Shire Integrated Flood Risk Management Project

Volume I - Final Report

October 2012

Plan Design Enable

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Abbreviations

Abbreviation	Meaning
1:100 year flood	Flood event with a 1 in 100 (or 1%) chance (probability) of occurrence
1D	One Dimensional (hydraulic modelling)
2D	Two Dimensional (hydraulic modelling)
ADC	Area Development Committee
AMAX	Annual Maximum (Flows and Levels)
AMC	Antecedent Moisture Condition
AMCI	Dry moisture conditions
AMCIII	Wet moisture conditions
AP	Annual Probability
CN Number	A parameter of the US SCS hydrological model
DAE	Department of Agriculture Extension
DC	District Commission (er)
DCCMS	Department of Climate Change and Meteorological Services
DCPC	District Civil Protection Committee
DEC	District Executive Committee
Defra	Department for Environment Food and Rural Affairs (UK Government Department)
DEM	Digital Elevation Model
DF	Debris Factor
DMIC	Disaster Management Information Centre
DNRDM	Department for National Relief and Disaster Management
EA	Enumeration Area
FFEWS	Flood Forecasting and Early Warning Systems
GIS	Geographic Information Systems
IFRMP	Integrated Flood Risk Management Project
Infoworks RS / IWRS	Infoworks River Systems (Linked 1D/2D hydraulic modelling software)
JICA	Japanese International Cooperation Agency
LiDAR	Light Detection and Ranging (A detailed DEM data collection technique)
Manning's n	Hydraulic roughness coefficient used in the hydraulic model
MDF	Malawi Defence Force
MoAFS	Ministry of Agriculture and Food Security
MWDI	Ministry of Water Development and Irrigation
MoEST	Ministry of Education Science and Technology
MoF	Ministry of Forestry
MoGCCD	Ministry of Gender, Children and Community Development
MoH	Ministry of Health
MoICE	Ministry of Information and Civic Education
MoLGRD	Ministry of Local Government and Rural Development
MoTPI	Ministry of Transport and Public Infrastructures
MRCS	Malawi Red Cross Society
NDPRC	National Disaster Preparedness and Relief Committee

NGO	Non Governmental Organisation
SADC	Southern African Development Community
SADC-HYCOS	SADC – Hydrological Cycle Observation System
SARFFG	Southern Africa Regional Flash Flood Guidance
SCS	Soil Conservation service
SDI	Spatial data Initiative (A web based GIS system)
SRTM	Shuttle Radar Topography Mission (A DEM data set provided by NASA)
TA	Traditional Authority
TOR	Terms of Reference
T_p	Time to Peak
UNISDR	United Nations International Strategy for Disaster Reduction
VCPC	Village Civil Protection Committee
VDC	Village Development Committee

1. Introduction

WS Atkins International Ltd, in association with LTS International, was commissioned by the World Bank in August 2011 to develop the Integrated Flood Risk Management Plan for the Shire Basin. The Department for National Relief and Disaster Management (DNRDM) is the main Implementing Entity and the Ministry of Water Development and Irrigation (MWDI) in collaboration with the Department of Climate Change and Meteorological Services (DCCMS) are key implementing partners.

In December 2011, Inception Workshops were held in Blantyre and Lilongwe and an Inception Report was submitted. At the interim stage, in February 2012, a further workshop was held in Lilongwe and an Interim Report was submitted.

This Final Report represents the completion of the project and is being submitted following a final workshop which was held in Lilongwe on 8th August 2012, where the draft final findings were presented, discussed and agreed with key stakeholders. This final report therefore incorporates comments from the client and key stakeholders.

1.1. Background

Malawi is affected by a number of natural and human-made disasters every year and between 1974 and 2003, hazards cumulatively affected 25 million people (GoM, 2010). Malawi is particularly vulnerable to severe weather events, with 40 weather related disasters in the last 40 years (GoM, 2010). This vulnerability is a result of a combination of physical geo-climatic factors (including erratic rainfall and tectonic activity), environmental factors and socio-economic vulnerability. There is widespread dependence on rain-fed agriculture and use of biomass for household energy. The nation has a narrow economic base and extensive rural poverty (GoM, 2011a). The intensity, frequency and number of people affected by such disasters appears to be increasing, a trend attributed to climate change, population growth, urbanisation and environmental degradation.

According to the Terms of Reference (ToR) 23 flooding events have occurred in Malawi in 29 years (1979 – 2008) which cumulatively affected 1.9 million people. Table 1-1 is a chronology of past flood events in tabular form while Figure 1-1 is a map of flood locations, based on the DNRDM list ‘National Profile of Disasters in Malawi’.

The Shire River and its tributaries are a major source of flooding, with the highest flooding frequency in the country occurring in the Lower Shire valley. The Shire River is economically and environmentally very important, with hydroelectric schemes generating 98% of Malawi’s electricity, extensive fisheries and wildlife conservation areas and provision of freshwater irrigation to cash crop plantations, industrial and domestic uses.

Table 1-1: Reported flooding based on DNRDM's National Profile of Disasters spreadsheet

Year	Location
1970	Chikwawa, Nsanje
1973	Chikwawa
1975	Machinga, Mangochi, Mulanje, Nsanje, Zomba
1982	Chikwawa, Mwanza
1986	Chikwawa
1989	Balaka, Chikwawa, Chiradzulu, Machinga, Mangochi, Mulanje, Mulanje, Nsanje, Nwanza, Salima, Zomba
1991	Chiringa, Mulanje, Phalombe
1995	Chikwawa, Karonga, Nkhatabay, Nsanje
1996	Nsanje
1997	Chikwawa, Nsanje, Karonga, Nkhotakota, Phalombe,
1999	Chikwawa, Nsanje
2000	Chikwawa, Karonga, Nkhotakota, Nsanje
2001	Blantyre, Chikwawa, Dedza, Karonga, Kasungu, Machinga, Mangochi, Mchinji, Mwanza, Nkhotakota, Nsanje, Phalombe, Salima, Thyolo, Zomba
2002	Balaka, Blantyre, Chikwawa, Dedza, Dowa, Karonga, Kasungu, Kasungu, Machinga, Mangochi, Nkhotakota, Nsanje, Ntcheu, Phalombe, Rumphi, Salima, Zomba
2003	Balaka, Bwanje, Chikwawa, Dedza, Dowa, Karonga, Lilongwe, Machinga, Mchenga, Mwanza, Mzuzu, Nsanje, Ntcheu, Nyungwe-Wovwe, Phalombe, Rumphi, Salima
2004	Chikwawa, Nsanje
2005	Chikwawa, Machinga, Mangochi, Mzimba, Nkhatabay, Nsanje, Ntcheu
2006	Chikwawa, Malindi, Salima
2007	Balaka, Blantyre, Chikwawa, Chiradzulu, Chitipa, Galonga, Karonga, Lilongwe, Lundu2, Machinga, Mchinii, Mtemangawa, Mzimba, Nkhatabay, Nsanje, Ntcheu, Phalombe

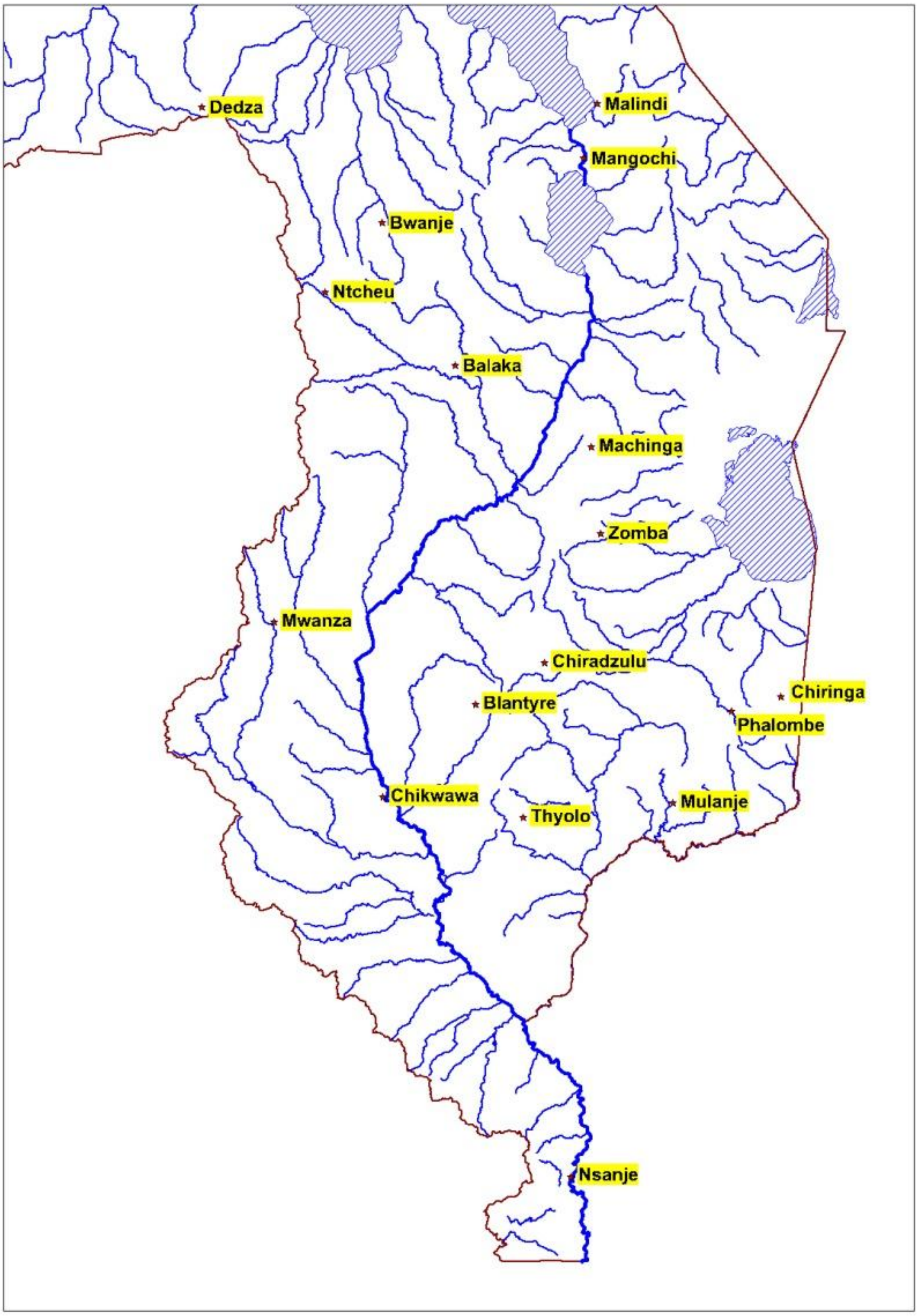

Figure 1-1: Location of areas where flooding has been reported

Approximately half a million people live in the Lower Shire valley and are regularly affected by flooding and water pollution. The highest risk areas in the Shire are Chikwawa and Nsanje districts, which are located in the lower section of the basin. In Nsanje 70% of the people are affected by the floods while in Chikwawa 40% of the people are affected. In Mangochi district just downstream of the Lake outflow in the upper section of the basin, flooding is caused when lake levels are high. Flooding has resulted in higher poverty and vulnerability levels in high risk districts. Since the 1970s, flooding in the basin has occurred once in every 2 - 5 years. The Shire River basin is important to the development of agricultural production and other economic activity given its geographic and climatic conditions and is therefore of national importance. If vulnerabilities and hazards could be addressed, intensified agricultural production, better transport linkages and secured homesteads can make the valley an economic hub of Malawi and the region, and lift many people out of poverty. In the short and medium term the focus should be on building interventions on a better understanding of the risk profiles, and mitigating immediate loss that occur almost annually.

A number of efforts are being implemented by the Malawi government and other stakeholders to reduce the risks and mitigate the impacts of floods in the Lower Shire valley. However the efforts are not harmonized and are being implemented in isolation by different agencies in the Shire basin, yielding little visible impact overall. Furthermore, community participation in catchment protection and management is limited and enforcement of catchment protection and institutional management approaches are weak in the region and the country as a whole.

The Integrated Flood Risk Management Plan for the Shire Basin is part of Component III of the umbrella Shire River Basin Management Project (SRBMP) (World Bank), which will address the interlinked challenges of poverty and a deteriorating natural resource base in the Shire River Basin, to reduce the process of environmental degradation and improve the productive potential of natural resources. The SRBMP project will promote integrated climate resilient investment planning in the basin, including institutional capacity building to plan and monitor changes in land use patterns at a basin level. Project activities will support strategic planning of large-scale infrastructure investments and adoption of sustainable land, forest and water management practices to reduce land degradation in production landscapes and improve the productivity and incomes of smallholder farmers. Project investments will be designed to support the Government of Malawi’s economic growth and development plans in the basin. The Project is organized in three components: (i) Institutional Capacity Strengthening for Basin Planning, Management and Development; (ii) Livelihoods-Based Watershed Management; and, (iii) Infrastructure Development to Mitigate the Impacts of Floods and Droughts to Support Sustainable Economic Growth and Food Security.

The main aim of Shire Integrated Flood Risk Management Project (Shire IFRMP) is to develop a 5-year Action Plan for strategic flood risk management of the Shire Basin, which will provide the Government of Malawi with an Integrated Implementation Plan, based on sound and detailed diagnostics, and essential guidelines to address the flood hazard situation in the Shire basin in an organized manner with ample attention to all components in an integrated way.

1.2. Terms of Reference and Project Objectives

The main objective of the Integrated Flood Risk Management Plan for the Shire Basin is given in the Terms of Reference as follows:

“ …… to assist the Government of Malawi in development of an Action Plan to address the flood risk situation in the Lower Shire in an integrated way, based on sound diagnostics and systems to assess and implement future interventions.”

Further, the Terms of Reference requires the Action Plan to

“**address both the hazard (water regime) and the vulnerability to these hazards (adaptation of human behaviour). Thus life and livelihoods are better protected from flood risks and enhance the capability of socio economic development in the basin. This is in harmony with Malawi growth and development strategies which emphasises sustainable growth and MDGs**.”

Key Tasks described in the Terms of Reference are as follows:

Task 1: Initial Inception Framework

Task 2: Model Framework Design and Development

Task 3; Flood forecasting and Early Warning System Development

Task 4: Flood Zone Mapping

Task 5: Flood Mitigation Measures Assessment

Task 6: Guidelines for Future Assessment

Task 7: Capacity Building and Institution Improvement Plan

Task 8: Detailed Development of a First Phase Action Plan

1.3. Structure of the Interim Report

The sections of the report that immediately follow this introduction describe our findings on the main themes of the project:

2. Overall Approach
3. Modelling Framework and Design
4. Flood Zone Mapping
5. Flood Forecasting and Early Warning (FFEWS) – Terms of Reference
6. Institutional Assessment
7. Guidelines for Future Assessment
8. Action Plan
9. Recommendations
10. Appendices

2. Overall Approach

The main aim of Shire Integrated Flood Risk Management Plan (Shire IFRMP) is to develop a 5-year Action Plan for strategic flood risk management of the Shire Basin, which will provide the Government of Malawi with an Integrated Implementation Plan, based on sound and detailed diagnostics, and essential guidelines to address the flood hazard situation in the Shire basin in an organized and holistic manner.

Whilst flooding is concentrated in the Lower Shire (and we have concentrated our assessments here), the IFRMP takes account of the influence of the Upper and Middle Shire in contributing to the cause of the floods. To this end our assessments extend from Liwonde down to the boundary with Mozambique, taking account of the influence of the Zambezi River.

Our approach to the assignment followed the Scope of Work described in the Terms of Reference (TOR) and as detailed in our proposal. Thus our work plan has been divided into the eight separate tasks and the three reporting phases – Inception, Interim and Final – as given in the TOR.

The 10 month project commenced in October 2011, with the Inception phase completed in December 2011 with workshops held on 8th December (DCs' Workshop) and 13th December (Inception Workshop) and delivery of the Inception Report. The interim phase was completed in February and culminated in a workshop on the 21st February in Lilongwe as well as initial model training on the 21st and 22nd February.

This document is the final report and includes a first phase Action Plan. As required by the TOR, this plan is comprised of details, costs and scheduling for further activities and interventions for the mitigation of flood impact on communities in the Shire Basin. The project culminated in a workshop on the 8th August in Lilongwe.

3. Modelling Framework

3.1. Background

A key component of the project is the development of a hydraulic modelling framework for ongoing hydraulic modelling and flood mapping of the Shire basin. The main aim of developing such a modelling framework is to provide a tool which will be handed over to the Malawi government for use in the future strategic management of flood risk in the Shire basin. Importantly, the modelling framework will be used to:

1) generate flood inundation maps for use in spatial planning to zone development away from high flood risk areas
2) assist in the design of flood mitigation measures including the sizing of structures such as culverts, bridges, levee heights
3) assess the technical feasibility and impact of mitigation measures both structural and non-structural
4) form the basis of emergency planning and response
5) form the basis of a flood forecasting model to be developed in the future

3.2. Study Area and Objectives

3.2.1. Study area

The study area covers the Shire River and tributaries from the Lake Malawi outflow down to the border between Malawi and Mozambique (Figure 3-1). As such, the upstream limit of the hydraulic model is the Liwonde Barrage. From here the river flows in a generally south westerly direction, until it reaches the Blantyre area before changing to a South Easterly direction. There is a large elevation change within the catchment, with the largest loss of elevation being in the Middle Shire – between Matope and Chikwawa. Once the river reaches Chikwawa, the catchment flattens out significantly and enters the Elephant Marshes. From here the gradient of the catchment is very gentle all the way down to the river’s confluence with the Zambezi. A number of highly significant tributaries flow into the catchment within the Elephant Marshes. The largest of these is the Ruo which often causes flooding in the Lower Shire on its own.

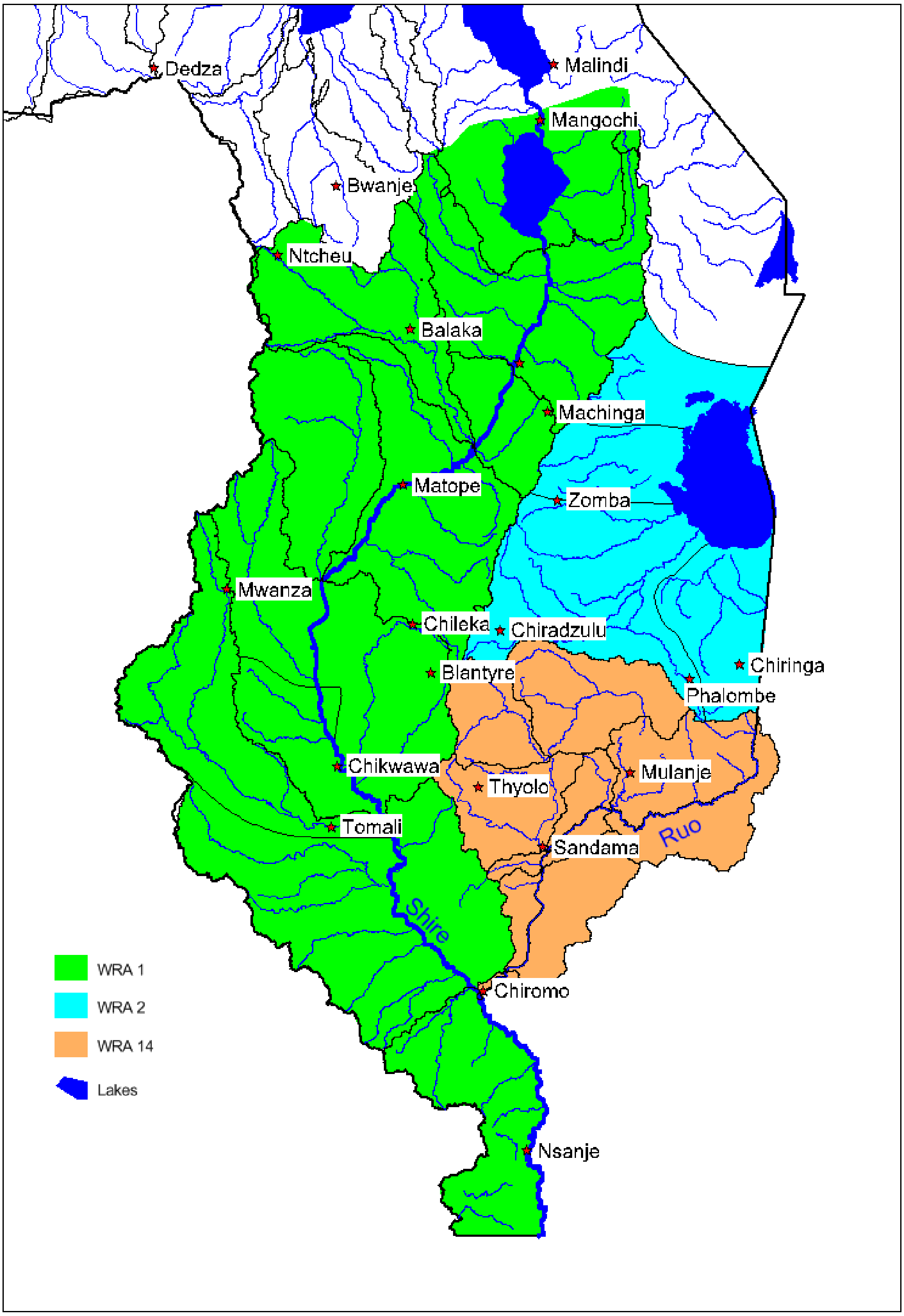

Figure 3-1: Overview of project area (WRA=Water Resources Area)

3.2.2. Modelling Objectives

The objectives of the Shire hydraulic modelling were as follows:

a. Construct and calibrate a hydrodynamic model of the catchment capable of accurately predicting inundation of the floodplain for extreme fluvial flooding.

b. Use the model to simulate floodplain inundation for a range of design flood scenarios

c. Produce flood maps of the catchment for a range of design modelling scenarios

d. Produce a model that can be used to assess the effectiveness of potential interventions to mitigate flood impact

e. Produce a model that can be updated in the future to improve its accuracy and reliability once better data becomes available for the catchment.

3.3. Summary of Data Sources

The following is a summary of data used in developing the modelling framework.

Topographic Data

- Shuttle Radar Topography Mission (SRTM) 90m resolution digital elevation model
- Limited channel topographic surveys of the Ruo and Shire at the confluence

Hydrometric Data

- Daily rainfall totals for 23 rain gauges from DCCMS
- Twice daily water levels, mean daily water levels, mean daily flow, AMAX data from MWDI
- Clock-work based chart recorder data for selected stations (from MWDI)
- Gauge ratings including rating history, spot gauging from MWDI

Physical Catchment Datasets

- Landuse, geology and soil type maps

3.3.1. Data Gaps

The data available to undertake the modelling was of a preliminary nature, but will need to be improved for future the development of the model. The main data gaps identified are as follows:

1) Topography. SRTM data is inadequate vertical accuracy and spatial resolution to provide the basis for detailed flood modelling and mapping. As part of the wider project, LiDAR is being flown for the catchment and it will be important to ensure that the model is updated with it
2) Flow and level data. Sub-daily rainfall and flow data is required for detailed and accurate flood modelling and this was not available during the project. Some sub-daily data has now been provide and it will be important to re-do the hydrological modelling using it.
3) Observed water level on the Shire and its tributaries to provide calibration data. This is a limitation of the location of gauges within the basin and once addressed in the future, will enable better calibration of the model.

3.4. Overview of Modelling Approach and Methodology

3.4.1. Hydrological modelling overview

The Shire basin has a number of tributaries feeding into it, which in total contribute significant inflow along its length. The tributaries have mainly been modelled as inflow boundaries, based on SCS rainfall-runoff modelling. The SCS model has been parameterised using a number of datasets of two main types. Physical data sets include as topography, landuse, geology and soil type, and timeseries data. In addition to the physical parameters, the SCS rainfall-runoff models have been developed using time varying rainfall data for different return periods (derived from depth-frequency statistical analysis of daily rainfall) as the main input and flow data, where available, to calibrate the model against. Rainfall-runoff modelling is deemed to be appropriate for the Shire as the volume and timing of inflows from each tributary is important to correctly representing flood risk in the catchment.

Details of the hydrological modelling undertaken, are provided in Appendix A.

3.4.2. Hydrodynamic modelling overview

A linked one dimensional (1D) and two dimensional (2D) hydraulic model has been developed of the Shire and its main tributaries. Much of the upper parts of the catchment lend themselves well to 1D modelling which is more appropriate to represent in-channel hydraulics, backwatering and the effects of structures such as Kapachira and Tdzani falls HPP dams, and for accurate prediction of flood level for rivers where the channel is conveying as much as, or more flood flow than the floodplain and where floodplain levels are closely linked to, or influenced by the levels in the main channel. While some areas in the upper part of the catchment could be modelled in 2D (such as the reach between Liwonde and Matope), the SRTM data in this area is of insufficient resolution to accurately model the flow path of the Shire in 2D. Once higher resolution LiDAR data is available, a change of approach to 2D modelling may be technically feasible in some parts of the Upper Shire.

In contrast to 1D modelling, 2D modelling is capable of dynamically routing shallow flow over extensive areas of floodplain, and has the advantage of being able to simulate the successive wetting and drying of the floodplain and the overtopping of defences. 2D models are best suited to wide flat floodplain areas, over which flood waters can travel a significant distance from the river channels. 2D modelling has been used to represent the elephant marches and the main Shire down to the Zambezi, as well as the main left and right bank tributaries.

Linked 1D-2D modelling provides the benefits of both types of models, allowing accurate representation of the in-channel hydraulics as well as accurately routing flood flows across the floodplain. Innovyze's[1] linked 1D-2D modelling package Infoworks RS has been used to develop the hydrodynamic model of the Shire basin and is the basis of the modelling framework.

The linked hydrological-hydrodynamic model was used to generate flood maps of different return periods and to assess the flood mitigation options that were short listed at the interim stage.

3.5. Flood Mapping

Flood maps have been generated for the 5, 10, 20, 50, 75, 100, 100+Climate Change and 500 year return period flood events. The 1 in 100 flood outline centred in the Elephant Marshes is shown in Figure 3-2, while the other flood outlines are provided in Appendix B – the flood Atlas of the Shire River Basin.

[1] Innovyze is the global leader in wet infrastructure modelling and management tools including the Infoworks suite of models. Infoworks RS 2D was used to develop the Shire hydrodynamic model

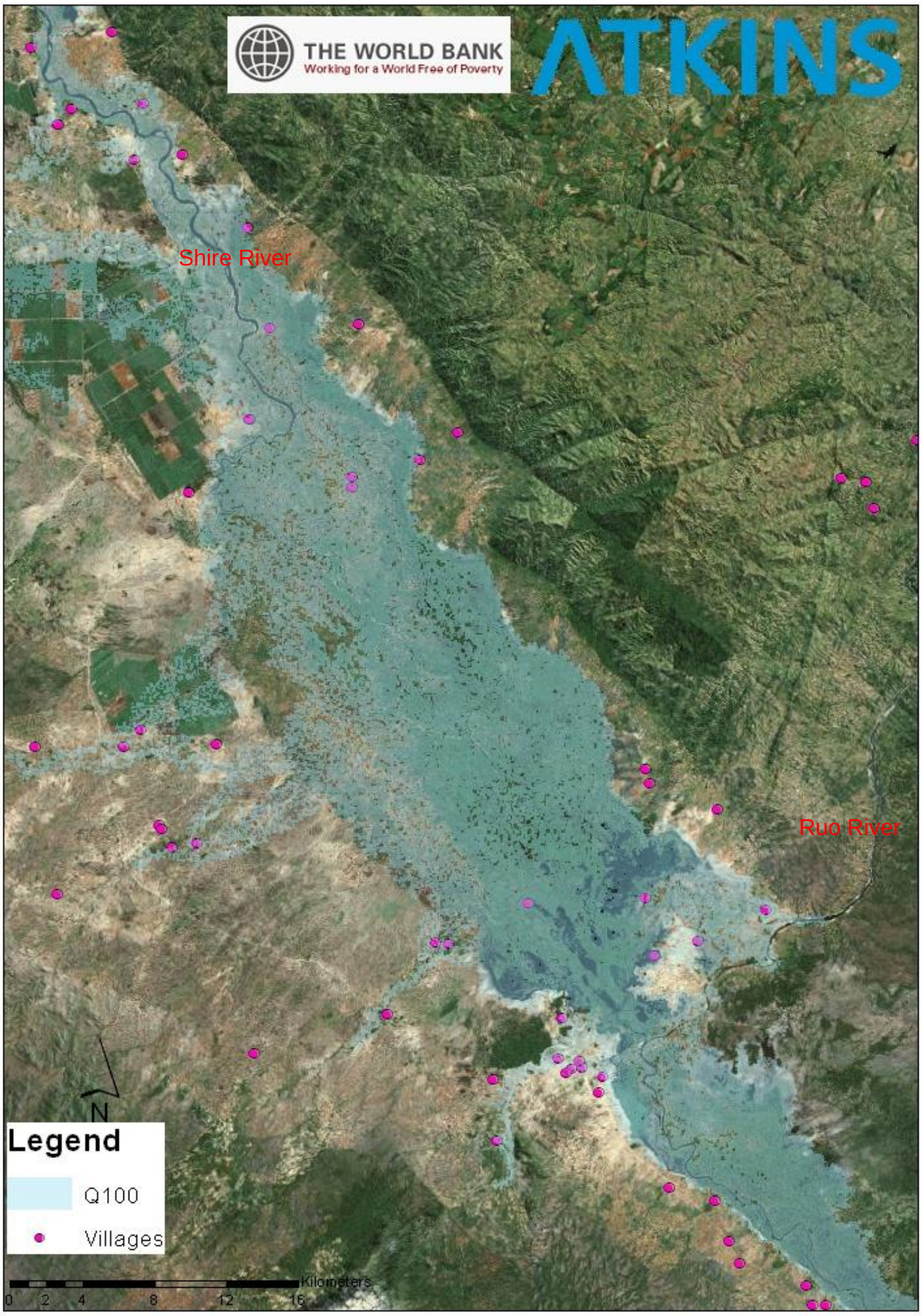

Figure 3-2: 100 year flood outline centred on the Elephant Marshes

3.6. Options Modelling

Consultations were undertaken during the interim phase with the District Executive Commissioners (DEC's) to identify those villages most affected by flooding and the rivers which cause flooding. A number of the critical villages were identified by the DEC's as being on tributaries of the Shire rather than on the main Shire. Hence, prior to options modelling a secondary model was constructed within the hydraulic modelling framework in order to examine flood risk to villages on those tributaries. This secondary model is 2D only in nature and covers the main tributaries of the Shire that enter the Elephant Marsh on the left bank of the Shire and the lower reaches of the Mwanza, the Namakilingo, the Lalanje and the Thangadzi West Rivers that enter the Shire on the right bank.

