Investigation Towards Alternative Water Resources

Mtwara, Tanzania

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This report is written as a study towards alternative water resources next to the actual used methods. The results should be read as an advise.

Preface

I would like to use this opportunity to thank Hermen Klomp and Pieter Filius of the Regional water authority Velt en Vecht located in Coevorden, the Netherlands. They have coordinated and advised me by providing technical input for my graduation study at AMREF Mtwara (Tanzania).

Furthermore, I would like to thank Joris van Oppenraaij from AMREF Netherland. His advices, critics and experiences were helpful for me. As well as the advises from Mark Rietveld and Dick Bouwman from Aqua for All. Their expertise in hydrogeology has been helpful. From Hogeschool van Hall – Larenstein, I would like to thank my teacher and coordinator Henk van Hoof. His support, enthusiasm and commitment to his job is an example for many.

Moreover, I would like to thank Ignatio Kagonji, project manager AMREF Mtwara (Tanzania) by advising me in executing the field visits and in controlling the scope of work. As well as Emmanuel Fungo, project officer AMREF Mtwara (Tanzania) who has attended me with all the field visits and by sharing a room in his house for giving me an unforgettable experience in the warm and friendly surrounding of Mtwara town.

And of course I would like to thank the other staff of AMREF, namely Said, Lwanji, Lawrence, Ligaga who warmly welcomed me in Mtwara and facilitated me with never ending enthusiasm.

Also I would like to thank all the local residents of Mtwara rural, who took their time to answer the questions and discuss the matters of access to safe and reliable water sources.

To my parents,

August 2010

Mattijn van Hoek

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1 Introduction

1.1 Background

The government of Tanzania declares in the national water policy that 'the availability of water is a basic need and entitled to everyone'. Based on findings of AMREF, the estimation of disease burden related due to the lack of safe drinking water and adequate sanitation in Tanzania is 70%.

To improve the water supply in the district, the African Medical, Research Foundation (AMREF) Tanzania and the Mtwara Rural District Council has started the WATSAN project in 2008. This project is about water, hygiene, and sanitation. AMREF hopes to finish this project in collaboration with water board Velt en Vecht (by providing technical assistance and function as co-financier) in 2011.

The project aims to improve the health and quality of life of selected marginalized communities of Mtwara district. Including 6 wards and 40 villages. This is done by increasing access to- and sustainable use of safe water and basic sanitation services by constructing boreholes in each village.

1.2 Objectives of the study

This study outlines a study towards more sustainable water sources in Mtwara region, Tanzania, according to the Tanzania national water policy.

The purpose of the investigation is to provide technical evidence for an addendum towards the European Union (main financier in this project) for adjustment of the scope towards development of alternative water sources.

This study, as defined in the Terms of Reference (appendix 1) has the following objectives:

1. *Exploring the possibilities of alternative water sources (apart from deep boreholes)*
2. *Standardize collected data in database formats and train the local staff where needed*

Ad1. The objective is to investigate possible alternative drinking water sources in the villages of phase three and other villages out of the project area. This possibility arises by the release of budget by reducing the number of boreholes from 51 to 40. Those, potential, alternative solutions will possibly offer the population a more reliable and affordable access to safe drinking water. Key elements for analysing alternative water resources are affordability, technical usability, and durability. The result is a method, which is based on these key elements.

Ad2. Setting up of a proper data management system will be done for water source monitoring, both qualitative and quantitative. With adequate monitoring, it is possible to intervene in time when recharge of a water source is insufficient or contamination takes place. The local staffs receive training in adequate monitoring and the use of databases in ArcGIS.

1.3 Methodology

The approach of this investigation is based on a participatory approach that involve community members, village and sub village governments and committees. The methods used to gather and analyse information include desk studies, data collection, field visits and different analyses. The investigation is started with the desk study and data collection. Together with the fields visit it is possible to analyse the objectives of the study. In appendix 2 is found the plan of approach for this investigation. Apart from the study there will take place a training in GIS and data management (the trained elements can be found in appendix 9)

1.4 Structure of this Report

The report focuses on the actual used water resources and the possible alternatives. For this, the study area will be discussed in chapter 2, the description of the study area. Thereafter, in chapter 3 the methods are discussed to come up with the result and findings in chapter 4. This chapter starts with presenting the actual approach towards water collecting and the finish with suitable alternatives which are analysed by different points, like the sustainability, performance and costs. Chapter 5 is the conclusion and the report finish with the discussion in chapter 6.

2 Description of study area

In this chapter, different aspects of the project area are discussed. The different aspects are geomorphology and hydrogeology, in order to receive an overview of the characteristics of the subsurface layers. Furthermore, the climate will be analysed for the meteorological characteristics, in order to get an insight in the precipitation potential. After land use & vegetation and actual used methods for water harvesting this chapter will end with the results (outcomes) of the discussions held during the village meetings.

2.1 Project area

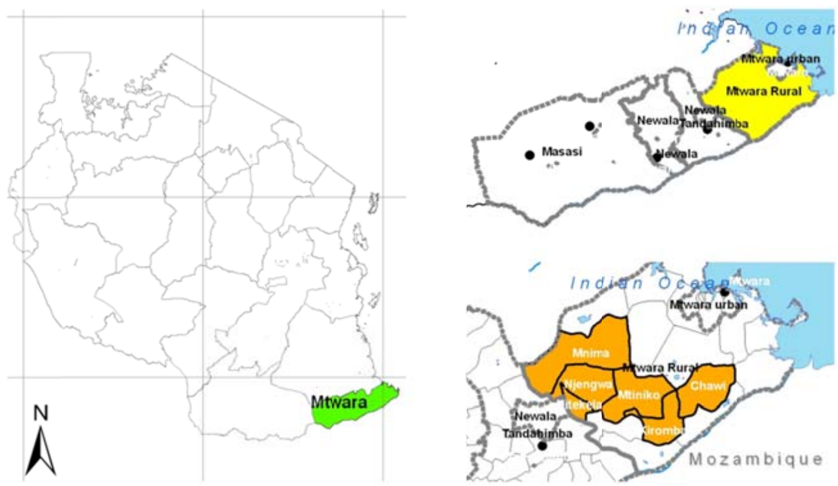


Figure 2.1
On the left the country Tanzania with Mtwara region in the southeast. Top right an overview of the five different districts, in yellow Mtwara Rural. Bottom right a small overview of the district Mtwara Rural with the different wards.

Within Tanzania the Mtwara region, located in the southeast, is still a remote area. The region consists of five districts, Masasi, Newala, Tandahimba, Mtwara urban and Mtwara rural (figure 2.1). The district Mtwara rural consist of six divisions, 18 wards en 119 villages. The total population of Mtwara is 231.554 (WATSAN Mtwara Baseline Survey Report) and has an estimated annual growth of 1.4%. The surface of Mtwara Rural is 3858 km^2 (ArcGIS 9.2, Wards_Tanzania). In the district, the majority of people do not have access to safe drinking water and adequate sanitation.

Each day, the collection of water takes 2 to 7 hours per household. In most cases, the collected water is not safe. Water scarcity results in an average use of 10 litres per person per day[1] where WHO prescribes a minimum use of 20l/p/d.

The AMREF project area consists out of 6 wards in the district Mtwara Rural.

The borders of Mtwara rural are as follows:

In the south it is the Ruvuma River, with 704 kilometres the longest river of Tanzania (Tanzania, Relief and drainage, Digital Cartography by M C Shand University of Glasgow 1997). The Indian Ocean is the border of the east side of Mtwara Rural. The northern border is the region Lindi and the western border is the district Tandahimba.

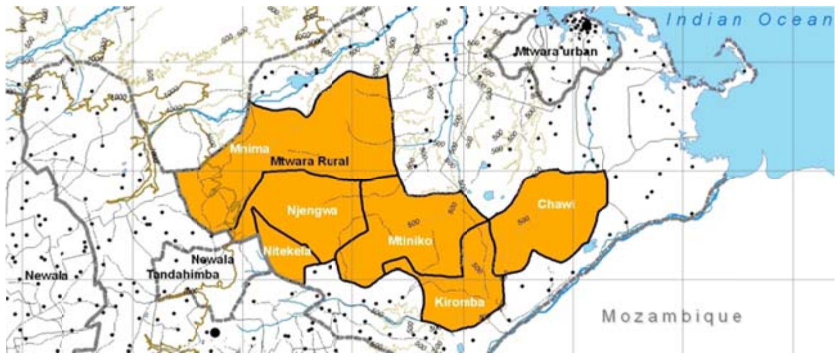


Figure 2.2
The 6 project wards located in the district Mtwara Rural.

The project wards are highlighted in figure 2.2 (original version in appendix 11). The names of the wards are Mnima, Njengwa, Nitekela, Mtiniko, Kiromba and Chawi. In table 2.1, the characteristics are shown (source of data: ArcGIS 9.2, Wards_Tanzania)

Table 2.1
Characteristics of the different project wards. The surface, population and density are shown.

Ward	Surface (km2)	Population	Density (population/km2)
Mnima	474.72	10573	22.29
Njengwa	223.33	8865	39.69
Nitekela	59.22	9223	155.74
Mtiniko	276.54	13009	47.04
Kiromba	162.22	8997	55.46
Chawi	236.1	6340	26.85
Total	**1432.13**	**57007**	**57.85** (average)

[1] Gleick, P,H. 1999. The human right to water. http://webworld.unesco.org/Water/wwap/pccp/cd/pdf/ educational_tools/course_modules/reference_documents/issues/ thehumanrighttowater.pdf

2.2 Geomorphology and hydrogeology

Geology determines soils. The soils of Mtwara Region consist almost entirely of red-earth soils. The Ruvuma river valley consists of alluvial soils with peat type humus soil. These are extremely fertile and easy to cultivate, even during the rainy season. Some black cotton type soils are dominant around the lakes near the Ruvuma River in the south part of the project area. At the top of the valleys, the soil is changing from a red earth into coarsely sandy soil. (Source: Regional Administration, Mtwara region, the socio-economic profile and investment potentials, 2010)

Geologically Mtwara region is divided in two parts. The eastern coastal part characterized by quaternary, tertiary sediments and Mesozoic cretaceous rocks and the western part with None-Marine Neocene Palaeozoic basement complex of highly metamorphosed rocks. As can be seen in the geological map, figure 2.3 (original version in appendix 11) the project area is mainly located in the formation Non-Marine Neocene. A small part of the northern part of the project area is positioned in a combination of Cretaceous and Alluvium & Quaternion formation. In the north east border there is a small area containing the formation Marine Neocene.

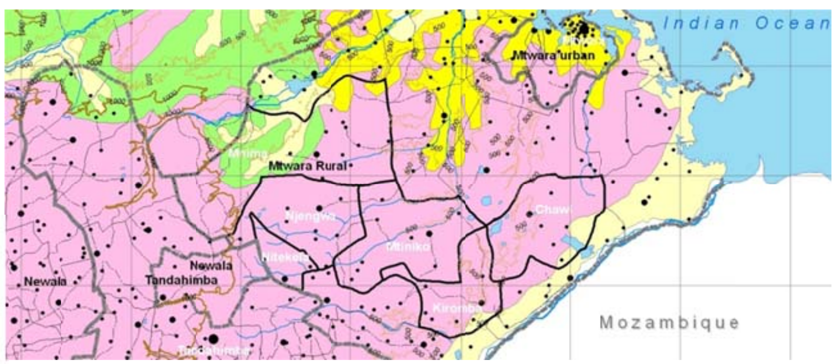


Figure 2.3
Geological map of Mtwara Rural. Generally the project area is located in the formation Non-Marine Neocene (pink colour).

2.3 Climate

General climate information is based on the program New_LocClim, a local climate estimator from FAO (http://www.fao.org). The data is based on 10 local stations that are located between 23 and 86km from the used coordinates.

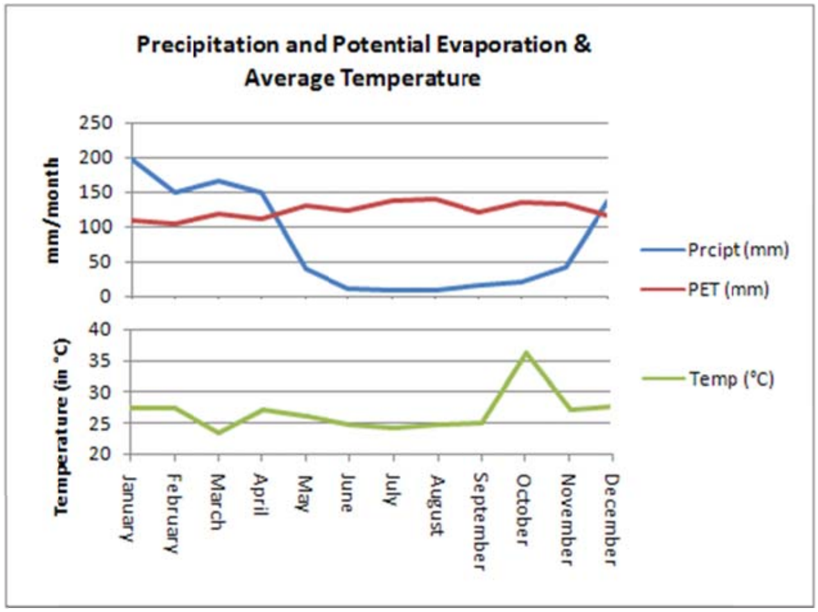


Figure 2.4
Graph of different meteorological characteristics. The precipitation consists out of a dry and wet period.

Prevailing winds are critical in determining climate for this region, which borders on the Indian Ocean. During the period November/December to April/May, the dominant winds are from the northeast. They bring a hot humid rainy season to the region, when they blow from southeast the region is dry, cooler and less humid. (Source: Planning Commission, Regional Commissioner's Office, 1997)

The rainy season of November/December to April/May is single peaked, the peak being reached in January but occasionally in February or March tends to vary with altitude. In Mtwara district rains vary from 935 mm to 1160 mm in the hills and the plateau area.

Likewise, temperatures vary from 35° as the highest monthly mean at Mtwara in October to 23° C in March.

2.4 Land use & Vegetation

The land use is based on the elevation. The project area exists out of valleys and plateaus varying between 50 to 200 metre above sea level.

The profile (picture 2.5) gives an overview of the land use. The villages are located on the plateau this is around 200 metres above sea level. By going down to the valley, on the hills, the land is used for cultivating tree crops. At some places, the valleys are used to cultivate rice, but contain mainly swamps and ponds. The swamps and ponds dry out slowly in the dry period.

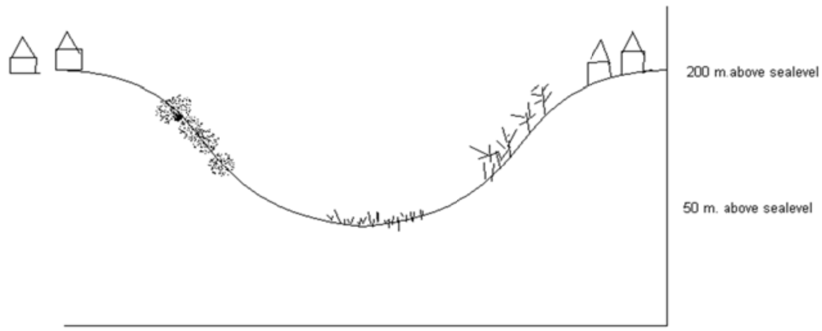


Figure 2.5
Profile of the region. The villages are on the plateau and the agriculture takes place on the slopes of the valley. The bottom of the valley is mainly swamp.

2.4.1 Agriculture

Land use in Mtwara, like the rest of Tanzania is predominately agricultural. The main occupation of the inhabitants of the region is farming. Major food crops produced in the region include cassava, sorghum, millet, and paddy and since ten years, maize has gained popularity. Various crops grown extensively as protein sources like pigeon peas, cowpeas, Bambara nuts and groundnuts. Mtwara is the leading cashew nut producer in the country. For this the majority of the households rely on agriculture (88%) (Source: AMREF Baseline survey Mtwara, 2008), apart from other rural activities like fishing, beekeeping and small-scale industries. Mtwara region has about 1,672,000 hectares of land out of which 85% is potentially arable. However, the actual utilized area for farming is estimated to be 27.3%, which is increasing by 7% every 10 years. The average farm size per rural household is estimated at 1.5 ha.

Farm mechanization is introduced slowly, the hand hoe is still the most common farming tool.

2.4.2 Mining

Prospects for the mining industry in the region are enormous, like the Mnazi Bay Natural Gas project, (MB-NG) which will be operating soon. (Source: Regional Administration, Mtwara region, the socio-economic profile and investment potentials, 2010)

2.4.3 Vegetation

The vegetation map (Figure 2.6, original version in appendix 11) shows that the project area is divided in five different vegetation types. The different types are mentioned in Table 2.2. Cultivation with tree crops is with 46% by far the highest percentage. Mainly cashew nut trees, those provide the people with income (cash crop). Woodland is the vegetation type for 25% of the area. The bushed grassland, 27% of the area is mainly used for cattle. The animal keeping is primarily based on goats, chickens and cows.

The ponds and small lakes comprise a total area of 10.3 km², what corresponds to 1% of the total surface of the project wards.

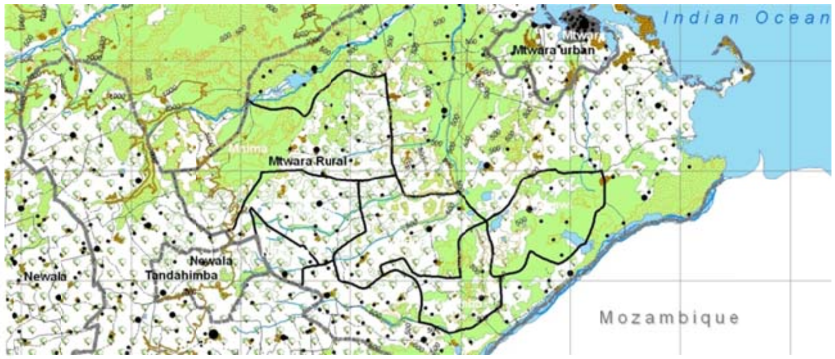


Figure 2.6
Vegetation map from Mtwara Rural. Cultivation with three crops is dominating the region

Table 2.2
The table shows the surface and the percentages of the different vegetation types in the project area.

