EREMOMELA	803	CAPE SPARROW
094	HADEDA IBIS	209	CROWNED CRANE	364	MEYER'S PARROT	494	RUFOUSNAPED LARK	655	GREENCAP EREMOMELA	804	GREYHEADED SPARROW
095	AFRICAN SPOONBILL	210	AFRICAN RAIL	370	KNYSNA LOURIE	495	CLAPPER LARK	656	BURNTNECK EREMOMELA	805	YELLOW THR SPARROW
096	GREATER FLAMINGO	211	CORNCRAKE	372	ROSS'S LOURIE	496	PLAPPET LARK	657	BLEATING WARBLER	808	SCALYFEATHERED FINCH
097	LESSER FLAMINGO	212	AFRICAN CRAKE	373	GREY LOURIE	497	FAWNCOLOURED LARK	658	BARRED WARBLER	807	THICKBILLED WEAVER
099	WHITEFACED DUCK	213	BLACK CRAKE	374	EUROPEAN CUCKOO	498	BARDTA LARK	659	STIERLING'S BARRED WARBLER	810	SPECTACLED WEAVER
100	FULVOUS DUCK	214	SPOTTED CRAKE	375	AFRICAN CUCKOO	501	SHORTCLAWED LARK	664	FANTAILED CISTICOLA	811	SPOTTEDBACKED WEAVE
101	WHITEBACKED DUCK	215	BAILLON'S CRAKE	377	REDCHESTED CUCKOO	505	DUSKY LARK	665	DESERT CISTICOLA	812	CHESTNUT WEAVER
102	EGYPTIAN GOOSE	216	(STRIPED CRAKE)	378	BLACK CUCKOO	506	SPIKEHEELED LARK	668	PALE CR CISTICOLA	814	MASKED WEAVER
103	S AFRICAN SHELDUCK	217	REDCHESTED FLUFFTAIL	380	GREAT SPOTTED CUCKOO	507	REDCAPPED LARK	671	TINKLING CISTICOLA	815	LESSER MASKED WEAVER
104	YELLOWBILLED DUCK	223	PURPLE GALLINULE	381	STRIPED CUCKOO	508	PINKBILLED LARK	672	RATTLING CISTICOLA	818	GOLDEN WEAVER
105	AFRICAN BLACK DUCK	224	LESSER GALLINULE	382	JACOBIN CUCKOO	511	STARK'S LARK	674	REDFACED CISTICOLA	818	BROWNTHROATED WEAVE
106	CAPE TEAL	226	MOORHEN	383	THICKBILLED CUCKOO	515	CHESTNUT B FINCHLARK	675	BL BACKED CISTICOLA	818	REDHEADED WEAVER
107	HOTTENTOT TEAL	227	LESSER MOORHEN	384	(EMERALD CUCKOO)	516	GREYBACKED FINCHLARK	676	CHIRPING CISTICOLA	820	CUCKOO FINCH
108	REDBILLED TEAL	228	REDKNOBBED COOT	385	KLAAS'S CUCKOO	517	BLACKEARED FINCHLARK	677	LEVAILL CISTICOLA	821	REDBILLED QUELEA
109	PINTAIL	229	AFRICAN FINFOOT	386	DIEDERIK CUCKOO	518	EUROPEAN SWALLOW	678	CROAKING CISTICOLA	822	REDHEADED QUELEA
110	GARGANEY	230	KORI BUSTARD	388	BLACK COUCAL	520	WHITE THR SWALLOW	679	LAZY CISTICOLA	824	RED BISHOP
112	CAPE SHOVELLER	231	STANLEY'S BUSTARD	389	COPPERTAILED COUCAL	522	WIRETAILED SWALLOW	681	MEDDICKY	826	GOLDEN BISHOP
113	SOUTHERN POCHARD	232	(LUDWIG'S BUSTARD)	390	SENEGAL COUCAL	523	PEARL BR SWALLOW	683	TAWNYFLANKED PRINIA	827	YELLOWRUMPED WIDOW
114	PYGMY GOOSE	233	WHITEBELLIED KORHAAN	391	BURCHELL'S COUCAL	524	REDBREASTED SWALLOW	685	BLACKCHESTED PRINIA	828	REDSHOULDERED WIDOW
115	KNOBBILLED DUCK	237	REDCRESTED KORHAAN	392	BARN OWL	525	MOSQUE SWALLOW	688	RUFOUSEARED WARBLER	829	WHITEWINGED WIDOW
116	SPURWINGED GOOSE	238	BLACKBELLIED KORHAAN	394	WOOD OWL	526	GREATER STR SWALLOW	689	SPOTTED FLYCATCHER	831	REDCOLLARED WIDOW
117	MACCOA DUCK	239	BLACK KORHAAN	395	MARSH OWL	527	LESSER STR SWALLOW	691	BLUEGREY FLYCATCHER	832	LONGTAILED WIDOW
118	SECRETARYBIRD	240	AFRICAN JACANA	396	SCOPS OWL	528	S AFR CLIFF SWALLOW	692	FANTAILED FLYCATCHER	833	GOLDENBACKED PYTILIA
120	EGYPTIAN VULTURE	241	LESSER JACANA	397	WHITEFACED OWL	529	ROCK MARTIN	694	BLACK FLYCATCHER	834	MELBA FINCH
121	HOODED VULTURE	247	PAINTED SNIPE	398	PEARLSPOTTED OWL	530	HOUSE MARTIN	695	MARICO FLYCATCHER	840	(BLUE B FIREFINCH)
122	CAPE VULTURE	265	RINGED PLOVER	399	BARRED OWL	531	GREYRUMPED SWALLOW	696	PALLID FLYCATCHER	841	JAMESON'S FIREFINCH
123	WHITEBACKED VULTURE	246	WHITEFRONTED PLOVER	401	SPOTTED EAGLE OWL	532	SAND MARTIN	697	CHAT FLYCATCHER	842	REDBILLED FIREFINCH
124	LAPPETFACED VULTURE	247	CHESTNUT B PLOVER	402	GIANT EAGLE OWL	533	BROWNTHROATED MARTIN	698	FISCAL FLYCATCHER	843	BROWN FIREFINCH
125	WHITEHEADED VULTURE	248	KITTLITZ'S PLOVER	403	PEL'S FISHING OWL	534	BANDED MARTIN	701	CHINSPOT BATIS	844	BLUE WAXBILL
126	YELLOWBILLED KITE	249	THREEBANDED PLOVER	404	EUROPEAN NIGHTJAR	536	(BL SAWWING SWALLOW)	703	PRIRIT BATIS	845	VIOLETEARED WAXBILL
128	BLACK KITE	252	CASPIAN PLOVER	405	FIERYNECKED NIGHTJAR	538	BLACK CUCKOOSHRIKE	706	FAIRY FLYCATCHER	846	COMMON WAXBILL
127	BLACKSHOULDERED KITE	254	GREY PLOVER	406	RUFOUS CH NIGHTJAR	539	WHITE B CUCKOOSHRIKE	710	PARADISE FLYCATCHER	847	BLACKCHEEKED WAXBILL
128	CUCKOO HAWK	255	CROWNED PLOVER	407	NATAL NIGHTJAR	541	FORKTAILED DRONGO	711	AFRICAN PIED WAGTAIL	852	QUAIL FINCH
129	BAT HAWK	256	BLACKSMITH PLOVER	408	FRECKLED NIGHTJAR	543	EUR GOLDEN ORIOLE	713	CAPE WAGTAIL	853	LOCUST FINCH
130	(HONEY BUZZARD)	259	WHITECROWNED PLOVER	409	MOZAMBIQUE NIGHTJAR	544	AFR GOLDEN ORIOLE	714	YELLOW WAGTAIL	854	ORANGE BR WAXBILL
131	BLACK EAGLE	260	WATTLED PLOVER	410	PENN WINGED NIGHTJAR	545	BLACKHEADED ORIOLE	715	GREY WAGTAIL	855	CUTTHROAT FINCH
132	TAWNY EAGLE	261	LONGTOED PLOVER	411	EUROPEAN SWIFT	547	BLACK CROW	716	RICHARD'S PIPIT	856	REDHEADED FINCH
133	STEPPE EAGLE	262	TURNSTONE	412	BLACK SWIFT	548	PIED CROW	901	MOUNTAIN PIPIT	857	BRONZE MANNIKIN
134	LESSER SPOTTED EAGLE	263	TEREK SANDPIPER	413	(BRADFIELD'S SWIFT)	550	(WHITENECKED RAVEN)	717	LONGBILLED PIPIT	860	PINTAILED WHYDAH
135	WAHLBERG'S EAGLE	264	COMMON SANDPIPER	415	WHITERUMPED SWIFT	552	ASHY TIT	718	PLAINBACKED PIPIT	861	SHAFTTAILED WHYDAH
136	BOOTED EAGLE	265	GREEN SANDPIPER	416	HORUS SWIFT	554	SOUTHERN BLACK TIT	719	BUFFY PIPIT	862	PARADISE WHYDAH
137	AFRICAN HAWK EAGLE	266	WOOD SANDPIPER	417	LITTLE SWIFT	556	RUFOUSBELLIED TIT	720	STRIPED PIPIT	863	BROADTAILED P WHYDAH
138	AYRES EAGLE	267	(SPOTTED REDSHANK)	418	ALPINE SWIFT	557	CAPE PENDULINE TIT	722	TREE PIPIT	864	BLACK WIDOWFINCH
139	LONGCRESTED EAGLE	268	REDSHANK	421	PALM SWIFT	558	GREY PENDULINE TIT	723	BUSHVELD PIPIT	865	PURPLE WIDOWFINCH
140	MARTIAL EAGLE	269	MARSH SANDPIPER	423	BOHM'S SPINETAIL	560	ARROWMARKED BABBLER	727	ORANGE THR LONGCLAW	867	STEELBLUE WIDOWFINCH
142	BROWN SNAKE EAGLE	270	GREENSHANK	424	SPECKLED MOUSEBIRD	561	BLACKFACED BABBLER	730	PINK THR LONGCLAW	868	YELLOWEYED CANARY
143	BLACK BR SNAKE EAGLE	271	KNOT	425	WHITE B MOUSEBIRD	562	WHITERUMPED BABBLER	731	LESSER GREY SHRIKE	870	BLACKTHROATED CANAR
144	W BANDED SNAKE EAGLE	272	CURLEW SANDPIPER	426	REDFACED MOUSEBIRD	563	PIED BABBLER	732	FISCAL SHRIKE	876	(BLACKHEADED CANARY)
145	BATELEUR	273	(DUNLIN)	427	NARINA TROGON	567	REDEYED BULBUL	733	REDBACKED SHRIKE	878	YELLOW CANARY
147	PALMNUT VULTURE	274	LITTLE STINT	428	PIED KINGFISHER	568	BLACKEYED BULBUL	734	SOUSA'S SHRIKE	881	STREAKTHEADED CANAR
148	AFRICAN FISH EAGLE	275	LONGTOED STINT	429	GIANT KINGFISHER	569	TERRESTRIAL BULBUL		(ISABELLINE SHRIKE)	887	BLACKEARED CANARY
148	STEPPE BUZZARD	278	PECTORAL SANDPIPER	430	HALFCOLL KINGFISHER	574	YELLOWBELLIED BULBUL	735	LONGTAILED SHRIKE	884	GOLDEN BR BUNTING
152	JACKAL BUZZARD	280	TEMMINCK'S STINT	431	MALACHITE KINGFISHER	576	KURRICHANE THRUSH	736	SOUTHERN BOUBOU	885	CAPE BUNTING
154	LIZARD BUZZARD	281	SANDERLING	432	PYGMY KINGFISHER	577	OLIVE THRUSH	737	TROPICAL BOUBOU	886	ROCK BUNTING
156	OVAMBO SPARROWHAWK	284	RUFF	433	WOODLAND KINGFISHER	60	GROUNDSCRAPER THRUSH	738	SWAMP BOUBOU	887	LARKLIKE BUNTING
157	LITTLE SPARROWHAWK	285	GREAT SNIPE	11	BROWN H KINGFISHER	581	(CAPE ROCK THRUSH)	15	CRIMSON BR SHRIKE		

( ) INDICATES THAT THE SPECIES MAY OCCUR IN BOTSWANA BUT THAT THIS HAS NOT YET BEEN PROVEN

stenographix 3466

Edition 2 : Jan 1

BOTSWANA BIRD LIST

DATE	LOCATION	NAME, ADDRESS
January '89	Motloutse	MMP
TIME, WEATHER	TYPE OF HABITAT	MAP REFERENCE /SQUARE NUMBER
V. dry	Mixed Acacia/Mopane	2127 D4

