REPUBLIC OF RWANDA

MINISTRY OF AGRICULTURE AND ANIMAL RESOURCES (MINAGRI)

LAND HUSBANDRY, WATER HARVESTING AND HILLSIDE IRRIGATION PROJECT (LWH)

ENVIRONMENTAL MANAGEMENT PLAN (EMP) FOR KARONGI 13- SUB PROJECT.

DRAFT REPORT

Prepared by
Green and Clean Solution Ltd.
Kigali, Rwanda.

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## Contents

1. INTRODUCTION ....................................................................................................................... 5

2. PROJECT DESCRIPTION AND LOCATION .............................................................................. 5
   2.1 Land use categories in Karongi – 13 ..................................................................................... 6
   2.2 Description of different land use categories ......................................................................... 7
       2.2.1 Water-Catchment area .................................................................................................. 7
       2.2.2 Silt-trap zone .................................................................................................................. 7
       2.2.3 Reservoir area/ Command area ....................................................................................... 8
       2.2.4 Command-Area Catchment ............................................................................................ 8
   2.3 Project Description /Components ......................................................................................... 8
       2.3.1 Dam Component ............................................................................................................. 8
       2.3.2 Irrigation Component .................................................................................................... 11
       2.3.3 Land Husbandry Component ....................................................................................... 13
   2.4 Equipment and Material Description .................................................................................... 24
       2.4.1 Equipment ....................................................................................................................... 24
       2.4.2 Materials that will be used in the construction works include ........................................ 24

3. BASELINE ENVIRONMENT/BACKGROUND OF THE AREA .................................................. 26
   3.1 Climate and Hydrology ......................................................................................................... 26
       3.1.1 Other Climatic data ....................................................................................................... 28
   3.2 Geology and Geotechnique .................................................................................................. 29
       3.2.1 Geology of the Project Site ............................................................................................ 29
   3.3 Vegetation and Crops ........................................................................................................... 35
   3.4 Socio-economics .................................................................................................................. 35

4. POTENTIAL ENVIRONMENTAL AND SOCIAL IMPACTS .................................................... 35
   4.1 Significant Positive Impacts .................................................................................................. 35
       4.1.1 Catchment Rehabilitation and Management .................................................................... 36
       4.1.2 Crop diversification: ....................................................................................................... 36
       4.1.3 Soil Conservation .......................................................................................................... 36
       4.1.4 Flood Control ............................................................................................................... 36
       4.1.5 Water Resources Conservation ..................................................................................... 36
       4.1.6 Birdlife Habitat .............................................................................................................. 36
       4.1.7 Improved soil conservation ............................................................................................ 36
       4.1.8 Improvement of previously water-logged areas .............................................................. 37
       4.1.9 Increased farm incomes from crop output ....................................................................... 37
       4.1.10 Environmental Protection ............................................................................................ 37
       4.1.11 Revegetation ............................................................................................................... 37
       4.1.12 Livestock Development ................................................................................................. 37
       4.1.13 Food Security .............................................................................................................. 38
       4.1.14 Poverty Alleviation ...................................................................................................... 38
       4.1.15 Raise Rural Income ..................................................................................................... 38
       4.1.16 Improved access to water for domestic purposes .......................................................... 38
       4.1.17 Improved nutrition ....................................................................................................... 38
       4.1.18 Water for domestic use-washing clothes, bathing livestock .......................................... 39
4.1.19 Other benefits .......................................................... 39

4.2 Significant Adverse (Negative) Impacts ........................................... 39
  4.2.1 Design and Planning Phase .................................................. 39
  4.2.2 Construction Phase .......................................................... 40
  4.2.3 Operation Phase .............................................................. 41

5. ENVIRONMENT MANAGEMENT PLAN IMPLEMENTATION ............ 46
  5.1 World Bank ........................................................................ 46
  5.2 Ministry of Agriculture and Animal Resources (MINAGRI) .............. 46
  5.3 Land Husbandry Hillside Irrigation and Water Harvesting Project ....... 47
  5.4 Rwanda Environment Management Authority .................................. 47
  5.5 Community Group/Project Beneficiaries ....................................... 48
  5.6 Contractors ....................................................................... 48
  5.7 Ministry of Health ................................................................ 48
  5.8 Local Authorities ................................................................ 48

6. MONITORING PLAN ............................................................... 54
  6.1 Water Quality Monitoring .......................................................... 55
  6.2 Monitoring Diseases spread .......................................................... 55
  6.3 Monitoring Seepage and leakage ..................................................... 55
  6.4 Surface movement measurement ................................................... 55
  6.5 Earthquake Measurement ............................................................. 55
  6.6. MONITORING FRAMEWORK ..................................................... 56

5. CONCLUSION ......................................................................... 59
ACRONYMS AND ABBREVIATIONS

- ARAPs: Abbreviated Resettlement Action Plans
- EMP: Environment Management Plan
- ETo: Evapotranspiration
- HCFs: Health Care Facilities
- FAO: Food and Agriculture Organization
- ISAR: Institut des Sciences Agronomiques du Rwanda
- IPM: Integrated Pests Management
- MINAGRI: Ministry of Agriculture and Animal Resources
- MINFRA: Ministry of Infrastructure
- MINISANTE: Ministry of Health
- LWH: Land Husbandry, Water Harvesting and Hillside Irrigation
- PAPs: Project Management Unit
- RAPs: Resettlement Action Plans
- PMF: Probable Maximum Flood
- REMA: Rwanda Environment Management Authority
- RPF: Resettlement Policy Framework
- WB: World Bank
ENVIRONMENTAL MANAGEMENT PLAN FOR KARONGI – 13 SUB PROJECT.

1. INTRODUCTION

This EMP should be implemented by several institutions, which are directly or indirectly involved in this subproject. These institutions are MINAGRI as the project implementer or borrower and sub contractors who were commissioned to construct the irrigation infrastructure and the subproject beneficiaries (farming communities in the area).

The persons and institutions responsible for implementing the plan will include cooperative/association members, LWH, MINAGRI, MININFRA, MINISANTE, REMA and contractors building the Karongi 13 dam and drainage network.

This Karongi 13 subproject EMP was prepared as part of other reports including the Resettlement Policy Framework (RPF), the Environmental and Social Management Framework (ESMF) and a full Environmental Impact Assessment (EIA) for the whole LWH program. Karongi 13 LWH subproject is one of the 8 subprojects selected to be implemented during the 1st phase of the LWH program. These subprojects include 2 sites in Karongi, 2 sites in Bugesera, 2 sites in Gatsibo, 1 site in Kayonza and 1 site in Nyanza.

The objectives of this Environmental Management Plan (EMP) are:
   1. To bring the project into compliance with applicable national environmental and social legal requirements and the World Bank’s environmental and social policies OP 4.01;
   2. To outline the mitigating/enhancing, monitoring, consultative and institutional measures required to prevent, minimize, mitigate or compensate for adverse environmental and social impacts and/or to enhance the subproject beneficial impacts;
   3. To address capacity building requirements to strengthen the Borrower’s environmental and social capacities if necessary.

2. PROJECT DESCRIPTION AND LOCATION

The project site of Karongi – 13 is found in the Karongi District of the Western Province. It is located at about 104km south west of Kigali, the country capital, of which the first 101km is asphalted and the rest 3 km is an all-weather dust road. The site is located at about 7km from Rubengera town, district capital. Specifically the dam site is situated at Nataruko stream that borders Karongi and Rutsiro districts. The names of the respective sectors at the site are Rubengera and Mukura, and for Cell Nyarugenge and Gako, and Umudugudu are Karusha and Kagusha.
2.1 Land use categories in Karongi – 13

For the sake of planning and implementation of the different land-husbandry options with distinct influence to the overall irrigation program, the entire watershed is partitioned and categorized into the following 5 major categories.

1. Water-catchment---- areas of the entire watershed that are the main source of the water to be harvested in the down-catchment reservoir and drains through the Silt-Trap zone
2. Silt Trap-zone ----a land part of the Water-catchment as it contributes to the water that drains directly to the Reservoir, and which is designed to filter the silt that comes from the water catchment to the reservoir
3. Reservoir ---- land designed to be filled by water draining from the Water-catchment and the Silt-trap Zone. This zone is further partitioned onto three sub-zones.
4. Command-area Catchment ---- land which is up-hill of the command area that could contribute run-off and flood to the down-catchment command area
5. Command area - -- lands designed to be irrigated in dry seasons by the water to be harvested in the reservoir during the rainy seasons.
2.2 Description of different land use categories

2.2.1 Water-Catchment area

The water catchment is an area characterized by all runoff being conveyed to the same outlet. In this case, the water catchment is the area from where the entire water yield comes to the reservoir. The water catchment may also yield sediment load to the reservoir.

The water catchment of Karongi – 13 project site is about 1140 ha including the silt trap zones and the water catchment covers 65% of the total land area of the project site. As shown in Table 1, in the water-catchment area, agricultural land covers 67% of the land. The topographic feature of the water catchment includes slope ranges greater than 80% and the agricultural land distributed in to all slope categories including above 80% slopes.

Table 1: Land use /land cover of different slope categories of the water-catchment (including the silt-trap zones)

<table>
<thead>
<tr>
<th>Land cover</th>
<th>0-6%</th>
<th>6-16%</th>
<th>16-30%</th>
<th>30-40%</th>
<th>40-60%</th>
<th>60-80%</th>
<th>&gt;80%</th>
<th>Total</th>
<th>% of land use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural land</td>
<td>27.98</td>
<td>72.87</td>
<td>113.64</td>
<td>115.47</td>
<td>264.89</td>
<td>126.94</td>
<td>19.35</td>
<td>741.14</td>
<td>67.3</td>
</tr>
<tr>
<td>Bush and Shrub land</td>
<td>0.88</td>
<td>3.29</td>
<td>6.75</td>
<td>8.48</td>
<td>31.69</td>
<td>25.95</td>
<td>5.26</td>
<td>82.3</td>
<td>7.5</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.79</td>
<td>2.53</td>
<td>3.6</td>
<td>3.67</td>
<td>5.89</td>
<td>1.21</td>
<td>0.28</td>
<td>18</td>
<td>1.6</td>
</tr>
<tr>
<td>Natural forest</td>
<td>18.54</td>
<td>25.22</td>
<td>27.68</td>
<td>18.1</td>
<td>26.29</td>
<td>10.87</td>
<td>1.53</td>
<td>128.23</td>
<td>11.6</td>
</tr>
<tr>
<td>Planted forest</td>
<td>1.97</td>
<td>6.77</td>
<td>15.25</td>
<td>14.69</td>
<td>42.56</td>
<td>40.24</td>
<td>10.17</td>
<td>131.65</td>
<td>12.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>50.16</td>
<td>110.68</td>
<td>166.92</td>
<td>160.41</td>
<td>371.32</td>
<td>205.21</td>
<td>36.59</td>
<td>1101.3</td>
<td>100.0</td>
</tr>
<tr>
<td>% OF SLOPE</td>
<td>4.55</td>
<td>10.05</td>
<td>15.16</td>
<td>14.57</td>
<td>33.72</td>
<td>18.63</td>
<td>3.32</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

2.2.2 Silt-trap zone

As it stands 87% of the area (33 ha) is agricultural. 21% of the agricultural land is found on slope category in between 30-80% slopes while the major portion of the land is in between 40-60% slope more than 10 ha out of 33. These lands that can be a huge source of silt to down-catchment reservoir.

Though, it surrounds the outlet of the Water-Catchment, there is no Riverine vegetation identified in this land unit. The land covered by bush and shrub is insignificant. The quality and stalking density is poor and requires good attention for improvement. Stalk refinement operations and enrichment planting is required.
Table 2: Table Land use /land cover of the Silt-trap zones in the different slope categories.

<table>
<thead>
<tr>
<th>Landcover</th>
<th>0-6%</th>
<th>6-16%</th>
<th>16-30%</th>
<th>30-40%</th>
<th>40-60%</th>
<th>60-80%</th>
<th>&gt;80%</th>
<th>Total</th>
<th>% of land use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural land</td>
<td>0.8</td>
<td>3.89</td>
<td>6.21</td>
<td>5.56</td>
<td>10.25</td>
<td>5.55</td>
<td>0.4</td>
<td>32.66</td>
<td>87.0</td>
</tr>
<tr>
<td>Bush and Shrub land</td>
<td>0</td>
<td>0</td>
<td>0.07</td>
<td>0.21</td>
<td>0.93</td>
<td>0.7</td>
<td>0.19</td>
<td>2.1</td>
<td>5.6</td>
</tr>
<tr>
<td>Grassland</td>
<td>0</td>
<td>0</td>
<td>0.1</td>
<td>0.03</td>
<td>0.01</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.14</td>
</tr>
<tr>
<td>Natural forest</td>
<td>0.01</td>
<td>0.04</td>
<td>0.1</td>
<td>0.05</td>
<td>0.88</td>
<td>0.98</td>
<td>0.12</td>
<td>2.18</td>
<td>5.8</td>
</tr>
<tr>
<td>Planted forest</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.44</td>
</tr>
<tr>
<td>Urban/settlement</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.01</td>
</tr>
<tr>
<td>TOTAL</td>
<td>0.81</td>
<td>3.93</td>
<td>6.53</td>
<td>5.91</td>
<td>12.21</td>
<td>7.42</td>
<td>0.71</td>
<td>37.52</td>
<td>100.0</td>
</tr>
<tr>
<td>% OF SLOPE</td>
<td>2.16</td>
<td>10.47</td>
<td>17.40</td>
<td>15.75</td>
<td>32.54</td>
<td>19.78</td>
<td>1.89</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

2.2.3 Reservoir area/ Command area

The reservoir is the structure holding the water and which will collect water from the water catchment, the silt-trap zones and from its area itself. About 9.24 ha of land is expected to be inundated by the proposed reservoir. The proposed reservoir area falls within land that is cultivated, where beans, sweet potatoes, irish potatoes and bananas have been planted.

The command area is located on the hill side slopes and on undulating plain in the valley. The area is being drained by an intermittent river which flows towards the southern direction. It is characterized by soils with relatively good agricultural potential. However, these potential is not fully exploited.

2.2.4 Command-Area Catchment

The command area catchment is more than 224 hectares and accounts for 13% of the entire project site. 65% of the command area catchment is intensively cultivated on all slope categories up till 80% slopes. More than 43% of the catchment lays in slope category greater than 30%. The dominant slope category of the command area catchment is in between 40-60% where this slope category covers 63ha or 28% of the catchment. In this catchment planted forest, mainly eucalyptus trees covers more than 16.3% of the catchment. Similar size of land as that of planted forests is covered by Bush and Shrubs. In respect to soil depth, 61% of the catchment covers by deep soils while the remaining balance is covered by shallow soils.

