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- The Metsi Team of Specialists;
- The LHDA Panel of Experts;
- LHDA.

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LIST OF ACRONYMS

IFR	Instream Flow Requirements
JPTC	Joint Project Technical Commission
LHDA	Lesotho Highlands Development Authority
LHWP	Lesotho Highlands Water Project
POE	Panel of Experts
RFP	Request for Proposals
SMEC	SMEC International Pty Ltd
SW	Southern Waters Ecological Research and Consulting Pty Ltd.

OBJECTIVES AND TERMS OF REFERENCE: TASK 6
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The objective of Task 6 was to design a long-term Monitoring Programme to allow the verification and refinement of the IFR estimates. This Monitoring Programme was discussed and the design finalised during a series of meetings in Maseru in October 1999, at which representatives of the biophysical and socio-economic specialist teams, the client, JPTC, and the LHDA Panel of Experts (POE) were present.

From the RFP (*brackets added by Consultant*)

A long-term monitoring programme shall be provided, which shall indicate:

- parameters to be observed;
- locations of monitoring (*sites*);
- timing and scheduling of field monitoring;
- personnel requirements (*in terms of trained personnel*);
- equipment requirements, including any additional flow-gauging stations required;
- budget.

SECTION 1:

BACKGROUND TO THE LHWP IFR MONITORING PROGRAMME

1.1 INTRODUCTION

The Lesotho Highlands Development Authority (LHDA) awarded the contract for provision of consulting services for The Establishment and Monitoring of Instream Flow Requirements (IFR) for River Courses Downstream of LHWP Dams (Contract LHDA 648) to Metsi Consultants. Metsi Consultants is a joint venture between Southern Waters of South Africa (SW) and SMEC International of Australia (SMEC).

The locations of the proposed LHWP dams are shown in Figure 1.1.

Broadly, the objectives of the study as stated in the scope of services of the RFP are:

- to assess the instream flow requirement for the Senqu, lower Senqunyane, lower Malibamatso and lower Matsoku Rivers;
- to assess the long-term impacts of the modified flow regimes resulting from the construction of the proposed Lesotho Highland Water Project (LHWP) dams, on the ecosystems of the study rivers, and to provide recommendations for mitigation against, and compensation for, significant impacts linked with the proposed projects;
- to recommend a long-term programme to monitor the efficacy of the IFR releases, the results of which can be used to adjust the IFR as required.

These objectives are encompassed in the following tasks:

Task 1: Review of IFR methodologies and other parameters used in instream flow assessments. The report for Task 1 was completed in December 1997 (Report No. 648-02).

Task 2: Collection of data to inform the instream flow assessments. This task also encompassed the IFR Planning Meeting for the biophysical team held in April 1998, and the Planning Meeting for the socio-economic team held in November 1998. The main focus of Task 2 was the collection of data, over one hydrological year,

relevant to the determination of the Instream Flow Requirement (IFR) for each designated river stretch. These activities are reported on in Report Nos 648-F-08 to 648-F-19.

Task 3: Determination of the IFR. This process commenced at the IFR Workshop in April 1999, at which the biophysical specialists described the consequences for the river ecosystem of a range of flow manipulations. The process used in Task 3 is reported on in Report No 648-F-03.

Task 4: Assessment of the likely impacts of the flow manipulations on:

- aquatic and riparian habitat are reported on in Report Nos 648-F-04 to 07;
- water availability is reported on in Report No 648-F-21; and
- rural communities are reported on in Report No 648-F-21.

Task 5: Assessment of the degree of dependence of the downstream rural people on the study rivers. These data, in combination with the ecological data obtained in Task 2, will be used to determine mitigation measures. The cost of mitigation measures, if any, will also be determined. Reports No 648-F-21 and 22 detail this section of the study.

Task 6: Design of a monitoring programme for the rivers downstream of the LHWP dams that could be used to assess the efficacy of the recommended IFR allocations. Determination of the human resources needed to maintain a monitoring programme, and the cost and the timing of such a programme, to enable it to be included in future budgeting. This report deals with Task 6.

Note: The final product of LHDA 648 outlined the predicted consequences of four possible future scenarios for the study rivers, each of which differed in terms of:

- its flow regime;
- the *biophysical changes* expected in the aquatic ecosystem under the modified flow regime;
- the *social impacts* expected as a result of the predicted biophysical changes; and the economic implications of the *social impacts*.

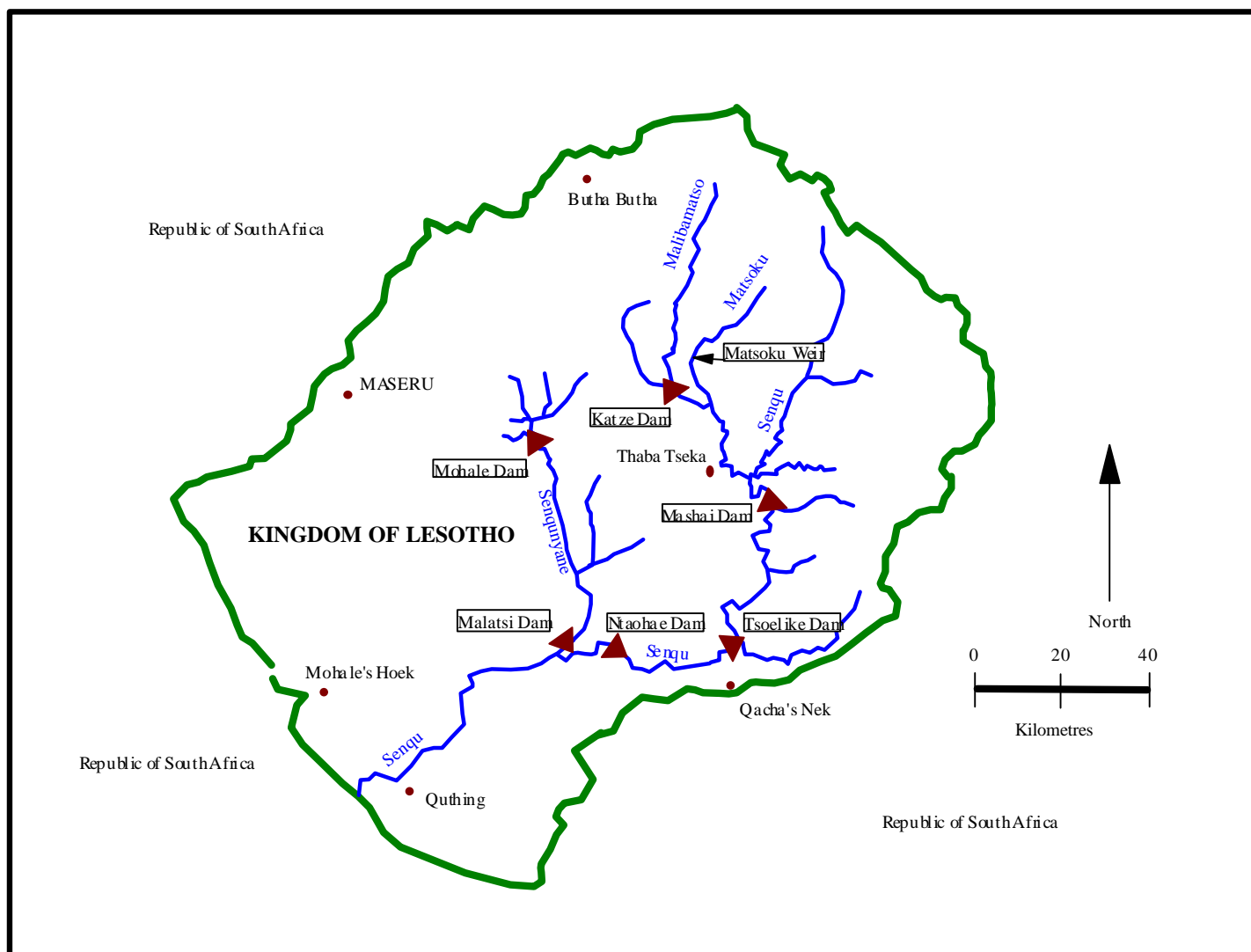


Figure 1.1 Location of the proposed and extant LHW dam projects

By the end of the project, LHDA had not decided on the scenario that would be implemented, making it neither possible nor desirable in Task 6 to design a monitoring programme specific to any one scenario. Thus, a generic Monitoring programme has been designed, that includes a list of recommended monitoring activities together with reasons for their inclusion. Once the final scenario is chosen, this generic Monitoring Programme should be revisited and refined in the light of the chosen scenario.

It is envisaged that, at that time, details of the number of replicates collected and the statistical analyses used will also be determined.

1.2 THIS REPORT

This document addresses Task 6. It describes a set of activities that together constitute a generic Monitoring Programme that should provide adequate data to assess the efficacy of the IFR releases.

The document was compiled following detailed discussions with the socio-economic specialists and some of the biophysical specialists at meetings held in Maseru on the 7 and 8th of October 1999. Representatives of LHDA and the LHDA Panel of Experts were also present at the meetings, and contributed towards the design of the Monitoring Programme.

Section 1, this section, addresses the need for a monitoring programme, and the value of different kinds of data and different kinds of sampling sites. Section 2 describes the study area. The objectives and envisaged structure of the biophysical and socio-economic components of the Monitoring Programme are provided in Sections 3, 4 and 5, respectively. Section 6 is a summary of the overall programme, and a budget for the monitoring activities is provided in Section 7.

1.3 NEED FOR IFR MONITORING AND KEY AREAS OF CONCERN

Monitoring of an ecosystem is a continuing process whereby the condition of key ecosystem components are measured at repeated intervals following a disturbance and the results compared with the same kinds of data collected prior to the disturbance.

In this project, Contract LHDA 648, the disturbance is the proposed construction of in-channel dams on rivers, which will affect the rivers' flow regime, water chemistry, and sediment and temperature regimes and, as a knock-on effect, their fauna and flora. The disturbance to the river ecosystems can be reduced by careful manipulation of flow releases from the dams, so-called instream flow requirements (IFRs). Most of Contract LHDA 648 has been dedicated to collecting data and then using these to predict how the rivers will change with flow manipulations and how this will impact on the people living downstream of the dams. Four possible future flow regimes (scenarios) have been considered for each part of each affected river. Each scenario consists of:

- a potential future flow regime for the river and the volume of water therein;
- the predicted river condition linked to this flow regime;
- the predicted social consequences of this river condition;
- the predicted economic implications of these social impacts;
- the volume of water that would not be involved in river maintenance and could thus be stored in the dam reservoirs.

These scenarios have been presented to the client, LHDA, and will be used by them in the decision on the amount of water that will be released downstream from any constructed LHWP dam.

Such provision of water for the maintenance of river ecosystems, and the monitoring of the efficacy of those provisions, are in their infancy in southern Africa. However, ecological monitoring has been used to assess the efficacy of different management strategies for decades or to guide ongoing strategies for management. For example, ecological monitoring is used to set fishing quotas for South Africa and Namibia's marine fisheries, and to determine the success of biological agents released to control invasive alien plants. For rivers, monitoring whether or not flows for environmental maintenance are occurring and are achieving their stated objectives is an essential part of their implementation.

Once a scenario has been decided upon and implemented, it will be necessary:

- to establish whether or not the agreed-on IFR is being released;
- to verify if the objectives linked to different components of the flow regime are being achieved, e.g., if reed beds are being inundated and maintained by a certain category of flow;
- to verify that the overall objective (i.e. a targeted river condition) is being achieved;
- if the overall objective is not being achieved, to be able to adjust either the IFR or the objective.

The degree of success of a monitoring programme is directly linked to its overall design and funding. Programmes that are well funded are likely to be more successful, as there is a clear commitment to support them, and paid specialists are employed to drive the programme. Many a well-intentioned plan fails simply because it is nobody's paid job to make it work, and everyone else is too busy to do it part-time. Funds for monitoring programmes should thus be secured and realistic, as part of the revenue derived from the dam, so that a long-term monitoring plan can be made and implemented.

1.3.1 Comments from the LHDA-appointed Panel of Experts

"Monitoring programmes risk falling into complacency and stagnation, especially where possible change is expected only in the long term" (Doolan, McMahon and Mentis, Lesotho Highlands Water Project, Panel of Experts, pers. comm.). Doolan *et al.* suggest that to minimise this risk, aspects to be monitored should be divided into those that change quickly and those that show long-term change. Data from rapidly changing variables can be assessed continuously, so that the monitoring design is tested and results provide issues that hold interest. Slow-responding variables can be used to generate and test long-term hypotheses.

For all components, it is essential to begin with the best possible predictions of the changes that are likely to happen within the chosen scenario, and to be able to show whether or not excursions beyond these occur.

1.3.2 Components for inclusion in the Monitoring Programme

The ecosystem components (or sub-components) that

will eventually be included in the Monitoring Programme will depend on the chosen scenario. For instance, the Treaty Scenario at IFR Site 2 (Katse Dam) does not stipulate any high flow releases, and so it would be pointless including any activity linked to determining whether or not the highflow releases flush sediments from riffles. Similarly, the Treaty Scenario stipulates a constant release of $0.5 \text{ m}^3\text{s}^{-1}$, thus it would not be necessary at IFR Site 2 to verify the accuracy of the hydraulic model at very low flows by making field measurements at say, $0.2 \text{ m}^3\text{s}^{-1}$.

As mentioned in Section 1.1, at this stage of the project, the scenarios to be implemented have not been chosen by the client. Therefore, as a first step a generic Monitoring Programme has been designed to include:

- all the disciplines addressed in the study. This includes biophysical, social, health and economic components (Table 1.1), to the extent deemed necessary by the respective specialists in the October 1999 meetings;
- activities for assessing the efficacy of the different parts or aspects of the flow regime (Table 1.2), where applicable.

The generic Monitoring Programme can be refined once a scenario has been agreed on and implemented. Because this refinement cannot be done yet each activity is explained and the links between different components identified. This will aid avoidance of unnecessary data collection in later refinement of the programme. For instance, monitoring both riffle condition and macroinvertebrate riffle communities may be a duplication that could be avoided, since changes in one may infer changes in the other.

It is recommended that elements drawn from this generic Monitoring Programme become part of a programme of base-line data collection in the study rivers as soon as possible. This will:

- ensure that there is continuity in data collection from that done as part of the IFR determination;
- allow for additional refinement of the Monitoring Programme where necessary, with some elements expanded and others reduced;
- allow for testing of the level of sampling effort required to attain desired levels of statistical

significance and of the sensitivity of recommended sampling procedures.

those aspects of their disciplines that reflect flow-related changes, and not others unrelated to impoundment of the study rivers. As flow is an integral part of the river system, it is often difficult to distinguish the two.

1.3.3 Separating cause and effect

The specialist teams were requested by the Consultant to suggest for inclusion in the Monitoring Programme

Table 1.1 Disciplines addressed in LHDA 648 that should provide input to the IFR Monitoring Programme

Socio-economic	Biophysical
<ul style="list-style-type: none"> • river-resource use • public health • animal health • water supply • economics 	<ul style="list-style-type: none"> • hydrology • hydraulics • geomorphology/sedimentology • habitat mapping • water quality, including parasitology and microbiology • riparian and instream vegetation • aquatic macroinvertebrates • fish • herpetofauna • mammals and birds

Table 1.2 Components of the flow regime

Lowflow	Highflows
<ul style="list-style-type: none"> • wet season lowflows • dry season lowflows • variability in lowflows 	<ul style="list-style-type: none"> • Class 1 within-year events • Class 2 within-year events • Class 3 within-year events • Class 4 within-year events • 1:2 year event • 1:5 year event • 1:10 year event • 1:20 year event

However, as an illustration, it would be inaccurate to attribute the lack of riparian seedlings to a lack of bank flooding when cattle were in fact grazing them. Similarly, high nutrient levels in downstream reaches may not be the result of flow reduction by a new dam, but of the coincident release of treated sewage from a new water-treatment plant.

nutritional status of the rural communities has implications for their overall health, and those people with a poor nutritional status are likely to become more ill, more often, than those with healthy, balanced diets. The

Many of the expected changes related to the implementation of a scenario may be related to flow changes, but only indirectly. Isolating the influence of flow on these is extremely difficult. For instance, the

social report for LHDA Contract 648 (Report No: 648-F-08) has shown that people harvest vegetables for domestic consumption from the riparian zone of the study rivers, thereby augmenting their diets. These vegetables are likely to decrease in abundance as a result of changes in river flow related to the LHWP dams. However, changes in nutritional status are also likely to occur as a result of changes in a multitude of other determining factors. For instance, in Lesotho, employment opportunities in South Africa (which affect household income levels and buying power) or rainfall in the highlands (which affects crop production) may both affect the nutritional status of the rural population. Thus, the likelihood of being able to conclusively link nutritional status with flow manipulations in the river is low. Consequently, inclusion of activities to monitor nutritional status in the Monitoring Programme is of questionable applicability. Similarly, other parameters that cannot be linked directly to flow, such as population growth and poverty indicators, have been excluded from the Monitoring Programme. This has been done because monitoring should be used mainly to identify a problem area and not necessarily to explain it. Programmes that include too many explanatory or diagnostic variables often fail due to the complexity and costs involved. These diagnostic variables often play a role later in the Monitoring Programme, when a problem has been identified and the causes of it need clarification. At such a stage, a core "lean" Monitoring Programme can be supplemented with additional appropriate investigations.

Thus, the generic Monitoring Programme designed here specifies the following:

- additional flow-related baseline data required before further LHDA dams are constructed on rivers, in order to be able to interpret data collected after their construction (see Sections 1.3.4 and 3.2.1);
- release-specific data required after the construction of the dams and the implementation of the IFR, to assess whether individual releases are fulfilling their required function (see Section 3.2.2);
- long-term monitoring data, to assess whether the expected river condition is being achieved (see Section 3.2.3).

1.3.4 The need for adequate baseline data

Understanding the natural fluctuations within any ecosystem is essential to successful monitoring. In rivers, changes in the position and extent of sandbars could be natural shifts well within the long-term norm for a river. Shifts in the species composition of fish communities can occur naturally during dry and wet cycles, around some dynamic equilibrium. The Monitoring Programme should be able to distinguish between natural and man-made, flow-related or flow-unrelated change. However, distinguishing long-term trends from inter-annual variability requires years of study. In the case of the Lesotho rivers, the range of natural temporal and spatial variability is not well known, and so monitoring will have to contribute to this knowledge rather than feed on it. Globally, this is by no means an unusual situation.

Limited data collection has already taken place during the IFR study and has been used, together with expert opinion and information from elsewhere, to create four scenarios (see Section 1.1). Although the data collected during the study do provide some baseline information against which future flow-related changes in the rivers can be assessed, they are limited by:

- the fact that Katse Dam was constructed before this project began and thus many of the IFR Sites were already impacted by flow changes (Figure 1.1);
- the data represent only a single hydrological year, and thus give no indication of inter-annual variability, nor if the rivers may differ in structure, functioning and condition in wet and dry cycles;
- the data collection was aimed primarily at determination of the consequences for the rivers of different levels of water abstraction, and thus may have excluded some kinds of data suitable for monitoring programmes.

Thus, in the context of Lesotho, the extent to which data collected during this and previous LHDA studies are adequate as baseline data for a Monitoring Programme was taken into account when designing the baseline data collection programme (see Sections 4 and 5).

1.4 REFERENCE SITES

Reference sites are areas outside the expected area of disturbance, which can be monitored to detect changes other than those caused by the disturbance. They can

thus be used to assess the extent to which the disturbance is contributing to a change within the main study area. Consideration was given to the possibility of establishing reference sites on rivers that will not be affected by LHWP dams, and using data obtained from these to assist in the interpretation of data collected at sites downstream of the dams (see Section 1.4.2). Data from these sites could be used in two ways:

- to ascertain the nature of the rivers prior to the construction of Katse Dam;
- to distinguish between changes in the rivers as a result of the construction of LHWP dams and changes that would have occurred anyway, as a result of phenomena such as changes in land use, population growth or global warming.

1.4.1 Socio-economic reference sites

The possibility of selecting reference sites for the socio-economic aspects of the Monitoring Programme was discussed at length. Eventually the social specialists recommended that social sites not be established. Instead, countrywide surveys should be used as the "reference-site data" against which to assess changes in the study area. The reasons for this decision were as follows:

- it is extremely difficult to select a single village to act as a reference/control site because (i) each social setting is unique and so it is difficult to select a statistically relevant number of villages, and (ii) separating out the influence of LHWP would be extremely difficult.
- regular nation-wide data are collected as part of poverty surveys, human development studies, population censuses, migration surveys and other initiatives from which data pertaining to the study area can be drawn. These data will be invaluable for distinguishing background trends in the monitoring data but would be prohibitively expensive, and unnecessary, to include in the Monitoring Programme.