Vegetation type	Surface (km2)	Percentage (%)
Bushed Grassland	391.2	27
Cultivation with Tree Crops	660.5	46
Inland Water	10.3	1
Woodland	351.7	25

2.4.4 Water catchments

Water catchments have different boundaries then the district boundaries. The boundaries of a watershed give information about the surface area, which is feeding the river basin. It is based on the elevation.

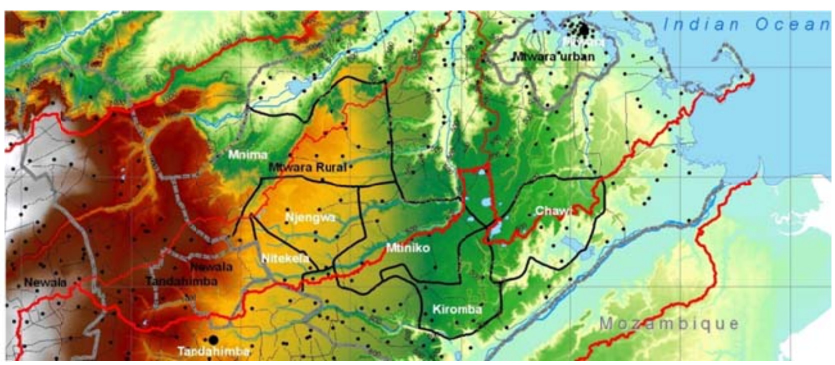


Figure 2.7
Water catchment map. The boundaries of the main and sub catchments are indicated by the red lines

With ArcGIS the boundaries of the watershed are lineated. In appendix 8 is given an overview of the necessary steps for lineation of the boundaries of the watersheds. In figure 2.7, the red lines are the boundaries of the different catchments. Stretched elevation of SRTM Satellite is projected as topographical background.

The project wards are located in four different water catchments. The watershed of the Ruvuma River is a major water catchment and the other shown watersheds are sub catchments. The Ruvuma River is the border with Mozambique.

The south part of the ward Mtiniko and the south part of Chawi and whole Kiromba are located in the water catchment that is flowing into the

Ruvuma River. The north part of Chawi is flowing to the small rivers that are flowing directly to the Indian Ocean in the north east of Mtwara region.

The north part of Mtiniko, Nitekela and almost whole Njengwa (except a small part in the north west) and the south east part of Mnima are flowing into the valley which is going north where it combines with the catchment of the north west of Mnima and the slice of Njengwa.

3 Methods

Different methods are used to get the findings as presented in the results. The methods used are discussed in the same order as the results are presented in chapter 4.

3.1 Actual ways for collecting water

The used methods for funding the results for the actual approach to collect water is done including, interviewees and field observations during field visits.

The interviewees find place after there is made an appointment with the representative person of each visited village. The representative person can be the village officer, the village chairman of the pump operator. If necessary, the representative person ask nearby villagers for help.

In this survey, the field observations are as well from importance to find out the actual ways for collecting water. The field observations are done by visiting the villages by car and visiting the local used water systems by walking.

3.2 Comparison of alternatives

A desk-study is conducted to obtain a comprehensive overview of possible alternative methods for the collection and the storage of rainwater. In this desk-study there is done a review of published literature on the subject covering local and foreign sources. By using the results (positive successes) of applied systems elsewhere in the world, it is possible to do evaluate the feasibility for this region.

The evaluation of the feasibility is done by analysing the alternatives to two aspects, namely ‘geomorphology and hydrogeology’ and the ‘Tanzanian water policy’. The evaluation is done together with the employees of AMREF.

3.3 Village meetings

In the village meetings the used methods are in detail presented in the strategy village meetings, appendix 5. The method of a village meeting is used to assess the possibility for alternative water collection methods within the study area and assess the demand of alternative water collection methods within the study area. The approach of the village meetings can be summarised as follow:

The first subject is to let the villagers think about any possible alternatives. It is a brainstorm activity whereby the villagers needs to mention any, according to them, suitable alternative.

Thereafter the suitable alternatives, based on the desk-study, are presented with the local villagers. In this presentation the alternatives are explained by making use of pictures and schematic overviews.

After summarize the mentioned alternatives by the villagers and the presented alternatives all alternatives are discussed once more towards the feasibility according the villagers.

3.4 Rainfall analysis

Methods which are used to analyse the precipitation data are mentioned as follow: the mean annual precipitation and the ranked annual precipitation gives insight in the average precipitation for the project area over the period of records. By ranking the annual precipitation the extreme highs and low annual precipitation are identified easily, as well as the ranger of average and average minus the standard deviation.

Thereafter the pattern analysis is done by analysing the variation of the annual precipitation around longer-term mean precipitation and the moving mean.

The variation of the annual precipitation around longer-term mean precipitation makes it possible to identity patterns of wet and dry years. The moving mean dampens the year-to-year fluctuations and the extreme values. This presents a smoother curve to show the general stream flow pattern.

With the rainfall analysis the different minimum annual repetition times needs to be calculated so they can be used as input for the performance calculations.

3.5 Constructing and drilling of boreholes

To find out the overview of the different elements in the system of constructing boreholes there has are executed interviewees with pump operators, AMREF employees. For receiving a comprehensive overview of the system, several field visits have find place to find out by personal field observations the exact elements in the system.

It is important to obtain a comprehensive overview of the different elements in the system to be able to decide the costs and to find out the probable bottlenecks.

3.6 Alternatives

Different methods are used for the calculations for analysing the alternatives. The following aspects will be used as method for analysing the different alternatives:

- Affordability

- Technical usability
- Sustainability
- Water quality
- Performance and cost analyse.

The last bullet, performance and cost analyse needs more explanation, for this the methods of the performance and cost analyse are discussed as well.

3.6.1 Performance and cost analyse

The calculations are done, by making use of the constructed models where different parameters are included. The underneath mentioned parameters are explained in detail in appendix 10, where the calculations of the models are discussed.

- Three different annual precipitation levels;
- Three different demand levels;
- Number of users
- Surface type of catchment area;
- Variation in size of storage facility;
- Efficiency of storage of water;
- Efficiency of fetching of water;
- Price for a of bucket of water

For analysing the performance of the different systems, different indicators are used. The different measurements provide information for different stakeholders who will be connected to the system. In the following paragraphs the performance of each indicator will be discussed.

Demand satisfaction

The demand satisfaction is measured in percentages by dividing the amount of water that is annual delivered to the water user and the annual demand of the water user.

This is the fraction of the annual demand that the system manages to deliver. In other words, it gives an answer to the question 'how well the water system performs'. The demand satisfaction is of special interest to the householder. (T.H. Thomas, D.B. Martinson, Roofwater harvesting).

By calculating the demand satisfaction, it is first needed to calculate the annual amount that is delivered. This is done by removing the annual overflow of the annual runoff (see formula 3.1).

The annual runoff will be that part of the amount of water that falls on the prepared surface and will be stored by the storage facility. Some of the precipitation will get lost by evaporation, infiltration or will be lost in the sand filter etc. The annual overflow is the amount of water that cannot be stored and will leave the storage facility through an escape or overflow structure. The storage facility can be a tank, reservoir, soil body etc.

Formula 3.1

The annual water that is delivered is calculated as follows:

$$Annual\ water\ Delivered\ (m^3) = Annual\ Runoff\ (m^3) - Annual\ Overflow\ (m^3)$$

By knowing the amount of water that is annually delivered into the water storage, it is possible to calculate demand satisfaction. This is done by dividing the annual amount of water that is delivered to the annual amount of water that will be used by the local households, the demand (formula 3.2).

Formula 3.2

$$Demand\ Satisfaction\ (\%) = \frac{Annual\ Water\ Delivered\ (m^3)}{Annual\ Water\ Demand\ (m^3)}$$

Efficiency

The efficiency is the fraction of the rainfall on the catchment area that can be used by the water user. It is the amount of water that is delivered to the water user in relation to the annual amount of water that is falling in the catchment area. The efficiency is of interest to the designer of the system. First the annual amount of water that is delivered is calculated by making use of formula 3.1 and the efficiency is thereafter calculated by using formula 3.3.

Formula 3.3

$$Efficiency\ (\%) = \frac{Annual\ water\ Delivered\ (m^3)}{Annual\ Catched\ Precipitaton\ (m^3)}$$

Reliability of supply

Another measurement for receiving an answer on the question ‘How well does the water system perform’ is by calculating the reliability of supply. The reliability of supply provides an overview in percentages as to how many days of a year the water storage facility runs dry. It is the percentages of days whereby the storage facility contains water.

Payback time

The payback time is an indicator tool to analyse the amount of time which is needed to payback the construction costs. This can be of interest to the funder. It is based on the cost price of water for a 20-liter bucket, the annual water demand of the water user(s) and the construction costs of the system. It is calculated in formula 3.4:

Formula 3.4

$$Annual\ Value\ of\ Water\ (TZS) = \frac{Costs\ water\ in\ bucket\ (20L)}{20} \times Annual\ Water\ Demand\ (L)$$

Knowing the annual value of water is it possible to calculate to payback time in months (see formula 3.5):

Formula 3.5

$$Payback\ time\ (in\ months) = \frac{Construction\ costs\ of\ system\ (TZS)}{Annual\ Value\ of\ Water\ (TZS)} \times 12\ months$$

Equivalent unit cost (for every water user)

By calculating the costs per litre for a storage tank it is possible to compare different storage. A more accurate way to compare the costs of different storage tanks is by making use of the equivalent unit cost. It scales down the particular system to the capacity of 1m³. It is calculated by dividing the costs of the water storage facility by the square root of the volume of the storage facility, as shown in formula 3.6. In other words it is the costs for every cubic metre.

Formula 3.6

$$Equivalent\ Unit\ Cost\ (TZS) = \frac{Construction\ costs\ of\ system\ (TZS)}{\sqrt{Volume\ of\ storage\ facility\ (m^3)}}$$

A small addition can be made to calculate as well the costs for each cubic metre/water user. This is done by dividing the equivalent unit cost by the number of water users that are using the system (formula 3.7).

Formula 3.7

$$Costs/wateruser/each\ cubic\ meter\ storage = \frac{Equivalent\ Unit\ Costs\ (TZS)}{Number\ of\ Water\ users}$$

Budget

By taking the depreciation of the different components into account and by adding the operation and maintenance it is useful to calculate the cost for each month to be able to operate and maintain the system. Based on a fluctuating usage of the systems where it is needed to pay for money the average use of monthly water consumed for the system is calculated (see appendix 13). Based on this number it is possible to calculate the costs of each cubic metre water which is consumed. When this amount is known it is also possible to compare it with the actual price of bucket (20-litres).

Because the water users pay for water there is an average monthly income and because of the depreciation of the components and the operation and maintenance of the system there are also monthly costs. By comparing the income and the costs there arise an insight if the system is profitable.

4 Results

In the results there will be presented all the results which are found by using the methods, explained in chapter 3. The following results are shown:

In paragraph 4.1 the actual used methods for collecting water is analysed to continue with the conclusions of the village meetings in chapter 4.2. The results of the rainfall analyses is given in chapter 4.3 where the construction and drilling of boreholes is discussed in chapter 4.4. In paragraph 4.5 the possible alternatives are introduced whereby theses are worked out in paragraph 4.6 till 4.8 to come up with an overview of the results in paragraph 4.9.

4.1 Actual ways for collecting water

Different methods are used for collecting water in the project area. The used methods are discussed in the following paragraphs.

4.1.1 Unprotected shallow wells

Due to the topographical position of the villages on the plateau, the shallow wells are all located on a distance of more than 500 metres, which is set as limit in the Tanzanian water act of 2005. In the dry season the time, spend on a round-trip for fetching of water from shallow wells takes 1 to 3 hours. Through the location of the shallow wells, at the bottom of the valleys, it is hardly possible to come there by bikes. The water quality varies. Some shallow wells are salty with a milky colour and some water is fresh, but with an iron colour. In figure 4.1 is shown an unprotected improved shallow well which contains water. However, most of the springs dry up in the middle of the dry season.

Figure 4.1
Unprotected shallow well in the valley nearby Maranje. The shallow well contains water year round.

4.1.2 Swamps in the base of the valleys

Downstream the water catchments in the wet season, there are ponds and swamps formed. Because of the stagnant water (see figure 4.2), the ponds and swamps are a breeding spot for mosquitoes. It is as well a place for fetching water. When the wet season comes to its end and the dry season is slowly entering, different swamps are running out of water. A few swamps contain water for a longer period water. There is a high pressure on these swamps and ponds. People of surrounding villages opt to go to these swamps, since the nearby located water source is dried up.

Figure 4.2
The swamps in the valley nearby the village Ngorongoro.

4.1.3 Ruvuma River

Villages nearby the Ruvuma River, like Ngorongoro and Bandariarusha, use the river (see figure 4.3) for washing, fishing as well as source for drinking water. (Per.Comm. Ismael A Mkoba, village executive officer, Bandariarusha) At the end of the dry season also villages which are located further away from the Ruvuma River come to fetch water at the River. For the villagers of Malamba, fetching of water at the Ruvuma water will cost 8 hours for a roundtrip. (Per.Comm. Twalib Faraji Chinanda, village executive officer, Malamba).

Figure 4.3
The floodplains of the Ruvuma River, nearby the village Bandariarusha)

4.1.4 Stored water in ground tanks in the villages

People who have the ability to purchase a hand dug reservoir can store water for a longer time. The availability of ground tanks is diverse among the villages. Some villages do not have any ground water tanks and other villages contain several ground tanks, especially Malamba which is located far from any other water source. The tanks that have been visited all have a depth of 2.4 metres (8ft). The diameter differs in a range of 3 to 5 metres (17-45 cubic metre). The streams that are formed by heavy rains are diverted toward the ground tank. Normally the small flow is making use of the unpaved walking pads on small slopes in the village. By leading those small flows to a subsurface reservoir, a catchment area is created.

The catchment area is unprotected, so contamination of the rainwater occurs, as well as losses by high infiltration into the sandy soil. The visited tanks were full of water and intensely used by villagers, even though contamination takes place and there are many losses in the catchment area (date observed: 06-05-2010)

They fetch the water by making use of a bucket on a rope. Normally no cover are constructed on the tank. Around the tanks a fence of wood is constructed to protect the children from falling into the reservoir.

Sporadically roof water harvesting takes place. A noteworthy example is shown in figure 4.4. The gutters are made of GI sheets or PVC and are established under a small slope towards the ground reservoir.

Figure 4.4
Reservoir in Malamba, where water from two roofs and from the surface are collected for filling the tank. A fence of wood is constructed to prevent falling in. A small door, in the front, give access to the water

4.1.5 Buying water from boreholes

In Bandariarusha and Maranje is still a working borehole, funded by the Japan International Cooperation Agency (JICA). The borehole in Bandariarusha is constructed in 2000 and the borehole in Maranje is constructed in 2002. The borehole in Maranje has, unlike other boreholes, not had any breakdowns till now.

In the wet season, the borehole is normally not functioning. The villagers harvest rainwater and fetch water of nearby unprotected shallow wells. In the dry season however, the villagers make use of the borehole and the water is even sold in the surrounding villages. Normally one cubic metre water cost €1,45. In figure 4.5 there is shown a drinking point.

Figure 4.5
Drinking points in Maranje. One tap is locked and one is unlocked.

4.1.6 Water from Roads

With the construction of new roads, drainage canals are made in the bank side of the road. The small drainage canals collect the precipitation to small ponds during rain. Here it is stored until it is used by cattle (namely goats), infiltrated or evaporated. By the staff of AMREF and on basis of personal observation it is not known whether the water is also used for human consumption.

In the dry season arises water scarcity. For the people who were able to store water can sell the water. For a bucket of 20 litres people pay from 200SH (€ 0,12) in the rainy season, for some villages (Malamba), up to 1000SH (€ 0,58) at the end of the dry season. The current value of water is 50SH (€ 0.03, March 2010). People who cannot afford this offer their labour for cultivating land in exchange for water. (Per.Comm. Nuran Issa Liyumba, pump operator, Malamba)

4.2 Comparison of alternatives

The desktop study is done according to a funnel-model. The scope started as broad as possible without excluding any alternative. After this the possibilities were filtered according to parameters (like topography, geology, rainfall) which are representative for the project area. Out of the new list, the technical staff of AMREF selects three alternatives, next to the actual method of drilling deep boreholes. Those three alternatives will be tested at the phase III villages of the project area. Three alternatives will be discussed in respect to:

- Affordability
- Technical usability
- Sustainability/durability
- Considerations

The not selected alternatives can be found in appendix 4. The selection is based on two criteria. The criteria of the methods are the geomorphology and hydrogeology of the area and the Tanzanian water policy, which prescribes are drinking point between 500 metres from each household.

The selected methods, meet the demand of the Tanzanian water policy. (The goal of the project of the AMREF boreholes is also reducing the distance for water fetching). The selected methods meet also the second criteria of the geomorphologic and hydro geologic characteristics of the area (as discussed in chapter 2.2)

Method	**Geomorphology and hydrogeology**	**Tanzanian water policy (<500 metres)**
Flooding technique with ditch pattern	Unsuitable	Unsuitable
Contour bending	Unsuitable	Suitable
Infiltration with percolation tank	Unsuitable	Unsuitable
Roof water harvesting	**Suitable**	**Suitable**
Recharge pit/shafts	Suitable	Unsuitable
Small earthen dam	Unsuitable	Unsuitable
Sand dam	Unsuitable	Unsuitable

Surface water harvesting for subsurface soil storage	**Suitable**	**Suitable**
Rock catchment	Unsuitable	Not applicable
Surface water harvesting with reservoir	**Suitable**	**Suitable**
Water pyramids	Suitable	Unsuitable

Table 4.1
Overview of possible alternatives, according to the desk study. On base of the criteria is made a selection of three suitable methods for this area.