2.3 Project Description /Components

This section describes the different components of the project, design and construction equipment description.

2.3.1 Dam Component

Geographically the dam axis is located at 438810 UTM Easting, 9774250 UTM Northing and at elevation of 1950masl. Karongi-13 headwork study and design envisages water harvesting by the use of Earth fill dam for hill side irrigation.

The main objective of all the structure is to provide safe and reliable water for irrigation. So the water in the reservoir has to be conveyed to the target command area this can be accomplished by
providing irrigation outlet. Irrigation outlet having inlet, conveyance and terminal structure is
designed. The inlet structure is drop intake structure with trash rack. The conveyance structure is
steel pipe with concrete cover and cut-off collar while the terminal structure is impact type stilling
basin. The length and diameter of the steel pipe is 72m and 0.50m respectively. In addition to
providing water for irrigation, it will also serve as reservoir evacuation conduit during emergency
time.

2.3.1.1 Salient features

Location
- Easting: 438795 – 438811E
- Northing: 9774403 -9774256N
- Altitude: 1950 masl

Reservoir
- Area submerged: 11.2 ha
- Maximum water level(MWL): 1957.6 masl
- NPL and Storage:1955.5 masl, 0.83 Mm3
- MDDL: 1947masl

Dam
- Type : Zoned Earth fill dam
- Crest length: 136m
- Height: 19.5m
- Top width: 8m

Spill way
- Type: Ogee
- Width: 6m
- Total Channel length: 188.5m

Outlet
- Pipe diameter: 500mm
- Pipe length: 72m

2.3.1.2 Dam Safety Instrumentation
The condition of the dam and its overall safety will need to be checked regularly to demonstrate
that the dam is performing safely in accordance with the design assumptions. Dam instrumentation
shall give meaningful information and clues to the various problems and play an important role in
checking the safety of structures. Their prime function will be to reveal abnormalities, which may
have the potential to develop into serious incidents or failure. Hence solution will be given to the
problem accordingly.
2.3.1.3 Types of Measurement
The parameters that are necessary in monitoring dam condition are:

- Pore water pressure and uplift
- Internal and External movement
- Seepage and Leakage
- Strains and stresses
- Seismic forces

Pore water pressure
Pore water pressure measurement enables to know the seepage pattern in the embankment and foundation after the reservoir impoundment. It will give valuable information of dam pore pressure at end of construction, at steady and draw down condition. The measured data helps to take remedial measures.

The vibrating wire piezometer is one of a device for measuring pore water pressure in a foundation and embankment. It is proposed to install the pore pressure piezometer at different levels, i.e. 4 in numbers at the foundation level, 5 numbers in the embankment section at different levels. All these are connected together through tubes and led to the terminal well located on the downstream side.

Seepage and leakage
Measurement of seepage through the dam body, foundations & abutments of the dam indicates erosion or blocking of downstream drains. Seepage measurements also indicate the fault zone which is labile to erosion of fill material and at higher level creation of piping. It provides useful information about the performance of the structure and seepage control measures. V-notch has to be installed in the surface drain at the toe of dam to measure seepage discharge at regular interval of time.

Movements
Measurement of internal and external movements created due to deformations of upstream and downstream slopes under different conditions of reservoir operations is necessary. It indicates the likely development of shear failure at weak points in the body of the embankment.

The measurement of surface movement of the embankment dam shall be made by means of installing 6 number of surface settlement points of which 3 of them are along the crest of the dam and the other are on downstream slope and shall be monitored by surveying instrument referenced to fixed bench mark.

Strains and stresses
Strains can be calculated from displacement or measured directly however stress measurement in earthen dam is difficult due to complex distribution. To use the measured data it needs considerable judgment in data interpretation.

The installations of instruments for measuring movements are provided at important locations. Maximum vertical movement normally occurs at mid height of structure and maximum horizontal movement at middle of slopes. Therefore two horizontal movement instrument at mid slope of structure and two vertical movement instruments are provided. For recording vertical movement
cross arms installation has been proposed. Similarly inclinometer instruments have been proposed for registering horizontal movements.

**Seismicity**

Instruments for measuring and monitoring the intensity of ground motions during the earthquake are required to be installed. Measurement of seismicity is important as it causes sudden dynamic loading. The instruments for recording of seismic events proposed to be installed for the dam consists of one accelerograph and structural response recorder at the top of the dam.

**Others**

Other measurements aid in interpretation of the main instrumentation data. Reservoir water level, wave height, meteorological data, silt deposit recorder are helpful in analyzing the main instrument observation.

Climatological station having rain gauge, thermometer, evaporation, wind speed and direction measurement has to established. Wind setup recorder has also to be installed near up stream face of the dam.

**2.3.1.4 Coffer dam**

Coffer dam helps to conduct construction in dry condition. Coffer dam is designed upstream of dam at a distance of 367m. It is connected to the irrigation outlet by diversion canal to convey the base flow through outlet. This urges the earlier construction of the dam outlet portion. The height of this coffer dam is 4m and its length is 77.5 m having top width of 3m, downstream slope of 1V:2H and Upstream slope of 1V:2.5H. It is also keyed to the natural ground by cut-off wall of 1.50m depth. The cut-off wall has side slope of 1V:1H and bottom width of 3m.

**2.3.1.5 Foot Bridge**

Foot Bridge is designed and provided, to have access to dam across the spillway on foot. It is aligned at the top of control structure leading to dam crest. It is RCC structure having 7m and 3m length and width respectively. All the requirements for Foot Bridge are fulfilled.

**2.3.1.6 Access road**

There is a need of constructing access road from nearby road to the dam axis. This road will serve during construction and after construction to have access to the dam. It is branching from gravel made all weather road leading from project area to the main road from Kigali to Karongi. The length of this road is 0.92km and its width is 7m to give construction trucks good space during hauling of construction material like sand and shell material. The road is sloping towards the natural river hence drainage will not be a problem; it is recommended to make the top surface free draining material.

**2.3.2 Irrigation Component**

The command area is divided into 41 smaller areas (field units) each served by secondary pipe lines. The partitioning of the command area into smaller units is done by considering the topography and the length of field channels. The length of the field channel is proposed to be 100m wherever possible and it can be increased or decreased depending on the topography. The
average size of the irrigation blocks is about 4.8 ha, though there are some blocks having areas greater than 10 ha and there are blocks as small as 1.0 ha.

2.3.2.1 Irrigation System Design
The command area is divided into 41 smaller areas (field units) each served by secondary pipe lines. The partitioning of the command area into smaller units is done by considering the topography and the length of field channels. The length of the field channel is proposed to be 100m wherever possible and it can be increased or decreased depending on the topography. The average size of the irrigation blocks is about 4.8 ha, though there are some blocks having areas greater than 10 ha and there are blocks as small as 1.0 ha.

2.3.2.2 Alignment of Main Canal
The main canal takes off from the outlet located at the right abutment of the dam. The design discharge of the main canal (MC-1) at the outlet is 0.254 m³/s. The main canal-1 (MC-1) runs along the contour with relatively steep slopes at the beginning. It has a total length of 1.2 Km with a series of small drops between chainages 690 m and 740m. The alignment is done based on the contour of the topography in order to minimize the excavation work.

Main canal 2 (MC 2) irrigates 143 ha of land to the left of the Ndaba River and main canal 3 irrigates (MC-3) irrigates 78 ha to the right of the River. Main canal 1 (MC-1) irrigates only about 11 ha of the river valley bottom after the outlet from the dam. Table 3 shows the hydraulic particulars of the main canals.

Table 3. Hydraulic particulars of main canals

<table>
<thead>
<tr>
<th>Main Canal</th>
<th>Reach length (m)</th>
<th>Bed width (m)</th>
<th>Flow Depth (m)</th>
<th>Free board (m)</th>
<th>Discharge (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC 1</td>
<td>1194</td>
<td>0.5</td>
<td>0.5</td>
<td>0.3</td>
<td>254</td>
</tr>
<tr>
<td>MC 2-1</td>
<td>1215</td>
<td>0.4</td>
<td>0.4</td>
<td>0.3</td>
<td>158</td>
</tr>
<tr>
<td>MC 2-2</td>
<td>900</td>
<td>0.4</td>
<td>0.4</td>
<td>0.3</td>
<td>138</td>
</tr>
<tr>
<td>MC 2-2</td>
<td>1717</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>42</td>
</tr>
<tr>
<td>MC 3</td>
<td>2425</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>85</td>
</tr>
</tbody>
</table>

2.3.2.3 Alignment of Secondary Pipe
The secondary pipes off take from the main pipe only on one side which is on the side of the downhill. These pipes are aligned across the contours in the direction of the hill slope and the field channels are off taking on both sides of the secondary pipes. The distance between secondary pipes is variable and is highly dependent on the curving nature of the main pipe alignment and the topography. Wherever straight reaches are available, a distance of 200m between two secondary pipe lines is maintained.

There are 39 secondary pipes (prefixed as SP-1, SP-2, SP-3, etc.) with lengths varying from 60m to 465 m. The total length of all the secondary pipes is 12,380 km.
2.3.2.4 Hydraulic Design of Irrigation Structures

Design of Weir and appurtenances
The regulation and control of the irrigation water will be done before the Ndaba stream drops into the fall. Control of the river water is difficult after the fall because the stream has a higher energy and enters into deep gorges. There exists an intake structure that is being used to divert the water into an existing canal downstream of the fall. However, it has been observed that the intake arrangement doesn’t allow withdrawing a higher amount of flow into the canal. Therefore, to have a better control of the irrigation water supply for the planned 230 ha of command area, a weir is required across the river just before the fall. The main function of the weir is to head up the water or raise the water level so that water will be diverted to a steel pipe that falls downward to feed the irrigation canals to the left and right side of the river.

Location of the weir
An appropriate location for the diversion weir is found about 20 m upstream of the fall. The stream has a well defined bank and has a straight reach.

Design Discharge of the weir
The selection of design flood return period is generally based on safety, economy, and the size and category of the hydraulic structure. For small diversion structures, a 50- year return period flood can be adopted to design the structure. The 50-year return period flood estimated for Karongi-13 is 109.0 m³/s. The area proportion method is used to derive the 50 years return flood for the weir site based on the 50 years flood estimated at the reservoir site of Karongi-13. Therefore, a flood magnitude of 133.2 m³/s is used to design the weir which has a recurrence period of 50 years.

2.3.3 Land Husbandry Component
LWH is an investment project devoted to integrated soil conservation, water-harvesting and hillside-irrigation management throughout the project site. It is focused to demonstrating possibilities for future intensified investments. Demonstrating integrated LWH in 1750 ha of Karongi-13 watershed is hoped to ignite such a comprehensive and integrated development throughout the district.

The locations of the five catchment units of the Karongi-13 watershed are shown in Figure 2 above. Majorly, five function-based land units form the entire watershed. These are the Water-catchment (nearly 1102 ha), the silt-trap zone (some 38ha), the Command-area catchment (nearly 224 ha) and the command area which is 375 ha. The Silt-trap zone is again partitioned into: grass layers, shrub layer and tree layers as we go further away from the periphery of the Reservoir. A live fence that is situated between along the outside perimeter of the grass strip and the inside perimeter of the shrub-layer is contained within the same Grass-strip zone. The land-husbandry program is intentionally decided to be at a watershed setting levels because watershed approach accommodates both the human and the physical environment in an integrated manner.

Under the project situation, the agriculture system in both the water-catchment and the Command-area Catchment will remain rain-fed while the command area is intensively cultivated under supplementary irrigation. In such a case, the yield increment for the watersheds would come from the improved agricultural management of the rain fed and from implementations of comprehensive
land-husbandry program. Still, in this scenario, land-husbandry would have to be practiced in all except at the area where it will be inundated by the reservoir.

Figure 2. Different land-husbandry units of the entire Karongi-13 site

Table 4: Area coverage of different land –type category of Karongi-13 project site

<table>
<thead>
<tr>
<th>Category of the entire watershed</th>
<th>Area in hectares</th>
<th>Coverage in percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Water catchment</td>
<td>1102.0</td>
<td>63.0</td>
</tr>
<tr>
<td>2. Silt trap</td>
<td>37.9</td>
<td>2.2</td>
</tr>
<tr>
<td>2-1 Silt trap- Tree-zone</td>
<td>19.5</td>
<td></td>
</tr>
<tr>
<td>2-2 Silt-trap-Shrub-zone</td>
<td>12.2</td>
<td></td>
</tr>
<tr>
<td>2-3 Silt –trap-Grass-zone</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>3. Reservoir</td>
<td>10.2</td>
<td>0.6</td>
</tr>
<tr>
<td>1-3 total Total water catchment area for the reservoir</td>
<td>1150.0</td>
<td></td>
</tr>
<tr>
<td>4. Command-area Catchment</td>
<td>224.0</td>
<td>12.8</td>
</tr>
<tr>
<td>5. Command Area</td>
<td>375.0</td>
<td>21.4</td>
</tr>
<tr>
<td>Total entire watershed</td>
<td>1750.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>
2.3.3.1 Land husbandry at the water catchment

The total area of the Karongi-13 watershed is estimated to be 1750 hectares of land. Out of the total, the water catchment and the command area catchment covers more than 1477 ha and the remaining 424 ha is planned to be under reservoir, silt trap and under irrigation. The Silt trap that is going to be constructed adjacent to the reservoir to trap the silt of the runoff from overlaying terrain is planned to cover around 38 ha.

Table 5. Area coverage of the Water-catchment of Karongi-13 project site in the different slope and corresponding soil depth categories

<table>
<thead>
<tr>
<th>SLOPE</th>
<th>Area coverage in ha by soil depth group</th>
<th>% by slope range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;=50cm</td>
<td>&gt;50cm</td>
</tr>
<tr>
<td>0-6%</td>
<td>48.27</td>
<td>1.89</td>
</tr>
<tr>
<td>6-16%</td>
<td>103.26</td>
<td>7.42</td>
</tr>
<tr>
<td>16-30%</td>
<td>145.67</td>
<td>21.73</td>
</tr>
<tr>
<td>30-40%</td>
<td>124.78</td>
<td>34.56</td>
</tr>
<tr>
<td>40-60%</td>
<td>255.67</td>
<td>115.63</td>
</tr>
<tr>
<td>60-80%</td>
<td>121.16</td>
<td>85.23</td>
</tr>
<tr>
<td>&gt;80%</td>
<td>18.26</td>
<td>18.25</td>
</tr>
<tr>
<td>TOTAL</td>
<td>817.07</td>
<td>284.71</td>
</tr>
<tr>
<td>% by Soil depth</td>
<td>74.16</td>
<td>25.84</td>
</tr>
</tbody>
</table>

The entire Karongi-13 watershed has been divided into seven slope categories; the undulating plain in the total watershed covers 4.5% or 50 ha and within the same slope category the shallow soils cover 48 ha while the deep soils covers only 2 ha. The dominant slope class among the seven which covers more than 33% of the project area is in the range between 40-60% slope-range which is rugged topography, where the significant portion of the watershed (371 ha) is situated. Seventy four percent of these areas are covered by shallow soils while the other is covered by deep soils. The second slope class which is found in the watershed is in between 60-80% slop which covers around 206 ha and 19% of the water catchment.