The tributary model and the main Shire model are separate models within the same framework which can be run separately, with the ability to input boundary conditions from one model to boundary conditions of the other. The impact of the whole system can be assessed by running the models concurrently.

The final model has been used to assess the baseline flood risk to the critical villages and, in conjunction with the economics assessment of flood damages, to assess the likely benefits of implementing the modelled options (see Section 7.4). The options modelled include, flood defences, catchment improvement through reforestation, and flood storage options.

3.6.1.1. Flood Defences to Villages

Flood defence bunds were considered for all villages. For each return period, it has been assumed that building of a defence would completely eliminate flooding up to a design standard equivalent to the annual probability for that event, some flooding would still occur for floods in excess of the magnitude of that event. Hence, the baseline model results from both the tributary model and the main model were used to identify the flood depth at each of the villages and therefore the height of flood defence bunds that are required for each standard of protection, Flood depths for these villages are shown in Table 7-2. These modelled flood depths were used to assign baseline flood depths and hence flood defence heights to the villages, as the basis for the economic benefits calculations. We have estimated the length of bunds but recognise that these need to be revisited. The exact length and therefore cost of the defences required, can then be re-calculated once the model has been updated with LiDAR data to refine the flood maps and flow routes by each of the villages, and when village extent information is available.

3.6.1.2. Catchment Improvement Modelling

Catchment Improvement has been tested on two sub-catchments within the Shire basin. These were the Ruo and The Mwanza. Catchment Improvement has been modelled by reducing the model parameter that controls runoff percentage, to represent reforestation within the catchment. We have modelled a 24 and 33 percentage increase in forest cover for the Mwanza and Ruo catchment respectively.

The catchment improvement option does provide an improvement to flood depth, on the Mwanza. The reduction in flood level is between 30mm and 290mm at the villages identified as critical by the DEC's. On the Ruo, the reduction in flood levels at critical villages was significantly smaller or non-existent. This is due to the proximity of these villages to the confluence with the Shire, which has a significant effect on flood levels in the area of these villages. Table 7-3 shows the reduction in flood depth at the critical villages within the Mwanza catchment. Figure 3-3 shows the current and catchment improvement 1 in 100 annual probability flood outlines for part of the Mwanza catchment. It shows some reduction in the flood extent, it should be noted that a greater change in flood extent is possible once the model has been updated with LiDAR elevation data. As a result, catchment improvement options should be re-evaluated once the model has been updated with LiDAR data.

It should be noted that a number of the villages identified as being critical are not in the above table as they are significant distances from any of the flood outlines; therefore, the sources of flooding at these locations requires further investigation.

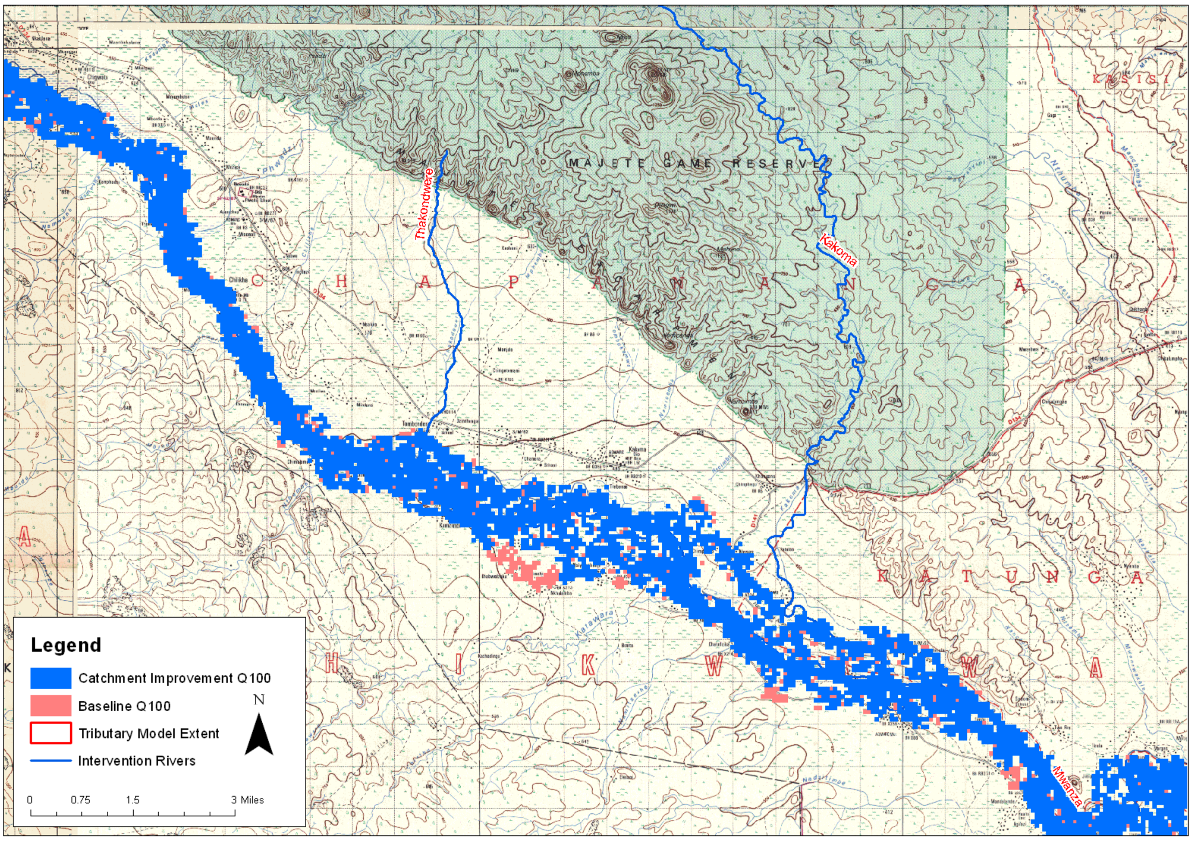

Figure 3-3: Current and Catchment Improvement Flood Outline for Part of the Mwanza Catchment

3.6.1.3. Flood Storage Options

The analysis also examined the potential for storing flood volumes in the upper part of the tributary catchments to alleviate flooding to critical downstream areas. The analysis showed that extremely large volumes would be required to store the Q10 and larger events, and that such storage reservoirs will pose major difficulties in the physical provision of diversion, storage and release facilities. At this stage, this option – provision of storage to allow a release of only 100 cumecs downstream - is considered to be impractical and does not merit inclusion in options for the Action Plan.

The possibility of storing a smaller flood, for example the Q10 volume, has been separately considered in terms of the effect on the Q100. The analysis showed that while there is some reduction in the flood outline, it is not a significant reduction for an event of this magnitude. This is because the Q10 flood volume is small in comparison to the Q100 flood and storage of the Q10 volume makes no appreciable difference to water levels downstream. The assessment of storage options can be examined in more detail once LiDAR data is available for the catchment.

.The impact of these options on the flood economics is discussed in Section 7.

3.7. Climate Change

To provide an indication of the likely magnitude of the influences of climate change, projections for changes in mean precipitation and mean temperature were derived from a selection of General Circulation Models (GCMs). Seasonal change factors were obtained by selecting individual model outputs from the results derived in a recent UNDP study (McSweeney *et al*., 2010).

The Climate Change Flow Factors derived are summarised in the table below. A more detailed description of the climate change methodology is provided in Appendix A.

	Shire (Proxy: WRA 5)			Ruo (Proxy: WRA 7)		
	CC Wet	CC Mid	CC Dry	CC Wet	CC Mid	CC Dry
Wet Season	11.9%	2.7%	-11.5%	12.0%	2.2%	-14.9%
Dry Season	1.2%	-7.4%	-16.0%	0.6%	-3.6%	-16.7%
Overall	11.0%	1.9%	-11.9%	10.2%	1.3%	-15.2%

The Wet Season Wet condition flow change (12 %) for both the Ruo and Shire was applied to the SCS rainfall runoff models to assess the impact of climate change on future flows within the catchment.

The climate scenarios used are fairly coarse – the area of Malawi would fit into two climate model grid boxes, although it spans six. A higher resolution could be achieved via downscaling which could be used to provide more detail in areas which are less typical of the grid box average. The statistical downscaling procedure could be used to generate change factors (rather than used stochastically) in order to reproduce areal rainfall series for use in rainfall-runoff modelling. Alternatively, it could be used to examine changes in extreme rainfall and therefore used in discrete event-based models. Note at present that only two climate models can be assessed using SDSM without further work to extract predictor variables.

Figure 3-4 shows the Q100 and the Q100 plus climate change flood outlines in the vicinity of the Ruo-Shire confluence. It shows very little difference between the two outlines and this is likely to be due to the very flat nature of the floodplain in this area, poor resolution vertical accuracy of the DEM and the small difference in flow (12%) between the Q100 and the Q100 + CC. Better DEM data will provide some refinement of the two outlines.

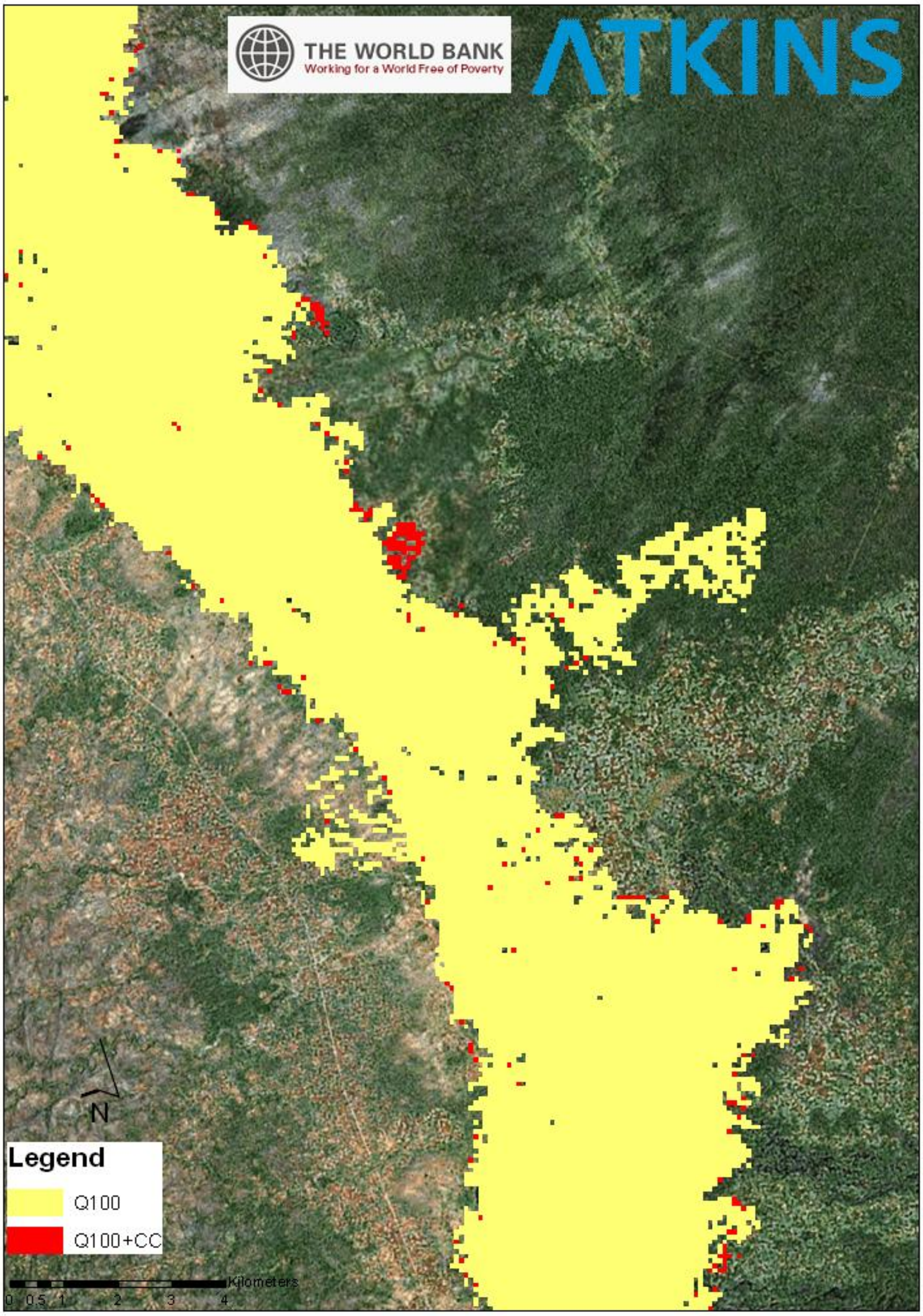

Figure 3-4: Q100 and Q100 + Climate Change flood outlines at the Ruo-Shire confluence

4. Development of flood zones for development planning, strategic spatial planning, and emergency planning

4.1. Introduction

Delineating flood zones is a vital element of any floodplain management strategy and an important step in proposing compatible development activities in each zone. Failure to understand the nature of flood hazards in each zone and hence the compatible uses for each zone can bring about increased flood risk particularly if development is allowed to occur unplanned.

Flood maps such as those developed as part of this project can be used for delineating flood zones, which can then be used for hazard identification, spatial planning including regulation of future development, establishing flood insurance flood zones and premium rates, identifying areas having unique natural and beneficial functions, development of emergency plans, raising public awareness and improving community preparedness. The flood maps and flood zone designations will benefit decision makers and all involved in natural hazard risk management at national and local level. They will also enable government and donor agencies to better focus their efforts in dealing with hazards in the basin in the future.

Development planners need to know how often, on average, the flood plain will be covered by water, for how long, and at what time of year. Natural changes, changes brought on by development activities and climate change affect the floodplain and must be understood, to identify appropriate development and natural resource management practices. Changes in floodplain utilization-such as urbanization and more intensive agricultural production can increase runoff and flood levels. It is critical for the planner to appreciate these and other effects of land-use change. Consideration of all uses of the floodplain during development planning is prudent, as it enables the planner to foresee and evaluate potential conflicts between present and proposed land use and their relationship to flood events and the hazards they may pose.

Acceptable risk criteria can help in distinguishing between different degrees of risk for different development activities. The chosen acceptable frequency of a particular flood event should be appropriate for the type of development activity. For example, it may well be worth the risk of occasional flooding to plant crops in the floodplain where soils are enriched by cyclical flooding and the deposition of sediments, where resulting sand and gravel deposits may lead to commercial exploitation. On the other hand, it is more appropriate to site a large agro-industrial or housing project in an area with a very small probability of a large flood occurring each year.

As certain types of development and the people who use and live in them are more at risk from flooding than others, development of flood zones and the development activities allowed in each, should be linked to probability of flooding as well as the vulnerability of types of development and it's likely occupants and users. Hence development can be divided into categories for example, essential or critical infrastructure, highly vulnerable, more vulnerable, less vulnerable and water compatible development which reflect the level of risk to users. This takes account of both the type of development and also the vulnerability of its users (children, the elderly and people with mobility problems may have more difficulty escaping from fast flowing water).

4.2. Landuse and Development Categories and physical planning guidelines

The different categories of development and activities that need to be considered when defining floodplain zones are:

1) Essential infrastructure
2) Highly vulnerable Infrastructure/users
3) More vulnerable infrastructure/users
4) Less Vulnerable infrastructure/users
5) Water-compatible infrastructure Activities

Other considerations include the provision of emergency services in the floodplain, and the zones within which flood insurance can be defined, if adopted as a flood mitigation measure. The following sections discuss each of these categories and uses of the floodplain in turn.

4.2.1. Essential/Critical infrastructure

Critical infrastructure such as transportation and utility services like electricity substations and water treatment works, that have to be in flood risk areas, should be designed to remain operational during floods, including access, particularly where this is necessary on a continuous basis. To be considered as 'critical Infrastructure' there must be evidence that there are no other reasonably available sites in areas of lower flood risk on which they could be located and still provide the functions and operational requirements they are intended to provide. The need for such development should outweigh the flood risk and the installation will need to be able to remain operational and safe at times of flood, and not increase flood risk, or impede water flows.

4.2.2. Highly vulnerable Infrastructure

Highly vulnerable infrastructure includes infrastructure which is required to be operational during a flood event (e.g. first responders during an emergency such as some police and fire stations and emergency response command centre, hospitals that might be needed to treat casualties of the emergency situation). In Malawi, churches, schools and communities centres which are used for flood relief centres will fall under this designation.

4.2.3. More Vulnerable Infrastructure

More vulnerable infrastructure includes infrastructure that is vulnerable due to the low probability of the type of structure physically withstanding a flood (such as mobile or temporary homes and camp sites with transient populations). Other infrastructure can be considered to be 'more' vulnerable due to the vulnerability or reduced capacity of its occupants to escape the flooded area, such as schools, old people's homes etc. More vulnerable infrastructure also includes hotels and hospitals (not necessarily needed to be operational during a flood, but which may house sick and therefore vulnerable people).

4.2.4. Less Vulnerable Infrastructure

Less vulnerable infrastructure includes police, ambulance and fire stations which are not required to be operational during flooding. Buildings used for commercial, financial, professional and other services, restaurants, offices, general industry, storage and distribution, non–residential institutions not included in 'more vulnerable', and assembly and leisure centres (not used for assembly during emergencies), land used for agriculture and forestry, waste treatment (except landfill and hazardous waste facilities), minerals working and processing (except for sand and gravel working), water treatment works which do not need to remain operational during times of flood, sewage treatment works (if adequate measures to control pollution and manage sewage during flooding events are in place).

4.2.5. Water compatible development

Some development which is 'water compatible' may need to include elements of other vulnerability classifications in order to operate. However, the development still needs to be designed to ensure the safety of occupants, with evacuation procedures clearly defined. It must not increase flood risk to others or affect the functionality of the floodplain.

Water compatible development includes, flood control infrastructure such as pumping stations, water transmission infrastructure like canals and irrigation schemes, navigation facilities like docks, wharves, nature conservation and biodiversity, outdoor sports and recreation areas and essential residential accommodation for staff required by uses in this category, subject to a specific warning and evacuation plan.

4.2.6. Emergency Services Infrastructure

Emergency services like police, fire and ambulance stations, hospitals, local health centres and buildings used for safe refuge from flooding such as churches, schools, communities etc. need to be located within their catchment even where it may be at high risk of flooding. Overall risk to life may be greater than the risk from floods if response times for emergency services are longer, hence the need to site such infrastructure close to the likely affected area. There needs to be a balance between preventing emergency services' control systems and equipment being disabled in a flood, whilst providing emergency service cover to existing communities already located in flood risk zones. It is therefore important that emergency services have clear strategies to manage their operability during a flooding event. Flood risk should be a key consideration to the location of emergency service provision.

4.3. Defining the Flood Zones

4.3.1. International Practice in Flood Zone designation

Flood zoning is defined as a basis for safe and appropriate land use and is normally defined and administered within a regulatory framework. Many developed countries have defined flood zones to enable the regulation of development activity in the floodplain.

USA

The US flood zones or flood hazard areas are identified on the Flood Insurance Rate Map as Special Flood Hazard Areas (SFHA), Moderate flood hazard areas (MFHA), and Areas of minimal flood hazards. SFHA are defined as the area that will be inundated by the flood event having a 1% chance of being equalled or exceeded in any given year. Moderate flood hazard areas, are the areas between the limits of the base flood and the 0.2% annual chance (or 500-year) flood. The areas of minimal flood hazard, are the areas outside the SFHA and higher than the elevation of the 0.2% annual chance flood.

UK

The UK, Environment Agency defines three floodplain zones as follows:

Zone 3 - The 100 year fluvial event or 200 year tidal event

Zone 2 - The 1,000 year event extent

Zone 1 - The remainder (i.e. > 1,000 year event)

Zone 3b - The "Functional Floodplain" (usually initially derived using the 20 year flood extent)

Zone 3a - Remainder

Australia

The State of New South Wales in Australia also defines three flood zones as follows:

Floodway - High conveyance (carries majority of the flow), high values of velocity and depth

Flood Storage - High depths, low velocities, stores significant volumes of water, attenuates flood wave

Flood Fringe - Shallow depths and/or low velocities, minor importance hydraulically.

4.4. Proposed Shire Flood Zones designation

This section provides proposed flood zones and discusses the types of activities that should be allowed or disallowed in each zone.

Based on the hazard and inundation maps derived from the modelling framework, flood zones have been defined with the following suggested zoning categories for the Shire River basin:

- Low flood Hazard - Outside the 500 year flood outline
- Moderate Flood Hazard - Between 100 and 500 year flood outline
- The floodplain - 1 in 100 year flood outline
- High Flood Hazard or Functional floodplain fringe - Between 20 and 100+CC flood outline
- Functional floodplain – between the river centreline and the 20 year flood outline

The following is a discussion of the suggested types of activities that could be allowed in each of the proposed flood zones. At this stage, the suggested flood zones are based on the return period of the flood only (similar to the UK approach), but once more detailed flood modelling has been done, it can be revised to incorporate consideration of the flood hazard within each zone (similar to the Australian approach). Hence, it is expected that these suggested flood zones and the activities to be designated within them will be further developed by the GoM during the implementation of the Action Plan, and will be enabled by an appropriate legislative and policy framework.

4.4.1. Low Flood Hazard Zone (> 500 year)

This zone comprises land assessed to be flooded in the 500 year or rarer event. All types of development is allowed within this zone, including critical infrastructure, highly vulnerable, more vulnerable, less vulnerable, water compatible infrastructure and emergency response infrastructure.

For future development in this zones, the vulnerability to flooding from other sources (for example pluvial flooding or groundwater flooding), the potential to increase flood risk elsewhere through the addition of hard surfaces in this zone, and the effect of future development on surface water run-off, should be assessed. In addition opportunities should be sought to reduce the overall level of flood risk in the area and beyond.

4.4.2. Moderate Flood Hazard Zone (100 to 500 year)

This zone comprises land at risk of flooding from a 100 to a 500 year flood. The types of development that are likely to be allowed in this zone include critical/essential infrastructure, more and less vulnerable infrastructure as well as water compatible infrastructure. Highly vulnerable infrastructure such as emergency services can be located here, but only if there is no where else to locate them in the low flood hazard zone or beyond.

For future development in this zones, the vulnerability to flooding from other sources (for example pluvial flooding or groundwater flooding), the potential to increase flood risk elsewhere through the addition of hard surfaces in this zone, and the effect of future development on surface water run-off, should be assessed. In addition opportunities should be sought to reduce the overall level of flood risk in the area and beyond.

4.4.3. High Flood Hazard Zone or Flood Fringe (20 year to 100 year)

The flood fringe is the portion of the floodplain which will be covered by flood waters during the one in 100 year flood, but which will mainly be standing or low velocity water (so hazard here is more likely to be due to the depth of the standing water rather than the velocity of the water). This zone comprises land at risk of flooding from the 20 year to 100 year event. Water compatible and less vulnerable development is permitted here, and it would be desirable to provide local protection to these as far as possible.

Highly vulnerable development should not be permitted in this zone, while the more vulnerable and essential infrastructure developments should be permitted in this zone only if there are no viable sites in lower risk zones. Essential infrastructure permitted in this zone should be designed and constructed to remain operational and safe for users in times of flood. It is essential that all development in this zone is cognizant of the likely extent of the 100 year flood under climate change. Hence development should be constructed to be safe up to the 100+CC flood level.

For all future development in this zone, the vulnerability to flooding from other sources (for example pluvial flooding or groundwater flooding), the potential to increase flood risk elsewhere through the addition of hard surfaces in this zone, and the effect of future development on surface water run-off, should be assessed. In addition opportunities should be sought to reduce the overall level of flood risk in the area and beyond, and to relocate existing development to land in lower flood hazard zones, and to create space for flooding to occur by allocating and safeguarding open space for natural flood storage.

4.4.4. Functional Flood plain (1 in 20 year)

The definition of the functional floodplain is a very important planning tool in maintaining the natural functions of the floodplain and reducing flood risk. In general, development should be directed away from the functional flood plain. Areas which would naturally flood with an annual exceedence probability of 1 in 20 (5 per cent) or greater, even if prevented from doing so by existing infrastructure or solid buildings, will not normally be defined as functional floodplain. That is, the functional floodplain is land within the 1 in 20 year flood outline.

Only water compatible and essential critical infrastructure development would be suitable for location in the functional floodplain and these should be designed and constructed to remain operational and safe for users in times of flood, result in no net loss of floodplain storage, not impede water flows, and should not increase flood risk elsewhere. Essential infrastructure should only be located in this zone if there are no other viable sites in lower hazard zones. Development in the functional floodplain should be designed to flood periodically to preserve flood storage volumes of the floodplain. The functional floodplain may also include areas intended to provide transmission and storage of water from other sources of flooding (e.g. surface water). The area defined as functional floodplain should take into account the effects of defences and other flood risk management infrastructure. Some areas, such as flood storage areas, may flood at a lower frequency than other parts of the functional floodplain, but should still be classified as functional for the part that they play in managing the impacts of large scale floods. The Elephant Marshes is an example of such an area.

For all future development in this zone, the vulnerability to flooding from other sources (for example pluvial flooding or groundwater flooding), the potential to increase flood risk elsewhere through the addition of hard surfaces in this zone, and the effect of future development on surface water run-off, should be assessed. In addition opportunities should be sought to reduce the overall level of flood risk in the area and beyond, and to relocate existing development to land in lower flood hazard zones, and to create space for flooding to occur by restoring functional floodplain and flood flow pathways and by identifying, allocating and safeguarding open space for flood storage.

It is recognised that the functional floodplain in Malawi, is an area of high productivity for the subsistence farmers that comprise the majority of floodplain occupants. It is therefore proposed that while not strictly sub-dividing the functional floodplain any further, the 5-year flood outline can be provided to show areas that are flooded cyclically and could therefore be high productivity areas. This could be used to identify high-productivity areas which would provide some further resilience to the backyard agriculture of the Shire. Hence, the definition of the 5-year outline, can be defined as the zone within which existing agricultural activity can continue, but within which other uses that are not water compatible and not essential infrastructure, will not be allowed. Section 4.5.8 discusses the types of floodplain cultivation to maximize floodplain transmissivity and storage and provide benefits to communities.

Figure 4-1 shows the different flood zones for part of the Shire. It should be noted that these flood zones will be revised when the modelling has been updated with LiDAR data.

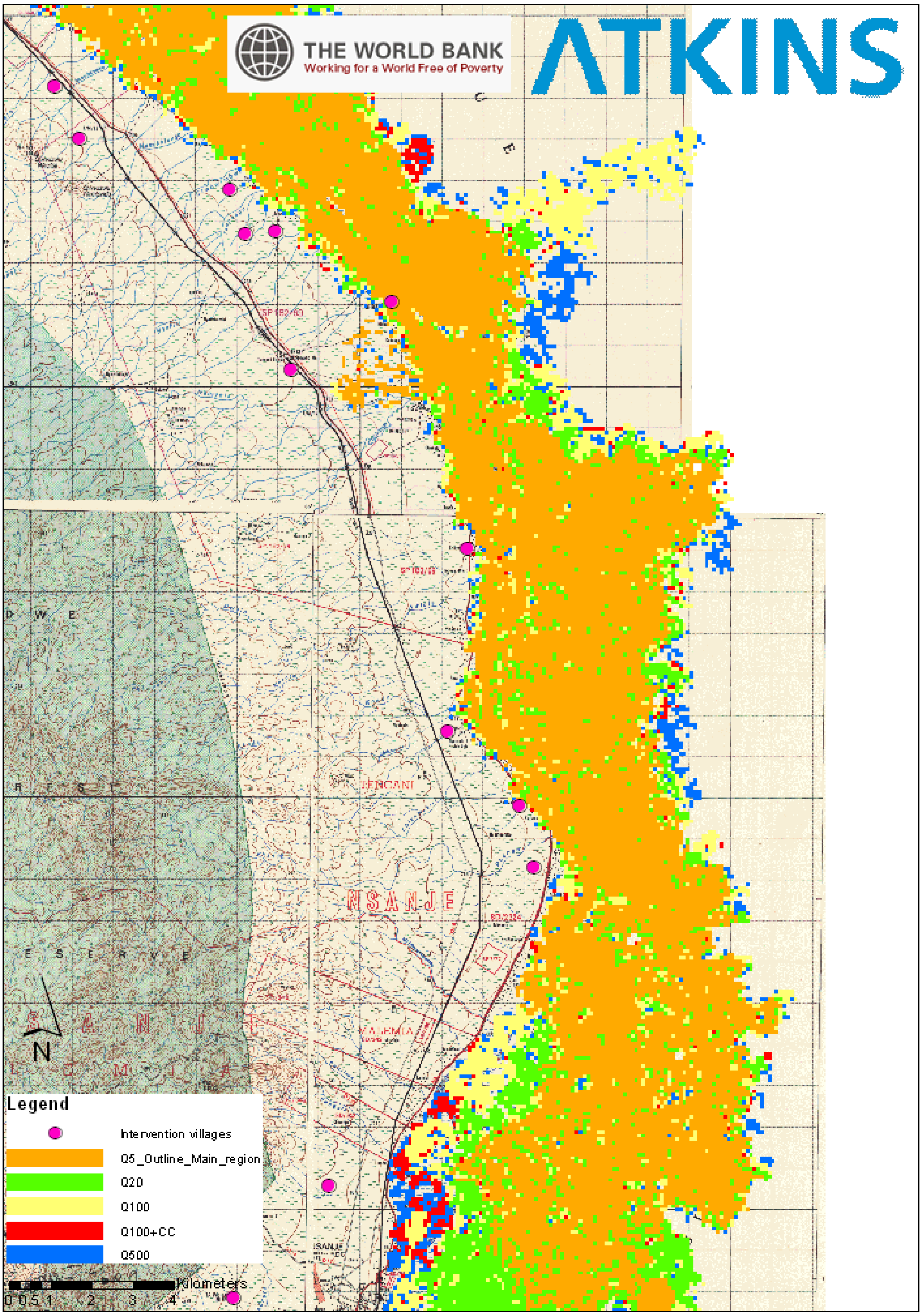

Figure 4-1: The proposed flood zones for the Shire River (zoomed in to area just upstream of the Elephant Marshes

Table 4-1: Summary of Flood Zones and types of permitted infrastructure

Flood Zone	Type of Infrastructure					
	Critical/Essential	Highly Vulnerable	More Vulnerable	Less Vulnerable	Emergency response infrastructure	Water Compatible
Low Flood Hazard Zone (<1 in 500 year)	☑	☑	☑	☑	☑	☑
Moderate Flood hazard Zone (100 year to 500 year)	☑	✗	☑	☑	✗	☑
High Flood Hazard Zone or Functional Floodplain fringe (20 to 100 year)	✗	❌	✗	☑	✗	☑
Functional Floodplain (> 1 in 20 year)	✗	❌	❌	❌	❌	☑

❌ - Indicates that the type of infrastructure is strictly not permitted

✗ - Indicates that the type of infrastructure is not permitted but will be allowed if no alternatives are available in lower risk zones

4.5. Other considerations in Flood Zone designation

4.5.1. Flood Insurance Zones

In the United States and the UK the definition of flood zones, have associated with them, the different zones within which insurance can be obtained based on the flood risk.