4.3 Village meetings

Seven villages out of 13 of the third phase of the AMREF project have been visited. The strategy of the village meetings and minutes of each meeting can be found in appendix 7 & 8. The village consultation consists of questions whereby the villages need to think about the case when there is no water available. Which possibility do they know or, in their opinion, may be possible in this area. After that the possible alternatives are explained and the villages may give a reaction on the feasibility of the alternatives. The following general results came out of the discussions:

I. The people in the village are aware of the risks of fetching water at unprotected water sources.

II. All people give utmost priority to a reliable water supply nearby the villages.

III. For the possible alternatives (in comparison to the deep boreholes), a difference needs to be made according to the location of the villages. The villages that are located near the Ruvuma River are positioned in low-lying areas. All the other villages in the project phase are located at elevated areas, on the Ruvuma plateau.

The view of the villagers according to the village meetings on reliable water supply in the village are:

I. A reliable water supply with fetching point nearby the village (in each sub village one drinking point)

II. For creating an impervious layer for storage facilities only concrete is seen as possible.

III. For storage pots, with a maximum size of 100 litres, Masasi-clay may be suitable.

4.3.1 Possible alternatives according to villages

Low lying villages

One village is located in the low-lying areas nearby the Ruvuma River. The possible alternatives are:

- Protected shallow wells
- Rain water harvesting by
  - Roof water harvesting
  - Hard surface water harvesting

Elevated villages

The possible alternatives mentioned in the villages, which are located on the plateau, differ. The mentioned possibilities are less. Protected shallow wells are not suitable and trials of placing protected shallow wells (by Finnwater) have not been successful (Ngorongoro). Rainwater harvesting is seen as the suitable solution, but adequate storage is lacking. In one village (Maranje) the annual amount of rainfall is considered as not sufficient for being a reliable source of water for the whole village (the explanation of the rainfall analyses that the annual rainfall is sufficient for the whole village was ignored).

Furthermore, the villagers who are living on the plateau come up with possibilities to improve the water storage in the valleys. One of the possibilities is constructing a, so-called, Lambo (in some villages called Rambo). A basin of concrete is constructed in the bottom of the valley. Hereby it is possible to collect water from the surrounding hills. Locations of these Lambo are unknown.

The construction of protected shallow wells in the valley is mentioned as well. In Nachume there have been several attempts to dig a shallow well, but all the times the shallow well is collapsed by the recharge of groundwater. A protected shallow well made of concrete rings is seen as the solution.

4.3.2 Opinions about presented alternatives

All the alternative possibilities are seen as suitable and normally the people prefer both the deep borehole and the alternatives.

In Bandariarusha, the first priority is given to the borehole and then to alternatives. Maranje

(Owners of a working borehole) are putting question marks by the annual amount of rainfall and if this can be sufficient for providing water whole-year-round for all the villagers. Besides, their own water supply, they prefer another borehole, so they will have the possibility to sell more water to people from other villages.

During the dry period all the villages, except Marnaje, are facing problems with scarcity. Maranje is the only village with a working deep borehole.

This borehole is constructed by JICA in 2002. To tackle the water scarcity, rainwater harvesting is seen as an essential solution. Lack of storage is seen as a problem in Malamba and Nachume.

The alternative whereby rainwater is used and stored in the soil is receiving possible attention. The alternative is based hard surface water harvesting. The rainwater is lead to an infiltration field where it is stored. At a certain depth is placed an impervious layer to avoid leaking of the infiltrated rainwater. By making use of a drainage system it is possible to lead the water to a well.

Roof water harvesting is seen as a possibility for local households. However, this cannot be considered as a source of water for the whole village, as there are not sufficient households with galvanized iron sheets as roof.

An impression of the village meetings can be seen in figure 4.6, where 4 different village meetings are shown.

Figure 4.6
An overview of different village meetings. The strategy is as follows: listening to the demand and the possibilities proposed by the villagers. Explanation of the possible alternatives and a discussion about the possible alternatives.

The pictures shows the village meeting in Nachume (top-left), Malamba (top-right), Maranje (bottom-left) and Ngorongro (bottom-right)

In underneath table 4.2 is given an overview of the demands of the visited villages and the mentioned possible alternatives.

The table is divided by the villages, which are located in the low-lying areas and that are located at the elevated areas. In each village meeting has been a discussion about the demands of the villages and the possible alternatives according to the villagers.

The conclusion of the demands for a village is a reliable water supply as close as possible to the village. If possible, a drinking point in each sub village. The mentioned possible alternatives are all based on used systems in the region. Some of the possibilities are mentioned but no active or inactive system is known in the area. The *lambo*, for example, it is mentioned several times but the people spoken to, have never seen it.

Village	Demands	Mentioned possible alternatives
	Low lying villages	
Bandariarusha	Reliable water supply in each sub village.	Deep Borehole Shallow wells Big roof for surface water harvesting
	Elevated villages	
Maranje	Another borehole with drinking points in every sub village	-
Malamba	High need for water. Roundtrip in dry period is up to 8 hours per day per household.	There is a unique place for a '*lambo'* (8km of the village) Replacing of the broken submersible pump of the JICA borehole. Water harvesting (roof & surface)
Mtopwa	Clean water without iron	Shallow wells in the valleys.
Mkahara	Concrete rings to prevent collapsing their dug shallow well. Water supply before the drilled AMREF borehole.	Big tanks by big roofs, for rainwater harvesting
Ngorongoro	A reliable water supply nearby the village. The fetching time is in the dry period 4 hours for a roundtrip.	Construction of shallow wells in the valleys. Construction of *'lambos´* in the valleys Use of roof water harvesting Collect water from small streams nearby village during wet period.
Nachume	Storage facilities for collecting rainwater. Filtering of dirty surface water.	Improve unprotected shallow wells in the valleys. A *'lambo'*, which is constructed in the valley

Table 4.2
The table shows an overview of the visited villages with their demands and mentioned possible alternatives. A division is made with low-lying villages and elevated villages.

4.4 Rainfall analysis

Rainfall data is obtained from weather station Naliendele Agromet, prepared by S.B. Pallangyo. The data covers a period of more than 14 years, from January 1995 to March 2010. Naliendele Agromet is located in the project area and with a radius of 30 km it covers the whole project area. It is assumed that in this area the deviation of the precipitation data is insignificant and for that reason the data of this weather station is representative for the whole area.

In figure 4.7 is shown a comparison with the FAO data (see chapter 2.3). The FAO data shows the same patron of line, but gives some small differences in the months February and March. In those two months the precipitation is, respectively 36 and 46 mm less by comparing it with the precipitation of weather station Naliendele. The used precipitation data for the calculations in this study are based on the weather station Naliendele,

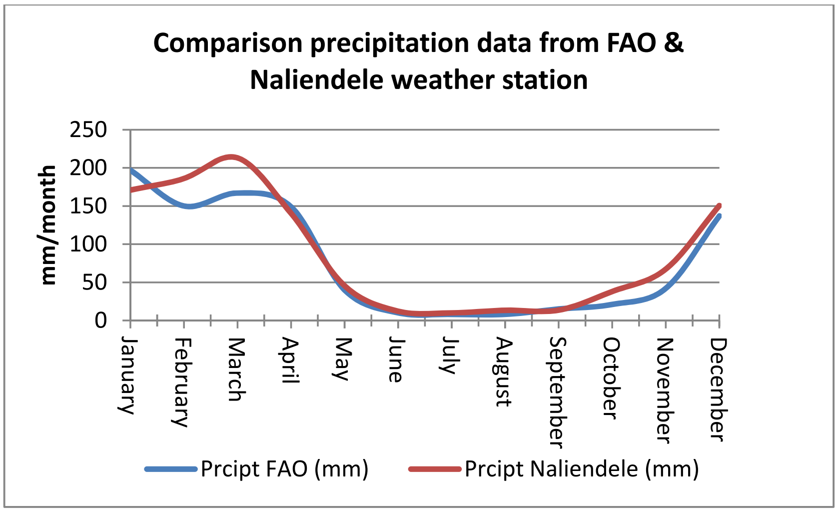


Figure 4.7
Graph with the comparison the precipitation of the FAO data (see chapter 2.3) with the data of the Naliendele weather station. In the months February and March the differences of the precipitation are, respectively 36 and 46 mm.

By ranking the annual precipitation and plotting the average within one standard deviation the annual precipitation that have occurred about 68% of the time, by a normal probability distribution. By calculating the probability of occurrence for each year, it is found that the lowest value between one standard deviation (the year 2007) is equivalent with a probability of 80%. This means that the annual precipitation of the year 2007 occurs in 8 out of 10 years and for this the repetition time is 1 in 5 years. For these reasons, priority is given to the precipitation of 2007 by the calculations in this study.

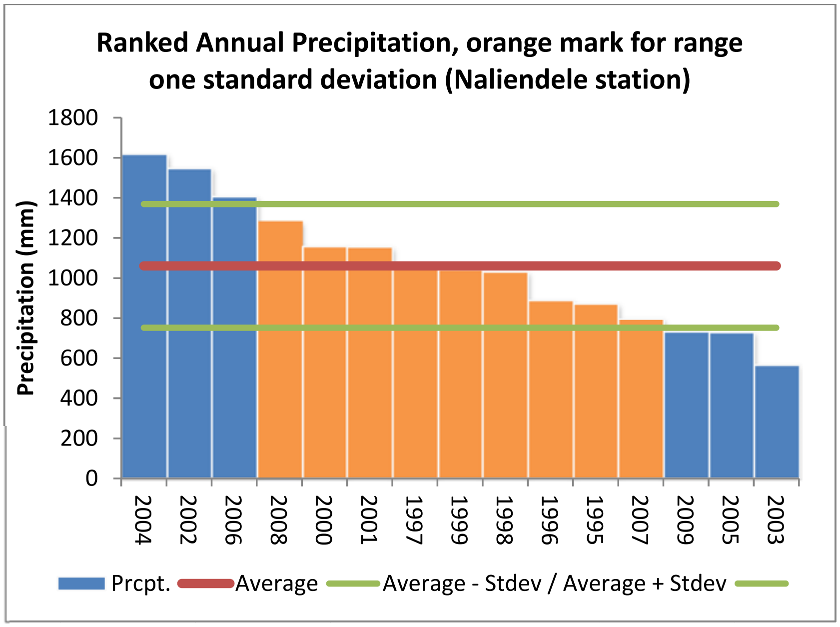


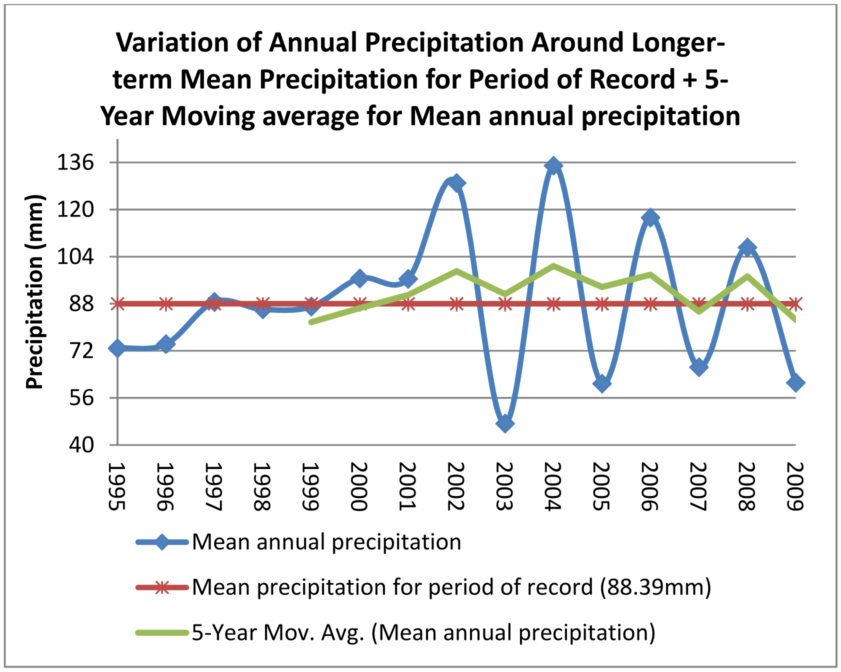
Figure 4.8
Graph of the distribution of the annual rainfall between 1997 and 2009. The red line is the average and the small green lines are the average minus standard deviation and average plus standard deviation.

In figure 4.8 is seen that the year 2007 is the year with the lowest precipitation that falls in the range of average minus one standard deviation. The probability for this year is 80%.

Mean annual precipitation is the average precipitation for the multi-year period of interest; it is obtained by dividing the sum of all monthly precipitation by the number of months a year. The annual precipitation differs from 567 mm in 2003 to 1619 mm in 2004. In figure 4.9 is seen that the mean annual precipitation is slowly increasing from 1995 to 2001. From 2002 to 2009 there arises a saw patron, with high and low peeks, decreasing by time.

By taking the 5-year moving average it is found that the average monthly precipitation remains between 80 and 100mm and that the high and low annual peeks are replaced by a smoother constant trend line.

Figure 4.9
Mean Annual Precipitation. In blue is plotted the average precipitation over the years 1995 to 2009. In red is plotted the average over the period of record and in green is plotted the 5-year moving average. The high and low peeks from the mean annual precipitation are faded in a smoother trend by visualising a 5-year moving average.



The annual variations are analysed, so the next focus will be on the monthly variations. In figure 4.10 the average monthly precipitation and the precipitation of 2007 is plotted. By taking a two year period the wet period comes up well in the period from September until May, whereby it is split if only one year is taken (on the left and right side of the graph).

By analysing the mean monthly precipitation, it is shown that there is one dry period and one wet period. The dry period starts in May and goes up to October, the wet period is from November to April. The top of the wet-period is in March followed by lower peeks in February and January. The top in March is around 213mm and in June, the precipitation is only 5mm. The overall precipitation for a year with reliability of 50% is 1063mm.

By analysing the precipitation of 2007 there are a few differences compared to the average. The dry period lasts one month longer and is from May until December. In the wet period, the precipitation is more concentrated in the months February and April. With a significant lower amount in precipitation in December and January, (less than 50% compared to the average). The overall precipitation for the year 2007 is 797mm. That is a difference of 266mm compared to the mean annual precipitation.

For different reasons the precipitation data of the year 2007 is taken as standard for further calculations in this study: The calculated repetition time of the minimum annual precipitation is 1 in 5 years. The rainfall intensity is not gradual over the whole year round, but 53% of the annual precipitation falls in two months (February and April). The storage facilities need to be dimensioned in a way that enough water can be stored to overcome seven months of dryness.

Characteristics for the year 2007:

- Repetition time is 1 in 5 years
- Dry period is 7 months
- Wet period is 5 months,
- Overall precipitation of 797.3mm
- 53% of the annual rain falls in two months, namely February and April.

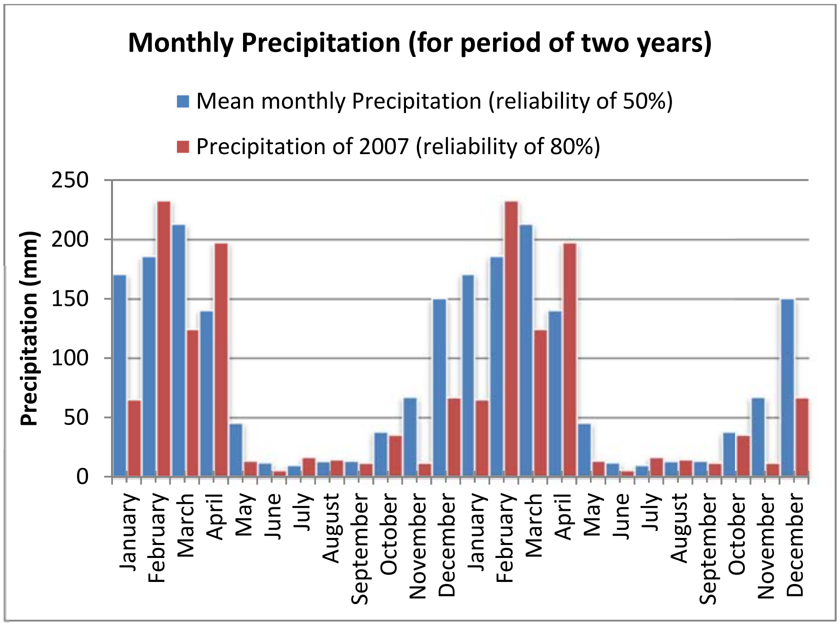


Figure 4.10
Two curves are plotted over a period of two years to visualize and obtain a better overview of the dry en wet period. The blue column signifies the mean monthly precipitation the red column shows the precipitation of the year 2007. The wet period for the mean monthly precipitation is smooth whereby the wet period of 1007 is concentrated on a few months

4.5 Constructing and drilling of boreholes

The actual approach is the drilling and construction of boreholes and water tanks. The water tanks have the capacity of 50 cubic metres. From the water tank the water is distributed to different drinking points. In figure 4.11 is shown an overview of the system

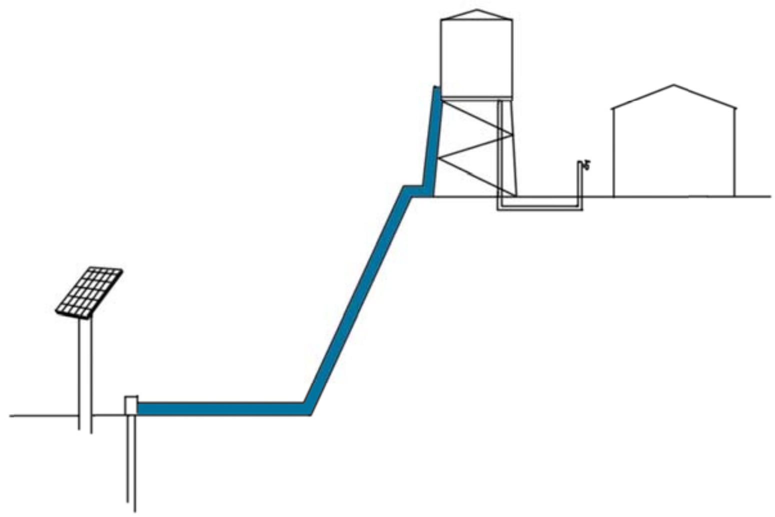


Figure 4.11
Overview of the system of boreholes. On the left side is the borehole with the solar panels. The water is pumped tot the elevated tank from where it is distributed to different drinking points.