Land-husbandry interventions are part of the hillside irrigation development, which is an issue here. In this detailed design and planning, soil and water conservation is viewed as part of the comprehensive land-husbandry practices. Often, soil conservation practices are viewed as artificial alterations of the land relief to control water movement, and tillage erosion while land-husbandry includes the use of improved farming practices which impact on changing the soil characteristic such as changing or modifying its chemical and physical characteristics such as soil fertility, acidity/alkalinity, infiltration rate/water holding capacity etc. Unless these alterations are made and the Soil fertility status of the farm land is enhanced, the maximum production response from the costly supply of irrigation water alone will not be realized to the fullest.

The technologies considered in this detailed design work include physical soil conservation measures such as earth/soil bunds, bench/radical terraces, grass strips, mulching, intercropping with legumes/green manuring, compost/farmyard manure application, liming, planting with trees/shrubs in required arrangement, etc. They are also aligned with the different land-unit types.
that have different capacities and suitability of production as manifested by the combined effect of the soil depth and slope category they exhibit. For instance, the land husbandry options for lands with slopes of less than 6 % and soil depth of greater than 50 cm have very different capacities when compared to lands, which are exhibiting less than 50 cm soil depth and are within slope ranges of greater than 40%. In the former group, even a grass strip could remedy the soil erosion problem and tree-crops could easily be grown. In the later group, even radical terraces would not fit and the rooting depth availability limits the use of trees for land management.

In the Karongi-13 project site the classical hillside irrigation could be exercised thus, all types of physical and biological soil conservation measures including radical terraces are recommended for appropriate slopes only. Thus, areas in more than 80% slope category are advised not to be cultivated for annual crops but for tree planting use only.

**On 0-6% Slope**
On 50 ha of land which falls in 0-6% slope category of the water catchment, trash line of crop residues and or grasses will be lined along the couture and grass strips shall be planted off farm lands in the same fashion as the trash line at 1km/ha density. On these farm plots, well prepared manure or compost, will be applied regularly as per recommended rates. In the first project, implementation period legumes shall be planted and at or before just before flower the crop shall be incorporated into the soil so that to enhance organic matter content of the soil and this shall be repeated for three to four consecutive seasons.

On the same slope category about 12ha land will be covered under annual crops such as Maize, Sorghum and Beans and the land will be reclaimed by agricultural lime. Lime raises the pH and reduces the effect of acidity of the soils. The reclamation of the acid soils is expected to raise available phosphate and to enhance the functions of beneficial micro and macro organisms of the soils, these in turn improve the physical and chemical properties and improve the production and productivity of the annual crops.

On the same slope category around 20 ha land is covered with planted forest during the project life the management of the forest will be improved and where appropriate the density of the forests will be improved.

**On 6-16% slope**
Level Soil bund shall be constructed on 110ha of land on an average at one meter vertical interval and the total length of the bund in this slope category is estimated to be 99 km considering 0.9 km/ha density of the bund. During bund construction, special attention will be given to construct the edges of the bunds so that the riser be constructed in such a way that it has to be inclined surface against the slope and maintain 1.04 meter height. The total area of the inclined surface is estimated to be 102ha or 1029600 m² within this slope category. To strengthen the inclined risers grass will be planted on the surface of the inclined surface as well as to strengthen the risers in addition to the planted grass trees also be planted just underneath the inclined riser at 1 meter interval thus a total of 102000 trees will be planted Similar to that of 0-6% slope category mulching, manuring and compost will be applied on agricultural lands as per given rates of application.
To reduce the velocity of the runoff and to encourage in situ infiltration and safe disposal of excess water cutoff drain at 0.03km/ha density and live check dams in 80% of the length of the secondary streams of the catchment shall be constructed.

On the same slope category an average of 25ha will be covered by annual crops such as Maize, Sorghum and Beans. The land under these crops will be treated by agricultural lime. Lime raises the pH and reduces the toxic effect of acidity of the soils. The reclamation of the acid soils is expected to raise available phosphate and enhance the functions of beneficial micro and macro organisms of the soils. These changes in turn, improve the physical and chemical properties of the soil and consequently, improve the production and productivity of the annual crops.

Similar to the 0-6% slope on 33 ha planted forest will be managed properly and the density of the planted forests will be improved to increase the income of the growers.

**On 16-30 slope**

On this slope category the major activity will focus on construction of Radical terraces. In this slope category, there are 167 ha of land that will be reconstructed to prepare radical terraces. Thus, there will be a total of 334km terraces at 2km/ha density and at 1 meter vertical interval. On the edges of the constructed terraces, the risers will be constructed in inclined fashion so that to have 334km length or 34.7 ha surface area at 1.04 meter vertical interval.

Similar to the other slope categories mulching, manuring and compost will be applied on agricultural lands as per given rates of application. Just after the terraces construction leguminous crops will be planted for at least three consecutive seasons so that to enhance the fertility status of the disturbed top soils.

On the constructed radical terraces, farmers will be advised to plant fruit trees to minimize the soil disturbances. During the project life extension dissemination will be strengthened and farmers shall be trained on the fruit tree management and on land management issues.

On the same slope category, an average of 83ha will be covered by annual crops such as Maize, Sorghum and Beans. The land under these crops will be treated by agricultural lime. Lime raises the pH and reduces the toxic effect of acidity of the soils. The reclamation of the acid soils is expected to raise available phosphate and enhance the functions of beneficial micro and macro organisms of the soils. These changes in turn, improve the physical and chemical properties of the soil and consequently, improve the production and productivity of the annual crops.

On 30-40% slope of the water catchment, the major activity will focus on construction of Radical terraces. In this slope category, there are 160 ha of land that will be reconstructed to prepare level Radical terraces. Thus, there will be a total of 477km Radical terraces at 3km/ha density and at 1.08 meter vertical interval. On the edges of the constructed terraces the risers will be constructed in inclined fashion so that to have 477km length or 47.7 ha surface area at 1.08 meter vertical interval. On these farm plots, well prepared manure or compost, will be applied regularly as per recommended rates. In the first project, implementation period legumes shall be planted and at or before flower the crop shall be incorporated into the soil so that to enhance organic matter content of the soil and this shall be repeated for a minimum of three to four consecutive seasons.
On 40 -80%
On 40-80% in this slope category, the total of land is 613ha. Though, the slope category does not permit crop production, currently, 411 ha are under intensive cultivation. Considering the population pressure and the farm land scarcity of the Karongi district the land could be used for cultivation of perennial trees with minimum regular cultivations. Thus, for this area, it is recommended only Live Terraces / biological terraces/ to minimize the soil movement of the steep slopes of mountain and hills side slopes. The pattern of planting trees and the configuration of the plants should follow the live fence design of the silt trap zone of the water reservoir; the dominant plants will be shrubs. The total planting materials per hectares will be, cuttings 1000 /ha and Seedlings 4000/ha.

On >80%
In an area where the slope category is greater than 80% slope it is advised not to cultivate but to cover the area with trees. Here at this type of topographic features, it is much more important to encourage infiltration and reduce the velocity of runoff through maintaining the proper densities of the natural vegetation. For the country like Rwanda protection of the peaks and especially steep slopes is the first step to be taken to properly treat the low laying terrains. Thus, farmers who cultivate the area at this slope category are advised to transform their type of production and concentrate on the perennials to substitute their classical produces.

Table 6. Technologies recommended and corresponding costs to be incurred in water catchment of Karungi-13

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Unit rate (RWF)</th>
<th>Total Cost (RWF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-6% slope (50 ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Grass strip 1 meter width</td>
<td>km</td>
<td>22</td>
<td>1100</td>
<td>24200</td>
</tr>
<tr>
<td>1.2</td>
<td>Trash line</td>
<td>km</td>
<td>28</td>
<td>1100</td>
<td>30800</td>
</tr>
<tr>
<td>1.3</td>
<td>Application of manure or compost on agricultural land</td>
<td>Mt</td>
<td>28</td>
<td>15,000</td>
<td>420000</td>
</tr>
<tr>
<td>1.4</td>
<td>Growing and incorporation of legumes</td>
<td>ha</td>
<td>28</td>
<td>15,000</td>
<td>420000</td>
</tr>
<tr>
<td>1.5</td>
<td>Application of mulch on agricultural land</td>
<td>m³</td>
<td>2800</td>
<td>1,100</td>
<td>3080000</td>
</tr>
<tr>
<td>1.6</td>
<td>Application of Lime</td>
<td>ha</td>
<td>12</td>
<td>13750</td>
<td>165000</td>
</tr>
<tr>
<td>2</td>
<td>6-16% slope (111 ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Level soil bund</td>
<td>km</td>
<td>99</td>
<td>250,000</td>
<td>24750000</td>
</tr>
<tr>
<td>2.2</td>
<td>Application of mulch on agricultural land</td>
<td>Mt</td>
<td>73</td>
<td>1,100</td>
<td>80300</td>
</tr>
<tr>
<td>2.3</td>
<td>Cutoff drain 0.03km/ha</td>
<td>km</td>
<td>3.06</td>
<td>250,000</td>
<td>765000</td>
</tr>
<tr>
<td>2.4</td>
<td>Growing and incorporation of legumes</td>
<td>ha</td>
<td>73</td>
<td>15,000</td>
<td>1095000</td>
</tr>
<tr>
<td>2.5</td>
<td>Tree planting to strengthen the bunds</td>
<td>Se</td>
<td>99000</td>
<td>82</td>
<td>8118000</td>
</tr>
<tr>
<td>2.6</td>
<td>Live check dams</td>
<td>km</td>
<td>0.7621</td>
<td>27500</td>
<td>20957.75</td>
</tr>
<tr>
<td>2.7</td>
<td>Application of manure or compost 10t/ha</td>
<td>Mt</td>
<td>730</td>
<td>15000</td>
<td>10950000</td>
</tr>
</tbody>
</table>
### 2.8 Application of lime

<table>
<thead>
<tr>
<th>Slope</th>
<th>Area (ha)</th>
<th>Amount</th>
<th>Cost (FRW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>13,750</td>
<td>206250</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>13,750</td>
<td>343750</td>
<td></td>
</tr>
</tbody>
</table>

### 3 Cutoff drain

<table>
<thead>
<tr>
<th>Slope</th>
<th>Length (km)</th>
<th>Cost (FRW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-30%</td>
<td>2.46</td>
<td>615000</td>
</tr>
<tr>
<td>30-40%</td>
<td>4.8</td>
<td>1200000</td>
</tr>
</tbody>
</table>

### 3.1 Cutoff drain

<table>
<thead>
<tr>
<th>Slope</th>
<th>Length (km)</th>
<th>Cost (FRW)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>615000</td>
</tr>
<tr>
<td>0.03</td>
<td>4.8</td>
<td>1200000</td>
</tr>
</tbody>
</table>

### 3.2 Application of mulch on agricultural land

<table>
<thead>
<tr>
<th>Area (Mt)</th>
<th>Amount (m³)</th>
<th>Cost (FRW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>59</td>
<td>11500</td>
<td>12650000</td>
</tr>
<tr>
<td>590</td>
<td>41100</td>
<td>45210000</td>
</tr>
</tbody>
</table>

### 3.3 Level radical terrace

<table>
<thead>
<tr>
<th>Slope</th>
<th>Length (km)</th>
<th>Cost (FRW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>165</td>
<td>1100000</td>
<td>524700000</td>
</tr>
<tr>
<td>477</td>
<td>1100000</td>
<td>524700000</td>
</tr>
</tbody>
</table>

### 3.4 Application of manure or compost

<table>
<thead>
<tr>
<th>Area (Mt)</th>
<th>Amount (m³)</th>
<th>Cost (FRW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>590</td>
<td>1150</td>
<td>12650000</td>
</tr>
<tr>
<td>4110</td>
<td>41100</td>
<td>45210000</td>
</tr>
</tbody>
</table>

### 3.5 Growing and incorporation of legumes

<table>
<thead>
<tr>
<th>Area (ha)</th>
<th>Cost (FRW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>59</td>
<td>885000</td>
</tr>
<tr>
<td>115</td>
<td>1725000</td>
</tr>
</tbody>
</table>

### 3.6 Application of lime

<table>
<thead>
<tr>
<th>Area (ha)</th>
<th>Amount (m³)</th>
<th>Cost (FRW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>13750</td>
<td>343750</td>
</tr>
<tr>
<td>29</td>
<td>13750</td>
<td>398750</td>
</tr>
</tbody>
</table>

### 4.1 Cutoff drain

<table>
<thead>
<tr>
<th>Slope</th>
<th>Length (km)</th>
<th>Cost (FRW)</th>
</tr>
</thead>
<tbody>
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<tr>
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<td>4.8</td>
<td>1200000</td>
</tr>
</tbody>
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### 4.2 Application of mulch on agricultural land

<table>
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<tr>
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</tbody>
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### 4.3 Level radical terrace

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</tbody>
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### 4.4 Application of manure or compost

<table>
<thead>
<tr>
<th>Area (Mt)</th>
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<td>45210000</td>
</tr>
</tbody>
</table>

### 4.5 Growing and incorporation of legumes

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<td>885000</td>
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<tr>
<td>115</td>
<td>1725000</td>
</tr>
</tbody>
</table>

### 4.6 Application of lime

<table>
<thead>
<tr>
<th>Area (ha)</th>
<th>Amount (m³)</th>
<th>Cost (FRW)</th>
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</tr>
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<td>13750</td>
<td>398750</td>
</tr>
</tbody>
</table>

### 4.7 Application of mulch on agricultural land

<table>
<thead>
<tr>
<th>Area (Mt)</th>
<th>Amount (m³)</th>
<th>Cost (FRW)</th>
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<td>41100</td>
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</tr>
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### 4.8 Application of mulch on agricultural land

<table>
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</tr>
<tr>
<td>4110</td>
<td>41100</td>
<td>45210000</td>
</tr>
</tbody>
</table>

### 4.9 Biological terraces/ Cuttings and seedlings

<table>
<thead>
<tr>
<th>Area (Mt)</th>
<th>Amount (m³)</th>
<th>Cost (FRW)</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>4110</td>
<td>41100</td>
<td>45210000</td>
</tr>
</tbody>
</table>

### 4.10 Application of manure or compost

<table>
<thead>
<tr>
<th>Area (Mt)</th>
<th>Amount (m³)</th>
<th>Cost (FRW)</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
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</tr>
</tbody>
</table>