001	OSTRICH	158	BLACK SPARROWHAWK	205	ETHIOPIAN SNIPE	426	GREY H KINGFISHER	583	SHORTTOED R THRUSH	740	PUFFBACK
006	GREAT CRESTED GREBE	159	LITTLE BANDED G'HAWK	207	BLACKTAILED GODWIT	427	STRIPED KINGFISHER	584	MOMBO ROCK THRUSH	741	BRUBRU
007	BLACKNECKED GREBE	160	AFRICAN GOSHAWK	208	BARTAILED GODWIT	429	EUROPEAN BEE-EATER	585	(EUROPEAN WHEATEAR)	742	3 STREAKED TCHAGRA
008	DABCHICK	161	GABAR GOSHAWK	209	CURLEW	430	OLIVE BEE-EATER	586	MOUNTAIN CHAT	744	BLACKCROWNED TCHAGRA
049	WHITE PELICAN	162	PALE CHANTING G'HAWK	210	WHIMBREL	440	BLUE CH BEE-EATER	587	CAPPED WHEATEAR	746	BOKMAKIERIE
050	PINKBACKED PELICAN	163	DARK CHANTING G'HAWK	211	GREY PHALAROPE	441	CARMINE BEE-EATER	588	FAMILIAR CHAT	748	ORANGE B BUSH SHRIKE
053	WHITE BR CORMORANT	164	(EUR MARSH HARRIER)	234	AVOCET	442	WHITE FR BEE-EATER	590	(TRACTRAC CHAT)	751	GREYHEADED B SHRIKE
056	REED CORMORANT	165	AFR MARSH HARRIER	235	BLACKWINGED STILT	444	LITTLE BEE-EATER	591	PICKLEWINGED CHAT	753	WHITE HELMETSHRIKE
060	DARTER	166	MONTAGU'S HARRIER	237	SPOTTED DIKKOP	445	SWALLOW T BEE-EATER	592	(KAROO CHAT)	754	RED B HELMETSHRIKE
062	GREY HERON	167	PALLID HARRIER	238	WATER DIKKOP	446	EUROPEAN ROLLER	593	MOCKING CHAT	755	WHITECROWNED SHRIKE
063	BLACKHEADED HERON	168	BLACK HARRIER	239	BURCHELL'S COURSER	447	LILACBREASTED ROLLER	594	ARNOT'S CHAT	756	WATTLED STARLING
064	GOLIATH HERON	169	GYMNOGENE	300	TEMMINCK'S COURSER	448	RACKETTAILED ROLLER	595	ANTEATING CHAT	761	PLUMCOLOUR STARLING
065	PURPLE HERON	170	OSPREY	301	DOUBLEBANDED COURSER	449	PURPLE ROLLER	596	STONECHAT	762	BURCHELL'S STARLING
066	GREAT WHITE EGRET	171	PEREGRINE FALCON	302	THREEBANDED COURSER	450	BROADBILLED ROLLER	597	WHINCHAT	763	LONGTAILED STARLING
067	LITTLE EGRET	172	LANNER FALCON	303	BRONZEWINGED COURSER	451	HOOPOE	599	MEUGLIN'S ROBIN	764	GLOSSY STARLING
068	YELLOWBILLED EGRET	173	HOBBY FALCON	304	REDWINGED PRATINCOLE	452	REDBILLED WOODHOOPOE	602	WHITETHROATED ROBIN	765	B BL EARED STARLING
069	BLACK EGRET	174	(AFRICAN HOBBY FALCON)	305	BL WINGED PRATINCOLE	454	SCIM BILL WOODHOOPOE	609	THRUSH NIGHTINGALE	766	L BL EARED STARLING
070	SLATY EGRET	178	REDNECKED FALCON	306	ROCK PRATINCOLE	455	TRUMPETER HORNBILL	610	BOULDER CHAT	767	SHARPTAILED STARLING
071	CATTLE EGRET	179	W REDFOOTED KESTREL	313	L BLACKBACKED GULL	457	GREY HORNBILL	613	WHITEBROWED ROBIN	768	REDWINGED STARLING
072	SQUACCO HERON	180	E REDFOOTED KESTREL	315	GREYHEADED GULL	458	REDBILLED HORNBILL	615	KALAHARI ROBIN	770	PALEWINGED STARLING
074	GREENBACKED HERON	181	ROCK KESTREL	321	GULLBILLED TERN	459	YELLOW B HORNBILL	617	BEARDED ROBIN	771	YELLOW B OXPECKER
075	RUFOUSBELLIED HERON	182	GREATER KESTREL	322	CASPIAN TERN	461	BRADFIELD'S HORNBILL	619	GARDEN WARBLER	772	REDBILLED OXPECKER
076	BL CROWNED N HERON	183	LESSER KESTREL	328	WHISKERED TERN	463	GROUND HORNBILL	620	WHITETHROAT	778	(COPPERY SUNBIRD)
077	WHITEBACKED N HERON	185	DICKINSON'S KESTREL	329	WHITEWINGED TERN	464	BLACKCOLLARED BARBET	621	TITBABBLER	779	MARICO SUNBIRD
078	LITTLE BITTERN	186	PYGMY FALCON	343	AFRICAN SKIMMER	465	PIED BARBET	625	ICTERINE WARBLER	780	(PURPLE B SUNBIRD)
079	DWARF BITTERN	188	CODUI FRANCOLIN	344	NAMAQUA SANDGROUSE	470	YFRONT TINKER BARBET	626	OLIVETREE WARBLER	784	MOMBO D COL SUNBIRD
080	BITTERN	189	CRESTED FRANCOLIN	345	BURCHELL'S SANDGROUSE	473	CRESTED BARBET	627	RIVER WARBLER	787	WHITEBELLIED SUNBIRD
081	HAMERKOP	193	ORANGE R FRANCOLIN	346	VEILL THR SANDGROUSE	474	GREATER HONEYGUIDE	628	GREAT REED WARBLER	788	DUSKY SUNBIRD
082	(SHOEBILL)	194	REDBILLED FRANCOLIN	347	DOUBLE B SANDGROUSE	476	LESSER HONEYGUIDE	631	AFR MARSH WARBLER	791	SCARLET CH SUNBIRD
083	WHITE STORK	195	NATAL FRANCOLIN	348	FERAL PIGEON	478	SHARP B HONEYGUIDE	633	EUR MARSH WARBLER	792	BLACK SUNBIRD
084	BLACK STORK	199	SWAINSON'S FRANCOLIN	349	ROCK PIGEON	479	SLENDER B HONEYGUIDE	634	EUR SEDGE WARBLER	793	COLLARED SUNBIRD
085	ABDIM'S STORK	200	COMMON QUAIL	352	REDEYED DOVE	481	BENNETT'S WOODPECKER	635	CAPE REED WARBLER	796	CAPE WHITE-EYE
086	WOOLLYNECKED STORK	201	HARLEQUIN QUAIL	353	MOURNING DOVE	483	GOLDEN T WOODPECKER	636	GR SWAMP WARBLER	797	YELLOW WHITE-EYE
087	OPENBILLED STORK	202	(BLUE QUAIL)	354	CAPE TURTLE DOVE	486	CARDINAL WOODPECKER	638	AFR SEDGE WARBLER	798	RED B BUFFALO WEAVER
088	SADDLEBILLED STORK	203	HELMETED GUINEAFOWL	355	LAUGHING DOVE	487	BEARDED WOODPECKER	643	WILLOW WARBLER	799	WH BR SPARROWWEAVER
089	MARABOU STORK	205	KURRICHANE B'QUAIL	356	NAMAQUA DOVE	489	(RED THR WRYNECK)	645	BARTHROATED APALIS	800	SOCIABLE WEAVER
090	YELLOWBILLED STORK	206	BLACKRUMPED B'QUAIL	358	GREENSPOTTED DOVE	490	(AFRICAN BROADBILL)	648	YELLOW BR APALIS	801	HOUSE SPARROW
091	SACRED IBIS	207	WATTLED CRANE	361	GREEN PIGEON	492	MELODIOUS LARK	651	LONGBILLED CROMBEC	802	GREAT SPARROW
092	GLOSSY IBIS	208	BLUE CRANE	362	CAPE PARROT	493	MONOTONOUS LARK	653	YELLOW B EREMOMELA	803	CAPE SPARROW
094	HADEDA IBIS	209	CROWNED CRANE	364	MEYER'S PARROT	494	RUFOUSNAPED LARK	655	GREENCAP EREMOMELA	804	GREYHEADED SPARROW
095	AFRICAN SPOONBILL	210	AFRICAN RAIL	370	KNYSNA LOURIE	495	CLAPPER LARK	656	BURNTNECK EREMOMELA	805	YELLOW THR SPARROW
096	GREATER FLAMINGO	211	CORNCRAKE	372	ROSS'S LOURIE	496	FLAPPET LARK	657	BLEATING WARBLER	806	SCALYFEATHERED FINCH
097	LESSER FLAMINGO	212	AFRICAN CRAKE	373	GREY LOURIE	497	PAWNCOLOURED LARK	658	BARRED WARBLER	807	THICKBILLED WEAVER
099	WHITEFACED DUCK	213	BLACK CRAKE	374	EUROPEAN CUCKOO	498	SABOTA LARK	659	STERLING'S BARRED WARBLER	810	SPECTACLED WEAVER
100	FULVOUS DUCK	214	SPOTTED CRAKE	375	AFRICAN CUCKOO	501	SHORTCLAWED LARK	664	PANTAILED CISTICOLA	811	SPOTTEDBACKED WEAVER
101	WHITEBACKED DUCK	215	BAILLON'S CRAKE	377	REDCHESTED CUCKOO	505	DUSKY LARK	665	DESERT CISTICOLA	812	CHESTNUT WEAVER
102	EGYPTIAN GOOSE	216	(STRIPED CRAKE)	378	BLACK CUCKOO	506	SPIKEHEELED LARK	668	PALE CR CISTICOLA	814	MASKED WEAVER
103	S AFRICAN SHELDUCK	217	REDCHESTED FLUFFTAIL	380	GREAT SPOTTED CUCKOO	507	REDCAPPED LARK	671	TINKLING CISTICOLA	815	LESSER MASKED WEAVER
104	YELLOWBILLED DUCK	223	PURPLE GALLINULE	381	STRIPED CUCKOO	508	PINKBILLED LARK	672	RATTLING CISTICOLA	816	GOLDEN WEAVER
105	AFRICAN BLACK DUCK	224	LESSER GALLINULE	382	JACOBIN CUCKOO	511	STARK'S LARK	674	REDFACED CISTICOLA	818	BROWNTHROATED WEAVER
106	CAPE TEAL	226	MOORHEN	383	THICKBILLED CUCKOO	515	CHESTNUT B FINCHLARK	675	BL BACKED CISTICOLA	819	REDHEADED WEAVER
107	HOTTENTOT TEAL	227	LESSER MOORHEN	384	(EMERALD CUCKOO)	516	GREYBACKED FINCHLARK	676	CHIRPING CISTICOLA	820	CUCKOO FINCH
108	REDBILLED TEAL	228	REDKNOBBED COOT	385	KLAAS'S CUCKOO	517	BLACKEARED FINCHLARK	677	LEVAILL CISTICOLA	821	REDBILLED QUELEA
109	PINTAIL	229	AFRICAN FINFOOT	386	DIEDERIK CUCKOO	518	EUROPEAN SWALLOW	678	CROAKING CISTICOLA	822	REDHEADED QUELEA
110	GARGANEY	230	KORI BUSTARD	388	BLACK COUCAL	520	WHITE THR SWALLOW	679	LAZY CISTICOLA	824	RED BISHOP
112	CAPE SHOVELLER	231	STANLEY'S BUSTARD	389	COPPERTAILED COUCAL	522	WIRETAILED SWALLOW	681	REDDICKY	826	GOLDEN BISHOP
113	SOUTHERN POCHARD	232	(LUDWIG'S BUSTARD)	390	SENEGAL COUCAL	523	PEARL BR SWALLOW	683	TAWNYFLANKED PRINIA	827	YELLOWRUMPED WIDOW
114	PYGMY GOOSE	235	WHITEBELLIED KORHAAN	391	BURCHELL'S COUCAL	524	REDBREASTED SWALLOW	685	BLACKCHESTED PRINIA	828	REDSHOULDERED WIDOW
115	KNOBBILLED DUCK	237	REDCRESTED KORHAAN	392	BARN OWL	525	MOSQUE SWALLOW	688	RUFOUSEARED WARBLER	829	WHITEWINGED WIDOW
116	SPURWINGED GOOSE	238	BLACKBELLIED KORHAAN	394	WOOD OWL	526	GREATER STR SWALLOW	689	SPOTTED FLYCATCHER	831	REDCOLLARED WIDOW
117	MACCOA DUCK	239	BLACK KORHAAN	395	MARSH OWL	527	LESSER STR SWALLOW	691	BLUEGREY FLYCATCHER	832	LONGTAILED WIDOW
118	SECRETARYBIRD	240	AFRICAN JACANA	396	SCOPS OWL	529	S AFR CLIFF SWALLOW	693	PANTAILED FLYCATCHER	833	GOLDENBACKED PYTILIA
120	EGYPTIAN VULTURE	241	LESSER JACANA	397	WHITEFACED OWL	529	ROCK MARTIN	694	BLACK FLYCATCHER	834	MELBA FINCH
121	HOODED VULTURE	242	PAINTED SNIPE	398	PEARLSPOTTED OWL	530	HOUSE MARTIN	695	MARICO FLYCATCHER	840	(BLUE B FIREFINCH)
122	CAPE VULTURE	245	RINGED PLOVER	399	BARRED OWL	531	GREYRUMPED SWALLOW	696	PALLID FLYCATCHER	841	JAMESON'S FIREFINCH
123	WHITEBACKED VULTURE	246	WHITEFRONTED PLOVER	401	SPOTTED EAGLE OWL	532	SAND MARTIN	697	CHAT FLYCATCHER	842	REDBILLED FIREFINCH
124	LAPPETFACED VULTURE	247	CHESTNUT B PLOVER	402	GIANT EAGLE OWL	533	BROWNTHROATED MARTIN	698	FISCAL FLYCATCHER	843	BROWN FIREFINCH
125	WHITEHEADED VULTURE	248	KITTLITZ'S PLOVER	403	PEL'S FISHING OWL	534	BANDED MARTIN	701	CHINSPOT BATIS	844	BLUE WAXBILL
126	YELLOWBILLED KITE	249	THREEBANDED PLOVER	404	EUROPEAN NIGHTJAR	536	(BL SAWWING SWALLOW)	703	PRIRIT BATIS	845	VIOLETEARED WAXBILL
126	BLACK KITE	252	CASPIAN PLOVER	405	FIERYNECKED NIGHTJAR	538	BLACK CUCKOOSHRIKE	706	FAIRY FLYCATCHER	846	COMMON WAXBILL
127	BLACKSHOULDERED KITE	254	GREY PLOVER	406	RUFOUS CH NIGHTJAR	539	WHITE B CUCKOOSHRIKE	710	PARADISE FLYCATCHER	847	BLACKCHEEKED WAXBILL
128	CUCKOO HAWK	255	CROWNED PLOVER	407	NATAL NIGHTJAR	541	FORKTAILED DRONGO	711	AFRICAN PIED WAGTAIL	852	QUAIL FINCH
129	BAT HAWK	258	BLACKSMITH PLOVER	408	FRECKLED NIGHTJAR	543	EUR GOLDEN ORIOLE	713	CAPE WAGTAIL	853	LOCUST FINCH
130	(HONEY BUZZARD)	259	WHITECROWNED PLOVER	409	MOZAMBIQUE NIGHTJAR	544	AFR GOLDEN ORIOLE	714	YELLOW WAGTAIL	854	ORANGE BR WAXBILL
131	BLACK EAGLE	260	WATTLED PLOVER	410	PENN WINGED NIGHTJAR	545	BLACKHEADED ORIOLE	715	GREY WAGTAIL	855	CUTTHROAT FINCH
132	TAWNY EAGLE	261	LONGTOED PLOVER	411	EUROPEAN SWIFT	547	BLACK CROW	716	RICHARD'S PIPIT	856	REDHEADED FINCH
133	STEPPE EAGLE	262	TURNSTONE	412	BLACK SWIFT	548	PIED CROW	901	MOUNTAIN PIPIT	857	BRONZE MANNIKIN
134	LESSER SPOTTED EAGLE	263	TEREK SANDPIPER	413	(BRADFIELD'S SWIFT)	550	(WHITENECKED RAVEN)	717	LONGBILLED PIPIT	860	PINTAILED WHYDAH
135	WAHLBERG'S EAGLE	264	COMMON SANDPIPER	415	WHITERUMPED SWIFT	552	ASHY TIT	718	PLAINBACKED PIPIT	861	SHAFTTAILED WHYDAH
136	BOOTED EAGLE	265	GREEN SANDPIPER	416	HORUS SWIFT	554	SOUTHERN BLACK TIT	719	BUFFY PIPIT	862	PARADISE WHYDAH
137	AFRICAN HAWK EAGLE	266	WOOD SANDPIPER	417	LITTLE SWIFT	556	RUFOUSBELLIED TIT	720	STRIPED PIPIT	863	BROADTAILED P WHYDAH
138	AYRES EAGLE	267	(SPOTTED REDSHANK)	418	ALPINE SWIFT	557	CAPE PENDULINE TIT	722	TREE PIPIT	864	BLACK WIDOWFINCH
139	LONGCRESTED EAGLE	268	REDSHANK	421	PALM SWIFT	558	GREY PENDULINE TIT	723	BUSHVELD PIPIT	865	PURPLE WIDOWFINCH
140	MARTIAL EAGLE	269	MARSH SANDPIPER	423	BOHM'S SPINETAIL	560	ARROWMARKED BABBLER	727	ORANGE THR LONGCLAW	867	STEEL BLUE WIDOWFINCH
142	BROWN SNAKE EAGLE	270	GREENSHANK	424	SPECKLED MOUSEBIRD	561	BLACKFACED BABBLER	730	PINK THR LONGCLAW	869	YELLOWEYED CANARY
143	BLACK BR SNAKE EAGLE	271	KNOT	425	WHITE B MOUSEBIRD	562	WHITERUMPED BABBLER	731	LESSER GREY SHRIKE	870	BLACKTHROATED CANARY
145	W BANDED SNAKE EAGLE	272	CURLEW SANDPIPER	426	REDFACED MOUSEBIRD	563	PIED BABBLER	732	FISCAL SHRIKE	876	(BLACKHEADED CANARY)
146	BATELEUR	273	(DUNLIN)	427	NARINA TROGON	567	REDEYED BULBUL	733	REDBACKED SHRIKE	878	YELLOW CANARY
147	PALMNUT VULTURE	274	LITTLE STINT	428	PIED KINGFISHER	568	BLACKEYED BULBUL	734	SOUSA'S SHRIKE	881	STREAKYHEADED CANARY
148	AFRICAN FISH EAGLE	275	LONGTOED STINT	429	GIANT KINGFISHER	569	TERRESTRIAL BULBUL		(ISABELLINE SHRIKE)	882	BLACKEARED CANARY
149	STEPPE BUZZARD	278	PECTORAL SANDPIPER	430	HALFCOLL KINGFISHER	574	YELLOWBELLIED BULBUL	735	LONGTAILED SHRIKE	884	GOLDEN BR BUNTING
152	JACKAL BUZZARD	280	TEMMINCK'S STINT	431	MALACHITE KINGFISHER	576	KURRICHANE THRUSH	736	SOUTHERN BOUBOU	885	CAPE BUNTING
154	LIZARD BUZZARD	281	SANDERLING	432	PYGMY KINGFISHER	577	OLIVE THRUSH	737	TROPICAL BOUBOU	886	ROCK BUNTING
156	OVAMBO SPARROWHAWK	284	RUFF	433	WOODLAND KINGFISHER	580	GROUNDSCRAPER THRUSH	738	SWAMP BOUBOU	887	LARK-LIKE BUNTING
157	LITTLE SPARROWHAWK	285	GREAT SNIPE	435	BROWN H KINGFISHER	581	(CAPE ROCK THRUSH)	739	CRIMSON BR SHRIKE		

) INDICATES THAT THE SPECIES MAY OCCUR IN BOTSWANA BUT THAT THIS HAS NOT YET BEEN PROVEN

Edition 2 : Jan 1987

BOTSWANA BIRD LIST

DATE	LOCATION	NAME, ADDRESS
January '89	Motloutse	MMP
TIME, WEATHER	**TYPE OF HABITAT**	**MAP REFERENCE /SQUARE NUMBER**
V. dry	Mixed Acacia / Mopane	2128 C4

001	OSTRICH	158	BLACK SPARROWHAWK	286	ETHIOPIAN SNIPE	436	GREY H KINGFISHER	583	SHORTTOED R THRUSH	740	PUFFBACK				
006	GREAT CRESTED GREBE	159	LITTLE BANDED G HAWK	287	BLACKTAILED GODWIT	437	STRIPED KINGFISHER	584	MIOMBO ROCK THRUSH	741	BRUBRU				
007	BLACKNECKED GREBE	160	AFRICAN GOSHAWK	288	BARTAILED GODWIT	438	EUROPEAN BEE-EATER	585	(EUROPEAN WHEATEAR)	743	3 STREAKED TCHAGRA				
008	DABCHICK	161	GABAR GOSHAWK	289	CURLEW	439	OLIVE BEE-EATER	586	MOUNTAIN CHAT	744	BLACKCROWNED TCHAGRA				
049	WHITE PELICAN	162	PALE CHANTING G HAWK	290	WHIMBREL	440	BLUE CH BEE-EATER	587	CAPPED WHEATEAR	746	BOKMAKIERIE				
050	PINKBACKED PELICAN	163	DARK CHANTING G HAWK	291	GREY PHALAROPE	441	CARMINE BEE-EATER	588	FAMILIAR CHAT	748	ORANGE B BUSH SHRIKE				
055	WHITE BR CORMORANT	164	(EUR MARSH HARRIER)	294	AVOCET	443	WHITE FR BEE-EATER	590	(TRACTRAC CHAT)	751	GREYHEADED B SHRIKE				
060	REED CORMORANT	165	AFR MARSH HARRIER	295	BLACKWINGED STILT	444	LITTLE BEE-EATER	591	SICKLEWINGED CHAT	753	WHITE HELMETSHRIKE				
060	DARTER	166	MONTAGU'S HARRIER	297	SPOTTED DIKKOP	445	SWALLOW T BEE-EATER	592	(KAROO CHAT)	754	RED B HELMETSHRIKE				
062	GREY HERON	167	PALLID HARRIER	298	WATER DIKKOP	446	EUROPEAN ROLLER	593	MOCKING CHAT	758	WHITECROWNED SHRIKE				
063	BLACKHEADED HERON	168	BLACK HARRIER	299	BURCHELL'S COURSER	447	LILACBREASTED ROLLER	594	ARNOT'S CHAT	760	WATTLED STARLING				
064	GOLIATH HERON	169	GYMNOGENE	300	TEMMINCK'S COURSER	448	RACKETTAILED ROLLER	595	ANTEATING CHAT	761	PLUMCOLOUR STARLING				
065	PURPLE HERON	170	OSPREY	301	DOUBLEBANDED COURSER	449	PURPLE ROLLER	596	STONECHAT	762	BURCHELL'S STARLING				
066	GREAT WHITE EGRET	171	PEREGRINE FALCON	302	THREEBANDED COURSER	450	BROADBILLED ROLLER	597	WHINCHAT	763	LONGTAILED STARLING				
067	LITTLE EGRET	172	LANNER FALCON	303	BRONZEWINGED COURSER	451	HOOPOE	599	HEUGLIN'S ROBIN	764	GLOSSY STARLING				
068	YELLOWBILLED EGRET	173	HOBBY FALCON	304	REDWINGED PRATINCOLE	452	REDBILLED WOODHOOPOE	602	WHITETHROATED ROBIN	765	G BL EARED STARLING				
069	BLACK EGRET	174	(AFRICAN HOBBY FALCON)	305	BL WINGED PRATINCOLE	454	SCIM BILL WOODHOOPOE	609	THRUSH NIGHTINGALE	766	L BL EARED STARLING				
070	SLATY EGRET	178	REDNECKED FALCON	306	ROCK PRATINCOLE	455	TRUMPETER HORNBILL	610	BOULDER CHAT	767	SHARPTAILED STARLING				
071	CATTLE EGRET	179	W REDFOOTED KESTREL	313	L BLACKBACKED GULL	457	GREY HORNBILL	613	WHITEBROWED ROBIN	769	REDWINGED STARLING				
072	SQUACCO HERON	180	E REDFOOTED KESTREL	315	GREYHEADED GULL	458	REDBILLED HORNBILL	615	KALAHARI ROBIN	770	PALEWINGED STARLING				
074	GREENBACKED HERON	181	ROCK KESTREL	321	GULLBILLED TERN	459	YELLOW B HORNBILL	617	BEARDED ROBIN	771	YELLOW B OXPECKER				
075	RUFOUSBELLIED HERON	182	GREATER KESTREL	322	CASPIAN TERN	461	BRADFIELD'S HORNBILL	619	GARDEN WARBLER	772	REDBILLED OXPECKER				
076	BL CROWNED N HERON	183	LESSER KESTREL	328	WHISKERED TERN	463	GROUND HORNBILL	620	WHITETHROAT	778	(COPPERY SUNBIRD)				
077	WHITEBACKED N HERON	185	DICKINSON'S KESTREL	329	WHITEWINGED TERN	464	BLACKCOLLARED BARBET	621	TITBABBLER	779	MARICO SUNBIRD				
078	LITTLE BITTERN	188	PYGMY FALCON	343	AFRICAN SKIMMER	465	PIED BARBET	625	ICTERINE WARBLER	780	(PURPLE B SUNBIRD)				
079	DWARF BITTERN	188	COQUI FRANCOLIN	344	MAMAQUA SANDGROUSE	470	YFRONT TINKER BARBET	626	OLIVETREE WARBLER	784	MIOMBO D COL SUNBIRD				
080	BITTERN	189	CRESTED FRANCOLIN	345	BURCHELL'S SANDGROUSE	473	CRESTED BARBET	627	RIVER WARBLER	787	WHITEBELLIED SUNBIRD				
081	HAMERKOP	193	ORANGE R FRANCOLIN	346	YELL THR SANDGROUSE	474	GREATER HONEYGUIDE	628	GREAT REED WARBLER	788	DUSKY SUNBIRD				
082	(SHOEBILL)	194	REDBILLED FRANCOLIN	347	DOUBLE B SANDGROUSE	476	LESSER HONEYGUIDE	631	AFR MARSH WARBLER	791	SCARLET CH SUNBIRD				
083	WHITE STORK	196	NATAL FRANCOLIN	348	FERAL PIGEON	478	SHARP B HONEYGUIDE	633	EUR MARSH WARBLER	792	BLACK SUNBIRD				
084	BLACK STORK	198	SWAINSON'S FRANCOLIN	349	ROCK PIGEON	479	SLENDER B HONEYGUIDE	634	EUR SEDGE WARBLER	793	COLLARED SUNBIRD				
085	ABDIM'S STORK	200	COMMON QUAIL	352	REDEYED DOVE	481	BENNETT'S WOODPECKER	635	CAPE REED WARBLER	796	CAPE WHITE-EYE				
086	WOOLLYNECKED STORK	201	HARLEQUIN QUAIL	353	MOURNING DOVE	483	GOLDEN T WOODPECKER	636	GR SWAMP WARBLER	797	YELLOW WHITE-EYE				
087	OPENBILLED STORK	202	(BLUE QUAIL)	354	CAPE TURTLE DOVE	486	CARDINAL WOODPECKER	638	AFR SEDGE WARBLER	798	RED B BUFFALO WEAVER				
088	SADDLEBILLED STORK	203	HELMETED GUINEAFOWL	355	LAUGHING DOVE	487	BEARDED WOODPECKER	643	WILLOW WARBLER	799	WH BR SPARROWWEAVER				
089	MARABOU STORK	205	KURRICHANE B'QUAIL	356	MAMAQUA DOVE	489	(RED THR WRYNECK)	645	BARTHROATED APALIS	800	SOCIABLE WEAVER				
090	YELLOWBILLED STORK	206	BLACKRUMPED B'QUAIL	358	GREENSPOTTED DOVE	490	(AFRICAN BROADBILL)	648	YELLOW BR APALIS	801	HOUSE SPARROW				
091	SACRED IBIS	207	WATTLED CRANE	361	GREEN PIGEON	492	MELODIOUS LARK	651	LONGBILLED CROMBEC	802	GREAT SPARROW				
093	GLOSSY IBIS	208	BLUE CRANE	362	CAPE PARROT	493	MONOTONOUS LARK	653	YELLOW B EREMOMELA	803	CAPE SPARROW				
094	HADEDA IBIS	209	CROWNED CRANE	364	MEYER'S PARROT	494	RUFOUSNAPED LARK	655	GREENCAP EREMOMELA	804	GREYHEADED SPARROW				
095	AFRICAN SPOONBILL	210	AFRICAN RAIL	370	KNYSNA LOURIE	495	CLAPPER LARK	656	BURNTNECK EREMOMELA	805	YELLOW THR SPARROW				
096	GREATER FLAMINGO	211	CORNCRAKE	372	ROSS'S LOURIE	496	FLAPPET LARK	657	BLEATING WARBLER	806	SCALYFEATHERED FINCH				
097	LESSER FLAMINGO	212	AFRICAN CRAKE	373	GREY LOURIE	497	FAWNCOLOURED LARK	658	BARRED WARBLER	807	THICKBILLED WEAVER				
099	WHITEFACED DUCK	213	BLACK CRAKE	374	EUROPEAN CUCKOO	498	SABOTA LARK	659	STIERLING'S BARRED WARBLER	810	SPECTACLED WEAVER				
100	FULVOUS DUCK	214	SPOTTED CRAKE	375	AFRICAN CUCKOO	501	SHORTCLAWED LARK	664	FANTAILED CISTICOLA	811	SPOTTEDBACKED WEAVER				
101	WHITEBACKED DUCK	215	BAILLON'S CRAKE	377	REDCHESTED CUCKOO	505	DUSKY LARK	665	DESERT CISTICOLA	812	CHESTNUT WEAVER				
102	EGYPTIAN GOOSE	216	(STRIPED CRAKE)	378	BLACK CUCKOO	506	SPIKEHEELED LARK	668	PALE CR CISTICOLA	814	MASKED WEAVER				
103	S AFRICAN SHELDUCK	217	REDCHESTED FLUFFTAIL	380	GREAT SPOTTED CUCKOO	507	REDCAPPED LARK	671	TINKLING CISTICOLA	815	LESSER MASKED WEAVER				
104	YELLOWBILLED DUCK	223	PURPLE GALLINULE	381	STRIPED CUCKOO	508	PINKBILLED LARK	672	RATTLING CISTICOLA	816	GOLDEN WEAVER				
105	AFRICAN BLACK DUCK	224	LESSER GALLINULE	382	JACOBIN CUCKOO	511	STARK'S LARK	674	REDFACED CISTICOLA	818	BROWNTHROATED WEAVER				
106	CAPE TEAL	226	MOORHEN	383	THICKBILLED CUCKOO	515	CHESTNUT B FINCHLARK	675	BL BACKED CISTICOLA	819	REDHEADED WEAVER				
107	HOTTENTOT TEAL	227	LESSER MOORHEN	384	(EMERALD CUCKOO)	516	GREYBACKED FINCHLARK	676	CHIRPING CISTICOLA	820	CUCKOO FINCH				
108	REDBILLED TEAL	228	REDKNOBBED COOT	385	KLAAS'S CUCKOO	517	BLACKEARED FINCHLARK	677	LEVAILL CISTICOLA	821	REDBILLED QUELEA				
109	PINTAIL	229	AFRICAN FINFOOT	386	DIEDERIK CUCKOO	518	EUROPEAN SWALLOW	678	CROAKING CISTICOLA	822	REDHEADED QUELEA				
110	GARGANEY	230	KORI BUSTARD	388	BLACK COUCAL	520	WHITE THR SWALLOW	679	LAZY CISTICOLA	824	RED BISHOP				
112	CAPE SHOVELLER	231	STANLEY'S BUSTARD	389	COPPERYTAILED COUCAL	522	WIRETAILED SWALLOW	681	NEDDICKY	826	GOLDEN BISHOP				
113	SOUTHERN POCHARD	232	(LUDWIG'S BUSTARD)	390	SENEGAL COUCAL	523	PEARL BR SWALLOW	683	TAWNYFLANKED PRINIA	827	YELLOWRUMPED WIDOW				
114	PYGMY GOOSE	233	WHITEBELLIED KORHAAN	391	BURCHELL'S COUCAL	524	REDBREASTED SWALLOW	685	BLACKCHESTED PRINIA	828	REDSHOULDERED WIDOW				
115	KNOBBILLED DUCK	237	REDCRESTED KORHAAN	392	BARN OWL	525	MOSQUE SWALLOW	689	RUFOUSEARED WARBLER	829	WHITEWINGED WIDOW				
116	SPURWINGED GOOSE	238	BLACKBELLIED KORHAAN	394	WOOD OWL	526	GREATER STR SWALLOW	689	SPOTTED FLYCATCHER	831	REDCOLLARED WIDOW				
117	MACCOA DUCK	239	BLACK KORHAAN	395	MARSH OWL	527	LESSER STR SWALLOW	691	BLUEGREY FLYCATCHER	832	LONGTAILED WIDOW				
118	SECRETARYBIRD	240	AFRICAN JACANA	396	SCOPS OWL	528	S AFR CLIFF SWALLOW	693	PANTAILED FLYCATCHER	833	GOLDENBACKED PYTILIA				
120	EGYPTIAN VULTURE	241	LESSER JACANA	397	WHITEFACED OWL	529	ROCK MARTIN	694	BLACK FLYCATCHER	834	MELBA FINCH				
121	HOODED VULTURE	242	PAINTED SNIPE	398	PEARLSPOTTED OWL	530	HOUSE MARTIN	695	MARICO FLYCATCHER	840	(BLUE B FIREFINCH)				
122	CAPE VULTURE	245	RINGED PLOVER	399	BARRED OWL	531	GREYRUMPED SWALLOW	696	PALLID FLYCATCHER	841	JAMESON'S FIREFINCH				
123	WHITEBACKED VULTURE	246	WHITEFRONTED PLOVER	401	SPOTTED EAGLE OWL	532	SAND MARTIN	697	CHAT FLYCATCHER	842	REDBILLED FIREFINCH				
124	LAPPETFACED VULTURE	247	CHESTNUT B PLOVER	402	GIANT EAGLE OWL	533	BROWNTHROATED MARTIN	698	FISCAL FLYCATCHER	843	BROWN FIREFINCH				
125	WHITEHEADED VULTURE	248	KITTLITZ'S PLOVER	403	PEL'S FISHING OWL	534	BANDED MARTIN	701	CHINSPOT BATIS	844	BLUE WAXBILL				
126	YELLOWBILLED KITE	249	THREEBANDED PLOVER	404	EUROPEAN NIGHTJAR	536	(BL SAWWING SWALLOW)	703	PRIRIT BATIS	845	VIOLETEARED WAXBILL				
126	BLACK KITE	252	CASPIAN PLOVER	405	FIERYNECKED NIGHTJAR	538	BLACK CUCKOOSHRIKE	706	FAIRY FLYCATCHER	846	COMMON WAXBILL				
127	BLACKSHOULDERED KITE	254	GREY PLOVER	406	RUFOUS CH NIGHTJAR	539	WHITE B CUCKOOSHRIKE	710	PARADISE FLYCATCHER	847	BLACKCHEEKED WAXBILL				
128	CUCKOO HAWK	255	CROWNED PLOVER	407	NATAL NIGHTJAR	541	FORKTAILED DRONGO	711	AFRICAN PIED WAGTAIL	852	QUAIL FINCH				
129	BAT HAWK	256	BLACKSMITH PLOVER	408	FRECKLED NIGHTJAR	543	EUR GOLDEN ORIOLE	713	CAPE WAGTAIL	853	LOCUST FINCH				
130	(HONEY BUZZARD)	259	WHITECROWNED PLOVER	409	MOZAMBIQUE NIGHTJAR	544	AFR GOLDEN ORIOLE	714	YELLOW WAGTAIL	854	ORANGE BR WAXBILL				
131	BLACK EAGLE	260	WATTLED PLOVER	410	PENN WINGED NIGHTJAR	545	BLACKHEADED ORIOLE	715	GREY WAGTAIL	855	CUTTHROAT FINCH				
132	TAWNY EAGLE	261	LONGTOED PLOVER	411	EUROPEAN SWIFT	547	BLACK CROW	716	RICHARD'S PIPIT	856	REDHEADED FINCH				
133	STEPPE EAGLE	262	TURNSTONE	412	BLACK SWIFT	548	PIED CROW	901	MOUNTAIN PIPIT	857	BRONZE MANNIKIN				
134	LESSER SPOTTED EAGLE	263	TEREK SANDPIPER	413	(BRADFIELD'S SWIFT)	550	(WHITENECKED RAVEN)	717	LONGBILLED PIPIT	860	PINTAILED WHYDAH				
135	WAHLBERG'S EAGLE	264	COMMON SANDPIPER	415	WHITERUMPED SWIFT	552	ASHY TIT	718	PLAINBACKED PIPIT	861	SHAFTTAILED WHYDAH				
136	BOOTED EAGLE	265	GREEN SANDPIPER	416	HORUS SWIFT	554	SOUTHERN BLACK TIT	719	BUFFY PIPIT	862	PARADISE WHYDAH				
137	AFRICAN HAWK EAGLE	266	WOOD SANDPIPER	417	LITTLE SWIFT	556	RUFOUSBELLIED TIT	720	STRIPED PIPIT	863	BROADTAILED P WHYDAH				
138	AYRES EAGLE	267	(SPOTTED REDSHANK)	418	ALPINE SWIFT	557	CAPE PENDULINE TIT	722	TREE PIPIT	864	BLACK WIDOWFINCH				
139	LONGCRESTED EAGLE	269	REDSHANK	421	PALM SWIFT	558	GREY PENDULINE TIT	723	BUSHVELD PIPIT	865	PURPLE WIDOWFINCH				
140	MARTIAL EAGLE	269	MARSH SANDPIPER	423	BÖHM'S SPINETAIL	560	ARROWMARKED BABBLER	727	ORANGE THR LONGCLAW	867	STEELBLUE WIDOWFINCH				
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146	BATELEUR	273	(DUNLIN)	427	NARINA TROGON	567	REDEYED BULBUL	733	REDBACKED SHRIKE	878	YELLOW CANARY				
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149	STEPPE BUZZARD	278	PECTORAL SANDPIPER	430	MALECOLL KINGFISHER	574	YELLOWBELLIED BULBUL	735	LONGTAILED SHRIKE	884	GOLDEN BR BUNTING				
152	JACKAL BUZZARD	280	TEMMINCK'S STINT	431	MALACHITE KINGFISHER	576	KURRICHANE THRUSH	736	SOUTHERN BOUBOU	885	CAPE BUNTING				
154	LIZARD BUZZARD	281	SANDERLING	432	PYGMY KINGFISHER	577	OLIVE THRUSH	737	TROPICAL BOUBOU	886	ROCK BUNTING				
156	OVAMBO SPARROWHAWK	284	RUFF	433	WOODLAND KINGFISHER	580	GROUNDSCRAPER THRUSH	738	SWAMP BOUBOU	887	LARKLIKE BUNTING				
157	LITTLE SPARROWHAWK	285	GREAT SNIPE	435	BROWN H KINGFISHER	581	(CAPE ROCK THRUSH)	739	CRIMSON BR SHRIKE						