If the system is well maintained the demand satisfaction, efficiency and the reliability of supply are 100%. The total costs of the different elements are shown in table 4.2.

Table 4.3
Description and costs of the different components for constructing a borehole.

Description of Components	Costs in Euro	*Costs in Shilling*
Water storage tank (50m³)	16.352,00	*28.158.144,00*
Distribution network	13.081,00	*22.525.482,00*
Construction of borehole	11.119,00	*19.146.918,00*
Pump house	5.000,00	*8.610.000,00*
Solar panels	30.000,00	*51.660.000,00*
Submersible pump	9.811,00	*16.894.542,00*
Total	**85.363,00**	***146.995.086,00***

In table 4.3 the costs of the different components are shown which can be seen in figure 4.11. The drilling and construction of a borehole cost €11.119. In the borehole is placed a submersible pump. This pump cost €9.881 and the energy is coming from the solar panels. Solar panels costs €30.000 and have a depreciation of 20 years. The water is pumped to the water tank of 50m³ and cost €16.352 from where it is distributed by to different drinking points. This distribution network cost €13.081, which include all the pipes and taps.

By taking into account the depreciation of each component and assuming that the labour price is included in the price of the investments the total cost/month is €442,11, table 4.3. Including the operation and maintenance the total cost for each month is €662.11.

Based on the average monthly cubic metre water consumed, the price per cubic metre water should be € 1.84. (total budget in appendix 13). At the moment the actual price for one cubic metre water is €1.45 (see chapter 4.1)

Calculation of costs per month and per m³ consumed	**Cost/month**	**Price per m³ (€)**
Investments (include labour costs)	442,11	1,23
Operation and Maintenance		
- Maintenance and repair	100,00	0,28
- Salary	120,00	0,33
Total	**662,11**	**1,84**

Table 4.4
Overview of the calculations of the monthly costs and the price for one cubic meter.

The total costs for each month are 662,11 and based on the average monthly consumption of water the monthly income for the system is 521,94. This means that there is a monthly loss of 140,17, as can be seen in table 4.5.

Monthly income (€)	521,94
Monthly costs (€)	662,11
Difference income and costs (€)	**- 140,17**

Table 4.5
Overview of the monthly income and costs. It can be seen that this alternative is not profitable.

4.6 Alternative 1. Surface water harvesting with subsurface storage

This method is based on a possibility found in a study for rain water harvesting in Sri Lanka. In this study, it is mentioned: “*A cheaper catchment surface can be made by laying a piece of plastic sheeting in a shallow excavated and levelled area*”.

The water storage capacity draining capacity of coarse sandy soil is 34%, this result in volumetric moisture storage of 340 Litres for every cubic metre. (Water Harvesting. A Guide for Planners and Project Managers / IRC. - The Hague, The Netherlands; IRC International Water and Sanitation Centre, 1992)

On the bases of field observations can be concluded that the soils around and in the villages are very sandy. On many places, there is totally no humus and on the places in the village where there is little agriculture, the depth of the layer of humus is only one to two decimetre. As a result, the precipitation will infiltrate quickly at the plateaus. Directly after a heavy downpour almost no water pools or ponds occur. However, the precipitation that drops at the hillsides will partly infiltrate and partly run off to the valleys. The top soil in the valleys contains more clay and makes them more suitable for agriculture. The valleys contain water for a longer period for two reasons:

I. Due to the hills around the valleys this result in a longer period of recharge by seepage of the infiltrated precipitation.
II. Clayish soil has a higher moisture supplying capacity, whereby it is possible to retain the groundwater for a longer period on a certain level.

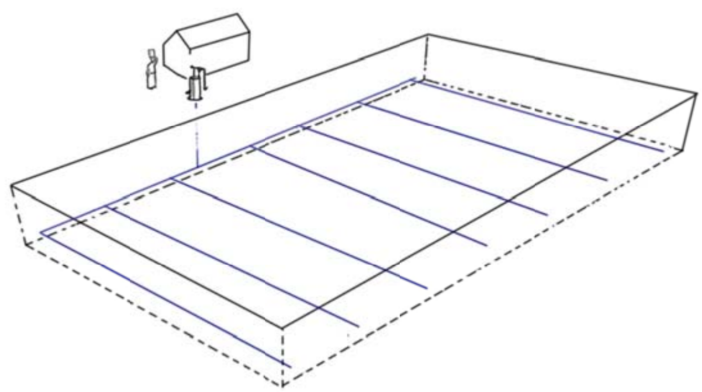


Figure 4.12
Schematic sketch of alternative 1. The water is stored in the soil and by making use of drains it is lead to a protected shallow well

Ponds and swamps are formed in the rainy season that can contain water for three to four months into the dry period.

The use of coarse sandy soil as storage facility has different advantages.

- Infiltration rate is high what results in a minimum loss to evaporation
- The soil is able to remove small contaminations because it act as a filter
- No mosquito breeding, by absence of stagnated surface water
- Process of mineralisation improves water quality

4.6.1 Affordability

Shown underneath are the elements for the costs. Point I and V are very time consuming. The costs of the placement of point II - IV can vary in price, based on the selection of material. The materials correspond to a related durability. The materials in this study are based on cost, availability and durability.

I. Movement of sand
II. Placement of the impermeable layer
III. Placement of drains
IV. Placement of fetching point
V. Replacement of sand

4.6.2 Technical usability

According to the list step II – IV can be seen as more difficult. Even though those steps do not require, high qualified staff and can be done with common sense and a basic level of understanding of plumbing. Local technicians can be very suitable to execute and supervise this work.

4.6.3 Sustainability

The subsurface storage method is making use of the sandy soils on the plateaus; it is very suitable due to the high infiltration rate and the low existence of humus. As well the central location, namely in the village, which is in line with the water policy of Tanzania that a drinking point needs to be between 500 metre of each household.

The materials that are used in this alternative are related to the choice of the impervious layer.

I. The durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack while maintaining the original properties and characteristics. The most potentially destructive weathering factor is freezing. In the project area this potential of destruction is not applicable. Normally if concrete is made in the right way the life time should reach up to 30 years.

II. By selecting EPDM rubber (Ethylene Propylene Diene Monomer), a synthetic rubber, the impermeability is guaranteed 25 years. The elasticity of EPDM sheet is 400%. The EPDM rubber sheet is environmental friendly and no chemicals of the sheet will pollute the environment by correct use (van Rhee, Geotop.nl)

III. LPDE Plastic (Low-Density Polyethylene) is a thermoplastic made from petroleum. LPDE Plastic has an excellent flexibility, but is vulnerable for cracks. The number of years without any problems can be 10 up to 15 years. Because LPDE plastic sheet is less elastic, the LPDE Plastic sheet is more sensitive for roots, but as mentioned before there is almost no presence of humus, so vegetation with strong roots are not problematic in this project area.

4.6.4 Water quality

The sandy soil of the infiltration field leads to a higher quality of water. By contact of rainwater with vegetation and geological formations the water becomes enriched with minerals. Precaution, don’t refill soil with high iron content. For exceeding plant growth maintenance is needed.

Preventing the water for pollution it is important that the infiltration field and the surrounding surface catchment will not come in contact with any faecal defecation. Hence it is necessary to build a good fence to keep out animals

4.6.5 Performance and cost analyse

The comparison is done by first analysing the performance indicators related to demand satisfaction, efficiency and reliability of supply. The next step is to compare the costs of the possible different materials of the systems with the other performance indicators, payback time, equivalent unit costs and the costs for water user for each cubic metre storage. The total costs of the system are also included.

Village population: 1918 (average 3rd phase villages)					*Village households: 383 (average 3rd phase villages)*								
Demand 15L/c/day					**Repetition time 1 in 2 years**			**Repetition time 1 in 5 years**			**Repetition time 1 in 10 years**		
Type of catchment	Size of storage / diameter(m)	N° of fields / surface roof(m^2)	Depth of storage (m) / volume (m^3)	Offset (m)	Demand satisfaction (%)	Efficiency (%)	Reliability of supply (%)	Demand satisfaction (%)	Efficiency (%)	Reliability of supply (%)	Demand satisfaction (%)	Efficiency (%)	Reliability of supply (%)
Subsurface soil storage	B.field	12	3	15	**120%**	**100%**	**100%**	90%	100%	84%	82%	100%	87%
		15	3	15	142%	95%	100%	**112%**	**100%**	**100%**	103%	100%	97%
		16	3	15	150%	94%	100%	120%	100%	100%	**110%**	**100%**	**100%**
	½ S. Field	3	2	25	**137%**	**97%**	**100%**	107%	100%	100%	98%	100%	93%
		4	2	25	171%	91%	100%	**137%**	**97%**	**100%**	**127%**	**97%**	**100%**
		4	2.5	25	189%	100%	100%	*142%*	*100%*	*100%*	*130%*	*100%*	*100%*
	S.field	2	1	25	**126%**	**77%**	**100%**	98%	80%	93%	88%	79%	90%
		2	1.5	25	144%	89%	100%	**116%**	**95%**	**100%**	**107%**	**95%**	**100%**
		2	2	25	*163%*	*100%*	*100%*	*122%*	*100%*	*100%*	*112%*	*100%*	*100%*

Table 4.6
The results of the performance indicators of alternative I, subsurface soil storage. The example is discussing the green cells and the blue cells are the results, based on the best performing dimensions

First an example on how to read table 4.6:

In the top is mentioned for how many water users the system is applicable. In this case, the subsurface ground catchment (seen on the row which is marked with the colour green) is applicable for a village population of 1918. This is the average population of the village of the 3rd phase in the project. The number of households is related to the population and for that 383 (each household exists out of 5 persons).
The demand is based on the baseline survey done prior to the execution of the project. The different repetition times are the amount of annual

rainfall. There are three different repetition times, 1 in 2 years, 1 in 5 years and 1 in 10 years. Based on the rainfall analyses it is decided that the system will be based on a repetition time of 1 in 5 years.

In the next row are the headers of the characteristics of the system and the first three performance indicators. The characteristics are as follow:

- type of catchment;
- size of storage / diameter (m)
- number of fields / surface roof (m²)
- depth of storage (m) / volume (m3)
- offset width (m)

By analysing the green cells, as an example, it is possible to understand the model to find the best system dimensions.

The type of the catchment is a surface catchment with ground storage. The size of the surface for the storage facility is set as the surface of a soccer field, this correspond to the size of 100m by 60m. The number of fields will be 2 and the depth of the field will be 1 metre. Around the surface of the field is 15 metre available to increase the catchment area. Summary: to cover the demand in an average village two infiltration fields with the size of a soccer field are needed. The infiltration fields will have a depth of 1 metre and the offset width around the infiltration fields is 15 metre.

The performance indicators give different values for the different annual rainfall. By taking a look at the results of an annual rainfall with a repetition time of once in two years the demand satisfaction is 126%. That means that annually more water is delivered than the water users were able to use. As explained, water that is delivered to the water users is the collected precipitation minus the overflow of the storage facility. By taking the performance of the whole year there has been more water in the storage facility than the water users annually need.

The efficiency is 77%, which means that not all the water that is collected by the catchment area was able to store in the storage facility; it means that there is overflow. Figure 4.4 shows that the storage facility was full of water from January to March. In these three months, there is overflow. Overflow leads to inefficiency. From April the storage is slowly declining.

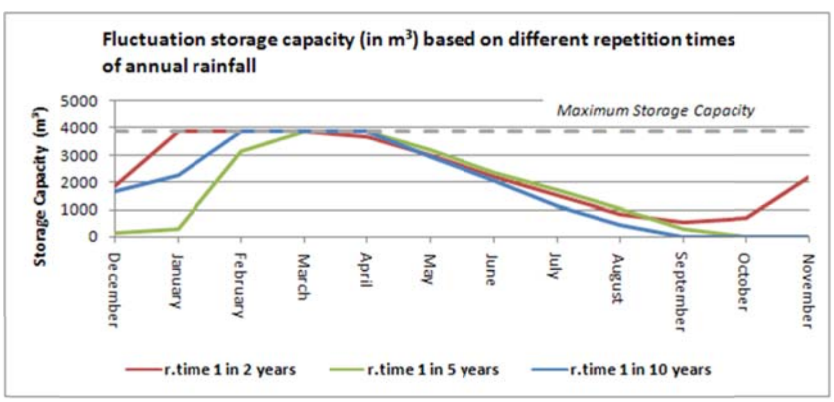


Figure 4.13
Graph of the fluctuation storage by different annual rainfall

The reliability of supply is 100%. That means that there were no days without water. All the days of the year, the storage facility is containing water.

By analysing the same performance indicators by a repetition time of once in five years the demand satisfaction is 98%, the efficiency is 80% and the reliability of supply is 93%. The efficiency is increasing because the overflow is declining; the reliability of supply and the demand satisfaction are becoming under the 100%. This means that there is insufficient water in the storage facility by an annual rainfall with a repetition time of 1 in 5 years.

It is even becoming worse in case of an annual rainfall with a repetition time of 1 in 10 years. The demand satisfaction and the reliability of supply are declining to representative 88% and 90%; the efficiency is decreasing with 1% to 79%.

Analysing the results with a repetition time of 1 in 5 years three different dimensions are considered,

- surface of a basketball field (28 metre by 15 metre)
- surface of half a soccer field (60 metre by 50 metre)
- surface of a soccer field (100 by 60 metre)

For each of the different surfaces, different dimensions have been analysed and the best results with realistic assumptions are placed in bold and have blue shading.

An average village has a population of 1918 people. By selecting the size of a basketball field as surface of the infiltration fields, 15 infiltration fields are needed. These infiltration fields' needs to have a depth of 3 metres and the offset width (catchment area) around the infiltration field should be at least 15 metre. The offset is needed to increase the size of the catchment area. With those dimensions, the system delivers a reliable supply of water, without overflow and whereby more water is collected than the demand. The demand for the average village is based on 15 litres per capita per day.

A reliable supply of water is also possible when the infiltration field has the size of half a soccer field. In this case, four fields needs to be dug, with a depth of 2 metres. There is a slightly overflow of 3%. By digging an infiltration field with the dimensions of a soccer field, a depth of 1.5 metres is needed. The reliability of supply is 100%, but 5% of the annual precipitation will overflow.

In figure 4.14, the fluctuations of the selected (in bold/blue, table) dimensions with the best results are shown. The results of the dimensions of a basketball field are similar to the results of the dimensions of a soccer field. By selecting, an infiltration field with the dimension of half soccer field the results shows a higher storage capacity.

The main reason why the infiltration field with the dimension of a 1/2 soccer field has a higher storage capacity is a bigger catchment area. In the wet season more rainwater is collected and stored in the storage facility. The storage capacity is bigger, what result in a higher level of water in the storage facility in the end of the dry season (November)

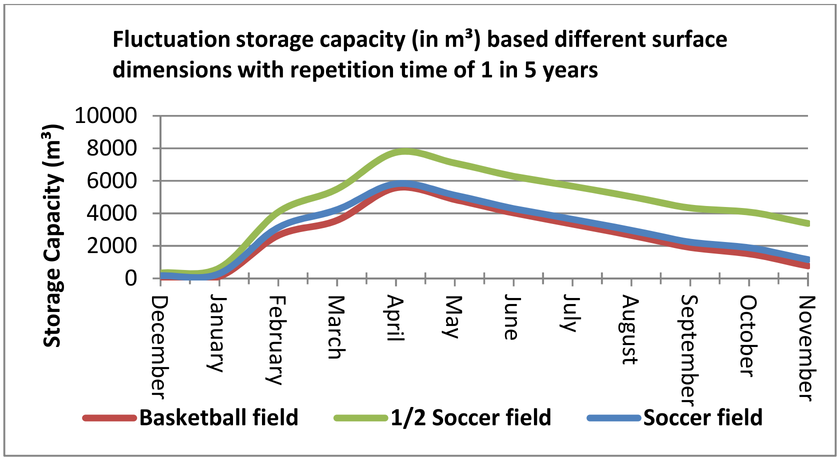


Figure 4.14
Graph of the fluctuation storage by different dimensions of the infiltration field. The repetition time of the annual rainfall is 1 in 5 years.

The next step is analysing the results of the performance indicators that are related to costs.

In the last example is discussed the dimension of a soccer field with an offset width of 30 metres. The number of infiltration fields is two and the depth is two metres. There is a choice of three different possible materials to construct an impervious layer. The three different materials are concrete, LPDE plastic sheet and EPDM rubber sheet. As discussed in the explanation of the method (see chapter 4.2.3) the different materials have different advantages and disadvantages.

By taking concrete as an example, the different results from the performance indicators are as follows:

The payback time is 43 months. This means that the money that is earned based on the annual water demand in 3 years and 6 months will be enough to pay back the construction costs. The total costs are almost € 55,000 - and the cost/m³/water user will be € 0,46.

By looking to the bold/blue cells in table 4.7 it can be conclude that the infiltration field with the surface of a soccer field has the cheapest construction costs (orange cell). By a depth of 1.5 metres the construction costs will be € 26,277.The payback time is 20 months and the construction cost for one cubic metre will be € 344. That means that the costs for 1m³ for each water user is € 0,18.

By increasing the depth with 0.5 metre to 2.0 metres, the efficiency is increased to 100% (see table 4.6), what means that there is no overflow. The total construction costs will increase with 5.8% to € 33,975.