---

**2.3.3.2 Silt-trap system design and management**

**Location and area coverage:** The silt-trap zone is intentionally designed to avoid silt coming with the water that originates from the water-catchment and from the silt-trap-zone itself. It covers the perimeter, which is a drainage contact with the reservoir down-slope. The silt-trap zone of the Karongi-13 project site is 37 ha which is partitioned into three distinct sub-zones. The first and outermost layer is the Tree-zone, which is further-down adjoined by shrub-zone. The tree zone covers 19 ha while the shrub-zone accounts for 12 ha. The zone between the reservoir and the shrub-zone is a 6 ha grass covered strip. Between the Grass strip and the shrub-zone, a 50 cm live fence is to be constructed so that the reservoir and the grass-zone are completely excluded from any human and livestock interferences.
Figure 3: The location of the tree-belt, grass-belt, shrub-belt and live-fence part of the entire Silt-trap Zone

Design of tree-belt
The tree belt is the outer and upper part of the silt-trap zone and covers an area of 19.49 hectares. This is the zone, which is to filter out and contain the boulders that are coming with run-off during the rains. As it has been discussed earlier in this Sub-volume, the water catchment will be given the necessary catchment treatment measures including gully rehabilitation works. However, experience has shown that the catchment –treatment may not be done as prescribed in the study documents and treatment procedures may be violated that up-stream run-offs may contain gravels and boulders when flowing down-stream. This will be environmentally detrimental to the fishes in the reservoir and life-span of the reservoir itself. Hence, filtering the boulders with the tree-crop becomes a necessity. The trees will be planted along the contour in a spacing of 1.0 meters along the same contour. The same spacing is recommended for the spacing of consecutive contour lines on which lines of trees will be planted. Commercial rain fed fruit tree species that are suited to Dry Lowland agro climatic zone such as Citrus medica, Casimiroa edulis, Tamarindus indica, and Ziziphus mauritiana, are recommended.
**Design of shrub-belt**
The shrub belt is the middle part of the silt-trap zone and covers an area of 12 hectares. This is the zone, which is to filter out and contain the gravels that are rolling to the Silt trap from over laying terrains. Therefore, the movement of boulders in this kind of slope terrain is very limited and with limited force of crawling (if any during heavy rains). Therefore, it can be handled by the shrub-belt effectively. Forage and fruit value species that also do well under rain fed conditions in Dry Lowland agro climatic zone such as *Ehretia cymosa*, *Citrus medica*, and *Zimenia americana* are recommended here.

**Design of Grass-belt**
The grass belt is the inner and lower part of the silt-trap zone and covers an area of 6.2 hectares. This is the zone that is to filter out and contain the silt that is escaping through the tree and shrub belt of the Silt-trapping zones.

This grass-belt needs to be very thick planted with coarse grass such as *Phalaris aquetica* to contain the silt and release only the filtered water down to the reservoir. In addition to protection of the reservoir from the silt deposition, Grass belt serves as a buffer zone for protecting the dam from any contaminant and hazards. In order to avoid any such hazard, a tight live fence will be constructed at the outer layer of the Grass-belt and this is estimated to be 2.45 km long.

*Dovyalis abyssinaica* and/or combined with *Erythrina brucei*. In the live fence construction, *Zimenia americana* and/or *Dovyalis abyssinica* will be planted in a spacing of 0.5 cm distance in a line and in two lines that are spaced 0.5 meters. The *Erythrina brucei* will be planted in a spacing of 1 meter within the planting of the *Dovyalis* or *Zimenia* and it will be in between the two lines that are planted in a staggered fashion. The *Dovyalis* or *Zimenia* planted along the two adjacent lines are put in a staggered fashion with the plants spaced 50 cm from one another. The *Zimenia Americana* and the *Dovyalis abyssinica* will be planted from seedlings while the *Erythrina brucei* will be planted from cuttings immediately after the rain period is completed. *Erythrina* cuttings required for the live fence will be 2450 while the *Zimenia* or *Dovyalis* seedlings needed for the live fence construction will be 9800.

In between the live fence and the water body, grasses that are have course culm and spreading sod such as Elephant Grass and Rhodes Grass will be planted along the contour. Cuttings of the Elephant grass will be planted in a spacing of 0.25 meters along the line and 20 cm between the adjacent lines. All lines will be oriented along the contours.

**2.3.3.3 Land Husbandry in the Command Area Catchment**
**On 0-6% slope**
On 11ha of land which falls in 0-6% slope category of the command area catchment, trash line of crop residues and/or grasses will be made along the couture lines and grass strips shall be planted off farm lands in the same fashion as the trash line. Thus on 9ha trash line and on 11ha grass strips will be planted at 1 km/ha density and 1 meter width along the couture. The total area of the grass strip would be 11.4 ha. On the farm plots, well prepared manure or compost, will be applied regularly as per recommended rates. In the first project implementation period legumes crops shall be planted and at or before flowering the green legume shall be incorporated into the
soil so that to enhance organic matter contents of the soil and this shall be repeated for three to four consecutive seasons.

**On 6-16% slope**

On 6-16% slope category soil bund shall be constructed on 31 ha of land on an average at one meter vertical interval and the total length of the bund in the command area catchment is estimated to be 28 km per 0.9 km/ha density of the bunds. During bund construction, special attention will be given to construct the edges of the bunds so that the riser be constructed in such a way that it has to be inclined surface against the slope and maintain 1.04 meter height. To strengthen the inclined risers on the surface of the inclined risers grass will be planted on the riser and in addition to the planted grasses, trees also be planted just underneath the inclined riser at 1 meter interval. The surface area of the risers will be 2.9ha and the number of trees that is going to be planted will be 28000 trees. Similar to the 0-6% slope category mulching, manuring and compost will be applied on agricultural lands as per given rates of application. To reduce the velocity of the runoff and to encourage in situ infiltration and safe disposal of excess water cutoff drain at 0.03km/ha density and live check dams in 80% of the length of the secondary streams of the catchment shall be constructed.

**On 16-30 Slope**

In the 16-30 slopes category of the Command area catchment the major activity will focus on construction of Radical terraces on49 ha. Considering the slope categories on 16-30% slope there will be 2.5km/ha density of the radical terraces. Based on these assumptions on 16-30% slope category there will be a total of 122 km radical terraces. On these terraces there will be a total of 12.2ha surface of the riser where there will be grass cover. In these slope classless, cutoff drain are the other technologies which will be constructed at 0.03km/ha density thus the total length of the cutoff drains will be 1.47km. Similar to the other slope categories mulching, manuring and compost will be applied on agricultural lands as per given rates of application. Just after the terraces construction leguminous crops will be planted for at least three consecutive seasons so that to enhance the fertility status of the disturbed top soils. On the constructed terraces, farmers will be advised to plant fruit trees to minimize the soil disturbances and to give the chance of in situ development of the soils. During the project life, extension dissemination will be strengthened and farmers shall be trained on the fruit tree management and on land management issues.

**On 30-40% slope**

In this slopes category of the Command area catchment, the major activity will focus on construction of Radical terraces on 37 ha. Thus, there will be 471 km length of the radical terraces based on 3.3km density. On these terraces there will be a total of 47.1ha surface of the riser where there will be grass cover. In these slope classless too cutoff drain are the other technologies which will be integrated with the radical terraces at 0.03km/ha density thus the total length of the cutoff drains will be 1.01km. Similar to the other slope categories mulching, manuring and compost will be applied on agricultural lands as per given rates of application. Just after the terraces construction leguminous crops will be planted for at least three consecutive seasons so that to enhance the fertility status of the disturbed top soils. On the constructed terraces, farmers will be advised to plant fruit trees to minimize the soil disturbances and to give the chance of in situ development to the soils. During the project, life extension dissemination will be strengthened and farmers shall be trained on the fruit tree management and on land management issues.
On 40-60% slope
The major activities will be to establish and maintain the progressive terraces of the area. Biological means just like the one described in the live fences of the silt trap zone will be practiced. In between the biological measures farmers are advised to use fruit trees and other perennial crops to minimize the disturbances of the soil.

On greater than 80% slope
Here on this slope it is advised not to do any activities related to cultivation it is good to manage the natural coverage of the terrain and to cover it with appropriate species

2.3.3.4. Land Husbandry in the command area
The irrigable (command) area of Karongi-13 project site is 375ha. The existing topography of Karongi-13 site is composed of flat, dissected, hilly and rolling Lands Grass strips of 1 meter width and spaced in every 10 m is planned for these lands. The grass strips will be inter-spaced by trash lines of half meter width and 20 cm height that are spaced in 5 meter interval either with the grass strip or adjacent trash line on 4 ha.

Lands in slope range of 40-60% are the dominant, 30% slope in one category. Here, progressive terraces are recommended to be constructed along the couture.

Soil bunds of 1 meter height that are spaced in one meter vertical interval are recommended and budgeted in 6-16% slope. The risers of the bunds are level in a horizontal vertical ratio of 1:3 and the surface is planted with fodder-value perennial grasses and/or herbs. For all bund/terrace stabilization Ciratro, green-leaf desmodium, Elephant grass, Rhodes grass, Phalaris, and any other to be approved by the Client are recommended.

Lands that require radical terraces for leveling (16-40) are also significant. About 190 ha or 50% of the command area is in this slope range. The major leveling possibility here is construction of radical terraces. Radical terrace construction, often buries the top soil. Usually, putting aside first the top soil and spreading it over the top surface after leveling is completed is advised. However, this often said than done. It is practically difficult and time consuming. In order to minimize such a problem, we advise that the cutting is started from the upper half of the lowest terrace that needs to be added to the lower untouched surface of the next above terrace. This will minimize but not avoid burial of the top soil.

Lands that exceed 40% slope are more than 148ha or 39% of the command area. Thus, the management of these sloppy lands requires close observations of the managing body in any ways not to damage the resources. Just after construction of the different slope reduction strips, bunds and terraces plus the installation of the irrigation schemes, the improved coffee and plantain will be planted as per the recommended spacing.
2.4 Equipment and Material Description
The following equipment and materials are planned for use during the construction phase of the project.

2.4.1 Equipment
The following equipment and materials are planned for use during the construction phase of the project. Earth moving equipment including excavators, tractors, trucks, Grader, Dozer/ excavator Loader, Tractor/Dump, Truck, Water truck and Crusher Mixer.

2.4.2 Materials that will be used in the construction works include
Cement, sand, water, boulders, wire mesh, pvc etc. Most of these materials are readily available in the local markets in Kigali however; local material will be sources as defined in the section below in order to reduce costs.

2.4.2.1 Identification of Natural Construction Materials
A search for natural construction materials has been conducted within the vicinity and outside the dam site. The search includes identifying fine-grained soil for the impervious core of a zoned dam or for the entire body of a uniform embankment dam, materials for the shell of a zoned dam, filter sand, stones for rip rap, sand and aggregates for concrete, and water for construction. The results of the search are presented in the following sections.

Material for Impervious Core
The steeply sloping area that is upstream extension of the right abutment of the dam site spanning beyond the strip of the alluvial deposit is found one appropriate and convenient source of material for the impervious core of the dam. Another borrow area is also proposed at downstream extension of the left abutment. Both the lateral extent and the thickness render these sources adequate for the intended purpose. An area of more than 3 hectares of land has been delineated for this purpose from both sites, one within the reservoir area and the other outside (figure 5). At least the top 2 to 3m of the soil can be exploited leaving behind a sufficient material of 1 to 2m thickness as blanket to minimize any risk of seepage especially for borrow area found inside the reservoir. Based on this consideration, a gross volume of more than 60000 to 90000 m3 of this soil can be borrowed from the proposed areas. If more material is required, there is possibility to extend the surface areas at both sources.

To characterize the required engineering properties of this soil samples were taken from the two borrow areas and the established result from laboratory tests. The quantity is sufficient to plan a zoned embankment dam or a homogenous dam as found appropriate. The hauling distance is insignificant, making the source quite attractive for this purpose.
Partially the borrow material site is within the reservoir area, which will partly be inundated by the impounded water, the associated environmental effect is kept at a minimum. But for the second borrow area, which is located moderate hill slopes, there is possibility of poundage of water.

![Figure 4. Schematic map of borrow pit area](image)

Shell Material

A source area is identified for the shell of a zoned dam at a relatively distant place from the dam site. A deposit of coarse-grained soil, which is likely of gabbroic rock origin, is identified at a location of some 8 km south west of the project site at a locality called Kanyira Mugozi. The geographic coordinates are 0434617mE, 9771730mN with an elevation of 1598 masl. It is found in Rubengera Sector, and Bubazi Cell. This borrow area is at about 1.5km from Rubengera town in the direction of Lake Kivu. It was a source area for different earth materials for a Chinese road construction company.

There exists a deposit of such material at a large quantity that left unused and also possibility of borrowing. The material is well-graded in texture and is available in a sufficient quantity. It is rich in granular soil predominated with gravel, with sand and some fines. This site is an existing borrow area, which has been exploited and conveniently located in view of minimizing environmental impact. It is found on an isolated hill top and slope, nearby a stream called Musogoro.

2.4.2.2 Rock source for Various Purposes

Rock source for different purposes like for masonry, rip rap, crushed aggregate and rock toe has been identified at a location similar to shell material (see above). Here, there is a limited deposit of Meta-Gabbro rock found as dyke within schist rock. This rock is strong, and resistant to weathering unlike to the main country- the talc-mica schist, which is decomposed easily by chemical reactions. The proposed rock type has characteristic dark gray color rock, and locally named as ‘Fundi’. It is presently quarried out by the local people for commercial purpose, but it was previously used by the Chinese Company for masonry works in the construction of drainages. The price of the rock is 3000 to 4000RWF per meter cube as informed from the miners.
The geographic coordinates of the site are 04348032mE, 9771910mN, with elevation of 1623 masl. The site can be accessed by an existing soil road that turns to the left from the main Rubengera – Kibuye (Lake Kivu) asphalt road. The proposed site is characterized predominantly by outcrops of the schist rock, but the required rock (Meta gabbro) is found at specific and localized unit forming some line or thickness. This rock unit is being used for local construction activities.

Though the rock is resistant to chemical weathering, it is, however, affected by some physical weathering as evidenced by discontinuities or joints. From this source angular to sub angular fragments can be collected for use as rip rap or quarried from the more intact material underneath. The products of the physical weathering, especially the gravel to pebble sizes, can also be used for the shell material as also indicated above.

**Filter Sand**
Granular soils dominated with sand have been identified at a junction of two streams named as Endaba and Kadasoma. This site is found in between the two Karongi projects, just at the side of the main asphalt road at a locality called Chivuruga. Here the material is being dugout from the streambed, especially from Endaba. The site is found at about 4 to 5Km from the dam site. The geographic co-ordinates of the area are 0441421mE and 9773710mN, with elevation of 2136masl.