Flood insurance has often been advocated as a long-term non-structural measure for building resilience among flood victims, and is one of a broad scope of risk management approaches that can be used as a financial instrument to help zone development away from high risk areas.

However, in developing countries, the status of flood insurance has been unsatisfactory, due to the lack of flood insurance schemes or the limited coverage and negligible impact as a flood mitigation measure. There could be several reasons for this including the reluctance of insurance companies to promote flood insurance because of the high cost of operating and administering them, compared to the revenue to be earned by them. The capacity of flood affected people in developing countries, to pay commensurate high premiums would be limited because the majority of them are poor. If uniform rates were charged, then insurers would find themselves burdened with an adverse selection of risks because people exposed to higher flood risks are the ones who are most likely to take out such a policy. If rates charged are proportionate to the risks, then the insurance premium might be higher than the paying capacity of the poor property owners in flood prone areas, thus excluding people who need insurance most. In addition, flood risk in chronically flood-affected areas can often be widespread and frequent, resulting in insurance companies having to pay out claims for several years in succession, to large parts of the population. This might result in companies going bankrupt.

Flood insurance can be an economically viable proposition for insurance companies if governments subsidize such schemes, using a number of measures. For example, if a part of the money spent by the government as flood relief is utilized for insurance subsidies, or if flood insurance is linked to some reinsurance scheme. The total pool of money available to the reinsurance companies would be considerably higher and the additional claims are likely to be a small fraction of other claims and could become manageable within the resources of insurance. The administrative cost could be reduced by taking the help of local communities and local administrations in the collection and compilation of basic data for working out a fair and equitable premium and settling claims for areas of varying flood risks. Costs can be reduced if local communities are fully involved in the process. Communities can play a major role in awareness raising, information dissemination, on the rationale of insurance and the mechanism of its operation. In this way, the community can be a bridge between the insurance company and the flood affected people.

A major problem with flood insurance in developing countries is the difficulty in verifying the claims. One of the interesting developments in recent years has been the emergence of alternative indexed insurance risk-transfer products which use a proxy measurement to pay for significant economic loss. For example, if it is known that extreme rainfall or temperatures is highly correlated with agricultural production losses, then these measures can be used to proxy loss and make payments in case of loss of production. One noteworthy advantage of indexed insurance contracts is that claims management is greatly reduced, since there is no need to validate losses; they are determined by a simple objective measurement. Such an approach helps solve a variety of problems associated with the usual public-sector response to catastrophic risk and to credit constraints in developed countries, namely traditional forms of agricultural insurance and *ad hoc* disaster aid. However, experience with index based insurance is largely limited to drought risk. There are only a couple of examples of their use in flood risk insurance.

For Malawi, index-based flood insurance could be used to help in the mitigation of flood risk, but it is best implemented within a flood risk management framework which provides the best balance between the provision of flood protection measures and, assessment and management of the residual risk that such measures fail to provide protection from. Hence if flood protection is provided to an acceptable level, and there is confidence in those protection measures (as is the aim of the Action Plan), then insurance premiums should be lower, as the residual risk would be low, compared to the situation when the standard of protection provided is low (i.e. the current situation), and the residual risk is high. In addition, the requirement for accurate and timely measurements to determine what insurance payouts needs to be made, will need to be supported by an appropriate monitoring system (as is the aim of the improved hydrometric network for the Shire), to provide the rainfall, and water level measurements required to verify losses. Hence the improved hydrometric network can be used in monitoring the flood indices which will trigger insurance payments.

A further consideration is the willingness/ability of government/donors to provide compensation/relief after flood events. If compensation/relief is traditionally inadequate and highly ineffective (as is the case in the Shire basin) then the approach of providing a financial framework such as flood insurance, for accessing compensation which will also act as a means of influencing choices when engaging in economic activities in the floodplain is appropriate. While government subsidies and relief may need to play a part in the development of a flood insurance scheme for Malawi, it will be important that any insurance scheme, if initially subsidised, is developed to eventually operate within a free market, otherwise, there would be a limit to the effectiveness of such a scheme in reducing activities in the floodplain, as owners backed with guarantees will continue to build there. The combination of an insurance scheme with a robust development zoning regulatory framework will improve its chances of success in the long-term.

Examples of where insurance has already provided effective risk management solutions in developing countries, particularly those most vulnerable to the impacts of climate change, include:

1. **The Caribbean Catastrophe Risk Insurance Facility (CCRIF)** is a public-private partnership designed to limit the financial impact of hurricanes and earthquakes for 16 Caribbean governments. Established in 2007, the Facility provides short-term liquidity (within 2 to 3 weeks) to participating governments when the policy is triggered by a catastrophe, such as the 2010 Haitian earthquake. The Facility uses a parametric mechanism to determine the potential future risk and trigger a payout whenever a pre-defined modelled loss level is exceeded. By pooling the risks of its members, CCRIF serves as a risk aggregator and can provide insurance coverage at a comparatively low premium for otherwise mostly uninsured catastrophe risks borne by sovereigns. CCRIF member states decide on the level of coverage for each peril insured. This Facility illustrates that dialogue between governments and insurers can create tailored, institutionally light and flexible solutions for particular regions.

2. **Horn of Africa Risk Transfer for Adaptation (HARITA)** is a parametric insurance scheme that brings together climate change risk mitigation and crop insurance for farmers and has been rolled out in five communities in Northern Ethiopia. Underwritten by a local company, and reinsured by a global reinsurer, it uses a rainfall index to trigger compensation for farmers growing the Ethiopian three staple grain crops in case of drought. It is unique, however, in allowing farmers to pay for their premiums through labour on projects that will mitigate the effect of climate change in their area, such as tree planting. To turn the labour into monetary value, the scheme takes advantage of a national government “cash for work” programme, which enables it to reach the most vulnerable farmers. HARITA therefore integrates insurance with both risk reduction and credit provision. By allowing very vulnerable farmers to pay their premiums through risk-reducing labour, farmers benefit even when there is no payout because these risk reduction activities will help minimise vulnerability to drought and improve yields. Lack of cash is the main reason that people do not participate in insurance schemes. Using this government national cash for work programme is a way to address this issue and to scale up the size of the programme. Cash-paying farmers also participate in the programme, advancing market development. The programme will roll out to the Tigray region in 2011. Nationally about eight million farmers are beneficiaries of the cash-for-work safety net.

3. **Weather insurance in Malawi.** The value of data collection in the establishment of insurance mechanisms is well demonstrated by a project in Malawi. A combination of sufficient weather stations and start-up assistance helped by the World Bank and World Food Programme helped start a pilot weather insurance project. The insurance pilot bundles loans and insurance for nearly 1,000 smallholder farmers enabling them to buy affordable index-based drought insurance. The insurance is linked to loans and both improve the creditworthiness of participating farmers and enable them to increase their farm productivity. A challenge with such initiatives tends to be scalability: current schemes tend to cover only a few hundred or thousand farmers but with government assistance this could be scaled up. An initiative in India launched in 2007 offered insurance with crop loans and was taken up by 700,000 farmers.

4. **Index-based insurance to promote climate resilience in Bolivia.** An insurance scheme has been developed in four provinces in the north and central Altiplano regions of Bolivia that combines incentives for proactive risk reduction and an insurance index mechanism. In this scheme the index is based on the production levels of reference plots of farmland in areas which are geographically similar in terms of temperature, precipitation, humidity, and type of soil. A group of farmers identify a peer who is considered to use the best available methods. That farmer serves as a technical assistance agent to help other farmers reduce their risks and improve their yields. The system encourages other farmers to match the reference farmers in implementing risk reduction efforts to reduce the effects of drought, excess rains, hailstorms and frost. The reference farmer’s land becomes the reference plot, the yields from which serve as an indicator of whether production levels

have been adversely affected by environmental factors (triggering an insurance payout) or by other factors within the farmer's control. The objective becomes to perform or outperform the reference plot by improving agricultural practices and reducing risk of damage from weather hazards.

Based on the discussion above, it is recognised that Malawi is some way from being able to implement an effective flood insurance scheme to be used as a financial instrument for influencing how people utilise the floodplain. However, flood insurance should be considered further as a future flood risk management instrument (and a means of off-setting the need to access relief/donor funds following flooding disasters). If eventually found to be viable and implement able in Malawi it is likely that either a single flood insurance zone will be defined within which insurance will be available at different rates (defined by different depths of flooding as is done in the US), or a number of insurance zones will be defined based on the probability of flooding. The flood maps developed as part of this project will be available for delineating flood insurance zones in the future.

4.5.2. Flood resilient development

Zoning development away from the highest risk areas, and following the landuse designations for each flood zone should reduce the damages to property and the loss of life experienced during flooding. However, where inappropriate development already exists in high risk areas (and where relocation is not an option), or where future development within high risk zones is essential (e.g. critical infrastructure in the functional floodplain), it will be necessary to ensure that the developments are made resilient to flooding as far as possible.

Flood-resilient buildings are designed to reduce the consequences of flooding and facilitate recovery from the effects of flooding sooner than conventional buildings. This may be achieved through the use of water-resistant materials for floors, walls and fixtures and the siting of electrical controls, cables and appliances at a higher than normal level. It also includes raising the floor levels above the predicted flood level. If the lowest floor level is raised above the predicted flood level, consideration must be given to providing access for those with restricted mobility. Raising floor levels above flood levels is widely practiced in parts of the developing world as a means of building in flood resilience (e.g. building houses on stilts as is widely done in parts of Asia and Central America). It also includes raising the levels of sanitation infrastructure such as latrine pits and water wells to avoid the spread of disease during and after floods. It also includes, the protection of food and grain to minimise the impact on the communities' ability to feed themselves during and after floods. Some flood resilience is already practised by the communities of the Shire basin such as the location of community grain store above flood levels. In considering appropriate flood resilience measures, it will be necessary to plan for specific circumstances and have a clear understanding of the mechanisms that lead to flooding locally.

We suggest that, under the Action Plan, a study should be undertaken, to identify existing flood resilience measures that are traditionally practised in Malawi, as well as taking from international best practice, made appropriate to Malawi, and these should be collated into a best practice guide to building flood resilience. This will act as a guide to communities living in the flood risk areas, as well as donor and NGO communities undertaking development work in these communities, to ensure that flood resilience is being built in where appropriate. This guidance could eventually be incorporated into building regulations for Malawi.

4.5.3. Appropriate Floodplain Cultivation – Floodplain Agro-forestry

The floodplains of the Shire river basin support a large percentage of largely subsistence agricultural activities which are disrupted and which incur losses when flooded. In general, seasonal floodplains retain water for months at a time, largely during the wet and post-wet seasons.

Extensive flood damages to floodplain cropland and the associated infrastructure are preventable with strategic agricultural practises including seasonal agriculture, designated cattle grazing and rearing pastures and agro-forestry. Major forms of damage that can be addressed by strategic management of agricultural activity include flooding, debris accumulation, scour erosion, and sand deposition. Historically, trees performed some important functions and their presence in the river floodplains significantly influenced the floodplain landscapes farmed today. Woody vegetation stabilized the soil and controlled scour erosion. Stands of trees absorbed the energy from floodwaters and caused the deposition of water borne sediments. Floodplain forests stored the overflow waters and drove many of the processes to support aquatic life systems and improve water quality. Woody vegetation on floodplains causes significant reductions in flow velocity and improves flood conveyance. Scour erosion is controlled by the dense mat of intertwined, fibrous roots that reinforce the top layers of soil in the forest floor. Trees develop root systems that can extend horizontal distances of up to 2 times tree height and the soil below the forest floor will contain the intermingled roots of several different trees. Some agro-forestry systems with specific application to floodplains include windbreaks to stabilize sandy soils, filter strips and riparian areas for bank stabilization and water quality, alley cropping for enhanced crop production and protection, wildlife habitat, woodlots and fuelwood plantations. Tree species adapted to the floodplains include species valued for their lumber, and those valued for their crop value such as nuts.

Given the challenges of balancing flood risk management and agricultural and economic activity in the Shire basin there is a clear need to promote multiple-use of the floodplain to maximise productivity of the floodplain, as well as environmental and ecological enhancement and avoidance of flood damage to crops and livestock. A range of innovative techniques (such as biotechnology) combined with integrated farm-level management can be employed to reduce exposure. These can be done as community-based initiatives to ensure multiple and seasonal floodplain use approaches to enhance the social and ecological resilience of the floodplain.

There are examples of some activities in this direction already taking place and Malawi and in the Shire basin specifically. Irish Aid has just completed a tree planting project in the Shire basin. Seedlings are generated in nurseries (Makoka Research Centre, Zomba, and Bvumbe in Blantyre) using donor funding and then the farmer is given guidance on planting etc. Some of these trees can yield benefits within one year.

The Department of Forestry has a number of recent and current projects which started in 1996 whereby the government provides seedlings for reforestation and catchment improvement for 2 farmers per district with 2 farmers being added per year per district. The government also provides guidance and support to farmers for reforestation activities.

In addition, a JICA project (COVAMS) in the Middle Shire has developed a system of “Training of Trainers” to train farmers and the communities. This enables knowledge to be easily disseminated and encourages the farmers to take responsibility. This project is soon to be followed by COVAMS II which is a small project with similar aims. Others larger programs are supported by EU (forestry program), MCC/MCA (in upper Shire), UNDP/GEF, USAID and DFID through NGOs on resilience programs.

There is a legislated requirement in the Forestry Act and elsewhere to formalise the agreement between the Govt and local communities for forestry management activities etc., which importantly, empowers the local communities to develop their own by-laws and management plans that are workable at a local level.

These activities that are already taking place are a good start, but they lack coordination and can benefit from a strategic approach that enables better scaling up. We suggest that Malawi-appropriate floodplain agro-forestry, seasonal cultivation and designated cattle grazing methods and systems should be investigated further, taking into consideration, all of the possible alternatives of maintaining productive agriculture. This should be done to strengthen existing and ongoing catchment improvement studies and should be undertaken as part of the Action Plan. The Shire River Basin Management Program will address inter-ministerial collaboration on catchment level planning, and basin level M&E of catchment management interventions, erosion and the state of the basin and will therefore directly result in improved forestry and agro-forestry for flood management.

4.6. Emergency Planning

Emergency Planning and response is one of the key elements of the flood preparedness and response and will be supported by flood forecasting and early warning. Under the project the Terms of reference for a FFEWS has been prepared and will form the basis of emergency response on the basin. This section discusses how the flood mapping can be used to assist in development of emergency plans for effective response during a flood disaster.

The actual response to an emergency might be multifaceted and time dependent. It may comprise evacuation or operation of flood defences (closure of flood gates), or returning population to the affected area after the event has passed. The best way to achieve an evacuation is to involve the people that live in areas at risk in the planning process. Here we suggest two main activities: public awareness and education campaigns and simulation exercises. Evacuation should be planned for all the areas susceptible to flooding. Information about number and vulnerability class of inhabitants (e.g., elderly communities), roads, and exact delimitation of the flood zones must be readily available. Another important point regarding evacuation is the need to include it in the legislation and the need to establish specific limits of the areas to be evacuated. Returning the population to evacuated areas must be a decision based on the conditions of the evacuated area as they were at least before the threat or impact of the hazard: safety, no-more risk-present, services operating (electricity, water supply, etc.). The decision to return to the evacuated area must be based on the advice of organisations responsible for damage assessment, public utilities, and security/evacuation.

Flood zone maps will be used to develop emergency plans by defining which zones are likely to need evacuating and in what order. Hence emergency responders will have maps which will outline communities to be evacuated during an event of a given return period. This is likely to be based on the depth of flooding and the likely hazard that will occur in the affected areas. Such emergency maps will be developed once the modelling has been updated, and in consultation with national and local contingency planners and emergency responders.

In addition to a definition of the flood zones, emergency planning requires information on flood risk such as:

- *Time of first inundation* at given locations (or the time of the start of flooding at given locations). Knowledge of the time of the start of inundation relative to the start of the rainfall event, will provide some warning time to help people prepare for the onset of flooding. Including moving themselves and valuables to higher ground before the arrival of the peak water level.
- *Time of peak inundation* at given locations. Knowledge of the time of peak water level relative to the start of the rainfall event (or relative to the start of inundation), will also provide people with additional warning time get themselves to safety. It also provides emergency responders with a lead time for accessing the affected areas and performing rescues before floods peak.
- *Duration of peak water levels* (or rate of fall of peak levels) to determine when the evacuated population can be expected to be returned to the area (the duration of peak flood levels is important in determining how long alternative shelter will be needed, how much food and other supplies will be needed etc.).
- *Hazard in given locations*. Hazard values at given locations will provide people and the emergency services with information on localised hazards during rescues. It also provides information on the types of people and vehicles that can traverse a particular area. For example, hazard will provide information of whether it is unsafe for old people and children, but safe otherwise. In addition, a given hazard that might be fatal to people on foot but might be safe to rescue vehicles. Such distinctions are important in identifying safe access and egress routes (defined by hazard along roads etc.). Knowledge of hazard values can enable the definition of access and egress routes along low hazard routes to enable people and emergency responders to safely get around and out of the inundated area.
- *Location of critical infrastructure* and vulnerable user groups (e.g. schools, hospitals etc.) and risk of inundation of such infrastructure. Importantly, hazard values at critical infrastructure such as road bridges will also provide planners with knowledge of secondary risks such as breaching or collapse of infrastructure.
- *Predicted depth of flooding*. This information is also important in helping the emergency services to plan their response. It is also helpful in informing the public of the impending danger.

The flood and hazard maps are useful in developing emergency plans and can provide information on flood extent, time of first inundation and time of peak inundation and duration of peak inundation, and depth of flooding at individual cells within the floodplain. In addition to showing the flood outline, Figure 4-2 shows the time of first inundation at key locations along the flooded area while Figure 4-3 shows time of peak inundation, as colour coded classified times. Hence red is 0-3 hours, orange is 3-6 hours, yellow is 6-12 hours, light green is 12-24 hours and dark green is greater than 24 hours. This information can be used directly by emergency planners to plan how they access areas for rescue. In addition, hazard maps (as provided in Appendix B), can be used to determine and plan access and egress routes for each event.

Flood outline and hazard maps can also be used for raising public awareness by making the maps available to the public with location specific information about flood risk in their areas, such as time of flood arrival, (and hence time for evacuation), safe egress routes for evacuation, along with information on how to prepare to take action including evacuation. Mapping information can be disseminated via the internet, by flyers and information packs provided to individuals, or by posting location-specific flood maps and information in community centres. Another way in which flood mapping and flood zones can be used in emergency planning is to translate the flood outlines into concrete, visible markers in the ground that indicates zones of given flood return period.

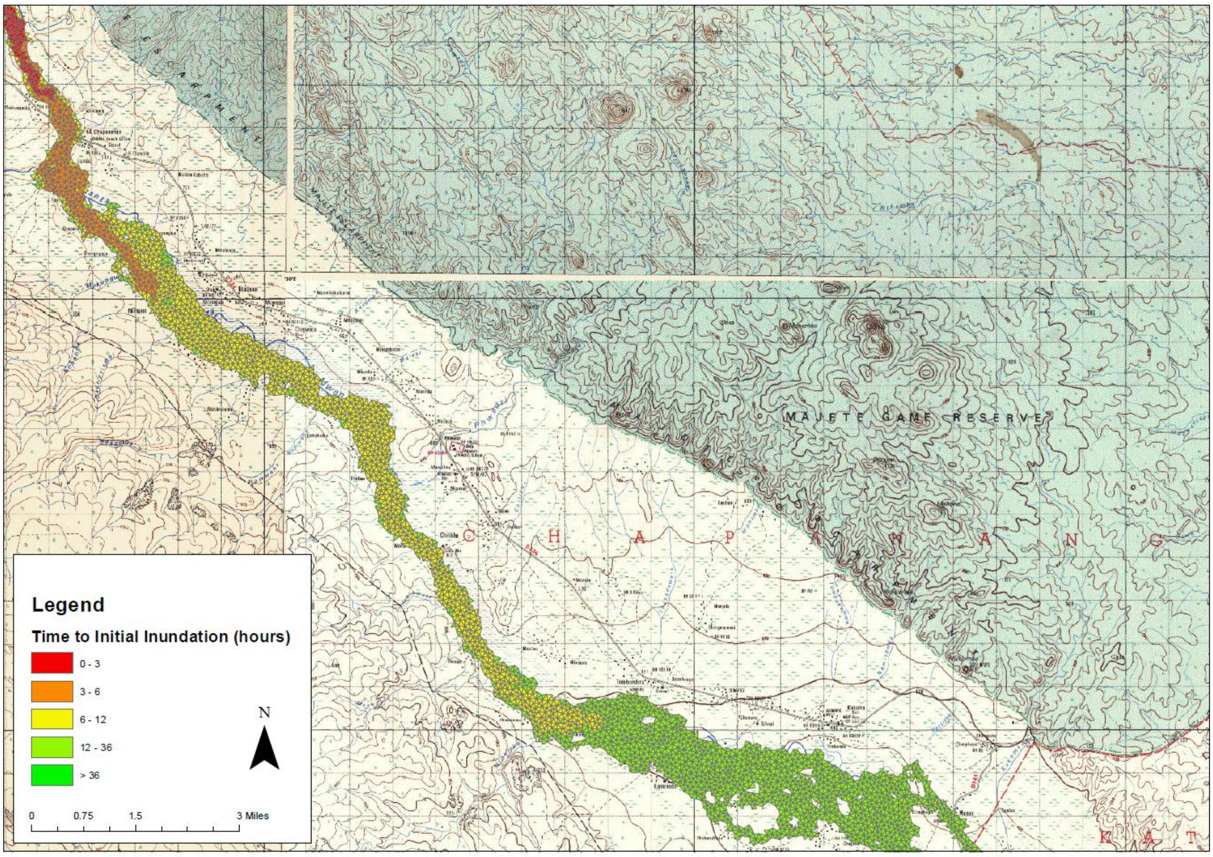

Figure 4-2: Time of Initial inundation along the Mwanza river

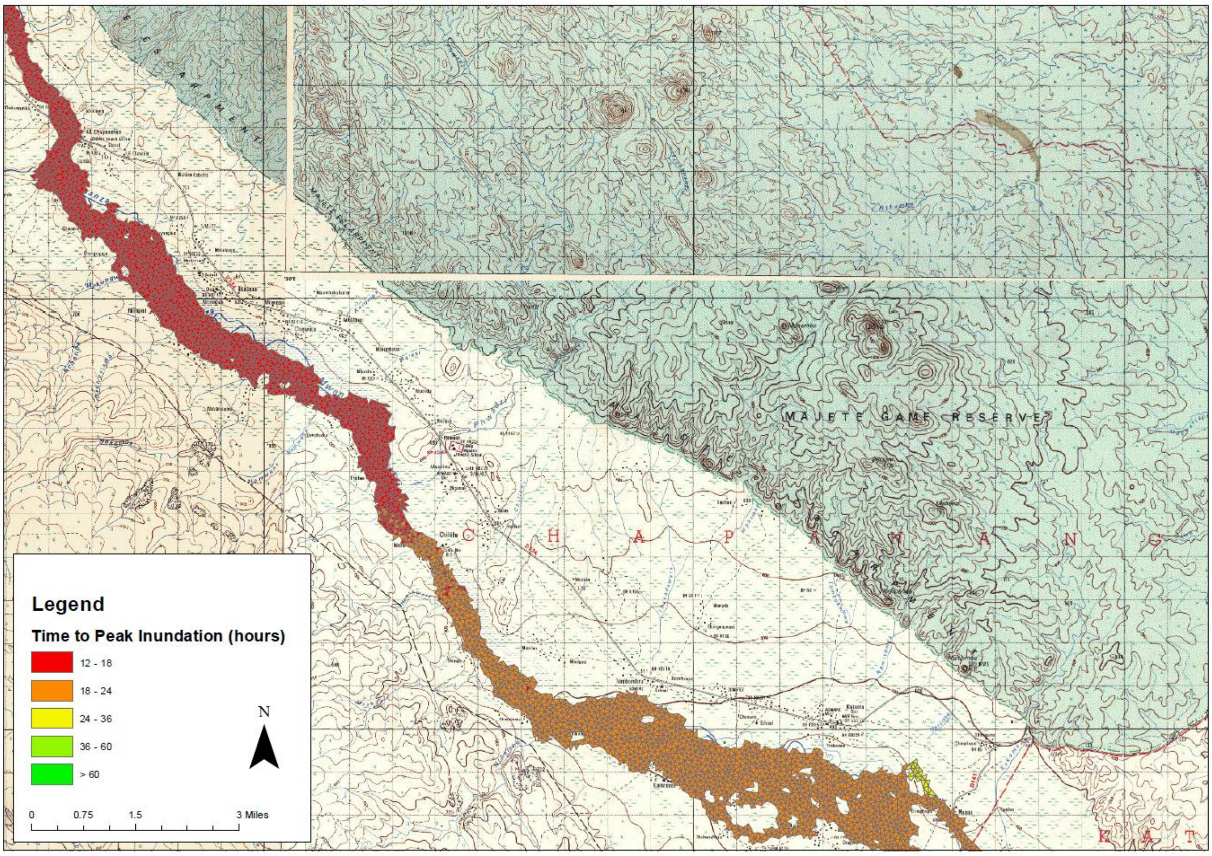

Figure 4-3: Time of peak water level for Mwanza River

5. Flood Forecasting & Early Warning

5.1. Present system

Flood warnings provide people with the opportunity to move to safety in advance of flooding, and to protect property, food stocks and livestock. Impacts on health and livelihoods can also potentially be reduced. As noted in the Interim Report, a number of flood warning systems are currently operated in the Shire Basin consisting of ministry, community-based and privately operated schemes.

At a ministry level, the “Flood Warning System for the Lower Shire Valley” has been operated by MWDI for several decades. In its current form, this makes use of rainfall observations and forecasts from DCCMS for an initial alert together with manual observations of river levels at the following four gauges in the Lower Shire basin: Ruo at Sandama (14D3); Ruo at Sinoya (14D1); Shire at Chiromo (1G1); and the Shire at Chikwawa (1L12). Information from the river gauges is relayed manually by gauge observers by cell phone, and warnings are issued based on a four-stage alert system using pre-defined threshold values. Section 6 describes the institutional and procedural aspects of this system and the current operational status.

In recent years, community-based schemes have also been established on the Mwanza and Lalanje rivers in Chikwawa District by District officers in collaboration with the Evangelical Association of Malawi and Christian Aid. For example, the scheme on the Mwanza was established in 2009 with technical support from MWDI, DCCMS and DNRDM plus additional training from the Red Cross and Area extension officers. Due to sedimentation in the lower reaches, the flood risk has been significantly increased on this river in recent decades, with one interviewee suggesting that floods occur up to 2-3 times per month in some villages during the flood season.

The main tasks in developing the Mwanza scheme included installation of manually operated rain gauges and colour-coded river level gauges in the lower, middle and upper reaches of the catchment, and provision of megaphones, protective equipment and cell phones with chargers to Village Civil Protection Committee (VCPC) members. The project also provided training in techniques for gauge reading, communications and search and rescue, the development of a flood response plan, and included training for Area Civil Protection Committee (ACPC) representatives, with approximately 120 volunteers receiving training. During a flood event, rainfall and river level observations are relayed to colleagues downstream and warnings are issued by megaphone and using more traditional methods such as flags and whistles. A temporary grain store was also constructed in the Lower Mwanza to protect food stocks from being damaged by flooding.

The Mwanza scheme was cited at the project inception workshops held in December 2011 as a good example to follow more widely in the Shire Basin, and it is understood that some other non-governmental organisations (in particular Irish Aid) may be planning further schemes of this type. More generally, some private sector organisations also have flood warning arrangements and flood response plans in place for staff and equipment; most notably Illovo and Escom.

During the course of the project it also became apparent that several other initiatives underway nationally or regionally include components which are relevant to improving the flood warning service in the Shire Basin, and these include the following studies:

- Southern Africa Regional Flash Flood Guidance system (SARFFG)
- SADC HYCOS
- Weather Risk Insurance for Small Farmers in Malawi
- Zambezi Flood Forecasting and Early Warning project (Zambezi FFEWS)
- Establishment of a Water Resources Monitoring System in Malawi
- AAP Climate change direct community systems for flood warning at District level

The key features of these projects are summarised in the FFEWS ToR presented in Appendix C. More generally, DCCMS are also responsible for providing Severe Weather Warnings, Heavy Rainfall warnings and Tropical Cyclone warnings nationally. These are based on weather station and satellite observations, regional weather forecasts based on an ensemble of global model outputs and a regional model for the SADC region, forecasts from the Tropical Cyclone Project Centre at La Reunion, and a locally operated mesoscale model.