Thus, it was decided not to select social reference sites.

1.4.2 Biophysical reference sites

Biophysical reference sites may be used to describe long-term climatic, resource-use or other changes in river reaches not affected by LHWP and factor this into

change being recorded in sites that are so affected. The following locations were considered as possible reference sites:

- Malibatso River at Kao;
- Matsoku River upstream of the headwaters of Matsoku Weir;
- Senqu River downstream of Mokhotlong;
- Senqu River immediately upstream of the confluence with the Malibatso River;
- Maletsunyane River upstream of the Semonkong waterfall;
- Lesobeng River upstream of the headwaters of the proposed Malatsi Dam.

The advantages and disadvantages of each location are discussed below.

1 Malibatso River at Kao

Accessibility: Good.

Hydrology: There is a gauging weir at Kao (G45), which is currently being repaired by LHDA and hourly hydrological data will be available for this site. Historic hydrological data are also available for this site.

Water quality: The site is not useful, as the characteristics of the Malibatso River at this point differ considerably from those of any of the IFR river reaches.

Geomorphology: The site is not useful, as the characteristics of the Malibatso River at this point differ considerably from those of any of the IFR river reaches.

Vegetation: The site could possibly be used as a reference site for IFR Site 1 or IFR Site 7. However, it is likely that vegetation characteristics will differ from those of these sites.

Fish: The site is not useful.

Invertebrates: The site is not useful.

Advantages of the site: Accessible and hydrological data are available. LHWP dams will not impact the site.

Disadvantages of the site: The channel morphology of the Malibatso River at this point is completely different from that in the reaches downstream of Katse Dam. In addition,

extensive mining at Kao has had impacts on the river.

II Matsoku River upstream of the headwaters of Matsoku Weir

Accessibility: Good.

Hydrology: There is a gauging weir downstream of proposed Matsoku Weir (G42). In addition, Matsoku Weir itself will be calibrated as a gauging weir, thus hourly hydrological data should be readily available for the site.

Water quality: The site is very useful as a reference site for IFR Site 1. Matsoku Weir does not have a large storage capacity, hence the site will be situated only c. 10 km upstream of the monitoring site at IFR Site 1, and the characteristics of the catchment and the river channel do not differ markedly between the two sites. Thus, it is unlikely that the chemical and physical characteristics of water at the two sites will differ much under natural conditions. However, it is critically important that daily hydrological data from Matsoku Weir be made available for use in the Monitoring Programme.

Geomorphology: The site is not useful.

Vegetation: It is likely that the site would be useful as a reference site for IFR Site 1. The reasons for this are much the same as those given for water quality.

Fish: The site is essential as a reference site for IFR Site 1. The reasons for this are much the same as those given for water quality, and are supported by the presence of the Maluti minnow at both sites.

Invertebrates: The site is very useful as a reference site for IFR Site 1. The reasons for this are much the same as those given for water quality. It is also essential that this site be included in the Monitoring Programme as construction of Matsoku Weir has begun, and thus the collection of additional baseline data at IFR Site 1 will not be feasible.

Advantages of the site: Accessible, and hydrological data are available. LHWP dams will not impact the site.

Disadvantages of the site: None.

III Senqu River downstream of Mokhotlong

Accessibility: Good.

Hydrology: There is a gauging weir downstream of Mokhotlong (G06), which has just been upgraded. Thus, hourly hydrological data will be available for the site.

Water quality: The site is not useful as a reference site as it is situated too far up the catchment.

Geomorphology: The site is not useful.

Vegetation: It is likely that the site would be useful as a reference site for IFR Sites 2, 3 and 7. However, this would need to be determined through the collection of baseline data.

Fish: The site is essential as a reference site for IFR Site 2, and possibly IFR Site 7. This is because it represents spawning grounds for the yellowfish, is un-dammed and is relatively unimpacted.

Invertebrates: It is likely that the site would be useful as a reference site for IFR Sites 2 and 3. However, this would need to be determined through the collection of baseline data.

Advantages of the site: Accessible, and hydrological data are available. LHWP dams will not impact the site.

Disadvantages of the site: The site is a long way from the other IFR sites, and part of its catchment is situated in a rain shadow, which may result in the site having different hydrological characteristics to the IFR sites.

IV Senqu River immediately upstream of the confluence with the Malibamatso River

Accessibility: Very difficult.

Hydrology: There is a gauging weir at Koma-koma (G04), which together with the weir upstream on the Senqu River (G06) and the one on the Malibamatso River at Paray (G08), could be used to derive daily data for the site by means of a mass-balance equation.

Water quality: The site is not useful, as interpretation of the water quality data requires hourly hydrological data.

Geomorphology: The site would be useful as a baseline site for mass balance of sediments but is not essential.

Vegetation: The site would be most similar to IFR Site 1, which would be better represented by the site on the Matsoku River upstream of Matsoku Weir.

Fish: The site would be useful as a baseline site but is not essential.

Invertebrates: The site is not useful.

Advantages of the site: Useful for the collection of baseline data for IFR Site 3, as IFR Site 3 itself is already impacted.

Disadvantages of the site: Poor access. The site will be inundated if Mashai Dam is constructed. Only daily hydrological data would be available.

V Maletsunyane River upstream of the Semonkong waterfall

Accessibility: Good.

Hydrology: There is a gauging weir upstream of the waterfall (number not known) but the data obtained from the weir are unreliable.

Water quality: The site is not useful.

Geomorphology: The site is not useful.

Vegetation: The site would be most similar to IFR Site 1, which would be better represented by the site on the Matsoku River upstream of Matsoku Weir.

Fish: The site would be useful as a baseline site but is not essential.

Invertebrates: The site is not useful.

Advantages of the site: Accessible and LHWP dams will not impact the site.

Disadvantages of the site: Although hydrological data are available for the site, they are unreliable. The site would be most similar to IFR Site 1, which would be better represented by the site on the Matsoku River upstream of Matsoku Weir.

VI Lesobeng River upstream of the headwaters of the proposed Malatsi Dam

Accessibility: Very poor.

Hydrology: There are no gauging weirs on the Lesobeng River.

Disadvantages of the site: The extremely poor access and lack of hydrological data disqualified this location as a potential reference site.

1.4.3 Final sites

After discussion, the following locations were chosen as recommended reference sites:

IFR Site 9: Matsoku River upstream of the headwaters of Matsoku Weir – reference for IFR Site 1.

IFR Site 10: Senqu River downstream of Mokhotlong – reference for IFR Sites 2, 3 and 7.

For the purposes of monitoring, these sites are numbered 9 and 10 to follow IFR Sites 1 –8.

There are no potential reference sites for IFR Sites 4, 5 and 6.

SECTION 2:

STUDY AREA AND PROPOSED MONITORING SITES

The study area for the proposed Monitoring Programme is the same as that for LHDA 648, plus additional reaches housing the reference sites:

- Malibamatso River downstream of the Katse Dam (LHWP Phase 1A) to the confluence with the Senqu River.
- Matsoku River downstream of the proposed diversion weir (LHWP Phase 1B) to the confluence with the Malibamatso River.
- Senqu River from the confluence with the Malibamatso River to the Lesotho/RSA border.
- Senqunyane River downstream of the Mohale Dam (LHWP Phase 1B) to the confluence with the Senqu River.
- extension of the study area upstream in the Matsoku and Senqu Rivers to include the two reference sites.

2.1 MONITORING SITES

Several types of sampling sites were used during LHDA 648, depending on the component under study and the statistical considerations pertinent to the data required for that component. It is envisaged that, apart from one or two exceptions listed below, the same sites will be used in the Monitoring Programme. The reasons for this are:

- (i) the number of sites used in LHDA 648 were considered to be the minimum number of sites that could represent the vast study area (> 500 km of river);
- (ii) data collected at these sites during LHDA 648 can be used as baseline data for the Monitoring Programme.

In addition, it is recommended that the two biophysical control sites identified in Section 1.4 be incorporated into the Monitoring Programme.

2.1.1 Location of the biophysical monitoring sites

Eight sites were selected to represent the study rivers in the main IFR study. It is anticipated that all of these sites will be incorporated into the Monitoring Programme. However, the type of data collected and

the frequency of sampling may differ between sites (see Section 4). These eight sites are (Figure 2.1):

- IFR Site 1. Matsoku River near the village of Seshote (29°15'21"S, 28°33'51"E), representing the Matsoku River from the site of the proposed Matsoku Weir to the confluence with the Malibamatso River (IFR Reach 1);
- IFR Site 2. Malibamatso River downstream of the Katse Bridge (29°21'08"S, 28°31'32"E), representing the Malibamatso River from Katse Bridge to the confluence with the Matsoku River (IFR Reach 2);
- IFR Site 3. Malibamatso River at Paray (29°29'52"S, 28°39'04"E), representing the Malibamatso River from the confluence with the Matsoku River to the confluence with the Senqu River (IFR Reach 3);
- IFR Site 4. Senqu River at Sehonghong (29°44'20"S, 28°45'19"E), representing the Senqu River from the confluence with the Malibamatso River to the confluence with the Tsoelike River (IFR Reach 4);
- IFR Site 5. Senqu River at Whitehills (30°03'56"S, 28°24'28"E), representing the Senqu River from the confluence with the Tsoelike River to the confluence with the Senqunyane River (IFR Reach 5);
- IFR Site 6. Senqu River at Seaka Bridge (30°02'11"S, 27°34'21"E), representing the Senqu River from the confluence with the Senqunyane River to the Lesotho/South Africa border (IFR Reach 6);
- IFR Site 7. Senqunyane River at Marakabei (29°32'09"S, 28°09'15"E), representing the Senqunyane River from the site of the proposed Mohale Dam to the confluence with the Lesobeng River (IFR Reach 7);
- IFR Site 8. Senqunyane River upstream of the confluence with the Senqu River (30°02'11"S, 27°34'21"E), representing the Senqunyane River from the

confluence with the Lesobeng River to the confluence with the Senqu River (IFR Reach 8).

The flows at IFR Sites 2 and 3 have already been noticeably affected by the presence of Katse Dam. Flows at IFR Site 4, 5 and 6 have also been affected, but to a much smaller degree and so represent a condition closer to natural than do IFR Sites 2 and 3. In Phase 1b, IFR Site 7, on the Senqunyane River, will be most affected by presence of Mohale Dam, and IFR Site 1 by Matsoku Weir. In Phase 2, the reaches represented by IFR Sites 2 and 3 will be inundated, and IFR Sites 4 and 5 will be the most affected downstream sites.

In addition, the suggested two reference sites are (see Section 1.4):

- IFR Site 9. Matsoku River upstream of the headwaters of Matsoku Weir, as a reference site for IFR Site 1.
- IFR Site 10. Senqu River downstream of Mokhotlong, as a reference site for IFR Sites 2, 3 and 7.

2.1.2 Location of the socio-economic monitoring sites

For the detailed socio-economic study of the present use of the rivers by riparian peoples (Report No 648-F-08), the study area was divided into the same eight river reaches as for the biophysical study (see Section 2.1.1). A corridor 5-km wide either side of the river (i.e., a total of 10 km width) was demarcated for each river reach and randomly-selected villages within this corridor were visited. Two hundred and ten household responses to a custom-designed questionnaire were gathered from villages within each reach. In total 144 villages were visited during the socio-economic survey, and 1680 responses to the questionnaires were gathered.

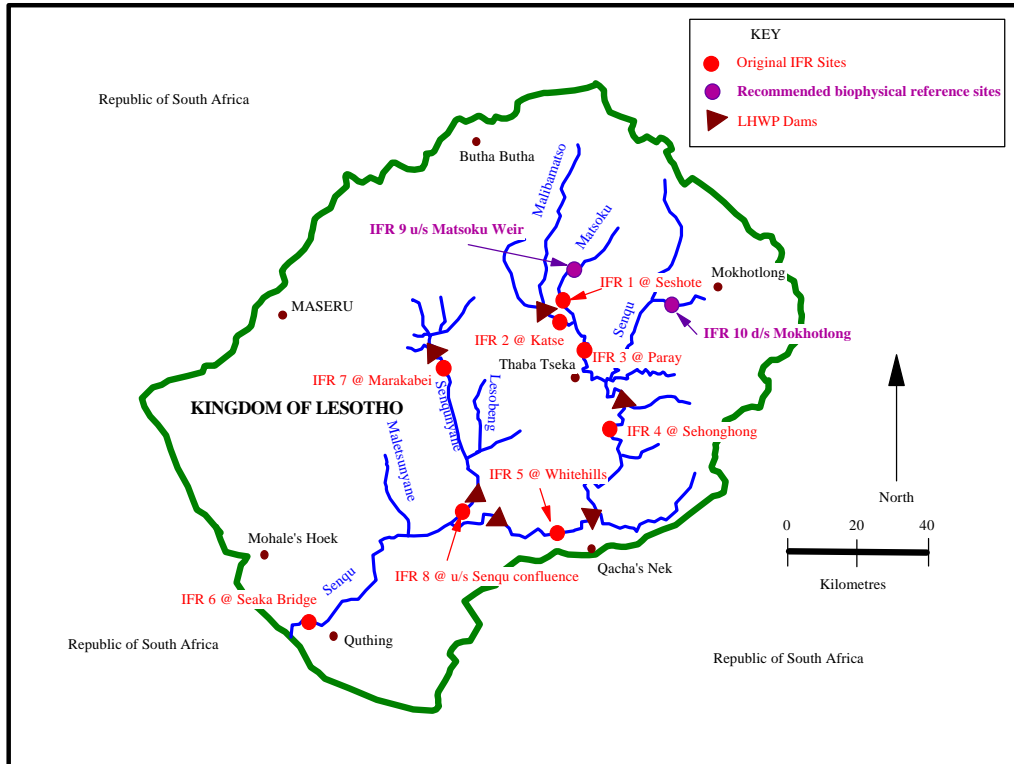


Figure 2.1 Location of the study rivers, the original IFR sites and reference sites recommended for inclusion in the Monitoring Programme

For the Monitoring Programme, it is proposed that some of the eight river reaches be combined, and the total number of social responses required reduced. This form of stratification will reduce the sample size from 1680 responses to 1050 responses. Also, it is anticipated that the frequency of sampling may differ between reaches. Five river reaches are thus recommended for monitoring purposes. These retain the numbering that links them to the biophysical reaches, namely:

Monitoring Reach 1/2/3: A combination of IFR Reaches 1, 2 and 3; i.e., downstream of Matsoku Weir and Katse Dam, to the confluence with the Senqu River.

Monitoring Reach 4/5: A combination of IFR Reaches 4 and 5, i.e., the Senqu River between the confluence with the Malibamatso River and the confluence with the Senqunyane River.

Monitoring Reach 6: IFR Reach 6.

Monitoring Reach 7: IFR Reach 7.

Monitoring Reach 8: IFR Reach 8.

In addition, the ten clinics that were used in the public health survey for LHDA 648 are also recommended for inclusion in the Monitoring Programme. These are (see Report No 648-F-09):

- Seshote Clinic (near IFR 1);
- Khohlo-Ntso Clinic (near IFR 2);
- Paray Hospital (near IFR 3);
- Mohlanapeng Clinic and Sehonghong Clinic (near IFR 4);
- Sekake Clinic (near IFR 5);
- Mount Moorosi Clinic, Phamong Clinic, Holy Cross Clinic (near IFR 6), and;
- Marakabei Clinic (near IFR 7).

2.1.3 Location of the gauging weirs in relation to IFR sites

If monitoring results are to be linked to flow-related changes in the study rivers, it is of the utmost importance that the biophysical data collected during the Monitoring Programme be linked to flow in the rivers, either directly or indirectly. Thus, the location of reliable hydrological gauging stations is at least as important a consideration as the location of IFR sites and villages. Table 2.1 provides a list of biophysical IFR Sites recommended for incorporation in the Monitoring Programme, the hydrological gauging weir nearest to each site, and an indication of the reliability of the data from each weir. For further details see Report No 648-F-13.

Comments and details on the condition of the weirs and the recommendations with respect to flow gauging in the study are provided in Section 4.1.

2.2 THE LHWP DAMS THAT WILL AFFECT EACH OF THE IFR SITES, SOCIAL REACHES AND CLINICS

The proposed LHWP dams, their location, proposed date of completion and the IFR sites (and the reaches they represent, which are the same as the social monitoring reaches) that each will affect are provided in Table 2.2.

Table 2.1 Gauging weirs located near to IFR Sites, and an indication of the quality of the data obtainable from those weirs.

Site	Gauging weir number	Reliability of the data
IFR 1	G42 (Seshote)	Fair
IFR 2	G41 (Bokong) and Katse Dam	Poor
IFR 3	G08 (Paray)	Fair
IFR 4	G05 (Koma-koma)	Fair

IFR 5	G04 (Whitehills)	Fair
IFR 6	G03 (Seaka)	Fair-poor
IFR 7	G17 (Marakabei)	Fair
IFR 8	G32 (Nkhaus).	Very poor
Biophysical Reference sites:		
IFR 9	G45 (Kao)	Fair
IFR 10	G06 (Mokhotlong).	Fair

Table 2.2 The proposed LHWP dams, their location, proposed date of completion and the IFR Sites, social reaches and clinics that each will affect

Proposed dam	LHWP Phase	River	Proposed date of completion	IFR Sites/Reaches affected	Social reaches	Relevant study clinics
Katse (extant)	Phase 1a	Malibamatso	Completed 1995	IFR 2, 3, 4, 5 and 6	1/2/3; 4/5 and 6	Khohlo-Ntso, Paray Hospital, Mohlanapeng, Sehonghong, Sekake, Mount Moorosi, Phamong and Holy Cross
Matsoku	Phase 1b	Matsoku	2000	IFR 1, 3, 4, 5 and 6.	1/2/3; 4/5 and 6	Seshote, Paray Hospital, Mohlanapeng, Sehonghong, Sekake, Mount Moorosi, Phamong and Holy Cross
Mohale	Phase 1b	Senqunyane	2005	IFR 7, 8 and 6. Also may affect IFR 5 reach.	7 and 8	Marakabei, Mount Moorosi, Phamong and Holy Cross
Mashai	Phase 2	Senqu	2008	IFR 4, 5 and 6. Would inundate IFR 2 and 3.	4/5 and 6	Mohlanapeng, Sehonghong, Sekake, Mount Moorosi, Phamong and Holy Cross
Tsoelike	Phase 3	Senqu	After Phase 2	IFR 5 and 6. Would inundate IFR 4.	4/5 and 6	Sekake, Mount Moorosi, Phamong and Holy Cross
Ntaohae	Phase 4	Senqu	After Phase 3	IFR 6. Would inundate IFR 5.	6	Mount Moorosi, Phamong and Holy Cross
Malatsi	Phase 5	Senqunyane	After Phase 4	IFR 6. Also would inundate most of IFR 8.	6	Mount Moorosi, Phamong and Holy Cross

SECTION 3:

OBJECTIVES AND ENVISAGED STRUCTURE OF THE SUGGESTED LHDA IFR MONITORING PROGRAMME

In this section, the overall design of the suggested Monitoring Programme is described. The details of what data should be collected or analysed are provided in Sections 4 and 5.

It is emphasised that this is a generic Monitoring Programme that should be refined by the appointed monitoring team once an IFR scenario has been chosen for implementation. Each specialist has provided his/her assessment of the vital data needs and any other non-essential data that would complement the monitoring data set. They have indicated analytical techniques that they feel would allow flow-related trends to be detected, and suggested some minimum lengths of monitoring periods and numbers of samples. These provide examples of possible details of the Monitoring Programme, and should not be seen as prescriptive.

IFR monitoring is still in its infancy and principles and techniques are still evolving. A full scientific appraisal of this field is not attempted here, but should be done by the appointed monitoring team. Such an appraisal should include consideration of the issues related to statistical analyses raised by the POE (*viz.* a discussion of the ideas presented in *inter alia*: Johnson 1999, Ellison 1996, Power et al. 1995, Mc Bride *et al.* 1993, Fairweather 1991, Reckhow 1990, Helsel and Hirsch 1988, Millard 1987, Montgomery and Loftis 1987). Rather, this document is intended to allow an understanding of the kinds of concerns that have been raised during the project, which the full IFR team feels should be addressed to adequately ensure sustainable river use.