**Water for Construction**
Water that can be used for compaction, concrete works and other purposes can be found from the project stream itself as it has significant surface flow. During the present investigation, about 40 l/sec liter per second natural flow has been observed.

### 3. BASELINE ENVIRONMENT/BACKGROUND OF THE AREA

#### 3.1 Climate and Hydrology
Karongi-13 site is located in Moist Mid-highland agro-climatic zone. Thus, rainfall pattern in terms of distribution, intensity, and reliability pose periodical difficulties in agricultural production.

The closest meteorological stations with relatively long-record data to be used for Karongi 13 LWH project site are Rubengera Meteo, Nyange, Butare and Gikongoro. These stations, however, do not have long term record (> 30 years). Karongi 13 dam watershed rainfall is estimated based on Nyange data from 1971-1993 and the remaining data filled in by correlating with Kigali Airport station data. Time series plot of Karongi 13 dam rainfall has shown that the data is homogenous with no trend. (Figure 5).
Figure 5: Time series plot of Karongi 13 dam watershed Rainfall (mm)

Shaded data is observed Nyange station data. Figure 5 shows the monthly distribution the rainfall.

Table 8. Rainfall data used for Karongi-13 project site in mm

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>ARF</th>
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<td>111</td>
<td>154</td>
<td>206</td>
<td>158</td>
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<td>18</td>
<td>51</td>
<td>103</td>
<td>137</td>
<td>156</td>
<td>127</td>
<td>1371</td>
</tr>
<tr>
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<td>317</td>
<td>390</td>
<td>387</td>
<td>137</td>
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<td>157</td>
<td>250</td>
<td>301</td>
<td>264</td>
<td>241</td>
<td>1834</td>
</tr>
<tr>
<td>Min</td>
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<td>75</td>
<td>113</td>
<td>37</td>
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<td>16</td>
<td>64</td>
<td>62</td>
<td>41</td>
<td>955</td>
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<tr>
<td>STDEV</td>
<td>48</td>
<td>50</td>
<td>61</td>
<td>71</td>
<td>81</td>
<td>42</td>
<td>37</td>
<td>44</td>
<td>54</td>
<td>54</td>
<td>57</td>
<td>53</td>
<td>203</td>
</tr>
</tbody>
</table>
3.1.1 Other Climatic data

Climate data such as temperature, humidity, sunshine hours, wind speed and evaporation are required to estimate reservoir evaporation (Eo) and potential evapotranspiration (ETo). Critical missed data in and around the project area are wind speed and relative humidity. Project area wind speed and humidity data are derived from Butare Aero and Rubengera Met stations with the assumptions.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Temp</td>
<td>(Deg. C)</td>
<td>18.4</td>
<td>18.1</td>
<td>18.4</td>
<td>18.2</td>
<td>17.8</td>
<td>18.2</td>
<td>18.8</td>
<td>19.1</td>
<td>18.8</td>
<td>17.8</td>
<td>18</td>
<td>18.1</td>
</tr>
<tr>
<td>Min Temp</td>
<td>(Deg. C)</td>
<td>16.1</td>
<td>15.8</td>
<td>16.2</td>
<td>16.0</td>
<td>15.7</td>
<td>14.7</td>
<td>15.6</td>
<td>15.9</td>
<td>16.0</td>
<td>15.6</td>
<td>15.8</td>
<td>15.9</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>(%)</td>
<td>75.2</td>
<td>73.2</td>
<td>77.6</td>
<td>81.2</td>
<td>79.9</td>
<td>70.2</td>
<td>58.8</td>
<td>59.4</td>
<td>62.5</td>
<td>73.3</td>
<td>77.1</td>
<td>78.4</td>
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<tr>
<td>Wind speed</td>
<td>(m/s)</td>
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<td>1.6</td>
<td>1.6</td>
<td>1.4</td>
<td>1.3</td>
<td>1.2</td>
<td>1.3</td>
<td>1.4</td>
<td>1.7</td>
<td>1.6</td>
<td>1.7</td>
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<tr>
<td>Sun Shine</td>
<td>(Hours)</td>
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<td>5.5</td>
<td>5.6</td>
<td>5.4</td>
<td>5.4</td>
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<td></td>
<td>140</td>
<td>140</td>
<td>138</td>
<td>123</td>
<td>110</td>
<td>102</td>
<td>112</td>
<td>119</td>
<td>146</td>
<td>142</td>
<td>146</td>
<td>146</td>
</tr>
</tbody>
</table>

The temperature fluctuation in Karongi seems to be limited. The variation is in between 17.8 and 19.1. The former being the lowest mean minimum for the maximum temperature in October and the latter one is the highest mean temperature, which occurs in August.
The most characteristics feature of the tropical climate is its uniformity with respect to temperature, solar radiation, humidity, wind speed and evaporation. The major climatic parameter which varies in time and space is rainfall (Weert, 1994).

3.2 Geology and Geotechnique
Since the project site lies within the Precambrian basement complex of the country, the site and its immediate environ are underlain by folded metamorphic rocks that are identified as Talc-mica schist intercalated with lenses of graphite. Outcrops of Talc-mica schist are observed at few places on slopes and hill sides and in streambed at areas located downstream of the dam site. These outcrops, however, are not fresh rather weathered to moderate to slight degree. The schist formation exhibits schistosity planes steeply dipping (nearly vertical) in the downstream direction and joints and discontinuities that form isolated beds of similar orientations. The rock is somehow affected by post hydrothermal an activity as featured by several quartz veins and vein lets that intersects the parent rock.

For the majority places it has underwent weathering ranging from high to complete weathering, resulting in clayey silt to silty clay residual soil. At the dam site the main rock unit is covered entirely by thick (more than 4m) soils of residual and transported origin. The predominant residual soil type is silt with little clay and some fine sand, and for the transported one Silty clay texture is significant.

3.2.1 Geology of the Project Site
3.2.1.1 Dam and Spillway Site
Interpretation of local geological conditions together with the subsurface geotechnical investigation (using test pits) revealed four engineering geological and geotechnical units. These include

- Organic alluvial Clayey Silt soil
- Inorganic alluvial silt soil
- Silty Clay Residual Soil
- Clayey Silt Residual Soil

Organic alluvial Clayey Silt Soil
This soil unit covers the entire valley floor area estimated to have an average width of 30 m at the dam site. It is dark in color, fine grained, loose, with some organic odor. It has about 3m thickness It is moist from top to 1m, below it gets saturated for 2m thickness. Within it some concentrated subsurface water seepage lines or holes have been observed. Below it is underlain by moist and inorganic silt soil. The valley is part of a syncline associated with the folded schist formation typical of the surrounding geology. It can be inferred that such a valley has been filled with these fine-grained stream sediments, which are results of weathering and consequent reworking (transportation, deposition,) and organic matter.

Inorganic Alluvial Silt Soil
This formation is observed below the organic soil at a depth of about 3m. Its total thickness is not known from the test pit as the excessive subsurface water hinders further penetration to depth. However, a geophysical survey has been conducted to infer its thickness. It reveals that the thickness is not more than 3m, below relatively high resistant unit has been indicated (see the
Silty Clay Residual Soil
This soil unit covers the surface of the majority of the hill foot and slopes (the abutments). It is reddish brown in color, dry, firm, strong. It is dominated by clay and silt textures. It is the result of complete degree of weathering of the underlying bedrock. It has variable thicknesses that ranges from few centimeters at right abutment to 2m as observed at left abutment slope. It is impermeable and stable soil horizon. It is underlain by Silt dominated soil.

Clayey Silt Residual Soil
This soil horizon is the result of high degree of weathering of the country rock. It is predominated by silt with some fine sand and little clay. It is dry, stiff, semi-pervious to impervious, and stable. The dominant foundation material for the dam is this soil. From the test pits, the thickness of this soil has not been known, but from the geophysical survey it is inferred to be thin. Ultimately it is believed that this soil is underlain by the highly weathered part of the bedrock that changed to the sandy silt soil.

The surface and subsurface observations presented above are combined with interpretations of the regional and local geology of the project site to prepare the geological cross section along the dam axis.

The spillway for this site is proposed on the left side. Initially it follows the slope of the left abutment hill and eventually joins the flatter stream valley. Both surface and subsurface investigation have been performed along an assumed route. From the topography and geological point of view the entire route of the spillway can be divided into two sections.

The first and initial section is characterized by a relatively steep slope and made up of the residual silty clay soil of 1 to 2m thickness, which in turn is underlain by the highly weathered and steeply dipping mica schist rock that is changed to the residual sandy silt soil. The top soil layers are stable and easily workable, though some extent of erosion is expected. In this case properly designed retaining walls may be necessary on both sides of the spillway. In addition to this, lining of the floor of the spillway may also be necessary due to the erodability of the soils.

The second section of the spillway follows the flat slope of the valley until it joins the stream channel. In this section, the natural ground is totally covered by thick alluvial sediment, which is dry down to a depth of 1 m, but saturated beyond this depth to 2m. Attention should be given to the erodibility of this material in the design of the spillway.

3.2.1.2 Reservoir Site
The central portion of the reservoir is mainly covered with the fine-grained alluvial deposits for more than 3m. The slope and rim areas, whereas, are totally made up of the residual soils described at dam site in the above section. Along the entire reservoir rim, there are no observed
problems of potential land instability or mass wasting. The entire reservoir area is so considered as impervious and free from any potential instability.

### 3.2.1.3 Seismic Assessment of the Site

By extracting the data from the Global Seismic Hazard Map prepared by the Global Seismic Hazard Assessment Program (GSHAP) explained in the Executive Summary of the LWH projects, the corresponding map for Rwanda is provided in Figure 2. According to this map, Rwanda may be divided into three zones: Zone 3, Zone 2 and Zone 1. The project site of karongi 13 lies in Zone 1 with the range of PGA of 0.8 to 1.6 m/s² or 8 to 16 % of gravitational acceleration.

![Seismic hazard map of Rwanda for 10% probability of exceedence in 50 years](developed from GSHAP global map) showing LWH projects.

Table 10: Recommended foundation soil parameters

<table>
<thead>
<tr>
<th>Soil parameter</th>
<th>Recommended value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk density</td>
<td>19 kN/m³</td>
</tr>
<tr>
<td>Natural moisture content</td>
<td>15.8 %</td>
</tr>
<tr>
<td>Permeability</td>
<td>2e-6 cm/s</td>
</tr>
<tr>
<td>$\phi'$</td>
<td>25°</td>
</tr>
<tr>
<td>$c'$</td>
<td>9 kPa</td>
</tr>
</tbody>
</table>

Regarding the alluvial deposit, though no permeability and shear tests are conducted, it is estimated that the top soil to be of medium to high permeability and low shear strength. Visual inspection of this alluvial deposit indicates that it is unsuitable as a foundation material. The
thickness of this weak horizon is about 3m. Laterally, it is estimated to extend for a width of about 40 m along the dam axis. It is advisable to remove a strip of this layer for at least the middle two-third base width of the dam cross section. In addition, it is recommended that it be replaced by the material selected for the construction of the impervious core of the embankment. This material should be compacted to at least a density 98 % of MDD. Below this layer, there is relatively firm alluvial soil of silt, with probably gravel and sand to depth of about 5 to 6m as revealed from the geophysical survey. Ultimately these alluvial soil units are believed to be underlain by the residual soil that derived from the weathering of the bedrock to some degree. It is hence, advisable to extend the cut-off to this depth for foundation stability and seepage control.

3.2.2 Soils
The project site is covered with truncated deep soils. The parent rocks are weathered materials which are furnishing the plant roots with the limited moisture and nutrients. In the district in general and in the project site in particular, the terrain does not encourage the in situ soil development. In the dry season the relatively “new” weathered parent materials exposed to the outer atmosphere so that macro and micro organisms start their standard functions in the weathering process till the rainy season starts. When the rainy season start all the soil development process disrupted and the new soil development process start again and again. This vicious circle with the change of the season continues so that every time the soil which starts to develop transported down to the low laying terrain. This situation of the soil development process continues till the weathered materials are available, however, this condition is not everlasting.

The two types of soils in the command area, namely Acrisols and Cambisols, are classified as medium textured soils and they have relatively good agricultural potential.

In terms of topographic configurations, Karongi-13 watershed shows all the seven distinct slope categories as it is depicted on Table 11. The slope category of Karongi-13 is the highest in the whole project sites where the major portion of the land is on 40-60% slope. Slopes that are more than or equal to 40% covers only about 48% of the catchment. This is, however, dissected topography with convex mountains and hills side slopes, where the major portion of the watershed (562 ha) is found. The depth of the soil is good, 80% of the areas are covered with deep soils.

<table>
<thead>
<tr>
<th>SLOPE</th>
<th>Area in hectare by soil depth</th>
<th>% by slope range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;=50cm</td>
<td>&gt;50cm</td>
</tr>
<tr>
<td>0-6%</td>
<td>8.58</td>
<td>32.74</td>
</tr>
<tr>
<td>6-16%</td>
<td>29.46</td>
<td>113.84</td>
</tr>
<tr>
<td>16-30%</td>
<td>44.65</td>
<td>190.77</td>
</tr>
<tr>
<td>30-40%</td>
<td>34.48</td>
<td>154.82</td>
</tr>
<tr>
<td>40-60%</td>
<td>63.89</td>
<td>302.78</td>
</tr>
<tr>
<td>60-80%</td>
<td>34.78</td>
<td>121.44</td>
</tr>
<tr>
<td>&gt;80%</td>
<td>8.23</td>
<td>31.53</td>
</tr>
<tr>
<td>TOTAL</td>
<td>224.07</td>
<td>947.92</td>
</tr>
<tr>
<td>% OF SOIL DEPTH</td>
<td>19.12</td>
<td>80.88</td>
</tr>
</tbody>
</table>

LWH Environmental Management Plan: Karongi 13
In terms of soil association, over 76% of the total watershed is occupied by Humic Acrisols. The soil is deep in its character and formed on deeply weathered materials usually on colluvial. The other soil that is deep like Acrisols is Umbric Gleysols, which covers some of the valley bottom lands. All the remaining three soil types are shallow soils. These soils cover 19% of the area. When we consider the five different kinds of soils that contribute in different amounts, soils of greater than 50 cm soil depth are well above 90%. Naturally, Dystric Cambisols is found at greater depth than 50 cm. However, due to steep slope of the area and due to the severity of soil erosion in Karongi site coupled with the soils susceptibility nature to erosion Cambisols are found to be shallow in the project site. The nature of the topographic feature of Karongi 13 is one of the reasons why land-husbandry in this watershed is crucially essential.