Although no longer in operation, it is worth mentioning the UNDP/WMO “Flood Forecasting and Warning System for the Lower Shire” project (UNDP/WMO Project MLW/88/011), which started operation in the late

1980s and continued up until about 1994. This included the installation of telemetry equipment at 8 river gauges in the Lower Shire and the Ruo catchment and about 10 rain gauges in and around the Ruo catchment, some of which were located at river gauges. Rainfall-runoff forecasting models were also developed using the Swedish Meteorological and Hydrological Institute HBV modelling software although it is understood that they were not implemented operationally. Further background on this project was requested but could not be located within the timescale of this project. However informal discussions suggest that the system stopped operation due to issues with landline telemetry, training, and support and maintenance for equipment.

5.2. Data Collection for FFEWS

To help in developing the overall concept for improvements to flood warning in the Shire Basin, where possible information was collected on these existing and proposed systems, and views were sought from a wide cross section of organisations. Some key stages in this data collection exercise included:

5.2.1. Hydrological analyses

Some initial analyses were performed of rainfall distributions during flood events, the time delays between rainfall and peak flows, and the time taken for flood waves to pass between key points in the basin. This was to provide a better understanding of the technical constraints on issuing flood warnings. However the extent of this work was severely limited due to the lack of sub-daily rainfall data for the Shire Basin which was only made available after the exercise was completed. Hence these analyses will need to be updated using sub-daily data as part of the detailed design studies.

5.2.2. Review of existing systems

An in-depth review was completed on the institutional and technical aspects of current flood warning arrangements in the Shire Basin and is described in Section 6. This included reviews of reports, consultation meetings, an institutional assessment of stakeholders concerned with flood warning, and a simple “role-play” flood warning exercise involving staff from MWDI, DCCMS and DNRDM.

5.2.3. Site visits to gauges

In collaboration with staff from MWDI and DCCMS, visits were made during May 2012 to approximately 10 river gauge and 10 raingauge locations in the Shire and Ruo basins to provide more information on the current operational status of gauges.

5.2.4. Stakeholder consultations

Discussions were held with representatives from organisations involved both in delivering the existing flood warning service in the Shire Basin, at ministry, district and community level, plus a selection of NGOs, community representatives, private sector organisations and individuals who require (or already receive) a flood warning service (see Appendix D). Meetings were also held with MACRA and Airtel regarding radio and cellular based communications in the Shire Basin.

Presentations on key findings and proposals for improvements to the flood warning service were made at the Inception (national, district) and Interim workshops. At the inception workshops, this included breakout sessions with a cross-section of national, district, NGO and other staff to seek views on how flood warning arrangements could be improved in the Shire Basin.

The stakeholder consultations were a particularly important aspect of this work and consisted of a combination of one-to-one technical meetings, group sessions and workshops, and site visits to the Mwanza flood warning scheme and other locations. Flood warning issues (current performance, requirements) were also discussed at the District Executive Committee (DEC) meetings. The topics considered included current institutional arrangements for providing flood warnings in the Shire Basin, technical issues such as telecommunications, dissemination of flood warnings, and river telemetry, and end user requirements for flood warnings (formats, lead times, delivery mechanisms etc.). Joint planning meetings were also held in December 2011, February 2012 and May 2012 with representatives from the three key organisations responsible for providing a flood warning service in the Shire Basin - MWDI, DCCMS and DNRDM - and were facilitated by representatives from the World Bank. These meetings provided the opportunity to obtain feedback on the proposals for flood warning improvements at key stages during the project, and additional ideas for implementation.

These various discussions and reviews provided a considerable amount of valuable information to assist with developing proposals for improvements to the flood warning service; for example, some key feedback regarding the improved system included:

- The identification of existing and planned initiatives will avoid duplication of effort
- The need to improve the flow of information available at national level to District-level and communities – river levels, rainfall, forecasts, warnings
- Some issues with delays and problems with communications during flood events, particularly for issuing warnings
- A wish for wider implementation of community-based schemes, which could also provide useful data/information to DNRDM, MWDI and Met Services nationally
- The need for the 'bigger picture' and wider situational awareness that could be provided by a centrally based system (rainfall, river levels etc.) e.g. information on Shire levels
- Training, capacity building, guidelines and monitoring and evaluation are important for any new techniques and systems which are introduced
- Suggestions for a range of technical solutions that could possibly be considered
- A number of other issues which require consideration e.g. communications costs during emergencies, payments to river gauge readers, vandalism of river gauges

The desire for sustainability of systems and the need for community involvement were also mentioned at most meetings.

However, as noted earlier documentation on the UNDP/WMO "Flood Forecasting and Warning System for the Lower Shire" project, and sub-daily rainfall data for key rain gauge sites in the Shire Basin, particularly in the Ruo and Lower Shire catchments, could not be made available within the timescale of the project and will need to be obtained as part of future studies (if possible).

5.3. Improved Flood Warning Service

The main aim of the 'Flood Forecasting & Early Warning' component (or FFEWS) was to develop a Terms of Reference (ToR) for the detailed design and implementation of an improved flood warning service in the Shire Basin, with a focus on the Lower Shire and Lower Ruo areas. That is to: "…..*develop a ToR for consultancy services (on detailed design, software development and testing, installation, and facilitation of roll-out of the flood forecasting and early warning system, and institutional capacity building on the same), as well as specified list of hardware requirements (to be finalized by the subsequent consultancy)."* The project specification also noted that *"The present forecasting system, based on a simple procedure of manually reading rainfall and water levels, will need to be professionalized".*

In developing the ToR, a range of options was considered, from procedural improvements to the existing manually-based approaches to a basin-wide decision support system[2] covering multiple applications (water supply, irrigation, hydropower, flood warning etc.). The Interim Report for this project also discusses the range of technical options considered in developing the proposed approach. These various choices were discussed at the workshops and joint planning meetings and in discussions within individual stakeholders, and the following general principles were established to guide development of the ToR:

- The focus should be on building technical and institutional capacity at all levels (national, district, community) introducing new technology as skills and resources permit
- The requirement is not for a single flood forecasting and early warning system, but rather for an integrated set of community-based, district and national level approaches – both manually operated and automated - with well-defined procedures for exchanging information and clearly defined roles and responsibilities
- The present manually-based approach to data transmission needs to be improved to support flood forecasting applications. An improved data transmission approach needs to enable real-time data to be acquired from gauges, and shared between the key government departments (DCCMS, MWDI and DNRDM in real time, and more widely in the basin (data sharing locally between communities to enhance regional flood warning). In addition, upgrading of manual observations to telemetered real

[2] Since the present project started, a proposal for a basin planning decision support system has now been included in Component A of the Shire RBMP, and would include refined versions of the flood forecasting tools developed as part of 5-year project described in the ToR

time observations will reduce the risks to observers during flood events (flood waters, night-time operation, snakes, crocodiles etc.). A centralised telemetry system on the scale of the UNDP/WMO system from the 1990s is desirable
- There are many planned and ongoing initiatives which provide opportunities to accelerate development of an improved flood warning service but which also present risks of duplication of effort
- The fast response of tributaries of the Shire (including the Ruo) means that an around-the-clock (24/7) service will need to be operated during flood events, involving all key participants in the flood warning process

The Terms of Reference developed in this project for the detailed design of the FFEWS therefore attempt to take account of these factors, and the following title is proposed for the detailed design study to reflect both the change in emphasis away from provision of a single system, and that the study should build on existing systems (rather than starting anew):

"Consultancy services for the detailed design and implementation of improvements to the flood warning and forecasting service in the Shire Basin"

In particular, the focus is on provision of an improved service to communities, with strong community involvement, defined standards of service, up-to-date and tested flood response plans, and routine performance monitoring and post-event reporting. In the disaster management literature, this is often termed a 'people-centred' or 'end-to-end' approach to early warning. Flood forecasting will also be a key component for some locations offering the potential to help duty officers to issue warnings earlier than would be possible based – as now - on observations alone. As a general principle, wherever appropriate, a risk-based approach, should be adopted in deciding where to focus investment and staff resources (ministry, district, community), depending on the level of flood risk.

Some additional benefits could potentially include:

- Developing procedures and systems to lay the foundations for developing a national flood warning service in future
- Provision of quality-controlled real-time and archived river and rainfall records which will be of use in other applications
- Developing methods and skills to contribute towards development of the wider Operational Decision Support System to be developed as part of the Shire River Basin Management Plan
- Contributing to wider public engagement and understanding of the causes of floods and how to reduce the risk from flooding to people, livestock, food stocks and property
- Providing some components to form a starting point (or pilot study) for a wider all-hazards emergency communications network and website

Although deciding on the warning messages and procedures to use forms part of the scope of the ToR, in general terms it is envisaged that the following staged approach will be used in the improved FFEWS system to be provided:

- Heavy Rainfall Warnings – to provide an initial 'heads-up' alert allowing district authorities and community leaders to make initial preparations from hours to a day or more ahead
- Flood alerts – generalised warnings of an increased flood risk along the Lower Shire and Lower Ruo (which is the current approach)
- Flash Flood Guidance – alerts for flash flood prone tributaries within the SARFFG project, typically for 3-6 hours ahead at a spatial scale of 100-300km^2
- Site-specific warnings – more specific warnings to communities of the likely timing duration, magnitude and extent of flooding for sites where suitable telemetry observations are available, primarily on the Lower Shire and Lower Ruo and selected tributaries

The need to develop institutional capacity at national, district and community level is central to the successful future operation of the improved service. In particular, long-term financial support from government sources is crucial in a number of areas, such as in staff to operate telemetry and warning dissemination systems (including site maintenance visits), to provide salaries and training for gauge observers, to provide the resources and computer and other support for 24/7 operations during flood events, and in capacity building at community and district level for improving the effectiveness of flood warnings which are provided.

Figure 5-1 presents the basic elements of a FFEWS system, and Figure 5-2 shows the present set up in Malawi. More generally, mapping and analysis of the present Institutional Framework generated the following observations:

- No institution is presently responsible for populating and maintaining a single database which can provide an adequate platform to improve flood forecasting and warning
- All institutions remarked that the quality of all forms of data available should be improved (real-time river level and rainfall, weather forecast, historic records).
- Analysis of river level data to provide a warning is presently based on 2005/6 manual threshold rules. These could be improved and rules specific to particular tributaries and communities developed – building upon the capacity and lead by MWDI.
- There is no flood forecasting modelling at present – interpretation of data is largely based on a qualitative decision based upon past flood conditions. Capacity building to support and utilise improved modelling is a critical requirement.
- Warnings are presently general in nature, but this is due mainly to the absence of sufficient data and forecasting tools. A future warning system should integrate all actors and institutions to enable them to play a clearly defined role in a “common” and more effective system.
- The present river gauging system is heavily degraded and reliance on it is a risk in itself. These institutional and capacity constraints must be overcome in any future system.
- The present rules for issuing a warning are by their design inherently slow. Full use of up–to-date communication technology is not employed. Warnings generally arrive too late. However these rules and systems can readily be updated. Institutional responsibilities for warning and dissemination should be clearly defined within a future system using new technology.
- Community based systems exist and work, but they could be usefully expanded and integrated as part of a national system. Improved institutional integration is necessary.

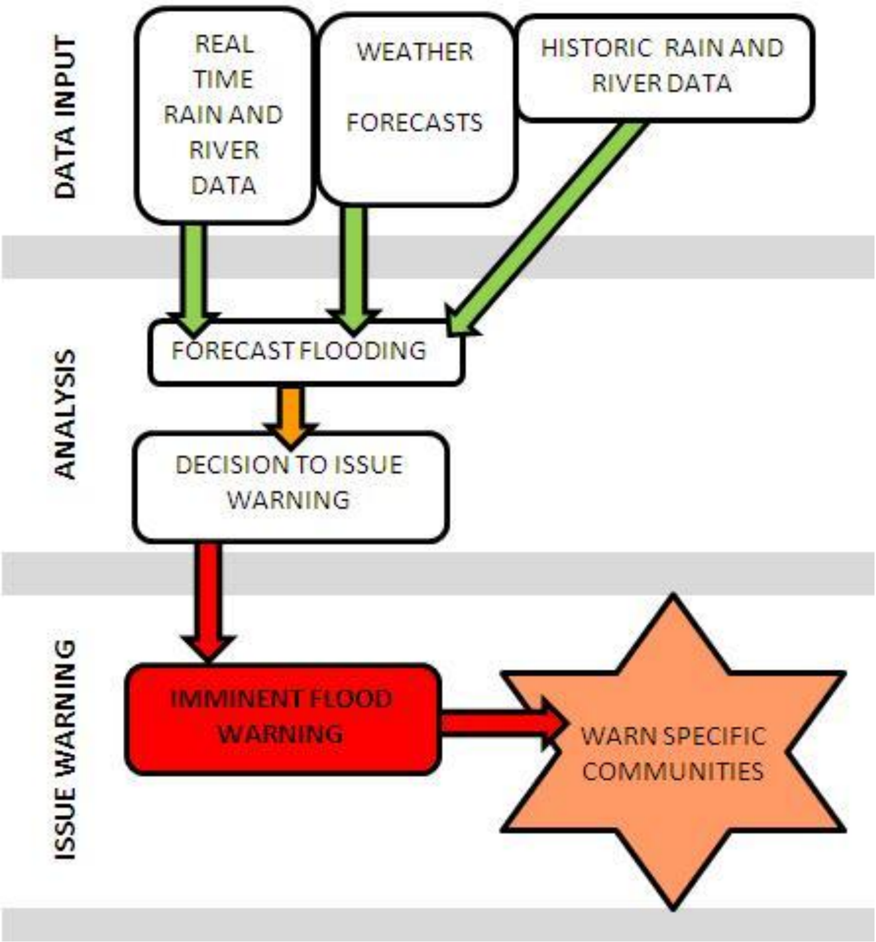

Figure 5-1: Basic Elements of a FFEWS

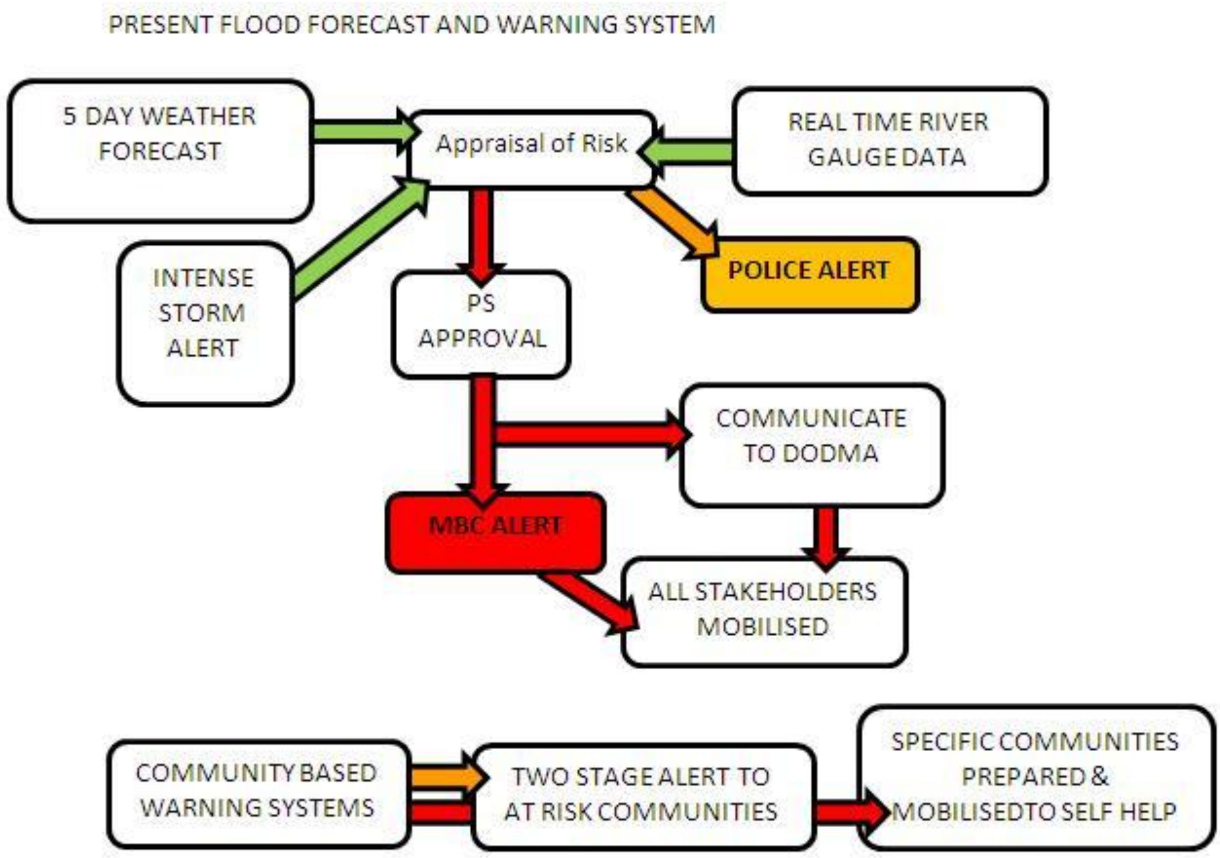

Figure 5-2: Present FFEWS in Malawi

Appendix C presents the proposed Terms of Reference for the detailed design and implementation of the improved flood warning service, and associated programme for implementation. This work is intended to be implemented during the 5-year period of the Action Plan proposed as part of this report. During that period proposals for follow-on funding will need to be made and funding secured if the system is to be sustainable beyond that period; for example as part of the wider Shire River Basin Management Plan (SRBMP). In particular, the Project Appraisal Document for the SRBMP notes that one of six key triggers for moving from the first to second phase of the 15 year program is for an "Effective flood early warning system operational in the Lower Shire".

The Terms of Reference propose that – following a tendering procedure – this work is most likely to be awarded to a consortium consisting of an international consultant in association with one or more non-governmental organisations with extensive experience in early warning systems and of community-based initiatives in Malawi, and a local contractor for site works.

The key tasks to be performed are summarised in Table 5-1 and, as indicated, additional subcontracts are envisaged for key equipment and some additional services, including annually-renewable support and maintenance contracts from equipment suppliers. The main subcontracts will be for river level gauges and raingauges and specialist communications and other equipment to support operations in MWDI, DCCMS and DNRDM. Also, following implementation of one scheme to develop best practice, it is envisaged that the implementation of additional community-based schemes would be awarded to one or more NGO/contractor groups.

The requirements will be developed by the consortium in collaboration with MWDI and others, guided by the indicative costs which appear for these items in the Action Plan. Any resulting subcontracts will be awarded by MWDI based on advice provided by the consortium on detailed design, specifications, and procurement procedures, with subsequent contract supervision, training and guidance from the consortium for the balance of the 5-year period.

Table 5-1: Summary of key tasks in the Terms of Reference

Task	Title	Summary
1	Inception Phase	Review of available documentation from past and ongoing studies; data collection and analysis; analysis of potential overlaps/duplication with other relevant projects; structured consultations with key stakeholders; field visits to selected communities, districts, gauges; develop work plan, risk matrix and programme for main phase
2	Monitoring - river and rainfall real-time data acquisition	Assessment of gauges to be improved or provided (in accordance with these ToR); identification of equipment required; preparation of tender documentation and advice on procedures for procurement; assistance with tender review and contract award; supervision of implementation; preparation of guidance documents and procedures; training and capacity building
3	Data interpretation and procedures for issue of flood warnings	Assessment of requirements (in accordance with these ToR); recommendations for implementation; preparation of guideline documents and procedures
4	Dissemination of warnings to districts and communities	Assessment of overall requirements (in accordance with these ToR); Identification of equipment required; preparation of tender documentation and advice on procedures for procurement; assistance with tender review and contract award; supervision of implementation; preparation of guidance documents and procedures; training and capacity building
5	Establishment of Community-based flood warning schemes	**Generic:** Identification of schemes; community engagement; training and capacity building. preparation of guidance documents and procedures **Schemes:** preparation of tender documentation and advice on procedures for procurement; assistance with tender review and contract award; supervision of implementation
6	Establishment of Lower Ruo/Lower Shire flood warning scheme	Design and implementation; preparation of guidance documents and procedures; community engagement; training and capacity building
7	Development of Flood Forecasting Capability	Design and implementation; preparation of guidance documents and procedures; training and capacity building

The complete Terms of Reference are included in Appendix C.

6. Institutional Assessment

6.1. The present institutional framework

6.1.1. Mapping of Institutions concerned with Flood Risk Management in Malawi

A broad range of stakeholders have a role or an interest in flood risk management of the Shire Basin. The UNDP funded Draft Interim Operational Guidelines for Disaster Risk Management in Malawi (20110 included mapping of stakeholders with respect to risk management. Further reference to these guidelines is made in Appendix E.

For the purposes of this project we have used a simple three category system – based on international practice – to differentiate between the different stakeholders and their responsibilities with respect to flooding events. This is shown in Table 6-1.

Table 6-1: Classification of stakeholder roles and responsibilities

	Responder Categories		
	Primary Responsibility	**Secondary Responsibility**	**Tertiary Responsibility**
Responder Functions	Direct established responsibilities regarding forecasting, warning, mitigation and preparedness.	Direct responsibilities to support primary stakeholders during flood events and with preparedness activities	Direct and indirect responsibilities to support long term mitigation and preparedness efforts
Typical stakeholder identity	Government departments, emergency responders, civil protection organisations	Line ministries, multi-lateral and bilateral agencies, local government departments, some NGOs /CSOs	Line ministries, Bilateral agencies, NGOs, CSOs, local government departments and the public
Forecasting	✓		
Warning	✓		
Response in the event of a flood	✓	✓	
Preparedness for emergency response.	✓	✓	
Mitigation of flood effects	✓	✓	
Preparedness for long term response.	✓		✓
Mitigation of flood causes			✓

In our stakeholder mapping the responsibilities of stakeholders were assessed with respect to the three responder categories and are shown in Table 6-2 below.

Table 6-2: Stakeholder Mapping and responsibilities

6.2. **Primary Responsibilities:** Direct established responsibilities regarding forecasting, warning and mitigation.			
6.3. DNRDM	6.4. Ministry of Agriculture, Irrigation and Water	6.5. Dept of Climate Change and Met Services	6.6. District Councils
6.7. Traditional Authorities	6.8. Communities		
Secondary Responsibility: Direct responsibilities to support primary stakeholders during flood events and with preparedness activities			
Ministry of Transport and Public Infrastructure	Environmental Affairs Department	Dept of Resource Land Conservation	
World Bank	Dept of Forestry	Min National Defence	MoH
JICA	EU	DFID	Irish Aid
Surveys Dept	GOAL	UNDP	Oxfam
FEWSNET	Illovo Estates	Christian Aid	ESCOM
EAM	Action Aid		Malawi Red Cross
Action against Hunger	ADRA	World Vision	MVAC
Tertiary Responsibility: Direct and indirect responsibilities to support long term mitigation efforts			
FAO	Dept Physical Planning	CISANET	MFDP
MCA-Malawi	MoEST	OPC	MLGRD
LDF/MASAF	MoGCCD	Bunda college	NICE

6.9. The present institutional framework

The present roles of key institutions in flood warning, response, preparedness, recovery and mitigation were mapped and analysed and are summarised as follows:

Table 6-3: Roles of key institutions in flood warning, response, preparedness and recovery

Role	*The Malawi Disaster Risk Reduction Framework 2010-2011 definition*	MWDI	MET Services	DNRDM	Districts	Communities
8. Preparedness	The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions.	Data collection and management. Flood forecasting Develop flood warnings	Data collection and management. Weather forecasting	Lead role as defined in DNRDM Act. DNRDM should support districts to be self reliant in a flood. DNRDM should take lead role if Districts cannot cope. Ensure national level agencies are prepared	Development of district contingency plans Mobilisation and capacity development of communities Networking and resource mobilisation	Development of village contingency plans Mobilisation and capacity development of communities Participatory risk mapping and assessment Local level coordination and capacity building

25. Early warning System	The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss.	Issue flood warnings	Short term weather forecasts and intense storm warnings	Ensure that flood warnings once issued are received by affected / responsible parties. Immediate responsibility to ensure communication of information on situation and immediate needs	Ensure flood warnings reach target communities once the national centre issues a warning	Implementation of responses to floods Community-based early warning system Capacity building
36. Response	The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.	Repair of infrastructure / water supplies/ sanitation.	n/a	Communication and coordination between agencies to assess and respond	Risk assessment Delivery of relief Coordination of local response at district level Effective implementation of response	Ensure that all risk groups abide by the national warning Capacity building Vulnerability mapping Coordination of local response at community level Effective implementation of response at community level
53. Recovery	The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors.	Repair of infrastructure / water supplies/ flood defences / sanitation.	n/a	Support District to perform these tasks	Medium term Long-term flood sensitive development planning	Ensure that livelihoods adapt to floods Sustaining flood management structures at community level

The overall present institutional map is shown in Figure 6-1. The figure shows the roles of Met Services and MWDI in deriving a flood warning based upon rainfall data and weather forecasts, together with real time river gauge data. Under the present system, approval of the PS is required to issue a flood warning which is then sent to the DNRDM secretariat as well as the Malawi Broadcasting Corporation. Overall preparedness is undertaken at the strategic level through annual updates of plans via a NDPRC meeting, which is supported by 8 technical sub-committees. DNRDM has the responsibility for training in preparedness and response at the National, District and sub district levels, via a system of civil protection committees at the various levels. In addition DNRDM has responsibilities for communication, coordination and facilitation of emergency response in the event of a flood. This would extend to increasingly direct involvement in the event of a District failing to cope with the situation – or in the event of a “State of Disaster” being declared using the DNRDM Act. It is noted that at the time of preparation of this report, discussions to change to the set up shown in Figure 6-1 were at an advanced stage with regard to structures below the district level.

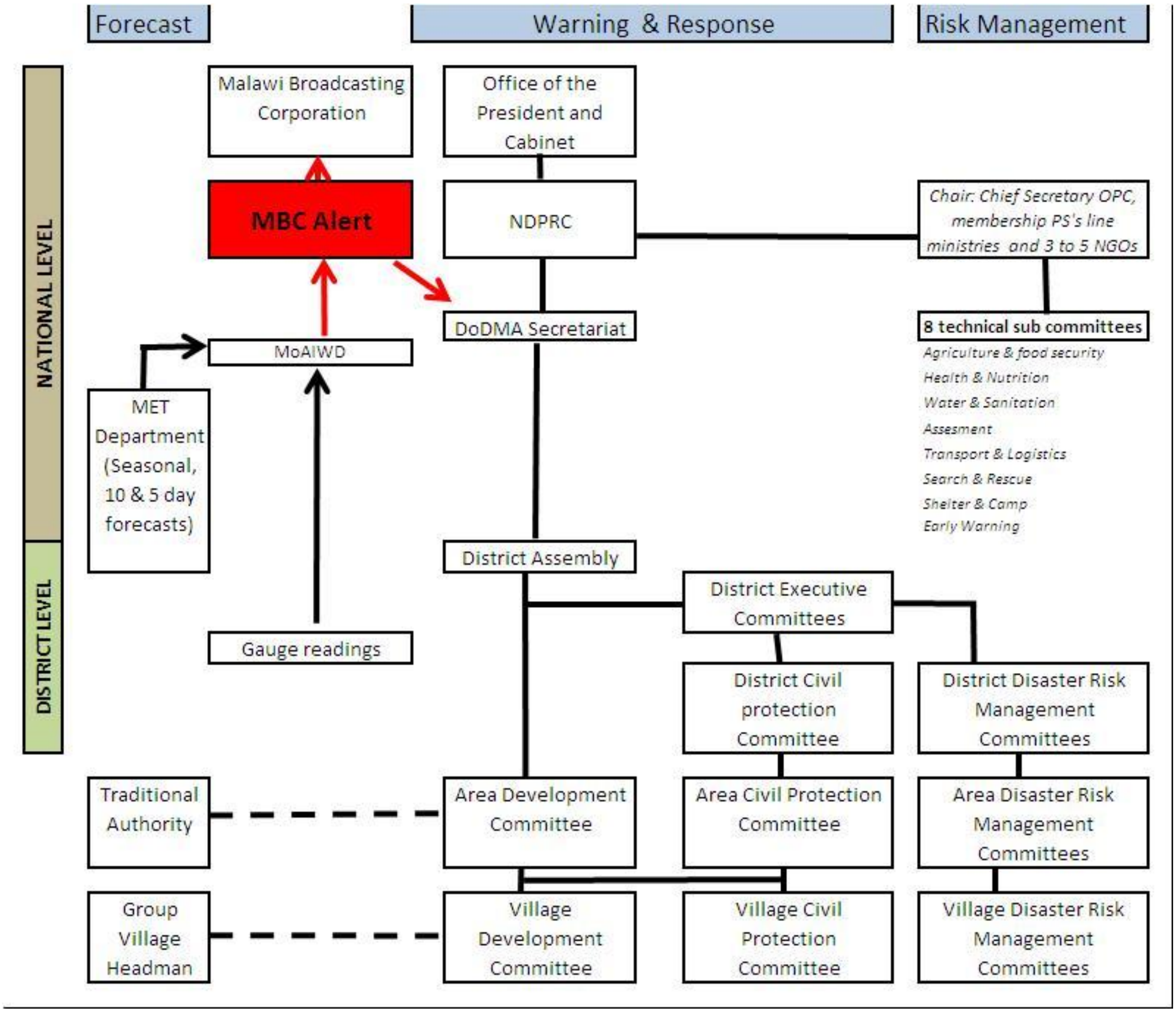

Figure 6-1: The present institutional framework

6.10. Main concerns to be addressed regarding the present institutional framework

6.10.1. MWDI

The present river real time river gauging system is heavily degraded and at best relies upon only four gauges, and the gauge reader's capacity to communicate readings to Lilongwe by cell phone. An improved river gauging system is needed. Historic data have not been compiled into a single database and are not used in flood forecasting. Flood warnings are derived manually on the basis of past experience. A set of rules developed for the Lower Shire in 2005/6 remain the basis to derive and issue a flood warning. That system is inherently slow and should be updated to incorporate modern technology and improved rules. Current design guidance for structures that may be affected by or reduce flood impact (for example culverts and flood defences) need to be updated to ensure they are resilient to changes in hydrology and geomorphology.