3.1 OBJECTIVES OF THE MONITORING PROGRAMME

The primary objective of the Monitoring Programme is to ascertain whether, for the chosen scenario(s), the stipulated IFR is being delivered to each site, and the predicted condition for each river (Figure 1.1, Section 1) involved in the LHWP is achieved.

To achieve this, the Monitoring Programme structure:

- takes into account local constraints in Lesotho, such as the difficulty in reaching the rivers at many access points;
- encompasses a generic set of activities that can be used to custom-build a Monitoring Programme for the chosen scenario;
- facilitates selection of a sub-set of activities, if wished;
- identifies the personnel required to implement the Monitoring Programme, including the qualifications and attributes that would best qualify a person for each job;
- explains and justifies the components to be monitored;
- provides a format in which the results should be stored;
- details how results should be analysed on an on-going basis;
- makes recommendations for capacity building within the Monitoring Programme.

3.2 ENVISAGED STRUCTURE OF THE MONITORING PROGRAMME

Three tiers of monitoring have been incorporated into the Monitoring Programme, *viz.*:

1. pre-construction, baseline data collection;
2. post-construction, release-specific data collection;
3. post-construction, long-term routine monitoring.

Each of these is explained briefly below, and detailed in Sections 4 and 5. For each tier, specialists have motivated for the collection of data relating to their disciplines. In making such motivations, specialists took cognisance of the objective and requirements listed in Section 3.1.

Within this structure, the programme addresses the collection of data related to two main areas (Table 1.1). They are:

1. biophysical components;

2. socio-economic components.

NB: Monitoring the effects on the downstream rivers of activities linked to the actual construction of the dams is outside the TOR for this project, Contract LHDA 648, and is not addressed here. However, it is strongly recommended that an Environmental Management Plan be created for each dam construction site, if not already done so, and adhered to.

3.2.1 Pre-construction: Baseline data collection

The need for data representing pre-impoundment conditions on the study rivers was discussed in Section 1.3.4. For the most part, the data collected during LHDA 648 are adequate as a baseline against which to assess flow-related changes in the study rivers. However, in some instances additional data collection has been recommended. The aims of this baseline data collection would be to collect:

- additional biophysical data that have been identified as being necessary to address knowledge gaps and to be able to distinguish between future flow-related changes in the rivers and other changes;
- data required to address the statistical aspects of data collection, such as, the minimum number of samples required.

3.2.2 Post construction: Release-specific data collection (biophysical only)

The release-specific data collection is confined to highflow events. The aims of the release-specific data collection would be to collect data that will allow an assessment of whether or not the rivers are responding to different components of the flow regime in the ways predicted. For instance, the fish specialist stated that within-year highflows would provide cues for fish passage or spawning. Thus, release-specific data collection would aim at determining if fish spawning and migration did in fact occur in response to the release of such a highflow. Because of the purpose of the release-specific monitoring, it is envisaged that only biophysical data will be collected during this stage of the Monitoring Programme.

The data from the release-specific collection activities

will be used to fine-tune IFR releases with respect to for instance, ensuring that freshes are released at times when water temperatures would be conducive to fish spawning. Predictions of future conditions may also have to be refined.

Since the sites closest to the LHWP dams will be both most affected by the flow changes and the easiest for which to deliver the required flows, release-specific monitoring should concentrate on the following sites:

- IFR Site 1 downstream of the proposed Matsoku Diversion Weir;
- IFR Site 2 downstream of Katse Dam;
- IFR Site 3 downstream of the proposed Matsoku Diversion Weir and of Katse Dam;
- IFR Site 4 downstream of Mashai Dam;
- IFR Site 7 downstream of Mohale Dam.

3.2.3 Post construction: Long-term routine monitoring

The aims of the long-term Monitoring Programme should be to:

- verify that the IFR releases produce the required flow patterns at the IFR sites;
- assess the condition of the rivers for comparison with the baseline data sets;
- assess the overall efficacy of the IFRs in meeting their objectives, and to provide data that can be used as motivation for adjusting the IFRs if necessary;
- evaluate whether the parameters selected for inclusion in the Monitoring Programme are appropriate, and whether the list of parameters should be increased or decreased.

For some of the socio-economic components of the Monitoring Programme, an additional objective of the long-term monitoring would be to ascertain the necessity for and extent of mitigation/compensation.

The data collected as part of the long-term routine monitoring will provide an indication of the condition of the study rivers as a whole. To this end, it is recommended that all the IFR sites, reference sites, villages and clinics listed in Section 2 be included in this component of the Monitoring Programme.

The long-term monitoring is designed to identify potential problems, which once identified may require additional investigation as part of a different sampling effort.

3.3 MANAGEMENT OF THE MONITORING PROGRAMME

The success of the Monitoring Programme will depend on the rigour of the data collection, and on the manner in which the data are stored and analysed. There is little point in spending time and money collecting data, if these are not collected, archived, analysed and interpreted correctly.

Thus, it is recommended that:

- a Monitoring Programme Manager should be appointed, who will be responsible for the co-ordination of the monitoring team and management of the programme;
- dedicated specialists should be appointed to take responsibility for specific aspects of the Monitoring Programme;
- each member of the monitoring team should keep a record of monitoring methods;
- quality control of all data and data-collection methods should be applied by the monitoring team, and should be the responsibility of the Monitoring Programme Manager;
- a database should be developed and housed at LHDA to store the data generated by the Monitoring Programme. This database should be analysed on an ongoing basis to check for anomalous data, and an analysis of trends produced annually. The database should link with other international databases currently being developed, which relate to IFRs and river condition. An example of such a database is the RIVERS DATABASE currently being developed by Southern Waters for the National Rivers Health Programme in South Africa.
- a regular interpretation of the results of the

Monitoring Programme should be published, preferably every three-five years.

- the Monitoring Programme should be audited annually (ideally by an independent group of specialists referred to here as the Monitoring Steering Committee) to verify:
 - the data are sample analysis are performing their tasks correctly;
 - the data are being stored in an efficient manner, and interpreted correctly;
 - the IFR is achieving the predicted river conditions, with the predicted social and economic costs.
- the Monitoring Steering Committee should consist of three members, one from each of the disciplines of sociology, ecology and water-resource management;
- the Monitoring Programme should be refined at intervals, if necessary.

If the IFR is not meeting its objectives there should be the twin facilities of being able to revise either the IFR being released, or the desired river condition it is meant to achieve.

The Client should be aware that IFR monitoring is a new field of science worldwide. For the foreseeable future IFR monitoring programmes will be required not only to be refined on an ongoing basis using data collected as part of them, but also to take cognisance of developments and trends in the field of environmental flow monitoring. It is suggested that, at least in the beginning of the programme, the Client might like to consider appointing a Consultant with knowledge and experience in aquatic ecosystem functioning and environmental flows to guide and assist the Monitoring Programme Manager and LHDA in establishing, coordinating and refining the Monitoring Programme.

**SECTION 4:
BIOPHYSICAL: EXPLANATION OF MONITORING ACTIVITIES**

4.1 HYDROLOGY

It is essential that reliable streamflow gauging, which provides accurate and easily accessible hydrological data, be available near each IFR site.

Table 2.1 provides a list of biophysical IFR Sites recommended for incorporation in the Monitoring Programme, the hydrological gauging weir linked to each site, and an indication of the reliability of the data from each weir. For further details see Report No 648-F-13.

If the IFR releases are to be verified it is essential that the current levels of accuracy of these weirs are improved. It has been assumed for the other biophysical components that the accuracy and reliability of the gauging weirs near the monitoring sites will be improved and maintained.

4.1.1 Reliable stream flow gauging

4.1.1.1 Objectives/purpose

To provide accurate hydrological data that will:

- allow for the characterisation of both naturally-occurring and IFR-release flood events in terms of discharge, stage height and duration at each site;
- inform on lowflow discharge;
- verify that the stipulated IFR has been released at each site;
- if possible, be available on a near real-time basis, i.e., immediately accessible for correlation with water quality and other biophysical data.

4.1.1.2 Data required

Hydrological data collection is on going in LHWP rivers. Thus, the division into baseline, release-specific and long-term data collection is somewhat artificial. However, the distinctions have been made here since they facilitate incorporation of this component into the overall Monitoring Programme design.

Baseline data: Continuous time-series stage-height data (6-minute intervals). This is not strictly

“baseline” data collection but rather a continuation of existing data collection.

Release specific data: As above.

Long-term data: As above.

4.1.1.3 Activities required to collect and analyse data

LHDA's Hydrology Department, through the Lesotho Department of Water Affairs, routinely collects hydrological data. The Monitoring Programme Manager should ensure that these data are collated and entered into the Monitoring Programme's database timeously and should ensure that the data are accurate by performing simple analyses or interpretation. In this regard, the following activities are recommended:

- installation of hydrometric stations at IFR Site 2 on the Malibatso River and Nkaus on the lower Senqunyane River, close to IFR Site 8, as these two sites are not served by accurate weirs;
- development of streamflow rating curves at these two new hydrometric stations (IFR Site 2 and IFR Site 8). Flow measurements should be made at the two new sites for a period of at least five years until accurate streamflow rating curves have been fully developed.

From the experience gained during this study, the existing hydrometric network requires urgent upgrading. In many instances the equipment used for recording the stage height is out of date and requires frequent maintenance. This has resulted in valuable information being lost. It was also found that data collected during the contract were not readily available for use in the contract, mainly because of a lack of capacity and funding at LHDA.

The LHDA hydrometric database system requires upgrading in order to speed up the publication of the verified data on at least a quarterly basis. Unverified data should be available within five days of collection. Timely publication of the data will be possible if there are full-time personnel allocated to this task and if LHDA are operating a network with up-to-date hydrometric

equipment. Thus, the network upgrading should specifically include the following:

- the equipment used at the stations to record the stage height and rainfall should be enhanced by adding data loggers, with the current chart records acting as back ups for logging failures, and the charts stored but not analysed unless required;
- the LHDA database software should be upgraded;
- the computers that operate the database should be upgraded;
- an operations and maintenance manual for the network of gauging weirs should be developed;
- training of personnel should be undertaken.

Also, the use of real-time data is recommended as it would provide almost immediate acquisition of data, and would be useful in flood fore-casting, which is required to match flood releases to rain fall.

4.1.1.4 How would the data indicate significant change?

The purpose of the hydrological monitoring, in the context of the Monitoring Programme, is to provide a basis against which biophysical responses to changes in flow can be measured, to monitor whether recommended IFR releases are in fact being made whether this delivers the required flow patterns at the site. Readings should be made continuously, and appropriate statistical analyses used to test for significant changes in flow. However, the accuracy of these data is the most important factor in their collection. Improvement in the methods of data collection and interpretation will allow for an increase in the accuracy and delivery of the data.

Changes in the flow regimes can be quantified with statistical methods such as flow-duration curves, flood frequency analysis, lowflow frequency analysis, monthly histograms and auto-correlation methods (Gordon *et al.* 1992). Auto-correlation refers to the correlation of data series with the same data "shifted" by some time interval, e.g., the difference between this year's flow and last year's flow.

Table 4.1 Personnel required, including qualifications and experience.

4.1.1.5 Where should data be collected

See Table 2.1.

4.1.1.6 Timing and frequency of data collection

Stage height gauging should be undertaken on a continuous basis (6-minute intervals).

4.1.1.7 Can these activities be carried out by one of the other disciplines?

No.

4.1.1.8 Equipment required

Hydrographic equipment for the two new hydrometric gauging stations, two four wheel-drive vehicles to be shared with all the other components of the Monitoring Programme. Database software updates, and computers and printers.

4.1.1.9 Personnel required, including qualifications and experience

See Table 4.1.

4.1.2 Summary

Table 4.2 is a summary of data needs, purpose, location, frequency and man-days for the essential monitoring actions for hydrological purposes.

4.1.3 Recommended additional (non-essential) data collection

None.

Personnel	Number required	Days per annum	Qualifications	Experience
Hhydrologist / hydrographer	1	Full time	BSc (hons)	<ul style="list-style-type: none"> At least ten years experience with hydrological data collection, storage and reporting.
Assistant Hydrographer	1	Full time	Matric	<ul style="list-style-type: none"> At least five years experience with hydrological data collection, storage and reporting.

Table 4.2 Summary of needs for the hydrological component of the Monitoring Programme.

COMPONENT: HYDROLOGY					
Sub-component	Purpose	Where data should be collected	Frequency of collection	Personnel required	Man-days per annum (incl. local travel)
BASELINE DATA:					
Continuous time-series stage-height data.	To provide accurate records of discharges at each IFR site.	At all gauging weirs as listed in Table 2.1.	Continuous	1 hydrologist/ Hydrographer 1 Assistant Hydrographer	Full time
RELEASE-SPECIFIC DATA					
Same as for baseline data.					
LONGTERM DATA					
Same as for baseline data.					

4.2 HYDRAULICS

The flow of water through a natural open channel and the physical dimensions of the channel are inter-dependent. The geometry and flow resistance of the channel determine the hydraulic conditions. The physical dimensions of the channel can be altered through changes in sediment and flow regimes, which in turn can affect habitat availability for river plants and animals.

4.2.1 River-channel dimensions and cross-sectional rating data

4.2.1.1 Objectives

To provide accurate hydraulic data that will:

- Allow development of the relationships between discharge, velocity, wetted perimeter and average depth at the IFR Sites;
- provide accurate survey data against which changes in river-channel dimensions can be assessed.

4.2.1.2 Data required

Baseline data: Sufficient data exist at IFR Sites but data are required for the reference sites (Sites 9 and 10). Also see baseline activities.

Release specific: None.

Long-term data: Cross-sectional survey data of the river channel at c. 1-m intervals, including horizontal and vertical dimensions of the channel and water-surface elevations;

Sequential readings of water depth, mean column velocity and substrata along the cross-

sections.

Key geomorphological, vegetational and macroinvertebrate points along the cross-sections.

4.2.1.3 Activities required to collect and analyse data

Baseline: Rating curves will need to be developed for cross-sections at the reference sites (Sites 9 and 10), so that discharges can be inferred from stage heights. Reinstallation of concrete beacons that were damaged or removed by herd boys during LHDA 648 will also need to be undertaken. It is important that these are re-installed or the data already collected cannot be related to fixed datum points and so are of limited value.

Release-specific: None.

Long-term: With changes in flow in the study rivers, the channel shape is expected to change. Thus, from time to time it will be necessary to re-survey the channel profile along the existing cross-sections at each IFR site. At the same time, data on water depth, mean column velocity and substrata should also be collected. If the shape of the channel has changed, then it would also be necessary to develop new rating curves for each cross-section so that discharges can continue to be inferred from stage heights. This would necessitate additional trips to record water-surface elevations at a range of different discharges (at least four).

4.2.1.4 How would the data indicate significant

change?

The data will be used in two ways:

- *To describe the direction of change in channel shape with changes in discharge and sediment load as a result of the dams:* The surveys of the channel profile would allow determination of whether or not at-a-site variations in channel geometry had occurred.
- *To develop hydraulic relationships for the cross-sections to allow the variations in depth, mean velocity and channel width with changes in discharge to be modelled for each cross-section at each IFR Site:* It is suggested that, at this stage, a steady-state backwater model for non-uniform flow profile computations (Channel Flow Profile) will be used. The accuracy of the developed hydraulic relationships will be dependent on the frequency of measured data points. These relationships are required to interpret data and predict changes in other components of the riverine ecosystem, such as sediment transport, water quality or vegetation. They would be used in much the same way as they were used during the IFR Workshop (see Report No 648-F-03).

4.2.1.5 Where should data be collected?

Baseline: All IFR Sites, plus cross-sections need to be established at the two reference sites, IFR Sites 9 and 10.

Release-specific: Probably IFR Sites 1, 2 or 7, depending from which dam flood releases are made.

Long-term: All IFR Sites.

4.2.1.6 Timing and frequency of data collection

Table 4.3 Personnel required, including qualifications and experience.

Personnel	Number required	Days per annum	Qualifications	Experience
Hydraulic engineer	1	c. 50 days (year 1)	MSc/PhD	<ul style="list-style-type: none"> • Five years experience in hydraulic modelling of lowflows, driver's license.
Surveyor	1	c. 40	Matric	<ul style="list-style-type: none"> • five years surveying, driver's license and experience driving in the mountains of Lesotho. Should speak S. Sesotho.
Assistant	1	c. 40	Matric	<ul style="list-style-type: none"> • Experience with data entry. Should speak S. Sesotho.

Baseline: As soon as possible. **Existing concrete beacons should be maintained, and damaged or lost ones replaced as a matter of urgency.**

Release-specific: As and when IFR-releases from LHWP dams are implemented.

Long-term: As and when IFR-releases from LHWP dams are implemented. Every two years for the first five years, thereafter every five years.

4.2.1.7 Can these activities be carried out by one of the other disciplines?

No.

4.2.1.8 Equipment required

For fieldwork: Total station and associated surveying equipment; camera.

For hydraulic modelling: Desktop computer and hydraulic software.

4.2.1.9 Personnel required, including qualifications and experience

See Table 4.3.

4.2.2 Summary

Table 4.4 is a summary of data needs, purpose, location, frequency and man-days for achieving accurate river-channel dimensions and cross-sectional rating data.

4.2.3 Recommended additional (non-essential) data collection

None.

Table 4.4 Summary of needs for the hydraulic component of the Monitoring Programme.

COMPONENT: HYDRAULICS					
Activity	Purpose	Where data should be collected	Frequency of collection	Personnel required	Man-days per annum (incl. local travel)
BASELINE DATA:					
Surveying of cross-sections at reference sites. Re-installation of beacons at existing IFR sites.	To provide benchmarks for surveys of channel dimensions and water levels.	All biophysical sites, incl. 9 and 10.	Once	1 hydraulic engineer 1 surveyor 1 assistant	10 days 10 days 10 days
RELEASE-SPECIFIC DATA					
None.					
LONGTERM DATA					
Resurveying of existing cross-sections.	To ascertain whether the channel shape has changed, and the direction of change.	All biophysical sites, incl. 9 and 10.	Every two years for the first five years, thereafter every five years.	1 hydraulic engineer 1 surveyor 1 assistant	20 days 20 days 20 days
Sequential measurements of hydraulic depth and velocity across cross-sections.	To determine hydraulic relationships and distributions along cross-sections.	As above	As above	As above	As above
Surveying in new water-surface elevations.	To develop water stage/discharge relationships for new channel shape	At sites where statistically significant changes in channel shape are recorded.	At least four times after each change in channel shape	1 surveyor 1 assistant	36 days 36 days
Hydraulic modelling	To predict the changes in hydraulic parameters with changes in discharge.	For the sites where statistically significant changes in channel shape are recorded.	Every two years for the first ten years, thereafter every five years, as required.	1 hydraulic engineer	10 days

4.3 SEDIMENTOLOGY AND GEOMORPHOLOGY

Changes in sedimentation patterns can be due to a number of factors including:

- changes in sediment transporting capacity resulting from changed flow patterns;
- changes in the supply rate of sediments to the river;
- changes in the characteristics of sediment being supplied to the river.

Changes are most readily detected in channel shape, the characteristics of the bed and bank sediments and the sediments being transported. These changes take place gradually and should become apparent five to ten years after modifications to the flow regime by damming. Changes in sediment patterns can result in shifts in river condition, including in the availability of habitat for animals and plants. Fluvial geomorphologists describe these changes as three-dimensional changes in river

topography, using gathered topographical information.

4.3.1 Changes in sedimentation and river topography

4.3.1.1 Objectives

To provide sufficiently detailed data to:

- characterise changes in sedimentation patterns;
- document and analyse changes in river topography.

4.3.1.2 Data required

The following data needs are considered to be the minimum essential:

Baseline data: Sufficient data exist (Report No 648-F-14).

Release specific data: Distribution and analysis of suspended-particle size and loads during

higher programmed releases (see water quality).

Long-term data: Repeated measurements of:

- River channel dimensions;
- Distribution and analysis of sediment-particle sizes.
- Photographic coverage of key geomorphological features.

4.3.1.3 Activities required to collect data

- Cross-sections should be surveyed in at each site to record the river channel dimensions. (see hydraulics).
- A rough approximation of 50 representative sediment samples should be collected annually at specified distances along each existing cross-section at each IFR Site.
- To inform on channel geomorphology, a set of fixed-point photographs should be taken of key geomorphological features at each IFR site at both high and low flows. Apart from providing invaluable visual information about the site, which can be used in the interpretation of other data, these photographs can be digitised and used to quantify changes.