Figure 8: Soils map of the entire project site
Table 12. Area coverage of the different soils in the different soil depth categories of the entire watershed

<table>
<thead>
<tr>
<th>SOIL TYPE</th>
<th>Area in ha by soil depth category</th>
<th>TOTAL</th>
<th>% by soil type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;=50</td>
<td>&gt;50</td>
<td></td>
</tr>
<tr>
<td>Humic Acrisols</td>
<td>0</td>
<td>897.98</td>
<td>897.98 76.62</td>
</tr>
<tr>
<td>Humic Cambisols</td>
<td>130.49</td>
<td>0</td>
<td>130.49 11.13</td>
</tr>
<tr>
<td>Dystric Cambisols</td>
<td>16.84</td>
<td>0</td>
<td>16.84 1.44</td>
</tr>
<tr>
<td>Umbric Gleysols</td>
<td>0</td>
<td>49.94</td>
<td>49.94 4.26</td>
</tr>
<tr>
<td>Dystric Leptosols</td>
<td>76.74</td>
<td>0</td>
<td>76.74 6.55</td>
</tr>
<tr>
<td>TOTAL</td>
<td>224.07</td>
<td>947.92</td>
<td>1171.99 100.00</td>
</tr>
<tr>
<td>% OF SOIL DEPTH</td>
<td>19.12</td>
<td>80.88</td>
<td>100.00</td>
</tr>
</tbody>
</table>

3.2.2.1 Topography and Soils of the Water-Catchment

The water catchment, excluding the Silt-trap zones is more than 440 ha in land coverage. In terms of soil depth, 91% of the water catchment is covered by deep soils and the remaining balance is covered by shallow soils. Almost half of the catchment lays in slope category greater than 40% slope up to greater than 80%. The major portion of the water catchment lays on deep soils while around 10% of the area covered by shallow soils.

Utilization and management of the soil types has to be dependent on the soil depth and on the soil fertility status of the project site. The soils of steep slope area should get adequate attention from the project management especially during the earth moving and leveling operation of the terraces. The top soils should be piled well before the earthmoving work start and after the land leveling operation accomplished the piled top soils should uniformly dress the leveled ground and the soil reclamation activities should proceed.

3.2.2.2. Topography and Soils of the Silt Trap Zones

The topography of the proposed silt –trap zone is located on the total area of 31.23 ha of land on rugged and dissected topography. 29% of the silt trap zone falls on 30-40% slope 22.4% falls on 40-60% and 17% of the area falls on 40-60% slope.

There are three types of soils that dominate this land unit: Acrisols, Cambisols and Gleysols. Acrisols occupy almost 79.7 % of the entire land unit. Similar to the other catchment categories, the dominant soil type even in the Silt-trap zones is Humic Acrisols. As it has been explained earlier, one can grow almost everything in this soil group. Detailed description for this soil could be referred in the description made under the Water Catchment.

3.2.2.3 Topography and Soils of the Command –area Catchment

The total area coverage of the command area catchment is estimated to be 459 ha out of these around 100 ha is covered by shallow soils while the remaining balance is covered by deep soils. The major portion of the command catchment area, around 142 ha falls in 40-60% Slope category.
followed by 16-30% slope class where 20.3% of the command area catchment lays. 17% of the catchment is found in an area where the slope categories exceed more than 60% slope.

The command catchment of Karongi-12 is the ridge of mountain to the Northern West direction of the Dam site. The command catchment as well as the whole watershed is covered by four types of soil units. The soil units that cover the area are Humic Acrisols and umbric Gleysols.

Characteristics of Humic Cambisols: Physical properties of Cambisols are generally good; contain at least some weather able minerals in the silt and sand fractions. Most Cambisols are medium-textured and have a good structural stability, a high porosity, good water holding capacity and good internal drainage.

3.3 Vegetation and Crops

The major crops cultivated in Karongi district are beans, sorghum, cassava, sweet potato irish potato, and plantain. The other crops which are cultivated in the district include rice, taro, green peas, and vegetables. Rice, maize, and vegetables are cultivated on the valley bottoms while Cassava and Sorghum are cultivated on the hillside. Passion fruit, cyphomandra, mangoes, are the most important fruits cultivated in the district. Coffee and Tea are the two traditionally exported crops widely produced in the study area. The LWH project is planning to concentrate on tea and coffee production in the command area.

3.4 Socio-economics

The dam site is intensively cultivated and covered with perennial crops. The hillsides are covered mainly with tree plantations. The crops grown in the area include sorghum, maize and sweet potatoes intercepted with cassava. The source of the water for irrigation is the drainage structures constructed along the road in the project area. Currently there is no house in the reservoir and in the command area that needs to be relocated.

The community is aware of the proposed development advantages and welcomes the project. However, the shortage of land could be worrisome, especially for those basing their livelihood on the proposed reservoir and the dam sites, unless the mitigation measures are taken.

4. POTENTIAL ENVIRONMENTAL AND SOCIAL IMPACTS

This section describes the potential significant positive and negative (adverse) impacts of the proposed project at different phases including design and planning and design, construction, operation and decommissioning phase.

4.1 Significant Positive Impacts

The Land Husbandry, Water Harvesting and Hillside Irrigation document identifies many of the positive impacts of the proposed activities. These include poverty reduction, food security, hillside restoration, rural development, irrigation efficiency among others.
4.1.1 Catchment Rehabilitation and Management
Soil erosion has been indirectly caused by degradation of catchments through farming and deforestation. The LWH project component on marshland and hillside development through reforestation and terracing of the hillsides is to a great extent a sound practice for protecting the catchments.

4.1.2 Crop diversification:
The implementation of the project will introduce new crop-husbandry practices that have not been used in the area previously, or even lead to expansion of existing crop enterprises. Within the entire water catchment area and command area catchment, land husbandry practices that will improve crop production will be adopted, but the prevailing cropping patterns will be maintained. However, in the command area (375.35 ha), three high value crops will be grown, i.e. Tea, Coffee and Plantain, with Tea occupying 40% of the command area, Coffee occupying 40% and Plantain occupying 20%. As a result, there will be an increase in the value of output from the command area.

4.1.3 Soil Conservation
The LWH Land Husbandry and Hillside Irrigation component is contributing to soil conservation on the much tilled sloppy hills. Due to land scarcity and high population density in all the territories of Rwanda, communities are farming hillsides without incorporating soil conservation measures. This trend will lead to reduced marshland sedimentation.

4.1.4 Flood Control
According to the socio-economic feasibility survey conducted it revealed that 13% of households within the project site experienced flooding in their farms which they indicated was detrimental to their crops. Houses falling within the command area were also affected by the flowing water during heavy rains. The dam to be constructed will help in controlling the effects of flash floods downstream by storing excess water during heavy rains. This is helping to minimize the flood related impacts downstream that could include crop and property destruction.

4.1.5 Water Resources Conservation
The Land Husbandry and Hillside Irrigation project investment by way of reforestation and terracing bunding etc will reduce soil erosion and in effect protecting the hydrological systems from sedimentation, flooding and contamination.

4.1.6 Birdlife Habitat
The dam reservoir area will attract birdlife in the project area. This is a beneficial impact on the biological environment of the project area.

4.1.7 Improved soil conservation
Improved soil conservation was perceived by 55% of the respondents who believed that there would be an improvement of the quality of the soil as a result of reduced erosion through slowed down run-off and through putting up soil conservation measures to contain the run-off. As a result from livestock diversification, there will be an increase in the volumes of manure used to replenish soil fertility. As a result from livestock diversification, there will be an increase in the volumes of manure used to replenish soil fertility. Continued use of this manure will improve the soil quality
and sustainably enhance soil fertility thus improving the yields. Improved soil conservation through improved land husbandry practices in the command area catchment (224.43 ha) and half of the water catchment area (550.89 ha) would lead to improved crop production resulting in an increase in output.

4.1.8 Improvement of previously water-logged areas
Forty nine percent (49%) of the respondents indicated that areas that had previously been water-logged during the rainy season would be put into productive use without the risk of losing all the crop as was previously the case, when submerged in the water. These were mainly the command area.

4.1.9 Increased farm incomes from crop output
An increase in farm incomes as a result of increased marketed crop output is expected. This would additionally be due to better and reliable market access of high-value crop produce that would fetch a good selling price as well as increased volumes of marketable output of different crops. An increase in output value by 137% from the current crop production in the command area based on gross margins of the projected high value crop output at the exporter’s prices and the current output’s gross margins. As a result of increased incomes, farmers will be able to access inputs which they will use to expand existing enterprises.

4.1.10 Environmental Protection
The project promotes intensification of agriculture as opposed to extension. This is arguably protecting marginal areas as more food is being produced in a smaller area. Sustainable agricultural intensification is not only important to increased employment and income, but also is critical to protecting the environment.

4.1.11 Revegetation
The LWH activities propose the protection of the hillsides which is a long term strategy of improving the vegetation of these erosion susceptible areas.

4.1.12 Livestock Development
Major constraints hampering the development of the livestock sector include Inadequacy of animal feed both in quality and quantity, which arises due to poor and narrow pastures and water shortage among other issues (MINAGRI, 2008). The implementation of the project interventions will indirectly lead to the development of the livestock subsector as a result of increased quality fodder production which will be harvested from fodder trees and perennial forage legumes intended for the water catchment protection through the project interventions, thus improving the low productivity of livestock on these farms. This will complement the government’s initiative on one-cow one-family thus improving the welfare of the farmers within the project site, through provision of required nutrients at household level and income that may be used to purchase essential goods and services. Availability of fodder for livestock will be an incentive for farmers to diversify and expand their livestock enterprises and enhance adoption rates of improved breeds which are early maturing and high yielders. Livestock development is envisaged to have a potential to contribute to poverty reduction through increased farm incomes. Livestock development projects often act as catalysts that enable farm households to join the market economy and thus to achieve a decent
standard of living (ILRI, 2007). In addition to contributing to household level welfare, the increased milk production will have a positive effect on the national dairy sector.

4.1.13 Food Security
The project will increase food production thus making it possible for community members to acquire available food. This would imply that if the production is improved, there will be more food thus resulting in a decrease in prices hence making it affordable to all the members within the community to have access to food.

4.1.14 Poverty Alleviation
The Rwandan Poverty Reduction Strategy Paper (PRSP, Rwanda, 2002) identifies five potentially competitive crops that will be targeted for expansion in addition to the traditional cash crops of coffee and tea. These are rice, maize, potatoes, soya and beans. Based on the Rwanda LWH, the project is in line with the objective of tackling poverty through promotion of agriculture.

At the local level, the irrigation infrastructure project will promote increased agricultural productivity, diversification of agricultural crops and commercialization of agriculture from subsistence. Improvement in crop productivity will raise the income for the rural poor above the poverty line of less than a dollar a day. This is an indirect impact that will take a long process that will be felt after many years.

4.1.15 Raise Rural Income
According to the socio-economic feasibility study conducted Ninety one percent (91%) of the sample households indicated that the implementation of the project will introduce new crop-husbandry practices that have not been used in the area previously, or even lead to expansion of existing crop enterprises. Within the entire water catchment area and command area catchment, land husbandry practices that will improve crop production will be adopted, but the prevailing cropping patterns will be maintained. However, in the command area, two high value crops will be grown, i.e. Pineapple and Plantain, with Plantain occupying 80% of the command area and Plantain occupying 20%.

4.1.16 Improved access to water for domestic purposes
Eighty five per cent (85%) indicated that provision of water in the reservoir will save the community from fetching water from far distances even during the dry season thus utilizing the time saved in tending to livestock, crop enterprises or household chores. They intend to use this water for livestock as well as domestic purposes such as washing clothes, bathing, cleaning and feeding livestock. This implies that the project interventions will indirectly lead to better hygiene practices which are vital in ensuring good health.

4.1.17 Improved nutrition
All the farmers were optimistic that through the project they would increase food production thus making it possible for community members to acquire available food. This would imply that if the production is improved, there will be more food thus resulting in a decrease in prices hence making it affordable to all the members within the community to have access to food.
4.1.18 Water for domestic use-washing clothes, bathing livestock
The farmers indicated that they intended to utilize the irrigation water for livestock. Feeding livestock was mainly in men’s domain hence they also fetched water for the livestock. Fetching water for livestock from the water reservoir would reduce the time they spend fetching it from far water sources. However, fetching of water for livestock was also done by women and children. This improved access to water for domestic purposes implies that there will be a general improvement of cleanliness within the homes hence healthier families. It also implies that it will be a time-saving strategy that has a potential of contributing to the improved participation of women in CCPIG meetings.

4.1.19 Other benefits

Appreciation of the value of land
Nominal land prices may increase thus making the high value irrigable land useful for cultivation and marketable which was otherwise less favoured due to flooding. They indicated that as a result, the relatively well-up members of the society would be the beneficiaries of the project.

Employment creation for community members
The project would not only benefit farmers within the irrigable area but would also create employment opportunities for other community members who will participate in labour provision in the farms (casual labouring) as well as stockists who will provide inputs and shopkeepers who stock household necessities.

Provision of fuelwood
Fifty five percent of the households (55%) perceived provision of fuelwood as a benefit that would accrue to them through the project. They indicated that through the project they would get fuelwood from within their locality or farms.

Empowerment of farmers
Empowerment of the farmers in the course of the implementation of the project, farmers will be sensitized and trained on the use of water and production of different crops, thus imparting skills to them for improved production as well as to access markets, which they will utilize even after the project’s exit.

4.2 Significant Adverse (Negative) Impacts
Significant negative impacts are those effects that will as a result of the implementation of the activities contribute to unintended results. These impacts have been described in the different phases of the project and are further categorized in terms of impact duration, magnitude and type respectively.

4.2.1 Design and Planning Phase
The design phase of this sub project involved identification of a suitable site for the infrastructure and undertaking of a detailed feasibility study. There are no adverse impacts expected during this stage, however, best practice was incorporated at this stage to ensure that the design takes into account the environmental issues to consider.
4.2.2 Construction Phase
In the construction phase the following activities are expected to occur namely; preparation of camping site, clearance of dam, coffer dam, trenches, spillway sites. Excavation of irrigation canals, construction of coffer dam including pond cut-off and trench excavation etc. These activities will give rise to the following potential adverse impacts all which are ranging from short to long term but reversible in nature and moderate in magnitude.

4.2.2.1 Destruction of Vegetation
The proposed reservoir area is 10.25 ha. Twelve households are settled within the proposed reservoir area and 5 are settled very close to the reservoir area thus recommended for relocation. There are no houses located within the reservoir area, hence there will be no physical displacement.

Mitigation Measure(s)
This impact is unavoidable and will be mitigated through compensation for crop and vegetation loss through the preparation of Abbreviated Resettlement Action Plans (ARAPs).

4.2.2.2 Relocation Impacts
Twelve households are settled within the proposed reservoir area and 5 are settled very close to the reservoir area thus recommended for relocation. Thus a total of 17 households will relocate.