6.10.2. Department for Climate Change and Meteorological Services (Met)

Met Services identified the need to improve the accuracy of their forecasting – using their existing systems and staff. Improvement of the rainfall gauging network and the availability of sub-daily data are necessary. These would have a direct impact upon the accuracy of weather forecasting and reporting. Data are needed from Mozambique Met Service and a direct move towards collaboration is called for.

6.10.3. DNRDM

Developments on the ground have rendered the DNRDM Act (1991) out of date because institutions and practical response mechanisms have grown from the Act and there is now a need to have more clarity regarding responsibilities, powers and procedures in place to guide these institutions.

Whilst a core function of DNRDM as established by the Act is to provide training and capacity building such that Districts can cope in the event of floods, DNRDM is critically under resourced with regard to specialist trainers and the operational budget to deploy them.

A further core function of DNRDM is to facilitate the dissemination of flood warnings and provide communication, coordination and information management support in the event of floods. Whilst present DNRDM staff have the capacity to perform these functions, communication is dependent upon email and mobile phones. Current “standard operational procedures” are not well designed or practiced, but these could readily be improved and a programme of “internal” training developed to practise and refine their use. An example would be a standard reporting template for Districts to provide a rapid assessment on a flood.

DNRDM may also benefit from additional advisory support concerning the broader disaster related tasks under their mandate, such support could also address cross cutting improvements including long term capacity building and staffing plans, decentralised procurement strategies and assisting DNRDM to develop its “state of disaster responsibilities” – which arise when Districts become overwhelmed and DNRDM takes up direct responsibilities.

6.10.4. District Councils and other decentralised structures

The following are the main decentralised institutional issues that need to be addressed in the context of floods in the Lower Shire. The issues have been identified through consultation, review of reports, workshops/meetings and district and community visits to Chikwawa and Nsanje.

6.10.4.1. Flow of information

Although flooding is an annual occurrence in the two Districts of Chikwawa and Nsanje, communities do not receive timely information about the likelihood of flooding to allow timely relocation. This leads to losses of life, assets and livelihoods. The two districts, including the catchment areas of the Shire and its tributaries have very few weather stations, making rainfall data collection inefficient. Some rain gauges installed in strategic locations have been vandalised by the surrounding communities. Programmes to promote operations and maintenance of gauge stations by communities are not existence.

There are significant procedural delays between data collection, synthesis and communication to local communities, who have to decide in a very short period of time to relocate, pending a flood event. Yet although rainfall data is gathered at local level, there isn’t a clear system of communicating that information to the communities immediately. Instead, warnings are issued at national level, passing through a number of bureaucracies and many departments - while the flooding rivers are not waiting for decisions at national level. Processing information between numerous departments causes delays, failing to achieve the intended purpose of early warning.

6.10.4.2. Limited capacity

The few gauge stations are managed by volunteers, paid MK150 per month, yet they are undertaking a key national role. Gauge readers collect rainfall data every morning and transmit to the Department of Climate Change and Meteorological Services (DCCMS). Accessibility of the gauge and has availability of mobile phone airtime, whether there is a signal in that area during a particular time, affects the quality of data being transmitted. According to experiences from NGOs who work in the two districts, because of such delays, coupled with the local knowledge that exist within communities (which has not been tapped adequately), communities have sometimes not taken flood warnings seriously since they feel they have better knowledge of the area. The most vulnerable members of the communities are children, women, those with disabilities, the chronically ill and the elderly. Communities that live along rivers and near confluences of the Shire and its tributaries are the most vulnerable and need the warning most. It is for this reason, that during a flood event, communities evacuate children and the vulnerable first, followed by evacuation of food and later household assets. Both Chikwawa and Nsanje districts have contingency plans, but these lack funding. Except where NGOs are present in the area, most VCPC have limited capacity and do not have trained personnel within the villages who can provide support in relocation and rescue. Households rely on assistance from the district which is usually too late to save any assets.

6.10.4.3. Weak coordination with upstream districts

There is also limited coordination between districts in the neighbouring Shire Highlands districts of Blantyre, Mwanza, Thyolo and Mulanje. The Evangelical Association of Malawi initiated the South West DRR Consortium which involved NGOs and district assemblies in Chikwawa, Mwanza, Thyolo and Nsanje Districts. Best practices were disseminated through this forum and through the National Consultative Workshop which was held in 2008. However, this initiative is not currently operational due to limited funds.

6.11. Future Institutional Responsibilities

A meeting was held to discuss specific responsibilities of core stakeholders under a future Institutional framework. DNRDM, DCCMS and MWDI were represented at that meeting and a general consensus regarding future operational responsibilities was reached, as shown in Figure 6-2 below.

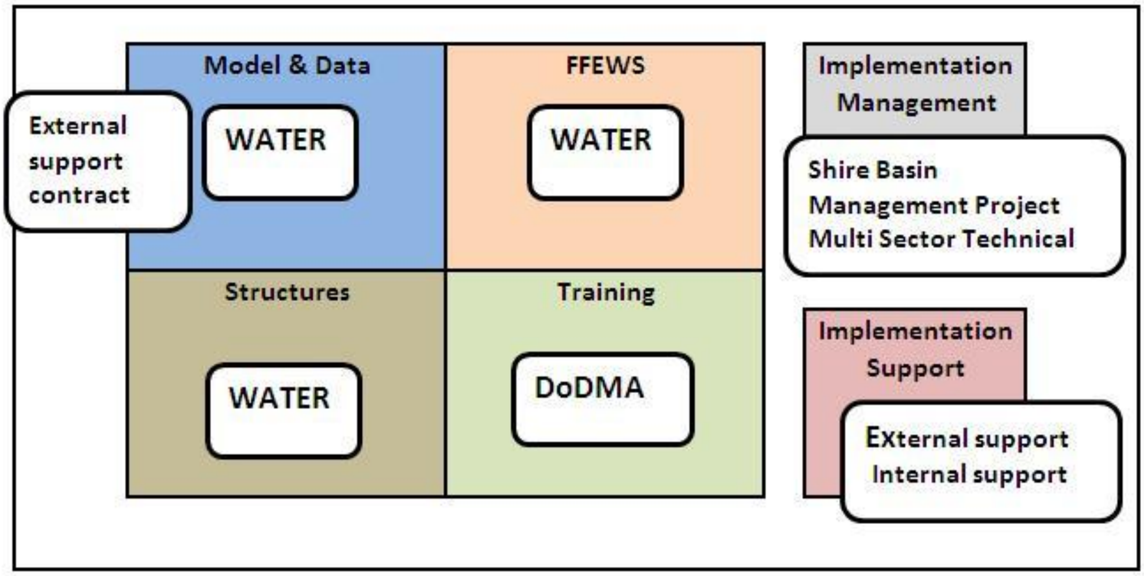

Figure 6-2: Summary of future roles and capacity building requirements for flood risk management

MWDI would have lead responsibility for managing the data platform and the modelling framework and would generate and issue flood warnings within the FFEWS. MWDI would have lead responsibility for the design / approval / implementation of any structural works which are flood related – including river bank protection. MWDI would let a support contract to outsource the maintenance, development and training necessary to ensure the model is updated, maintained and remains a viable tool.

DNRDM would have the lead responsibility for training with regard to flood preparedness, recovery and response including training on how a new FFEWS system would operate.

The overall management of interventions envisaged under an Action Plan to improve FFEWS would, in the future, most likely fall under the Shire Basin Management Project Multi Sector technical team – with a specific Programme Manager being appointed for the purpose of implementing the plan. A number of implementation support interventions would be outsourced by the Programme Manager to suppliers within and outside Malawi, as appropriate.

With respect to the Draft Interim Operational Guidelines for Disaster Risk Management in Malawi (2011) in which long term disaster risk management responsibilities for all key stakeholder organisations in Malawi have been mapped and their responsibilities presented, our stakeholder mapping and analysis points to a very important long term requirement, which will have to be addressed in the short term if headway is to be made in protecting the catchments in the Shire Basin. Past and on-going human impacts on the catchments, environment and hydrology of the Shire Basin are a major factor impacting upon the severity of flooding in the basin. Remedial measures will take considerable time to have an effect – as these will involve forestation, intensive land husbandry and land use controls to be in place and coordinated. As part of the Action Plan, provision has been made to initiate close and focussed cooperation between the key governmental and civil society organisations responsible and concerned with catchment management. It is anticipated that the future SBMP will spearhead practical interventions to improve catchment status, management and regulation, however due to its importance the Action Plan seeks to kick start this collaboration focussed on the Shire Basin.

6.12. Institutional and Capacity Building Elements of the Action Plan

An Institutional and Capacity Development Plan has been developed as an integral component of the Integrated Flood Risk Management Plan. This is presented in full in Appendix E of this report. Its key elements are presented in the Action Plan in Section 9 of this report. The key components of the Development Plan are summarised below.

Stakeholder	Interventions
MWDI	• Training in installation and maintenance of new river gauges. • Training for staff to update, operate and maintain the hydraulic model • Financial support to appoint programme management including training support package. • Financial support to develop construction guidelines and provide training in their use.
MET services	• Training in installation and maintenance of new rain gauges. • Financial support to enable staff to digitise new and historic data. • Support to improve weather forecasting • Support to initiate data exchange with Mozambique
DNRDM	• Provision of vehicles and communications equipment • Provision of financial support to enable DNRDM to deliver its training responsibilities • Support to enable DNRDM to improve and test standard operational procedures and internal management tasks.

The Institutional Capacity Development Plan was designed around the key changes which a new FFEWS and HD modelling framework would introduce together with the broader responsibilities of DNRDM with regard to flood preparedness, response and recovery. The plan ensures that critical capacity development and training is supported to enable the key stakeholders to fulfil their roles under a new FFEWS and HD model system and maintain the relevant systems upon which the FFEWS will depend. The plan recognised the emergence of a Shire River Basin Management Organisation and envisages that in five years' time – as the Action Plan is fulfilled – much of the institutional framework for a FFEWS could then be devolved to the SRBMO.

7. FLOOD MITIGATION OPTIONS ASSESSMENT

7.1. Option Long Lists

A long list of 72 potential options for the mitigation of flooding in the Shire Basin was developed during the initial stages of the project. This list was based on the project team's initial understanding of the issues and on initial meetings and consultations held with stakeholders. At that stage, there was no attempt to undertake assessment of the options – the objective was simply to compile a list of all and any potential options. This provided a "starting point" for option short listing which followed later.

This list was presented at the DCs' and Inception Workshops held in December 2011 where break-out sessions reviewed the options and prioritised those for potential inclusion in the 5 year Action Plan. This prioritisation by the workshop delegates was made under the following headings:

- Structural High Priority Options
- Non Structural High Priority Options
- Institutional High Priority Options

The break-out groups also identified other options for inclusion.

The December workshop reviews were subsequently complemented by an assessment by the project team using their improved knowledge of the issues, information gained through site visits and consultations over the first five months of the project, and the experience and judgement of the team. The assessment considered hydraulics/hydrology, flood forecasting and early warning, water resources, technical/engineering and institutional issues.

At that stage, environmental, costs and socio-economic considerations were not included. It was recognised that insufficient information was available at that time for assessment of these criteria but due account was taken of these later in the short listing process.

It was clear from the assessments made at the workshops and by the project team that three shortlists of options could be generated – Quick Wins, 5 Year Action Plan, and Future Options.

The Quick Wins shortlist would comprise options where benefits could be realised immediately or within a short time scale. Those options to be included in the 5 Year Action Plan would specifically address the objectives of the terms of reference of the project and, by definition, would seek to mitigate the impact of flooding on communities in the Shire Valley over a five year period. The Future Options shortlist would comprise those options of relatively low priority but which could potentially provide benefits in the longer term.

At a meeting with the directors of MWDI, DCCMS and DNRDM on 22nd February, the options were presented under four "themes" and these have subsequently been adopted for the arrangement of options during the process of shortlisting. These themes, together with the number of potential options identified in February for the Interim Report, are as follows:

- Modelling and Data Management (11 options)
- FFEWS and Communications (6 options)
- Training and Preparedness (10 options)
- Structural Interventions (17 options)

7.2. Option Short Listing

Further analysis of the options has been undertaken by means of further, detailed investigations and further consultations with stakeholders.

Options for Modelling and Data Management for shortlisting have been based on the requirement in the Terms of Reference to establish a modelling framework for the Shire Basin for flood forecasting, for flood zone mapping and for the assessment and design of flood mitigation measures. As explained elsewhere in this report, whilst a modelling "tool" has been established under the project, the accuracy of the model will need to be improved in the future by the addition of improved data. So, in addition to the purchase and maintenance of software and hardware, shortlisted options for the HD Model will include detailed topographic and hydrographic surveys of the main tributaries and critical reaches of the Shire River and the extension of the model to include tributaries, as well as the on-going and improved use of the model to assess and design flood mitigation measures.

Terms of Reference (TOR) for consultancy services for Flood Forecasting and Early Warning is one of the main deliverable of this project and options for shortlisting for inclusion in the Action Plan are centred on the detailed design and implementation of flood warning systems to serve the communities in the Shire Valley. Assessments of different potential systems have been made and after discussion of these with stakeholders the TOR has now included for the provision of both centrally based and community based systems. Field investigations of the location and condition of existing river and rainfall gauges and of communication options as part of the project has enabled confirmation of the inclusion in the options shortlist of new gauges, of new and improved communication systems with associated equipment, and of training and support to DCCMS, MWDI and DNRDM.

"Training and Preparedness" relates particularly to institutional improvement and capacity building and potential options here for shortlisting have been generated by means of our assessments of those institutions critically involved with flood issues in Malawi – DNRDM, MWDI and DCCMS – and through important discussions with representatives from these institutions, from other stakeholders including NGOs, and from potential donors.

The long list of structural options included flood defences, flood-proof food stores, catchment improvements, dredging, river channel diversion or straightening, and flood storage both in-channel and off-channel storage. The short-listing process required these generic options to be assessed more specifically. To assist this process the project team held meetings with the District Executive Committees (DECs) of the districts affected by flooding in the Lower Shire – namely, those in Chikwawa, Nsanje, Mwanza, Mulanje, Thyolo, and Blantyre. The DECs in these districts prioritised critical rivers and the villages most severely affected by flooding and suggested the form of intervention that would provide alleviation from flood impact and improvement of community resilience. From the information provided by the DECs, "high priority" tributaries and villages were selected for further investigation using the HD model:

Chikwawa	5 tributaries, 24 villages
Nsanje	7 tributaries, 28 villages
Mulanje	4 tributaries, 4 villages
Thyolo	4 tributaries, 4 villages
Mwanza	13 tributaries, 28 villages
Blantyre	3 tributaries, 12 villages

The assessment of the long listed structural options for shortlisting and inclusion in the Action Plan is discussed below.

Flood Defences

As explained in Section 7.3 below, flood defence embankments for villages in Chikwawa and Nsanje were assessed using the HD Model and costed for potential inclusion in the options shortlist. The lack of sufficiently accurate or reliable topographic information was a constraint here and although proposed flood defences have been included in the Action Plan for Chikwawa and Nsanje districts, the poor quality of data in the other four districts has precluded the specific identification and inclusion in the Plan of any defences for villages in these districts. At this stage, a budgetary allowance has been made in the Action Plan for the assessment, design and implementation of flood defence embankments for critical villages in Mulanje, Thyolo, Mwanza and Blantyre.

Flood Proof Stores and Buildings

The merits of flood resilient grain stores have been considered for short listing. Whilst not providing flood protection to the community, it is apparent that such stores have been and will be beneficial in preventing flood damage to grain and other food stuffs.

The Option Long List included the provision of flood proof shelters – either the construction of new shelters or the flood proofing of existing buildings such as churches and schools. Meetings with the DECs indicated that flood proof shelters are not a high priority, that churches and schools and other building are currently used in many GVHs as shelters. For the purposes of this project, emphasis has been placed on the provision of flood defences to critical villages which, if effective, will obviate the need for shelters. However, an allowance is made in the Action Plan for assessing the need for the provision of shelters in critical and less critical villages.

Catchment Improvements

Again, as described in Section 7.3 below, catchment improvements were assessed using the HD model for the Mwanza and Ruo rivers. The reduction in flood depth resulting from either full re-forestation or the planting of “scattered” trees in farmers’ fields was derived and, the economic benefits have been assessed. At this stage, only an indicative assessment of catchment improvement has been made on the Mwanza and Ruo rivers but this assessment has been able to demonstrate that significant benefits are achievable in terms of the reduced impact of flooding to villages in the lower Mwanza catchment. Again, allowance has been made in the Action Plan for improvements to the upper catchments of the Mwanza and Ruo, based on this assessment, and a budgetary provision has been made also for similar improvements to other critical catchments in the Lower Shire.

Dredging

Dredging is currently undertaken along tributaries of the Shire – either in conjunction with the construction/rehabilitation of flood embankments or to maintain the discharge capacity of culverts and bridges.

Where flood defence embankments have been shortlisted, an allowance for dredging has been included. Separate consideration has been given to the inclusion in the short list of dredging at bridges such as that over the Mwanza River and at culverts beneath important roads.

River Channel Diversion

Diversion or straightening of rivers can, in some instances, be beneficial in the alleviation of flooding but they can also worsen the current situation. Such measures need to be carefully appraised and designed and an understanding of the geomorphology is of crucial importance.

The coarseness of the currently available topographic data and the absence of any geomorphological studies have precluded, at this stage, consideration of these measures for inclusion in the Action Plan shortlist. The focus currently is to provide flood defences – embankments or bunds – at critical locations. Further geomorphological studies will be allowed for in the Action Plan which may demonstrate the effectiveness of straightening or diversion of critical rivers.

An earlier study has highlighted the possible merits of diversion of the Ruo River into the Elephant Marsh. The study, although not detailed, had suggested that diversion of the Ruo near the village of Osiyana might be considered. Diversion would be into a canal located through TA Mlolo and which would discharge into the Elephant Marsh. A brief examination of the Ruo diversion has been attempted as part of this study. Figure 7-1, Figure 7-2 and Figure 7-3 show the flood outlines for the 500, 100 and 50 year floods compared to the same flood with the Ruo diverted from around the village of Osiana. It shows for each a reduction in flood extent such that two previously flooded villages are not flooded as a result of the diversion. These results were achieved by simply moving the Ruo inflow from the upstream end of the Ruo 1D model and placing it onto the 2D model at a point within the Elephant Marsh (shown on diagram). In each case the baseflow was left in the Ruo to maintain environmental flows.

As a separate exercise, the potential channel sizes were investigated by using the rough slope between Osiana and the chosen diversion outflow point, and the distance between the two points. Table 7-1 summarises the required channel dimensions based on rough sizing. It shows that very large channels will be needed for any proposed diversion to take the majority of the Ruo flow. Obviously diversion of part of the flow would require smaller channels, but these scenarios have not been examined here. It should also be noted that this crude exercise does not take account of routes (it assumes a straight line route) and geomorphological implications of such a scheme.

Table 7-1: Required channel dimensions for Ruo diversion

	Q500 = 8315 cumecs	Q100=6367 cumecs	Q50=5558 cumecs
Channel side slope	1 in 4	1 in 4	1 in 4
Base flow width (m)	5	5	5
Flow depth (m)	17.1	15.41	14.61
Channel side slope	1 in 4	1 in 4	1 in 4
Base flow width (m)	10	10	10
Flow depth (m)	16.5	14.8	14.03
Channel side slope	1 in 4	1 in 4	1 in 4
Base flow width (m)	15	15	15
Flow depth (m)	15.94	14.27	13.48
Channel side slope	1 in 4	1 in 4	1 in 4
Base flow width (m)	30	30	30
Flow depth (m)	14.42	12.78	12.01

Clearly this scheme requires a study to assess the technical, economic and environmental feasibility and provision has been made for the inclusion of such a study in the Action Plan.

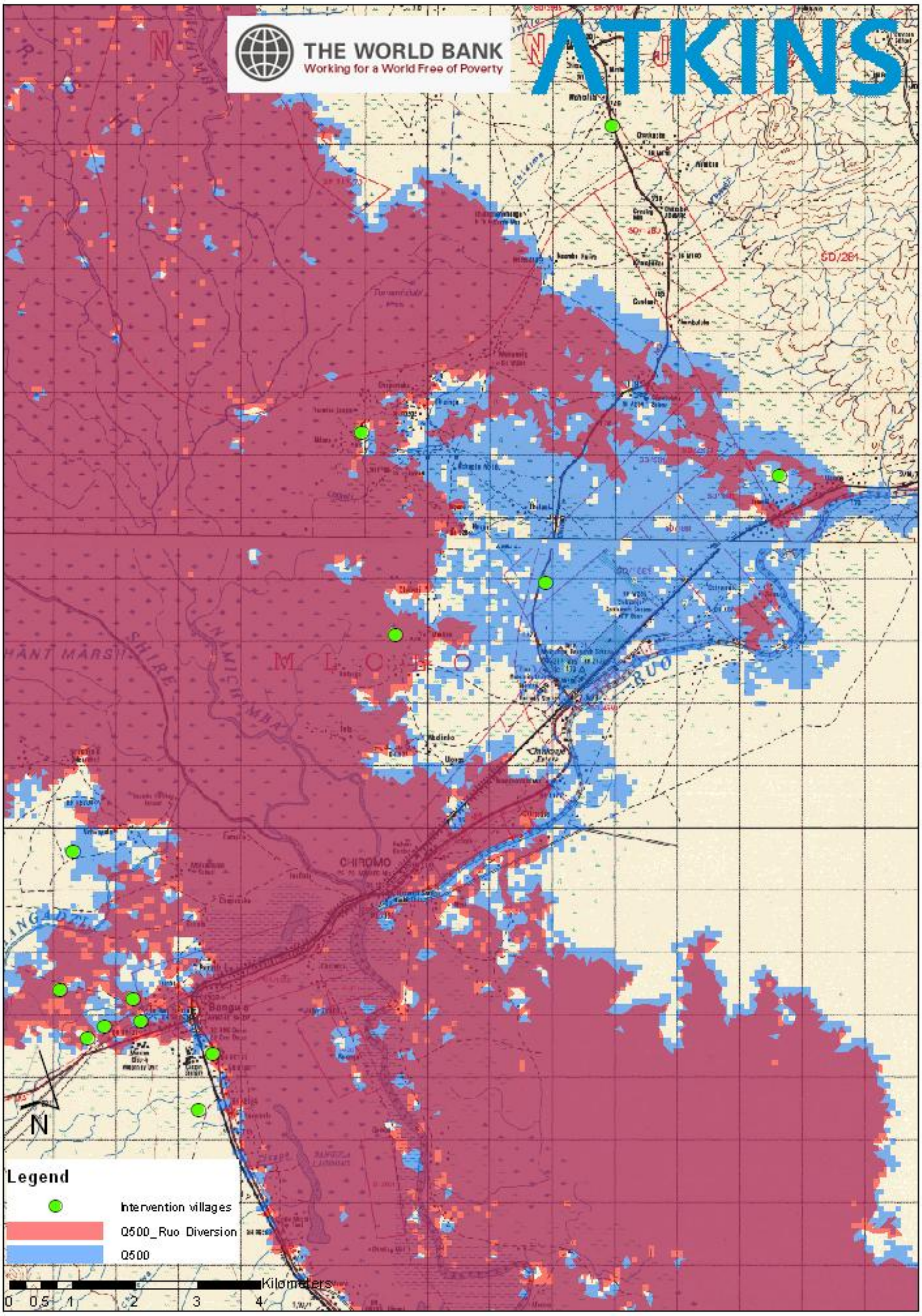

Figure 7-1: Q500 flood outline with and without Ruo diverted

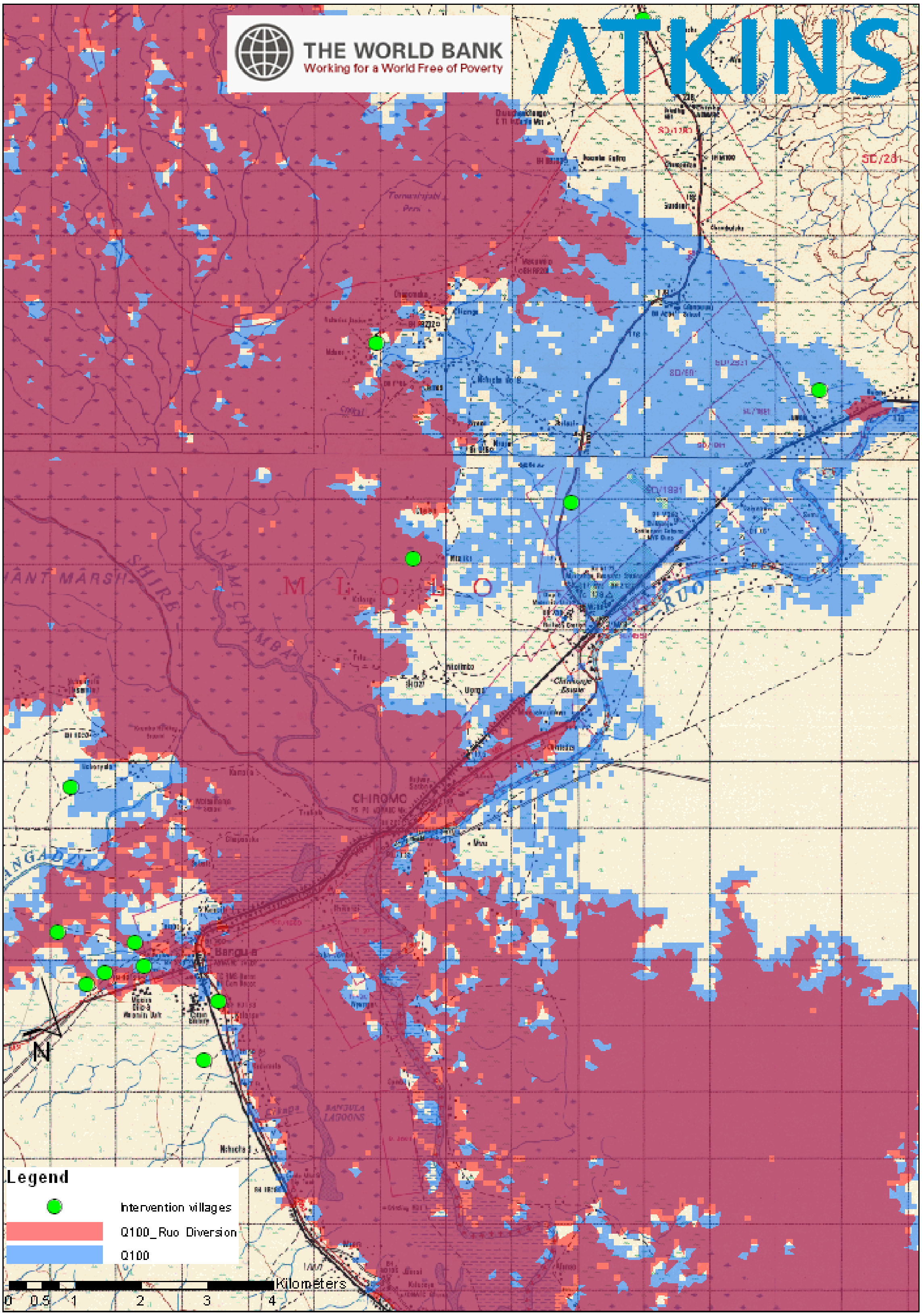

Figure 7-2: Q100 flood outline with and without Ruo diverted

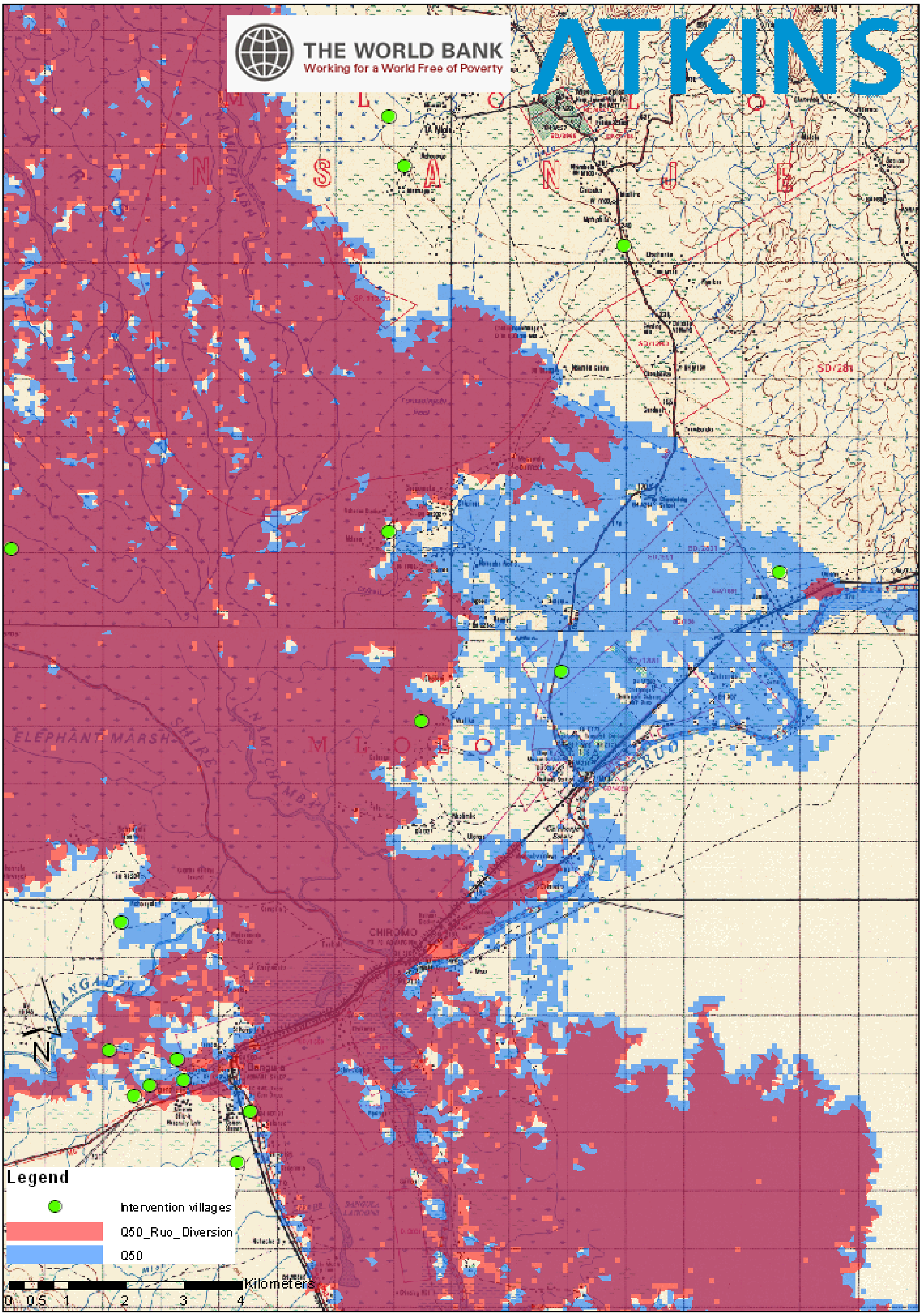

Figure 7-3: Q50 flood outline with and without Ruo diverted

Flood Storage

The effects of off-channel storage were assessed using the HD model for the Mwanza river. The assessment concluded that an appreciable reduction of flood depths downstream could only be achieved by diversion and storage of very large volumes of water. It was considered that the impracticalities and high cost of the structures required for diversion and conveyance, and for provision of storage were sufficient to reject off-channel storage for inclusion in the Action Plan at this stage – on the basis of the information available at this time.