4.3.1.4 How would the data indicate significant change?

Changes in the size distribution of sediments would reflect the impact of changing sediment-transporting capacity as well as of availability. Statistically-significant differences in particle size could be tested for using a standard Analysis of Variance (ANOVA). Changes in cross-section dimensions would also reflect changing sediment-transport patterns and their impact on

morphology, e.g., changes in pool depth or infilling of finer sediments in between cobbles.

Due to the long-term nature of changes in sediment patterns and subsequent changes in river morphology, annual surveying and measurement would be adequate to monitor such changes. The data should be tested for significance using multivariate techniques, such as ANOSIM (Clarke and Warwick 1994).

4.3.1.5 Where should data be collected?

All biophysical Monitoring Sites, excluding Sites 9 and 10.

4.3.1.6 Timing and frequency of data collection

These activities should be done annually, starting in 2000.

4.3.1.7 Can these activities be carried out by one of the other disciplines?

Partly. The water-quality team can undertake event-related sampling of suspended solids, such as that required for release-specific sampling. The hydraulics team will produce data that will indicate changes in the shape of the surveyed cross-sections (see 4.2).

4.3.1.8 Equipment required

Camera, sediment samplers and sample bottles. Experienced laboratories should do analyses of sediment samples.

4.3.1.9 Personnel requirements including qualifications and experience

See Table 4.5.

Table 4.5 Personnel requirements including qualifications and experience.

Personnel	Number required	Days per annum	Qualifications	Experience
Specialist	1	c. 20 days (year one only)	PhD/MSc	<ul style="list-style-type: none"> • 10 years experience in sedimentology.
Researcher	1	c. 20 days	BSc (Hons)	<ul style="list-style-type: none"> • Field experience in sedimentology. Should speak S. Sesotho.

4.3.2 Changes in active channel habitat

Changes in sediment transport will affect the pattern of sediment deposition and the geomorphological character of the rivers. These will cause changes in habitat availability for the aquatic biota and thus in river resources.

4.3.2.1 Objective

To detect geomorphological change at ecologically-relevant scales.

4.3.2.2 Data required

Baseline data: Sufficient exists (see Report No 648-F-12).

Release-specific data: Data on the quantity and distribution of fine sediments in the riffle areas before and after high flows released from LHWP dams.

Long-term data:

- data on aggradation or degradation of the channel;
- data on the quantity and distribution of fine sediments in the channel, especially in the riffle areas;
- data on the distribution of habitats at each IFR site (for comparison with existing data).

4.3.2.3 Activities required to collect data

Baseline: None.

Release-specific: Information on the scouring of sediments from a riffle during highflow releases can be accomplished using several simple tools. Examples are:

- Installation of erosion pins at intervals across a representative riffle habitat at the IFR Site.
- Use of scour chains.
- Use of a habitat grid (25x25 squares).

Long-term data: Repeated surveys at fixed cross-sections (see hydraulics) should be used to monitor aggradation or degradation in the channel at each study site. This will provide an indication, on a large scale, and over the long-term, of whether, for a given cross-

section, sediments are being deposited or eroded.

Mapping of the substrata at each IFR site (these maps should be compared with the existing habitat maps to assess change (see Report 648-F-12).

Photographic coverage of sections of river bed at each site to aid in interpretation.

Collection of sediment for sediment-size analyses.

Detailed monitoring of riffle sections to assess the extent of build-up of fine sediments in between cobbles (embeddedness). The methods used here should be the same as those used to assess scour for the riffles in the release-specific monitoring.

4.3.2.4 How would the data indicate significant change?

Trend analysis should be used to detect long-term trends. A period of at least 20 years is required to detect changes in active channel habitat. Statistically significant changes in embeddedness could be tested for using standard statistical tests.

4.3.2.5 Where should data be collected?

At all biophysical monitoring sites.

4.3.2.6 Timing and frequency of data collection

The re-surveying of cross-sections is covered in the hydraulics section, and will not be repeated here. Long-term data collection should commence in 2000 and should be done annually. Note: It is anticipated that the geomorphological changes will be greater if IFRs are not implemented. Thus, there is no motivation for delaying the long-term monitoring until such time as IFRs are implemented. Release-specific data collection should commence as and when IFRs are implemented.

4.3.2.7 Can these activities be carried out by one of the other disciplines?

Yes, as follows:

Cross-section surveys:	Hydraulics team.
Habitat mapping:	Macroinvertebrate team.

4.3.2.8 Equipment required

Rods, grids, or similar depending on methods; trowel; camera; tape measure; graph paper.

Table 4.6 is a summary of data needs, purpose, location, frequency and man-days for geomorphological purposes.

4.3.2.9 Personnel requirements including qualifications and experience

No additional.

4.3.4 Recommended additional (non-essential) data collection

None.

4.3.3 Summary

Table 4.6 Summary of needs for the sedimentology and geomorphology component of the Monitoring Programme.

COMPONENT: SEDIMENTOLOGY/GEOMORPHOLOGY					
Activity	Purpose	Where data should be collected	Frequency of collection	Personnel required	Man-days per annum (incl. local travel)
BASELINE DATA:					
None.					
RELEASE-SPECIFIC DATA					
Measurements of movement of fine sediments from riffles.	To determine whether highflows intended to flush sediments from the riffle areas accomplish this.	At IFR Sites immediately downstream of LHW/P dams, viz. IFR Sites 1, 2 and 7.	Each time a flood release is made from a dam, up until five successful releases have been made.	Can be done by a member of the release-specific Monitoring Team (see Section 6.3)	n/a
LONGTERM DATA					
Re-surveys of cross-sections.	To monitor changes in channel shape.	All biophysical sites	Once every two years for the first five years, thereafter every five years.	Data collected by hydraulics team.	n/a
Mapping of substrata	To guide on choice of appropriate biomonitoring sampling points, and to track changes in channel and physical habitat..	All biophysical sites.	Annually	Data collected by macroinvertebrate team.	n/a
Photographic coverage	To provide visual data to assist interpretation of changes in geomorphological features.	All biophysical sites.	Annually	1 Researcher 1 Assistant	20 days 20 days
Collection of sediments	To provide data on particle-size distributions of sediments.	All biophysical sites.	Annually	As above	Included above
Measurements of fine sediments in riffles.	To monitor embeddedness of riffle areas.	All biophysical sites.	Annually	As above	Included above

4.4 WATER QUALITY

Flow-related changes in water quality in the project rivers due to upstream dams could include:

- reduction in the levels of total suspended solids;
- changes in the magnitude and variability of nutrients;

- changes to the downstream water temperature profile.

Water quality in the study rivers is naturally variable, both within years (high and low flows) and between years (wet and dry years). To be able to address whether an IFR is meeting its objectives, a

comprehensive pre-impoundment or baseline dataset needs to be established. The first two years for this dataset were collected in LHDA 648.

4.4.1 Changes in water quality associated with flow modifications in the study rivers

4.4.1.1 Objectives

To provide accurate water quality data that will:

- serve as a pre-impact comparison for changes associated with modified flow regimes;
- allow for verification and possible modification of the IFRs;
- detect any long-term trends in water quality.

4.4.1.2 Data required

The following data needs are considered to be the minimum to meet the objective:

Baseline and long-term data: Daily data on total suspended solids (TSS) concentrations;
 Daily data on nutrient (nitrates and phosphates) concentrations;
 Event-related data on total suspended solids (TSS) and nutrients;
 Monthly data for a full spectrum of water quality variables;
 Continuous data for dissolved oxygen (DO), electrical conductivity and turbidity, using water-quality loggers;
 Continuous temperature data;
 Continuous stage height (water level) data.

Release-specific data: Data on total suspended solid (TSS) and nutrient (nitrates and phosphates) concentrations before, during and after flood releases from the Phase 1 dams;
 Continuous temperature data before, during and after flood releases from the Phase 1 dams;
 Continuous stage height (water level) data before, during and after flood releases from the Phase 1 dams.

4.4.1.3 Activities required to collect data

Baseline data: Sufficient exists – but please note that the water quality data collection activities started during LHDA 648 should be maintained in order to ensure an unbroken water quality record.

Hence, no distinction has been made between baseline and long-term data collection.

Release-specific data: Water samples for analysis of total suspended solid (TSS) and nutrient (nitrates and phosphates) concentrations should be collected before, during and after flood releases from LHWP dams;

Temperature data should be collected at six-minute intervals for the duration of the releases using temperature data loggers. These data are vital to guide multi-level releases and timing of freshes.

Long-term data: Daily sampling of TSS and nutrients at each IFR site (365 samples for each of ten sites – per annum). Note: local observers should be used to collect the samples at each site. It is easier and more cost effective for these observers to collect a sample every day (hence the 365), however, only selected samples (*viz.* those that coincide with rainfall events, or droughts or other periods of interest) need to be analysed (200 per site per annum). ;

Monthly sampling of full spectrum of water quality variables. This could be undertaken at the same time as the samples are collected from the local observers and the water quality loggers are downloaded and re-calibrated.

DO, EC, turbidity and temperature data should be monitored on a three-hourly basis using water-quality loggers. The loggers should be downloaded and calibrated on a monthly basis.

Note, it is essential to measure temperature at all biophysical monitoring sites (incl. IFR 9, *i.e.*, excl. Site 10). The water-quality data loggers at IFR Sites 3 (Paray), 5 (Sekake) and 7 (Marakabei) (the “IFR Super-Sites”) record temperature. Water temperature probes attached to data loggers should be installed at the remaining six sites and in the forebays of Katse, Mohale and Mashai Dams.

4.4.1.4 How would the data indicate significant change?

Multivariate techniques should be used to search for trends in the water quality data.

4.4.1.5 Where should data be collected?

Baseline data: See long-term.
 Release-specific data: Sites immediately downstream of LHWP dams.
 Long term data: At all biophysical Monitoring Sites, incl. Site 9.

Recording of data using water quality and temperature loggers - CONTINUOUS.

4.4.1.6 Timing and frequency of data collection

Contract LHDA 648 developed a water-quality database for two full hydrological years. Ideally, data collection should be continued to provide a long-term data set for the study rivers. Thus, data collection for the long-term data collection should be started immediately.

Baseline sampling: See long-term sampling.

Event-related sampling: FIVE EVENTS PER ANNUM at the sites directly downstream of the relevant dams. The frequency of sampling will depend on the size and duration of the event being sampled. Ideally, event-related sampling should continue for five years after the implementation of IFR releases.

Long-term data:

TSS and nutrients – DAILY.

Full spectrum of water quality variables – MONTHLY.

4.4.1.7 Can these activities be carried out by one of the other disciplines?

No.

4.4.1.8 Equipment required

Data loggers (3); probes, housings and padlocks for the data loggers; nine temperature probes (one at each site as well as three in the forebays of Katse, Mohale and Mashai Dams); sample bottles (with preservative); data sheets; marker pens; Pentium 2 laptop computer, EPA Analytical standards; freezers (one at each site) and cool boxes.

4.4.1.9 Personnel requirements including qualifications and experience

See Table 4.7.

Table 4.7 Personnel requirements including qualifications and experience.

Personnel	Number required	Days per annum	Qualifications	Experience
Specialist	1	40 days.	MSc/PhD	<ul style="list-style-type: none"> Experience in water quality sampling, water chemistry, biological assessment, statistical analysis and report writing, able to train team.
Researcher	1	180 days	BSc (hons)	<ul style="list-style-type: none"> Experience in water quality sampling, water chemistry, biological assessment, statistical analysis and report writing. Driver's license.
Technician	1	180 days	Matric	<ul style="list-style-type: none"> Experience in water quality sampling and biological assessment. Computer literate. Basic understanding of statistics. Should speak S. Sesotho. Driver's license.
Driver	1	48 days	Driver's license	<ul style="list-style-type: none"> Five years driving experience.
Observers	10	Full time.	Read and write	<ul style="list-style-type: none"> No experience necessary. Preferably should be literate.

4.4.2 Microbiology and Parasitology

4.4.2.1 Objectives

To provide a sufficiently detailed data set that will:

1. allow for changes in the levels of total coliforms to be assessed;
2. allow for changes in the levels of *Giardia*, *Entamoeba histolytica* and *Cryptosporidium* to be assessed.

4.4.2.2 Data required

The following data are considered essential:

Baseline data: Sufficient exists.

Release specific data: None.

Long-term data: Number of total coliforms per 100 ml river water at each IFR site;
 number of *Giardia*, *Entamoeba histolytica* and *Cryptosporidium* cysts per 100 l river water at each IFR site.

4.4.2.3 Activities required to collect data

Baseline data: None

Release specific data: None

Long-term data: Coliforms: 100 ml river water to be filtered at each site. The filtered material is incubated for 24 hours in the field. The number of total coliform colonies to be counted after 24 hours.
Giardia, *Entamoeba histolytica* and *Cryptosporidium*: 100 l river water to be filtered at each site. The filter papers are kept cool and transferred to a laboratory for cyst counts.

4.4.2.4 How would the data indicate significant change?

Changes in the number of total coliforms will be tested for significance using non-parametric methods to test for

presence/absence. Multivariate techniques will be used to test for significant changes in the numbers of parasite cysts.

4.4.2.5 Where should data be collected?

All biophysical Monitoring Sites, incl. Site 9.

4.4.2.6 Timing and frequency of data collection

The data collection should be undertaken on a monthly basis as part of the routine water quality sampling.

4.4.2.7 Can these activities be linked to another component?

No.

4.4.2.8 Equipment required

Filtration apparatus for total coliforms and parasites. Portable incubator. Note: This equipment was bought during the present project (LHDA 648).

4.4.2.9 Personnel requirements including qualifications and experience

See Table 4.8.

4.4.3 Summary

Table 4.9 is a summary of data needs, purpose, location, frequency and man-days for detecting changes in water quality associated with flow modifications.

4.4.4 Recommended additional (non-essential) data collection

None.

Table 4.8 Personnel requirements, including qualifications and experience.

Personnel	Number required	Days per annum	Qualifications	Experience
Researcher	1	40 days	BSc (Hons)/MSc	<ul style="list-style-type: none"> • Background in biological sciences with emphasis on microbiology. • Driver's license.
Technician	1	30 days	BSc (Hons)	<ul style="list-style-type: none"> • Field data collection experience. • Driver's license.

Table 4.9 Summary of needs for the water quality component of the Monitoring Programme.

COMPONENT: WATER QUALITY					
Activity	Purpose	Where data should be collected	Frequency of collection	Personnel required	Man-days per annum (incl. local travel)
BASELINE DATA:					
Not applicable – see long-term data collection.					
RELEASE-SPECIFIC DATA					
Event-related sampling of TSS and nutrients	To provide specific flood event data for highflows released from the dams.	Immediately downstream of the LHWP dam(s), i.e., IFR Sites 1, 2 and 7 (later 4).	Each time a flood release is made from a dam, up until five successful releases have been made.	Water quality specialist	c. 10 days per release
LONGTERM DATA:					
Daily sampling of TSS and nutrients.	To provide data on magnitude and variation of TSS and nutrients.	At all biophysical monitoring sites.	Daily	10 Observers 1 Researcher 1 Assistant/Driver	365 days ea. 180 days 180 days
Monthly sampling.	To provide data on seasonal trends in water quality.	As above.	Monthly	1 Water quality specialist 1 Researcher 1 Assistant	Included above.
Total coliform and parasite cyst counts.	To provide data that allow for changes in the numbers of total coliforms and parasite cysts to be assessed.	At all biophysical monitoring sites.	Monthly	1 Researcher 1 Assistant/Driver	40 days 30 days (must be linked to above tasks)
Continuous WQ monitoring using loggers.	To provide continuous data on DO, turbidity, EC and temp at IFR Sites 3, 5 and 7.	IFR Site 3, 5 and 7.	Continuous (three hourly).	1 Researcher 1 Assistant/Driver	Included above.
Continuous temperature monitoring.	To provide continuous water temperature data.	IFR Sites 1,2,4,6, 8 and 9 (NB – also being done at 3, 5, and 7).	Continuous (three hourly)	1 Researcher 1 Assistant	Included above.
Continuous stage height recording.	To continuous discharges data for all other components.	At all biophysical monitoring sites, incl. 9.	Hourly	Data collected by hydrology team	See Hydrology

4.5 RIPARIAN VEGETATION

The riparian communities will respond to habitat changes related to changes in water level as follows:

- changes in distribution of species along the vertical axis (i.e., up the banks), and along the rivers (i.e. longitudinal zones);
- changes in relative species abundance;

- the loss of existing species or the gain of new species.

4.5.1 Changes in the riparian communities associated with flow modification in the study rivers

4.5.1.1 Objectives

To provide sufficient data on the riparian communities that will:

- (i) allow assessment of changes in seasonal, vertical and longitudinal distributions associated with changes in flow regime;
- (ii) allow for verification and help guide possible modification of the IFRs;
- (iii) detect long-term trends in the riparian community.

4.5.1.2 Data required

There is a need to establish and monitor plots of vegetation to obtain quantitative information on density and abundance of riparian-vegetation species. These data were not collected during LHDA Contract 648 because the emphasis there was on linking the phenology of these plants to aspects of the flow regime. Thus, the establishment and monitoring of plots is described here under baseline data.

Baseline data: Data on the vitality of indicator species and economic plants, i.e., plants that are heavily utilised by the rural communities. This should include data on plant growth rates.

Data on changes in plant zonation.

Data on the percentage vegetation cover. This will provide an indication of whether plant densities are increasing or decreasing over the longterm. Special emphasis should be placed on those species that were identified as being of economic importance.

Data on the density and frequency of algal growth in pools and riffles.

Photographic records to monitor general, widespread species.

Release specific: None.

Long-term data: As for baseline data.

4.5.1.3 Activities required to collect data

Baseline and longterm data: Permanently-marked, 2-m wide, cross-sections should be established along two of the existing cross-sections at each IFR site. These would be used to indicate the precise vertical zonation boundaries, viz. wetbank, drybank, and so on. Initially, these should be surveyed in across the whole macro-channel. This survey should be accompanied by

identification of the plant communities in each zone.

Permanently marked plots should be established within these cross-sections and density counts of shrubs within them should be done annually. A vertical photograph should be taken of each marked plot (showing the whole plot). Care should be taken that the [plots are not grazed or in other ways disturbed. Each photograph should indicate the markers for the plot and the scale. The photographs should be analysed for evidence of recruitment, changes in plant density, changes in species composition and plant development.

At least ten individuals of each of six or seven selected perennial species (e.g., *Cyperus marginatus*, *Gomphostigma virgatum*, *Phragmites australis*, *Salix babylonica*, and *Salix mucronata*) should be marked and their survival monitored.

Algal samples should be collected in the river along lines parallel to each bank.

Release specific: None.

In addition, there should be strong liaison with the social component of the Monitoring Programme, to ensure relevant, interpretable data on grazing patterns and riparian zone land use are collected, since these activities could obscure flow-related changes in the riparian vegetation.

Plant collections should be made so that a specialist can check species identifications on an *ad hoc* basis. It is suggested that a random selection of species samples is sent for verification on an annual basis.

4.5.1.4 How would the data indicate significant change?

The data will be analysed using multivariate techniques such as CANOCO or the ANOSIM procedure in PRIMER (Clarke and Warwick 1994), which are designed to reveal patterns and trends in biotic distributions.

4.5.1.5 Where should data be collected?

At all biophysical monitoring sites.

4.5.1.6 Timing and frequency of data collection

Baseline and longterm: Once per annum in early autumn;
Release-specific: None.

4.5.1.7 Can these activities be carried out by one of the other disciplines?

Partly, the hydraulics team should survey in the permanently-marked cross-sections. This means that the field-data collection trips for these two components of the Monitoring Programme should coincide.

4.5.1.9 Equipment required

Surveying equipment, digital camera, pole with camera mount; specimen bags; tape measure; clinometer; plastic bottles; identification guide, plant press.

4.5.1.10 Personnel requirements and qualifications

See Table 4.10.

4.5.2 Summary

Table 4.11 is a summary of data needs, purpose, location, frequency and man-hours for the essential monitoring action for the provision of representative data for riparian vegetation.

4.5.3 Recommended additional (non-essential) data collection

See Table 4.12.

Table 4.10 Personnel requirements and qualifications.

Personnel	Number	Days per annum	Qualifications	Experience
Specialist	1	20 days	PhD/MSc	<ul style="list-style-type: none"> Ten years riparian studies.
Botanist	1	30 days	MSc/BSc (hons)	<ul style="list-style-type: none"> Five years riparian studies. Should speak S. Sesotho.
Technician	1	30 days	Matric	<ul style="list-style-type: none"> Computer literate. Should speak S. Sesotho.
Taxonomist	1	6 days	PhD/MSc	<ul style="list-style-type: none"> Specialist in plant taxonomy.