Village population: 1918 (average 3rd phase villages)																
Demand 15L/c/day					Concrete				LPDE Plastic sheet				EPDM Rubber sheet			
Type of catchment	Size of storage/diameter	N° of fields/surface roof	Depth of storage/volume	Offset	Payback time (months)	Cost/1m3 (€)	Cost 1m3/water user (€)	Total costs (€)	Payback time (months)	Cost/1m3 (€)	Cost 1m3/water user (€)	Total costs (€)	Payback time (months)	Cost/1m3 (€)	Cost 1m3/water user (€)	Total costs (€)
Subsurface soil storage	B.field	12	3	25	41	762	0.40	53304	23	428	0.22	29933	28	522	0.27	36525
		15	3	25	52	852	0.44	66550	**29**	**478**	**0.25**	**37336**	35	583	0.30	45576
		16	3	25	55	879	0.46	70968	31	493	0.26	39806	38	602	0.31	48595
	½ S. Field	3	2	25	44	737	0.38	56262	20	349	0.18	26617	27	458	0.24	34978
		4	2	25	58	849	0.44	74800	**27**	**400**	**0.21**	**35273**	38	527	0.27	46422
		4	2.5	25	65	851	0.44	83830	33	437	0.23	43039	42	554	0.29	54544
	S.field	2	1	25	43	881	0.46	54889	14	298	0.16	18579	22	462	0.24	28820
		2	1.5	25	49	832	0.43	63506	**20**	**344**	**0.18**	**26277**	28	482	0.25	36778
		2	2	25	56	819	0.43	72123	26	385	0.20	33975	35	508	0.26	44734

Table 4.7
The performance indicators of the different materials towards the costs. It is linked with table 4.6. On base of table 4.6 the dimensions of the system are selected. Based on those dimensions the costs of the system with different materials are analyzed.
In green is first explained an example. In blue are selected the best options for the different dimensions of the infiltration fields. In orange is highlighted the best option

Now there is insight in the investment costs of the different components for the dimensions with the best performance it is important to look to budget whereby the depreciation of the different elements are taken into account, as well as the operation and maintenance. The overview of the budget can be found in appendix 13.

Table 4.8 shows an overview of the monthly costs and the price of water consumed per cubic metre. The total costs for each month is 349,14. This is included labour costs, investments and the operation and maintenance. The price per cubic metre water consumed is €0,97. In this price the labour costs are accountable for the highest part with €0,35.

Calculation of costs per month and per m³ consumed	Cost/month	Price per m³ (€)
Labour costs	125,13	0,35
Investments	86,63	0,23
Operation and Maintenance		
- Maintenance and repair	20,00	0,06
- Salary	120,00	0,33
Total	**349,14**	**0,97**

Table 4.8
Overview of the costs per month and the costs for each cubic metre water consumed

The monthly costs are 349,14 and the monthly income is 521.94. The monthly income is based on the average monthly consumption. The price for one cubic metre of water is set as the same as the actual price of €1.45.

As can be seen in table 4.9, the difference in income and costs is €172,80. This means that the system with surface water harvesting with subsurface soil storage is profitable.

Table 4.9
Presented is the difference of the income and the costs. By making use of this alternative the system will be profitable.

Monthly income (€)	521,94
Monthly costs (€)	349,14
Difference income and costs (€)	**172,80**

4.7 Alternative 2. Surface water harvesting

This alternative is based on ground surface catchments, which are used for collecting rainwater run-off. Part of the rainfall will be lost as it serves to wet the ground, is stored in depressions, or disappears through evaporation. The losses can be reduced by constructing laying tiles, concrete, asphalt, or plastic sheeting to form a smooth impervious surface on the ground. Sometimes simply compacting of the surface is adequate. The amount of rainwater that can be collected in a ground catchment depends on whether the catchment is flat or sloping, and on the infiltration capacity of the top layer. (J. Mbugua, Rainwater harvesting)

By preparation of the ground surface, a sufficiently rapid flow of the water to the point of collection and storage can be assured in order to reduce evaporation and infiltration losses. The portion of rainfall that is harvested ranges from about 10% for a pervious, flat ground catchment, to some 90% for a sloping strip catchment covered with impervious materials. In figure 4.15 is shown a schematic overview of the method

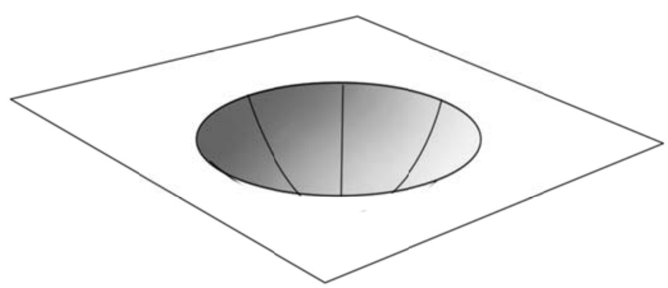


Figure 4.15
Schematic sketch of alternative 2. The water is lead by the surface catchment to the subsurface reservoir

4.7.1 Affordability

The biggest investment is the subsurface reservoir. The subsurface reservoir should have a volume that is enough to collect a sufficient amount of water to overcome the seven month dry period. The catchment area should be big enough to catch a sufficient amount of rainwater. An investment in an impermeable pavement can be needed to increase the potential of the catchment area.

4.7.2 Technical usability

The difficulty in technical usability is not very high; this can be concluded as well by the fact that several local households were able to construct similar systems. A pickaxe and a shovel is needed for digging the subsurface reservoir, some strong men are needed to do this work.

4.7.3 Sustainability

The sustainability depends on the maintenance. By proper maintenance, it is possible to bring down the losses due to infiltration or water that is flowing away from the storage tank. The risk of contamination is increasing due the fact that the water is flowing on areas that might be used for other purposes as well. For increasing the sustainability, it is recommended to install a fence around the catchment area.

4.7.4 Water quality

Considering the water quality it might be necessary to install a sand filter before the water is entering the subsurface reservoir. A fence around the catchment area is also needed to prevent people and animals to enter the catchment area. By a possibility to enter the catchment area the risk of contamination increases.

4.7.5 Performance and cost analyse

The surface ground catchment is a solution on small scale. The different options that have been analysed are based on different number of households. The different options are:

- 1 subsurface reservoir with surface catchment for 1 household
- 1 subsurface reservoir with surface catchment for 2 households
- 1 subsurface reservoir with surface catchment for 10 households (a so called 10-cell)

The performance of each of this selection has been weighted to the different repetitions times. The results can be seen in table 4.10. For one tank for each household the tank needs to have a diameter of 3 metre and the depth of the storage needs to be 2.5 metres by an offset of 3 metres. With these dimensions, the performance indicators by a repetition time of 1 in 5 years are as follows:

The demand satisfaction is reaching 122%, the efficiency is 99% and the reliability of supply is 100%. The efficiency of 99% suggest that there is a little overflow and the demand satisfaction of 122% means that there is annually more water collected then the annual water demand.

For one subsurface reservoir for two households the best results are shown when the dimension of the offset is increased to 5 metre and diameter of the tank is enlarged to 5 metres. The depth of the tank will stay the same, 2.5 metres.

The demand satisfaction is 122% and the efficiency and the reliability of supply are 100%. There is no spilling of water by overflow.

When the decision is made that every ten households should need to have one subsurface reservoir, the catchment area around the tanks needs a radius of 30 metres and the diameter of the tank needs to be 8 metres and the depth is increased to 3 metres.

By selecting those dimensions the results of the performance indicators are 112% for the demand satisfaction, the efficiency will be 98% and the reliability of supply is 100%. The efficiency is 98% so not all the water that is collected will be released for fetching but some is spilled.

If there is an annual rainfall (dry year) that occurs once in ten years the reliability of supply is decreasing to 97%, what means that in 3% (11 days) of the year there will not be sufficient water. By increasing the diameter to 9 metre, the system will be suitable for a one in ten-year rainfall situation.

By comparing the fluctuation storage in figure 4.16 it shows the difference in storage capacity. The storage capacity that is needed for a 10-cell is many times larger than the storage capacity that is needed for a tank that is used for two households. The storage fluctuation of the tank for two households has a higher peak in April compared to the tank that is needed for singe household. Because the water use of the tank for two households is higher, the storage is also decreasing faster. Based on the calculations it is shown that at the end of the dry period the capacity of the tank for a single household is higher compared to the capacity of the tank for two households. Because of the higher demand of a double household is the slope of the fluctuation graph steeper.

Table 4.10
The performance indicators of the different materials towards the costs. It is linked with table 4.2. On base of table 4.2 the dimensions of the system are selected. Based on those dimensions the costs of the system with different materials are analysed.

Village population: 1918 (average 3rd phase villages)								*Village households: 383 (average 3rd phase villages)*						
Demand 15L/c/day					**Repetition time 1 in 2 years**			**Repetition time 1 in 5 years**			**Repetition time 1 in 10 years**			
Type of catchment	Size of storage/diameter	N° of fields/surface roof	Depth of storage/volume	Offset	Demand satisfaction	Efficiency	Reliability of supply	Demand satisfaction	Efficiency	Reliability of supply	Demand satisfaction	Efficiency	Reliability of supply	
Surface ground catchment	2	1 H.hold 1	2.5	3	108%	78%	93%	85%	81%	84%	78%	81%	87%	
	3		2.5	3	**151%**	**92%**	**100%**	**122%**	**99%**	**100%**	**113%**	**100%**	**100%**	
	4		2.5	3	199%	100%	100%	150%	100%	100%	137%	100%	100%	
	3	2 H.holds 1	2.5	5	106%	87%	**90%**	85%	92%	84%	80%	98%	87%	
	4		2.5	5	***136%***	***97%***	***100%***	105%	100%	93%	96%	100%	93%	
	5		2.5	5	162%	100%	100%	**122%**	**100%**	**100%**	**111%**	**100%**	**100%**	
	7	10 H.holds 1	3	30	**123%**	**85%**	**100%**	99%	91%	97%	91%	92%	90%	
	8		3	30	137%	91%	100%	**112%**	**98%**	**100%**	103%	99%	97%	
	9		3	30	154%	96%	100%	120%	100%	100%	**110%**	**100%**	**100%**	

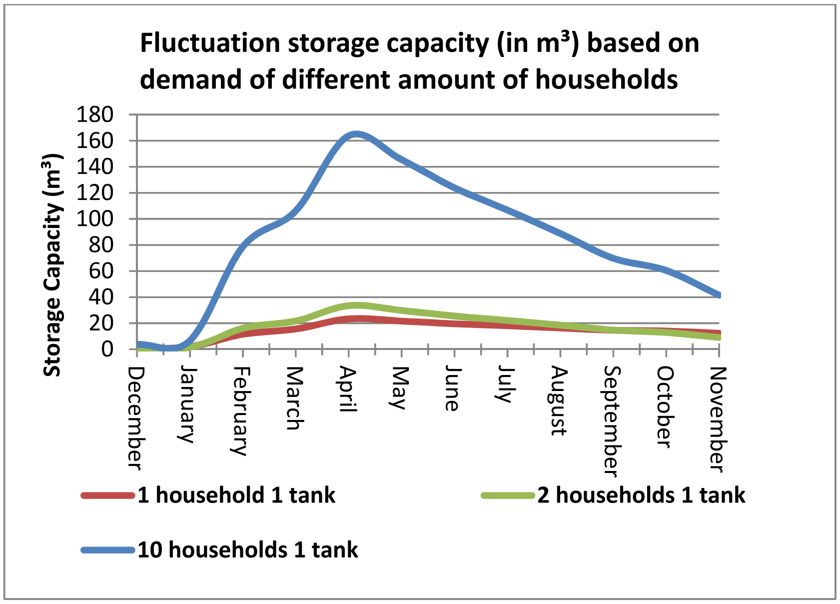


Figure 4.16
The fluctuation storage of the storage capacity, which is based on different number of households.

By analysing the next step we include the costs with the performance indicators we see the following remarkable characteristics as shown in table 4.11.

The total costs for 1 subsurface reservoir for a single household will costs more when it is decided to use the material ferro-cement instead of LPDE plastic sheet. EPDM rubber sheet is 28 dollar more expensive than LPDE plastic sheet. EPDM rubber sheet has a lifeline longer than 25 years while LPDE plastic sheet needs to be replaced after 10 years.

By comparing the performance indicators of costs with the best results from the performance indicators of usage (the bold and blue cells) the differences are as follows:

The construction costs (with LPDE plastic) are respectively for one storage facility for a single household, one storage facility for every two households and for one storage facility for each 10-cell € 725,- € 880,- and € 1328,-. Because all the different systems have a different storage volume and different amount of water users it is hard to compare. By calculating the equivalent unit cost, *the cost for each cubic*, metre the results are as follow: € 197,- for 'one tank single household', € 144,- for 1 tank 2 households and € 124,- for 'one tank ten households'. The costs for 1m³ are the cheapest by constructing a tank for single household and the most expensive for a 10-cell. By comparing as well the number of water users with the equivalent unit costs, the tank for ten households is by far the lowest, with € 2,50 compared to € 39,00 and € 14,00 for the tanks for a single household and for two households. The payback time is as well the lowest for the tank for 10 households. The payback time will be 40 months instead of 218 or 132 months for the other two possibilities.

When the choice will be made on the 10-cell option and it will be used for an average village the total number of subsurface reservoirs, with a surface catchment, will be 38 pieces. The total costs will be € 25,346 to provide the total population of average village sufficient water, year round.

Demand 15/L/c/day					Ferro-Cement				LPDE Plastic sheet				EPDM Rubber sheet			
Type of catchment	Size of storage/diameter	N° of storage/volume	Depth of storage/volume	Offset	Payback time (months)	Cost/1m³(€)	Cost 1m³/water user (€)	Total costs (€)	Payback time (months)	Cost/1m³(€)	Cost 1m³/water user (€)	Total costs (€)	Payback time (months)	Cost/1m³(€)	Cost 1m³/water user (€)	Total costs (€)
Surface ground catchment	2	1 H.hold 1	2.5	6	227	308	61	753	206	280	56	684	212	288	57	703
	3		2.5	6	248	224	44	822	218	197	39	725	227	205	41	752
	4		2.5	6	277	188	37	918	235	159	31	780	247	167	33	819
	3	2. H.holds 1	2.5	10	120	218	21	801	114	206	20	755	118	231	21	782
	4		2.5	10	132	179	18	875	122	165	16	810	128	173	17	849
	5		2.5	10	146	158	15	970	132	144	14	880	141	152	15	934
	7	10 H.holds 1	3	25	41	147	3	1384	36	128	2.6	1206	39	140	2.8	1312
	8		3	25	46	145	2.9	1552	40	124	2.5	1328	44	136	2.7	1462
	9		3	25	52	144	2.9	1743	44	121	2.4	1466	49	135	2.7	1631

Table 4.11
This table is the continuations of table 4.10. In table 4.10 the performance indicators towards reliability of supply, efficiency and demand satisfaction are analysed. The best dimensions are found an in this table the comparative indicators towards costs are analysed. In blue the best performing materials are highlighted. In orange the best overall performance is indicated.

Now there is insight in the investment costs of the different components for the dimensions with the best performance it is important to look to budget whereby the depreciation of the different elements are taken into account, as well as the operation and maintenance. The overview of the budget can be found in appendix 4.13.

With the depreciation the labour costs will be €91,33 monthly and the investments €267,12 (table 4.12). For the operation and maintenance the total monthly costs are €170,00. In total the total monthly costs are €528.45. This means that the price per cubic metre is €1.47, whereby the investments of the components in the system are the biggest part of the price per cubic water consumed.

Table 4.12
Overview of the costs per month and the costs for each cubic metre water consumed. The price for one cubic metre water is 1.47. Two cents more expensive than the actual marked price of water.

Calculation of costs per month and per m³ consumed	**Cost/month (€)**	**Price per m³ (€)**
Labour costs	91,33	0,25
Investments	267,12	0,74
Operation and Maintenance		
- Maintenance and repair	50,00	0,14
- Salary	120,00	0,33
Total	**528,45**	**1,47**

The monthly costs is 528,45 and the monthly income is 521.94. The monthly income is based on the average monthly consumption. The price for one cubic metre of water is set as the same as the actual price of €1.45.

As can be seen in table 4.13, the difference in income and costs is €6,51 negative. This means that the system with surface water harvesting with subsurface reservoir storage is not profitable. The monthly loss of money is insignificant and the monthly income and costs are almost even.

Table 4.13
Presented is the difference of the income and the costs. By making use of this alternative the system is almost turning even, a monthly loss of €6.51 takes place

Monthly income (€)	521,94
Monthly costs (€)	528,45
Difference income and costs (€)	**- 6,51**

4.8 Alternative 3. Roof water harvesting

Rain falls onto hard surface roofs and then runs off. The run-off is extremely variable (for the typically 99% of each year that it is not raining, and so the roof run-off is zero). However if the run-off is channelled into a tank, water can be drawn from that reservoir whenever it is needed. Moreover, as the tank is generally located immediately next to the house, here is no need for the water to be carried or piped from elsewhere. (T.H. Thomas, D.B. Martinson, Roof water harvesting)

The essential elements of a roof water harvesting system, as shown in figure 4.17, are a suitable hard surface roof, a water reservoir and a means of leading run-off flow.

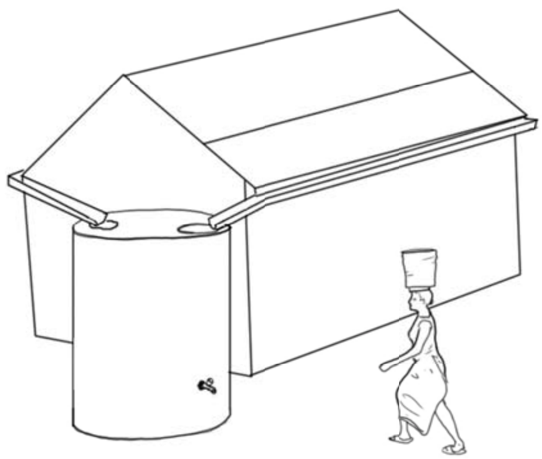


Figure 4.17
Schematic sketch of alternative 3. The water is lead from the roof to the gutters and stored in a storage facility

4.8.1 Affordability

To be 'suitable' the roof should be made of some hard material that does not absorb the rain or pollute the run-off. Thus, tiles, metal sheets and most plastics are suitable, while grass and palm-leaf roofs are generally not suitable, as they produce less runoff.