Storage in-channel, by construction of a dam or other impoundment structure was included in the Long List of options developed early in the project. The volumes of water required to be stored would be similar to those identified by the model analyses for the off-channel options. Therefore, such options would require major structures and large storage reservoirs to achieve any appreciable attenuation of flood waters. The scope and cost of these cannot be justified for inclusion in the Action Plan at this stage although future studies, based on improved topographic data, may be considered.

7.3. HD Model Output

The main objective of options modelling described in Section 3.6 was to provide an assessment of the effectiveness of each option in reducing flood risk. In addition, options modelling output was key to providing inputs to the economics appraisal of each option and the cost-benefit analyses. These analyses would determine the options providing the highest benefits, thus enabling prioritisation for consideration for inclusion in the Action Plan.

7.3.1. Flood Defence Embankments

As explained above, consultations were undertaken during the interim phase with the District Executive Commissioners (DEC's) to identify those villages most affected by flooding and the rivers which caused the floods. A number of the critical villages were identified by the DEC's as being on tributaries of the Shire rather than on the main Shire. The economics assessment is based on a prioritised list of the critical villages identified by the DEC's.

As described in Section 3.6.1.1 flood defence bunds were considered for all villages in Chikwawa and Nsanje districts. For each return period, it has been assumed that building of a defence would completely eliminate flooding up to a design standard equivalent to the annual probability for that event, whilst accepting that some flooding would still occur for floods in excess of the magnitude of that event. Hence, the baseline model results from both the tributary model and the main model were used to identify the flood depth at each of the villages and therefore the height of flood defence bunds that are required for each standard of protection. Flood depths and hence defence heights for these villages are shown in Table 7-2 below. These modelled flood depths were used to assign baseline flood depths and damages to the villages, and enabled determination of a conceptual arrangement and cost estimates for construction of a flood embankment to provide defence/protection at each village – as described later in this report.

For conceptual design, cost estimation and economic assessment of the flood embankments, protection for the 100 year event was selected as the design standard.

It should be noted that a number of the villages identified as being critical have not been included in the model assessment. This is because they are a significant distance from any of the flood outlines and the specific source of flooding was unclear. Further investigation will be required during the implementation of the Action Plan to enable flood protection to these villages to be assessed.

The model was used to examine the effect of building flood defences by comparing the flood extent with and without a flood embankment in place. Figure 7-4 illustrates how this works. The green line represents the flood defence which has been added to the model as a wall of appropriate height, while the pink and blue outlines are the without and with defence flood outlines. It shows that flood defences can be used to effectively protect individual villages. Importantly, it shows that the model can be used to examine the effectiveness of each flood defence in protecting the village, and also the effect on villages upstream and downstream of the target village. The model can be used in this way, in the detailed design of all flood embankments.

Table 7-2: Flood Depths and critical villages in Nsanje and Chikwawa

District	River	Village	Q5	Q10	Q50	Q100	Q500
Nsanje							
	Ruo						
		Osiyana	0.07	0.17	0.42	0.51	0.93
		Kalonga	1.89	2.12	2.95	3.29	3.98
		Mchacha James	0.98	1.14	1.39	1.50	1.65
		Kadyamba	0.77	1.02	1.90	2.22	2.89
	Lalanje						
		Mbenje	0.49	0.69	0.93	1.03	1.24
	Thangazi (W)						
		Nyan'ga	0.46	0.56	0.76	0.83	1.00
		Fulukiya	0.22	0.43	0.76	0.88	1.09
		Tchenyere	0.34	0.77	1.05	1.13	1.25
		Chithumba	0.22	0.29	0.42	0.51	0.70
		Tambo	0.16	0.24	0.89	1.00	1.25
	Nyamadzete						
		Malemia	0.16	0.37	0.70	0.82	1.02
	Chimbwimbwe						
		Mtolongo	0.13	0.62	1.69	2.07	2.83
		Mphamba	0.15	0.99	2.06	2.43	3.21
Chikhwawa							
	Mwanza						
		Galonga	0.19	0.22	0.29	0.32	0.40
		Lundu	0.08	0.25	0.62	0.77	1.11
		Chikuse	0.38	0.87	1.11	1.20	1.38
		Kanzimbi	0.60	0.69	0.88	0.96	1.12
		Tiyimbenao	0.61	0.87	1.33	1.48	1.76
	Mkombezi						
		Suweni	0.16	0.18	0.24	0.30	0.38
		Ndakwera	0.03	0.60	1.00	1.14	1.43
		Kampani	0.13	0.24	0.40	0.46	0.62
		Mangulenji	0.47	0.88	1.09	1.18	1.37
		Nkhwazi	0.58	0.73	0.94	1.01	1.47
	Lalanje						
		Mchacha	0.14	0.29	0.57	0.65	1.26
		Mwananjob	0.02	0.04	0.14	0.18	0.28
	Nyakamba						
		Malemia	0.16	0.37	0.70	0.82	1.02
		Chimpamba	0.00	0.04	0.15	0.20	0.29
	Namikalango						
		Malikopo	0.09	1.78	1.93	1.99	2.16
		Goma	0.09	0.35	0.52	0.60	0.75
		Mpheza	0.65	0.79	1.10	1.21	1.45

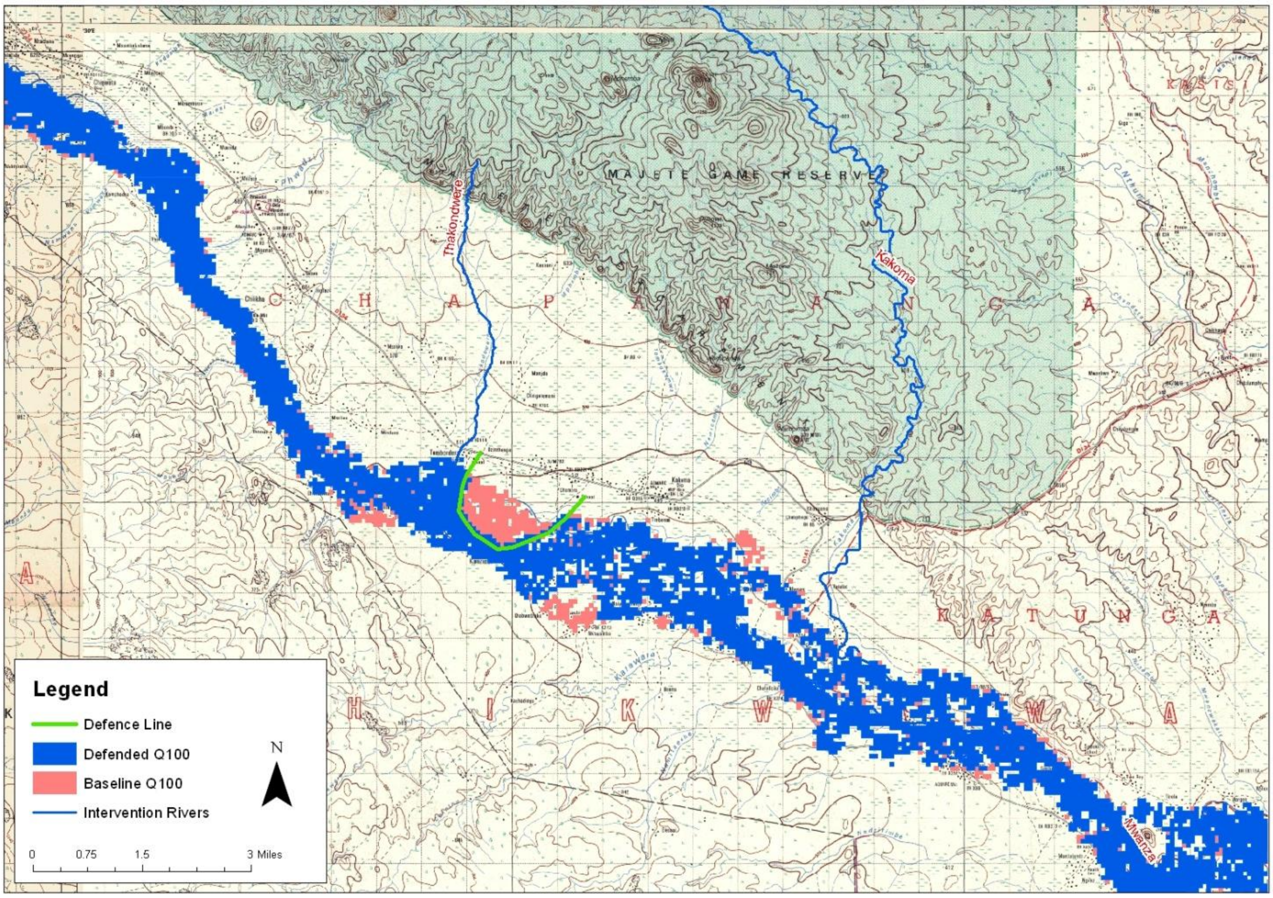

Figure 7-4: Flood outlines for the 100 year event with and without a flood defence

7.3.2. Catchment Improvement Modelling

As described in Section 3.6.1.2 catchment Improvement has been tested on the Ruo and the Mwanza sub-catchments within the Shire basin. Catchment Improvement has been modelled by reducing the model parameter that controls runoff percentage, to represent reforestation within the catchment. Percentage increases in forest cover of 24 and 33 percent were modelled for the Mwanza and Ruo catchments, respectively.

Table 7-3 shows the reduction in flood depth at the critical villages within the Mwanza catchment for flood events with different return periods.

Table 7-3: Reduction in flood levels at critical villages as a result of reforestation of the Mwanza Catchment

Village	Q10 Reduction (mm)	Q50 Reduction (mm)	Q100 Reduction (mm)	Q500 Reduction (mm)
Galonga	34	43	44	55
Chikuse	151	132	130	123
Kampani	123	93	97	110
Kanzimbi	98	109	111	110
Lundu	177	217	225	228
Mangulenje	93	120	132	132
Ndakwera	209	228	212	199
Timbenao	290	255	228	192

7.3.3. Flood Storage Options

The analysis examined the potential for storing flood volumes in the upper part of the tributary catchments to alleviate flooding to critical downstream areas. Table 7-4 shows the volumes that would be required for the Q10 and Q100 events if a maximum flow of 100 cumecs was allowed downstream of a storage reservoir.

Table 7-4: Flood storage volumes required for the Q10 and Q100 events

Tributary	Q10 Storage Volume (m^3)	Q100 Storage Volume (m^3)
Mwanza	26,654,986	52,442,352
Thangadzi West	4,005,338	14,932,260
Lalanje	787,532	4,635,990

It can be seen that these are extremely large volumes and that they will pose major difficulties in the physical provision of diversion, storage and release facilities. At this stage, this option – provision of storage to allow a release of only 100 cumecs downstream - is considered to be impractical and does not merit inclusion in options for the Action Plan.

The possibility of storing a smaller flood, for example the Q10 volume, has been separately considered in terms of the effect on the Q100. The analysis has showed that while there is some reduction in the flood outline, it is not a significant reduction for an event of this magnitude. This is because the Q10 flood volume is small in comparison to the Q100 flood and storage of the Q10 volume makes no appreciable difference to water levels downstream. The assessment of storage options can be examined in more detail once LiDAR data is available for the catchment.

7.4. Cost Estimation

All cost estimates are base dated June 2012 and no allowance has been made for escalation.

A contingency allowance of 15% has been included in all cost estimates although in some instances, where there is less certainty, an allowance of 20% or 25% has been used.

Cost estimates for HD Modelling, FFEWS and Institutional Development have, in general, comprised the following categories:

- Provision of external (international) professional and/or consulting services
- Provision of local (Malawian) staff and/or services
- Supply and installation of equipment

The costing of the provision of international services and the provision of international staff for training etc has been derived from an estimate of the staff inputs required and using typical rates for personnel with the appropriate skills. Where possible, these estimates have been benchmarked against recent projects of a similar nature. Mobilisation, travel, accommodation and subsistence have been included

Local staff costs have been based on current remuneration rates for senior, junior and field Malawi Government staff. Where appropriate, allowances have been included for travel and for daily subsistence.

Cost estimates for the supply of equipment – river and flow gauges, communication equipment etc – have been derived either directly from manufacturers or suppliers, or from similar projects or installations. Shipping or other transport costs have been included. Where costs include for installation, estimates have been generated for inputs from local and international staff and extended at appropriate charge rates, together with costs for establishment, transport and equipment, and for attendance for maintenance.

Further explanation of the derivation of cost estimates is included in Appendix J.

7.4.1. Structural Interventions

Cost estimates for flood embankments, food stores and catchment improvements have been derived using rates for local labour, materials and equipment. Where appropriate, costs for design, overheads and supervision of construction have been included. In the case of flood embankments, the design life has been estimated at 20 years with refurbishment allowed after 10 years.

The height of a bund or embankment to protect critical villages in Chikwawa and Nsanje was determined based on 1 in 100 year flood, this being selected as the design standard for flood defences for the purposes of this project. The limited topographic information available at this time has constrained the accuracy of determination of the required length of each bund and also the accuracy of the cost estimate for construction. Once LiDAR data is available a more accurate determination of embankment length will enable an improvement in the estimation of cost and in the economic assessment.

Flood embankments are assumed to be constructed of earthfill with plastic sheeting on the riverside slope and protection from either rockfilled gabions or sandbags. A nominal allowance has been included for dredging. Food stores comprise brick built structures on a concrete foundation and with a galvanised sheet metal roof – based on a design provided by the Ministry of Agriculture. .

Catchment improvement costs are based on either thick vegetative cover – complete re-forestation – or scattered vegetative cover, comprising either fruit or fertiliser trees. Costs for provision of seedlings have been obtained from the Ministry of Forestry and Chitedze Agricultural Station. In the case of scattered trees, it is assumed that the local communities will plant and tend the seedlings themselves.

7.5. Economic Assessment

7.5.1. Introduction

An economic appraisal has been completed for the shortlisted options. The purpose of this appraisal is to test the economic viability of each option at each location, in order to be able to rank the options and identify those most suitable for further investigation.

The economic appraisal has therefore sought to measure the benefits offered by each option, rather than the total losses from flooding. Many other studies have attempted to quantify the losses to Malawi from flooding (e.g. “The impact of droughts and floods on food security and policy options to alleviate negative effects” Stephen Devereux. AGEC Blue book. 2007, and “Economic Losses and Poverty Effects of Droughts and Floods in Malawi” Malawi Strategy Support Program (MaSSP) however the purpose of this appraisal is not to repeat this work, but to specifically consider the shortlisted options.

7.5.2. Methodology

A detailed description of the methodology is presented in Appendix F. A summary is included here. The main cost arising from flooding is the provision of aid to the affected population. The National Contingency Plan provides an assessment of the aid required and this has been used in the appraisal. The food allowance in the National Contingency Plan is a basic minimum requirement only and is limited to maize, beans and oil. In order to provide a nutritious health sustaining diet, a wider range of foods is required and so the CFCS “food basket” costs have been used as a valuation of the replacement of food requirements while people are displaced. National statistics have been used to count the average livestock, property type and population groups. Property losses and inventory has been taken from the RMSI report (Ref “Malawi: Economic Vulnerability and Disaster Risk Assessment” RMSI, 2010) and range between zero and 572US$ per property per flood event based on depth and property type.

Table 7-5 presents a summary of the damages assumed for the Base Case Do Nothing/existing situation, which assumed that nothing is done to prevent flooding or flood damage. Present value damages for the critical villages in Chikwawa and Nsanje are presented in

Table 7-6. All options are compared against this baseline. Table 7-7 shows the assumptions for the benefits (reduction in damages) available for each option.

Table 7-5: Flood losses per household affected per flood event (US dollars)

Category of Flood Loss	Do Nothing Baseline (per household)
Property Loss	based on modelled depth
Inventory Loss	based on modelled depth
Food stores and aid Based on 3 months of Food Basket costs plus one month of food aid	$314
Health, water and shelter aid From National Contingency Plan	$624
Education loss/aid From National Contingency Plan	$23
Agricultural Recovery From National Contingency Plan	$11
Livestock From national livestock count statistics	$446

Table 7-6: Do Nothing Present Value Flood Damages per village (over 20 years)

			Do Nothing Present Value Damages $'000						
District	**River**	**Village**	**Property and Inventory Damage**	**Food stores and aid**	**Health and shelter aid**	**Education loss/aid**	**Agricultural Recovery**	**Livestock**	**Total PVd**
Nsanje									
	Ruo								
		Osiyana	39	286	568	21	10	406	1,330
		Kalonga	273	212	422	16	7	302	1,231
		Mchacha James	529	577	1,146	42	20	819	3,133
		Kadyamba	56	63	126	5	2	90	343
	Lalanje								
		Mbenje	38	69	137	5	2	98	348
	Thangazi (W)								
		Nyan'ga	69	143	285	11	5	204	717
		Fulukiya	8	23	46	2	1	33	113
		Tchenyere	12	23	45	2	1	32	114
		Chithumba	13	55	109	4	2	78	261
		Tambo	98	360	716	26	13	512	1,725
		Kalenzo	350	626	1,245	46	22	890	3,179
	Nyamadzete								
		Malemia	0	0	0	0	0	0	0
	Chimbwimbwe								
		Mtolongo	13	29	58	2	1	42	145
		Mphamba	57	114	226	8	4	162	572
Chikhwawa									
	Mwanza								
		Galonga	52	312	620	23	11	444	1,462
		Lundu	62	340	676	25	12	483	1,598
		Chikuse	241	471	935	34	17	669	2,367
		Kanzimbi	196	248	493	18	9	353	1,317
		Tiyimbenao	234	280	556	21	10	398	1,497
	Mkombezi								
		Suweni	27	201	399	15	7	286	935
		Ndakwera	86	220	437	16	8	312	1,079
		Kampani	40	251	498	18	9	357	1,173
		Mangulenji	122	220	437	16	8	312	1,115
		Nkhwazi	33	55	109	4	2	78	280
	Lalanje								
		Mchacha	98	421	836	31	15	598	1,998
		Mwananjobvu	3	69	137	5	2	98	313
	Nyakamba								
		Malemia	150	577	1,146	42	20	819	2,754
		Chimpambana	80	668	1,328	49	23	950	3,097
	Namikalango								
		Malikopo	39	69	137	5	2	98	351
		Goma	26	138	274	10	5	196	649
		Mpheza	80	116	231	9	4	166	606

Table 7-7: Flood Benefits assumed for each short listed option

Option	**Assumed Benefits**
Flood Warning	Save all inventory and 50% of livestock
Provision of safe food stores	Save food stocks, worth $17 per household per flood event

Bunding of villages	Save all building and inventory, save food stores, high nutrient gardens, (food aid costs drop to $120 per household), save educational facilities, agricultural recovery costs less as some supplies saved in village, 90% of livestock saved.
Catchment Management options	Fewer villages flooded, based on modelling results.
Flood Storage	A high level test undertaken assuming no flooding to a 1 in 10 year event, and a reduction in flood extent above this.

7.5.3. Results

The appraisal has been carried out for a 20 year appraisal period, and has applied an 8% discount rate over that time period. The event damages have been converted to a present value so that damages avoided (benefits) can be directly compared to option costs, which are also presented over a 20 year period. A simple approach to option comparison has been applied, namely the calculation of a benefit to cost ratio. A ratio greater than one means that, within the limitations of the appraisal, the benefits are greater than the costs.

Costs have been prepared for the villages in Chikwawa and Nsanje districts considered to be critical in terms of flood impact – 17 villages in Chikwawa and 14 villages in Nsanje. However, the GIS process of producing the flood risk information provided data for all the villages within the modelled flood plain, and this allowed option benefits to be generated for these additional villages too. Table 7-8 presents benefit cost ratios for the intervention villages. However in the case of flood warning and flood storage options, for the same cost, many more villages would benefit and so a B:C for the flood warning and a PV benefit for the flood storage option including all modelled villages has also been presented

Table 7-8: Benefit cost ratios for Short listed options, PV benefits for Flood Storage Option

			Benefit to cost ratio					PV Benefits $'000's
River	**Village**	**Population count**	**Flood Warning**	**Safe Food stores**	**Bunded village, B:C and construction type**		**Catchment Management Options**	**Flood Storage Option 1:10 in benefiting area**
All modelled villlages		33,999	1.6					55,028
All intervention villages		26,879	0.9					37,855
Nsanje intervention villages								
Ruo							0.0	not modelled
	Osiyana	1,059	-	3	137	Sand Bags		
	Kalonga	786	-	7	21	Sand Bags		
	Mchacha James	2,135	-	15	169	Gabion		
	Kadyamba	235	-	1.6	9	Sand Bags		
Lalanje							not modelled	
	Mbenje	255	-	1.3	158	Sand Bags		292
Thangazi (W)							not modelled	
	Nyan'ga	531	-	2.4	78	Sand Bags		717
	Fulukiya	86	-	0.3	17	Sand Bags		92
	Tchenyere	84	-	0.4	16	Sand Bags		93
	Chithumba	204	-	0.7	64	Sand Bags		215
	Tambo	1,334	-	5	123	Sand Bags		1,425
	Kalenzo	2,320	-	11	127	Gabion		3,179
Nyamadzete							not modelled	not modelled
	Malemia	84	-	0.0	0	0	-	
Chimbwimbwe							not modelled	not modelled
	Mtolongo	109	-	0.5	4	0		
	Mphamba	422	-	1.9	13	Sand Bags		
			-					
Chikhwawa								
Mwanza							0.4	
	Galonga	1,156	-	3	746	Gabion	0.8	1,208
	Lundu	1,259	-	3	145	Gabion	5	1,306
	Chikuse	1,743	-	8	225	Gabion	31	1,933
	Kanzimbi	919	-	6	204	Sand Bags	3	1,086
	Tiyimbenao	1,036	-	7	34	Sand Bags	4	1,229
Mkombezi							not modelled	not modelled
	Suweni	744	-	1.9	287	Sand Bags		
	Ndakwera	814	-	3	221	Gabion		
	Kampani	929	-	2	803	Gabion		
	Mangulenji	814	-	4	218	Gabion		
	Nkhwazi	202	-	1.0	46	Sand Bags		
Lalanje							not modelled	
	Mchacha	1,558	-	4.9	NA			1,998
	Mwananjobvu	255	-	0.5	NA			300
Nyakamba							not modelled	not modelled
	Malemia	2,135	-	6.9	462	Gabion		
	Chimpambana	2,474	-	5.6	1561	Gabion		
Namikalango							not modelled	not modelled
	Malikopo	256	-	1.2	19	Sand Bags		
	Goma	512	-	1	165	Sand Bags		
	Mpheza	431	-	2	46	Sand Bags		

Table 7-8 above shows the results for the shortlisted options considered. Flood warning provides a benefit to all the villages, not just those included in the appraisal. It offers many other benefits too, e.g. weather forecasting and the modelling can help aid better planning and investment decisions. Because it is not possible to split up the flood warning costs for each individual village, a total benefit cost ratio has been generated for the critical villages, and also for all the villages covered by the hydrodynamic model. The benefit cost ratios of 0.9 and 1.6 respectively are therefore acknowledged to be an underestimate, and the actual ratio is larger than this.

The provision of safe food stores provides a benefit cost ratio above 1 in the majority of the villages. This is based on a cost of $10k for a food store. Where the ratio is less than one, cheaper construction methods for food stores should be considered.

Bunding of the villages offers the highest benefit cost ratios. Two different construction methods were considered: gabions and sandbags. Where the gabions offered a ratio greater than 5 then this is the approach recommended, otherwise the results for sandbags are presented.

The catchment management option of reforestation and increasing vegetation cover was investigated for the Ruo and the Mwanza. The Ruo only showed a minimal reduction in flood damages due to the fact that the villages at risk are actually in the floodplain of the Shire. However the approach is shown to be viable for the villages in the Mwanza, with ratios between 3 and 31 for most villages. Again the benefits presented in this appraisal are underestimated as these trees will also provide a yield of fruit and timber, and this has not been included in the appraisal.

Flood storage was investigated using the HD model for the tributaries of Lalanje, Thangazi West and Mwanza. Costs have not been produced for this option, as potential locations have not been identified. A flood storage facility capable of storing the additional water in a 1 in 10 year annual chance event was investigated. Table 7-8 presents the PV benefits applicable to flood storage in the villages in these three catchments for this scenario. However the benefits cover the downstream reaches as well. Total benefits for critical villages and for all the villages included within the hydrodynamic model have been presented at the top of Table 7-8, and these benefits would all be realised as a result of the storage in these three catchments.

These benefits can be compared to high level estimates of the costs for the flood storage option to test the viability of these options. The engineering assessment concludes that such a storage option is not viable.

7.6. Environmental Assessment

A high level environmental appraisal has been carried out of the structural flood risk management options that have been identified for the Shire river basin, and the full results are reported in Appendix G. The principal aim of the environmental appraisal work is to ensure that the likely environmental effects of the proposed structural options are identified early, and at an appropriate level of detail, to help identify future environmental work that may be required at the project level, and inform project planning. The approach taken has a focus on scoping and identifying the key issues that are likely to be associated with each option, and makes recommendations for further work at the project level to address them. This will ensure that the options do not compromise the broader aspirations for the Shire River Basin. This appraisal has not attempted to quantify the significance of the potential environmental effects as insufficient data is available at this stage to do so.

7.6.1. Relevant legislation and key environmental issues

The environmental appraisal has been undertaken with due regard to the requirements for Environmental Impact Assessment in Malawi, as set by the Environmental Management Act of 1996, and the 1997 Malawi EIA Guidelines. The following key documents have also been reviewed and used to develop a summary of the social and environmental baseline for the Shire River Basin:

- Water, Waste and Environment Consultants, 2012. *Shire River Basin Management Project – Environmental and Social Assessment (ESA) & Environmental and Social Management Framework (ESMF).*
- AGRIFOR Consult, 2006. *Country Environmental Profile for Malawi – Final Report*
- Environmental Affairs Department (Malawi Government), 2006. *National Biodiversity Strategy and Action Plan*.

The review of these documents, which represent the most up to date available baseline information for the strategy area, has highlighted the following primary social and environmental issues that are relevant to flood risk and flooding problems:

- Deforestation is a key environmental problem. This is predominantly linked to timber harvesting for fuel wood and conversion of land to agriculture. Loss of tree cover and consequent soil erosion and land degradation exacerbates flood events and can result in flash flooding.

- A decline in fisheries has been attributed to siltation problems (linked to land degradation) and the conversion of riparian land to farmland;
- Water-borne diseases including malaria, diarrhoea and cholera are all prevalent and negatively impact on human health. The incidence of these diseases is exacerbated in the rainy season and/or by flood events.
- More than 40% of natural disasters in Malawi have been caused by severe flooding.
- Sedimentation, biological contamination and eutrophication are increasingly degrading water resources in the Shire River Basin. Silt loads in surface water runoff lead to water flow problems, high turbidity, and increased water treatment costs. Siltation of rivers can also exacerbate flooding problems as flow conveyance is reduced.

7.6.2. Key findings of the Environmental Appraisal, conclusions and recommendations

This environmental appraisal has looked at the potential issues associated with the implementation of five different structural intervention options that have been considered in this project for implementation in the Shire Basin. None of the options is considered likely to be unacceptable from an environmental perspective at this stage, but there are significant gaps in current environmental data, and the details of the options have not yet been developed sufficiently to allow a definitive judgement to be made. Table 7-9 below summarises the key positive and negative impacts identified to date that have been identified for each option, and any significant gaps that should be addressed as part of any follow on work.

Table 7-9: Summary of Environmental Impacts of Flood Mitigation Options

Option	Key positive impacts	Key negative impacts	Significant gaps to be addressed
Flood warning	Reduces risk to life during flood events, may give affected population more time to secure possessions prior to flooding.	No specific negative effects identified, but the option does not actually reduce the impact of flooding, so there are few benefits.	None
Provision of safe food stores	Reduces dependence on food aid following flood events.	No specific negative effects identified, but the option does not actually reduce the impact of flooding for either people or property, so there are few benefits.	None
Flood bunds	Directly reduces the impact of flooding, in terms of risk to life and risk to property. Reduced risk of displacement from homes and reduced risk of flooding-related disease outbreaks.	Construction of flood bunds to encircle villages may result in land severance, limit future development and/or create social division in the future.	Consultation with affected communities will be required to ensure that the alignment of defences is planned to avoid severance or future restrictions. There is currently insufficient information to allow any assessment of impacts on habitats, species or cultural property – this information should be gathered during later stages of work.
Catchment	Directly reduces the impact of flooding, in terms of risk	No adverse effects identified, but it is recognised that this is a	Community consultation and involvement to

improvement	to life and risk to property. Reduced risk of displacement from homes and reduced risk of flooding-related disease outbreaks. Secondary benefits could be generated from including crop trees. Management of improvement areas could generate local employment. Could contribute to reversal of land degradation. Possible secondary benefits to habitats/ species.	long term option that would require significant time and resource commitment to ensure its success.	ensure that local people are fully engaged and appropriate areas are targeted for improvement. Environmental baseline studies to help define areas that could be improved.
Flood storage	Directly reduces the impact of flooding, in terms of risk to life and risk to property. Reduced risk of displacement from homes and reduced risk of flooding-related disease outbreaks.	Construction of flood storage areas could affect current or future land use within the proposed storage area. Large raised reservoirs are associated with risk of catastrophic breaching which would endanger lives downstream	Consultation with affected communities will be required to ensure that the location of the storage area is planned to avoid adverse effects on land use. There is currently insufficient information to allow any assessment of impacts on habitats, species or cultural property – this information should be gathered during later stages of work.