Table 4.11 Summary of needs for the vegetation component of the Monitoring Programme.

COMPONENT: VEGETATION					
Activity	Purpose	Where data should be collected	Frequency of collection	Personnel required	Man-days per annum (incl. local travel)
BASELINE AND LONGTERM DATA:					
Establishment and monitoring of zonation cross-sections.	To provide detailed data on changes in plant zonation.	At all biophysical monitoring sites.	Annually	1 Specialist (1 st year only) 1 Botanist 1 Technician.	20 days. 30 days. 30 days.
Establishment and monitoring of permanently marked density plots.	To provide detailed data on changes in plant density.	At all biophysical monitoring sites.	Annually	1 Botanist 1 Technician.	Included above.
Monitoring of individuals of key species.	To provide baseline information on survival and vitality of important species	As above.	Annually.	As above.	Included in above.
Algal monitoring.	To monitor changes in algae density and species composition.	As above.	Annually.	As above.	Included in above.
Verification of species names	To check that plants are being identified correctly	n/a	Annually.	1 Botanical taxonomist.	6 days.
RELEASE-SPECIFIC DATA					

None.

Table 4.12 Recommended additional (non-essential) data collection.

Additional monitoring	Data required	Data collection activities	Comments
Phenology	Time of flowering and setting of seed.	Monthly monitoring of groups (10 individuals) of selected species to ascertain their relationships with the flow regime. This information would enhance confidence in the predictions of change.	This could be undertaken in collaboration with the National University of Lesotho as part of a BSc (Hon) or MSc programme.
Physiological stress	Fluorescence and photometry of selected plants at times of high water stress.	Monthly sampling of permanently marked plants during low flow, low rainfall periods to ascertain their relationships with the flow regime. This information would enhance confidence in the predictions of change.	As above.

4.6 AQUATIC INVERTEBRATES

Dams cause physical and chemical changes in the downstream riverine environment. These changes are likely to lead to changes in the structure of the downstream biota, including the macroinvertebrate communities.

4.6.1 Changes in the aquatic invertebrate communities associated with flow modification in the study rivers

4.6.1.1 Objectives

To provide a comprehensive aquatic invertebrate dataset that will:

- (i) allow for comparisons of pre-dam and post-dam aquatic invertebrate communities in terms of species present and relative abundance;
- (ii) allow, if necessary, for verification of the predicted changes in macroinvertebrate communities and guide modification of the IFRs.
- (iii) allow for the characterisation of long term trends in the aquatic invertebrate communities.

4.6.1.2 Data required

Baseline data: Sufficient exists (Report No 648-F-17).

Release specific data: None.

Long-term data: Data on the species composition and relative abundances of the macroinvertebrate communities in each of three major habitat types at each IFR Site.

Data on the availability and condition of macroinvertebrate habitats at each of the IFR Sites.

4.6.1.3 Activities required to collect data

Baseline data: None.

Release specific data: None.

Long-term data: Sweep-sampling of macroinvertebrate communities in the three dominant habitats at each IFR Site using 300 µm mesh nets. The three most dominant habitats will be selected from : stones-in-current (riffle); stones-out-of-current (backwater); marginal vegetation; sand-in-current; sand-out-of-current; standing backwaters with sand; standing backwaters with mud.

The collected specimens sorted and then identified, preferably to species level. The identifications checked by a recognised taxonomic expert.

Mapping of the substrata and flow types at each IFR site (these maps should be compared with the existing habitat maps to assess change (see Report 648-F-12).

It will be extremely important to ensure that, at the outset, the long-term Monitoring Programme links up with the sampling done during LHDA 648, in terms of habitats samples at the different IFR sites and the methods used (see Report No 648-F-17).

4.6.1.4 How would the data indicate significant change?

The significance levels would depend on the intensity of sampling (how many samples are collected and sorted) as well as the taxonomic identification. It is always difficult to assess upfront the level of significance likely to be achieved. However, the ten samples per each of three habitat types should allow for thorough statistical analysis. Multivariate techniques such as CANOCO or ANOSIM in the software package PRIMER (Clarke and Warwick 1994) should be used to distinguish natural from impoundment-related changes in community structure. Changes in the relative proportions of key taxa (*Baetis*, *Cheumatopsyche* and *Simulium*) should also be analysed, since these groups have relatively well-studied responses to impoundments.

4.6.1.5 Where should data be collected?

At all biophysical monitoring sites, incl. Site 9.

4.6.1.6 Timing and frequency of data collection

The surveys of the aquatic invertebrate communities should be done annually when the summer highflows have subsided.

4.6.1.7 Can these activities be carried out by one of the other disciplines?

No.

4.6.1.8 Determining/confounding factors other than flow that could influence change in the issue of concern

Changes in water quality associated with changes in land use, agricultural practices, industrialisation and

sewage effluent would affect the macroinvertebrate community structure. However, considerable expertise has been, and continues to be, developed in southern Africa in the interpretation of macroinvertebrate community results, and dam-related changes should be distinguishable from changes from other causes. Because of this and the inherent sensitivity of macroinvertebrates to change in environmental conditions, data on their presence and abundance provide an invaluable "catch-all" for the sort of monitoring required downstream of LHWP dams.

4.6.1.9 Equipment required

Sampling nets (300 µm mesh); sample bags/bottles; 80% alcohol; tweezers; sorting tray; marker pens, pencils; specimen tubes; data sheets, formalin.

4.6.1.10 Personnel required including qualifications and experience

See Table 4.13.

4.6.2 Summary

Table 4.14 is a summary of data needs, purpose, location, frequency and man-days for the provision of representative aquatic invertebrate data.

4.6.3 Recommended additional (non-essential) data collection

See Table 4.15.

Table 4.13 Personnel required including qualifications and experience.

Personnel	Number required	Days per annum	Qualifications	Experience
Specialist	1	20 days (first year only)	MSc/PhD	<ul style="list-style-type: none"> Five years experience in invertebrate studies (sampling, life cycles, distribution and taxonomy). Ability to train team.
Researcher	1	20 days	BSc (hons)	<ul style="list-style-type: none"> Background in biological sciences. Experience in invertebrate studies. Should speak S. Sesotho.
Technician	1	20 days (after first year only)	Matric	<ul style="list-style-type: none"> Experience in field work in the highlands Should speak S. Sesotho.

Taxonomist	1	100 days	BSc (hons)	<ul style="list-style-type: none"> • Experience in, and talent for, the identification of aquatic invertebrates.
Taxonomy specialist	1	6 days	MSc	<ul style="list-style-type: none"> • Five years specialist experience in invertebrate taxonomy, preferably from one of the museums that houses macroinvertebrate type specimens for southern Africa.

Table 4.14 Summary of needs for macroinvertebrate component of the Monitoring Programme.

COMPONENT: AQUATIC INVERTEBRATES					
Activity	Purpose	Where data should be collected	Frequency of collection	Personnel required	Man-days per annum (incl. local travel)
BASELINE DATA:					
None.					
RELEASE-SPECIFIC DATA					
None.					
LONGTERM DATA					
Sampling of macroinvertebrate communities in the three dominant habitats.	To provide composition and relative abundance data for comparison.	At all biophysical monitoring sites, incl. 9..	Once per annum (autumn)	1 Specialist (first year) 1 Researcher 1 Technician	20 days 20 days 20 days
Mapping of aquatic habitat.	To provide habitat data at an ecologically-relevant scale.	At all biophysical monitoring sites, incl. 9..	Once per annum	1 Specialist (first year) 1 Researcher 1 Technician	Included in above
Identification of macroinvertebrates to species level.	To provide species level data.	All samples collected.	Ongoing	1 Taxonomist	100 days
Verification of macroinvertebrate identifications.	Quality control	All samples collected.	Once per annum.	1 Specialist	6 days

Table 4.15 Recommended additional (non-essential) data collection.

Additional monitoring	Data required	Data collection activities	Comments
Side stream survey	Species list. Relative abundances. These data should provide an indication of the importance of the side streams to macroinvertebrates in the study rivers. It will also contribute to the distributional data for macroinvertebrates in Lesotho rivers.	Surveys in selected side streams. Identification of animals to the species level.	This would form an ideal MSc or PhD study at NUL or one of the South African Universities.
Taxonomic studies of <i>Neoperla spio</i> , <i>Bifasciata centropiloides</i> and <i>Hydropsyche longifurca</i>	Identification of adult specimens in order to check the taxonomic status of these groups.	Light trapping. Collection of emerging adults (in field and laboratory). This should be done at IFR sites 1, 2, 3, 5 and 7 (one per site).	This could be undertaken in collaboration with the National University of Lesotho as a MSc or PhD (depending on the level of detail included).
Life histories of key species	Length/frequency distributions in order to ascertain the timing of key life-history stages, and to link this to flow and/or climate.	Bi-weekly sampling of selected species at IFR sites 1,2,3,5 and 7 (one sample per site).	This could be undertaken in collaboration with the National University of Lesotho as part of an honours programme.

4.7 FISH

The fish communities of the study rivers will be affected in several ways by flow regulation. These include both beneficial and adverse effects. Some species may increase in abundance in the rivers whereas others may be lost from a specific reach. Transfer of water from one river to another may also result in the introduction of exotics, such as trout, to reaches where they have not previously been recorded.

4.7.1 Changes in the fish populations associated with flow modification in the study rivers

4.7.1.1 Objectives

To provide data on the fish communities that will:

- (i) assess whether the fish communities are adversely or beneficially affected by changes to the flow regime in terms of fish assemblage structure, species population structure and reproductive processes;
- (ii) allow for verification of the predicted changes in fish communities and guide modification of the IFRs, if necessary;
- (iii) detect any long term changes in fish community structure.

4.7.1.2 Data required

Baseline data: Sufficient data exist (Report No 648-F-18).

Release specific data: Data to indicate whether fish spawning and migration occurred in response to releases from dams, e.g., records of upstream movement of fish or visual records of activities on spawning beds.

Data to indicate whether lateral habitats were created for and (if spawning occurred) used by larvae and juvenile fish following releases from dams.

Data to indicate the survival rates of larvae (if spawning occurred).

Long-term data: Data on fish species composition, age structure and relative abundances at each IFR Site.

4.7.1.3 Activities required to collect data

Baseline data: None.

Release specific data: Visual records of activity on the spawning beds by observers stationed at habitats that are suitable for spawning. The spawning beds should be observed continuously during a release. When possible, photographs should be taken to confirm observations.

Other sections of the channel should also be observed for fish movement that would be indicative of migration activities.

Small drift nets (300 µm mesh) could be stationed downstream of the spawning beds in order to sample eggs washed off the spawning beds. These nets would probably not allow the collection of quantitative data but are recommended because they may help to detect spawning activity that is missed by the observers.

Backwaters and side channels should be sampled for larvae and fry at intervals of a few days to a few weeks after a release.

The fish team should link closely with the hydraulics, water quality and macroinvertebrate teams during the release-specific sampling, since they will require information on, *inter alia*, stage height and lateral-habitat inundation, and water temperatures.

Long-term data: Routine fish surveys. Fish should be sampled using a wide variety of methods to maximise the chance of capturing individuals present at each IFR site. The methods should include electro-fishing, seine-netting, gill-netting and angling.

For each fish captured, its length, weight, general health, sex, age, gonad development stage and gonad weight should be measured and recorded.

Surviving fish should be marked and released.

The fish team should link closely with the sociology team, as catch records from the villagers could be an invaluable data source on species distributions in the study rivers. In this regard, village record-keepers (as recommended in Section 5.1) could provide valuable, seasonal information on fish catches from the study rivers.

4.7.1.4 How would the data indicate significant change?

It is difficult to determine how long it will take to reveal statistically significant changes in the fish communities, since this is closely dependent on the number of fish that are sampled. This in turn is a combination of sampling effort, sampling method and the abundances of fish. For instance, if catches are high, then the capture/recapture procedure should yield some valuable data. Thus, we have recommended a level of effort that should yield useful results, but this may need to be revisited (and increased or decreased) later on in the programme.

4.7.1.5 Where should data be collected?

At all biophysical monitoring sites, incl. Site 9.

4.7.1.6 Timing and frequency of data collection

Baseline data: None.

Release specific data: Each time a flood release is made from a dam, until five successful releases have been made.

Long term data: For the first year, the fish surveys should be conducted four times (in spring, summer, autumn and winter). Thereafter, they should be conducted annually towards the end of the dry season.

4.7.1.7 Can these activities be carried out by one of the other disciplines?

No.

4.7.1.8 Equipment required

Electro-shocker, nets (sieve 2 x 50m sheets, gill 10 x 10m different mesh sheets), drift nets (300 µm mesh), pegs (for anchoring drift nets) flow meter, graduated stick, boat, field balance, callipers, camera, binoculars (for release-specific observations), field guide.

4.7.1.9 Personnel required including qualifications and experience

See Table 4.16.

4.7.2 Summary

Table 4.17 is a summary of data needs, purpose, location, frequency and man-days for the provision of representative fish data.

4.7.3 Recommended additional (non-essential) data collection

See Table 4.18.

Table 4.16 Personnel required including qualifications and experience.

Personnel	Number required	Days per annum	Qualifications	Experience
Specialist	1	First year – 100 days Thereafter - 25 days Release-specific – c. 50 days (depending on the number of releases).	MSc/PhD	<ul style="list-style-type: none"> Five years experience in fish studies.
Technician	2	First year –100 days Thereafter –25 days Release-specific – c. 50 days (depending on the number of releases).	Matric	<ul style="list-style-type: none"> Experience in field work in the highlands Should speak S. Sesotho.

Table 4.17 Summary of needs for the fish component of the Monitoring Programme.

COMPONENT: FISH					
Activity	Purpose	Where data should be collected	Frequency of collection	Personnel required	Man-days per trip (incl. local travel)
BASELINE DATA:					
None.					
RELEASE-SPECIFIC DATA:					
Records of spawning or migration activity.	To monitor spawning and migration responses to within-year flood releases.	Immediately downstream of the LHWP dam(s), i.e., IFR Sites 1, 2 and 7 (later 4).	Each time a flood release is made from a dam, until five successful releases have been made.	1 Specialist 2 Technicians	10 days each per release
Pre- and post-release sampling for juveniles and fry.	To monitor whether breeding is occurring.	Immediately downstream of the LHWP dam(s), i.e., IFR Sites 1, 2 and 7 (later 4).	Each time a flood release is made from a dam, until five successful releases have been made.	1 Specialist 2 Technicians	10 days each per release
LONGTERM DATA					
Routine fish surveys.	To provide data on fish species composition, age structure and relative abundances.	At all biophysical monitoring sites, incl. 9.	Four times in the first year, thereafter annually.	1 Specialist 2 Technicians	Year 1: 100 days each
					Thereafter: 25 days each

Table 4.18 Recommended additional (non-essential) data collection.

Additional monitoring	Data required	Data collection activities	Comments
Investigation of the diets of key fish species in Lesotho rivers.	i. Chlorophyll a and drift organisms ii. Organisms eaten (for comparison with a, i.e., those available).	i. Sampling of drift at times of programmed releases ii. Filtration of water to determine chlorophyll a concentration iii. Analysis of gut contents of fish	These sorts of studies provide ideal subjects of a MSc degree, in which case the student would need to collect their data themselves.
More detailed investigations of spawning and migration cues.	Fish movement and spawning activities	Sampling of fish populations at times of selected flood events.	General life history studies such as represented by spawning and migration studies can form the basis of MSc or PhD studies.

4.8 AVIFAUNA, MAMMALS AND HERPETOFAUNA

The effects of flow modification on the birds, mammals and amphibians can be summarised as direct effects on specific water-dependent species and indirect effects on other species utilising some parts of the aquatic, lower or back dynamic zones as part of the suite of resources

incorporated in their home ranges.

Water-dependent bird species will be most affected, whereas it is anticipated that mammals, with the possible exception of the Cape clawless otter, will be affected minimally. It is not possible to quantify the effects on the herpetofauna without detailed studies on their habitat and lifecycles.

4.8.1 Changes in the populations of water-dependent bird species

4.8.1.1 Objectives

- (i) To monitor changes in populations of water-dependent bird species.
- (ii) To monitor changes in bird communities in the lower dynamic zone as an indicator of short-term indirect effects of changes in flow regimes on terrestrial wildlife.
- (iii) To monitor changes in bird communities in the back dynamic zone as an indicator of long term indirect effects of changes in flow regimes on terrestrial wildlife.

4.8.1.2 Data required

Baseline data: Insufficient data exist, but the links between these groups and flow in the rivers are far less obvious than for the other components of the sampling programme, making them generally relatively unsatisfactory as flow indicator species. A low-level monitoring programme to alert to possible major changes seems more appropriate than a major data collection programme to support formal statistical analyses (see long-term data).

Release specific data: None.

Long-term data: Population data for water-dependent bird species.

Population data for bird species in the back and lower dynamic zones.

4.8.1.3 Activities required to collect

Baseline data: None.

Release specific data: None.

Long-term data: Species-specific counts of water-dependent birds along a 2-km river length at each IFR site.

Species-specific counts of population data for bird species in the back and lower dynamic zones at each IFR Site. The areas used for these counts will probably differ between sites, depending on vantage points and the vegetation zonation offered by each. However, essentially, some form of abundance or relative abundance records would be ideal. If this is not possible, then presence absence data collected in a standardised way, together with some indication

of the percentage time the birds spend in the back and lower dynamic zones would suffice.

4.8.1.4 How would the data indicate significant change?

A density index should be calculated for each bird species and compared with other sites and other years at the site using non-parametric statistics. Variation in density indices in relation to gross vegetation and geomorphological features should be assessed using multiple linear regression analysis.

4.8.1.5 Where should data be collected?

All biophysical monitoring sites, incl. Sites 9 and 10.

4.8.1.6 Timing and frequency of data collection

Monitoring should commence in 2000 at the end of the summer period. This should be repeated annually for at least the first five years, until a pattern of natural variability is established. Thereafter, the surveys could be done every five years.

4.8.1.7 Can these activities be carried out by one of the other disciplines?

Table 4.19 Personnel required, including qualifications and experience.

Personnel	Number required	Days per five years	Qualifications	Experience
Ornithologist	1	15	MSc/PhD	<ul style="list-style-type: none"> Three years experience with bird species identification in the field.

No. However, the ornithologist should link up with other teams when they do their fieldwork, since this will obviate the need for additional vehicles or field assistance.

4.8.1.8 Equipment required

Binoculars, camera, field guide, data sheets.

4.8.1.9 Personnel required, including qualifications and experience

See Table 4.19.

4.8.2 Summary

Table 4.20 is a summary of data needs, purpose, location, frequency and man-days for the essential monitoring action for avifauna.

4.8.3 Recommended additional (non-essential) data collection

See Table 4.21.

Table 4.20 Summary of needs for the avifauna, mammal and herpetofauna components of the Monitoring Programme.

COMPONENT: AVIFAUNA, MAMMALS AND HERPETOFAUNA					
Data required	Purpose	Where data should be collected	Frequency of collection	Personnel required	Man-days per five years (incl. local travel)
BASELINE DATA:					
Population counts of bird species.	To monitor changes in bird communities correlated with changes in river features.	At all biophysical monitoring sites.	Once a year for the first five years, thereafter once every five years.	1 Ornithologist	15 days
RELEASE-SPECIFIC DATA					
None.					
LONGTERM DATA					
As for baseline.					

Table 4.21 Recommended additional (non-essential) data collection.

Additional monitoring	Comments
Life-history studies of herpetofauna, with an emphasis on flow-related aspects.	These sorts of studies provide ideal subjects for a MSc degree, in which case the students would need to collect their data themselves.

SOCIO-ECONOMIC: EXPLANATION OF MONITORING ACTIVITIES

5.1 SOCIOLOGY

In order to escape the dis-empowering nature of an ongoing external socio-economic monitoring programme, it is suggested that the IFR Monitoring Programme aim at actively involving the affected communities in the monitoring process. Indeed few are better suited to assess the socio-economic impacts of the chosen IFR Scenario than the affected communities themselves. A significant portion of outside input and control will still be required in order to ensure that the inherent potential of self-monitoring is translated into actions and outputs of high quality.

A community-run monitoring programme has not, however, been designed here as before such a programme is designed it will be necessary to decide exact data that need to be collected, and then determine if a community monitoring programme is appropriate/possible for all or part of the data collection.