If there are no hard materials present as roof surface for the house, the household needs to consider investing in it. The investment can be too high (TSH 6500/m² = € 3.77/m²).

A roof water harvesting system will perform better with a large water reservoir then a small water reservoir. A small reservoir will overflow often in the wet season. However, a small store is cheaper than a larger one.

The size of the tank is based on the annual rainfall and the demand of the water user. Out of the rainfall analyses, it is concluded that the amount of annual rain with a repetition time of 1 in 5 years contains 7 dry months. To overcome a dry period of 7 months a large water storage facility is needed. For roof water harvesting system the water tank is the most expensive part.

The gutters are normally made of PVC pipes or parts of GI sheets. The materials and the quantities of the materials of the tank are based on the Bill of Quantities as written in ‘Technical handbook – water from roofs’ by Erik Nissen-Petersen and Catherine W. Wanjihia. The cost of the provision is based on the local price for the used materials, see appendix 12.

4.8.2 Technical usability

Technical knowledge is needed to construct the tank. People should have had technical education for constructing tanks. Local technicians are able to construct the gutters and, if is decided to construct a subsurface ground tank strong men are needed for digging a hole.

4.8.3 Sustainability

For constructing a tank, there are different possibilities. Normally NGO’s are under pressure of both, clients and funders and so they will prefer safe solutions to minimize failure. These solutions are often more expensive and need high maintenance.

For increasing the durability of the roof water harvesting system, the tank and gutters needs to be checked and cleaned every year. By removing obstacles in the gutters a decreasing in roof run-off can be avoided. The tank needs to be checked to avoid small leakages.

4.8.4 Water quality

Rainwater does not contains is not enriched with minerals. This means that the water is not full of taste.

According the health is it possible that the galvanized iron sheets leads to a risk of zinc pollution. For this reason it is necessary to control the water quality frequently

4.8.5 Performance and cost analyse

The technology of making use of the roof catchment is, similar to the subsurface reservoir with surface catchment, a small-scale solution. It is a solution for a single household. The results of the roof surfaces are based on four different aspects, namely:

- Different roof surfaces
- Different materials
- Different tank sizes
- Different minimum annual precipitation

The roof catchment is based on a household of five people, according to the Mtwara Baseline survey (Source: EWAREMA Consult, Final baseline survey report, Mtwara, water, hygiene and sanitation project, September 2008)

Based on the rainfall analyses (see chapter 4.4) is concluded that the priority of the precipitation will be based on a minimum annual rainfall with a repetition time of 1 in 5 years. Based on the roof distribution analyses (see appendix 3) can be concluded that the roof surface will be based on a roof surface with the dimensions of an average roof surface minus one standard deviation. The average roof surface of the houses with GI sheet is 67.2m^2 and the standard deviation is 16.3m^2. The average roof surface minus one standard deviation is becoming 50.9m^2.

The calculations are done for three different minimum annual rainfalls and the roof surfaces are calculated for the average roof surface, average minus one standard deviation and the average minus two standard deviations. In table 4.14 the results are shown.

The storage facility with a capacity of 5 m^3 does not have the capacity to overcome the dry season. The efficiency is 70%, what means that 30% of the annual rainfall will overflow/spill from the tank. Due to the lack of storage the reliability of supply is 67% that means that tank does not contain water for 120 days in a year. By an increasing of tank size to 11 m^3 the efficiency is 82% and the reliability of supply is 92%. Compare to the tank with 5m^3 storage is it a big improvement, but there are still 29 days each year where the tank does not contain water.

When taking a storage facility of 15m^3 for each household by a roof surface of 50.9m^2 (roof surface μ-1σ) the reliability of supply will be 100%. The efficiency is 90%, what means that there is still some overflow. In figure 4.18 this can be seen by the red line.

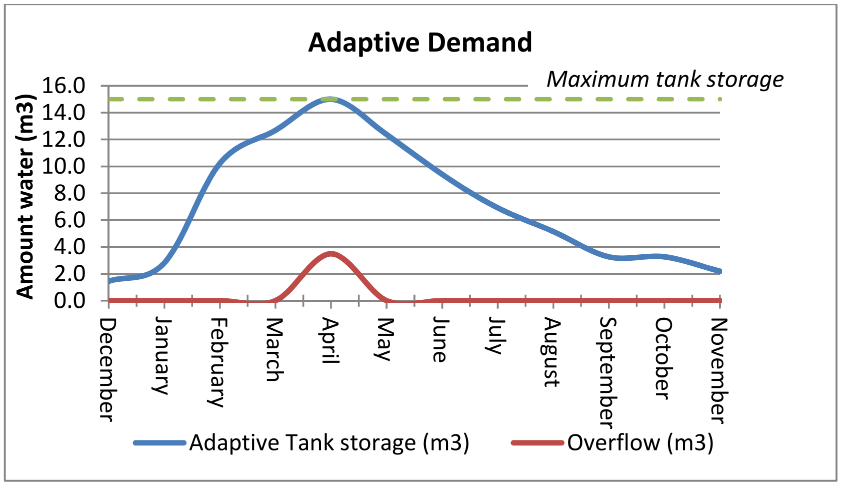


Figure 4.18
The fluctuation of a storage facility with 15m³ is only in April totally filled. With an adaptive demand (water use of water user is based the presence of water in the storage facility)

Only the tank with a storage capacity of 15 m³ is sufficient for a household. For this, only the performance indicators of the 15m³ tank will be discussed

By taking a look to the different options for materials there are different options, whereby the costs depends on the material prices in Mtwara. The performance indicator tools, which are related to the costs, show that the tank made of Ferro-cement is the cheapest method (table 4.15). The overall costs are €497,20. This results in an equivalent unit cost (cost/1m³) of €128.43. The payback time is construction costs versus annual demand. The construction costs are based on the material and size of the tank and the annual demand is based on the roof surface, which is related to the amount of rainfall. The payback time is the lowest by the biggest roofsurface, because, as assumed, the usages of water will increase when the size of the surface is increasing. Because the income is based on 50 TZS (€0.03) for the use of every 20 litre, the incomes will increase when the demand is increasing. This results in a payback time of 131 months.

Table 4.15
This table is the continuation of table 4.14. On the left, the different materials for the tank are mentioned and on the right the indicators of total costs, the cost/m³ and the cost/m³/water user are shown.

Type of catchment	Material tank	Size of storage (m³)	Surface roof (m²)	Payback time (months)	Cost/1m³ (€)	Cost 1m³/water user (€)	Total costs (€)
Roof catchment	Concrete	15	67.2	176	172	34.4	665
			50.9	185			
			34.5	225			
	Ferro-Cement	15	67.2	131	128	25.7	497
			50.9	138			
			34.5	168			
	S.C. Blocks	15	67.2	212	207	41.4	802
			50.9	223			
			34.5	272			

When is decided that 50% (based on expectations that in 10 year 50% of the households will have a hard surface as roof) of the households will receive a water tank the overall costs for an average village (households 383) is €190.351.
During the field visits, the measurements are taken of the roof surface from the houses with GI sheets. They are analysed on the surface distribution and the total amount of households with a galvanized iron sheet as roof surface is 6.4% of the project area. The used roof surface for calculation is the average roof surface in the area minus one standard deviation that means that 84% of the households with an iron sheet as roof will receive a tank. The total amount of households, which are selected to acquire a roof water harvesting system, will be 5.4%. The cost for providing 5.4% households of an average village with a storage tank for roof water harvesting is € 10,088.

Now there is insight in the investment costs of the different components for the dimensions with the best performance it is important to look to budget whereby the depreciation of the different elements are taken into account, as well as the operation and maintenance. The overview of the budget can be found in appendix 13. For the budget the number of households for receiving a tank is set as the whole village, namely 383 tanks.

The labour costs is €234,77, this mean that the cost for each cubic metre water consumed is €0,65. The monthly investment costs is 1480,50. Because there are no operation costs the costs for operation and maintenance are only €50,00 monthly. The total price for each cubic water consumed is €4,83.

Table 4.16
Overview of the costs per month and the costs for each cubic metre water consumed. The price for one cubic metre water is €4,83, widely more than the actual price of water.

Calculation of costs per month and per m³ consumed	**Cost/month (€)**	**Price per m³ (€)**
Labour costs	234,77	0,65
Investments	1480,50	4,12
Operation and Maintenance		
- Maintenance and repair	50,00	0,06
Total	**1.735,27**	**4,83**

The total costs for each month is €1735.27 and the monthly income is €521,96. For this the difference is €978.56 negative. For this the investments for this systems seems to be not suitable, because the lack of profitable aspects.

Table 4.17
Presented is the difference of the income and the costs. By making use of this alternative the system is not profitable. More than €975,- are the netto monthly costs

Monthly income (€)	521,94
Monthly costs (€)	1.735,27
Difference income and costs (€)	**- 978,56**

4.9 Overview results

In table 4.18 is shown the comparison of the best performing dimensions of the different analyzed alternative methods.

The actual method is the drilling and construction of a borehole with a 50 cubic metre water tank.

Alternative 1 is based on a surface catchment with subsurface soil storage, the total costs for are 26.277 for 2 infiltration field with a surface of 100 metres by 60 metres and a depth of 1.5 metre. The impervious layer is made of LPDE plastic. This method will provide sufficient water to an average village of 383 households.

Alternative 2 is based on a surface catchment with subsurface ground tank. The subsurface ground tank has a diameter of 8 metre and a depth of 3 metres. The catchment area around the ground tank needs to be at least 30 metres. This method will provide sufficient water for a 10-cell

Alternative 3 is based on hard roof water harvesting with tank made of ferro-cement. The volume of the tank is 15m³ and the roof surface needs to be bigger than or equal to 50.9m². This method will provide sufficient water for a single household

Table 4.18
The best performing systems, for alternative water sources. Method 1 is the surface catchment with subsurface soil storage made with LPDE plastic. Method 2 is a surface catchment with ground tank storage made of LPDE plastic and method 3 is based on roof water harvesting with a tank made of ferro-cement.

	Borehole	**Alternative 1**	**Alternative 2**	**Alternative 3**
Demand satisfaction (%)	*100*	116	112	107
Efficiency (%)	*100*	95	98	90
Reliability of supply (%)	*100*	100	100	100
Total costs (€)	*85.363,00*	26.277,00	40.214,71	212.801,00
Monthly costs (€)	*662.11*	349,14	528,45	1735,27
Price per m³ water (€)	*1,84*	0.97	1.47	4.83

5 Conclusions & Discussion

5.1 Objectives of investigation

The goal of this investigation is to analyze the possibilities towards alternative water sources next to the actual used method of drilling and constructing of boreholes. The objectives of this study are formulated as follow:

1. *Exploring the possibilities of alternative water resources (apart from deep boreholes)*
2. *Standardize collected data in database formats and train the local staff where needed*

The objectives are achieved by conducting a desk study and a field survey, including consultation of communities in the project area regarding preference of water source and by a intensive training in ArcGIS and data management.

5.2 Conclusions

The actual used method is the drilling and construction of deep boreholes, beside the borehole there is constructed a 50 cubic metre water tank. The total costs for one system is € *85,363*. The cost of one cubic metre water is € 1.84.

Three methods are compared, which can be an alternative water source. The different methods are

I. Subsurface soil storage with surface water harvesting
II. Surface water harvesting with subsurface storage reservoirs
III. Roof water harvesting with storage tanks

5.2.1 Alternative I. Surface harvesting with subsurface soil storage

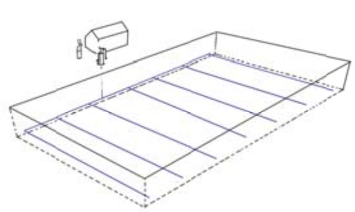


Figure 5.1
Alternative 1. Surface water harvesting with subsurface soil storage. Village based solution

For the subsurface soil storage with surface harvesting, the best solution is an infiltration field with the surface of a soccer field for an average village with the population of 1918. The dimensions of a soccer field correspond with the dimensions of 100 by 60 metres. In figure 5.1 is seen a schematic sketch of the system

The needed depth is 1.5 metre and the offset around the infiltration field needs to be at least 15 metre to increase the size of the catchment area. The water resistant layer is LPDE plastic and the total costs will be

€ 26.277,00. The cost for every cubic metre water consumed the price is €0.97.

Even is chosen for a more durable material, EPDM rubber, the total cost is *€ 36,778*.

5.2.2 Alternative II. Surface harvesting with subsurface reservoir

The best selection for the subsurface reservoir with surface catchment will be constructing a subsurface reservoir with a diameter of 8 metres, a depth of 3 metres and an offset of 30 metres. A schematic sketch is seen in figure 5.2. This will result sufficient amount of water for every 10-cell in the village. The total costs for ach 10-cell will be € 667,- and the payback time is 20 months. By up scaling this technology to an average village will cost *€ 40.214,71*. This will provide sufficient water for a village with 383 households and 38 10-cels. The cost for every cubic metre water consumed is € 1.47.

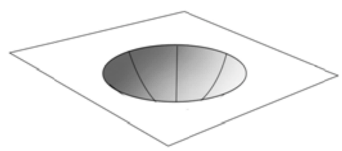


Figure 5.2
Alternative 2. Surface water harvesting with subsurface reservoir. 10-cell based solution

5.2.3 Alternative III. Tank storage with hard roof harvesting

The best size for a storage facility for hard roof water harvesting is a tank with the capacity of 15m³. If the roof surface is bigger than 50.9m², the roof surface will provide sufficient water for the whole year on the condition of a minimum annual rainfall with a repetition time of 1 in 5 years. A schematic sketch is shown in figure 5.3. The total number of households with a galvanized iron sheet upward of 50.9m² is 5.4% (2010) and the total amount of households with a galvanized iron sheet is 6.8%. The costs for constructing one tank is € 497,20 and for constructing tanks for all the houses with a GI sheet roof with a surface bigger than 50.9m² will cost *€ 10.088*. The cost for every cubic metre water consumed is € 4,83

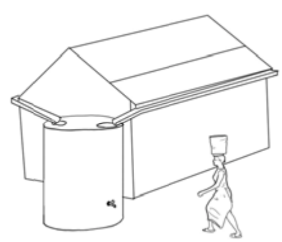


Figure 5.3
Alternative 3. Surface water harvesting with subsurface reservoir. Household based solution

In short

Out of the performance indicators, the best option is method I. Method I is based on the sand formation on the plateau. By a surface with the dimension of 100 metres by 60 metres and a depth of 1.5 metre, the subsurface soil storage is able to provide sufficient water for an average village with 383 households. The cost for every cubic metre is more than method II, but the number of water users is higher. Both the materials LPDE plastic and EPDM rubber are cheaper than the actual used methods. If is decided for a durability of 10 years the total costs for the alternative is €26.277 whereby the actual used method cost €85.363. This is a difference of €59.086. If is decided for a system with a durability of 25 years the alternative is still € 48,858 cheaper than the actual used method of construction and drilling a borehole.

5.3 Discussion

By executing the alternative options for a water source it is recommended to introduce earning potentials. Instead of earning only salary, the local villagers can also chose to build up credits for a part of their salary. These credits can be used to buy water for a reduced offer of charge. This will decrease the labour cost and introduce the possibilities for investing.

On the bases of the field observations it is recommended to execute a project whereby the construction is done by the local villagers. This will result in a more understanding of the system and a more responsible attitude towards maintaining of the system. At the moment maintenance of the system is the bottle-neck of the success of the system, for this more attention needs to be given to a community based maintenance plan of the constructed system.

To increase the storage volume the subsurface soil storage facility it is recommended to introduce filter cloth. Filter cloth can be used to separate different layers in the storage facility. With this it is possible to use aggregate on the bottom, as one cubic metre aggregate has a higher storage capacity than one cubic metre coarse sand (see figure 5.3).

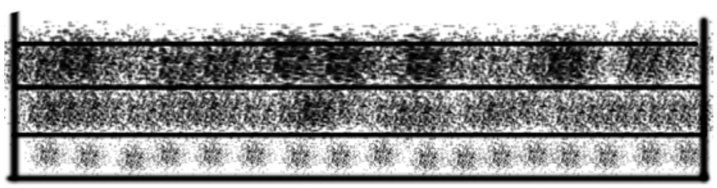


Figure 5.3
Possible improvement of the alternative. Introduce filter cloth for different soil porosity to increase the storage capacity

For the next steps it is recommended to set up a pilot project to get practical experiences and challenges, which still needs to be tackled.

Challenges which needs to be tackled is the issue of land owner ship of the land. It may be needed to use communal land or the land that needs to be used should be bought ore swapped.

References

Nissen-Petersen, E., Wanjihia, C.W., (2006). Danish International Development Assistance, Technical Handbooks, Kenya, ASAL Consultants Ltd,

Hapugoda, K.D., (1995). Action research study on rain water harvesting, Sri Lanka, community water supply & sanitation project, ministry of housing, construction & public utilities

Smet, J., Wijk van, C., (2002). Small Community Water Supplies: Technology, people and partnership. Delft, The Netherlands, IRC International Water and Sanitation Centre. (Technical Paper Series; no. 40). 585 p.

Thomas, T.H. and Martinson, D.B. (2007). Roofwater Harvesting: A Handbook for Practitioners. Delft, The Netherlands, IRC International Water and Sanitation Centre. (Technical Paper Series; no. 49). 160 p.

Waes van, B., Bouwman, D. Aqua for All (2007). Smart Water Harvesting Solutions. Apeldoorn, The Netherlands, Aforma Drukkerij.