( ) INDICATES THAT THE SPECIES MAY OCCUR IN BOTSWANA BUT THAT THIS HAS NOT YET BEEN PROVEN

stenographix 3466

Edition 2 Jan 1

DATA LIST K – E4.1

THREATENED PLANT TAXA OCCURRING IN BOTSWANA (Hall et al. 1980)

Family	Taxon	Status
Acanthacea	Ruspolia hypocrateriformis var australis	Uncertain
Annonaceae	Friesodielsia obovata	Uncertain
Amaryllidaceae	Crinum crassicaule	Rare
Asclepiadaceae	Hoodia lugardii	Uncertain
	Orbea maculata	Vulnerable
Fabaceae	Acacia hebeclada subspecies chobiensis	Rare
	Acacia hebeclada ssp minima	Rare
	Albizia amara ssp sericocephala	Uncertain
	Albizia antunesiana	Uncertain
Cabombaceae	Brasenia schreberi	Uncertain
Capparidaceae	Boscia foetida ssp minima	Rare
Lamiaceae	Hyptis spicigera	Uncertain
Meliaceae	Turraea zambesica	Uncertain
Nymphaeaceae	Nymphaea lotus	Rare
Rutaceae	Citropsis daweana	Rare

Conservation status categories

The various categories defining the conservation status of a species as used in this report follow the definitions used by the International Union for the Conservation of Nature and Natural Resources (IUCN).

ENDANGERED: In immediate danger of extinction if the causal factors continue operating. Included are taxa whose populations are so critically reduced that a breeding collapse due to a lack of genetic diversity becomes possible, whether or not they are threatened by human activity.

VULNERABLE: Used for a species that was recently more widespread, but is on the decline, and is likely to become endangered if the causal factors for its decline continue operating.

RARE: Used for a species with a relatively small world population that is not declining and is under no known immediate threat. Because of its rarity, the species should be checked regularly for a decline due to some unexpected pressure.

INDETERMINATE: A temporary category for species that are known to be either endangered, vulnerable or rare, but due to lack of study, cannot yet be placed convincingly in one category in preference to another.

UNCERTAIN: A temporary category for species that are so little known that there is an even chance that they could prove to be safe.

DATA LIST K – E5.1

LIST OF ECOLOGICALLY, ECONOMICALLY, AND MEDICINALLY IMPORTANT PLANT SPECIES OCCURRING IN THE MOTLOUTSE CATCHMENT

Introduction

Wherever a known economic, medicinal or social use of the plant has been recorded in the literature or in the field this is listed. An asterisk donotes medicinal uses as indicated by the Traditional Doctors who accompanied the ecologist. Overall, the uses are not restricted to those exclusively adopted by people in the Motloutse valley as the information obtained from discussions with traditional doctors has been supplemented by published information (Coates – Palgrave, 1977; Moss and Taylor, 1983)

Key: A = aphrodisiac
B = browse for livestock and wildlife
C = construction material including use for carving
D = beverage (including alcoholic drinks)
E = edible; used as food by people
F = fuelwood
H = tanning
I = implements/tools
M = medicinal uses
N = nectar
O = oils
P = pharmacological uses
R = ropes; fibres for baskets
S = fencing materials
T = traditional use (eg. protection against bad luck)
V = veterinary uses
W = soap substitute
X = toxic, used as an insecticide
Y = source of dyes

Data list K – E5.2
Listing of Dicotyledons recorded in the Motloutse catchment and their economic uses

Abbreviations For A Known Use (see text)

	BINOMIAL	FORM	WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM	
1	Abutilon angulatum	Erect shrub									1
2	Abutilon grandiflorum	Herb/soft shrub									2
3	Abutilon matopense	Perennial herb									3
4	Abutilon rehmannii	Shrub									4
5	Acacia albida	Large tree		C,F,I		B	M	B			5
6	Acacia arenaria	Tree/shrub									6
7	Acacia burkei	Tree		F		B		B			7
8	Acacia caffra	Tree/shrub		F,S		B,M	M	B			8
9	Acacia erioloba	Tree		C,F,R		B	M	B,M		E	9
10	Acacia erubescens/shrub	Tree		C,F,S		B		B		E	10
11	Acacia fleckii	Tree/shrub		C,F,I		B		B		E	11
12	Acacia galpinii	Large tree		C,F,I	R	B		B			12
13	Acacia gerrardii	Tree/shrub		F		B		B			13
14	Acacia grandicornuta	Tree		F		B	R	B			14
15	Acacia karroo	Tree	N	C,F,S	M	B	H,R,V	B		E,P	15
16	Acacia mellifera - ssp. detinens	Shrub/small tree	N	B,C,F,S		B	M,R	B		E	16
17	Acacia nebrownii	Shrub								E	17
18	Acacia nigrescens	Tree		C,F,S	H	B		B			18
19	Acacia nilotica - ssp. kraussiana	Tree		F,S		B	M	B		E	19
20	Acacia robusta - subsp. clavigera	Tree		F		B		B			20
21	Acacia schweinfurthii	Shrub/climber									21
22	Acacia senegal	Tree/shrub									22
23	Acacia sieberana	Tree		F		B		B			23
24	Acacia tenuispina	Shrub									24
25	Acacia tortilis - ssp. heteracantha	Tree/shrub	N	F,S		B		B			25
26	Acalypha indica	Woody herb									26
27	Acanthosicyos naudinianus	Perennial herb									27
28	Acanthospermum sp.	Herb									28
29	Achyranthes aspera - var. sicula	Herb									29
30	Achyropsis leptostachya	Herb									30
31	Adansonia digitata	Tree					B,R,T	E	M,T		31
32	Adenia digitata	Sub-herb. climber									32
33	Adenia glauca	Climber/shrubby									33
34	Albizia amara	Tree			W	B		B,M			34
35	Albizia anthelmintica	Tree/bush				B	M,X	B			35
36	Albizia brevifolia	Tree/bush				B		B			36

Data list K – E5.2

Listing of Dicotyledons recorded in the Motloutse catchment and their economic uses (contd)

Abbreviations For A Known Use (see text)

	BINOMIAL	FORM		WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM	
37	Albizia harveyi	Tree		M	I		B		B			37
38	Alternanthera nodiflora	Herb										38
39	Alternanthera pungens	Spiny herb										39
40	Amaranthus hybridus	Often tall herb										40
41	Antherothamnus pearsonii	Shrub										41
42	Aptosimium lineare	Herb	*			M						42
43	Argemone mexicana = Argemone subfusiformis	Prickly herb	*	P		M	M,X				M	43
44	Artabotrys brachypetalus	Shrub/small tree							D,E			44
45	Asystasia schimperi	Herb										45
46	Azanza garckeana	Tree			C,I			R	E			46
47	Balanites pedicellaris	Shrub/tree										47
48	Barleria affinis	Shrub/shrublet										48
49	Barleria holubii	Shrub/shrublet										49
50	Barleria lugardii	Shrub/shrublet										50
51	Barleria senensis	Shrub/shrublet										51
52	Bauhinia petersiana	Bush/small tree					B,M			B,D		52
53	Becium filamentosum	Herb										53
54	Becium kirkii	Herb										54
55	Berchemia discolor	Tree/shrub			C			R,Y	E			55
56	Bergia sp.	Herb										56
57	Bidens pilosa	Herb										57
58	Blepharis serrulata	Woody herb	*			M						58
59	Blepharis transvaalensis	Herb										59
60	Blumea decurrens	Herb										60
61	Blumea gariepina	Woody herb	*			M	B					61
62	Boerhavia erecta	Herb										62
63	Boerhavia oppositifola	Herb										63
64	Bolusanthus speciosus	Tree			C,F,I			M				64
65	Boscia albitrunca	Tree	*	T		D,E,M	E,B,V		E			65
66	Boscia foetida	Large shrub/tree					B					66
67	Bridelia mollis	Small tree			T				E		M	67
68	Burkea africana	Tree			C,F		B	M,H	B,H			68
69	Cadaba aphylla	Shrub/small tree	*		M,I							69
70	Cadaba termitaria	Shrub/tree	*			T						70
71	Canthium huillense (now Psydrax livida)				I		B					71
72	Caralluma rogersii	Climbing herb		E								72
73	Cardiospermum corindum	Climber										73
74	Cassia abbreviata - ssp. beareana	Shrub/tree	*		F	M	B,M	M,T		M		74
75	Catophractes alexandri	Shrub/tree										75

Data list K-E5.2

Listing of Dicotyledons recorded in the Motloutse catchment and their economic uses (contd)

Abbreviations For A Known Use (see text)

	BINOMIAL	FORM		WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM	
76	Ceratotheca triloba	Herb										76
77	Chamaesyce eyelesii was Euphorbia eyelesii	Herb										77
78	Chamaesyce mossambicensis was Euph. mossambicensis	Herb										78
79	Chamaesyce neopolycnmoides was Euph. neopolycnmoides	Herb										79
80	Chenopodium ambrosioides	Herb					B					80
81	Chenopodium carinatum	Herb					B					81
82	Cissus cornifolia	Climbing shrub	*		T				E			82
83	Cissus quadrangularis	Climbing herb	*	T								83
84	Clematis brachiata	Woody climber										84
85	Cleome augustifolia	Herb										85
86	Clerodendrum myricoides	Shrub/small tree				M,V			E,M			86
87	Clerodendrum ternatum	Woody herb/shrub										87
88	Coccinea sp.	Climbing herb										88
89	Cocculus hirsutus	Climbing herb										89
90	Colophospermum mopane	Tree/shrub			C,F,I,S	M	B		B			90
91	Combretum apiculatum - ssp. apiculatum	Tree/shrub			C,F,M,S	M	B,M					91
92	Combretum erythrophyllum	Tree			C	M	B					92
93	Combretum hereroense	Tree	*		C,F,I	M	B		D			93
94	Combretum imberbe	Large tree/shrub		P,T,Y	C,F,I,S		B,M			B		94
95	Combretum molle	Tree	*		F,I,S	M	M,P	M				95
96	Combretum mossambicense	Shrub/small tree										96
97	Commicarpus helenae	Herb										97
98	Commicarpus pentandrus	Herb										98
99	Commicarpus squarrosus	Herb										99
100	Commiphora africana - var. africana	Shrub/small tree			I	E	B	M	M		M,X	100
101	Commiphora marlothii	Tree	*		I		B	T				101
102	Commiphora mollis	Tree	*		I		B	M				102
103	Commiphora pyracanthoides	Shrub/tree		S	I	E	B				E	103
	- ssp. glandulosa	Shrub/tree	*	S	I	E	B	M			E	
104	Commiphora tenuipetiolata	Bush/small tree					B					104
105	Conyza bonariensis	Herb										105
106	Corbichonia decunbens	Herb										106
107	Corchorus asplenifolius	Herb					B,E,M	R	E			107
108	Crabbea velutina	Herb										108
109	Craterostigma plantagineum	Herb										109

Data list K – E5.2

Listing of Dicotyledons recorded in the Motloutse catchment and their economic uses (contd)

Abbreviations For A Known Use (see text)

	BINOMIAL	FORM		WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM	
110	Croton gratissimus	Shrub/tree			P	M	B,O	M				110
	- var. gratissimus		*									
111	Cucumis hirsutus	Climbing herb										111
112	Cucumis metuliferus	Climbing herb										112
113	Cucumis tributus	Climbing herb										113
114	Cullen obtusifolia	Woody herb										114
115	Cyphostemma puberulum	Climbing herb										115
116	Dalbergia melanoxylon	Shrub/tree			C,F,i	M						116
117	Datura innoxia	Woody herb										117
118	Datura stramonium	Herb		P			P		P			118
119	Decorsea schlechteri	Perennial herb	*			M,T						119
120	Dicerocaryum eriocarpum	Trailing herb										120
121	Dichrostachys cinerea	Shrub/tree			F,I	M	B,M	M,R	B			121
122	Dicoma schinzii	Herb										122
123	Diospyros lycioides	Shrub/tree				I	B		B,E			123
	- ssp. lycioides											
124	Dombeya rotundifolia	Shrub/small tree			C,I,F		B	M	B			124
125	Dregea macrantha	Herb	*		R							125
126	Ehretia amoena	Shrub/small tree			I							126
127	Ehretia rigida	Shrub/small tree	*	T		M,T,V						127
128	Elephantorrhiza burkei	Shrub		H,M			B		E			128
129	Elephantorrhiza goetzei	Shrub/tree	*			M,H,Y		R				129
130	Endostemon tereticaulis	Herb										130
131	Erianthemum ngamicum	Parasitic epiphyte										131
132	Erythrina latissima	Tree						M				132
133	Euclea divinorum	Shrub/tree			C,I,T		B	Y	B,E,M,Y			133
134	Euclea undulata	Shrub/tree			F,I,S	M	B	M	E			134
135	Euphorbia cooperi	Spiny tree									X	135
136	Euphorbia griseola	Succulent spiny										136
	- ssp. griseola	shrub										
137	Euphorbia guerichiana	Woody shrub/tree										137
138	Euphorbia ingens	Tree									M,X	138
139	Euphorbia tirucalli	Succulent tree		S		P					X	139
140	Evolvulus alsinoides	Herb	*	T		V						140
	Faidherbia albida = Acacia albida											
141	Ficus abutilifolia = Ficus soldanella	Tree							E			141
142	Ficus cordata	Tree							E			142
	- ssp. salicifolia											
143	Ficus tettensis	Tree							E			143
144	Flaveria bidentis	Herb										144