The start-up costs of a community-based monitoring programme are likely to be somewhat higher than those of an external programme. However, in the long-term, a community-based monitoring programme would probably be more cost effective. More importantly, the funds would be fed back into the affected communities. Community participation would also foster a sense of ownership of the monitoring process and provide training and capacity-building opportunities for community members. Higher start-up costs are linked to the need to:

- select suitable communities;
- identify and recruit individuals within the community to undertake the monitoring;
- sensitise those chosen to the need for and purpose of monitoring;
- train the chosen people in the methods of data collection, and record keeping.

5.1.1. River usage by rural communities

5.1.1.1 Objective

To record changes in utilisation of riparian and instream resources among the affected communities along the LHWP-affected rivers.

5.1.1.2 Data required

Baseline data: Already collected, no further data collection required (see Report LHDA 648-F-08).

Release specific data: None.

Long-term data: Quantitative data on the level of use of riparian and instream resources by rural communities.

5.1.1.3 Activities required to collect data

- The primary activity should be completion of a questionnaire very similar to the one used for the establishment of the baseline data (Report LHDA 648-F-08). This is a relatively open-ended questionnaire, which is designed to reduce possible biases that could arise, for instance, from only negative impacts being monitored. A general weakness of every structured questionnaire is that the complexities and ambiguities of social realities are too complicated to be fully captured. Structured questionnaires generally allow only predefined answers, while the respondent may give answers that do not fit the answer categories. However, the extensive pilot and detailed research during the IFR programme has provided what, at this stage, is felt to be the best questionnaire available, as it reflects the social and economic realities of communities along LHWP-affected rivers as well as possible. The survey structure, its purpose and analysis of its results, are described in detail in Report No. LHDA-648-08.
- A second activity should be completion of daily or weekly records of river-related activities, such as fetching water or collecting vegetables or fish. Observers should be hired in each of the villages to keep the records for that village.

5.1.1.4 How would the data indicate significant change?

It is recommended that results be analysed using the chi-square test. For each reach, 210 responses must be gathered in order to record statistically significant change (95 % confidence limits), in that reach (explanation in Report No. Report LHDA 648-F-08).

5.1.1.5 Where should data be collected?

The questionnaire should be applied to 210 randomly selected households in each of the five designated Monitoring Reaches, namely: Reaches 1/2/3, 4/5, 6, 7 and 8, i.e., 1050 households in total.

5.1.1.6 Timing and frequency of data collection

Starting from 2000:

First five years: Once a year;

After five years: Once each second year.

5.1.1.7 Can these activities be carried out by one of the other disciplines?

No. However, the social survey will provide data for other components of the Monitoring Programme, specifically public and animal health, and the fish and vegetation components of the Monitoring Programme.

5.1.1.8 Equipment required

Vehicle, stationery, camera.

5.1.1.10 Determining/confounding factors other than flow that could influence change in river usage

The extent of use of river resources by rural communities is dependent on a wide variety of factors. For instance, an increase in the wool price can lead to an increase in the number of sheep. This in turn can lead to increased grazing in the riparian zone. Similarly, the provision of piped water in the villages could result in a significant decline in river use for washing, drinking and cooking water. It is virtually impossible to list all the potential confounding factors that could influence change in river usage. However, it is proposed that these factors be dealt with in the following manner:

1. Through the inclusion of diagnostic questions in the questionnaire. For instance: Has any household member caught fish in the last six months? If yes, give information on amounts caught per month. If the number has declined, then why? (The last question is a diagnostic one).
2. Through comparison with data collected as part of countrywide surveys, which will indicate trends outside of the study area, i.e., changes not related to changes in flow in the study rivers.

5.1.1.9 Personnel required, including qualifications and experience

See Table 5.1.

Table 5.1 Personnel required, including qualifications and experience.

Personnel	Number required	Days per annum	Qualifications	Experience
Sociologist	1	30	BA(hons)/MA	<ul style="list-style-type: none"> • Three years experience with questionnaire design, use and data analysis in rural areas.
Field supervisor	1	25	Matric	<ul style="list-style-type: none"> • Experience with questionnaire administration in rural areas.
Technicians	4	25	Std 8	<ul style="list-style-type: none"> • Experience with data entry.
Data entry assistants/ Community-based record keepers.	8	Full time	Must be literate.	<ul style="list-style-type: none"> • No experience required, but training may be necessary (can be same observers as used for WQ component).

5.1.2. Standard of living in rural communities

5.1.2.1 Objective

To record changes in the overall standard of living of the rural communities as a result of the influences of LHWP, against which changes in riverine usage can be compared. River usage may drop as a result of an improvement in the standard of living in the villages, for instance, through the supply of reticulated water to the villages, which would obviate the need to collect water from the river.

5.1.2.2 Data required

Baseline data: Many of the data used to assess standard of living have already been collected. These data could be augmented by data from other studies, using for instance, national data on public health. There is no requirement for the collection of additional baseline data.

Release specific data: None.

Long-term data: Qualitative data on the standard of living in the communities affected by LHWP.

5.1.2.3 Activities required to collect data

These data can be collected as part of the same activities listed in Section 5.1.1.3, viz.:

1. questionnaire;
2. record keeping.

5.1.2.4 How would the data indicate significant change?

As for Section 5.1.1.4.

5.1.2.5 Where should data be collected?

As for Section 5.1.1.5.

5.1.2.6 Timing and frequency of data collection

As for Section 5.1.1.6.

5.1.2.7 Can these activities be carried out by one of the other disciplines?

No. However, the social survey will provide data for other components of the Monitoring Programme, specifically public and animal health.

5.1.2.8 Equipment required

No additional.

5.1.2.9 Personnel required, including qualifications and experience

No additional.

5.1.2.10 Determining/confounding factors other than flow that could influence change in the standard of living of rural communities

As is the case with changes in river usage, the standard of living of people in the villages will be affected by a variety of factors not connected to changes in river flow. See Section 5.1.1.10 for examples, and the way this will be dealt with.

5.1.3 Summary

Table 5.2 is a summary of data needs, purpose, location, frequency and man-days for the essential monitoring action for sociological purposes. Several data requirements for other components have been incorporated into the sociological questionnaire. These requirements are for the Public Health (Section 5.2), Animal Health (Section 5.3) and Water Supply (Section 5.4) components, but are included here for completeness.

5.2 PUBLIC HEALTH

There are four main public health concerns that should be monitored as part of the IFR Monitoring Programme. These are the potential for increases in the following diseases:

- malaria;
- *Schistosomiasis* (bilharzia)
- Anthrax;
- water-related diseases.

The health of the rural communities in the study area, and indeed in the whole of Lesotho, is determined by a wide variety of factors, most of which are unrelated, or only indirectly related, to flow in the study rivers. For instance, the level of immunisation among the people living in the rural areas will greatly influence the health of those people. Programmes aimed at detecting changes in these sorts of factors form part of the routine activities of organisations such as the Department of Health and

do not warrant inclusion in the Monitoring Programme. However, data on these factors are extremely useful for interpreting the results obtained from the Monitoring Programme. Such national data, which may be used for diagnostic purposes in the Monitoring Programme, include:

- Nutritional status of the rural communities, including weight and height of under five-year-olds. Detailed nutritional surveys have not been recommended as part of the IFR Monitoring Programme because it would be extremely

difficult to relate changes in nutrition to changes in flow in the study rivers. However, qualitative questions related to nutrition will be included in the sociological questionnaire.

- The availability and use of rural water supply.
- The water quality of household water points other than in the study rivers, such as springs or tributaries.
- The volume of water used per person per day.
- The availability and use of pit latrines.
- Immunisation coverage of the rural communities.

Table 5.2 Summary of sociological requirements for the Monitoring Programme.

COMPONENT: SOCIOLOGY					
Sub-component	Purpose	Where data should be collected	Frequency of collection	Personnel required	Man-days per annum (incl. local travel)
BASELINE DATA:					
None					
RELEASE-SPECIFIC DATA					
None					
LONGTERM DATA					
River usage	To assess changes in the level of use of river resources.	In all selected study villages as outlined in Section 2.1.2.	Annually for five years, then bi-annually.	1 sociologist 1 field supervisor 4 Technicians 8 data entry assistants/ community-based record keepers.	30 25 25 each Each full time
Standard of living	To assess changes in the standard of living of rural communities.	As above	As above	As above	Included in above
Public health	To augment data for public health component (see Section 5.2).	As above	As above	As above	Included in above
Animal health	To augment data for animal health component (see Section 5.3).	As above	As above	As above	Included in above
Water supply	As above (see Section 5.4).	As above	As above	As above	As above

5.2.1. Malaria

5.2.1.1 Objective

To record changes in the distribution of the *Anopheles* mosquitoes in the study area, as an indication of the potential for malaria.

5.2.1.2 Data required

Baseline data: Sufficient data exist.

Release specific data: None.

Long-term data: Qualitative data on the presence of *Anopheles* mosquitoes in the study rivers.

5.2.1.3 Activities required to collect data

Sampling for *Anopheles* mosquito larvae at all the biophysical sites, incl. Site 9.

5.2.1.4 How would the data indicate significant change?

Anopheles mosquitoes are currently not recorded in the study area as conditions are not suitable. Any record of a *Anopheles* mosquito larvae within the study area would be considered significant, as it would indicate a change in conditions in favour of these mosquitoes.

5.2.1.5 Where should data be collected?

All Monitoring and Reference sites.

5.2.1.6 Timing and frequency of data collection

From 2000:

First five years: Once a year

After five years: Once every second year.

5.2.1.7 Can these activities be carried out by one of the other disciplines?

Yes. The macroinvertebrate surveys would record any increase in mosquito larvae in the study rivers, and include routine identification to species level of these larvae.

5.2.1.8 Equipment required

Field microscope. See also macroinvertebrate component in Section 4.

5.2.1.9 Personnel required, including qualifications and experience

No additional.

5.2.1.10 Determining/confounding factors other than flow that could influence change in the incidence of malaria

There are incidences where malaria has been imported into a country through the inadvertent transport of the hosts. For instance, an infected mosquito that is trapped in a car could be transported from the north to Lesotho. However, at worst these instances lead to a few isolated cases of malaria. This is because conditions are not suitable for the mosquitoes to become established in

Lesotho. There have also been reports of a southward spread of malaria in Africa. However, this trend is monitored through routine mosquito surveys in South Africa. Thus, should mosquitoes be recorded in the study area it is anticipated that sufficient data will be available to ascertain whether their presence was the result of the southward spread on malaria.

5.2.2. Schistosomiasis

5.2.2.1 Objective

To record changes in the distribution of the *Bulinus* snail, which is the host for *Schistosomiasis*, in the study area.

5.2.2.2 Data required

Baseline data: Sufficient data exist.

Release specific data: None.

Long-term data: Quantitative data on the abundance of *Bulinus* snails in the study rivers.

5.2.2.3 Activities required to collect data

Bulinus snail sampling at all the biophysical sites, incl. Site 9.

5.2.2.4 How would the data indicate significant change?

Bulinus snails are currently not recorded in the study area as conditions are not suitable. Any record of *Bulinus* snails within the study area would be considered significant, as it would indicate a change in conditions in favour of these snails.

5.2.2.5 Where should data be collected?

All biophysical Monitoring and Reference sites.

5.2.2.6 Timing and frequency of data collection

Once every two years.

5.2.2.7 Can these activities be carried out by one of the other disciplines?

Yes. The macroinvertebrate team can collect these data during their surveys.

5.2.2.8 Equipment required

No additional. See macroinvertebrate component in Section 4.

5.2.2.9 Personnel required, including qualifications and experience

No additional.

5.2.2.10 Determining/confounding factors other than flow that could influence change in the incidence of Schistosomiasis

Changes in *Bulinus* distributions in the short- and medium-term would most probably be related directly to flow changes. In the long-term, global warming may affect changes in distribution of *Bulinus*.

5.2.3. Anthrax**5.2.3.1 Objective**

To record changes in the incidence of Anthrax outbreaks in the study area.

5.2.3.2 Data required

Baseline data: Sufficient data exist.

Release specific data: None.

Long-term data: Quantitative data on the number of Anthrax outbreaks reported in the study area.

5.2.3.3 Activities required to collect data

A detailed record of any reports of Anthrax in animals or humans in the whole of the study area, viz. 5 km either side of the study rivers. With every case it is important that the circumstances around the death or disease be investigated. Details recorded should include the time of year, climatic conditions, number of infections and where the disease originated, i.e., where contact with Anthrax spores is likely to have occurred.

5.2.3.4 How would the data indicate significant change?

The number of reported incidences should be analysed to test for correlations with potential driving factors, such as flow in the river, climate and /or location. The number of data points will be determined by the number of reported incidences of Anthrax, and thus, unless there is a major outbreak, it will be difficult to attach statistical significance to the results in the early part of the programme. However, with time more data are likely to

be forthcoming and trends could be analysed using a standard regression analysis.

5.2.3.5 Where should data be collected?

The data should be obtained from clinics and woolsheds in the study area. The socio-economic researchers and record keepers should also make a note of any Anthrax outbreaks.

5.2.3.6 Timing and frequency of data collection

Once every two years.

5.2.3.7 Can these activities be carried out by one of the other disciplines?

Yes. The socio-economic team can collect these data during their annual surveys. However, since the activities will be in addition to their normal duties, additional time (approximately ten days per annum) should be allocated for this team to visit woolsheds and clinics. The same data required here would also be required in the animal health monitoring (see Section 5.3). The Department of Agriculture and the Department of Health also collect these kinds of data. The person in charge of the Monitoring Programme would need to take overall responsibility for ensuring that these data are obtained and incorporated into the database.

5.2.3.8 Equipment required

No additional.

5.2.3.9 Personnel required, including qualifications and experience

No additional.

5.2.3.10 Determining/confounding factors other than flow that could influence change in the incidence of Anthrax outbreaks

The factors that lead to Anthrax outbreaks are not clearly understood. They are however related to, *inter alia*, climate, and to movement of livestock, particularly the concentration of animals using a particular drinking place, and the amount of mud at those places. Comparisons between the incidence of Anthrax in the study areas and nationally should indicate if an abnormal trend is evolving.

5.2.4. Water-related diseases

5.2.4.1 Objective

To record changes in the prevalence of key water-related diseases, including typhoid and chronic diarrhoea.

5.2.4.2 Data required

Baseline data: Sufficient data exist.

Release specific data: None.

Long-term data: Quantitative data on the number of cases of water-related diseases in the study area.

5.2.4.3 Activities required to collect data

Data should be collected on:

- the prevalence of water-related diseases recorded at clinics serving the rural communities (see Section 2.1.2 for a list of the clinics in the study area);
- the prevalence of water-related diseases in the communities (this is because these diseases are often not reported to the clinics);
- *Escherichia coli* and *Giardia lamblia* distributions and concentrations in the study rivers.

5.2.4.4 How would the data indicate significant change?

An increase of 20 % or more above base level would be considered significant from a public health point of view (Dr Rose Phillips, Medical Research Council, pers. comm.). Base level is defined as present-day levels. The number of reported incidences of disease will determine the number of data points, and thus, it will be difficult to attach statistical significance to the results in the early part of the programme. However, with time, more data are likely to be forthcoming.

Sample sizes will differ with the baseline disease prevalence level for each disease, e.g., the prevalence of skin diseases vs. diarrhoeal disease prevalence. For instance, an assumed baseline 3% prevalence of ocular signs of vitamin A deficiency plus an increase of 15-20% that would be statistically significant, a total sample of under fives is calculated to achieve the desired 95% confidence interval.

5.2.4.5 Where should data be collected?

Data on disease prevalence should be obtained from clinics in the study area (see Section 2.1.2). The socio-economic researchers and record keepers should also make a note of incidences of water-related diseases (see Section 5.1).

The data on parasites and microbes in the study area should be collected at each of the biophysical Monitoring Sites and Reference Site 9 (see Section 2.1.1).

5.2.4.6 Timing and frequency of data collection

Clinic and community data should be collected annually.

Data on aquatic parasites and microbes should be collected monthly.

5.2.4.7 Can these activities be carried out by one of the other disciplines?

Yes. Data on disease prevalence are recorded as part of the normal duties at the clinics. These data simply need to be obtained from the clinics and entered into the IFR Monitoring Programme database. The socio-economic team could do this as part of their annual surveys. However, since the activities will be in addition to their normal duties, additional time (approximately 5 days per annum) should be allocated for this team to collect clinic data. The socio-economic team would also record the prevalence of water-related disease in the villages and the level of use of water from the study rivers for drinking, cooking and washing.

The water quality team should test for faecal contamination in the study rivers as part of the routine water quality sampling (see Section 4.4) and need time (approximately four days per annum) added for this activity.

5.2.4.8 Equipment required

Equipment was purchased as part of LHDA 648, and so no additional equipment is required.

5.2.4.9 Personnel required, including qualifications and experience

No additional.

5.2.4.10 Determining/confounding factors other than flow that could influence change in the prevalence of water-related diseases

The prevalence of water-related diseases is dependent on a wide variety of factors. Thus the possibility of being able to conclusively link changes in water-related diseases to changes in flow in the study rivers is small. However, if an increase in water diseases was correlated with an increase in faecal indicators in the study rivers, then this would infer a causal relationship between disease prevalence and the condition of the study rivers. Deteriorating river condition, however, may not be flow

related, but due to behavioural or other changes in river communities. Thus, in this situation, further diagnostic data might need to be collected to explain an increase or decrease in disease organisms in the study rivers.

5.2.5 Summary

Table 5.3 is a summary of data needs, purpose, location, frequency and man-days for the essential monitoring actions for public health. Several data requirements for this component have been incorporated into the biophysical components of the Monitoring Programme (see Section 4).

Table 5.3 Summary table of public health requirements for the Monitoring Programme. n/a = this task has been incorporated into the tasks for one of the other monitoring components and time for the task has been budgeted as part of that component.

COMPONENT: PUBLIC HEALTH					
Activity	Purpose	Where data should be collected	Frequency of collection	Personnel required	Man-days per annum (incl. local travel)
BASELINE DATA:					
None					
RELEASE-SPECIFIC DATA					
None					
LONGTERM DATA					
<i>Anopheles</i> surveys.	To assess risk of malaria.	At all biophysical sites, incl 9	Every two years.	n/a	n/a
<i>Bulinus</i> snail surveys	To assess risk of <i>Schistosomiasis</i>	At all biophysical sites, incl 9	Every two years.	n/a	n/a
Clinic records	To provide an indication of disease prevalence	In all study clinics	Annually.	Sociologist	10 days.
Water analysis for parasites and microbes.	To provide an indication of faecal contamination in study rivers.	At all biophysical sites, incl 9	Monthly.	Water quality team.	Included in water quality monitoring requirements.

5.3 ANIMAL HEALTH

The main animal health concerns relate to the potential for increases in the following types of infections:

- viral;
- bacterial;
- parasitic.

These have been dealt with together below, since many of the same monitoring activities are required for all three types of disease.

As was the case with public health, animal health in Lesotho is determined by a wide variety of factors, most of which are unrelated, or only indirectly related, to flow in the study rivers. Hence, only those diseases and other issues of concern that are closely related to the condition of the study rivers have been included in the Monitoring Programme. Other data may be required for interpretation of the monitoring data, but these should be obtained from other sources if and when they are required. Such external data might include:

- immunisation coverage of the livestock in the study area;
- quality of wool;

- wool sales.

In the case of animal health, it is suggested that the Monitoring Programme be used to evaluate and, if possible, reduce (see below) the cost of mitigation and compensation as a result of flow changes in the study rivers.

How can the Monitoring Programme reduce the cost of mitigation or compensation?

There is a level of cost to the rural communities and to Lesotho as a whole involved in animal health at present. This cost may increase with flow changes. However, this cost could also decrease, or increase less, if mitigation (such as immunisation programmes) is done. It should be possible with additional data on the current situation to provide a general description (model) of the present situation. It should be possible to then measure if the death/illness rate increases or decreases in the future, to a level outside the range expected in the present situation. If it does exceed the modelled normal range, it should be possible to ascertain if this could be flow related.

Also, the rural communities are affected by illness of disease in their livestock, regardless of whether or not that illness is flow related. Thus, it may be that the money that would be spent on mitigation/compensation for flow related changes could be put to more effective use in some other area of animal health, e.g., immunisation against a more damaging, but non-flow related, disease.

5.3.1 Incidence of key animal diseases

The key animal diseases that are related to water are:

- Viral: Blue Tongue, Horsesickness.
Bacterial: Anthrax, Black Quarter and Pulpy Kidney.
Parasitic: Roundworms and flukes.