NWP. (2006). Smart Water Solutions. Apeldoorn, The Netherlands, Aforma Drukkerij

Lee, M.D., Visscher, J.T., (1992). Water Harvesting. A Guide for Planners and Project Managers. Delft, The Netherlands, IRC International Water and Sanitation Centre. (Technical Paper Series; no. 30) 116 p.

Japan Interntational Cooperation Agency, Jica, (2001). The Study on Water Supply and Sanitation in Lindi and Mtwara regions. Tokyo, Japan. Kokusai Kogyo Co.

Finnwater, (1977). Mtwara-Lindi Water Resources Inventory and Development Plan, Helsinki, Finnland. Polytypos

Planning Commision, Dar Es Salaam, Regional Commissioner's Office Mtwara (1997). Mtwara region, Socio-Economic Profile

Regional Commissioner's Office (2010). Mtwara region, The Socio-Economic Profile and Investment Potentials.

Tanzania, Relief and drainage, Digital Cartography by M C Shand University of Glasgow 1997

Appendices

Appendices

1 Terms of Reference

MTWARA WATER, HYGIENE AND SANITATION PROJECT

Terms of Reference for internship Mattijn van Hoek

(March – June 2010)

Introduction

The African Medical and Research Foundation (AMREF) Tanzania in collaboration with Mtwara Rural District Council is now on implementation of a four-years water, hygiene and sanitation project in 6 wards and all 40 villages contained in those wards.

The project is designed to facilitate community participation and involvement, so as to achieve the maximum community participatory planning and implementation of project activities which ensure the priorities of disadvantaged groups. The focus is on approaches/technologies and mechanisms that work in rural and low-income urban areas. The emphasis is also on affordable, acceptable, appropriate and evidence based technology that becomes familiar with the target population for easy operation and maintenance.

The Project Overall objective is to contribute to halving by 2015 the proportion of people without sustainable access to safe drinking water and adequate basic sanitation services.

Specific objective is to improve the health and quality of life of selected marginalized communities of Mtwara district in Tanzania by increasing access to and sustainable usage of safe water and basic sanitation services.

Background Information

The proposed TA internship follows a successful and effective mission held in February 2010. During this mission the content and process for the technical assistance process that is provided by Water board (Velt en Vecht) and Aqua for All to AMREF in Tanzania, was agreed upon. In the TA work plan the agreed process and content are defined in detail.

Preferred period of internship

21 March - 30 June 2010; covering 3 months

Objectives of the planned internship

In line with the overall TA work plan, the objectives of the internship are the following:

- Increased skills and knowledge about alternative water source and adjustment of project scope towards a more diversified water scheme for the phase III area and for the expanded project area as envisaged by the project management

- Increased skills and knowledge about data management and water source monitoring, both qualitative and quantitative

Scope of works

In order to meet the above-mentioned objectives it is envisaged that the intern will engage on the following scope of works in collaboration with the project staff:

- Conducting desk study and field survey into the feasibility of alternative sources, including consultation of communities regarding preference of water source in the project area where phase III of implementation is planned and in the envisaged expanded project area.
- Support in formulating proposal / addendum for adjustment of scope towards development of alternative water sources
- Support in setting up an integrated monitoring plan for the water sources
- Support in design of an effective data management system (software and organizational arrangements)
- Support in standardization of data collection
- Support in using data for effective reporting (using tools like GIS)

Deliverables

- Alternative sources survey report
- Appropriate data management and monitoring system, specifically for water sources.
- Complete database of realized water sources

Materials required for the internship

The intern has to bring a computer with the appropriate software for data management with the possibility to transfer/copy that software to the AMREF office in Mtwara.

Roles and responsibilities

The principal of Mattijn will be water board Velt en Vecht. AMREF takes no responsibility for meeting insurance, accommodation and upkeep expenses. AMREF in Tanzania will facilitate the search for accommodation in Mtwara.

AMREF in Tanzania will be responsible for meeting the logistical requirements for successful implementation of the internship.

The project manager, Ignatio Kagonji, will provide guidance to the intern in Mtwara. This means that Mattijn and Ignatio will discuss progress of the internship on a regular basis.

Contact persons

- Program Manager Tanzania: Martin Mkuye; martin.mkuye@amref.org
- Program Manager Netherlands: Joris van Oppenraaij; joris@amref.nl
- Project Manager Mtwara: Ignatio Kagonji; ignatio.kagonji@amref.org

2 Plan of Approach for three months study-period

By Mattijn van de Hoek, March 17th 2010

Introduction

The government of Tanzania declares in the national water policy that ‘the availability of water is a basic need and entitled to everyone’1. Based on findings of AMREF, the estimation of disease burden related due to the lack of safe drinking water and adequate sanitation in Tanzania is 70%.

Within Tanzania the Mtwara district, located in the southeast, is one of the most vulnerable areas. The district consist of six divisions, 18 wards en 119 villages. The total population of Mtwara is 231.554(WATSAN MTwara Baseline Survey Report) and has an estimated annual growth of 1.4%. In the district, the majority of people are devoid of safe drinking water and adequate sanitation.
Each day, the collection of water takes 4 till 7 hours. In most cases, the collected water is not safe. Water scarcity results in an average use of 10 litres per person per day[2] where WHO prescribes a minimum use of 20L/p/d.

To improve the water supply in the district, the African Medical, Research Foundation (AMREF) Tanzania, and the Mtwara Rural District Council has started the WATSAN project in 2008. This project is about water, hygiene, and sanitation. AMREF hopes to finish this project in collaboration with water board Velt en Vecht and Aqua for All (by providing technical assistance and function as co-financiers) in 2011.

The project aims to improve the health and quality of life of selected marginalized communities of Mtwara district. Including 6 wards and 40 villages. This is done by increasing access to- and sustainable use of safe water and basic sanitation services by constructing boreholes in each village.
Unfortunately, due to the complexity in the hydro geological conditions, the construction of boreholes in the project area is difficult. .
The goals in this study period are twofold. This document discusses the two goals separately:.

1) Exploring the possibilities of alternative water resources (on top of only boreholes).
2) Standardize collected data in database formats and train the local staff where needed

Objectives of the 3 month study period

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[1] National Water Policy of the United Republic of Tanzania, page 4

[2] Gleick, P,H. 1999. The human right to water.
http://webworld.unesco.org/Water/wwap/pccp/cd/pdf/
educational_tools/course_modules/reference_documents/issues/ thehumanrighttowater.pdf

1. Alternative water resources

The objective is to investigate possible alternative drinking water sources in the villages of phase three and other villages out of the project area. This possibility arises by the release of budget by reducing the number of boreholes from 51 to 40. Those, potential, alternative solutions will possibly offer the population a more reliable and broad access to safe drinking water.

The purpose of the investigation is to provide technical evidence for an addendum towards the European Union (main financier in this project) for adjustment the scope towards development of alternative water sources.

Core elements for analyzing alternative water resources are affordability, technical usability, and durability. The result is a selection method by distinguish alternative water resources on those elements.

Detailed investigation in respect to alternative water sources

I. Present area description
   a. hydro-geological background
   b. socio-economical situation
   c. water supply sector
II. What alternatives for collecting drinking water are suitable for this area?
III. To what extent can these alternatives be applied?
IV. Distinguish alternative methods by:
   a. affordability
   b. technical usability
   c. sustainability/durability

   } by making use of a matrix

Answers to the above investigation provide a good basis for the identification of alternative sources.

Add. I. The first question will provide detailed insight in the area. This is of utmost importance for a good understanding of the situation subsurface and above ground. This will provide information on the reliability of the constructed and planned boreholes. The certainty of pin-pointing an aquifer will increase, compared to the actual trial-and-error strategy. In addition, a good understanding of the area will provide a solid answer for the most successful alternative solutions.

The current water collection methods are described. What result in insight in the local technical capabilities. This will be used for distinguish the technical usability of alternative possibilities.

Add. II. To provide insight in the broad amount of technologies for collecting of water. To narrow this down analyses and discussion on possible alternatives is necessary. For a meaningful and effective, survey only the best suitable alternatives will be investigated. For this reason, a selection of appropriate alternatives for this area will be made.

Add. III. Next to the selection of alternatives, the research to the degree of applicability is important. By this investigation, a map will highlight the potential areas for each method. A potential map provides a comprehensive insight in the demands of and the possibilities in an area, which give leads for community based decision making for the purpose of water supply.

Add. IV. By constructing a matrix for alternative water resources the following elements affordability, technical usability, and sustainability are included. In planning sessions the matrix can be used to provide the local population a complete overview. This matrix overview may function as a tool for selecting the best method, based on their needs and demands. Community based planning + decision-making will increase by providing this approach of selecting.

Results
A matrix with a comprehensive overview of advantages and disadvantages of the possible, alternative methods per village.

2. Database and monitoring

Setting up of a proper data management will be done for water source monitoring, both qualitative and quantitative. With adequate monitoring, it is possible to intervene in time when recharge of a water source is falling out of range or contamination takes place. The local staff receives training in adequate monitoring and the use of database(s) in ArcGIS and Ms Acces.

Investigative questions in respect to a monitoring plan

I. Why is monitoring needed?
II. Which essential elements are needed for monitoring?
III. Which measurements are necessary to monitor correctly?

Add I. Monitoring of boreholes is needed to identify adverse trend in the recharge of the water source. Clearly, mechanisms are needed to assess this development in time. Monitoring is also needed for evaluating whether the project has achieved the desired objectives, or whether new measures need to be put in place.

Add II. Monitoring can be done for an variety of parameters. By this question the parameters for monitoring are discussed and the essential elements for monitoring are mentioned.

Add III. The result will be an overview of steps that are necessary for measuring the parameters. To obtain reliable data the method for collecting for each step needs to be described carefully.

Results
A database plan for the monitoring of the boreholes
Instruction on use + maintenance of database in ArcGIS and Ms Acces

Methodology

The study comprises the following methods

I. Desk studies
    a. Preparation of a work plan for the study
        i. Preparation plan (in Netherlands)
        ii. Survey plan (in Tanzania)
        iii. Finalizing report plan (in Netherlands)
    b. A review of published literature on the subject covering local and foreign sources
        i. Description project area
        ii. Actual used methods for all water resources in Mtwara, Tanzania

iii. Overview methods for alternative water recourses
c. Monitoring
i. Setting up a monitoring plan for the drilled boreholes
ii. Design of an effective data management system linked to GIS.
d. An analysis of rainfall data

II. Collection of data
a. Collection of data on rainfall from meteorological weather station Mtwara
b. Collection of data in technical experiences for collecting drinking water

III. Field visits
a. Survey of the existing rainwater harvesting experiences
b. Survey of the drilled boreholes
i. From phase I (and where possible phase II) from the project of AMREF
ii. From previous projects (JICA and Finnwater)
c. Asses the possibility for alternative water collection methods within the study area
d. Asses the demand of alternative water collection methods within the study area
e. Standardization of data collection regarding monitoring
f. Teaching in using tools like ArcGIS and Ms Acces to local water council

IV. Analyze
a. Project area analyze, of the physical, socio-economic and institutional environment
b. Cost-benefit analyze, of the possible alternative methods for water collection

To achieve the objectives, the study is divided in three core steps. The activities and scheduling are described in each core step. These steps are:

- Preparation in Netherlands
- Survey in Tanzania
- Finalizing in Netherlands

Annex I provide the schedules for each step
Annex II provide an overview of the different phases in the investigation, included the input and output per phase.
Annex III provide a preliminary table of contents of the thesis report.

Related parties

This research is done by a collaboration of regional water authority Velt en Vecht, Aqua for All and AMREF. Water board Velt en Vecht and Aqua for All providing technical assistance in this project.

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Aqua for All is an institution committed to the improvement of access to safe drinking water and sanitation facilities in developing countries, headquartered in Nieuwegein, Netherlands. Aqua for All links money and expertise of the Dutch water sector to water- and sanitation projects in developing countries. It does not execute projects by itself, but strengthened projects by advice, monitoring, and co-financing.

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AMREF is an international African organization headquartered in Nairobi, Kenya. AMREF's mission is to ensure that every African can enjoy the right to good health by helping to create vibrant networks of informed communities that work with empowered health care providers in strong health systems.

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Van Hall Larenstein, University of Applied Sciences, is a university that focus on nature and environment, human and animal health, and responsible entrepreneurship.

Annex I: Schedules for each step

Overal schedule

		Weeknumber																								
			March					April				May					June				July				August	
Subject	Weeks	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Preparation Tanzania	3		x	x	x																					
Survey Tanzania	14-15					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x						
Accumulation weeks Tan:	2-3																				x	x	x			
Finalizing report Tanzania	2-3																						x	x	x	
Preparation colloqium	1-2																								x	x

Subject	Detailed explanation in schedule		Detailed activities	
Preparation Tanzania	A:	Weeks 9-11 in Coevorden, Netherlands	F:	Preparation plan
Survey Tanzania	B:	Weeks 12-13 in Dar Es Salaam/Mtwara		
Survey Tanzania	C:	Weeks 14-25 in Mtwara		
Survey Tanzania	D:	Week 26 in Dar Es Salaam		
Finalizing report Tanzania	E:	Week 29-31 in Coevorden, Netherlands		

A: Weeks 9-11 in Coevorden, Netherlands		Hours	Date																																		
			1		2		3		4		5			8		9		10		11		12			15		16		17		18		19			22	
			ma		di		wo		do		vr			ma		di		wo		do		vr			ma		di		wo		do		vr			ma	
			m	a	m	a	m	a	m	a	m	a		m	a	m	a	m	a	m	a	m	a		m	a	m	a	m	a	m	a	m	a		m	a
1	**Obtain background information**	**32**																																			
a	Research geohydrological data	12			x			x																								x					
b	Research climate information	8				x			x																												
c	Research Socio-Economic data	12					x			x		x																									
2	**Plan of Approach in Tanzania**	**52**																																			
a	How-to reseach local used methods	4																							x												
b	How-to research alternative solutions	*28*																																			
i	*Overview methods*	*12*												x	x			x																			
ii	*Desciscion making alternatives*	*4*																	x																		
iii	*Establishment method*	*12*																		x		x	x														
c	How-to construct the database	*12*																																			
i	*Selecting SI derived units*	*4*																			x																
ii	*Fieldwork forms*	*4*																									x										
iii	*Set up of database*	*4*									x															x											
d	How-to transit the using of the database	*8*																																			
i	*Elements to be trained*	*4*																											x								
ii	*How to train/educate*	*4*																												x							
3	**Reports**	**6**																																			
a	Outline report WVV/Amref	4														x																					
b	Outline report Larenstein	2															x																				
4	**Surplus**	**5**																																			
a	List of needs (checklist)	2															x																				
b	Clarity in budget	1																										x									
c	Clarity in malaria medicins	1																										x									
d	Clarity in dates	1																										x									

5	**Overview hours**	
1	Obtain background information	32
2	Plan of Approach in Tanzania	52
3	Reports	6
4	Surplus	5
6	**Total**	**95**

B: Weeks 12-13 in Dar Es Salaam/Mtwara

Objectives	mo	tu	we	th	fr	sa	so	mo	tu	we	th	fr	sa	so
Dar Es Salaam														
Meeting AMREF/Dar Es Salaam	x													
Meeting JICA		x												
Meeting University DES			x											
Department of Geology				x										
Travelling to- and settling in Mtwara					x									
Mtwara														
Meeting AMREF/Mtwara								x						
Meeting DWE/DD									x					
Meeting Ruvuma										x				
Exploring the project area								x	x	x	x	x		
Refinement of methods for field research			x	x							x	x		

C: Weeks 14-25 in Mtwara

Objectives	days	mo	tu	we	th	fr	sa	so
Field research excecution	33	x	x	x				
Report writing	6					x		
Teaching (Acces & GIS)	6					x		
Maintaining database	11				x			
20% buffer (1 day/week)	11						x	
Spare time	11							x

D: Week 26 in Dar Es Salaam

Objectives	mo	tu	we	th	fr	sa	so
Meeting AMREF/Dar Es Salaam	x	x	x				
Report writing	x	x	x				
Teaching (Acces & GIS)			x				
Travelling to Dar Es Salaam	x						

E: Week 29-31 in Netherlands

Objectives	mo	tu	we	th	fr	sa	so	ma	tu	we	th	fr	sa	so	mo	tu	we	th	fr	sa	so
Finalizing report	x	x	x	x	x			x	x	x	x	x									
Report checking Waterboard	x	x	x	x	x			x	x	x	x	x									
Report checking AMREF	x	x	x	x	x			x	x	x	x	x									
Report checking Aqua for All	x	x	x	x	x			x	x	x	x	x									
Report checking Larenstein	x	x	x	x	x			x	x	x	x	x									
Preparation colloqium															x	x	x	x	x		

F: Preparation plan

Activities

I. Obtain background information
   a. Research hydro geological data
      Geographical position, elevation, lithology, aquifers, groundwater chemistry
   b. Research climate information
      Precipitation, wet days, temperature, humidity, wind speed, evapotranspiration. Based on FAO
   c. Research Socio-Economic data
      Population and human development, economic conditions, land cover/land use, water, agriculture/food, energy, biodiversity. Based on IPCC