Data list K – E5.2

Listing of Dicotyledons recorded in the Motloutse catchment and their economic uses (contd)

	BINOMIAL	FORM		Abbreviations For A Known Use (see text)							
				WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM
145	Fluggea virosa = Securinega virosa	Bushy shrub/tree	*		I	M,P	B	M	E,M,P		
146	Fockea angustifolia	Perennial herb	*			E					
147	Gardenia spatulifolia	Tree			I						
148	Gardenia thonningii	Tree	*			M,V			M		
149	Gardenia volkensii	Tree				M			M		
150	Geigeria acaulis	Woody herb									
151	Geigeria burkei – ssp. burkei	Woody herb	*	M							
152	Geigeria ornativa	Woody herb									
153	Gisekia africana	Herb									
154	Glinus bainesii	Herb									
155	Glinus oppositifolius	Herb	*	M							
156	Gomphocarpus tomentosus	Herb	*			M					
157	Gomphrena celosioides	Herb									
158	Gossypium herbaceum – var. africanum	Shrublet									
159	Grewia bicolor	Shrub				M	B	R	E		
160	Grewia flava	Shrub/tree			I,T		B	M,R,T	E		
	Grewia flavescens	Shrub			I		B	R	E		
161	– var. flavescens										
162	– var. olukondae										
163	Grewia monticola – may be G.subspathulata	Shrub/tree			C		B	M	E		
164	Grewia retinervas	Shrub/tree					B		E		
165	Grewia subspathulata – hybrid bicolor * monticola?	Shrub/tree			C				E		
166	Grewia villosa	Shrub/tree							E		
	Gynandropsis gynandra	Woody herb					E		O		
167	Harpagophytum procumbens	Trailing herb				M	W				
168	Harpagophytum zeyheri – ssp. sublobatum	Trailing herb	*			M,P	B				
169	Helichrysum argyrosphaerum	Woody herb					D				
170	Helichrysum candolleanum	Woody herb					D				
171	Heliotropium steudneri	Herb									
172	Hermbstaedtia odorata	Herb									
173	Hermannia kirkii	Prostrate herb									
174	Hermannia quartiniana	Annual herb									
175	Heteromorpha trifoliata	Shrub/tree	*		M	M	M		O		
176	Hibiscus calyphyllus	Shrub/peren. herb									
177	Hibiscus dongolensis	Shrub/woody herb									

Data list K – E5.2

Listing of Dicotyledons recorded in the Motloutse catchment and their economic uses (contd)

Abbreviations For A Known Use (see text)

	BINOMIAL	FORM		WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM	
178	Hibiscus engleri	Herb										178
179	Hibiscus micranthus	Shrub										179
180	Hibiscus mutatus	Shrub										180
181	Hibiscus ovalifolius	Perennial herb		M								181
182	Hibiscus praeteritus	Perennial herb										182
183	Hibiscus schinzii	Perennial herb										183
184	Hibiscus sidiformis	Annual herb										184
185	Hibiscus subreniformis	Pern.herb/shrublet										185
186	Hibiscus vitifolius	Shrub/peren. herb										186
187	Holubia saccata	Herb										187
188	Hypertelis bowkeriana	Herb										188
189	Indigofera circinnata	Shrub/Herb										189
190	Indigofera cryptantha - var. cryptantha	Woody herb/shrub				V						190
191	Indigofera holubii	Herb										191
192	Indigofera trita	Shrub/Herb										192
193	Indigofera vicioides - var. rogersii	Perennial herb										193
194	Ipomoea bolusiana	Perennial herb										194
195	Ipomoea magnusiana	Perennial herb										195
196	Ipomoea obscura	Perennial herb										196
197	Jasminum stenolobum	Climbing shrub										197
198	Jatrophe sp.	Herb										198
199	Justicia flava	Herb										199
200	Justicia metammensis	Herb										200
201	Kohautia aspera	Herb										201
202	Kalanchoe brachyloba	Succulent	*			M						202
203	Kalanchoe rotundifolia	Succulent										203
204	Kalanchoe thyrsiflora (?)	Succulent										204
205	Kirkia acuminata	Tree	*		C,I	T	B	M				205
206	Kleinia longiflora	Herb	*	T								206
	Lannea schweinfurthii	Tree										
207	- var. stuhlmannii											207
208	- var. tomentosa											208
209	Lantana camara	Woody herb/shrub										209
210	Leonotis sp.	Annual herb										210
211	Leucas glabrata - var. glabrata	Herb					M,X					211
212	Leucas sexadentata	Herb										212
213	Limeum fenestratum	Herb										213
214	Limeum sulcatum	Herb										214

Data list K – E5.2

Listing of Dicotyledons recorded in the Motloutse catchment and their economic uses (contd)

Abbreviations For A Known Use (see text)

	BINOMIAL	FORM		WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM	
215	Lippia javanica	Shrub					B					215
216	Lonchocarpus capassa	Tree		T	C,I	M,X	B,M	X	M			216
217	Lonchocarpus nelsii	Bushy tree			I		B					217
218	Lycium cinereum	Shrub										218
219	Lycium shawii	Shrub										219
220	Maerua angolensis	Tree	*		M							220
221	Maerua juncea - ssp. crustata ?	Shrub/small tree										221
222	Maerua parvifolia	Shrub	*	T								222
223	Markhamia acuminata	Tree			C,I	M						223
224	Markhamia zanzibarica	Shrub/tree										224
225	Maytenus heterophylla - var. heterophylla	Shrub/tree										225
226	Maytenus senegalensis	Shrub/tree	*		F,T	A,M	B,M	M				226
227	Melhannia acuminata	Shrublet										227
228	Melhannia forbesii	Shrublet										228
229	Melia azedarach	Tree					B		X			229
230	Merremia kentrocaulos - var. pinnatifida	Woody twining herb										230
231	Merremia palmata	Twining herb										231
	Merremia tridenta = Xenostegia tridenta											
232	Mollugo cerviana	Herb										232
233	Mollugo nudicaulis	Herb										233
234	Momordica balsamina	Climbing herb										234
235	Momordica repens	Climbing herb	*			M						235
236	Monechma sp.	Herb										236
237	Monsonia burkeana	Herb										237
238	Monsonia glauca - ssp. glauca	Herb										238
239	Nelsonia nova											239
240	Nicotiania glauca	Tree					X					240
241	Nidorella auriculata	Perennial herb										241
242	Nidorella resedifolia	Annual herb										242
243	Ochna inermis	Shrub/small tree										243
244	Ochna pulchra	Tree				T				M,W,X		244
245	Ocimum canum = Ocimum fruticulosum	Woody herb/shrublt	*	M		M,P	M					245
246	Ocimum urticifolium	Woody herb	*			M						246
247	Opuntia ficus-indica	Succulent							B			247
248	Osteospermum muricatum	Perennial herb										248
249	Otoptera burchellii	Shrub										249

Data list K – E5.2

Listing of Dicotyledons recorded in the Motloutse catchment and their economic uses (contd)

	BINOMIAL	FORM		Abbreviations For A Known Use (see text) WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM	
250	Oxygonum sinuatum	Herb										250
251	Ozoroa paniculosa	Shrub/tree										251
252	Pappea capensis	Tree	*		C	M	B,M	M	B,E	M,O		252
253	Pavetta gardeniifolia – var. subtomentosa	Shrub/small tree										253
254	Pavonia burchellii = Pavonia patens	Shrublet/shrub	*		M							254
255	Pavonia senegalensis	Woody herb										255
256	Peltophorum africanum	Tree	*		C,F,I	M	B	M				256
257	Pergularia daemia	Climbing herb	*			T	E,M					257
258	Peristrophe kotschyana	Woody herb ?										258
259	Peristrophe paniculata	Herb										259
260	Philyrophyllum schinzii	Herb										260
261	Phyllanthus maderaspatensis	Woody herb/shrublet										261
262	Phyllanthus pentandrus	Woody herb										262
263	Phyllanthus reticulatus	Shrub										263
264	Piriqueta capensis	Undershrub	*	M								264
265	Plectranthus caninus	Woody herb										265
266	Plexipus pinnatifidum (was Chascanum pinnatifidum)	Herb										266
267	Plicosepalus kalachariensis	Parasitic epiphyte										267
268	Pluchea leubnitziae	Woody herb	*		M	M	M,O					268
269	Plumbago zeylanica	Shrub/shrublet	*			M	B					269
270	Polygala sphenoptera	Herb/shrublet										270
271	Polygonum lapathifolium	Herb										271
272	Portulaca kermesina	Succulent herb										272
273	Portulaca quadrifida	Succulent herb										273
274	Pouzolzia hypoleuca = Pouzolzia mixta	Shrub/small tree			R							274
275	Psiada arabica	Shrub										275
	Psydrax livida (see Canthium huillense)											
276	Pterococcus africanus	Perennial herb										276
277	Pterodiscus ngamicus	Fleshy herb										277
278	Pterodiscus speciosus	Fleshy herb										278
279	Pupalia lappacea – var. lappacea	Woody herb		T								279
280	Raphionacme monteiroae	Perennial herb										280
281	Rhigozum brevispinosum	Shrub/tree										281
282	Rhinacanthus gracilis	Herb										282
283	Rhus leptodictya	Shrub/tree					B		B,D			283
284	Rhus pyroides	Shrub/tree			I,S		B		B,E			284

Data list K – E5.2

Listing of Dicotyledons recorded in the Motloutse catchment and their economic uses (contd)

Abbreviations For A Known Use (see text)

	BINOMIAL	FORM		WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM	
285	Rhynchosia totta - var. totta	Climbing herb										285
286	Ricinus communis	Shrub			M	M				M,O,P		286
287	Rorippa fluviatilis	Herb										287
288	Ruellia capitata	Undershrub										288
289	Ruellia patula	Undershrub										289
290	Salvadora angustifolia - var. australis	Shrub/small tree					M		E			290
291	Sarcostemma viminale	Scandent shrub										291
292	Schotia brachypetala	Tree			C,I			H,M		E		292
293	Sclerocarya birrea	Tree		C,T				M	B,D,E,T	E,O		293
294	Sclerocarya caffra	Tree		C,T				M	B,D,E,T	E,O		294
295	Seddera suffruticosa	Woody herb										295
296	Senecio sp.											296
297	Sericorema remotiflora	Herb										297
298	Sesamothamnus lugardii	Succulent shrub										298
299	Sida alba	Woody herb										299
300	Sida chrysantha	Shrublet										300
301	Sida cordifolia	Annual shrublet										301
302	Sida hoepfneri	Herb										302
303	Solanum delagoense	Woody herb										303
304	Solanum incanum	Spiny undershrub	*			M,T,X	M,X		P			304
305	Solanum kwebense	Shrublet										305
306	Solanum nigrum	Herb										306
307	Solanum panduriforme	Perennial herb										307
308	Solanum supinum	Perennial (?) herb										308
309	Solanum tomentosum	Woody herb	*			M						309
310	Sonchus sp.	Herb										310
311	Spermacoce senensis	Herb										311
312	Sphaeranthus peduncularis - ssp. peduncularis	Herb										312
313	Spirostachys africana	Tree			T						M,X	313
314	Stapelia gigantea	Succulent herb	*	T								314
315	Steganotaenia araliacea	Tree/Shrub	*	T		M		M,T				315
316	Sterculia africana	Tree						R				316
317	Sterculia rogersii	Tree	*					I,R				317
318	Stomatostemma monteiroae	Scrambling herb	*			T,V						318
319	Streptopetalum serratum	Herb										319
320	Strophanthus kombe	Shrub										320
321	Strychnos madagascariensis	Small tree							E			321
322	Strychnos pungens	Small tree				M	M		E			322

Data list K–E5.2

Listing of Dicotyledons recorded in the Motloutse catchment and their economic uses (contd)

Abbreviations For A Known Use (see text)

	BINOMIAL	FORM		WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM	
323	Stylosanthes fruticosa	Per. herb/shrublet										323
324	Talinum tenuissimum	Herb										324
325	Tapinanthus oleifolius	Parasite										325
326	Tapinanthus sambesiacus	Parasite										326
327	Tarchonanthus camphoratus	Shrub/tree			F,I,S		B					327
328	Tephrosia purpurea	Herb										328
	- ssp. leptostachya											
	- var. pubescens											
329	Terminalia brachystemma	Bushy tree			I	M						329
330	Terminalia prunoides	Tree/shrub			C,F,I		B,D					330
331	Terminalia sericea	Tree		P,T	C,F,I,S	M,Y	B,M,Y	M,Y		B		331
332	Thunbergia neglecta	Herb										332
333	Tinospora caffra	Herbaceous twiner										333
334	Tragia okanyua	Herb	*			M						334
335	Tribulus terrestris	Herb										335
336	Tricliceras schinzii	Herb										336
337	Turraea obtusifolia	Shrub										337
338	Tylosema esculenta	Shrub/climber					B			B,E		338
339	Vahlia capensis	Herb										339
	- ssp. vulgaris											
340	Vangueria infausta	Bush/tree		T		E,M	B		E			340
341	Verbesina enceloides	Herb										341
342	Vernonia cinerascens	Shrub										342
343	Vernonia glabra	Shrub/tree										343
344	Vernonia fastigiata	Herb										344
345	Waltheria indica	Herb	*			M						345
346	Wissadula rostrata	Shrublet										346
347	Xanthium spinosum	Evergreen herb										347
348	Xanthium strumarium	Herb										348
349	Xanthocercis zambesiaca	Tree			I		B		E			349
350	Xenostegia tridentata	Trailing herb										350
351	Ximenia americana	Shrub/tree			I	M	B,M	M	D,E,M	O		351
352	Ximenia caffra	Shrub/tree										352
353	Zaleya pentandra	Herb	*			T						353
354	Ziziphus mucronata	Tree/shrub	*		C,F,I	M	B,M	M	B,E			354
355	???	Climber					B					355

FAMILIES INCLUDED IN DATA LIST K-E5.2

1 ACANTHACEAE
2 AIZOACEAE
3 AMARANTHACEAE
4 ANACARDIACEAE
5 ANNONACEAE
6 APIACEAE (UMBELLIFERAE)
7 APOCYNACEAE
8 ASCLEPIADACEAE
9 ASTERACEAE (COMPOSITAE)
10 BALANITACEAE
11 BIGNONIACEAE
12 BOMBACEAE
13 BORAGINACEAE
14 BRASSICACEAE (CRUCIFERAE)
15 BURSERACEAE
16 CACTACEAE
17 CAPPARACEAE
18 CELASTRACEAE
19 CHENOPODIACEAE
20 COMBRETACEAE
21 CONVOLVULACEAE
22 CRASSULACEAE
23 CUCURBITACEAE
24 EBENACEAE
25 ELATINACEAE
26 EUPHORBIACEAE
27 FABACEAE (LEGUMINOSAE)
- sub-family CAESALPINIACEAE
- sub-family MIMOSACEAE
- sub-family PAPILIONACEAE
28 GERANIACEAE
29 LAMIACEAE (LABIATAE)
30 LOGANIACEAE
31 LORANTHACEAE
32 MALVACEAE
33 MELIACEAE
34 MENISPERMACEAE
35 MOLLUGINACEAE (See also AIZOACEAE)
36 MORACEAE
37 NYCTAGINACEAE
38 OCHNACEAE
39 OLACACEAE
40 OLEACEAE
41 PAPAVERACEAE
42 PASSIFLORACEAE
43 PEDALIACEAE
44 PLUMBAGINACEAE
45 POLYGALACEAE
46 POLYGONACEAE
47 PORTULACACEAE
48 RANUNCULACEAE
49 RHAMNACEAE
50 RUBIACEAE
51 SALVADORACEAE
52 SAPINDACEAE
53 SCROPHULARIACEAE
54 SIMAROUBACEAE
55 SOLANACEAE
56 STERCULIACEAE
57 TILIACEAE
58 TURNERACEAE
59 URTICACEAE
60 VAHLIACEAE
61 VERBENACEAE
62 VITACEAE
63 ZYGOPHYLLACEAE

Data list K-E5.3

Listing of Monocotyledons recorded in the Motloutse catchment and their economic uses

				Abbreviations For A Known Use (see text)								
	BINOMIAL	FORM		WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM	
1	Aloe greatheadii	Succulent shrub										1
2	Aloe littoralis	Succulent shrub	*			M					M,Y	2
3	Andropogon festuciformis	Grass										3
4	Aneilema hookii	Herb										4
5	Ansellia africana	Orchid-epiphytic	*	A								5
6	Aristida adscensionis	Grass										6
7	Aristida barbicollis	Grass										7
8	Aristida canescens	Grass										8
9	Aristida congesta	Grass										9
10	Aristida rhiniochloa	Grass										10
11	Aristida scabrivalvis - subsp. contracta	Grass										11
12	Brachiaria deflexa	Grass										12
13	Brachiaria eruciformis	Grass										13
14	Brachiaria nigropedata	Grass										14
15	Bulbostylis hispidula	Sedge										15
16	Cenchrus ciliaris	Grass										16
17	Chloris virgata	Grass										17
18	Commelina africana - var. krebsiana	Herb										18
19	Commelina diffusa	Herb										19
20	Commelina livingstonia	Herb										20
21	Crinum sp.	Bulbous herb	*			T						21
22	Cymbosetaria sagittifolia	Grass										22
23	Cynodon dactylon	Grass										23
24	Cyperus dives	Sedge										24
25	Cyperus fulgens	Sedge										25
26	Cyperus holostigma	Sedge										26
27	Cyperus involucratus	Sedge										27
28	Dactyloctenium aegyptium	Grass										28
29	Digitaria milanjiana	Grass										29
30	Digitaria nuda	Grass										30
31	Digitaria perrottetii	Grass										31
32	Digitaria velutina	Grass										32
33	Echinochloa colonum	Grass										33
34	Enneapogon cenchroides	Grass										34
35	Enteropogon macrostychyus	Grass										35
36	Eragrostis biflora	Grass										36

Data list K – E5.3
Listing of Monocotyledons recorded in the Motloutse catchment and their economic uses (contd)

	BINOMIAL	FORM		Abbreviations For A Known Use (see text) WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM	
37	Eragrostis cilianensis	Grass										37
38	Eragrostis cylindriflora	Grass										38
39	Eragrostis lehmanniana	Grass										39
40	Eragrostis pallens	Grass										40
41	Eragrostis porosa	Grass										41
42	Eragrostis racemosa	Grass										42
43	Eragrostis rigadior	Grass										43
44	Eragrostis superba	Grass										44
45	Eragrostis trichophora	Grass										45
46	Eriospermum bakerianum	Geophyte										46
47	Eriospermum sphaerophyllum	Geophyte										47
48	Eucomis cf. autumnalis	Bulbous herb										48
49	Fimbristylis hispidula	Sedge										49
50	Fuirena pubescens	Sedge										50
51	Hyphaene natalensis	Palm							E		D	51
52	Hyphaene petersiana	Palm					C				D	52
53	Kyllinga alba	Sedge										53
54	Ledebouria hyacinthina	Bulbous herb										54
55	Ledebouria revoluta	Bulbous herb										55
56	Mariscus hamulosus	Sedge										56
57	Mariscus rehmannianus	Sedge										57
58	Microchlora caffra	Grass										58
59	Oropetium capense	Grass										59
60	Panicum deustum	Grass										60
61	Panicum maximum	Grass										61
62	Phoenix reclinata	Palm									D	62
63	Phragmites mauritianus	Grass			C							63
64	Pogonarthria squarrosa	Grass										64
65	Protasparagus africanus	Climber/woody base	*	T		M	W		E			65
66	Protasparagus exuvialis	Climber/woody base	*									66
67	Protoasparagus laricinus	Climber/woody base										67
68	Protasparagus suaveolens	Climber/woody base	*	T		M	W		E			68
69	Rhynchelytrum repens	Grass										69
70	Sansevieria aethiopica	Succulent	*			T						70
71	Scadoxus puniceus	Bulbous herb										71
72	Schmidtia kalahariensis	Grass										72
73	Schmidtia pappophoroides	Grass										73
74	Setaria pumila	Grass										74
75	Setaria sagittifolia	Grass										75
76	Setaria ustilata	Grass										76

Data list K–E5.3
Listing of Monocotyledons recorded in the Motloutse catchment and their economic uses (contd)

			Abbreviations For A Known Use (see text)							
	BINOMIAL	FORM	WHOLE PLANT	STEM/ WOOD	ROOTS	LEAVES	BARK/ FIBRE	PODS/ FRUITS	SEEDS	SAP/ GUM
77	Setaria verticillata	Grass								77
78	Sporobolus festivus	Grass								78
79	Sporobolus ioclados	Grass								79
80	Stipagrostis uniplumis	Grass								80
81	Tragus berteronianus	Grass								81
82	Tricholaena monachne	Grass								82
83	Urginea cf. altissima	Bulbous herb	*			T				83
84	Urochloa mosambicensis	Grass								84
85	Urochloa panicoides	Grass								85
86	Urochloa trichopus	Grass								86
87	Xerophyta humilis	Peren. woody herb								87
88	Xerophyta retinervis	Peren. woody herb								88
89	Xerophyta schlechteri	Peren. woody herb								89
90	Not yet identified	Grass								90