As mentioned above, implementation of the LWH project at the Karongi – 13 project site will have resettlement implications, with the affected households falling in three categories:

1. Households owning farms within the proposed reservoir area (10.25 ha), will lose their land permanently. Based on the average farm sizes (1.38 ha/household) in the area, it is estimated that 8 households will be affected.

2. Households with housing structures within the proposed reservoir. There are 12 households settled within the proposed reservoir area, and an additional 5 settled very close to the proposed reservoir area recommended for relocation. Hence a total of 17 households.

3. Farmers with land parcels surrounding the water reservoir. An estimated 27 farmers (based on the average farm sizes (1.38 ha/household) with farms surrounding the reservoir area will change their land-use. This will be the silt-trap zone (37.52 ha), comprising of a grass-zone, shrub-zone and tree-zone protecting the water reservoir from siltation. The proposed reservoir area and the silt trap zone has mainly been used for crop production mainly for subsistence purposes, with little surplus for sale. After the vegetation within the silt-trap zone is established and becomes productive, households owning those pieces of land will control the benefits. Though the grass-covered fields could yield within three months time, the shrub and tree zone will generate income after 4 years.
Mitigation Measure(s)
This impact is unavoidable and will be mitigated through compensation for crop and vegetation loss, land and housing through the preparation of Abbreviated Resettlement Action Plans (ARAPs) and guided by the Resettlement Policy Framework (RPF) document.

4.2.2.3 Borrow Pit Impacts
Borrow pit are generally associated with scaring of the general environment and landscape owing to the excavation related works. If not backfilled immediately and replanted, the borrow pits end up becoming a health hazard and a source of spread of water borne related diseases like bilharzia, malaria etc. This is because the pits end up collecting water that stagnate and hence becoming a rich breeding ground for the disease vectors. Borrow pits are also known to be potential sources of hazards especially accidental drowning of livestock and human beings.

Mitigation Measure(s)
This site is an existing borrow area, which is being actively exploited and conveniently located. The environmental effect due to the additional exploitation is thus kept at a minimum.

4.2.2.4 Soil Erosion
During the construction of the dam and its ancillary facilities which will involve clearing of vegetation, excavation works etc the soil will be exposed to the agents of erosion, mostly water. This impact occurs during project construction and operational phase.

Mitigation Measure(s)
Institution of soil control measures during construction is necessary.

4.2.3 Operation Phase
The operation phase entails the actual irrigation of the hillsides after the water has been harvested. The potential adverse impacts in this phase include;

4.2.3.1 Reduced Water Flow/Down Stream Flooding
Dam construction for irrigation and construction of water deviation canals involves blocking and deviation of the flow of water to the marshlands or valleys. Due to this the downstream water users might experience temporary shortfall (until the reservoirs fill) in the amount of water available therefore disrupting activities and sources of livelihood that depend on the waters. This is a short term impact that only happens when the water will be diverted to the dam. The impact will change flood plain, land use and ecology downstream for a short period especially the nearby River Ndaba.

Mitigation Measure(s)
The valley where the dam is going to be constructed has base flow. Though this base flow is intercepted by the dam, downstream use would not be affected at least for two reasons.
- The irrigation canal that conveys water from the dam serves primarily areas just downstream of the dam.
- In less than a 100m from the dam toe, branching valleys from the main dam valley contribute water for downstream users.
• In the dam design, a coffer dam will be constructed for retaining the water during construction this will abate the downstream impact effect.

This impact is short term and will only be experienced during the initial operation phases of the project when the reservoir will require filling up.

4.2.3.2 Fear of an overflow of water if it rained so heavily
The PAPs interviewed during the public consultation exercise expressed fear of water overflowing out of the reservoir in case unusually heavy rains occurred causing havoc in the project area.

Mitigation Measure(s)
The project design has included spillways to address this potential adverse impact which is considered long term and expected to occur throughout the project operation phase. During the sensitization and awareness meetings, it will be important to reassure them of the intentions of having a spillway to address this.

Spillway has been designed to have discharging capacity sufficient enough to pass the inflow floods corresponding to a return period of 1 in 100 years, as it is defined as large dam from the height aspect and a small one from the storage capacity aspect.

International standards (Indian Standards) specify that if the failure of dam poses danger to human life, the spillway must have sufficient capacity to accommodate the routed flood discharge corresponding to probable maximum Flood (PMF) and if the failure of dam would result only in heavy damage to property but does not pose appreciable risk to life then the spillway may be designed for flood discharge corresponding to 1 in 10,000 year return period.

Internal Seepage Control Measures
The design of adequate filters in zoned embankment dams is vital to control erosion of the earth core and dam foundations under the forces generated by seepage through and under the dam. These filters are essential to the performance of the dam. Their failure to perform satisfactorily can lead to piping failure of the dam.

Filters designated as “Critical” will be placed in areas of the embankment where the prevention of erosion is vital. Other Filters designated as “Non-Critical” will be also provided upstream of the earth fill core, beneath riprap and in other selected places.

As described by Indraratna and Locke (1999), to function correctly, filters must be:
• Sufficiently fine grained such that the pore constrictions (smallest opening between pores) are small enough to retain the core material which may wash out into the filter
• Sufficiently permeable to facilitate seepage flow out of the base soil, preventing the buildup of pore pressure
• Non-cohesive so that any cracks in the base are not propagated into the filter and they cannot develop cracks due to deformation.
The critical filters of the dam have been designed using the recommendations of Indraratna and Locke (1999). This is based on the work by Sherard and Dunnigan (1985) and some more recent research.

4.2.3.3 Increased Spread of Water Borne Diseases

An increase in the incidences of malaria because the water reservoir would serve as a breeding ground for mosquitoes and this is an impact that is associated with all dam projects. Project Affected Persons also feared that there would be a “cool breeze” prevailing as a result of the water mass that would result in respiratory related problems due to continuous exposure of residents. They also cited stomach-related disorders specifically infestation by worms, as a result of young household members using the irrigation water for domestic purposes (drinking and cooking) when not supervised.

**Mitigation Measure(s)**

LWH should support the introduction of fish in the dam as a strategy for reducing the breeding of mosquitoes in order to contain malaria spread.

The LWH should develop a program in collaboration with the Ministry of Health (MINISANTE) and the local communities which undertakes bi-annual survey of health records in Health Care Facilities (HCFs) to ascertain the spread of malaria. This data should then be used to develop a malaria prevention project within LWH that could include use of Insecticide Treated Nets, Indoor Residual Spraying among others.

However, similar to the live fencing, the project implementation has taken this into consideration and the project design includes introduction of fish species that feed on mosquito larvae.

Additionally, it includes planting of *Phytolaca decocandra* which will destroy the snails that serve as hosts of systomiasis. This adds to diversification of income through fish farming.

4.2.3.4 Canal Siltation

Canal siltation is an adverse impact that clogs the canals leading to less flow of water into the command area and farming fields and this can reduce the crop yields. Increased soil erosion and siltation is generally impacting the hydrology of the marshlands and rivers negatively. Furthermore, clogged canals could soon become possible breeding site for mosquitoes if not maintained and unclogged.

**Mitigation Measure(s)**

Silt traps have been included in the general design of the project and the canals will be flushed as frequent as possible to minimize this impact. Frequent flushing of the canals will also be undertaken by the local farmers and cooperatives.

**Training on maintenance of the water canals**

The project team should provide training for the local farmers on how to operate and maintain the water intake points and canals to ensure that there is no blockages or flooding.
4.2.3.5 Dam Safety Impacts
The construction of the dam is faced with a potential collapse of the dam wall due to earth tremors, treks etc that can be a source of destruction of crops and property and even life if the walls fail and cause flooding downstream when there are heavy rains that the walls of the dam cannot withstand.

Mitigation Measure(s)
The dam site is located in a seismic zone of low intensity and there is no earthquake recording station in the vicinity of the project area. Records to show the earthquake events experienced in the project area are not there.

Seepage and leakage
Measurement of seepage through the dam body, foundations & abutments of the dam may indicate erosion or blocking of downstream drains and relief wells by increase or decrease of seepage respectively at constant reservoir level. Seepage and erosion may take place along the lines of poor compaction and through the cracks in formation and fills. This may be indicated by such measurement. Measurement of seepage water at interface of dam and its foundation will provide direct indication of the efficiency of cutoff and indicate about the necessary remedial measures. The chemical analysis of water will provide the information of seepage of water through the foundation drainage arrangement and any foundation material being washed out. Corrective measures could be planned. The wet spots on the downstream slope or at abutment locations would indicate seepage problem, and remedial measures could be suggested.

Surface movement measurement
The measurement of surface movement of the embankment dam shall be made by means of installing 6 number of surface settlement points on the dam slope, dam crest at 50.0 m center to center and shall be monitored by using a theodolite at regular intervals from bench mark established and readings each time taken shall be compared with the earlier reading to arrive at the settlement of the surface.

Earthquake Measurement
The dam site is located in a seismic zone of low intensity and there is no earthquake recording station in the vicinity of the project area. Records to show the earthquake events experienced in the project area are not there:

The instruments for recording of seismic events proposed to be installed for the dam consists of one acceleograph at the base of the dam and one at the top of the dam. Strong motion accelerographs and structural response recorder are to be installed at the base and at the top of dam. The location selected should be free from the background seismic noise erected due to vibrations of the appurtenant works. The instrument located at the top would provide information about responses of structure resulting from earthquake.

Spillway has been designed to have discharging capacity sufficient enough to pass the inflow floods corresponding to a return period of 1 in 100 years, as it is defined as large dam from the height aspect and a small one from the storage capacity aspect.
International standards (Indian Standards) specify that if the failure of dam poses danger to human life, the spillway must have sufficient capacity to accommodate the routed flood discharge corresponding to probable maximum Flood (PMF) and if the failure of dam would result only in heavy damage to property but does not pose appreciable risk to life then the spillway may be designed for flood discharge corresponding to 1 in 10,000 year return period. The dam location is in an area where failure may probably remain restricted to the irrigation farms and the dam area itself. Loss to human life would probably be minimal. For such a situation and for the sake of economy, a routed flood discharge corresponding to 1 in 200 years return period has been considered as there is not much habitation downstream of the dam site. The flood with a return period of 1 in 200 years as computed in the hydrology resulted in a flood lift of 0.56 m and spillway width of 4.0 m. Hence, the spillway has adequate capacity.

**Dam Safety Monitoring /Measuring Instruments**
The program plans to buy and install instruments for recording seismic events. The instruments for recording of seismic events proposed to be installed for the dam consists of one accelegraph at the base of the dam and one at the top of the dam. Strong motion accelerographs and structural response recorder are to be installed at the base and at the top of dam. The location selected should be free from the background seismic noise erected due to vibrations of the appurtenant works. The instrument located at the top would provide information about responses of structure resulting from earthquake.

**Other Measurements**

**Wave Height Recorders:** Wave height Recorders installed would be helpful in finding the wave height and in deciding the free board requirements on a more realistic way.

**Rainfall:** measurement of rainfall will be helpful for interpretation of pore measurement and seepage development in earth dam.

**4.2.3.6 Drowning of livestock and children**
During the public consultation process respondents expressed fears in drowning incidents of children and livestock that they foresee with the implementation of the project. However, the project design includes a silt-trap and live fencing which will take care of these fears effectively. The study revealed that households within the project site had not experienced incidences of drowning for humans or livestock.

**Mitigation Measure(s)**
- The LWH should before the construction undertake education and awareness of the local communities and making them aware of the hazards related to unrestricted entry into the dam reservoir.

- LWH should fence the reservoir area, erect warning signs and control access of the dam while efforts should be put on teaching local people proper safety behavior and swimming.

- LWH should also construct water drinking points for the local communities as a strategy and a way for reducing increased access to the dam reservoir to get water which causes incidents.
4.2.3.7 Agro-Chemical Pollution
The use of fertilizers and pesticides in the farming areas is going to be a potential source of introducing nutrients into the water resource of the marshland and the stream that flows through the area. Runoff agrochemicals (compound of phosphate, nitrates and ammonium) and pesticides are most likely being dispersed downstream into confluence of the marshland which drains into the Ndaba River.

Mitigation Measure(s)
The LWH project is already preparing an Integrated Pest Management Plan for the entire project which will provide guidance on the judicious use of chemicals in the cultivation and production of crops.

Training and Capacity Building Mitigation Measures
Pesticide/Fertilizer Application Training
The LWH Agronomist and the provincial level field agronomist should conducting training to the local farmers on the safe application of pesticides and fertilizers. This is a practice that can immensely contributing to the reduction of possible chemical pollution of the marshlands The training on pesticide application touches on the quantities to apply, timing (when), and protective gears to wear among others and should be incorporated in the Pest Management Plan that is under preparation.

Establishing Baseline Data for current water quality with respect to agrochemical pollution.
These baseline data should be collected before the LWH project begins. This will help in monitoring and controlling pollution caused by the use of Pesticides/Fertilizers.

5. ENVIRONMENT MANAGEMENT PLAN IMPLEMENTATION

This EMP will be implemented by the several institutions mentioned below who are directly or indirectly involved in this subproject.

5.1 World Bank
World Bank is the financier of the project including the implementation of the EMP within the budget of LWH. The main role of the bank is to ensure that compliance is achieved as per the requirements of the EMP.

5.2 Ministry of Agriculture and Animal Resources (MINAGRI)
Ministry of Agriculture and Animal Resources (MINIAGRI) through the LWH is the lead agency in the implementation of this EMP and the project. The role of the LWH is to implement mitigation measures, building the capacity of other actors in IPM, and in environmental management.

The LWH agronomist will be the focal point for training in IMP and agrochemical application and will liaise with the ministry of agriculture for technical support. It should be noted that all the capacity building activities should be hands-on through the FFS approach. The project should establish one farm in one of the project areas which will act as the field school.
The ministry through LWH will also supervise infrastructure design and construction including dams and drainage. The role of MINAGRI will to ensure that the dams and drainages are constructed according to the specifications international technical and safety standards.

**Training on IPM**
The training program will cover amounts of fertilizer to be applied per hectare of land and during what conditions should be undertaken before commissioning of the project. The types and amounts of pesticides should also be part of this training. This training should be a hands-on that can be introduced in the Farmer’s Field School (FFS) model adopted by the project. Food and Agriculture Organization (FAO) and ISAR and the RSSP II project have the capacity to undertake this activity and could be partners with LWH.

**Training in Fertilizer and Pesticides Application**
The training objective is to ensure beneficiary farmers in the project area do not pollute water resources through unsustainable application of inorganic fertilizers. This capacity building activity can undertake by MINAGRI with technical support from *Institut des Sciences Agronomiques du Rwanda*.

**5.3 Land Husbandry Hillside Irrigation and Water Harvesting Project**
Land Husbandry Hillside Irrigation and Water Harvesting Project (LWH) is the lead agency in the implementation of this EMP and the project. The role of the LWH will be to implement mitigation measures, coordination of monitoring activities maintenance of monitoring information, building the capacity of other stakeholders in collection and analysis of monitoring data.