Of the five options, the option that provides the best environmental benefits at this stage is to undertake catchment improvement. This option has a range of potential environmental and social benefits and relatively few potential adverse effects have been identified.

In order to address the identified gaps in the baseline data and inform future decision making or any required Environmental and Social Impact Assessment, the following actions have been recommended at this stage:

- Consultation with local communities (e.g. via interviews or workshops) to identify local features of importance to the community, understand current land use and future aspirations;
- Accurate mapping data showing the defined/gazetted boundaries of National Parks, Wildlife Reserves and Conservation Areas; and
- Completion of ecological baseline surveys at an appropriate level of detail for specific locations where works are proposed.

These actions should be included in any future funding plans to take forward the Shire Integrated Flood Risk Management Strategy.

7.6.3. Assessment Summary

The preceding sections of this report describe the process of assessment of the broad themes and, in some cases, specific options considered for flood mitigation - with respect to technical suitability, economic viability and environmental impact.

The conclusions from these assessments are summarised in Table 7-10.

Table 7-10: Summary of Assessment of Flood Mitigation Options

	Technical	Economic	Environmental
HD Model	Essential tool for flood forecasting, flood zone mapping and for assessment of flood mitigation options	Economic viability not investigated	n/a
Flood Forecasting and Early Warning	ToR prepared for detailed design and implementation to improve forecasting systems and to provide clearer, timely warnings to communities	Critical villages in Chikwawa and Nsanje show b/c ratio of 1.6. All villages show b/c ratio of 0.9 but consideration of all benefits will show viability	No negative impacts
Institutional Improvements	Essential activities to improve capability of key stakeholders to undertake critical flood related responsibilities	Economic viability not considered separately	n/a
Structural Interventions:			
Flood Defence Embankments	Technically feasible – earthfill bunds with erosion protection. Appropriate designs required but local labour can be engaged. Concern that regular maintenance or reconstruction will be required unless improvements are made in upper catchments	Generally, high b/c ratios are demonstrated – with variation dependent on type of erosion protection proposed to riverside of the bund	May create land severance, limit development and may create social divisions
Food Stores	Proven means of protecting grain from damage by flood waters	Most critical villages show a b/c ratio above unity	No negative impacts
Catchment Improvement	Essential means of alleviating soil erosion and increased run-off but benefits to downstream communities may not be realised in the short term	Of the two tributaries investigated, only the Mwanza show b/c ratio above 3. Villages on Ruo gave low b/c ratios due to Shire being main source of flooding	No negative impacts
Flood Storage	Large volumes of diverted water will require costly diversion and storage facilities – potential storage sites not identified	Costs not assessed and hence economic viability not determined	Could affect current or future land use

The foregoing assessment of shortlisted options, together with cost estimates, has enabled a more detailed determination of their scope and cost for potential inclusion in the Action Plan.

Features of the proposed options for inclusion in the Action Plan are summarised below.

7.6.4. HD Model

Establishment of the HD model will require the purchase of software and hardware and training of modellers for the tasks of operation, maintenance and upgrading. Crucial to the usefulness of the model in the future is the incorporation of improvements and upgrading and, in particular, additional survey data will be needed to extend the model coverage to tributaries of the Shire. Included also will be the use of the model for improvements to flood zone mapping, for the on-going study and design of flood mitigation measures, and for support to the new/improved flood forecasting and early warning systems.

7.6.5. Flood Forecasting and Early Warning

Here, provision will be made for the engagement of a consultant for the detailed design and implementation of the new/improved FFEWS, for the purchase and installation of rain and river gauges, for the provision of new equipment for MWDI operations, and for communication equipment for the key stakeholders as well as districts and communities.

7.6.6. Institutional Improvements

As explained above, our assessment of the current capacity of DNRDM, MWDI and DCCMS has highlighted the requirement for the provision and training of new staff. In particular, there is a requirement for preparation of improved protocols and procedures and for training in their implementation – all to ensure that key institutions are better equipped to fulfil their roles and responsibilities.

7.6.7. Flood Defence Embankments

Flood defence embankments have been investigated for critical villages in Chikwawa and Nsanje districts. Optimisation of embankment types for these villages has been achieved by means of modelling and economic analysis although the inaccuracy of the topographic data on which these analyses are based has meant that embankment lengths could not be accurately determined. Provision is needed to cater for possible increases in embankment length when designs are finalised.

Also, the lack of accurate survey data has meant that assessment of flood defence embankments in Mulanje, Mwanza, Thyolo and Blantyre districts has not been possible and provision will be needed for the assessment, design and implementation of embankments in these districts when improved data is available.

7.6.8. Food Stores

Construction of food stores in critical villages in Chikwawa and Nsanje districts will be included - based on standard designs - and provision will be made for the construction of similar stores in the other districts.

7.6.9. Catchment Improvement

From the investigation of the Mwanza and Ruo tributaries only catchment improvements in the upper Mwanza were shown to be viable. Provision will be needed for further assessment. This will include assessment of other catchments and of the relative merits of complete re-forestation or scattered vegetative cover.

7.6.10. Flood Storage

The investigation of this option concluded that extremely large volumes of water would need to be stored off-channel to make any difference to flood depths downstream. Therefore, although the economic assessment of this option is incomplete, viability remains unproven. Accordingly, this option has not been included in the Action Plan.

Development of the options has been undertaken to incorporate the above details and, taking due account of the technical, economic and environmental assessment and cost estimates, the options have been carried forward to the proposed Action Plan. This is described in Section 8.0 of this report.

8. ACTION PLAN

8.1. Five Year Action Plan

The 5-year Action plan is comprised of a prioritised list of costed options and activities which have been grouped under the following themes:

1) Hydrodynamic Modelling Framework
2) Flood Forecasting and Early Warning System
3) Institutional Development and Capacity Building
4) Structural Interventions

These themes are further broken down into a number of activities which have been evaluated through technical, economic and environmental assessments and costs estimates to enable prioritisation within the Action Plan.

The action plan is presented in Volume II of this report as a standalone document. It also includes an accompanying excel workbook comprising worksheets as follows:

1) A costed and prioritised list of options and activities
2) An activities programme based on packaging of the options
3) An Action Plan risk log – to be developed during implementation, for detailing and managing the risks associated with each main theme in terms of barriers to achieving the desired outcomes and the consequence or impact on the overall action plan should the risk be realised. We have also provided a methodology for assigning overall risk probability and
4) A detailed description of each option including the assumptions used in deriving costs

The proposed Action Plan is shown in Table 8-1 to Table 8-4 below. These tables show interventions respectively for HD Modelling, Flood Forecasting and Early Warning, Institutional Development and Capacity Building, and Structural Interventions. For each intervention, indicative expenditure is shown for each of the five years and an estimated total cost.

Table 8-1: Action Plan – Hydrodynamic Modelling Framework

High level Goals	Theme	Intervention	Detail of Action	Funding	Responsible Agency and Implementing Partners	Evaluation/Indicators of success	Y1 (US$)	Y2 (US$)	Y3 (US$)	Y4 (US$)	Y5 (US$)	Total (US$)
Enabling Flood Risk Management in Malawi through provision of flood risk assessment tools	**1.Hydrodynamic Modelling Framework**											
Rank	**1.1 Topo Surveys**											
7	**1.1.1**	Topo Surveys at Ruo/Shire confluence	10-15km immediately downstream to fully characterise the confluence flow (if this is available from the JICA report then it isn't necessary to do it)	Action Plan	MWDI with contractor partners	Critical reaches of the Shire river and it's tributaries fully characterised through topographic surveys within acceptable QA framework	**160000**					**160000**
4	**1.1.2**	Topo Surveys at critical tributaries		Action Plan/SRBMP-I			**750000**					**750000**
7	**1.1.3**	Topo Surveys at critical reaches of Shire	Critical reaches on the Shire identified as needing topo surveys. Likely to be reaches upstream of Chikwawa	Action Plan/SRBMP-I			**750000**					**750000**
10	**1.1.4**	Topo surveys of gauge locations	Initial Topo surveys of gauges locations for new and existing gauges	Action Plan/SRBMP-I			**300000**					**300000**
	1.1.5	Systematic Topo Surveys at Gauges, structures and key locations	Annual/biannual topo Surveys at gauges, structures and key locations	Action Plan/SRBMP-I				**80000**	**80000**	**80000**	**80000**	**320000**
11	**1.1.6**	Additional Surveys for lower priority vulnerable tribs	Allowance for surveys later in Action Plan	Action Plan						**100000**	**100000**	**200000**
	1.2 Model Establishment, development and Update											
2	**1.2.1**	Modelling software purchase	Initial Purchase of modelling licences	Action Plan/SRBMP-I	MWDI with consultant partners	Modelling framework fully installed and functioning within the identified organisations within the first year of the Action plan. Model developments achieved within year 1 and appropriate maintenance throughout the 5-year plan	**250000**					**250000**
2	**1.2.2**	Modelling software maintenance	Maintenance essential to ensure software provider support	Action Plan/SRBMP-I			**9500**	**10000**	**10500**	**11000**	**12000**	**53000**
2	**1.2.3**	Modelling hardware purchase	Dedicated high spec computers for developing and running the model	Action Plan/SRBMP-I			**5000**			**7000**		**12000**
5	**1.2.4**	Extend model to include tributaries		Action Plan/SRBMP-I			**100000**					**100000**
1	**1.2.5**	Updating the model for sub-daily data, LiDAR data and new topo surveys	Essential when LiDAR data becomes available. This will be essentially a re-build within the framework provided	Action Plan/GFDRR DRM program			**100000**					**100000**
6	**1.2.6**	Update economics assessment of options using updated model	Essential following update of model with LiDAR data.	Action Plan/GFDRR DRM program			**50000**					**50000**
	1.3 Data Sharing and management											
1	**1.3.1**	Digitise existing paper copies of sub-daily rainfall and flow data	Needed for model calibration, design modelling and establishment of catchment response, and for FFEWS	Action Plan/SRBMP-I	MWDI with DCCMS and DNRDM as partners	Historical data digitised and managed with central hydrometric database. Improved data collection and archiving procedures. Data sharing protocols and systems in place	**10000**					**10000**
8	**1.3.2**	Improve the collection and archiving of sub-daily rainfall and flow data in the future	Establish data collection and archiving procedure. Possible review of database systems between Met and MWDI	Action Plan/ ECRP (DFID, Ireland & Norway)SRBMP-I			**50000**	**36000**	**36000**	**36000**	**36000**	**194000**
8	**1.3.3**	Improve data sharing between Met, MWDI and DNRDM	Establish data sharing procedures and protocols.	Action plan/GFDRR DRM Program/UNDP/SRBMP-I			**50000**	**10000**	**10000**	**10000**	**10000**	**90000**
	1.4 Additional Modelling studies											
6	**1.4.1**	Annual modelling and seasonal assessment	For flood forecasting in support of annual Emergency planning meeting	Action Plan	MWDI with consultant	Reports and output from modelling	**5000**	**5000**	**5000**	**5000**	**5000**	**25000**

6	1.4.2	Refinement of flood zone mapping policy	As model is updated, flood zone policy will need to be refined/developed	Action Plan	partners	studies in support of geomorphological assessments, sedimentation studies. Annual modelling assessment for flood season risk management			20000			20000
9	1.4.3	Geomorphological baseline assessment/modelling	Essential for further detailed assessment of the options	Action Plan			175000					175000
9	1.4.4	Sedimentation options assessment	Including development of sedimentation mitigation measures	Action Plan				120000				120000
9	1.4.5	Geomorphological modelling	For detailed options feasibility assessments	Action Plan				20000	20000	20000	20000	80000
10	1.4.6	Adaptation of the Shire Model to provide a distributed (grid-based) hydrological model for the full Shire basin to be developed for real-time use (e.g. based on a threshold-frequency approach)		Action Plan			20000					20000
10	1.4.7	A flood estimation study to develop statistical and unit hydrograph methods for the Shire Basin and associated guidelines, including flash flood guidance indicators for use both off-line and in real-time use		Action Plan				200000				200000
10	1.4.8	An investigation of the accuracy of the current Meteosat and TRMM satellite precipitation products and other sources (e.g. the weather radar at Beira in Mozambique, and the planned Global Precipitation Mission outputs), with recommendations on communications and other improvements needed for real-time operation		Action Plan					100000			100000
	1.5 Modelling for feasibility studies											
12	1.5.1	Reconstruction of Chiromo Bridge		JICA	MWDI with consultant partners	Reports and output from modelling studies in support of options feasibility and design studies.		80000				80000
12	1.5.2	Diversion of Ruo into Elephant Marshes		JICA					80000			80000
12	1.5.3	Detailed design of Structural measures		Action Plan/SRBMP-I			100000	100000	100000	100000	100000	500000
12	1.5.4	Detailed design of catchment management (non-structural) options		Action Plan			20000	20000	10,000			50000
12	1.5.5	Modelling study to support FFEWS		Action Plan/SRBMP-I			50000					50000
	1.6 Training and Support											
3	1.6.1	HD Model Support and Training	Train up at least 1 modeller from each organisation.	Action Plan/SRBMP-I	MWDI, DCCMS, DNRDM with consultant partners	Structured training and support programme delivered over the 5-year period. 2-3 Malawians university trained in flood risk assessment and management methods by year 5	50000	50000	50000	50000	307000	507000
			Total Modelling Cost									5346000

Table 8-2: Action Plan - Flood Forecasting and Early Warning Systems

High level Goals	Theme	Intervention	Detail of Action	Funding	Responsible Agency and Implementing Partners	Evaluation/Indicators of success	Y1 (US$)	Y2 (US$)	Y3 (US$)	Y4 (US$)	Y5 (US$)	Total (US$)
Enhancing Flood Preparedness and response through development of a flood forecasting and early warning system for the Shire basin	**2. Flood Forecasting and Early Warning Systems**											
	2.1 Terms of Reference for Consultancy Services for FFEWS design and operation											
1	**2.1.1**	Inception Phase		Action Plan/SRBMP-I	MWDI with consultant partners	Fully developed ToR for FFEWS, procurement of contractor and completion of the design of the FFEWS. Support and training for FFEWS practitioners in new FFEWS system	**58800**					**58800**
	2.1.2	Design, specs and tender docs (1 or more contracts)		Action Plan/SRBMP-I			**103500**					**103500**
	2.1.3	Data interpretation and procedures for issue of flood warnings		Action Plan/SRBMP-I			**148000**					**148000**
	2.1.4	Acceptance testing of ICT equipment		Action Plan/SRBMP-I			**31000**					**31000**
	2.1.5	Dissemination of warnings to districts and communities		Action Plan / UNDP / ECRP (DFID, Ireland & Norway)SRBMP-I			**17500**	**14500**				**32000**
	2.1.6	Establishment of Community based flood warning systems		Action Plan / UNDP / ECRP (DFID, Ireland & Norway)			**100000**	**11500**	**11500**	**11500**	**11500**	**146000**
	2.1.7	Establishment of Lower Ruo/Lower Shire Scheme		Action Plan/SRBMP-I			**121000**	**11500**	**11500**	**11500**	**11500**	**167000**
	2.1.8	Training of District personnel		Action Plan/UNDP				**35500**				**35500**
	2.1.9	Training of MWDI staff		Action Plan/SRBMP-I				**35500**				**35500**
	2.1.10	Consultant Support for FFEWS		Action Plan/SRBMP-I			**9000**	**7000**	**5000**	**3500**	**2000**	**26500**
	2.1.11	Flood Forecasting (support, assistance, procurement advice, reviews and reports)		Action Plan/SRBMP-I			**11500**	**83000**	**11500**	**11500**	**11500**	**129000**
	2.1.12	Institutional Support for FFEWS (management of data and warning procedure; training)		Action Plan/ UNDP/SRBMP-I			**0**	**0**	**0**	**0**	**0**	**0**
2	**2.2 River level gauges - Provision of 15 new/upgraded river level gauges**											
	2.2.1	Purchase, ship telemetry & other equipment		Action Plan / AfDB/NWDP SRBMP-I, SADC HYCOS / ECRP (DFID, Ireland & Norway)	MWDI, and consultant partners	Procured and installed river level gauge and telemetry equipment at 15 river gauging sites. Support, maintenance and training provided over the 5-year period	**197000**	**98000**				**295000**
	2.2.2	Install telemetry & other equipment at MWDI sites - to include raingauges at some sites		Action Plan / AfDB/NWDP SRBMP-I, SADC HYCOS / ECRP (DFID, Ireland & Norway)			**44500**	**22000**				**66500**
	2.2.3	Civil works		Action Plan / AfDB/NWDP SRBMP-I, SADC HYCOS / ECRP (DFID, Ireland & Norway)			**45400**	**22700**				**68100**
	2.2.4	River gauging equipment		Action Plan / AfDB/NWDP SRBMP-I, SADC HYCOS / ECRP (DFID, Ireland & Norway)				**200000**				**200000**

	2.2.5	Include raingauges at up to 10 river gauge sites		Action Plan / AfDB/NWDP SRBMP-I, SADC HYCOS / ECRP (DFID, Ireland & Norway)			**11000**					**11000**
	2.2.6	Supplier support, maintenance and training (5 years)		Action Plan / AfDB/NWDP SRBMP-I, SADC HYCOS / ECRP (DFID, Ireland & Norway)			**22800**	**22800**	**22800**	**22800**	**22800**	**114000**
2	**2.3 Raingauges - Provision of 15 new raingauges**											
	2.3.1	Purchase, ship telemetry & other equipment		Action Plan /SRBMP-I/ DCCMS plans (climate risk)	DCCMS, MWDI, consultant partners, and contracting partners	Procured and installed raingauges (15). Support, maintenance and training provided over the 5-year period	**175900**	**88000**				**263900**
	2.3.2	Install telemetry & other equipment at DCCMS sites		Action Plan / SRBMP-I/DCCMS plans (climate risk)			**44000**	**22000**				**66000**
	2.3.3	Civil works		Action Plan /SRBMP-I/ DCCMS plans (climate risk)			**4000**	**2000**				**6000**
	2.3.4	Supplier support, maintenance and training (5 years)		Action Plan /SRBMP-I/ DCCMS plans (climate risk)			**0**	**26500**	**26500**	**26500**	**26500**	**106000**
3	**2.4 Telecoms Fees - Annual telecommunications fees for 5 years - telemetry and warning dissemination**											
	2.4.1	SMS and call charges from 20 sites		Action Plan / AfDB/NWDP SRBMP-I, SADC HYCOS	MWDI, DCCMS	SMS charges cost over 5-year period	**1400**	**1400**	**1400**	**1400**	**1400**	**7000**
	2.4.2	Toll free numbers		Action Plan			**3300**	**3300**	**3300**	**3300**	**3300**	**16500**
3	**2.5 Equip MWDI Ops room**											
	2.5.1	Meteosat ground station purchase ship install etc.	Purchase ship install etc.	Action Plan / possibly SADC HYCOS	DCCMS, MWDI, DNRDM and consultant partners	Procured and installed telemetry software, hardware and Ops room equipment. Fully equipped and functioning Ops room after 5 years	**18000**	**0**	**2000**	**2000**	**2000**	**24000**
	2.5.2	Ops room telemetry software	Supply, set up, training	Action Plan / AfDB/NWDP SRBMP-I, SADC HYCOS			**28000**					**28000**
	2.5.3	Ops room IT hardware	Supply and support	Action Plan /UNDP/ AfDB/NWDP SRBMP-I, SADC HYCOS			**14000**					**14000**
	2.5.4	Provide backup for GWAN at MWDI	Broadband rental	Action Plan			**13200**	**13200**	**13200**	**13200**	**13200**	**66000**
	2.5.5	Support package - IT equipment		Action Plan / UNDP / SRBMP-I				**1100**	**1100**	**1100**	**1100**	**4400**
	2.5.6	Alarm dissemination	Software, hardware and support	Action Plan/SRBMP-I			**22000**	**1700**	**1700**	**1700**	**1700**	**28800**
	2.5.7	Operations centre equipment and security		Action Plan/SRBMP-I			**36500**	**73500**				**110000**
	2.5.8	Additional equipment for DCCMS Forecasting Centre	Telemetry software, support and training	Action Plan/SRBMP-I/UNDP			**17000**					**17000**
	2.5.9	Ops room IT hardware	Supply and support	Action Plan/SRBMP-I			**6500**	**600**	**600**	**600**	**600**	**8900**
	2.5.10	Upgrade DNRDM Ops. Room for flood warning related equipment		Action Plan/ UNDP				**27000**				**27000**
3	**2.6 Radios**											
	2.6.1	HF Radio	Connect 5 districts, DNRDM, MWDI & Met (supply, support and training)	Action Plan	MWDI, DCCMS, DNRDM with consultant partners	Procured and installed radio equipment in 5 district and DNRDM,	**116500**	**11000**	**11000**	**11000**	**11000**	**160500**

	2.6.2	VHF Radio	Reliable back up voice communications	Action Plan		MWDI and DCCMS. Support and training provided in the used of equipment	**40500**	**17000**	**18500**	**20000**	**21000**	**117000**
4	**2.7 Warning Dissemination**											
	2.7.1	Cell broadcast	Feasibility study and 3 month trial	Action Plan/ UNDP(2.3,2.7 &2.8)/ECRP(DFID, Irish Aid & Norway) / UNDP/SRBMP-I	MWDI	Procurement and provision of cell phones and other equipment to communities. Website designed and implemented	**148000**					**148000**
	2.7.2	Website	Feasibility study and implementation	Action Plan / WB SDI, SRBMP-I, AfDB/NWDP				**11000**	**22000**	**22000**	**22000**	**77000**
	2.7.3	Cell phones	For reception of auto generated alarms and cell broadcast including chargers	Action Plan/ECRP (DFID, Irish Aid & Norway) / UNDP			**15500**					**15500**
	2.7.4	Community-based scheme equipment	Megaphones, bicycles, flags, posters, personal safety equipment etc	Action Plan /ECRP (DFID, Irish Aid & Norway)/UNDP/ possibly SRBMP-I			**89500**	**89500**	**89500**	**89500**	**89500**	**447500**
5	**2.8 Flood Forecasting**											
	2.8.1		Forecasting System and models	Action Plan / SRBMP-I Operational DSS	MWDI, DCCMS	Forecasting system and models procured, installed and fully operational at the end of 5-year period		**73500**	**127000**	**95000**	**65000**	**360500**
6	**2.9 National Flood Warning Initiatives**											
	2.9.1	National Flood Warning Investment Strategy	Development of national strategy and in particular recommendations on how the Shire Basin FFEWS will be funded beyond Year 5 of the Action Plan	Action Plan/UNDP/SRBMP-I	MWDI, DNRDM, DCCMS and consulting partners	Fully developed national flood warning investment strategy by end of year 1	**102000**					**102000**
			Total FFEWS Costs									3888900

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Table 8-3: Action Plan - Institutional Development and Capacity Building

High level Goals	Theme		Intervention	Detail of Action	Funding	Responsible Agency and Implementing Partners	Evaluation/Indicators of success	Y1 (US$)	Y2 (US$)	Y3 (US$)	Y4 (US$)	Y5 (US$)	Total (US$)
Building Capacity for Flood Risk management in Malawi - Institutional Strengthening	**3. Institutional Development and Capacity Building**												
	3.1 MWDI												
2		**3.1.1**	MWDI to be involved - install, commission, manage and maintain improved river gauging - manual and telemetered	Staff should be involved in the procurement, installation, commissioning, management and maintenance of new and rehabilitated river gauges	Action Plan / AfDB/NWDP SRBMP-I, SADC HYCOS	MWDI	MWDI staff recruited and fully employed in management of the Action Plan and the activities included in developing and installing the FFEWS equipment			**3000**			**3000**
1		**3.1.2**	Provide a staff member to be the modeller	Staff will be trained on the job under elements of the Action Plan	Action Plan			**12000**	**12000**	**12000**	**12000**	**12000**	**60000**
3		**3.1.3**	Provision of a programme manager / administrator and support services	MoIAWD will appoint a programme manager and associated support staff	Action Plan			**20000**	**20000**	**20000**	**20000**	**20000**	**100000**
3		**3.1.4**	Project Management support and Training for MWDI	External expertise will be used to develop and deliver a programme of training to emerging MOIAWD staff including the programme manager	Action Plan/SRBMP-I			**23000**	**18000**	**18000**	**18000**	**18000**	**95000**
3		**3.1.5**	Provision of MWDI Sub programme manager		Action Plan			**15000**	**15000**	**15000**	**15000**	**15000**	**75000**
	3.2DCCMS												
2		**3.2.1**	Met to be involved - install, commission, manage and maintain rain gauges.	Staff should be involved in the procurement, installation, commissioning, management and maintenance of new and rehabilitated rain gauges	Action Plan / DCCMS plans (climate risk)	DCCMS	DCCMS staff recruited and fully employed in the activities included in developing and installing the FFEWS equipment			**3000**			**3000**
3		**3.2.2**	Met data digitisation and entry	Allowance to enable junior met staff member to digitise and enter all relevant data (including water) to model database	Action Plan/SRBMP-I								**0**
	3.3 Weather Forecasting												
7		**3.3.1**	MET services improve accuracy of 5 day, 10 day, long term and intense storm forecasts	MET services improve accuracy of forecast	Action Plan/UNDP?/SRBMP-I	DCCMS	Improved accuracy of met forecast by 10% in each year over the 5-year period (measured by number of forecasts that are within 70% expected values???)	**14000**					**14000**
7		**3.3.2**	Met Services to share data from Mozambique	Exchange visit to initiate data sharing and follow up	WMO? / Action plan			**10,000**	**10,000**	**10,000**	**10,000**	**10,000**	**50000**
	3.4 DNRDM												
6		**3.4.1**	Ensure warnings are followed up and delivered	Develop protocol with external assistance	Action Plan/UNDP (PSD 5.1)	DNRDM	Established and implemented protocols for warning dissemination and follow up, flood event coordination procedures, emergency procedures and for the development of contingency plans. Training of regional and national partners in new protocols	**25,000**	**25,000**	**25,000**	**25,000**	**25,000**	**125000**
5		**3.4.2**	DNRDM - support districts during flood events	Vehicle with communications equipment which can act as operations centre deployed to flooded area(s)	Action Plan			**170000**					**170000**
4		**3.4.3**	DNRDM - Coordination procedures	Develop protocol / standard procedures with external assistance	Action Plan								**0**
6		**3.4.4**	Training by DNRDM of all stakeholders in warning systems	Training of trainers and district level training courses	Action Plan/UNDP PSD 1.4 , 2.7 and 2.8			**35000**	**12000**	**12000**	**12000**	**12000**	**83000**
5		**3.4.5**	DNRDM training	Training at regional, national , international partner level on response under a "State of Disaster" with external assistance	Action Plan/UNDP PSD 5.1 and 3.1				**13500**	**3500**	**3500**	**3500**	**24000**
5		**3.4.6**	DNRDM Finance Procedures	Develop protocol / standard procedures for emergency procedures with external assistance	Action Plan/UNDP PSD 5.1 and 3.1								**90000**

5	**3.4.7**	DNRDM Operating Procedures	Development of standard operating procedures and plans for the event of state of disaster due to flooding with external assistance	Action Plan/UNDP PSD 5.1 , 3.1 and 3.4)								**90000**
5	**3.4.8**	DNRDM Communications	Connectivity and synchronisation between local national and international agencies with external assistance	Action Plan/UNDP PSD 5.1, 3.1 and 3.3)								**50000**
5	**3.4.9**	DNRDM - procedures for Recovery	Development of contingency plan for recovery efforts with external assistance and training	Action Plan/UNDP PSD 5.1 and 3.1								**90000**
6	**3.4.10**	DNRDM/NGOs - Community awareness training	NGO support to update existing community schemes, new schemes trained	Action Plan			**5000**	**5000**	**5000**	**5000**	**5000**	**25000**
	3.5 Monitoring and Evaluation											
7	**3.5.1**	Monitoring so that improvements and adjustment can be made to ensure its progress and success	External expertise will be used to make an annual technical audit of progress and propose modifications and actions	Action Plan/SRBMP-I	External audit (consultant) partner	Results of annual audits	**23000**	**13000**	**13000**	**13000**	**13000**	**75000**
	3.6 Guidelines											
7	**3.6.1**	Flood defence design guidelines	Local or possibly external expert to develop revised design manuals	Action Plan/SRBMP-I	MWDI with consultant partners	Flood defence guidelines document produced in year 1	**20000**					**20000**
8	**3.6.2**	Training course on use of guidelines	Expert will train target users on the guidelines	Action Plan/SRBMP-I			**20000**					**20000**
			Total Institutional Costs									**1262000**

Table 8-4: Action Plan - Structural Interventions

High level Goals	Theme	Intervention	Detail of Action	Funding	Responsible Agency and Implementing Partners	Evaluation/Indicators of success	Y1 (US$)	Y2 (US$)	Y3 (US$)	Y4 (US$)	Y5 (US$)	Total (US$)
Reducing flood risk and building resilience in Malawi	**4. Structural Interventions**											
	4.1 Flood Defences - Gabion protected bunds											
1	**4.1.1**	Nsanje	Construction of defence according to detailed design	Action Plan/ECRP (DFID, Ireland & Norway)/SRBMP-I	MWDI with contractor partners	Flood defences built to appropriate standards		**380000**	**455000**			**835000**
2	**4.1.2**	Chikwawa	Construction of defence according to detailed design	Action Plan/ECRP (DFID, Ireland & Norway)/SRBMP-I				**670000**	**365000**	**91000**		**1126000**
2	**4.1.3**	Allow for increased bund length (Nsanje & Chikwawa)	Construction of defence according to detailed design	Action Plan/ECRP (DFID, Ireland & Norway)/SRBMP-I				**500000**	**400000**	**45000**		**945000**
3	**4.1.4**	Allow for other Districts	Construction of defence according to detailed design	Action Plan/ECRP (DFID, Ireland & Norway)					**200000**	**200000**	**200000**	**600000**
	4.2 Flood Defences - Sand Bag protected bunds											
1	**4.2.1**	Nsanje	Construction of defence according to detailed design	Action Plan/ECRP (DFID, Ireland & Norway)/SRBMP-I	MWDI with contractor partners	Flood defences built to appropriate standards		**107000**	**36000**	**4000**	**65000**	**212000**
2	**4.2.2**	Chikwawa	Construction of defence according to detailed design	Action Plan/ECRP (DFID, Ireland & Norway)/SRBMP-I				**44000**	**8000**	**7000**	**31000**	**90000**
2	**4.2.3**	Allow for increased bund length (Nsanje & Chikwawa)	Construction of defence according to detailed design	Action Plan/ECRP (DFID, Ireland & Norway)/SRBMP-I				**75000**	**20000**	**5000**	**50000**	**150000**
3	**4.2.4**	Allow for other Districts	Construction of defence according to detailed design	Action Plan/ECRP (DFID, Ireland & Norway)					**200000**	**200000**	**200000**	**600000**
	4.3 Catchment Improvement											
4	**4.3.1**	Mwanza Catchment (allowance - awaits further assessment)	Implementation of catchment management plan	Action Plan/ECRP (DFID, Ireland & Norway)	MWDI with MoA, Forestry Department and external partners	Catchment Improvement Plan completed and implemented by end of 5-year period			**200000**			**200000**
5	**4.3.2**	Ruo Catchment (allowance - awaits further assessment)	Implementation of catchment management plan	Action Plan/ECRP (DFID, Ireland & Norway)					**200000**			**200000**
5	**4.3.3**	Other Catchments (allowance - awaits further assessment)	Implementation of catchment management plan	Action Plan/ECRP (DFID, Ireland & Norway)						**1000000**		**1000000**
	4.4 Food/Grain Stores											
2	**4.4.1**	Nsanje	Construction of district flood/grain stores	Action Plan/ECRP (DFID, Ireland & Norway)/SRBMP-I	MWDI with contractor partners	Number of grain stores built and fully functioning in each district	**20000**	**30000**	**30000**	**30000**	**30000**	**140000**
2	**4.4.2**	Chikwawa	Construction of district flood/grain stores	Action Plan/ECRP (DFID, Ireland & Norway)/SRBMP-I			**20000**	**30000**	**40000**	**40000**	**40000**	**170000**
6	**4.4.3**	Allow for other Districts	Construction of district flood/grain stores	Action Plan/ECRP (DFID, Ireland & Norway)				**40000**	**40000**	**40000**	**40000**	**160000**
	4.5 Dredging											
	4.5.1	Maintenance of waterways at critical culverts and bridges	Annual dredging	Action Plan	Min of Transport		**20000**	**20000**	**20000**	**20000**	**20000**	**100000**

	4.6 Flood Proofing of Buildings											
	4.6.1	Study of benefits of flood proofing of existing buildings to act as flood shelters	Local or external expert to assess practicalities, cost and benefits	Action Plan	MWDI			**20000**				**20000**
			Total Structural Interventions Costs									**6548000**

The total cost of all proposed interventions is presented in Table 8-5 below:

Table 8-5: Action Plan Summary Costs

	Estimated Cost (US$)
HD Modelling	5,346,000
Flood Forecasting and Early Warning	3,888,900
Institutional Development and Capacity Building	1,262,000
Structural Interventions	6,548,000
Sub Total	17,044,900
All Contingency (15%)	2,556,735
TOTAL ACTION PLAN COST	19,601,635

As explained in Section 7.4, cost estimates for each activity or intervention have included a contingency allowance – with the allowance applied being generally appropriate to the level of confidence of estimation of cost for that activity. The development of proposals for the Plan has been undertaken in the context of a US$20million budget assigned by the World Bank. With this budget in mind, we have applied an overall contingency allowance of 15% to the Action Plan – to provide some protection to the possibilities of overspend. The Action Plan tables include a column to show Funding. Here, whilst World Bank has committed to funding the Action Plan up to the "budget" of US$20million, it is apparent that other donors are currently funding or are proposing to fund projects that overlap with some of the activities shown in the Plan. Accordingly, we have indicated where we are aware of such overlaps or of the intention of other donor funded projects to implement these interventions. At this stage, this cannot be viewed as a definitive interpretation and it is intended that the proposed Action Plan is discussed with donors so that the overall funding arrangements can be clarified.