GENERA INCLUDED IN DATA LIST K-E5b

AGAVACEAE	ARECACEAE (PALMAE)	CYPERACEAE	POACEAE (GRAMINAE)
ALOEACEAE (LILIACEAE)	ASPARAGACEAE (LILIACEAE)	HYACINTHACEAE (LILIACEAE)	VELLOZIACEAE
AMARYLLIDACEAE	COMMELINACEAE	ORCHIDACEAE	

DATA LIST K – E6.1

SUPPLIERS OF SOLAR POWERED ELECTRIC FENCING

The following firm markets solar – powered electric fencing manufactured by Gallagher Power Fencing Systems (Gallagher Electronics Ltd., Private Bag, Hamilton, New Zealand):

Electro Farming (Pvt.) Ltd,
P.O. Box 357,
Kwekwe
ZIMBABWE

Phone: Kwekwe (263 – 55 –)247722

Information on the supply of MEPS electric fencing can be obtained from:

Dr David Lawson,
Department of Wildlife and National Parks,
P.O. Box 131,
Gaborone
BOTSWANA

DATA LIST K-E7.1

ECOLOGY REFERENCES

Brooke R.K.	1984	South African Red Data Book - Birds. South African National Scientific Programmes Report, 97, 1-211.
Campbell A.	1983	Traditional wildlife populations and their utilisation. In: Which Way Botswana's Wildlife? Kalahari Conservation Society, Gaborone.
Crane E.	1985	Bees and honey in the exploitation of arid land resources. In G.E. Wickens, J.R. Goodin and D.V. Field (eds). Plants for Arid Lands. George Allen and Unwin, London.
DHV	1980	Countrywide animal and range assessment project: Volume V. Interpretation of animal distributions. DHV Consulting Engineers, Amersfoort, The Netherlands.
Dye P.H. and Spear P.J.	1983	The effect of bush clearing and rainfall variability on grass yield and composition in south-west Zimbabwe. Zimbabwe Journal of Agricultural Research, 20, 103-117.
Field D.I.	1976	A Handbook of Common Grasses in Botswana. Ministry of Agriculture, Gaborone.
Gibbs-Russell	1984	Intensity of plant collecting in Southern Africa.
G.E.,Retief and Smook L.	-	Bothalia, 15, 131-138.
Gilmore K.S.	1978	A fisheries survey of Shashe Dam, Botswana. Ministry of Agriculture, Gaborone. Typescript.
Hall A.V., de Winter M., de Winter B. and Van Ooosterhout S.A.M.	1980	Threatened plants of Southern Africa. South African National Scientific Programmes Report, 45, 1-241
Hart R.C. and Allanson B.R. (eds)	1984	Limnological criteria for management of water quality in the southern hemisphere. South African National Scientific Programmes Report, 93, 1-179.
Kelly R.D. and Walker B.H.	1976	The effects of different forms of land use on the ecology of a semi-arid region in southern Rhodesia. Journal of Ecology, 64, 553-576.
Key R.M.	1976	The geology of the area around Francistown and Phikwe, Northeast and Central Districts, Botswana. Memoir of the Geological Survey of Botswana, 3, 1-121.

Maclean G.L.	1984	Robert's Birds of Southern Africa. John Voelcker Bird Book Fund, Cape Town.
MMP	1988	Motloutse Dam Feasibility/Preliminary Design Study. Scheme Identification Report. Sir M MacDonald & Partners for Department of Water Affairs, Republic of Botswana.
Moss H. and Taylor, F.	1983	The potential for commercial utilisation of indigenous plants and insects in Botswana: Volume II. The resource and its management. Government Printer, Gaborone
Petersen R.G., Woodhouse W.W. and Lucas H.L.	1956	The distribution of excreta by freely grazing cattle and its effect on pasture fertility: II. Effect of returned excreta on the residual concentration of some fertilizer elements. Agronomy Journal, 48, 444 – 449
Robarts R.D. and Zohary T.	1984	*Microcystis aeruginosus* and underwater light attenuation in a hypertrophic lake (Hartebeespoort Dam, South Africa). Journal of Ecology, 72.
Smithers R.H.	1971	The Mammals of Botswana. Museum Memoirs of the National Museums and Monuments of Rhodesia, 4, 1 – 340.
Smithers R.H.	1983	The Mammals of the Southern African Subregion. University of Pretoria, Pretoria.
Smithers R.H.	1986	South African Red Data Book – Terrestrial Mammals. South African National Scientific Programmes Report, 125, 1 – 214.
Tyson P.D.	1986	Climatic change and variability in southern Africa. Oxford University Press, Cape Town.
Weare P.R. and Yalala A.	1971	Provisional vegetation map of Botswana. Botswana Notes and Records, 3, 131 – 147.
Wild H.	1961	Harmful aquatic plants in Africa and Madagascar. Kirkia, 2, 1 – 66.
Wild H. and Barbosa L.A.G.	1967	Vegetation map of the Flora Zambesiaca Area. Flora Zambesiaca (Supplement), 1 – 71.
White F.	1983	The vegetation of Africa: a descriptive memoir to accompany the Unesco/AETFAT/UNSO vegetation map of Africa. Unesco, Paris
Water Utilities	1975	Fifth Annual Report and Accounts for the Corporation year ended 31st March 1975. WUC, Gaborone

APPENDIX K – F

APPENDIX K – F

CHAPTER K – F1
FORESTRY AND VEGETATION MANAGEMENT

K – F1.1 Introduction

The results of a semi – detailed forestry survey of the reservoir area are given in the following section. This establishes baseline data identifying areas of similar vegetation, species distribution and timber volumes. It also provides a planned approach to any removal of valuable timber resources prior to the contractor's clearing of the dam site and quarry areas. This appendix should be read in conjunction with Appendix K – E which provides the results of the ecology survey. Table K – F1.1 shows the breakdown of relevant areas in the overall reservoir reserve area.

Table K – F1.1
Breakdown of Total Reservoir FSL Areas by Vegetation Type (ha)

Ref No.	Vegetation Community	Downstream Permanent Works	Woodland Areas Reserved	Woodland Areas Conserved	Areas For Bush Clearing Dam Wall	Phase 1	Phase 2	Total Area	Net Area to be Cleared
1.1	Commiphora/croton Kopje Woodland (rocky outcrops)	1 (0)	– (0)	3 (0)	0 (0)	17 (3)	0 (0)	21 (3)	17
1.2	Commiphora/kirkia Kopje Woodland (rocky outcrops)	9 (1)	– (0)	7 (1)	21 (2)	0 (0)	0 (0)	37 (4)	21
2.1	Combretum/acacia Riverine Woodland	4	–	39	2	33	46	124	81
2.2	Combretum/peltophorum Riparian Woodland	12	–	0	3	58	26	99	87
3.1	Acacia/boscia Woodland	0	–	0	0	32	1	33	33
3.2	Mixed Acacia Woodland	6	–	0	2	80	184	272	266
3.3	Acacia/combretum Woodland	0	–	43	2	128	22	195	152
4.1	Colophospermum/acacia Woodland	0	–	0	0	14	14	28	28
4.1.1	Colophospermum/combretum Woodland	103	–	1	19	226	228	577	473
4.1.2	Colophospermum Woodland	55	–	54	11	27	0	147	38
4.2	Colophospermum/commiphora Woodland (rocky outcrops)	0 (0)	– (0)	29 (0)	0 (0)	148 (2)	43 (0)	220 (2)	191
5.1	Acacia Scrubland	19	–	0	12	343	194	568	549
6	Catophractes/rhigozum Shrubland	0	0	0	0	4	0	4	4
7	Cleared land	2	–	0	2	34	12	50	48
8	Bare land	6	–	0	0	19	11	36	30
9	River/stream beds	9	–	0	2	49	79	139	130
	Totals	226	0	176	76	1212	860	2550	2148

Source: Consultant's field surveys

The woodland areas indicated in the Table are within the downstream fence line, but outside the permanent works.

K – F1.2 Survey Methodology

The survey was based on field transects, carried out by both the ecologist and forester in February 1989, and interpretation of the 1:10 000 aerial photography taken in November 1988. Areas of similar tree vegetation were mapped as shown in Map K.2

Five major vegetation communities were identified containing 25 major tree species. Cleared land, unvegetated land and rocky outcrops are classified separately. Some minor associations were also identified and are discussed in Appendix K – E.

A standard relascope inventory survey was carried out to estimate the timber volumes. Standardised data, related to a basal area at a height of 1.3 m above ground level, were used to derive figures for volumes in cubic metres per hectare. The formula used takes average usable height multiplied by basal area. A form factor is then applied to allow a conversion from straight cylindrical measures to the shape of specific species. The calculated volumes are shown in Table K – F1.2. Accuracy of the data, according to the methods employed, are within the range of ±30%. This table also provides the specific weights of drywood and derives the total weight of timber from the volumes.

K – F1.3 Species and Vegetation Communities

Table K – F1.3 lists the most common species identified from the field surveys and gives the estimated volume contributed to the overall timber found in each major vegetation community. The main species include seven species of Acacia, five of Combretum, three of Commiphora and nine other species. The dominant species include Colophospermum mopane, Acacia tortilis, Acacia grandicornuta, Acacia karoo, Combretum hereroense and Commiphora mollis. In addition to these very many smaller and less common trees and shrubs are found. Appendix K – E gives the main species identified and their main uses (Data Lists E.1 and E.5(a) respectively).

Characteristics of forest vegetation in the reservoir area are shown in Table K8.2. Some 93% of the proposed designated reservoir reserve area is forested. Mopane woodland and shrubland dominates, covering 43% of the forested area. Riverine and riparian woodland occupies only 7% of the forested area but are considerably more important in their contribution to the total volume of valuable timber. Acacia shrubland occupies 24% of the total reserve area and is typical of the vegetation regrowth on areas of abandoned cattle posts and cultivated land. The encroachment of Acacia tortilis is believed to be due to the high intensity of browsing by goats which increased considerably in number during recent decades in response by stock owners to the pressure of drought on cattle and the greater capacity of goats to be able to survive. The acid treatment of the A. tortilis seeds in the goat's digestive process and its undamaged presence in the droppings while browsing greatly enhances the germination and spread of this species.

Table K – F1.2

Standing Usable Timber Volumes and Weight (on bark)

Ref No	Vegetation Community	Av. Basal Area (sq m/ha)	Average Height (m)	Form Factor (cu m/ha)	Volume	Area (ha)	Total Volume (cu m)	Specific Weight	Total Weight (tonnes)
1.1	Commiphora/croton Kopje Woodland	4.0	3.5	0.85	11.9	17	202	0.622	126
1.2	Commiphora/kirkia Kopje Woodland	8.2	7.4	0.85	51.6	21	1083	0.560	607
2.1	Combretum/acacia Riverine Woodland	8.9	11.2	0.78	77.8	81	6298	0.814	5126
2.2	Combretum/peltophorum Riparian Woodland	7.6	5.7	0.79	34.2	87	2977	1.004	2989
3.1	Acacia/boscia Woodland	4.0	4.0	0.76	12.2	33	401	0.941	378
3.2	Mixed Acacia Woodland	3.7	4.3	0.76	12.1	266	3216	0.964	3101
3.3	Acacia/combretum Woodland	2.6	2.8	0.75	5.5	152	830	1.011	839
4.1	Colophospermum/Acacia Woodland	3.5	4.8	0.81	13.6	28	381	1.120	427
4.1.1	Colophospermum/ Combretum Woodland	2.8	2.9	0.80	6.5	473	3073	1.132	3478
4.1.2	Colophospermum Woodland	3.7	4.3	0.81	12.9	38	490	1.191	583
4.2	Colophospermum/ Commiphora Woodland	1.0	2.3	0.81	1.9	191	356	1.200	427
5.1	Acacia Scrubland	0.6	2.0	0.80	1.0	549	527	0.950	501
6	Catophractes/rhigozum Shrubland	0.0	0.0	0.00	0.0	4	0	0.000	0
	Total					1940	19834		18581

Source: Consultant's field surveys

Table K-F1.3
Standing Usable Timber Volumes by Species and Vegetation Communities

Ref No. Community	1.1 Comm/ Crot	1.2 Comm/ Kirk	2.1 Comb/ Acac	2.2 Comb/ Pelt	3.1 Acac/ Bosc	3.2 Mxd Acac	3.3 Acac/ Comb	4.1 Colop/ Acac	4.1.1 Colop/ Comb	4.1.2 Colop	4.2 Colop/ Comm	5.1 Acacia Scrub	Total Volume	%
Acacia														
tortilis	0	0	1386	655	217	1930	158	0	0	0	0	105	4450	22.4
karroo	0	0	1952	268	0	0	0	0	0	0	0	0	2220	11.2
grandicornuta	0	0	441	357	120	643	0	15	61	0	0	0	1638	8.3
nilotica	0	0	0	30	0	0	0	0	0	0	0	0	30	0.2
erubescens	0	0	63	179	0	354	224	0	184	34	0	105	1144	5.8
nigrescens	0	0	0	0	0	0	25	19	0	0	0	0	44	0.2
galpinii	0	0	252	0	0	0	0	0	0	0	0	0	252	1.3
mellifera	0	0	189	149	20	161	25	0	0	0	0	0	544	2.7
Combretum														
apiculatum	0	22	0	0	0	0	83	0	61	0	0	0	166	0.8
imberbe	0	0	0	89	0	0	0	0	0	0	0	53	142	0.7
molle	24	0	0	0	0	0	0	0	0	0	0	0	24	0.1
hereroense	0	0	504	595	0	0	0	0	0	0	0	0	1099	5.5
erythrophyllum	0	0	567	0	0	0	0	0	0	0	0	0	567	2.9
Commiphora														
mollis	0	412	0	0	0	0	25	0	0	0	0	0	436	2.2
marlothii	152	130	0	0	0	0	0	0	0	0	0	0	282	1.4
pyracanthoides	0	0	0	0	0	0	83	0	0	0	0	0	83	0.4
Ziziphus														
mucronata	0	0	945	0	0	0	0	0	0	0	0	0	945	4.8
Colophospermum														
mopane	0	0	0	595	32	64	133	309	2366	455	356	0	4310	21.7
Boscia														
albitrunca	0	0	0	30	12	64	50	38	399	0	0	264	857	4.3
Sclerocarya														
birrea	0	22	0	0	0	0	0	0	0	0	0	0	22	0.1
Ficus														
tettensis	26	0	0	0	0	0	0	0	0	0	0	0	26	0.1
Cassia														
abbreviata	0	54	0	0	0	0	0	0	0	0	0	0	54	0.3
Kirkia														
acuminata	0	444	0	0	0	0	0	0	0	0	0	0	444	2.2
Sterculata														
rogersii	0	0	0	0	0	0	25	0	0	0	0	0	25	0.1
Peltophorum														
africanum	0	0	0	30	0	0	0	0	0	0	0	0	30	0.2
Total (Cu m)	202	1083	6298	2977	401	3216	830	381	3073	490	356	527	19834	100.0

Source: Consultant's Surveys

CHAPTER K-F2

BUSH CLEARING PROGRAMME

K-F2.1 Programme Context

Three options for removal of timber have been examined.

- bulldozing and on-site burning or removal for charcoal/firewood
- labour intensive hand clearance under professional supervision
- unsupervised removal by local people

It will be necessary to phase the bush clearing programme to fit in with the contractor's requirements. The expropriation and any clearing of land in the dam site, borrow and quarry areas will need to proceed first, followed by a programme for the remaining land which will not be required for construction but which will flood after the dam is commissioned. From Table K-F1.1 the programme areas are as follows:

- Phase 1 Dam Site, Downstream Reservoir Area and Downstream Permanent works.

  Total area is 1288 ha of which 1182 ha will require bush clearing.

- Phase 2 Upstream reservoir area.

  Total area is 860 ha, of which 758 ha will require bush clearing.

If the option of a fenced reservoir were chosen there would be a third phase which would involve the selected cutting and removal of non flood tolerant species.

Table K-F2.1 provides estimates of the total volume and weight of potentially usable timber by community separated into the two main proposed programme areas.

K-F2.2 Preliminary Assessment of Options

A policy of indiscriminate bulldozing and on-site burning is not recommended. Firstly, this would result in a considerable natural energy resource going to waste. It is estimated that the available wood is sufficient to supply the annual wood fuel needs of 40 000 people, i.e. 80% of the current population of Selebi-Phikwe. Secondly, most of the ash minerals would be washed back into the reservoir and would encourage the growth of algae as discussed in Appendix K-E and Chapter K8. In the case of non-usable timber it is best bulldozered into the riverbed (once the usable sand resource has been extracted) and then fired so that the next flood will wash the ash downstream of the dam site. This will require that it is carried out prior to the rainy season before the reservoir commences impoundment.

If bulldozers are to be used to clear the tree vegetation then the recommended option is to push the usable timber to the outside of the FSL so that it can be used by local people. Another option could be to convert the wood into charcoal. However, charcoal has a very limited market in Botswana and no such operation has previously been undertaken here. Should this option of charcoal making be deemed desireable further investigations would be required.

Table K – F2.1

Usable Timber by Programme Area

Ref No.	Vegetation Community	Item	Units	Total Yield by Area Phase 1	Phase 2	Total
1.1	Commiphora/croton	Volume	Cu m	202	0	202
	Kopje Woodland	weight	Tonnes	126	0	126
1.2	Commiphora/kirkia	Volume	Cu m	1083	0	1083
	Kopje Woodland	weight	Tonnes	607	0	607
2.1	Combretum/acacia	Volume	Cu m	2721	3577	6298
	Riverine Woodland	weight	Tonnes	2215	2911	5126
2.2	Combretum/peltophorum	Volume	Cu m	2088	890	2977
	Riparian Woodland	weight	Tonnes	2096	893	2989
3.1	Acacia/boscia	Volume	Cu m	389	12	401
	Woodland	weight	Tonnes	366	11	378
3.2	Mixed Acacia	Volume	Cu m	992	2225	3216
	Woodland	weight	Tonnes	956	2145	3101
3.3	Acacia/combretum	Volume	Cu m	710	120	830
	Woodland	weight	Tonnes	718	121	839
4.1	Colophospermum/acacia	Volume	Cu m	191	191	381
	Woodland	weight	Tonnes	213	213	427
4.1.1	Colophospermum/combretum	Volume	Cu m	1592	1481	3073
	Woodland	weight	Tonnes	1802	1677	3478
4.1.2	Colophospermum	Volume	Cu m	490	0	490
	Woodland	weight	Tonnes	583	0	583
4.2	Colophospermum/commiphora	Volume	Cu m	276	80	356
	Woodland	weight	Tonnes	331	96	427
5.1	Acacia	Volume	Cu m	341	186	527
	Scrubland	weight	Tonnes	324	177	501
	Totals	Volume	Cu m	11073	8761	19834
		weight	Tonnes	10336	8245	18581

Source: Consultant's field surveys

Choosing a labour intensive approach to timber clearing would seem more desireable as this would guarantee the utilisation of the timber and job creation would also result, well in advance of the contractor starting work. The volume to be cleared would involve the need for a large labour force and qualified supervision and management. In the first stage of the analysis the hand clearing of the total volume of timber was considered based on the primary assumption that the timber would be sold and valued as general firewood. Tables K-F2.2 and K-F2.3 provide the labour requirement and a budget for the extraction of the total usable timber. This would require that the Phase 1 area is made available for cutting well before the construction contract commences.

Table K-F2.2

Estimates of Labour Required to Extract Total Usable Timber (man days)

Ref No.	Vegetation Community	Mandays per hectare	Area to clear (ha) Dam wall & Phase 1	Area to clear (ha) Phase 2	Labour required Dam wall & Phase 1	Labour required Phase 2	Total Labour Required
1.1	Commiphora/Croton Kopje woodland	30	17	0	510	0	510
1.2	Commiphora/Kirkia Kopje woodland	50	21	0	1050	0	1050
2.1	Combretum/Acacia Riverine woodland	80	35	46	2800	3680	6480
2.2	Combretum/Peltophorum Riparian woodland	50	61	26	3050	1300	4350
3.1	Acacia/Boscia Woodland	35	32	1	1120	35	1155
3.2	Mixed Acacia Woodland	35	82	184	2870	6440	9310
3.3	Acacia/Combretum Woodland	30	130	22	3900	660	4560
4.1	Colophospermum/Acacia Woodland	35	14	14	490	490	980
4.1.1	Colophospermum/Combretum Woodland	30	245	228	7350	6840	14190
4.1.2	Colophospermum Woodland	35	38	0	1330	0	1330
4.2	Colophospermum/ Commiphora Woodland (rocky outcrops)	30	148	43	4440	1290	5730
5.1	Acacia Sorubland	1	355	194	355	194	549
6	Catophractes/Rhigozum Shrubland	0	4	0	0	0	0
	Total		1182	758	29265	20929	50194

Source: Consultant's field surveys and estimates

Table K – F2.3

Budget for the Removal of the Total Volume of Usable Timber
(Pula)

Cutting Team		
– Labour	133 Nr. for 3 years each 126 days @ P4	201 096
– Equipment	Chainsaws 6 Nr. @ P 200	12 000
	Bowsaws 200 Nr. @ P 40	8 000
	Axes 200 Nr. @ P 40	8 000
	Safety equipment sum	1 000
	Spare parts provision sum	2 000
– Tractor Hire	4 Nr. for 3 years each 126 days @ P 200	302 400
Sub Total		534 496
Management/Supervision		
– Coordinator	3 years @ P 700/month	25 200
– Field Manager	6 months/year @ P 600/month	10 800
– Foreman	5 Nr. for 6 months/year @ P 250/month	22 500
– Vehicles	2 Nr. @ 80 km/day over 378 days	24 192
Sub Total		82 692
Total		617 188
Contingencies @ 10%		61 719
Overall Total		678 907
Cost per tonne for 15 000t removed:		
Cutting Team		39
Management		6
Total cost per tonne		45

Source: Consultant's field surveys and estimates

It can be seen that the total operation would involve the need for a labour force of around 130 workers over three years, if it is assumed that only the six months of the dry season are used. This totals to 50 200 man days and would require a management and supervision team comprising seven persons. This operation would require a budget of P 678 907 which is a cost equivalent of P 45 per tonne. At the current time timber bought as firewood would be in the order of P 35 per tonne based on a minor survey of fuelwood loads on the side of the main Francistown road and donkey carts entering Selebi – Phikwe. Therefore, it can be seen that this operation, like that costed at the Bokaa dam, would be uneconomic. This again reflects the current undervaluation of local supplies of fuel wood in relation to its true financial cost.