5.3.1.1 Objective

To record changes in the key animal diseases in the study area.

5.3.1.2 Data required

Baseline data: Information on the current incidence of these diseases exists, although it is not specific to the IFR reaches. However, it is felt that sufficient information exists to be able to make comparisons between the present-day situation and possible future situations as described by the long-term data. Having said that, there is an urgent requirement for directed training of veterinary technicians currently working in the area in order to ensure better diagnoses of diseases, and a need for additional equipment in some of the state laboratories.

Release specific data: None.

Long-term data: Quantitative data on the number of incidences of key diseases in the study area.

5.3.1.3 Activities required to collect data

Viral: The incidence of Blue Tongue and Horsesickness should be assessed by taking blood samples from a percentage of the livestock population and testing them for antibodies. The blood can be analysed either at Onderstepoort Veterinary Research Institute, Pretoria or in Maseru Central Veterinary Laboratory (MCVL), provided MCVL was given funds to purchase the necessary equipment and train additional staff. One hundred samples per IFR reach per annum should be collected for each of sheep, goats and horses (i.e., 2400 samples per annum). The costs of analysis vary widely, depending on which option is used for blood analysis, with the MCVL having the dual advantages of being considerably cheaper, and of supporting and building the necessary expertise in Lesotho (see Section 7).

Bacterial: The incidence of Anthrax, Black Quarter and Pulpy Kidney should be assessed by taking blood samples from a percentage of the livestock population and testing them for antibodies. These tests can be done at Maseru Central Veterinary Laboratory.

Parasitic: Roundworms and flukes can be monitored by collecting stock faeces from the villages in the study area and testing for eggs and worms. Faecal samples should be analysed for parasites at Maseru Central Veterinary Laboratory.

5.3.1.4 How would the data indicate significant change?

The data will be analysed using standard t-tests (Zar 1984) to test against previous years, and national records for statistically significant changes in the incidence of disease. The number of data points will be determined by the number of reported incidences of disease, and thus, it will be difficult to attach statistical significance to the results in the early part of the programme. However, with time, more data are likely to be forthcoming.

From an animal health perspective, the following levels of change would be significant:

Viral: 10% increase.

Bacterial: Anthrax and Black Quarter – 10% increase.
Pulpy Kidney - 50% increase.

Parasitic: Roundworms - 50% increase.
Fluke - 10% increase.

5.3.1.5 Where should data be collected?

Blood for antibody analysis should be collected from animals visiting woolsheds within 5 km of the study rivers. Stock faeces should be collected from the villages for analysis of parasitic infections.

5.3.1.6 Timing and frequency of data collection

For the first two years:

Viral: Annually.

Bacterial: Annually.

Parasitic: Twice a year.

Thereafter all should be repeated at five-yearly intervals.

5.3.17 Can these activities be carried out by one of the other disciplines?

There is a team working in the area of animal health survey in the Department of Livestock Services, Ministry of Agriculture and Co-Operatives and Marketing in Lesotho. It is strongly recommended that the team be utilised to assist with data collection for the Monitoring Programme, as this would avoid unnecessary duplication of activities. Networking would also allow resources and diagnostic services to be managed more effectively.

The nature of any diagnostic service offered, e.g., by the Department of Livestock Services, is determined by (i) the disease involved, (ii) the availability of trained personnel, (iii) the infrastructure available, (iv) material and financial resources, (v) linkage with other surveillance services, and (vi) quality of management. While the Department of Livestock Services carries out some of these functions and has infrastructure in place, its potential to be more effective in disease surveillance is critically constrained by inadequate material and financial resources, e.g., reliable supplies of quality-controlled reagents for rapid identification of diseases. Assistance by LHDA in this area for disease surveillance in the IFR reaches will result in cost savings for LHDA and a general improvement in the services offered to farmers in Lesotho.

In this regard, Onderstepoort offers a two-week refresher course on antibody testing, which staff from Department of Livestock Services or Maseru Central Veterinary Laboratory could attend.

5.3.1.8 Equipment required

The following equipment will be required:

- needles;
- vials;
- chemical reagents;
- antigen serum and conjugate;
- microscope;
- glassware;
- Microtitre platelasher;
- 4x4 vehicle.

In addition, the survey team will require access to a laboratory to analyse samples.

5.3.1.9 Personnel required, including qualifications and experience

See Table 5.4.

Table 5.4 Personnel required, including qualifications and experience.

Personnel	Number	Days per	Qualifications	Experience
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	required	annum		
Parasitologist	1	20	B.Sc, MSc.	<ul style="list-style-type: none"> Experienced in Lesotho conditions.
Veterinary technicians	3	40	BSc (hons)	<ul style="list-style-type: none"> Trained in the collection and storage of data.
Epidemiologist	1	20		<ul style="list-style-type: none"> Experienced in Lesotho conditions.

5.3.1.10 Determining/confounding factors other than flow that could influence change in the prevalence of key animal disease

The biggest problems likely to be encountered by this component of the Monitoring Programme are limited diagnostic and record-keeping skills of technicians at the woolsheds. The accuracy and reliability of the data obtained from these woolsheds is entirely dependent on these technicians. For instance, sudden death of an animal, which is often assumed to only occur as a result of Anthrax, can also be due to food poisoning or an allergic reaction. Thus, it is strongly recommended that:

- technicians at the woolsheds receive training and financial assistance in return for keeping records for the Monitoring Programme;
- the specialist animal survey team that already exists in Lesotho be approached to assist with data collection for the Monitoring Programme (also in return for financial assistance).

5.3.2 Incidence of injuries and bogging

Increased mud and slipperiness in the study rivers could result in increased injuries to animals crossing the river, or an increase in the number of animals being bogged down next to the river. Although it is not anticipated that this will be a significant problem, it is suggested that the injuries and or reports of bogging at the study rivers should be recorded as part of the routine data collection at the woolsheds.

5.3.2.1 Objective

To record changes in the injuries or bogging of animals at the study area.

5.3.2.2 Data required

Baseline data: As for long-term data collection.

Release specific data: None.

Long-term data: Quantitative data on the number of incidences of injury as a result of slipping and/or bogging while using the study rivers.

5.3.2.3 Activities required to collect data

These records should be kept at woolsheds as a matter of course. They should then be collected from the woolsheds and entered into the Monitoring Programme database.

5.3.2.4 How would the data indicate significant change?

The data will be analysed using standard t-tests (Zar 1984) to test against previous years and national records for statistically significant changes in the incidence of injury or bogging.

5.3.2.5 Where should data be collected?

At woolsheds where blood samples are taken (see 5.3.1.5).

5.3.2.6 Timing and frequency of data collection

Ongoing.

5.3.2.7 Can these activities be carried out by one of the other disciplines?

Yes, the team responsible for the incidence of key diseases (see 5.3.1.7) can collect these data.

5.3.2.8 Equipment required

As for 5.3.1.9.

5.3.2.9 Personnel required, including qualifications and experience

As for 5.3.1.9.

5.3.3 Influence of dip tanks on water quality in the study rivers

In the Lesotho mountains, effective control of sheep scab has been achieved through dipping of animals. However, many of the diptanks are situated close to rivers, and hence may have a localised effect on the water quality in those rivers. This is a result of both spillage from the diptanks themselves and from animals crossing the rivers immediately after having been dipped. It is anticipated that, with reduced flows and thus decreased dilution in the study rivers, these localised effects will be more severe than they are at present. Should the effect of the diptanks on river-water quality be significant then the diptanks would need to be relocated.

Relocation of the diptanks would also necessitate relocation of the shearing sheds, since these two should always together.

5.3.3.1 Objective

To determine the localised effects of diptanks on the quality of the water in the study rivers.

5.3.3.2 Data required

Baseline data: Water chemistry data upstream and downstream of diptanks, and animal crossings.

Release specific data: None.

Long-term data: As for baseline data.

5.3.3.3 Activities required to collect data

Baseline data: Once-off collection of water and sediment samples upstream and downstream of several diptanks that are situated near to the study rivers, and place where animals are crossing the river immediately after having been dipped. This could take place over a two-week period during the dipping season. These samples would then have to be analysed for chemical constituents occurring in sheep-scab dip.

Release specific data: None.

Long-term data: As for baseline data.

5.3.3.4 How would the data indicate significant change?

The data could be analysed using paired t-tests (Zar 1984) to test compare data collected upstream and downstream of diptanks, and animal crossings.

5.3.3.5 Where should data be collected?

Upstream and downstream of diptanks that are situated near to the study rivers, and of places where animals are crossing the river immediately after having been dipped.

5.3.3.6 Timing and frequency of data collection

Baseline data: Once off.

Release specific data: None.

Long-term data: Every two years, for those diptanks that are not relocated.

5.3.3.7 Can these activities be carried out by one of the other disciplines?

Yes, the water-quality team could undertake these surveys. However, the activity has been costed separately under animal health.

5.3.3.8 Equipment required

4x4 vehicle; sampling bottles; fixative.

5.3.3.1 Personnel required, including qualifications and experience

See Table 5.5.

5.3.4 Epidemiology of internal parasites

5.3.4.1 Objective

To assess the impact of flow changes on the distribution and abundance of eggs and larvae of these parasites occurring in riparian and marginal vegetation.

5.3.4.2 Data required

Baseline data: Data on the present epidemiology of internal parasites in relation to flow-related changes in the study rivers.

Release-specific data: None.

Long-term data: Data on the changing epidemiology of internal parasites in relation to flow-related changes in the study rivers.

5.3.4.3 Activities required to collect data

Baseline: A thorough survey would be required to establish the epidemiology of internal parasites in relation to flow levels at the various IFR sites. Parasite eggs and larvae should be collected

from marginal and riparian vegetation three times a year (spring, summer and winter) for two years.

Release-specific data: None.

Long-term data: Follow-up survey to determine changes in the epidemiology of internal parasites as a result of flow changes.

5.3.4.4 Where should data be collected?

At all biophysical Monitoring and Reference Sites.

5.3.4.5 Timing and frequency of data collection

Baseline data: Three times a year in spring, summer and winter, for two years.

Release specific data: None.

Long-term data: Three times a year in spring, summer and winter, every five years.

5.3.4.6 Can these activities be carried out by one of the other disciplines?

No.

5.3.4.7 Equipment required

Laboratory reagents; nets, sample vials, microscope, 4x4 vehicle.

5.3.4.8 Personnel required, including qualifications and experience

See Table 5.6.

5.3.5 Changes in abundances of blackflies and biting midges

5.3.5.1 Objective

Table 5.5 Personnel required, including qualifications and experience.

Personnel	Number required	Days per annum	Qualifications	Experience
Researcher	1	14 days	BSc (Hons)	• Aquatic chemist.

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Table 5.6 Personnel required, including qualifications and experience.

Personnel	Number required	Days per annum	Qualifications	Experience
Helminthologist/Parasitologist	1	110 days	MSc/PhD	• Five years experience in parasitological/epidemiological studies.
Technician	1	45 days	BSc (Hons)	• Background in biological sciences

To assess the impact of flow changes on the numbers of blackflies and midges.

5.3.5.2 Data required

Baseline data: Sufficient data exist.

Release-specific data: None.

Long-term data: Data on the relative abundance of blackflies and biting midges.

5.3.5.3 Can these activities be carried out by one of the other disciplines?

Yes. The macroinvertebrate team will collect these data as part of their activities.

5.3.6 Summary

Table 5.7 is a summary of data needs, purpose, location, frequency and man-days for the essential monitoring actions for animal health.

5.4 WATER SUPPLY

There are two issues of concern for the water supply component, namely:

- the quality of the water in the study rivers, and;
- the quantity of water abstracted from the study rivers for local use.

Water quality is dealt in the water-quality components (Section 4) study, and will not be addressed further here. The activities required for monitoring the quantity of river water used by rural people are detailed below.

				with emphasis on parasitology.
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Table 5.7 Summary of the animal health requirements for the Monitoring Programme. n/a = this task has been incorporated into the tasks for one of the other monitoring components and time for the task has been budgeted as part of that component.

COMPONENT: ANIMAL HEALTH					
Activity	Purpose	Where data should be collected	Frequency of collection	Personnel required	Man days per annum (incl. local travel)
BASELINE DATA:					
Collection and analysis of blood samples	To determine the incidence of key diseases.	At all study woolsheds.	Annually for two years.	Parasitologist. Three veterinary assistants. Epidemiologist.	20 days 20 days ea. 20 days
Faecal collections	To assess the incidence of parasitic infections	In all study villages	Two times per year.	Veterinary technician.	20 days
Collection of woolshed records.	Collation of records to provide an indication of present injury and bogging.	In all study woolsheds.	Annually.	Veterinary assistant.	20 days
Collection of water quality data on effects of diptanks	To assess the localised affects of diptanks	In study rivers near to diptanks and animal crossings from diptanks	Once-off.	Researcher	14 days
Epidemiological study of internal parasites	To assess the incidence of parasitic infections.	At all biophysical Monitoring and Reference sites.	Three times per year, for two years.	Helminthologist Technician	110 days 45 days
RELEASE-SPECIFIC DATA					
None					
LONGTERM DATA					
Collection and analysis of blood samples.	To determine changes in incidence of key diseases.	At all study woolsheds .	Every five years	Parasitologist Veterinary assistant Epidemiologist	20 days 20 days 20 days
Collection of woolshed records.	Collation of records to provide an indication of changes in injury and bogging.	In all study woolsheds.	Annually.	Veterinary assistant	20 days
Faecal collections	To assess change in incidence of parasitic infections	In all study villages	Three times per year.	Veterinary technician	20 days
Collection of water quality data on effects of diptanks	To assess the localised affects of diptanks	In study rivers near to diptanks that have not been moved and animal crossings from diptanks	Every two years.	Researcher	14 days
Collection of relative abundance data on blackflies and midges	To assess changes in abundance of blackflies and midges.	At all biophysical Monitoring and Reference sites.	Annually.	Macroinvertebrate team	n/a
Epidemiological study on internal parasites	To assess changes in the incidence of parasitic infections.	At all biophysical Monitoring and Reference sites.	Three times a year, every two years	Helminthologist Technician	110 days 45 days

5.4.1 Changes in the quantity of water abstracted from study rivers

No additional.

5.4.1.1 Objective

To record changes in the quantity of water abstracted from the study rivers by rural dwellers.

5.4.1.9 Personnel required, including qualifications and experience

No additional.

5.4.1.2 Data required

Baseline data: Sufficient data exist.

Release specific data: None.

Long-term data: Quantitative data on the extent to which water from study rivers is used in the catchment for drinking, washing, irrigation, and other uses.

5.4.1.10 Determining/confounding factors other than flow that could influence change in the volume of water abstracted from the study rivers

Water use could be affected by, *inter alia*:

- population growth;
- animal ownership;
- a change in *per capita* water consumption;
- future irrigation developments;
- provision of tapped water from boreholes;
- industrial growth;
- population migration.

5.4.1.3 Activities required to collect data

Data on community use of the study rivers. This can be collected as part of the sociological survey (see Section 5.1).

Data relating to many of these aspects will be collected as part of the Monitoring Programme. However, if a significant change in water usage is detected, then it may be necessary to research one or two of the above areas before the cause of the change can be determined.

5.4.1.4 How would the data indicate significant change?

The between year data could be analysed using standard t-tests (Zar 1984) or some other appropriate statistical analysis, to test for statistically significant changes in amount of water abstracted from the study rivers. A $\geq 10\%$ increase in water demand would be considered significant.

5.4.2 Summary

Table 5.8 is a summary of data needs, purpose, location, frequency and man-days for the essential for the essential monitoring actions for water supply.

5.4.1.5 Where should data be collected?

At all study villages.

5.5 ECONOMICS

5.4.1.6 Timing and frequency of data collection

Annually

There are no data collection activities required for economics. Any economic analyses that are done in the future will use data collected as part of the other components.

5.4.1.7 Can these activities be carried out by one of the other disciplines?

Yes. The sociological team would collect the data.

5.4.1.8 Equipment required

Table 5.8 Summary of water supply requirements for the Monitoring Programme. n/a = this task has been incorporated into the tasks for one of the other monitoring components and time for the task has been budgeted as part of that component.

COMPONENT: WATER SUPPLY					
Activity	Purpose	Where data should be collected	Frequency of collection	Personnel required	Man-days per annum (incl. local travel)
BASELINE DATA:					
None					
RELEASE-SPECIFIC DATA					
None					
LONGTERM DATA					
Collection of water quality data.	To assess potability of water in the study rivers.	At all biophysical Monitoring and Reference Sites.	Monthly	Water quality team	n/a
Completion of social questionnaire.	To assess change in use of water from the study rivers.	In all study villages.	Annually	Social team	n/a

SECTION 6:

SUMMARY OF RECOMMENDED ESSENTIAL MONITORING ACTIVITIES

6.1 PURPOSE OF THIS SECTION

The previous sections provided information on the data collection activities and their purpose for each biophysical and socio-economic component. This section summarises the activities and timing recommended for baseline, release-specific and long-term data collection. It also provides the composition of the monitoring team that should be gathered to undertake the activities. Please note the personnel requirements provided below assume that a Monitoring Programme Manager has already been appointed, and that data collection will be a co-ordinated undertaking with duplication of effort avoided where possible. Hence, in this section some rationalisation has taken place relative to the personnel lists provided in the previous two sections. Additionally, Section 6.5 below gives the personnel requirements for data analysis and interpretation and report writing.

A central assumption in this Monitoring Programme summary is that the people appointed to co-ordinate the work and undertake the sampling have received basic training in the aspects of the programme for which they are expected to take responsibility. For instance, it is assumed that the botanist appointed to undertake the vegetation sampling is able to identify riparian plant species. If this is not the case, a training programme should be funded separately. Specialists have been included in some initial sampling activities. However, the time allocated to them is for component-specific, training of assistants and to ensure an adequate link up with the data collected during LHDA 648. The schedule provided does not allow sufficient time for assistants to be trained from scratch, thus it is important that they have some scientific background.

6.2 BASELINE DATA COLLECTION

Table 6.1 is a summary of data collection activities required for baseline data collection, and Table 6.2 is the suggested composition of the baseline monitoring team.

Note: The research allowed for in Table 6.2 is based on the assumption that that person has sufficient training to

collect and analyse soil samples, undertake routine water-quality tasks (e.g., downloading of data loggers, collection of water samples and *in situ* microbe analysis) and collect macroinvertebrate samples. Also assumes that researcher will collect river water-quality samples associated with diptanks.

6.3 RELEASE-SPECIFIC DATA COLLECTION

It is envisaged that the release-specific data collection activities (Table 6.3) will concentrate on within year flood releases from the impoundments. Thus, they will focus on:

- the biophysical monitoring sites immediately downstream of the dam of concern, e.g., IFR Site 2 for Katse Dam and IFR Site 7 for Mohale Dam;
- measuring the biophysical responses to the released events, and compare these to the predicted responses in the biophysical consequences reports (Report LHDA 648.22).

The release-specific data collection should take place for a minimum of five within-year flood releases of each Class. The number of flood classes will depend on the chosen IFR Scenario, since some scenarios do not require releases to provide floods from all four within-year flood classes.

It is anticipated that experienced specialists will be required to undertake the release-specific sampling as it is expected to be the most difficult and varied of the monitoring activities. In order to be useful, the data that arise from the sampling must be highly focused. The results will require careful interpretation and may be used to modify the within-year flood releases. Table 6.4 is the suggested composition of the release-specific monitoring team.

6.4 LONG-TERM DATA COLLECTION

Table 6.5 is a summary of data collection activities required for long-term data collection, and Table 6.6 is the suggested composition of the long-term monitoring team.

Table 6.1 Summary of data collection activities required for baseline data collection.

Component	Tasks	Where data should be collected	Frequency of collection
BIOPHYSICAL			
Hydrology	Continuous time series stage height data.	At all gauging weirs as listed in Table 2.1.	Continuous.
Hydraulics	Installation of beacons and surveying of cross-sections.	At all biophysical Monitoring and Reference Sites.	Once-off.
Sedimentology	None.		
Water Quality	None.		
Riparian Vegetation	Establishment of zonation cross-sections.	At all biophysical Monitoring and Reference Sites.	Once-off.
	Establishment of monitoring of plots.	At all biophysical Monitoring and Reference Sites.	Once-off.
	Marking of individuals of key species.	At all biophysical Monitoring and Reference Sites.	Once-off.
	Algal monitoring.	At all biophysical Monitoring and Reference Sites.	Once-off.
Macroinvertebrates	None.		
Fish	None.		
Mammals and Birds	None.		
Herpetofauna	None.		
SOCIO-ECONOMIC			
Sociology	None.		
Public Health	None.		
Animal Health	Collection and analysis of blood samples	At all study woolsheds.	Annually for two years.
	Faecal collections	In all study villages.	Two times per year.
	Collection of woolshed records.	In all study woolsheds.	Annually.
	Collection of water quality data on effects of diptanks	In study rivers near to diptanks and animal crossings from diptanks.	Once-off.
	Epidemiological study of internal parasites	At all biophysical Monitoring Sites, plus Site 9	Three times per year, for two years.
Water Supply	None.		