The Environmental Officer of LWH will be the focal point for the EMP and will liaise with other stakeholders to executive the plan.

**5.4 Rwanda Environment Management Authority**
Rwanda Environment Management Authority is the oversight authority over the environment in Rwanda. Its role will be of monitoring environment indicators as identified in this EMP. The role of Rwanda Environment Management Authority (REMA) includes:

**Oversight Monitoring**
As the lead agency responsible for the protection of environment in Rwanda, REMA will play the leading oversight role of monitoring the activities of the project according to the Organic Law establishing REMA and its functions.

**Site Inspection Visits**
REMA will undertake regular site visits to inspect and verify for themselves the nature and extent of the impacts. REMA will undertake also undertake regular site visits to inspect and verify for themselves the extent to which the mitigation measures proposed in this EMP are being complied with or vice versa. They will then be expected to make viable recommendations based on their findings to the LWH.
Periodic Reports
REMA will prepare periodic environmental consolidated reports on the monitoring progress of the marshland development.

5.5 Community Group/Project Beneficiaries
The project beneficiaries being the people on the ground will have the role of execute some of the mitigation measures, collecting and monitoring the identified indicators and practicing sustainable farming as well as catchment rehabilitation and management. The project beneficiaries are organized in cooperatives which have management committees for water, production and maintenance.

5.6 Contractors
The contractor will be in charge of designing and constructing the infrastructure according to the World Bank operation policy on dam safety, restoring the borrow pits and degraded areas, ensuring the safety of the users and others.

5.7 Ministry of Health
Due to possible health impacts especially malaria and bilharzia in the subproject areas, the ministry of heath comes into the picture of this project. The role of the ministry of health will be to promote environmental health, health prevention methods including sleeping in treated nets and monitoring incidences of malaria and bilharzia.

5.8 Local Authorities
The LWH subprojects are being implemented in several districts which are administered by the respective district authorities. These local authorities have jurisdiction over the subproject areas and control the marshlands including use and conservation. The marshland farmers pay taxes to the respective authorities for use of these areas. The department of agriculture and animal husbandry would be the focal point in the respective local authorities.

The role of the local authorities will be to monitor and ensure sustainable utilization of the marshlands after the project period. They will be the agency close to the project and will ensure the EMP is implemented by the different stakeholders as indicated.
## CONSTRUCTION PHASE

<table>
<thead>
<tr>
<th>Activity</th>
<th>Adverse Impacts</th>
<th>Mitigation Measure(s)</th>
<th>Implementation Schedule</th>
<th>Responsibility</th>
<th>Budget (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civil Works&lt;br&gt;Removal/destruction of all vegetation from the subproject site /Site clearing/civil works/earth moving works, trenching, excavations, construction of camping site, excavation of borrow materials.</td>
<td>Loss of crops, vegetation and trees.&lt;br&gt;Loss of land</td>
<td>Compensate for property loss, crop loss and land loss</td>
<td>Compensation should occur in line with the ARAP and before construction commences.</td>
<td>LWH</td>
<td>Will be reflected in the ARAP.</td>
</tr>
<tr>
<td></td>
<td>Soil erosion.</td>
<td>Create contour drains during construction&lt;br&gt;Soil Erosion Management strategies to include revegetation, creation of erosion berms</td>
<td>During the construction</td>
<td>Contractor</td>
<td>Factored in the contractor cost</td>
</tr>
<tr>
<td></td>
<td>Borrow sites create disease vector breeding ground and hazards</td>
<td>Backfilling and leveling of the borrow pits to prevent water percolation.</td>
<td>Immediately after the construction</td>
<td>Contractor</td>
<td>Factored in the contractor contract</td>
</tr>
</tbody>
</table>
### Activity

<table>
<thead>
<tr>
<th>Activity</th>
<th>Adverse Impacts</th>
<th>Mitigation Measure(s)</th>
<th>Implementation Schedule</th>
<th>Responsibility</th>
<th>Budget (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fugitive dust generated during excavation works could cause respiratory diseases</td>
<td>Wetting the surface during construction</td>
<td>Construction process</td>
<td>Contractor</td>
<td>None as water is available and near the sites</td>
</tr>
</tbody>
</table>

#### Workers Accident

- Wetting the surface during construction
- Providing all workers with PPEs

**OPERATION PHASE**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Adverse Impacts</th>
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<th>Implementation Schedule</th>
<th>Responsibility</th>
<th>Budget (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir filling</td>
<td>Reduced water flow downstream during the time that the reservoir will be filling up.</td>
<td>Control abstraction rates to half the river flow to replicate natural flooding regime. Proper design and operation of dam spillways and gates (timing and volume of discharges). Construct coffer dam</td>
<td>Design and operation phases</td>
<td>LWH staff</td>
<td>Part of the contract costs</td>
</tr>
<tr>
<td>Activity</td>
<td>Adverse Impacts</td>
<td>Mitigation Measures</td>
<td>Implementation Schedule</td>
<td>Responsibility</td>
<td>Budget (US$)</td>
</tr>
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<td>--------------------------------------------------------------------------------</td>
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</tr>
</tbody>
</table>
|          | Increased spread of water borne disease vector including Malaria, Cholera, Bilharzia etc | Fill the reservoirs during wet season when there is high flow  
- Introduce fish in the dam  
- Create awareness on malaria prevention methods  
- Provide treated mosquito nets | Operation phase                      | LWH staff                      | None                      |
|          | Flooding                                                                        | Increase overflow spill capacity                                                    | Continuous              | LWH and Ministry of Health     | LWH          |
|          | Safety Hazards (drowning, flooding and breakage of dam wall)                     |  
- Fencing of the reservoir area  
- Provision of community water access points  
- Conduct community awareness and sensitization  
- Posting of a security guard | Construction and Operation            | Contractor and LWH             | Part of LWH budget for hillside interventions | Included in the contract design document |
<table>
<thead>
<tr>
<th>Activity</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Design of dam safety measures including dam instrumentation for seepage and leakage analyses, quake recording and movements analysis</td>
<td>During the Design and construction stage</td>
<td>LWH and contractors,</td>
<td>Cost of the instruments are included in the contract document</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Construct the dam to meet international technical and safety standards</td>
<td>During the Design Phase</td>
<td>Contractor (A clause in the contract)</td>
<td>None</td>
</tr>
<tr>
<td>Soil Erosion</td>
<td></td>
<td>Terracing of the sloppy areas of the land and plating of nappier grass along the canals.</td>
<td>Construction and Operation phase</td>
<td>Construction contractor</td>
<td>Included in the contract document</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contour drainage to slow down surface runoff.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Land leveling to prevent erosion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduced Water Flow</td>
<td></td>
<td>Regulate water abstraction through practices and design of the intake structures</td>
<td>During construction and operation</td>
<td>LWH &amp; Cooperative/association members</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Undertake hydrological assessment of the catchments</td>
<td>Should be done before project commissioning</td>
<td>LWH &amp; contractor</td>
<td></td>
</tr>
</tbody>
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*LWH Environmental Management Plan: Karongi 13*
<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Application of agrochemicals (fertilizer and pesticides)</td>
<td>Water Pollution and degradation through chemicals</td>
<td>• Prepare an Integrated Pest Management Plan (PMP).</td>
<td>Planning and operation stages</td>
<td>LWH</td>
<td>Part of the LWH budget</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A training program application of agrochemicals under field conditions.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Adopt Integrated Pest Management approach</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. MONITORING PLAN

The monitoring plan defines and identifies monitoring activities will take place, when and by whom and identifies the indicators and data collection methods and identifies training and capacity building needs of the institutions and persons to implement the plan.

As indicated on the monitoring schedule below, monitoring will be done by numerous institutions and persons but coordinated by M&E division of LWH secretariat in Kigali and the focal person will be the Environmental Officer who should be employed by LWH immediately before the commencement of the project.

To ensure effective and reliable data collection, the key persons from the institutions to be involved in the monitoring will be trained on the indicators to be monitored, sampling methods, and data collection techniques to be used. The LWH M&E division will organize a 2 day training program in one of the project sites and train the participants. The key resource persons for this training will be the Environmental Officer and the M&E coordinator. Participants for this training will be from the institutions involved in implementation of the monitoring plan which are LWH M&E division, Environmental Officer, Agronomist, and irrigation engineer, REMA, Cooperative/association members from each subproject site, MINAGRI, Ministry of Health diseases surveillance division or public health and engineers from Ministry of infrastructure (MININFRA). LWH can commission a consultant to develop modules for M&E if need be.

The LWH M&E division will be the monitoring data depository and bank and will coordinate the collection of these data as described in the schedule. The division will need to install a monitoring and tracking system.

Technical data that might not be collected by the cooperative members /beneficiaries, LWH provincial M&E officers will be in charge of this.

LWH Project secretariat will need to facilitate the Environmental Officer to purchase sample collection equipment especially for water sample collection. The national metrological survey will be responsible for monitoring the river flows. A portable hydro flow meter (river flow measuring gadget) will be ideal for a project of this nature that has many sites to be monitored.

As the LWH has M&E component with budget, the cost of implementing this plan will be minimal as the plan will be integrated into the project component.

Food and Agriculture Organization seasonal crop assessments capacity can be used in monitoring food security indicators in all the subproject sites.

It should be noted that, LWH is a project of MINAGRI and as such it will come to an end after the already determined cycle, while the project operations will continue even after the end of the project. At the end of the project, the responsibility of monitoring the project impacts will rest with the respective agencies and REMA and the respective cooperative members.
6.1 Water Quality Monitoring
During the operation period, monitoring is proposed for water quality especially to determine the level and concentration of pesticides and fertilizer content in the command area.

The consultant proposes the identification of different points of the command area in order to monitor the quality of water. Periodic taking of water samples should be undertaken preferably twice a year during the cultivation season to determine water quality. Water sampling points should be at the beginning of the command area, middle and at the mouth of the marshland where it drains into the Lake Rimura. These samples should be taken by the provincial agronomist to the LWH environmental officer who should then take them in an accredited laboratory for testing. The results should be used to design appropriate water quality mitigation programs. The same will apply to analysis of water quantities in relation to the abstraction impacts. Different stations will need to be identified and flow quantities recorded during different times of the year preferably during the wet and dry season respectively. The results should be used to deduce the impacts of the abstraction of water on the hydrology of the marshlands and the wider catchment basin.

6.2 Monitoring Diseases spread
In order to monitor the possible impacts of the marshland development to malaria and bilharzia spread in the area, the LWH sociologist together with the provincial LWH staff need to undertake periodic surveys of the health records around the marshland to ascertain prevalence of disease spread. The surveys should be done 2 times in a year. Even though it cannot be proven that the LWH project could be directly contributing to the spread of these diseases, the results can be used to assist LWH increase its interventions on malaria and bilharzia prevalence.

6.3 Monitoring Seepage and leakage
Measurement of seepage through the dam body, foundations & abutments of the dam may indicate erosion or blocking of downstream drains and relief wells by increase or decrease of seepage respectively at constant reservoir level. Seepage and erosion may take place along the lines of poor compaction and through the cracks in formation and fills. This may be indicated by such measurement. Measurement of seepage water at interface of dam and its foundation will provide direct indication of the efficiency of cutoff and indicate about the necessary remedial measures. The chemical analysis of water will provide the information of seepage of water through the foundation drainage arrangement and any foundation material being washed out.

6.4 Surface movement measurement
The measurement of surface movement of the embankment dam shall be made by means of installing 6 number of surface settlement points on the dam slope, dam crest at 50.0 m center to center and shall be monitored by using a theodolite at regular intervals from bench mark established and readings each time taken shall be compared with the earlier reading to arrive at the settlement of the surface.

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6.6. MONITORING FRAMEWORK
<table>
<thead>
<tr>
<th>Impact</th>
<th>Parameter</th>
<th>Indicator</th>
<th>Method</th>
<th>Frequency of Measurement</th>
<th>Responsibility</th>
<th>Costs Estimates (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical Environment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water pollution</td>
<td>Quality</td>
<td>Nutrient Load (Nitrates, phosphates, potassium, pesticide residue, COD &amp; BOD, Turbidity)</td>
<td>Bi-Annually during wet and dry season (samples should be taken from the inlet and outlet points of the developed area)</td>
<td>Seasonally</td>
<td>LWH</td>
<td>30,000.00</td>
</tr>
<tr>
<td>Reduced Water flow</td>
<td>Quantity</td>
<td>Flow rates per second</td>
<td>River/stream gauging</td>
<td>Seasonally</td>
<td>MINITERE &amp; LWH (Environnemental Officer) &amp; REMA</td>
<td></td>
</tr>
<tr>
<td>Soil erosion</td>
<td>Soil cover loss</td>
<td>Soil productivity, gullies, water turbidity</td>
<td>Observation</td>
<td>Continuous</td>
<td>LWH, MINAGRI, REMA &amp; Community beneficiaries</td>
<td></td>
</tr>
<tr>
<td>Flooding</td>
<td>Area inundated</td>
<td>Floods downstream of project area</td>
<td>Observation and reported cases of flooding</td>
<td>Continuous</td>
<td>Community beneficiaries &amp; LWH</td>
<td></td>
</tr>
<tr>
<td>Water wastage</td>
<td>Water availability</td>
<td>Install water meters in the intake point</td>
<td>Continuous</td>
<td></td>
<td>LWH, REMA &amp; contractor</td>
<td></td>
</tr>
<tr>
<td><strong>Socio-economic Environment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact</td>
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<td>------------------------</td>
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<td>----------------------------------------------------------------------------</td>
<td>---------------------------------------------</td>
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<td>--------------------------------------------------------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Water-borne Diseases</td>
<td>Disease prevalence</td>
<td>Increased cases of malaria and bilharzias among other waterborne diseases</td>
<td>Review of health records</td>
<td>Quarterly</td>
<td>LWH (Social and Environmental Officer), community and Ministry of Health</td>
<td>Part of the project M&amp;E budget</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety Hazard</td>
<td>Safety of live stock and humans</td>
<td>Reported cases of incidences and accidents</td>
<td>Review and evaluation of incidents and accidents register Instrumentation equipment including; Acceleograph, theodolite</td>
<td>Continuous monitoring of leakages, seepages, movements through instrumentation</td>
<td>LWH (engineer) &amp; MININFRA</td>
<td>Part of the project M&amp;E budget</td>
</tr>
</tbody>
</table>
5. CONCLUSION

The LWH Karongi – 13 sub project activities considered in this study are environmentally feasible due to the fact that proposed interventions are environmentally friendly e.g. hillside irrigation and land husbandry. In addition, the adverse impacts anticipated can be effectively managed by following the designed EMP which includes mitigation measures already thought out in the design and feasibility study phase.