Should it be deemed desireable (for national resource utilisation or welfare aims) to proceed with the hand removal of the total timber resource from the reservoir area two options are possible to provide the subsidy that will be needed to overcome the potential cash flow deficit. One solution would be to allocate the operation to the labour intensive drought relief

scheme. A second option would be to apply for funds from the Rural Energy Supply Fund administered through the Energy Unit of the Ministry of Water Affairs and Mineral Resources.

The final option of the unsupervised removal of timber by local people has the advantage of a little or no need for management and infrastructure. However, there is no way that the local people could possibly handle or consume the quantity of timber involved within the likely time constraints which are expected to be imposed. In practice by far the majority of the timber would end up being bulldozer cleared and burnt.

K – F2.3 Rationalised Programme

This first stage of the analysis gave no consideration to the role which valuable hardwoods could play if a selective clearing operation was considered to extract these trees for purposes other than general firewood. Two categories of more valuable timber were analysed: high quality firewood and commercial sawlogs. Table K – F2.4 provides the volumes of the selected species which fall into these categories.

Table K – F2.4

Volumes of Selected Valuable Hardwoods

Species	Firewood (m^3)	Sawlogs (m^3)	Total (m^3)	Specific Weight(t/m^3)	Total Weight(t)
Acacia erubescens	1 143	0	1 143	1.07	1223
Acacia mellifera	544	0	544	1.00	544
Acacia galpinii	151	101	252	0.70	176
Acacia nigrescens	31	13	44	1.10	48
Combretum imberbe	85	57	142	1.20	170
Combretum hereroense	879	50	929	0.90	836
Ziziphus mucronata	945	0	945	0.88	832
Colophospermum mopane	2 453	0	2 453	1.20	2944
Totals	6 231	221	6 452		6773

Source: Consultant's survey and estimates

The main problems faced in the planning of the timber extraction for firewood relate to storage and marketing and scale of operations. All timber species which cannot withstand termite and borer attack have to be eliminated from the extraction programme as the quantities involved could not easily marketed. These species are also generally known as the less desireable firewood in the consumer markets. In general the urban markets make a price distinction which reflects differing quality and use. These depend upon whether fuel wood is required for heating or cooking purposes. Preliminary enquiries in Gaborone found one major retailer (Timber Treatments) that would be prepared to purchase 400 tonnes of high quality fuel wood annually for a price up to P 110 per tonne. Further enquiries will be necessary to market the remaining timber of this quality estimated at 4 200 tonnes. Interest has also been expressed by the Cooperative.

The only commercial sawmilling operation in Botswana is operated out of Chobe District and is based around the timber concessions issued for the removal of Mukwa (Pterocarpus

angolensis) and Mukusi (Baikiae plurijuga). One large furniture manufacturer (Noble Furnishers) in Gaborone operate a bench saw and have already expressed a keen interest in purchasing all the commercial sawlogs which may be available from the Letsibogo reservoir. They are prepared to pay between P 125 and P 150/m^3. The required specifications would be for a minimum diameter of 20 cm and lengths between 2 – 8 m. The field survey indicated that approximately 220 m^3 of this quality can be found in the reservoir area. Areas which contain timber of sawlog quality have been noted in Map K.4. In addition there are many scattered trees of Combretum imberbe of sawlog quality in vegetation communities 2.1, 2.2 and 5.1. These would have to be individually identified, assessed and cut.

Table K – F2.5 provides a budget for the removal of the selected valuable timber. This indicates that the removal and sale of commercial sawlogs is economic and can generate a profit. The removal and sales of high quality fuel wood would appear to have the potential to make a small profit.

It should be noted that the inference of the analysis is that if such large quantities of timber enter the local market in such a short space of time, the local markets will not have the capacity to absorb the output and prices are likely to fall. It would also seriously disadvantage the existing small scale wood cutters and traders to whom this activity is a very valuable source of supplementary cash income. It should be noted that there is a price advantage in concentrating on smaller quantities of specific types and quality of firewood particularly for the urban markets and specialist timber outlets. This is the factor which creates the difference between a economically viable or non – viable programme. There are shortages of high quality fuel wood for Gaborone and this will allow the sale of the reservoir timber to proceed without a major risk of depressing the market price or undermining existing traders as would be the case for local sales into Selebi – Phikwe and Francistown.

Therefore, it could be recommended that this selective process of clearing should be given serious consideration. The significant reduction in the total volume of timber to be extracted will simplify the management of the whole operation. The main problem will be that of pre – financing the programme until such time as returns from buyers have come through. This can be overcome by appropriate allowances in the programme budget.

K – F2.4 Assessment of Additional Forestry Losses to a Fenced Reservoir

If it were decided to fully fence the reservoir reserve area then a further 1229 ha of existing forest resources would be enclosed between FSL and the fence line. The forestry in this area should obviously be retained to try and maintain its function of preventing soil erosion and environmental degradation. Ideally infill planting should be carried out and attempts made to manage the resource so that balanced stands of forestry develop both in terms of species and age. Being a fenced area this could be a unique opportunity to allow mature vegetation cover to develop without the present pressures of over grazing and timber cutting. Against this the removal of such a large area of resource from use by the community will inevitably increase the pressure on land immediately above the fence line and this is highly likely to increase still further the existing serious problem. In addition the loss of forestry resources to the local community would have to be compensated for and being such a large area this will considerably increase the compensation costs. These and other reasons outlined in Section K8.3 reinforce the recommendation that it is undesirable to fence the reservoir. The method employed for the assessment of volumes and weights of timber resources in this area is identical to that for the rest of the reservoir and the calculations for this are given in Table K – F2.6.

Table K – F2.5

Budget for the Removal of the Selected Valuable Timber

		Pula
Cutting Team		
– Labour	84 Nr. for 3 years each 84 days @ P4	84 672
– Equipment	Chainsaws 6 Nr. @ P 200	12 000
	Bowsaws 100 Nr. @ P 40	4 000
	Axe 100 Nr. @ P 40	4 000
	Safety equipment sum	1 000
	Spare parts, provisional sum	1 000
– Tractor Hire:	3 Nr. for 3 years each 84 days @ P 200	151 200
Management/Supervision		
– Coordinator	3 years @ P 700/month	25 200
– Field Manager	3 years for 5 months/year @ P 600/month	9 000
– Foreman	4 Nr. for 4 months/year @ P 250/month	12 000
– Vehicles	2 Nr. @ 80 km/day over 252 days	16 128
Contingencies @ 10%		32 020
Total		P352 220
Costs per tonne for 6 930 tonnes removed		
Cutting Team		41
Management		10
Total		51
Rail Transport Costs		
Loading and delivery to Selebi – Phikwe		19
Loading and delivery to Gaborone		29
Price delivered to buyer		99
Likely selling price		110 to 140
Profit margin		11 to 41

Source: Consultant's field surveys and estimates

Table K – F2.6

Additional Timber Losses for a Fenced Reservoir

Ref No.	Area (ha)	Unit Vol (m^3/ha)	Total Vol (m^3)	Specific Wt(t)	Total Wt (t)
1.1	4	11.9	47.6	0.622	30
1.2	11	51.6	567.6	0.560	318
2.1	8	77.8	622.4	0.814	507
2.2	38	34.2	1299.6	1.004	1305
3.1	6	12.2	73.2	0.941	69
3.2	86	12.1	1040.6	0.964	1003
3.3	22	5.5	121.0	1.011	122
4.1	57	13.6	775.2	1.120	869
4.1.1	406	6.5	2639.0	1.132	2987
4.1.2	0	12.9	0.0	1.191	0
4.2	206	1.9	391.4	1.200	470
5.1	355	1.0	355.0	0.950	337
6	4	0.0	0.0	0.000	0
C.L.	13	0.0	0.0	0.000	0
B.L.	6	0.0	0.0	0.000	0
River	7	0.0	0.0	0.000	0
Total	1229		7932.6		8016

APPENDIX K – G

APPENDIX K-G

RESERVOIR FISHERY MANAGEMENT

K-G1.1 Introduction

The study of the biological properties of man-made reservoirs in Africa is a relatively new science and is constrained by a lack of data. From what previous studies have been carried out, it appears that the ecological conditions that develop in man-made lakes are highly variable, even in areas of similar climatic conditions. Prediction of the likely nature of these ecological conditions prior to the impoundment of the lake is difficult and risky, however certain criteria have been observed and would appear to apply to all impounded waters. The principal issues related to fishery potential after the impoundment of the Letsibogo reservoir are:

1. New man-made reservoirs and lakes give rise to a potentially high fish production soon after impoundment. The reasons for this include the overall increase in the water mass, the presence of protective vegetative cover for fry and fingerlings and the abundance of suitable food from decaying organic matter.

2. This unusually high yield is short-lived. The catch per unit of effort invested in fishing will decrease steadily into a state of equilibrium consistent with an ordinary annual turn over of nutrients in the reservoir and its upstream run-off.

3. The level of production thereafter is determined principally by such factors as the seasonal nutrient status, the temperature changes of the water and the changing variations in the volume and depth of the water mass. The latter variable affects the availability of suitable breeding and nursery grounds for the various fish populations which will become established.

The sudden creation of a reservoir in a region previously devoid of permanent surface water brings with it many consequences and problems which have to be anticipated. New health hazards will have to faced as the habitats for aquatic disease vectors become more extensive, particularly if there is a major thrust towards exploiting the amenity and recreational value of the reservoir. The Letsibogo reservoir will inevitably receive nutrient run-off from a catchment densely stocked with livestock. Seasonal nutrient levels in the reservoir could lead to water quality problems of the drinking water supplies intended for urban consumers, as has happened at the existing Shashe reservoir. Fisheries can play an important role in enhancing water quality, public health and promoting the amenity and recreational value of the reservoir through angling.

K-G1.2 Fishery Potential

The following formula, although not the only one, is now frequently used to provide a guide to the potential fish yield in freshwater, particularly where there is little or no existing data to estimate the levels of fish abundance.

$$\frac{\text{Conductivity x area (hectares)}}{\text{Mean depth (metre)}} = \text{Production (kgs)}$$

For a relatively small reservoir, such as that proposed at Letsibogo, the quotient will be variable reflecting the rapid changes in surface area. Within the first decade after

impoundment the extent of drawdown is expected to be less significant than that in later years. This is a function of the rate of growth in urban water demand and the relative overcapacity of the system in the early years. Using a conservative estimate of the mean surface area of the reservoir to be 7km^2 for its early operational phase and assuming an average depth of 10m, then based on 1976 conductivity data for the sand river near the dam site a realistic production target for total annual fish catches would be 20 tonnes.

As the monitoring and future planning studies proceed this cautious figure can be refined. To improve on these estimates and to provide necessary information for future planning and management, regular monitoring of the reservoir's physical and chemical characteristics will be required. Preliminary sampling from wells in the dry river bed indicates a future water environment above the dam which would be conducive to primary production and a healthy standing fish population. Sampling and analysis of the water from the first floods of the rainy season has not yet been carried out and it is likely to give very different results. This will provide indications as to the likely seasonal changes in water quality and resulting ecology and its likely effect on fish populations.

If a fishery were established in the years soon after impoundment it could form a control against which a longer term programme could be monitored. This would allow the impact of the more regular and extensive draw downs of later operations to be assessed together with those occasions when the reservoir becomes empty or nearly empty. Provision for speedy re-stocking will have to be made for these more extreme and irregular events.

The composition and relative abundance of stocks of riverine fish, both below and above the dam, will alter quite radically as increasing impoundment occurs. To a limited degree it is possible to predict what changes might occur under these conditions, however to improve on this it is necessary to better the knowledge of the ecological requirements of the existing species so that more accurate forecasting can be made.

It will first be necessary to confirm an inventory of all the species which are presently to be found in the river and floodplain complex. A modest list of the ecological requirements for the principal food fishes will include:

- the character and location of the spawning grounds
- the timing, character and duration of the spawning seasons
- the food and feeding habits of the different species
- the range and optimum conditions of temperature, oxygen and current

From this basic database it will be possible to indicate which species will or will not flourish in the new river and reservoir environment. It would also be necessary to carry out a limnology survey to finalise these assessments. As this is in any case required for the monitoring of the schistosomiasis risk, it is logical to combine the requirements into an integrated Terms of Reference for the limnology survey.

The nature of the established riverine fish populations usually means that it is rare to find ecological niches which have not been filled. However, it is possible that not all of the newly created lacustrine habitats in the proposed reservoir will be fully utilised. Pre-impoundment studies would assist in anticipating this likelihood and identify whether a stocking programme for indigenous species amenable for the new environment would be desireable. As a result of the unfortunate experiences with the introduction of exotic species into other man made lakes in Africa it is considered that on no account should this be contemplated at Letsibogo, even if this were seen as a means of improving the recreational attractions of the reservoir. There is insufficient knowledge to be able to do this and the consequences of a mistake can be very serious indeed.

The ultimate fish stock composition within the reservoir may also be determined by the effect the dam will have on migratory fish species. The main species likely to be involved on the Motloutse are *Hydrocynus sp.* and *Alestes sp.*. It will be necessary to ascertain the various individual migratory patterns at an early date and if judged significant then to suggest if there are advisable and economic ways of overcoming the barrier effect of the dam which could effectively prevent reproduction of these specific fish species. Since the quantities of fish involved are relatively small, it may be possible to trap migrants at the dam, both before and after spawning, and arrange for them to be physically carried around the dam.

K – G1.3 Spawning Grounds

Effective reservoir management planning require a good understanding of the ecological requirements of the principal species. It will be necessary to identify the nature and location of the historic spawning grounds, since in many cases these will be drowned as the reservoir impounds. Successful reproduction is essential to the ultimate fish yields and where it is possible to identify risk areas in advance, counter measures may be justifiable prior to final impounding. Habitat improvement can be achieved either through earthmoving to provide alternative sites, or possibly by introducing water level control during the spawning period. Loss of spawning grounds caused by impoundment can particularly affect several species of *Tilarpia* and *Catfish*, both of which will be dominant genera in the proposed reservoir, the former being of high food value.

K – G1.4 Fishing Operations

To obtain maximum efficiency and economic returns the selected fishing grounds in the reservoir must be, as far as is possible, clear of physical obstruction hazards in order to facilitate operations and prevent the loss or damage of valuable fishing equipment. The detailed bush clearance programme to be finalised as part of the detailed design phase of the study, should give special attention to the specialised requirements of fisheries for breeding habitats and fishing operations. The definition of "suitable areas" depends upon the conformation of the reservoir area, the density of vegetation, the funds available for removal, the location of breeding and nursery grounds and the type of fishing techniques to be introduced. This will require a specialist input during the detailed design studies.

More diverse catching gear can be employed for the fishing of the relatively still waters of a reservoir than in the original river system. The regular equipment which could be used for a commercial fishery operation mounted as part of this programme, would comprise gill nets (both bottom and top set), various traps (including modified fyke nets), and several forms of hook and line along with reduced long lines. If fishery requirements are adequately integrated into the implementation of the bush clearance programme, seine nets (additional to small beach seines), will have to be designed specifically to be capable of being operated from unpowered small craft. The available literature does suggest that there is room for improvement in the fishing practices and experimentation with gear design more appropriate to conditions in Botswana.

Only a few small craft would be required for a limited fishery operation. The selection of appropriate craft will require care to ensure that whatever gear is utilised can be safely operated. Specifically the craft must provide a stable platform from which to operate the wide variety of gear that is likely to be utilised. This may require the boats specifically designed for that purpose. It must also be borne in mind that there is very little experience of operating such craft in Botswana.

The number of people who could be supported full time by commercial fishing is unlikely to exceed 20 and experience from previous similar projects indicates that outsiders who have previous experience in fishing are likely to move in to take up such opportunities. Consideration would need to be given to the socio-economic factors involved in the siting of any fishing community settlements particularly with regard to road access to Mmadinare and the methods of transport found to be appropriate for the removal of fish catches. It is not possible to predict the numbers of subsistence or part time fishing people who could be involved if there were an improvement in fishing techniques and longer life gear. Some short term training would be required to establish these new practices amongst the first cadre of reservoir fishing people.

It will be important that there is overall control of any fisheries activity so that it can be managed in a sustainable way. The Fisheries Section of the MOA would seem to be the most appropriate body to do this but it is at present a very poorly supported operation. It will need to have the power to limit the nature and extent of the fishing effort and efficiency and relate this to the life cycles and habits of the principal food fish and other species which have other roles to play in the judicious management of the reservoir.

K-G1.5 Commercial Fish Farming

There are two possibilities for commercial fish farming which should be explored. These are a hatchery and rearing pond complex below the dam site where all water would be fed by gravity. The other is a hatchery (either gravity fed below the dam or by pumping to a site above the dam) and rearing cages in the reservoir itself. One advantage of creating an on-site fish farm would be that it could assist the re-stocking of the reservoir if it were to infrequently dry out. To elaborate on these possibilities would require a complete appraisal of the situation on the ground. If the Fisheries Section believe this opportunity merits further action the necessary surveys should be completed well in advance of dam construction.

K-G1.6 Management Strategy

When the reservoir first impounds decomposed organic material will be taken into suspension and will provide the necessary nutrients for improving primary production. Durable hardwoods could be selectively left to create an environment suitable for the evolution of varied aquatic life, including fish but these factors alone will not establish a balanced ecology. Fluctuating water levels and the resulting growth and decay of vegetation on the drawdown areas will create an unstable environment where, without any management interventions, unacceptable concentrations of flora and fauna and the lowering of pH can occur which can be harmful to fish stocks. Furthermore, nutrients from decaying vegetation are a prime mover in the growth of bacterial and phytoplankton blooms. The creation of a new standing body of water will also increase the risk of the introduction of schistosomiasis and endemic malaria by providing a suitable habitat for the snails and mosquitos concerned.

Control of insects or algal blooms by chemical processes is indiscriminate and can directly destroy vital links in the balance of the bio-system and fish stocks. It can also have indirect effects by the resulting interference with the food chain within and adjacent to the reservoir. Fish can play a part in the control and management of these potential problems.

The indigenous *Labeo lunatus* readily consumes vegetable detritus. Certain species of *Cichlid* found in Botswana are also known to eat the algae responsible for undesirable blooms. Although the common carp *C. carpio* has been introduced to the country, it is not known if it has established a niche for itself amongst the indigenous species and natural environment. It this were confirmed then it could make a valuable contribution to the control

of certain species of water weed which could potentially invade the reservoir. Certain species of fish, particularly amongst the *Synodontidae* and *Cyprinidae*, are known to eat snails. Similarly, the incidence of malaria and any re-introduction of trypanosomiasis through the re-establishment of the tsetse fly in local habitats can be reduced through weed control and by the action of *Cychlids* which will eat egg rafts and mosquito larvae.

However, biological controls alone cannot be regarded as being wholely effective. Only coordinated action involving a number of authorities will ensure effective solutions as are discussed in other sections of this report. In particular, regular and carefully designed monitoring programmes need to be stressed. With careful preliminary study and planning fishery development has much to offer in assisting the enhancement of water quality and public health. This would seem a stronger argument for fisheries management than the prospects for economic use of the resource the returns from which are not thought to be great.

K-G1.7 The Function of the Fishery Section

If the government intends to establish the proposed strategy of integrated reservoir management and to develop fisheries potential in a rational manner, the Fisheries Section will have an important and multifarious part in this programme. This would involve them with:

1. Research into the life histories and habitats of those fishes valuable as a source of protein and of those which provide a degree of aquatic biological controls.

2. The monitoring of certain aspects of reservoir characteristics and change which affect either the nature of the fish stocks or the methods of their exploitation.

3. The establishment, development and control of a viable fishery for both artisanal and subsistence fishing people with adequate means to manage and conserve the resource in a rational manner.

4. Exploration of the possibilities to introduce commercial fish farming particularly in the context of the operation of the existing fish canning operation in Selebi-Phikwe.

5. In collaboration with public health officials, social workers and the other members of the proposed Management Unit, address an integrated strategy for the reduction of those elements of the reservoir ecology which could lead to risks to public health or poor water quality, and to seek to make economic use of the productive resource which the new environment of the reservoir will provide.

6. To coordinate with the Ministry of Health in the education of fishing communities in improved standards of hygiene and health care.

The cost of providing the Fisheries Section with the expertise and facilities to accept the responsibilities for the relatively small fishery which the reservoir can be expected to support would appear to be out of all proportion to any economic return. However, it is stressed that this knowledge and capability will apply to all other impounded water areas, existing and planned, and will do much to ensure that there their resultant management will provide the greatest benefit to the country. The efficient and full development of the fishery potential of

these reservoirs efficiently will require the Fisheries Section of the MOA to be strengthened and the means established to ensure their effective integration with other institutions to be involved in reservoir management.