Table 6.2 Personnel for baseline monitoring.

INITIAL SPECIALIST INVOLVEMENT		
No.	Personnel	Once-off time allocation (in days)
	Monitoring programme Manager	Full Time
1	Hydraulic engineer	10 days
1	Botanist (specialist)	20 days
1	Parasitologist/Helmithologist	130 days
1	Epidemiologist	20 days
1	Ornithologist	15 days
CORE TEAM		
No.	Personnel	Annual time allocation (in days)
1	Hydrographer	Full time (these data are required by many programmes dealing with LHWP, and may thus already have full time personnel attached to them).
1	Assistant hydrographer	Full time
1	Surveyor	30 days
1	Botanist	30 days
1	Researcher*	210 days
2	Assistants	60 days ea.

3	Veterinary assistant	60 days ea.
1	Driver	170 days

Table 6.3 Summary of data collection activities for release-specific monitoring.

Component	Tasks	Frequency of collection
Hydrology	Continuous time-series stage-height data.	Continuous.
Hydraulics	Water-surface elevations and measurement/simulation of local hydraulics.	Hourly for the duration of the event.
Sedimentology	Riffle sedimentation.	Before and after an event.
Water quality	Event-related sampling of TSS and nutrients.	Hourly for the duration of the event.
	Temperature.	Continuous during the event.
Fish	Monitor spawning and migration responses to within-year flood releases.	Continuous during the event, and after the event a survey for fry and larvae in the backwaters.

Table 6.4 Personnel for release-specific monitoring.

Component	Personnel	Time allocation (in days)
Coordination	Programme Manager	No additional time required (- see Baseline/Long-term).
Hydrology	Hydrologist	No additional time required (should be ongoing - see Baseline).
Hydraulics	Hydraulic engineer	For duration of event (plus 2 days travel). Events range between 3 and 10 days in length. Allow ten days
	Technician	For duration of event (plus 2 days travel). Events range between 3 and 10 days in length. Allow ten days
Sedimentology	Data can be collected by one of the researchers in the sampling party. No additional personnel required.	Before and after an event
Water quality	Water quality specialist	For duration of event (plus 2 days travel). Events range between 3 and 10 days in length. Allow ten days
Fish	Fish specialist	For duration of event (plus 2 days travel). Events range between 3 and 10 days in length. In addition, the specialist will need to sample for fry before and a couple of weeks after the event. Allow ten days
	2 Technicians	Same as fish specialist, plus 10 days after the release to look for larvae and fry. Allow ten days

Table 6.5 Summary of data collection activities required for long-term data collection.

Component	Tasks	Where data should be collected	Frequency of collection for the first five years (post-construction)	Frequency of collection after the first five years (post-construction)
BIOPHYSICAL				
Hydrology	Continuous time series stage height data	At all gauging weirs as listed in Table 2.1.	Continuous.	Continuous.
Hydraulics	Re-survey of cross-sections	At all biophysical monitoring sites, plus 9.	Every two years.	Every five years.
	Hydraulic relationships	At all biophysical monitoring sites, plus 9.	Every two years.	Every five years.
Sedimentology	Fixed point photography	At all biophysical monitoring sites	Once per annum.	Once per annum.
	Sediment size distribution	At all biophysical monitoring sites	Once per annum.	Once per annum.
Water quality	Routine daily sampling of TSS and nutrients	At all biophysical monitoring sites, plus 9.	Daily.	Daily.
	Routine monthly sampling	At all biophysical monitoring sites, plus 9.	Monthly.	Monthly.
	WQ monitoring using loggers	At IFR Sites 3, 5 and 7	Continuous.	Continuous.
	Temperature monitoring	At all biophysical monitoring sites, plus 9.	Continuous.	Continuous.
	Stage height recording	At all biophysical monitoring sites, plus 9.	Continuous.	Continuous.
Riparian vegetation	Zonation	At all biophysical monitoring sites, plus 9 and 10.	Once per annum in early autumn.	Once every two years early autumn.
	Monitoring of plots	At all biophysical monitoring sites, plus 9 and 10.	Once per annum in early autumn.	Once every two years early autumn.
	Key species	At all biophysical monitoring sites, plus 9 and 10.	Once per annum in early autumn.	Once every two years early autumn.
	Algal monitoring	At all biophysical monitoring sites, plus 9 and 10.	Once per annum in early autumn.	Once every two years early autumn.
Fish	Routine fish surveys.	At all biophysical monitoring sites, plus 9.	Four times in the first year. hereafter, once per annum.	Once per annum.
Macro-invertebrates	Initial intensive survey	At all biophysical monitoring sites, plus 9.	Once at the end of the wet season (autumn).	Once at the end of the wet season (autumn).
	Annual monitoring	At all biophysical monitoring sites, plus 9.	Once per annum (autumn).	Once per annum (autumn).
	Habitat mapping	At all biophysical monitoring sites, plus 9.	Once per annum.	Once per annum.
Birds	Population counts	At all biophysical monitoring sites, plus 9 and 10.	Once per annum.	Once every five years.
SOCIO-ECONOMIC				
Sociology	Social survey	In all selected study villages as outlined in Section 2.1.2.	Once a year.	Once every two years.
Public health	<i>Anopheles</i> surveys	In all selected study villages as outlined in Section 2.1.2.	Once a year.	Once a year.
	<i>Bulinus</i> snail surveys	At all biophysical monitoring sites	Once a year.	Once a year.
	Collection and collation of data from clinic records	In all study clinics.	Once a year.	Once a year.
	Community record keepers and surveys	In all study villages.	Once a year.	Once a year.
	Parasites and microbes	At all biophysical monitoring sites.	Once a year.	Once a year.

Table 6.5(cont.) Summary of data collection activities required for long-term data collection.

Component	Tasks	Where data should be collected	Frequency of collection for the first five years (post-construction)	Frequency of collection after the first five years (post-construction)
SOCIO-ECONOMIC (cont.)				
Animal Health	Collection and analysis of blood samples	At all study woolsheds.	Annually.	Every five years.
	Faecal collections	In all study villages	Annually.	Every five years.
	Collection of woolshed records.	In all study woolsheds.	Annually.	Every two years.
	Collection of water quality data on effects of diptanks	In study rivers near to diptanks that have not been moved and animal crossings from diptanks.	Every two years.	Every two years.
	Epidemiological study of internal parasites	At all biophysical Monitoring Sites, plus Site 9	Three times per year,	Every five years.
ECONOMIC				
None				

Table 6.6 Personnel for long-term monitoring.

No.	Personnel	Annual time allocation (unless otherwise stated)
BIOPHYSICAL		
1	Hydrographer	Full time (these data are required by many programmes dealing with LHWP, and may thus already have full time personnel attached to them).
1	Assistant hydrographer	Full time.
1	Hydraulic engineer	20 days (in years where data collection required – see Table 6.5).
1	Surveyor	56 days (in years where data collection required – see Table 6.5).
1	Assistant Surveyor	56 days (in years where data collection required – see Table 6.5).
1	Sedimentology specialist	20 days for first year only
1	Water Quality Researcher	220 days.
1	Botanical specialist	20 days
1	Botanist	30 days.
1	Macroinvertebrate specialist	20 days for the first year only.
1	Macroinvertebrate Researcher	20 days.
1	General Technician	Full time.
1	Fish specialist	100 days for the first year only, thereafter 25 days per annum
2	Fish technician	100 days for the first year only, thereafter 25 days per annum
10	WQ Observers/Community data entry assistants	Full time
1	Driver	Full time
1	Macroinvertebrate taxonomist	100 days
1	Ornithologist	15 days (every five years)
SOCIO-ECONOMIC		
1	Sociologist	40 days (incl. collection of clinic records)
1	Field supervisor	25 days
4	Technicians	25 days
8	Community data entry assistants	Covered under biophysical
1	Parasitologist	20 days

1	Epidemiologist	20 days
3	Veterinary assistant	40 days ea.

6.5 PERSONNEL REQUIREMENTS FOR DATA ANALYSIS AND INTERPRETATION, AND REPORT WRITING

Table 6.7 is a summary of personnel requirements for data analysis, interpretation and reporting. The personnel estimates provided assume:

- the production of annual Monitoring Reports;
- that the Monitoring Programme Manager (see Section 3.3) will collate the data collected in Sections 6.2 – 6.4 above, co-ordinate data analysis and report writing, and collate the annual report.

However, it is assumed that the Monitoring Programme Manager will require some input from specialists in the different fields in the form of statistical analysis of data, interpretation and writing of sections of the Monitoring report.

See also Section 3.3.

Table 6.7 Personnel requirements for data analysis and interpretation and report writing.

Component	Personnel	Time allocation (in days per annum)
Hydrology	Hydrologist	No additional (this should form part of a full time hydrologist's duties)
Hydraulics	Hydraulic engineer	10 days
Sedimentology	Sedimentologist	6 days
Water quality	Water quality specialist	20 days
Macroinvertebrates	Macroinvertebrate specialist	6 days
	Macroinvertebrate taxonomist	6 days
Riparian vegetation	Botanist	14 days
	Botanical taxonomist	6 days
Fish	Fish specialist	10 days
Sociology	Sociologist	10 days
Public health	Medical doctor	6 days
Animal health	Veterinarian	6 days
Water supply	Water resources engineer	1 day

SECTION 7: ESTIMATED BUDGET FOR MONITORING

7.1 SUMMARY BUDGET

The summary budget for the all the aspects of monitoring is given in Table 7.1, and detailed in the following sections. The costs are broadly broken into two categories:

- personnel costs;
- equipment and consumables start-up costs.

The following aspects of the Monitoring Programme have been costed:

- personnel and number of hours required to undertake the sampling;
- travel time within Lesotho;
- accommodation in the field;
- specialist, component-specific training;
- consumables related to the collection and analysis of samples;
- sample analyses required;
- start-up equipment required.

The following aspects have not been costed:

- an overview consultant (see Section 3.3);
- Monitoring Steering Committee;
- general scientific training;
- community set up for sociological monitoring;
- travel outside of Lesotho;
- accommodation in Maseru or outside of Lesotho;
- database development;
- replacement of equipment;

- two-week Onderstepoort Training Course;
- inflation.

7.2 PERSONNEL COSTS

In personnel costs are annual costs, divided into those for:

- base-line monitoring;
- dam release monitoring;
- long-term monitoring;
- data analysis and reporting.

These costs are summarised in Tables 7.2, 7.3, 7.4 and 7.5. Basic salary costs for various specialists, using the generalised qualifications deemed necessary for each job (see Section 4 and 5), are given in Table 7.6. The salary costs used here are averages for the southern African region. In addition, a 25% surcharge has been incorporated to cover the costs of recreation, leave, sick leave and holidays to the Employer.

7.3 COST OF EQUIPMENT AND CONSUMABLES

The summary costs of equipment and consumables are given in Table 7.1 and the details of equipment cost is provided in Table 7.6 and the consumables are given in Table 7.7.

Table 7.1 Summary costs for the Monitoring Programme

ITEM	One-time Cost	Annual cost	
		First five years	After five years
	Maluti	Maluti	Maluti
PERSONNEL COST			
Personnel for baseline data	679 220		
Personnel for release-specific monitoring (2 per year)		94 712	94 712
Personnel for long-term monitoring		1 589 555	1 528 334
Data analysis and reporting		113 117	113 117
SUB-TOTAL	679 220	1 797 384	1 736 163
EQUIPMENT			
Capital Cost	744,700		
Consumables		846 800	846 800

TOTAL	1 423 920	2 644 184	2 582 963
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Table 7.2 Personnel costs associated with the baseline component of the Monitoring Programme.

Personnel	No	Time (days per year)	Cost per year (Maluti)	Cost per day (Maluti)	Total cost (Maluti)
Hydrology	Included in long-term monitoring				
Hydraulics Engineer	1	10		473	4 735
Botanist	1	20		1184	23 674
Parasitologist	1	130		1184	153 883
Epidemiologist	1	20		1184	23 674
Ornithologist	1	15		1184	17 756
Fish Specialist	1	100		1184	26 042
Fish Technician	2	100		473	94 697
Macroinvertebrate	1	20		1184	23 674
Sedimentologist	1	20		1184	23 674
SUB-TOTAL					249 763
Hydrographer/Hydrologist	Included in long-term				
Assistant Hydrographer	Included in long-term				
Surveyor	1	30		473	14 205
Botanist	1	18		710	12 784
Researcher	1	210		473	99 432
Assistants	2	60		284	34 091
Veterinary Assistant	3	60		473	85 227
Driver	1	170		114	19 318
Field allowance		548		300	164 400
SUB-TOTAL					429 457
TOTAL					679 220

Table 7.3 Personnel costs associated with the release-specific component of the Monitoring Programme.

ITEM	Personnel	No	Time allocated (days per year)	Cost/day (Maluti)	Total cost (Maluti)
Hydrology	Hydrologist	1	Included in long-term		
Water Quality	WQ Specialist	1	10	1184	11 837
Fish	Fish Specialist	1	10	1184	11 837
	Technician	2	20	284	5 682
Field allowance			60	300	18 000
TOTAL					47 356

Table 7.4 Personnel costs associated with the long-term component of the Monitoring Programme.

ITEM	Personnel	No	Total allocated (Days/year)		Costs in Maluti			Comments
			Total	Field	Per day	1 st five years	After five years	
Programme Manager		1	365	50	-	187 500	187 500	Full time
BIOPHYSICAL								
Hydrology	Hydrographer	1	365	100	-	187 500	187 500	Continuous
	Ass. hydrographer	1	365	100	-	125 000	125 000	Continuous
Hydraulics	Hydraulics Engineer	1	20	15	11837	4 735	1 818	Every two years for five years thereafter every five years.
	Surveyor	1	56	10	13258	5 303	5 091	Every two years for five years thereafter every five years.
	Ass. surveyor	1	56	10	142	3 977	3 977	Every two years
Sedimentology	Specialist	1	20		Costed in baseline			
Water Quality	Researcher	1	220	154	473	104 167	104 167	Once a year.
Vegetation	Specialist	1	20	18	1184	23 674	11 837	Once a year for five years, thereafter every two years.
	Botanist	1	30	20	473	14 205	14 205	Once a year.
Macroinvertebrates	Specialist	1			Costed in baseline			
	Researcher	1	20	10	473	9 470	9 470	Once a year.
	Technician	1	365	250	473	125 000	125 000	Once a year.
Fish	Specialist	1	100		Costed in baseline			
		1	25	25	710	17 756	17 756	Once a year.
	Technician	1	100	100	Costed in baseline			
		2	25	20	473	23 674	23 674	Once a year.
Water Quality	Observers	10	365			75 000	75 000	Continuous.
	Driver	1	365	80		30 000	30 000	Continuous.
	Taxonomist	1	100		473	47 348	47 348	Once a year.
	Technicians	1	20		Costed under macroinvertebrates			
	Ornithologist	1	15	6	1184	3 551	3 551	Once a year for five years, thereafter every five years.
SOCIO-ECONOMIC								
	Sociologist	1	40	25	710	28 409	14 205	Once a year for five years, thereafter every two years.
	Field supervisor	1	25	25	473	11 837	5919	Once a year for five years, thereafter every two years.
	Technicians	4	25	10	284	28 409	14 205	Once a year for five years, thereafter every two years.
	Community data entry assistants	8			Costed under biophysical			
	Parasitologist	1	20	10	1184	23 674	23 674	Once a year.
	Epidemiologist	1	150	10	1184	177 557	177 557	Combination.
	Vet. assistants	3	40	30	473	26 515	26 515	Combination.
Field allowance				928	300	278 400	278 400	Average field days
TOTAL						1 589 555	1 528 334	

Table 7.5 Personnel costs associated with data analysis and interpretation and report writing components of the Monitoring Programme.

Component	Personnel	No	Time Days per annum	Cost/Day Maluti	Total Maluti
Hydraulics	Hydraulics Engineer	1	10	1 184	11 837
Habitat mapping	GIS digitiser	1	10	682	6 820
Sedimentology	Sedimentologist	1	6	1 184	7 102
Water Quality	Specialist	1	20	1184	23 674
Macroinvertebrates	Macroinv. Specialist	1	6	1 184	7 102
	Macroinv. Taxonomist		6	710	4 261
Riparian Vegetation	Botanist	1	14	1 184	16 572
	Botanical Taxonomist		6	710	4 261
Fish	Fish Specialist		10	1 184	11 837
Sociology	Sociologist		10	473	4 735
Public Health	Medical Doctor		6	1 184	7 102
Animal Health	Veterinarian	1	6	1 184	7 102
Water Supply	Water Resources Eng.		1	710	710
TOTAL					113 117

Table 7.6 Estimated salaries used to calculate personnel costs.

ITEM	Qualifications	Costs in Maluti				
		Basic Annual Salary	25% surcharge	Annual Salary Cost to LHDA	Monthly Rate	Daily Rate
Specialists and researchers						
Level 1	Ph.D.	250 000	62 500	312 500	26 042	1 184
Level 2	M.Sc.	150 000	37 500	187 500	15 625	710
Level 3	B.Sc.	100 000	25 000	125 000	10 417	473
Technicians						
Level 1	B.Sc.	100 000	25 000	125 000	10 417	473
Level 2	Matric	60 000	15 000	75 000	6 250	284
Level 3	Matric	60 000	15 000	75 000	6 250	284
Assistants						
Field Assistant	-	30 000	7 500	37 500	3 125	142
Field Observers	-	6 000	1 500	7 500	625	28
Drivers						
Driver		24 000	6000	30 000	2 500	114

Table 7.7 Estimated start-up costs of equipment for the Monitoring Programme.

Component	Equipment	Units	Unit Price (Maluti)	Total (Maluti)	Comment
General	Digital Camera	1	6 000	6 000	
	4x4 Vehicle	2			Use 648 vehicles
	Flow Measurement - current meters	2	80 000	160 000	
	Field guides	3	400	1 200	
Hydrology	Data Loggers	12	32 000	384 000	
	Database Software	1	40 000	40 000	
	Desktop Computers + Printers	2	20 000	40 000	
Hydraulics					
	Survey Equipment	1			See rental in consumables
Botany	Clinometer and other minor equipment	-	6 000	6 000	
Fish	Electroshocker	1	10 000	10 000	
	Binoculars and other minor equipment	-	10 000	10 000	To be shared.
Sedimentation	Sediment Samplers	3	6 000	18 000	
Water Quality	Temperature Probes	9	4 500	40 500	
	Laptop Computer P-2	1	15 000	15 000	
	Field Microscope	1			Use from Contract 648
	Freezers	7	2 000	14 000	Use from Contract 648
	Data loggers (incl. housing etc.)	3			Use from Contract 648
Microbiology and Parasitology	Filtration apparatus for total coliforms				Use from Contract 648
	Portable incubator				Use from Contract 648
TOTAL				744 700	

Table 7.8 Estimated annual costs of consumables. WQ = water quality.

Component	Item	Units	Months	Unit Price (Maluti)	Total (Maluti)	Comments
General	4x4 Vehicle maintenance and insurance	2	12	4 500	108 000	For all aspects of monitoring
	Laboratory analysis of samples	-	12	40 300	483 600	Lab costs
Hydrology	Stationary	1	12	500	6 000	
	Equipment installation and training	1		60 000	60 000	
Hydraulics	Hydraulic modelling software		1	100 000	10 000	
	Surveying equipment rental	1		5 000	5 000	
Sedimentation	Consumables		12	500	6 000	
Geomorphology	Consumables	1		5 000	5 000	
Water Quality	Consumables		12	3 000	36 000	
Microbiology	Consumables		12	500	6 000	
Riparian Vegetation	Consumables		12	1 000	12 000	
Aquatic Inverts	Consumables		12	500	6 000	
Fish	Consumables		12	800	9 600	
Mammals and birds	Consumables		12	200	2 400	
Socio-Economic	Consumables		12	200	2 400	
Public Health	Consumables		12	200	2 400	
Animal Health	Consumables		12	200	2 400	
TOTAL					846 800	

**SECTION 8:
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