8.2. Prioritisation

An important objective of the Action Plan has been to establish a prioritised list of interventions – so that the most urgent requirements are clearly identified for the earliest implementation.

The prioritisation of activities listed under each of the four headings in the Action Plan has been undertaken following the consideration of various criteria. These criteria are different for the different Action Plan headings, as shown below:

- HD Modelling Framework
    - Importance to the Action Plan objectives
    - Cost
- Flood Forecasting and Early Warning (FFEWS)
    - Importance to the Action Plan objectives
    - DEC and main stakeholder comment
    - Cost
- Institutional Development and Capacity Building
    - Importance to the Action Plan objectives
    - DEC and main stakeholder comment
    - Cost
- Structural Interventions
    - Technical impact/effectiveness
    - Practicality of implementation
    - DEC Comment
    - Economic viability
    - Cost
    - Environmental Impact

Initially, consideration had been given to the establishment and use of a decision matrix to guide prioritisation but this was rejected as inappropriate for this project. Rather, the use of the criteria shown has, in the main, been based on judgement, which in turn has been based on an understanding of the prevailing situation in the Shire Basin and on information provided by stakeholders.

Thus, the prioritisation of the HD Modelling Framework activities has been largely based on the TOR requirements to establish, maintain, improve and operate a hydraulic model.

Similarly, the priority of activities for FFEWS has been primarily influenced by the requirement to provide terms of reference for the design and implementation of a new/improved flood forecasting and early warning system. Other important considerations that influenced the priority are the comments and feedback from the communities and stakeholders and cost.

Determination of the priority of Institutional activities has taken account of the required urgency for support and training for the major institutions – to enable realisation of the objectives of the Action Plan – having regard also to information gathered from the stakeholders and activity cost.

For structural interventions, the technical effectiveness – in minimising flood impact – and the practicalities of construction have been considered. As explained earlier, large capital intensive projects have not been recommended for inclusion in the Action Plan due to difficulties in demonstrating their viability at this stage and because their cost is likely to exceed the currently available budget. Thus cost effectiveness, based on benefit/cost ratio, and the ranking of priorities by the DECs has been taken account of. Future assessments will take further account of environmental issues.

Thus the most critical villages in Chikwawa and Nsanje have been identified and structural interventions to mitigate the flood impact to these villages have been assessed largely on the basis of technical viability and cost effectiveness. Further assessment will be required to confirm priorities once improved topographical data has been obtained, enabling re-assessment using the HD model, improved cost estimates and a re-evaluation of benefit–cost ratios. Similarly, improved topographical data will enable assessment and prioritisation of measures to minimise impact to villages in Mulanje, Mwanza, Thyolo and Blantyre districts.

It should be emphasised that the priorities – the ranking to show those activities for the earliest implementation – will need to be reviewed periodically. As studies are progressed and as further data is generated, it is expected that priorities will change and it is important that those responsible for the management of the Action Plan recognise the need for review and regular updating.

The concept of prioritisation is crucial to the success of the Action Plan. This concept will ensure that the most critical activities are undertaken first – that mitigation is provided first to the most severely impacted communities – that resources are deployed most efficiently and that funding is directed to where it is most needed. It is important that donors and stakeholders “buy-in” to this concept at the outset and that their commitment is maintained as assessments are improved and prioritisations are confirmed.

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8.3. Quick Wins

Consideration has been given to those activities or interventions that can be undertaken quickly – requiring minimal administration, in some cases lesser cost, and the potential for providing early benefits.

The proposed "Quick Wins" have been highlighted in Tables 8-1 to 8-4 and are listed below:

Table 8-6: Quick Win Options

Option Index	Options title
1.2.1	Purchase HD Modelling Software
1.2.3	Purchase HD Modelling Hardware
1.2.5	Update the HD Model for LiDAR and sub-daily data
1.3.1	Undertake key topographic surveys for extension of HD Model
1.3.1	Assistance with digitising paper copies of sub-daily rainfall and flow data
1.6.1	Provide a MWDI staff member to be the Modeller
3.1.2	HD Model Support and Training
3.5.1	Establishment of a Monitoring and Evaluation (M&E) Procedure
3.6.1	Initial visit(s) to Mozambique to facilitate data exchange
3.6.2	Study/draft new guidelines for design of flood defences

The procurement of the above "Quick Wins" may need separate procurement arrangements. These are discussed in Section 8.4.

8.4. Procurement Plan

The options proposed for inclusion in the Action Plan have been assembled into packages appropriate for procurement – having regard to their scope, cost, complexity and proposed timing.

The proposed packages are listed in Table 8-7 below.

Table 8-7: Proposed packaging of activities for the Action Plan

	Package	Description
A	HD Model Services	Model improvement and support; further option assessments; geomorphological studies and modelling
B	HD Model Software	Supply and maintenance of model software
C	HD Model Hardware	Supply of hardware for use with the HD Model
D	Assistance with Data Provision	Digitising of rainfall and flow data and improvement of data collection
E	Topographic Surveys	Topo and hydrographic surveys of tributaries and critical reaches of the Shire
F	Consultancy Services for FFEWS	Design, training and support for new FFEWS including management and maintenance of installations
G	Rain and Flow Gauges	Supply, installation and maintenance of rainfall and flow gauges
H	Assistance to DNRDM and MWDI	Technical and management support to DNRDM and MWDI
J	IT and Communication Equipment	Supply, installation and maintenance of IT and Communication equipment
K	Community Based FFEWS schemes	Installation, commissioning and maintenance
L	Structural Interventions	Installation and maintenance including design participation

Indicative scheduling of these packages over the five years of the Action Plan is shown in Figure 8-1.

Due to the extended programme for the Action Plan – over five years - and, in some cases, the varied geographical location, it is expected that some of the packages will be divided into sub-packages:

Package E, Topographic Surveys – it is intended that these surveys will be undertaken by local survey companies as discrete packages of works, appropriate to their size and geographical location.

Package H, Assistance to DNRDM and MWDI – this package contains a miscellany of assistance services that will require different skills and will be undertaken at different times during the Action Plan period.

Package K, Community Based FFEWS Schemes – the Action Plan provides for implementation of up to 10 community based schemes over a five year period. It is envisaged that the first of these schemes will be implemented in Year 2 by an NGO/Contractor consortium. Implementation of successive schemes by the same consortium will need consideration – it is likely that continuation by the same consortium would be based on their performance on the initial scheme.

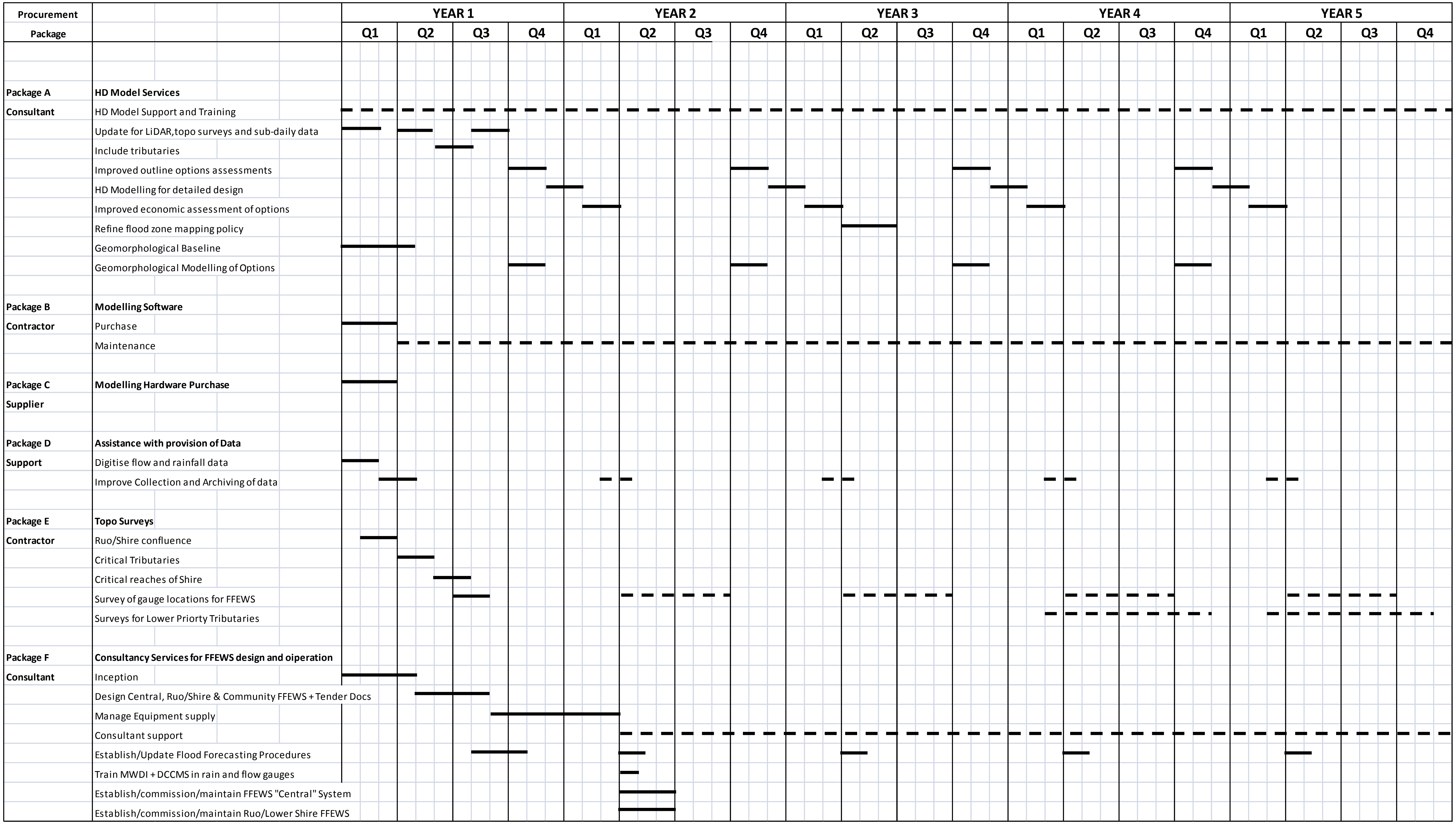
Package L, Structural Interventions – these interventions will include construction of flood defence bunds, food stores, catchment improvements and dredging. The variety of skills required, the varied geographical location and the intermittent timing of construction will require these works to be let as separate sub-packages. Also, it is anticipated that communities will participate in many of these schemes – perhaps under the supervision of MWDI or an NGO – and any tendering and contract award procedures for these schemes will have to take account of such arrangements.

Also, the Quick Wins listed in Table 8-6 are likely to be procured by means of separate contract packages – via sub-packages as suggested in Table 8-8 below.

Table 8-8: Proposed Arrangements for Procurement of Quick Wins

Package	Sub Package	Option
Package A	Sub Package A1	Update the HD Model for LiDAR and sub-daily data
	Sub Package A2	HD Model Support and Training
Package B	Complete	Provide HD Model Software
Package C	Complete	Provide HD Model Hardware
Package D	Complete	Assistance with Data Provision
Package E	Sub Package E1	Topo Surveys to enable initial extension of the HD Model
Package H	Sub Package H1	Provision of MWDI staff as Modeller
	Sub Package H2	Establishment of M&E procedures
	Sub Package H3	Flood Defence Design Guidelines

Figure 8-1: Action Plan Programme



Package G	**River Level Gauges**
Contractor	Tender Procedures and Award
	Purchase and ship
	Install + civil works + commission
	Supplier support and maintenance
	Rain Gauges
	Tender Procedures and Award
	Purchase and ship
	Install + civil works + commission
	Supplier support and maintenance
Package H	**Technical/Managerial Support**
	Programme & Sub Programme Manager for MWDI
	Project Management Support for MWDI
	Flood Defence Design Guidelines
	Training in FD Design Guidelines
	Procedures and Training for DNRDM
	M&E Guidelines and Support
Package J	**Equipment for MWDI, DCCMS + DNRDM Operations**
Contractor	Tender Procedures and Award
	Purchase and ship
	Install + commission
	Supplier support and maintenance
	Communication Equipment
	Tender Procedures and Award
	Purchase and ship
	Install + commission
	Support contract
Package K	**Establish/commission/maintain FFEWS**
Contractor	Community Based Systems Type 1
Package L	**Structural Interventions**
Contractors	Flood Embankments
	Catchment Improvements
	Food Stores

8.5. Future Plan

Beyond the five years of the Action Plan, there will be a requirement for the continuation of key activities.

A summary of those activities that are likely to require external funding beyond Year 5 is given in Table 8-9 below.

Table 8-9: Activities beyond Action Plan requiring External Funding

Theme	Options
HD Model Services	Topo Surveys to extend the coverage of the Model
	Modelling for Feasibility Studies
	HD Model Support
FFEWS	Provision of rain gauges (extend coverage_
	Provision of flow gauges
	Community based scheme equipment
	Improvements to Flood Forecasting
	Support to National Flood Warning Investment Strategy
Institutional Development	Support to MWDI – Project Management and Modeller
	Training and support to DNRDM
Structural Interventions	Flood defence embankments – all districts
	Catchment improvements – critical tributaries
	Food stores – all districts
	Assess requirement for flood proofing of churches and schools to act as community shelters
	Off-channel and in-channel storage – feasibility studies

The requirement and programming of these activities will be integrated with the Shire Basin Management Organisation which is expected to assume responsibility for water management in the Shire Valley in the years to come.

9. Guidelines for Future Assessment

This project has undertaken the assessment of flood mitigation options in the Shire Basin using data available, additional data gathered in the course of the project, and new tools – such as the HD Model – established as part of the project.

Assessment of new options, as well as the improved assessment of those options already screened, will be required in the future. The assessment will take account of technical, cost, economic and environmental issues.

Summary guidelines are given below for the assessment of future flood mitigation options.

9.1. Review of Overall Flood Hazard Situation

Updated flood hazard maps should be reviewed to verify the impact of flooding and to confirm the priority for implementation of flood mitigation measures.

Priorities for mitigation – for construction of flood defences – have been determined in Nsanje and Chikwawa districts using flood mapping and advice given by the District Executive Committees (DECs). This has highlighted those tributaries and villages that are most severely impacted by flooding and are most likely to merit the design and construction of flood defences.

The concept of the Action Plan is to address the implementation of all interventions – including flood mitigation measures – in terms of their priority. That is, protection to those villages that are most severely affected should be provided first. It is important that designers, donors, managing institutions, NGOs and contractors adhere to this concept so that efforts are focussed in the neediest areas and that resources and funding are utilised in the most efficient way.

9.2. Model Assessment

It is intended that the HD model will be continuously updated and improved. In the first instance, LiDAR data and sub-daily rainfall data will be used to upgrade the model. Then, over subsequent months further data will be added for improvement of the model.

These improvements will encompass extension of the model to include tributaries of the Lower Shire.

The model will used to determine flood depths at critical locations. This will establish the baseline flood risk to villages and communities – that is, without intervention or protection. For this project, model “runs” have been made for the 5, 10, 20, 50, 75, 100 and 500 year return period floods. The 100 year flood event has been selected for the purposes of design of flood protection measures.

Following establishment of the baseline flood depth, potential arrangements of flood defence, or mitigation, can be investigated. Successive model “runs” can be made with trial arrangements of defence. In the first instance these are likely to be embankments, but other options such as catchment improvement and storage, may be possible. The trial arrangements will comprise alternative configurations of embankment – location, height and length – and the improvement in terms of flood impact will be given by the model. The improvements given by these options – in terms of flood depth and extent – will be generated by the model for each return period, although, as stated above, the 100 year return period is considered suitable for design.

Appendix H provides guidelines for the modelling framework and provides guidance to the use of the modelling framework for modelling and assessing flood mitigation options.

9.3. Cost Estimate

For each modelled option, an estimate of cost of construction will be prepared. The cost estimate will include the initial costs of construction - under the following headings – as well as maintenance and improvement costs over a 20 year period:

- Provision of materials (earthfill, rock, gabion baskets etc)
- Construction (plant/equipment and labour)

Design and supervision

Contractor establishment (preliminary and general) costs

Contingencies

The design and arrangement of the defence will be in accordance with the new guidelines proposed to be prepared under the Action Plan.

The above costs need to take due account of the proposed arrangements for procurement. Construction may be by a private contractor, or by the community itself, with or without the assistance and support of an NGO. These alternatives will give rise to different costs, which, as discussed below, will generate different benefit/cost ratios and thus, will affect selection for implementation.

9.4. Economic Assessment

In the first instance, the baseline case will be generated – this representing the Do Nothing/Existing situation, or the costs arising if no improvement or mitigation is undertaken.

The baseline will be generated using average losses per household under various categories. Typical values for these for the districts of Nsanje and Chikwawa are shown in Table 9-1 below.

Table 9-1: Flood losses per household affected per flood event (USD)

Category of Flood Loss	Do Nothing Baseline (per household)
Property Loss	based on modelled depth
Inventory Loss	based on modelled depth
Food stores and aid Based on 3 months of Food Basket costs plus one month of food aid	$314
Health, water and shelter aid From National Contingency Plan	$624
Education loss/aid From National Contingency Plan	$23
Agricultural Recovery From National Contingency Plan	$11
Livestock From national livestock count statistics	$446

The values in Table 9-1 may need to be adjusted for different districts and should be reviewed and updated annually.

The above Do Nothing costs are based on the principle that the provision of aid is the main cost arising from flood impact. So, using the average losses in Table 9-1 - adjusted to suit the district under consideration - total damages for the village, or villages, for which flood defences is being considered can be calculated in the form of the table given in Table 9-2 below.

Table 9-2: Form for calculation of flood damages

	Property & Inventory Damage	Food Stores and Aid	Health & Shelter Aid	Education loss/aid	Agricultural recovery	Livestock	Total Damages (US$)
Village X							

The "Total Damages" is, in effect, the benefits that would be realised – or the damages avoided - if the flood defence was constructed.

Thus, costs and benefits (damages) will have been determined for the flood defence option investigated, for the village under consideration, which, in turn, will allow a benefit/cost ratio to be determined.

Benefit/cost ratios can then be compared for all villages investigated and for all flood defence options. This comparison will enable those options with the highest and most robust benefit/cost ratio to be selected for earliest construction. Benefit/cost ratios above unity might, be considered adequate for implementation in some circumstances. However, in the case of flood mitigation measures in the Shire Basin, b/c ratios exceeding 5 should be expected, for justification of implementation.

The spreadsheet developed for calculation cost-benefit analysis for the Shire is provided as an excel spreadsheet accompanying this report.

9.5. Environmental Assessment

The flood defence options under consideration should be screened for environmental impact.

The description above has focussed on the assessment of a flood defence embankment, but other mitigation options will also be considered and will need similar assessment. These include catchment improvement and flood storage.

The preliminary environmental assessment undertaken as part of this project identified positive and negative impacts of each of these options, and highlighted issues that will need further consideration. These are summarised in Table 9-3 below.

Table 9-3: **Environmental Impacts of Structural Options**

Option	Key positive impacts	Key negative impacts	Significant gaps to be addressed
Flood bunds	Directly reduces the impact of flooding, in terms of risk to life and risk to property. Reduced risk of displacement from homes and reduced risk of flooding-related disease outbreaks.	Construction of flood bunds to encircle villages may result in land severance, limit future development and/or create social division in the future.	Consultation with affected communities will be required to ensure that the alignment of defences is planned to avoid severance or future restrictions. There is currently insufficient information to allow any assessment of impacts on habitats, species or cultural property – this information should be gathered during later stages of work.
Catchment	Directly reduces the impact of flooding, in terms of risk to life	No adverse effects identified, but it is recognised that this is	Community consultation and involvement to ensure that

improvement	and risk to property. Reduced risk of displacement from homes and reduced risk of flooding-related disease outbreaks. Secondary benefits could be generated from including crop trees. Management of improvement areas could generate local employment. Could contribute to reversal of land degradation. Possible secondary benefits to habitats/ species.	a long term option that would require significant time and resource commitment to ensure its success.	local people are fully engaged and appropriate areas are targeted for improvement. Environmental baseline studies to help define areas that could be improved.
Flood storage	Directly reduces the impact of flooding, in terms of risk to life and risk to property. Reduced risk of displacement from homes and reduced risk of flooding-related disease outbreaks.	Construction of flood storage areas could affect current or future land use within the proposed storage area.	Consultation with affected communities will be required to ensure that the location of the storage area is planned to avoid adverse effects on land use. There is currently insufficient information to allow any assessment of impacts on habitats, species or cultural property – this information should be gathered during later stages of work.

These impacts should be explored in detail as part of the overall assessment of flood mitigation options.

9.6. Assessment Conclusion

The ranking, or prioritisation of the options derived after the economic analysis will be used with the results of the environmental assessment to determine:

- Whether or not the option merits implementation – is the benefit/cost ratio sufficiently robust and can any environmental impacts be mitigated?
- The scope/arrangement of the option – as determined from investigation of the various scenarios using the model
- The optimal method of procurement – by comparison of the costs of alternative methods and their impact on the benefit/cost ratio

Thus, the assessment will give confidence that the most suitable option has been selected for implementation.

10. Recommendations

This report – the Final Report of the Integrated Flood Risk Management Plan – has presented a five year Action Plan for the mitigation of flood impact in the Shire Basin.

The Action Plan includes details of intervention activities under the "themes" of HD Modelling, Flood Forecasting and Early Warning, Institutional Development and Capacity Building, and Structural Interventions. A proposed programme for implementation of the Action Plan has also been presented.

The interventions recommended for implementation are summarised below under the headings of "Quick Wins", "Action Plan" and "Future".

10.1. Quick Wins

Recommendations for "Quick Wins" are summarised below:

- Digitise existing paper copies of sub-daily rainfall and flow data; update the model for sub-daily data, LiDAR data and new topo surveys
- Purchase modelling software and hardware and arrange maintenance for software
- Provide HD Model Support and Training
- Train a MWDI staff member to be the modeller
- Establish Monitoring and Evaluation procedure for Action Plan, including training
- Develop flood defence design guidelines, including training

10.2. Action Plan

Recommendations for actions/interventions during the five year period of the Action Plan are summarised below and are show in terms of their priority under each of the four "themes".

10.3. HD Modelling

1. Topo Surveys at critical tributaries and include in the Model
2. Using updated model, update economics assessment of options, refine flood zone mapping policy and undertake seasonal assessments of flood forecasting
3. Topo Surveys at critical reaches of Shire and at shire/Ruo confluence
4. Improve the collection and archiving of sub-daily rainfall and flow data, and data sharing between key stakeholders
5. Studies of geomorphology and sedimentation and develop sediment mitigation measures
6. Topo surveys of gauge locations and for lower priority tributaries, and add to the Model
7. Use Model for studies for improvements and rehabilitation of infrastructure and flood mitigation measures

10.4. Flood Forecasting and Early Warning

1. Consultancy Services for FFEWS design and operation
2. Provide new rain gauges and new/refurbished river level gauges
3. Purchase and install equipment for MWDI and DNRDM Ops Rooms, and provide communications equipment for MWDI, DNRDM and the districts
4. Feasibility studies for cell broadcasts and a website, and provide equipment for community based schemes
5. Improve flood forecasting models
6. Develop National Flood Warning Investment Strategy and review national flood warning messages

10.5. Institutional Development and Capacity Building

1. Ensure involvement of MWDI and DCCMS – respectively - with installation, commissioning, management and maintenance of new river gauges and rain gauges
2. Provide MWDI manager for programme management of Action Plan, together with sub-programme manager, training and support

3. Develop standard procedures for DNRDM – coordination, flood response, operation, finance etc – including support and training
4. Provided vehicle for DNRDM support to districts, and awareness training in districts and communities
5. DCCMS improve communications with Mozambique and improve accuracy of weather forecasting

10.6. Structural Interventions

1. Gabion protected flood defence embankments to 2 villages in Nsanje district
2. Gabion protected flood defence embankments to 7 villages in Chikwawa district
3. Sand bag protected flood defence embankments to 11 villages in Nsanje district
4. Sand bag protected flood defence embankments to 9 villages in Chikwawa district
5. Food/grains stores in Nsanje district
6. Food/grain stores in Chikwawa district
7. Flood defence embankments in Mwanza, Mulanje, Thyolo and Blantyre districts
8. Assess catchment improvements on Upper Mwanza
9. Assess catchment improvements on other critical tributaries

10.7. Future (Beyond the 5 Year Action Plan)

As explained in earlier sections of this report, many of the activities recommended for implementation during the five years of the Action Plan will be continued in the future. The need for their continuation will be assessed and confirmed at the end of the Action Plan period.

Therefore, although it is not possible to be definitive about those activities that will be recommended for implementation after five years, at this stage it is envisaged that a list of such activities could include the following:

- Topographic Surveys to extend the coverage of the Model
- Modelling of Feasibility Studies for improvements to infrastructure and flood defences
- HD Model Support
- Provision of rain gauges and flow gauges - extend coverage
- Equipment for further community based FFEWS schemes
- Improvements to Flood Forecasting
- Support to National Flood Warning Investment Strategy
- Support to MWDI – via the Shire River Basin Management Organisation
- Training and support for DNRDM
- Flood defence embankments – all districts
- Catchment improvements – critical tributaries
- Food stores – all districts
- Off-channel storage – feasibility studies

It is expected that these activities will be managed by the Shire River Basin Management Organisation which will be established before the expiry of the Action Plan period.

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Appendix A - Hydrodynamic Modelling Framework

Appendix B – Flood Inundation and Hazard Maps

Appendix C - FFEWS Terms of Reference

Appendix D - List of Stakeholder Consultations

Appendix E - Institutional Capacity Development Plan

Appendix F - Economics assessment

Appendix G - Environmental Assessment

Appendix H - Guidelines for Hydrodynamic Modelling framework

Appendix I – Action Plan

Appendix J - Basis of Costing

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