At present the staff of the Fisheries Section comprises the Fisheries Officer based in Gaborone, the Fisheries Field Officer and a Senior Field Assistant at the operational headquarters in Maun, and six Field Assistants posted to the major landing centres, with the exception of one who is training in the U.K. The overall objectives of the Section at the moment are to encourage improved production and marketing of fish and in this respect government should offer every encouragement.

However the establishment also makes provision for two more professional posts, that of aquaculturalist and another for a Fisheries Research Officer. In view of the above observations it would seem prudent to fill these without delay and initiate a programme to overcome the dearth of vital information relating to all fishery matters and the investigation into the potential development of aquaculture. It is considered a matter of urgency to begin these studies and may require government to consider the recruitment of expatriate staff as an interim measure whilst local personnel are trained in these sciences.

APPENDIX K – H

APPENDIX K-H

COMPENSATION CALCULATIONS

K-H1.1 Loss of Livestock Resources

The valuation of woodland and range resources is very difficult; the more so since grazing and browse is highly valued by the community and known to be a declining resource under pressure from both environmental degradation and by expansion of the cultivated areas.

In addition to land and woodland lost, one veterinary department cattle crush and one kraal facility run by Mmadinare council for stray animals would need relocation. The location of veterinary infrastructure throughout the catchment is shown in Figure K-H1.

Livestock play a key role in the financial and risk management systems of local families. These have to counter the extremes and variability of the climate and vegetation of the area. The effect of increased pressure on livestock reverberates into the viability of, and strategies adopted with, other enterprises. It is difficult to reflect the importance of this system of linkages and dependencies in economic terms. One might expect compensation values to be higher for grazing systems than for arable systems bearing in mind that the returns to livestock are considerably higher than arable cultivation. However, analysis usually adopts land as the unit of measure and as only extensive management systems are viable in this marginal environment. This leads to low returns to land and the basis for lower compensation values per hectare than for arable land.

Previous assessments have ranged between P 5-15/ha depending upon quality. Local assessments of quality are influenced by issues over and above nutritional value. Upland grazing distant from water is set aside as winter dry season reserves. Here is where minimum maintenance levels persist simply to allow survival. The importance of browse species for cattle is also evident here where the late fall of mopane leaves often provides the only resource available to see the cattle through to the flush of grass stimulated by the first rains.

The economic productivity of the system is generated by the value of the riverain areas. Current grazing pressure is still high, despite the losses of the recent drought, with the density of cattle being shown in Figure K.2.12, sheep and goats in Figure K-H.2 and equines in Figure K-H.3. The overall distribution of livestock stocking density is shown in Figure K-H4. If resources recover with the breaking of the drought, the loss of riverain grazing to the reservoir will have a major impact on those stock owners who habitually draw on this riverain area. The vegetation survey indicates that some 223 ha of riverain grazing/browse and 2052 ha of upland grazing/browse will be lost if the reservoir is not fenced.

If the reservoir were to be fenced then the losses would be considerably higher as indicated in Table K7.2. Specific measures to ameliorate loss of access should a fence line be decided upon would include:

- the provision of a fenceline maintenance track on the outer side of the fence to give the community access possibilities along the outside of the reservoir.
- the introduction of new replacement water supplies for both cattle and people at the cattle posts
- relocation of the cattle crush and council kraal for strays

If these amelioration measures were found to be inadequate then additional cash compensation payments might need to be made. It is likely that such amelioration measures will be conditional items incorporated into any lease agreement.

K-H1.2 Loss of Forestry

Appendix K-F assesses the useable timber that could be extracted by a programme of managed selective cutting. This data can also be used to estimate the standing value of the forestry resource lost to the local community both as a standing asset and as a future resource. At present the reservoir area is not exploited to any significant extent for timber, with plentiful supplies in closer proximity to the main areas of habitation. There are difficulties in valuing woodland assets using conventional economic theory as its opportunity cost is normally regarded as nil until labour is utilised and the timber enters into a market system. This can create the situation where the market value of the good is lower than the cost of commercial extraction. The standing woodlands have their main value in sustaining the landscape and the ecological systems within it. This cannot be quantified in conventional commercial or economic terms. In the absence of truly representative techniques to value the woodlands two elements of their value could be considered. The first would calculate the current commercial value of logged timber and from this derive a notional annual income lost to the community over one regenerative cycle of woodland. The second would estimate the costs of replanting an area equivalent to that lost. Together these probably indicate something of the true costs to the community of removing naturally adapted vegetation which sustain the local bio-system.

In terms of income, logged timber is at present being locally sold at around P 35/tonne. This price includes the cost of extraction, transport and other labour costs. As a lost asset to the community, this would have to be replaced in the short term by purchases of similar quality in from other areas and in the long term by replanting on other grazing or arable land. The current costs of planting are estimated at around P1 500 per ha with a 20 year natural replacement cycle. To purchase alternative supplies to the 875 tonnes per year that naturally replaces itself in the reservoir area (sufficient for the firewood needs of 1 750 people) would cost P30 625 per year. Replanting the equivalent of 17 500 tonnes would require a replanting programme of 58 ha per year for a 20 year period at a cost of P87 000 per year. This would total P1 740 000 for the replanting programme plus P306 250 to cover for the shortfall while it were being grown on a phased programme. This would total P2 046 250 in all. Alternatively the technique of assessing the annual net income, or asset value, of the resource over its 20 year cycle could be used. After allowing for labour and transport costs, this value may approximate to half of the current commercial price of P 35/tonne.

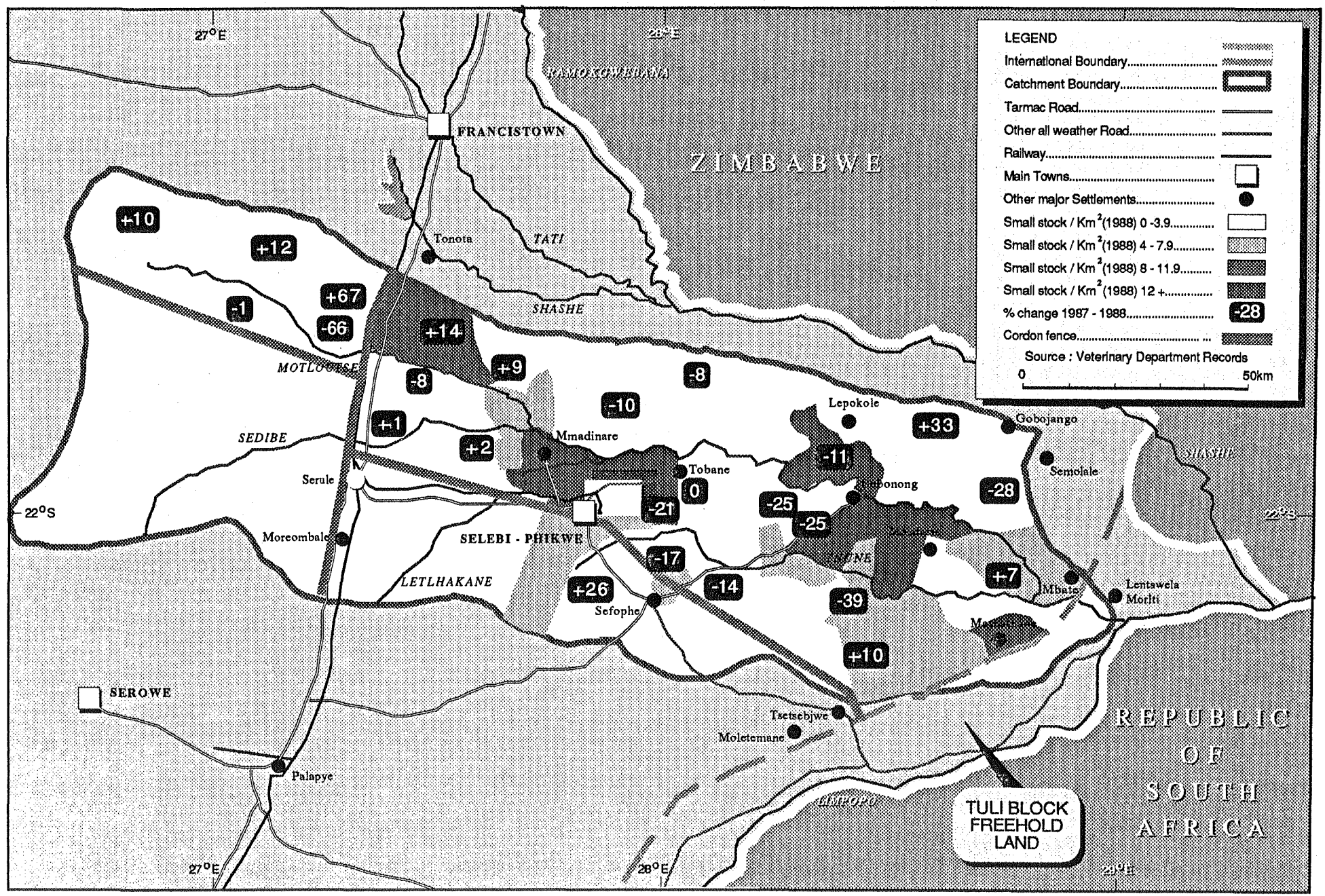
Table K-H1.1 gives the surveyed and calculated forestry volumes and weights of timber from an unfenced reservoir. The vegetation classes are mapped in Map K2 at the end of this Annex. These quantities have then been used in the valuation of lost resources and possible compensation for communal forestry assets. The loss of livelihood to people cutting and selling firewood has not yet been assessed and will be an issue for individual compensation.

The annual income over 20 years cycle assuming 10% offtake per year (1 746 tonne/yr) is thus equivalent to P30 550 (1 746 tonnes @ P17.50/tonne). The present value of income to perpetuity at 8% discount rate (factor of 12.5) is P382 000. It would seem realistic to assume this as a minimum figure as a basis for negotiation and the cost of providing a replacement resource at P2 046 250 as a maximum figure.

If it were decided to fence the reservoir then there would be considerably greater losses. Table K-F2.6 lists the additional timber losses to a fenced reservoir. These total an additional 8 016 tonnes (i.e. an extra 46%) which would increase the compensation required

Location of Veterinary Infrastructure

Figure K-H.1



Sheep and Goat Density 1987 / 1988

Figure K-H.2

Figure K-H.3

Catchment Equine Density 1988

Livestock Density and Distribution

Figure K-H.4

proportionately. This would give a minimum figure of P557 700 and a maximum of P2 987 525 for compensating the forestry resources of the whole reserve area.

Table K – H1.1

Assessment of Forestry Losses to an Unfenced reservoir

Vegetation Type	Area Lost ha	Unit Volume m^3/ha	Total Volume m^3	Specific Wt t/m^3	Total Weight t
1.1	20	11.9	238	0.622	148
1.2	0	51.6	0	0.560	0
2.1	79	77.8	6 146	0.814	5 002
2.2	84	34.2	2 872	1.004	2 884
3.1	33	12.2	402	0.941	379
3.2	264	12.1	3 194	0.964	3 079
3.3	150	5.5	825	1.011	834
4.1	28	13.6	380	1.120	426
4.1.1	454	6.5	2 951	1.132	3 341
4.1.2	27	12.9	348	1.191	415
4.2	193	1.9	367	1.200	440
5.1	537	1.0	537	0.950	510
6	4	–	–	–	–
Total	1873				17 458

K – H1.3 Loss of Sand Resources

K – H1.3.1 Introduction

Letsibogo dam will stop natural movement of sand down the river from the upstream catchment and hence the area downstream presently exploited by the BCL mine and held as a lease from the Land Board will also be effected. Even when the dam spills there is likely to be very little natural recharge as the main sand source is carried in the bed load of the river which will be deposited in the upstream arms of the reservoir to form deltas when it meets the standing water in the reservoir. Even the operation of a bottom outlet to the dam to provide compensation releases is unlikely to provide any recharge except perhaps a small quantity of fine material. Recharge of the sand lease area will only occur from the Letlhakane river and other lateral inflows downstream of the dam. To assess the implications of this, the present natural recharge characteristics are being studied in more detail to give estimates of the quantity that will no longer be replenished. This will also allow estimates to be made of the existing remaining supplies within the present sand lease area and the 3 km upstream extension recently applied for by BCL. The locations of the lease area are shown in Figure K.2.8. Discussions have been held with the BCL management and the sand supplier for the last 6 years. To advise on the recharge conditions, a specialist geomorphologist has recently visited the area.

K – H1.3.2 Present Situation

River sand has been extracted by the mine over the last 15 years for flux in the smelter process. The present extraction rate is 160 000 tonnes (or 100 000 m^3) per year. The sand lease, which extends up to the year 1997 but with provision for extension, permits a maximum annual extraction of 200 000 tonnes within the lease area. Extraction has been concentrated along the Motloutse for the first 3 km upstream of the Letlhakane confluence. This length of river, even after the very high flows of 1988 and the 1988/89 wet season, has been exhausted. This indicates that the rate of extraction has removed all the stored resource and is obviously higher than the natural rate of replenishment. Due to this the supplier was planning to move further upstream in mid 1989. In addition about 2 to 3 months supply per year is consistently extracted from a 4 km length of the Letlhakane upstream of the BDF camp as shown in Figure K.2.7. The amount extracted annually from here is unknown but probably of the order of 20 000 to 30 000 m^3 as a long term average. A very limited amount of extraction has occurred on the Motloutse downstream of the Letlhakane confluence and there is evidence of degradation over the first 1 km. The supplier prefers to avoid the 10 km stretch downstream of the Letlhakane confluence as, due to the constant discharges from the mine and sewage works, the sand is saturated requiring a different and more expensive extraction operation plus the need for drying.

The level of degradation, even after the high flows of 1988, indicates that the rate of extraction exceeds the natural recharge, although, over the 15 year period, extraction has generally been confined to a 5 km length of the Motloutse river plus the 4 km along the Letlhakane. The mine have however recently made an application to the Land Board for a 3 km extension on the Motloutse immediately upstream of the present sand lease. It is understood that the mine have also investigated the possibility of using more efficient flux techniques in the smelting operation which would require granulated quartz rather than sand as much of the present sand flux is to fine for the process. A possible location of a quartz quarry is known but it is understood that the costs are too high and there are known difficulties in handling quartz in such a form.

K – H1.3.3 Sand Resources Following Dam Construction

Under the proposed project programming, the dam will required to be completed immediately prior to the 1994/95 wet season with closure across the river channel carried out in the preceding dry season. Hence natural recharge will continue up to and including the 1993/94 wet season. It is envisaged that by this time the sand supplier will have extended his operations further upstream along the Motloutse from the present 3 km upstream of the confluence. Using the present estimates it has been assumed that a total length of 5 km upstream of the Letlhakane confluence will have been fully exploited by the time that the dam is completed.

Approximate estimates have been made of the remaining volume of exploitable sand within the present sand lease along the Motloutse plus the 3 km upstream extension; these amount to 0.5 and 1.0 $m^3 10^6$ upstream and downstream of the Letlhakane confluence respectively.

For these estimates a maximum depth of 1 to 1.25 m has been assumed corresponding with the present extraction operation. It is evident, from the present degradation, that exploitation to a greater depth will result in a significant loss of the sand aquifer and create pools of surface water with the subsequent risks of contamination without the filtering effect of the sand. The resulting water quality would probably prove unacceptable for downstream users, particularly downstream of the Letlhakane confluence due to the discharges from the mine and sewage works, which are at present 'filtered' by the river sands.

Exploitation downstream of the Letlhakane confluence will either require use of a dragline plus double handling for drying or gradual stripping of the sand, as at present, but with a channel excavated to one side of the river (most probably the north side) to draw down the water table in the sand. This channel would be excavated to a greater depth in stages as required and is probably the preferred option in view of the difficulties in adequately drying stockpiled sand.

The sand supply in the Letlhakane river would continue to be available, unless a decision were taken to dam it, and for the present estimates a long term annual replaceable supply of 20 000 m^3 has been assumed. Including this, the volume of sand available within the lease, based on the present extraction rate, should be sufficient for 16 years from the closure date for the dam, i.e. up to the year 2010, and up to 2007 at the maximum extraction rate. These estimates do not include for recharge of the Motloutse by either the Letlhakane or other lateral inflows downstream of the dam site.

The present lease for the mine expires in 1999 and this is its present planning horizon. However there are proven ore deposits to last until 2014 and there is an ongoing prospecting programme beyond this. Depending upon the world price for copper and nickel it is likely that the life of the mine may extend considerably beyond this. Sand supplies would need to be guaranteed for this eventuality and possible alternative sources after the present lease area is fully exploited are:

(1) Further downstream of the existing lease up to Tobane village. Haul distance is between 15 and 18 km. Volume available is 800 000 m^3. Further downstream the volume available is at least 100 000 m^3 per km length.

(2) Upstream of Letsibogo reservoir in both the Sedibe and Motloutse rivers. Volume available for 5 km upstream in both rivers is 500 000 m^3. Haul distances range between 25 and 32 km.

(3) From the Letsibogo reservoir area prior to impounding, with stockpiling at a suitable location. Volume available 0.9 to 1.5 $m^3 10^6$ depending on the depth exploited. Double handling will be necessary and a large amount of plant required to remove the volume of sand in the 2 to 3 year period prior to impounding. Average haul distance is 20 km.

A further alternative of extending the lease between the presently proposed extension and the dam is not considered acceptable in view of the proximity of Mmadinare. Similarly extraction to a greater depth than 1 m has been ruled out due to the resulting fall in the level of the sand river aquifer and the resulting environmental impact.

Alternative (3) would only be a feasible option if a long extension to the mine's life could be confidently predicted 2 to 3 years in advance of construction of the dam. Alternative (2) has a greater haul distance and would probably not be acceptable if the reservoir area is developed into an amenity. Alternative (1) appears to be the preferred option. The costs of haulage presently quoted by the sand supplier have been used as the basis of calculation of the increased costs incurred as a result of the construction of the Letsibogo dam. Allowing for the continued use of the Letlhakane and other natural recharge the annual additional volume required has been estimated as 70 000 m^3 from 2010.

The present sand supplier has an agreement with BCL to supply sand from anywhere within the sand lease at a fixed rate per m^3. For the additional haul for extraction outside the lease, the supplier has provided a budget quotation rate of P 0.35/tonne per km.

The average haul distance for the replacement supplies is 16.5 km, involving an additional 8.5 km over and above the probable existing haul requirements at year 2010. Assuming a density of the sand of 1.6 tonne/m^3, the additional cost of hauling the sand is estimated at P 313 000 per year. In addition haul roads would need to be made and maintained which with an estimated cost of P 6 000/km per year, would give a further cost of P 51 000 per year. Thus the additional costs to the sand extraction operation due to the construction of the Letsibogo dam would total P 364 000 per year from the year 2010.

K – H1.4 Estimation of average compensation rates per household for private assets not including land

Detailed enumeration surveys would be carried out following upon Government's decision to implement the scheme. Detailed surveys prior to this, particularly in the irrigation areas where the probability of full implementation is low, creates uncertainty, anxiety and may raise expectations as well as opening up the risk of speculation and manipulation. At this stage compensation estimates for the irrigation areas have been generated using average levels of asset figures from the Bokaa project with a comparison to the Letsibogo reservoir area. The calculation of average assets per household for Bokaa are indicated in Table K – H1.2 below and amount to P 2 376 per household, not including land. The average developed land holding at Bokaa was found to be 3.8 ha per household, whereas in the irrigation areas the figure is considerably higher at 6.4 ha. This confirms indications from the household surveys that the level of asset holding in the Motloutse area is higher than at Bokaa and generally people farming on the Motloutse valley are higher up the socio – economic scale. This is perhaps related to their well developed mixed farming system and it is likely to be the case that their homesteads are larger and of greater value than those at Bokaa.

By comparison the valuation of homestead assets in the Letsibogo reservoir area, which is a cattlepost area with few fixed homesteads, is P 3 188 per household. This again would seem to confirm that the rates for the irrigation areas are likely to be far higher than at Bokaa reservoir, despite both being Lands areas. However, for estimates at this stage of the study, a figure of P 4 000 per household in the irrigation areas appears reasonable. Any permanent urban houses of which there are some in the eastern parts of IR5 would need to be individually assessed. Due to the far greater disruption and value of these, concerted efforts should be made to avoid destroying any of these and with sensitive irrigation layout design this should be possible. It should also be pointed out that due to the use of a piped sprinkler distribution system each of the individual irrigation units can be developed independently of any others. This allows assessments of losses to each individual unit to be made and, if necessary, the design modified or in some cases of severe loss, the decision can be taken to not develop a specific unit, without this affecting the operation of the other units.

It should also be pointed out that these compensation figures do not often represent the realistic market valuations of the asset, nor do they cover the cost of replacement if this were done by an outside contractor. This is particularly the case with Lands area huts, where the rates in the MLGL guidelines are unrealistically low. Provision may well have to be made for increasing these rates to try and mitigate against any resentment that is likely to result, particularly in the Tobane Lands area, should a decision be taken to go ahead with irrigation in IR5. It should also be noted that the expropriation of a significant area of the Tobane Lands area, probably some 30% of the best quality land available to the village, will itself create inflation in the price of unauthorised land transactions, which have determined the present valuation of the P 50/ha asset value of land. This could make it difficult for people to purchase replacement land from existing occupiers, if there were insufficient replacement land available.

Table K – H1.2

Estimation of Average Compensation Rates for Private Assets, Excluding Land, for Households in the Bokaa Reservoir Area

Households – 12 Nr.

Huts	23 at P 300.0	6 900
Fence thorn	9 415 m at P 0.6	5 649
Wood paling	482 m at P 1.0	482
Post and wire	1 872 m at P 0.4	748
Mud walls	170 m at P 5.0	850
Threshing floors	6 Nr total 535 m^2 at P 2.0	1 070
Trees: Mature	44 at P 75.0	3 300
Average	41 at P 50.0	2 050
Young	11 at P 25.0	275
Wells	23 at P 200.0	4 600
Sub – total		25 924
Displacement @ 10%		2 592
Total		28 516
Average per Household		2 376

Letsibogo Reservoir

Households	14
Huts	39
Threshing floors 386m^2 = 28 m^2 / household	
Total without land but including one well per household	44 362
Average per Household	3 188

APPENDIX K-I

APPENDIX K-I

GUIDELINES FOR WATER POLLUTION CONTROL

The following guidelines are extracted from a report on the water pollution control within the Gaborone Dam catchment area, and are considered directly relevant to Kolobeng, Metsemotlhaba, Bokaa or other public water supply reservoirs in Botswana.

Zone I — **Inside the Reservoir or the Designated Reservoir Area**

No development of any nature permitted.

Zone II — **A Five-hundred Metre Wide Strip Bordering the Designated Reservoir Area:**

No new building or structures whatsoever, no intensive agricultural activites involving application of fertilisers, pesticides or fungicides. Applications for other types of development should be referred to Department of Water Affairs and Water Utilities Corporation for vetting.

Zone III — **The Rest of the Catchment Area**

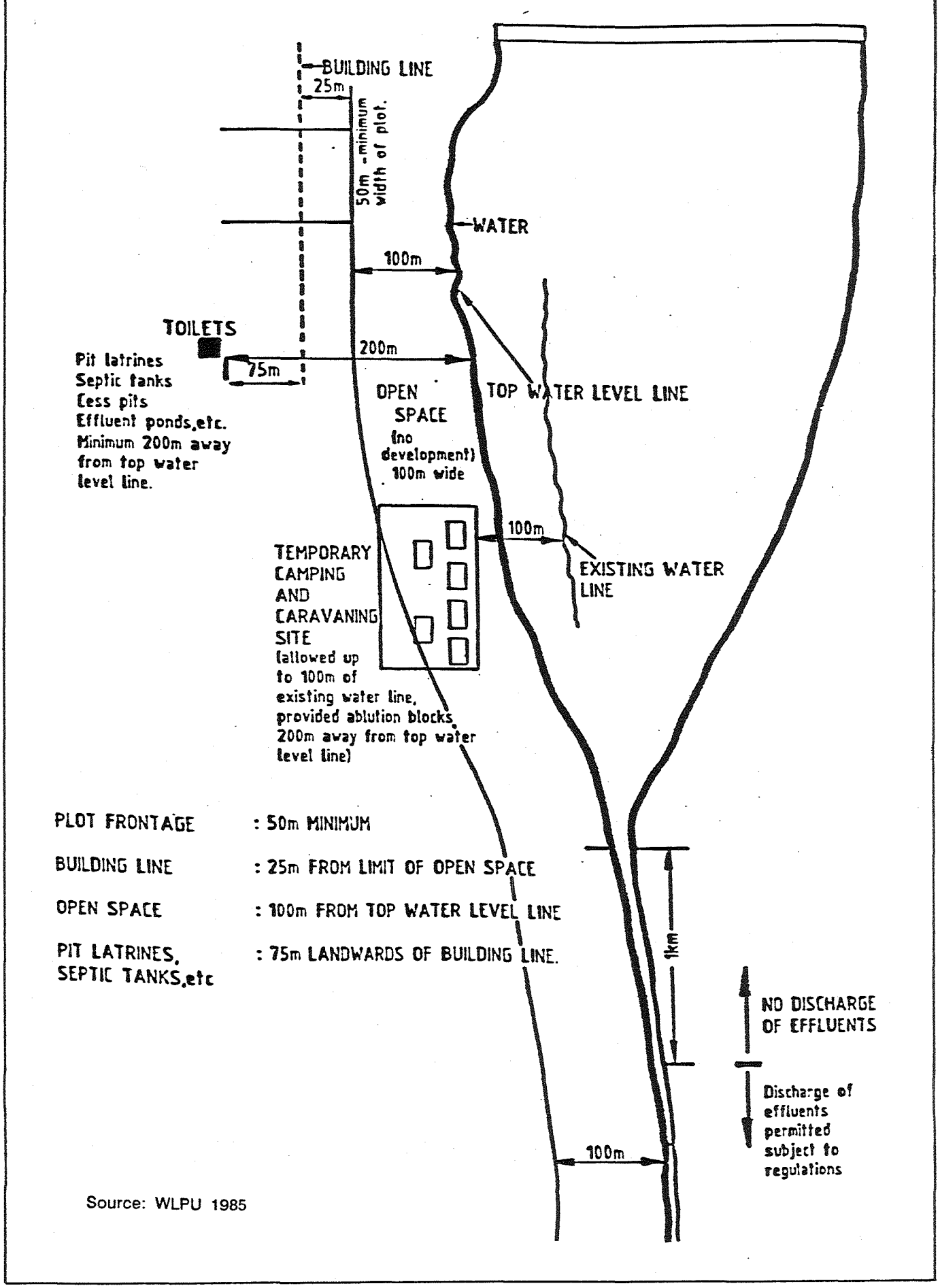
The followng types of projects and development proposal should be referred to Department of Water Affairs and Water Utilities Corporation for approval:

(1) Industrial
(2) Commercial
(3) Institutional
(4) Intensive animal production units
(5) Intensive arable farming
(6) Disposal sites for domestic and industrial wastes including sewage sludges and pit latrine
(7) Subdivisions of estates and farms
(8) High density housing schemes

Source: WLPU 1987

Figure K-I.1

Suggested Control Around Dams and Watercourses



Source: WLPU 1985

APPENDIX K – J

Motloutse Dam Project
Farm Plot Enumeration Survey

OFFICE USE

Plot Area Flooded _____ha

Sheet No _____ Plot No _____ Plot Area Unflooded _____ha

Full Name of Plot Occupier _____

Head of Plot Occupiers Household _____

Ward or Settlement of Residence of Plot Occupier _____

Improvements in the Flooded Part of the Plot

Trees Mature Average Young

Fruit Trees(Types) _____
Shade Trees (Types) _____
Other Economic Trees (Types) _____

Field Wells, Construction _____ Depth _____ Diam _____Yield _____

Fencing Type/Material _____ Length _____ Height_____

Crops:
Perrenial Crops – Types and % Cover in Whole Plot_____

Annual Crops – Standing Crops and % Cover in Plot_____ Yield _____

How many years ago was the plot first and last cultivated?_____

Bush Clearance (%) of flooded Part None Partly Fully
Debushed _____
Destumped _____
Destoned _____

Other uses of the plot : Firewood collection Others

Is the plot flooded ? Totally None Grazing Partially

The occupier must be told if the plot is flooded or not and if so when the last crop is to be sown and harvested by and when the plot will be expropriated.

Enumerator _____ Land Board Representative _____

Date _____

- -

FARM PLOT CARD (To be given to the plot occupier)

Sheet No _____ Plot No _____

Full Name of plot occupier _____

Settlement of residence of plot occupier _____

Motloutse Dam Project
Household Enumeration Survey

Name of Household Head _____ Sex _____ Age_____

Compound/Household No (to be marked on air photo and on house) _____

Is the house below the reserve line? Yes No

Ward or settlement of residence of plot occupier _____

Number of people in the household

	Adults		Children under 21	
	Male	Female	Male	Female

Improvements – Housing

	1	2	3
Shape			
Size			
Wall Materials			
Roof Materials			
Floor Materials			
Plaster Materials			

	1	2	3
Foundations			
Ceiling			
Windows with Glass Nos			
Any Service Connections			
Pit latrine			
Threshing floor size			

Wells	Construction/Lining	Depth	Diam	Yield
Outside Compound				
Inside Compound				

Fencing/Walls : Type/Materials _____ Length _____ Height _____

Trees in Compounds	Mature	Average	Young
Fruit Trees (Types)			
Shade Trees (Types)			
Other Economic Trees			

Farm Plots occupied by members of the household (see plot identity cards)

Plot Nos	Cultivated in last 5 years		Other allocated land	
	Flooded (ha)	Unflooded (ha)	Flooded (ha)	Unflooded (ha)
Totals				

Kraals occupied by the household

Fencing Type _____ Length _____ Height _____

Burial Grounds

Are there any burial grounds/graves close by? _____

Are any members of your family buried close buy ? _____

Use of Communal Lands (wetlands) Tick those utilized
River Water – (Livestock/domestic watering)
Communal Wells (Livestock/domestic watering) Pasture Firewood Thatching grass

dry season wet season
Where do you get drinking water from ? Domestic _____
Livestock _____

Disturbance/relocation entitlement Yes/No

Loss of opportunity entilement : details _____

Enumerator _____ Land Board Representative _____

Household Head _____ Date _____

Socio Economic Follow – Up to Household Enumeration

A. Your house is flooded and you will have to more elsewhere.

You have _____ ha of land presently allocated to you of which you cultivate _____ ha. Of these cultivated lands _____ ha are flooded.

You have _____ ha of unflooded land allocated to you which you do not at present farm. What stops you from farming it ?

- Lack of Labour
- Cost of bush clearance
- Quality of the land/soil
- Not economically worthwhile
- Others

Would you consider moving next to your unflooded land ? _____

Is there unallocated land close by ? _____

Where would you like to move to ? _____

Is there land that you could farm at that place ? _____

What other economic activities do you and members of your house hold do ?

a) Livestock	Owned and herded locally by household	Mafised in	Mafised Out	Totals
Cattle				
Sheep				
Goats				
Donkeys				
Pigs				
Poultry				

b) Wage paid labour/off farm employment ?

Details _____

c) Others

What mean of transport do you have?

Are you able to rebuild your house yourself ?

Recommended strategy :–

Socio Economic Follow-Up to Household Enumeration

B. Your house is not flooded but _____ ha of your presently cultivated land is flooded. You have _____ ha of land allocated to you which is unflooded but you do not cultivate it at present.

What stops you from farming it ?

- lack of labour
- cost of bush clearance
- Quality of the land/soil
- Not economically worthwhile
- Others

If assistance were given to clear it would you then farm it ? _____

Is there unallocated land close by ? _____

What other economic activities do you and members of your household do ? :-

a) Livestock	Owned and heard locally by household	Mafised in	Mafised out	Total
Cattle				
Sheep				
Goats				
Donkeys				
Pigs				
Poultry				

b) Wage paid labour/off farm employment?

Details _____

c) Others

What means of transport do you have ?

Recommended strategy :-

Motloutse Dam Project

Enumeration of other resources outside farm plots and homesteads.

Hand Dug wells : Owner

Depth Diameter Construction/Lining Yield

Borehole: Owner

Depth Diameter Casing Yield

Fixed Equipment

Wetlands
- Domestic watering
- Livestock watering
- Livestock grazing
- Firewood
- Thatching Grass

Sand extraction

Cattle Dips

Dams

APPENDIX K – K

APPENDIX K-K

LAND AND WATER MANAGEMENT STUDY OF THE MIDDLE MOTLOUTSE VALLEY DRAFT TERMS OF REFERENCE

K-K1.1 Background

During the environmental impact studies for Motloutse Dam Feasibility/Preliminary Design Study it became evident that there was a risk that uncontrolled take-up of land for small-scale irrigation along the middle reaches of the Motloutse river could result in a significant lowering of the watertable in the river sand aquifer. This would affect rural communities downstream, who use the river for domestic water supply and for cattle watering.

The length of river under consideration is between Mmadinare and Bobonong, but with particular emphasis on the section between Mmadinare and Tobane where the number of new plots is increasing significantly. This probably reflects the encouragement being given to small-scale irrigation by the Selebi-Phikwe Regional Development Project (SPRDP) combined with the proximity of Selebi-Phikwe. In addition the probability of a future dam at Letsibogo has undoubtedly served to concentrate the minds of local people on the potential of the Motloutse valley.

Every encouragement should be given to agricultural development in the area but it is essential that it is carried out in a controlled manner such that there will not be competition for the limited resources, most specifically water. The study will provide guidelines to the District Land Board and the Water Apportionments Board on river front land allocations and licenses for irrigation abstraction.

There have been several studies covering the land and/or water resources of the middle Motloutse valley. These include the DWA studies on the sand river by Wikner in 1980 and Nord in 1985, the 1985/86 MOA/FAO study of the agricultural potential of the soils over a 2 km strip either side of the river and the recent Motloutse Dam Feasibility/Preliminary Design Study (MDS). As regards water resources, MDS concentrated primarily on the potential of a major storage dam (Letsibogo) meeting urban water supply requirements and/or formal irrigation. However, as part of the overall study, a broad picture was obtained of the activities of the area and their corresponding linkages, which prompted the recommendation for the need for this study. Examples are the socio-economic studies, which identified the dependency of rural communities on the riverain areas; agricultural soils studies, which established the comparative scarcity of good agricultural land; ecological studies, particularly with regard to the riverain vegetation, and water resources which included the development of computer models of the sand river behaviour.

It is in part the intention of this study to bring together the findings of these earlier studies specific to the agricultural/water resource potential of the sand river, supplemented by additional data from monitoring programmes set up as part of the study. The SPRDP has carried out agricultural and marketing studies specific to small-scale irrigation in the Motloutse valley and potential irrigators have been identified and irrigation layouts prepared and costed for these farmers. With further help and encouragement from SPRDP, it would be expected that many of these plots may be developed. This study will provide a water resource database to assist SPRDP's work of encouraging small-scale irrigated agriculture.

It is not the intention of this study to undertake a detailed land use study of the area, as this will be undertaken by the District Land Use Planning Unit (DLUPU), as part of a country wide programme being initiated by MLGL.

It is envisaged that this study could provide the foundation for studies on the water resource potential and related environmental impact of other sand rivers in Botswana.

K-K1.2 Study Objectives

The objectives of the study are to provide the District Land Board and Water Apportionment Board with specific guidelines for managing the land and water resources of the middle Motloutse valley over the next five years prior to the commissioning of Letsibogo dam. This will ensure that development is consistent with both the present available resources of the sand river and with the proposed water resources programme stemming from construction of the dam.

Within these objectives and given the Government's desire for greater self-sufficiency in food, there is a need to obtain a better and more detailed understanding of the sand river resource such that agricultural development is not unnecessarily restricted, whilst existing users of the sand river, particularly the rural communities, are in no way disadvantaged by any such development. In other words a balance must be found between effective use of the available water resource and the existing dependency on the river and riverain areas.

The studies to date have indicated that the construction of Letsibogo dam scheduled for impounding in 1995, will probably have little or no influence on the present downstream extraction, so long as Mmadinare's present water supply from the river is transferred to a direct supply from the dam. However, considerably greater downstream development would result in a significant lowering of the sand river watertable, whether the dam is built or not. To support this form of development, it may be possible to release water from Letsibogo, but this would impinge on other users of the reservoir. It should therefore be assumed that there will be no releases and the extent of the annual recharge will be dependant solely on runoff contributions downstream of the dam.

K-K1.3 Scope of Study

K-K1.3.1 Introduction

The particular emphasis of the study will be the accurate estimation of the available water resources from the sand river, which can be exploited without causing difficulties or hardship to existing users. The particular concern is for the rural communities in the middle Motloutse valley, who are almost totally dependant on the sand river for water supply and cattle watering. In addition, the riverine and riverain areas are important grazing resources which could be threatened by significant lowering of the sand river water levels. Clearly there are important linkages and the study will have to cover several disciplines.

K-K1.3.2 Socio-Economic Studies

The data and findings from the socio-economic studies carried out for MDS should provide a good foundation for establishing the degree of dependency, both present and future, on the riverain resources. It is hoped that the Land Use study to be instituted by MLGL will be sufficiently advanced to supplement this data. The recently flown 1:50 000 scale air photography will be available plus the SPOT satellite imagery and larger scale aerial photography, obtained as part of MDS.

A detailed inventory of existing and proposed development plots within 2 km either side of the river will need to be established using as a starting point the data collected as part of SPRDP. In addition to this, an inventory of all existing users of the water resources of the river including village water supplies and irrigation will be required.

The degree of dependency of the rural communities on the riverain resources, specifically water supplies and grazing, will need to be established with, in the case of water supplies, estimates of volumes involved for inclusion in the water resources studies.

K-K1.3.3 Agricultural Soils Studies

The MOA/FAO soils team carried out surveys in 1985/86 covering a 2 km width either side of the river with mapping produced at 1:50 000 scale. This scale is too small to delineate suitable plots down to 1 ha size, particularly given the variability of the alluvial soils. However, from this survey, it is expected to be possible to delineate certain areas which should not be considered further. This will enable an estimate to be made of the maximum land resource along the river. Use should also be made of the soils studies carried out as part of MDS.

There will be no requirement to carry out detailed soil surveys to identify the most suitable plots, as the probable size of plot and the variability of the alluvial soils would dictate a very large study which cannot be justified in relation to the scale of any likely development. Instead, it is proposed that a brief manual should be prepared, covering the more important and straightforward elements of soil survey practice and requirements specific to the area. This will be provided to the Land Board to help determine the suitability of each application for irrigation.

K-K1.3.4 Water Resources

As part of MDS, a programme of flow measurements using the outflow from the BCL mine was carried out to determine the probable losses in the sand river. As a check these losses were incorporated into a steady state computer model of the sand river based on a standard backwater analysis. This exercise identified that the losses could be attributed almost completely to evaporation from the sand river bed with no evident losses into bank storage or groundwater. These conclusions were based on very limited field data and so a programme of monitoring of water levels should be initiated as part of the study covering the river sands and in the adjacent alluvial terraces. Boreholes installed with piezometers would be placed at selected riverain locations and it is hoped that, during the study, it will be possible to obtain sufficient water level measurements to establish the groundwater response to river flows, and if inflow or outflow conditions prevail in the dry season.

The results of the steady state model were used in MDS to develop a water balance model of the sand river which could simulate its behaviour under varying inputs and outputs over an extended period. The model covered the length of river from the Letsibogo dam site to 20 km downstream of Tobane village with the primary purpose of establishing if construction of the dam would reduce downstream water supplies and, if so, the extent of any required compensation releases. It was also used to examine the possibility of using the river as a means of conveyance for formal medium or large scale irrigation downstream.

The model determines the water levels in the sand river under varying inflow and outflow conditions, the latter including the various extractions down the river and losses. In addition to rainfall and runoff, inflows include the flow from the BCL mine and Selebi-Phikwe sewage works. The limitation on extraction from the river will be the acceptable level of drawdown at the end of the dry season and as such the model is seen as the ideal tool, suitably uprated, to determine the water resource potential of each individual length of the river. The uprating will include extending the model for a further 40 km as far as Bobonong.

The model used the survey and river profile data from the Wikner 1980 study, which gives both the sand surface cross-sections and the underlying rock profile. Unfortunately survey data from an earlier study, covering the length of river from 12 km downstream of Letsibogo to Tobane village, was not available and assumptions had to be made for this section. This will require re -probing and surveying as part of the study.

This section of river also includes a 5 km length directly upstream of the Letlhakane confluence, where the BCL mine have been extracting sand over a 15 year period resulting in a significant reduction in the sand aquifer. The implications of this and future sand extraction on the water resource potential should also be examined. The survey data from this exercise will also provide a useful starting point for establishing the annual sand recharge. This will be useful in the context of quantifying the probable reduction in sand recharge due to the construction of Letsibogo dam.

At present there is a considerable outflow from the BCL mine, amounting to approximately 400 m^3/hr plus the water from the Selebi-Phikwe Sewage Works, both of which enter the Letlhakane just upstream of its confluence with the Motloutse. Under conservation measures which the mine are at present instituting and also possible reuse of the sewage water, this flow would be expected to reduce substantially in the next two years. This should be taken into account in the water balance. A programme of water sampling will also be necessary to confirm that the quality meets drinking and irrigation standards.

It is understood that Tobane will be obtaining its future water supply from the flood plain area north of the village, which will be replenished from the river. This and Bobonong's present and future water supply should be included in the water resource assessments.

With the requirement to efficiently utilise the water resource potential of the sand river whilst at the same time maintaining water supplies to rural communities downstream, possible site specific and economical engineering solutions should be examined which may assist in achieving this objective. It will, however, be essential that these are as much as possible maintenance and operation free. Possibilities which should be considered include the construction of weirs at selected rock bars and the provision of watering points to compensate in areas where pumping for irrigation results in a greater drawdown of the

aquifer. Recommendations should also be made on different abstraction alternatives depending on the required discharge, to enable the Land Board to advise farmers.

K-K1.3.5 Ecological Studies

As referred to earlier, the riverain zones provide important grazing and a greater understanding of these ecologically sensitive areas is necessary. It is hoped that the water level monitoring, as part of the water resources study, will establish the hydraulic relationship between the sand river and these areas. In conjunction with this, it is proposed that ecological studies, carried out as part of MDS, are extended to determine the particular ecological dynamics in these areas such that they can be preserved.

K-K1.4 Liason and Public Participation

Close liason will be necessary with the District Officers based in Serowe and the Sub-District Officers and Land Board officials in Mmadinare, Tobane and Bobonong. In addition the officers of the Selebi-Phikwe Town Council will need to be consulted as will the consultants working on SPRDP. Local farmers will need to be interviewed, particularly those who are presently intending to irrigate. Close liason should be maintained with DWA, MOA and MLGL.