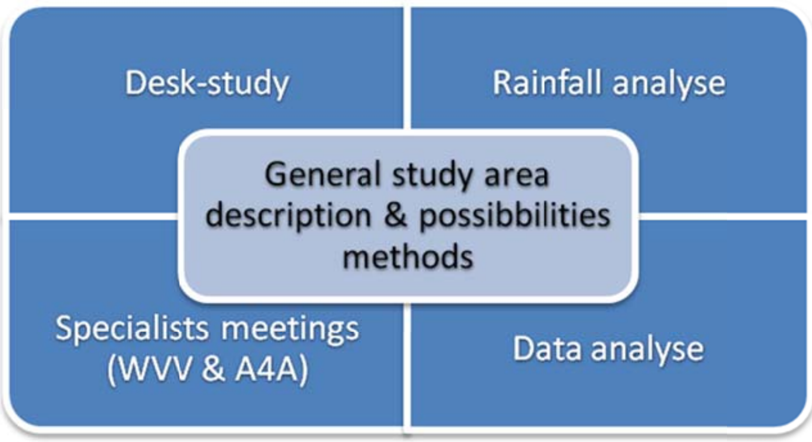
II. Plan of approach in Tanzania
   a. How-to research local used methods
   b. How-to research alternative solutions for drinking water
      i. Accurate overview of- and knowledge about diverse methods (to acquire drinking water)
      ii. Decision-making about alternatives that will be investigated
      iii. Establish a method to distinguish the alternatives
   c. How-to construct the database
      i. Which SI derived units needs to be selected (how does it need to be expressed)
      ii. Create standard fieldwork forms
      iii. Set up of database
   d. How-to transit the using of the database (in combination with GIS) towards AMREF Mtwara, District Water Office and Ruvuma River Basin and South Coast Authority
      i. Which elements need to be trained
         Estimation catchment areas
      ii. How to train/educate
         From beginning on
         Apply structure (once a week) to maintain database (show the necessity)

III. Outline report

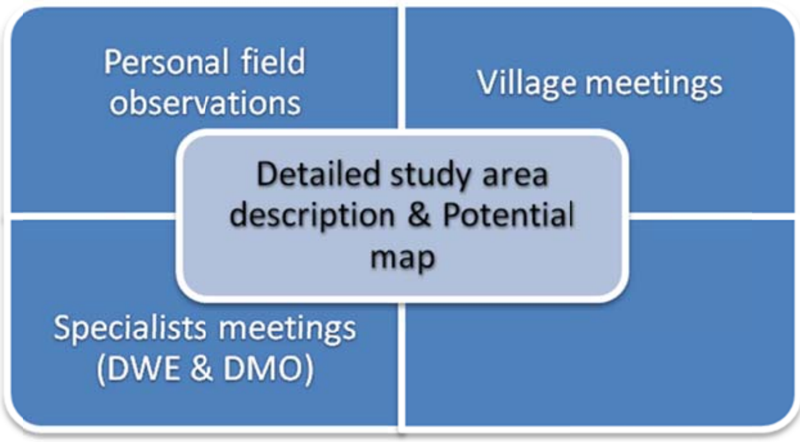
IV. Surplus
   a. List of needs (checklist)
   b. Clarity in budget
   c. Clarity in malaria medicines
   d. Clarity in dates
   e. Possibility of using GIS without license

Annex II: Overview phases

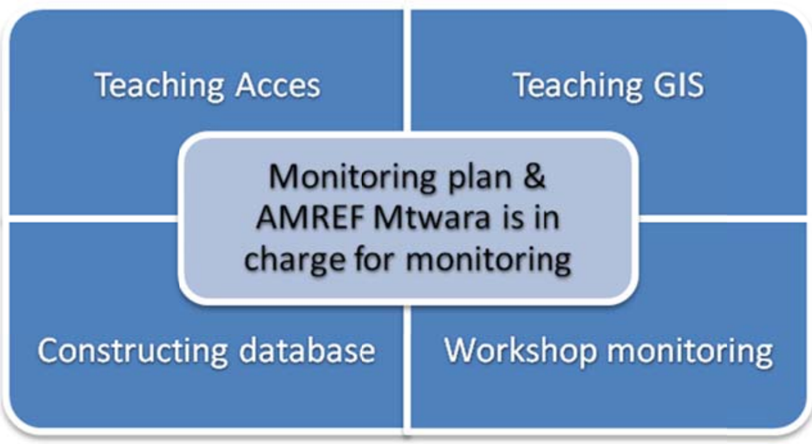
Dark blue boxes show the input and the light blue boxes show the output



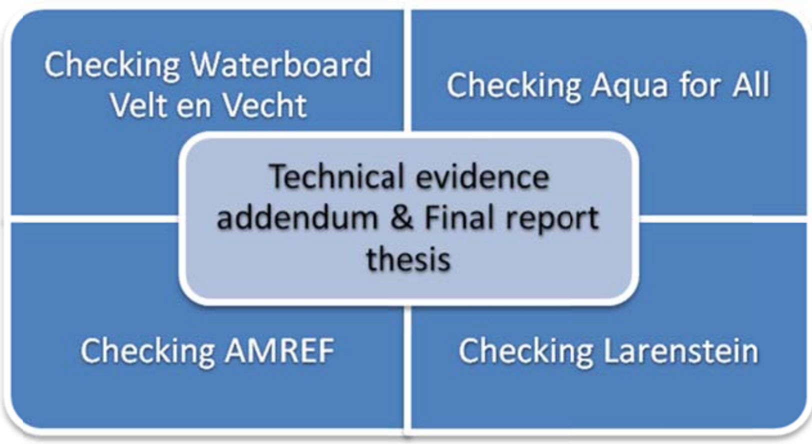
Phase 1: Preparation



Phase 2a: Field survey



Phase 2b:



Phase 3 Evaluation & finalizing

Annex III: Preliminary table of content of the thesis report

1. Abstract
2. Preface
3. Executive summary
4. Introduction
   a. Purpose
   b. Study area
   c. Methodology
5. Project area analyse
   a. Geomorphology and geohydrology
   b. Climate
   c. Socio-economic
   d. Actual used methods for water harvesting
6. Cost-benefit analyse
   a. Advantages and disadvantages of alternative water source methods
   b. Feasibility
      i. Rain fall
      ii. Water demand
      iii. Water supply
   c. Economics
      i. Cost scenario
   d. Social
7. Results
8. Conclusion and recommendations
9. Discussion
10. Literature
11. Annexes

3 Distribution Roof Surfaces + Data

The distribution of the roof is analysed by measuring (almost) all the roofs with iron sheet in the projected phase 3 villages of the project area.

For selecting appropriate tank sizes it is important to analyses the distribution of the houses with iron sheet. The best solution for the householders is that the all the houses will get a tank which size is based on the surface of the roof. In this case the efficiency will be 100% for every house, what means that all the water what will fall on the roof will be delivered to the householder. The tank will not overflow.

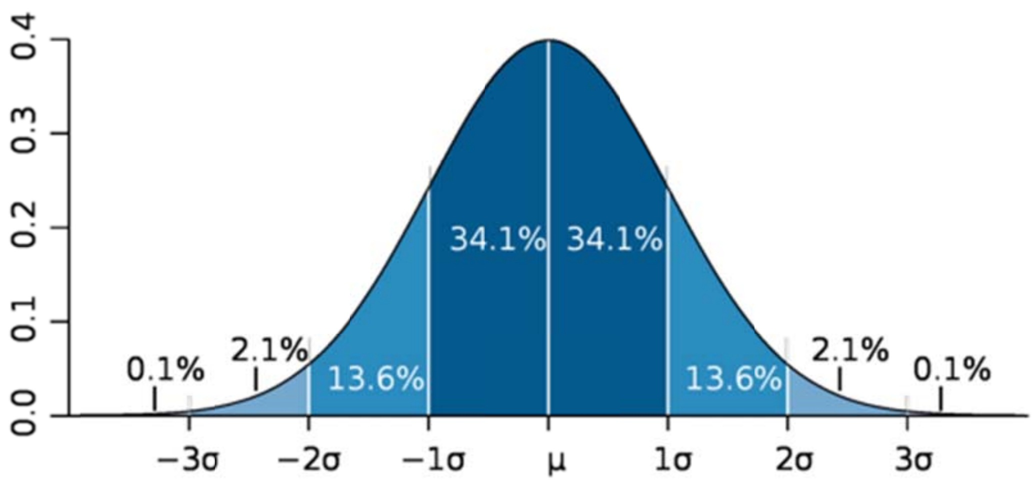
For finding the arithmetic mean the next formula is used:

$$\bar{x} = \frac{1}{n} \times \sum_{i=1}^{n} x_i$$

And for finding the standard deviation

$$\sigma = \sqrt{\frac{(x_1 - \mu)^2 + (x_2 - \mu)^2 + \cdots + (x_N - \mu)^2}{N}}$$

By assuming a normally distribution of the roof surface and the roof surface is set as ‘mean minus one standard deviation’. Than the annual water delivered is in 84% of the households sufficient to meet the demand (the considered water demand is based on the ‘mean minus one standard deviation’ roof surface).



Model Roof water harvesting can be used to optimise storage volume to available roof surface (Annex 10)

Data Roof Dimensions

roof	rank	56,88	36	66,42	72	77,19	108
27,44	1	56,98	37	67,16	73	78,2	109
32,4	2	57,12	38	67,2	74	78,3	110
37,82	3	57,72	39	67,24	75	78,4	111
38,25	4	57,76	40	67,76	76	79,17	112
39	5	59,13	41	68,04	77	79,2	113
40,32	6	59,13	42	68,4	78	79,68	114
40,32	7	59,2	43	68,8	79	79,9	115
41,61	8	59,2	44	68,85	80	79,98	116
42	9	59,25	45	69	81	81,9	117
42,09	10	59,25	46	69,66	82	81,9	118
43,5	11	59,64	47	71,38	83	82,8	119
44,16	12	59,86	48	71,38	84	82,8	120
44,84	13	60	49	72,09	85	84	121
45,26	14	60	50	72,24	86	86,1	122
47,12	15	60,68	51	72,25	87	86,48	123
48,3	16	60,75	52	72,25	88	89	124
48,98	17	61,56	53	72,25	89	90,2	125
48,99	18	61,6	54	72,54	90	91	126
48,99	19	62,16	55	72,68	91	91,14	127
48,99	20	62,32	56	72,8	92	91,3	128
49,7	21	62,32	57	72,9	93	92,4	129
50,32	22	62,32	58	72,98	94	93,15	130
50,4	23	62,64	59	73	95	94,5	131
50,82	24	63,75	60	73,04	96	95	132
51,1	25	63,75	61	73,04	97	96,6	133
51,12	26	63,99	62	73,1	98	96,8	134
51,8	27	64,38	63	73,87	99	96,8	135
51,83	28	64,38	64	73,92	100	97,75	136
53,25	29	64,38	65	74,52	101	101	137
54,76	30	64,78	66	75,65	102	101,2	138
55,08	31	64,97	67	75,68	103	101,2	139
55,48	32	65,45	68	76,5	104	104,5	140
56	33	66	69	76,5	105	109,25	141
56,16	34	66,22	70	76,5	106		
56,58	35	66,4	71	76,54	107		

4 Desk study Possible Alternatives

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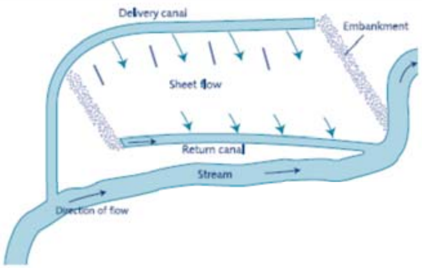
<td>
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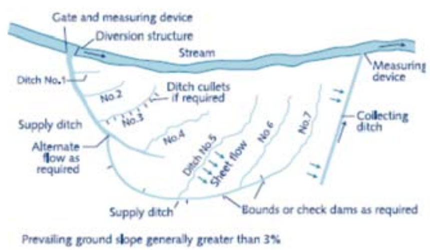
<td>
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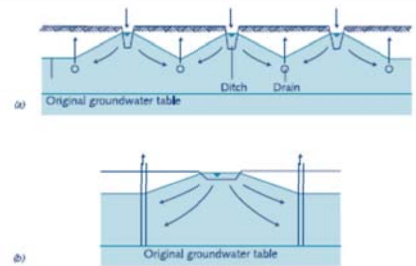
<td>
</td>
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<tr>
<td>Flooding technique</td>
<td>Latteral ditch pattern</td>
<td>Direct recharge in shallow (a) and deep aquifer (b) with drains and boreholes as recovery method</td>
<td>Water pyramid. Purification of saline water by condensation.</td>
</tr>
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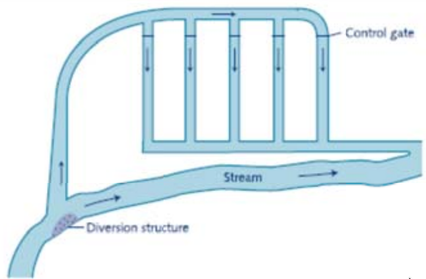
<td>
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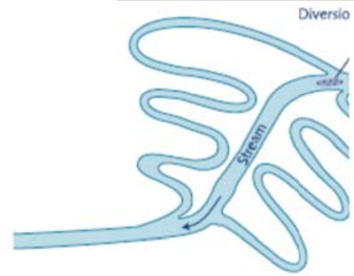
<td>
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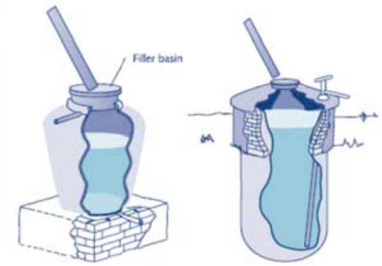
<td>
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<tr>
<td>Ditch and furrow method</td>
<td>Dendrite ditch pattern</td>
<td>Contour ditch pattern</td>
<td>a) Ferro cement jar b) partially underground tank</td>
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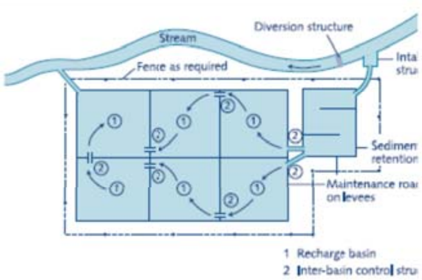
<td>
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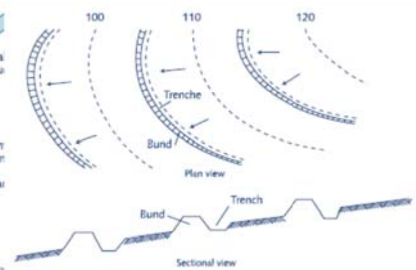
<td>
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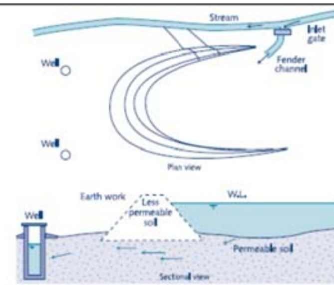
<td>
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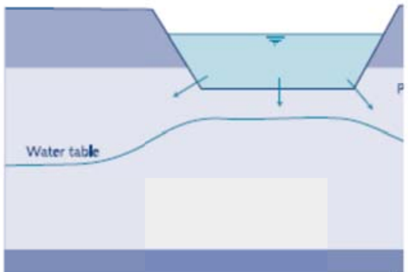
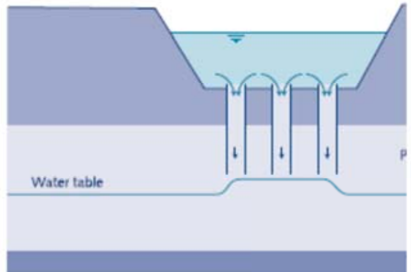
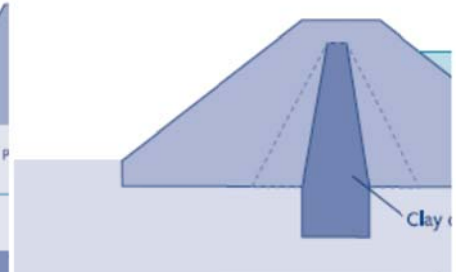
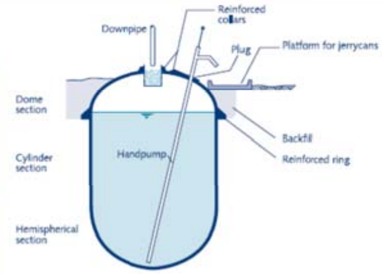
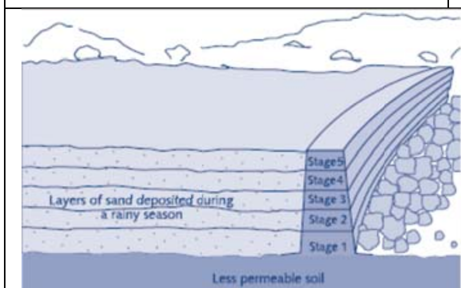
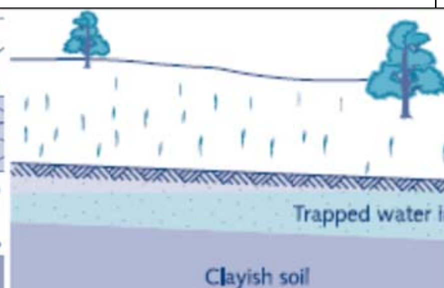
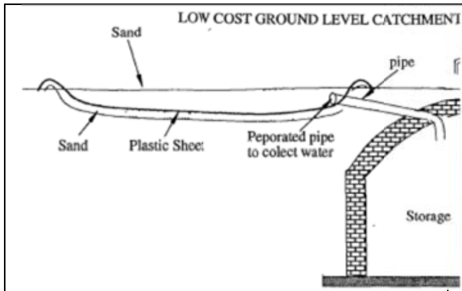
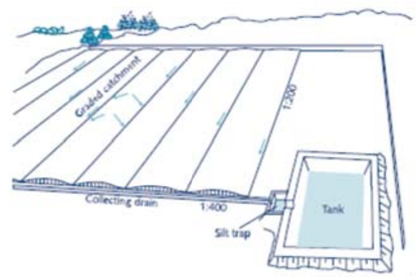
<tr>
<td>Recharge basin</td>
<td>Schematic diagram of contour bending</td>
<td>Schematic diagram of percolation tank</td>
<td>Semi-spherical underground water tank</td>
</tr>
</table>

			
Recharge pit	Recharge shafts	Cross-section of a small earthen dam with an impermeable clay core	Simple underground rainwater storage well
			
Sand dam	Sub-surface clay dam	Sub-surface masonry dam	Rainwater filter system built in down-pipe

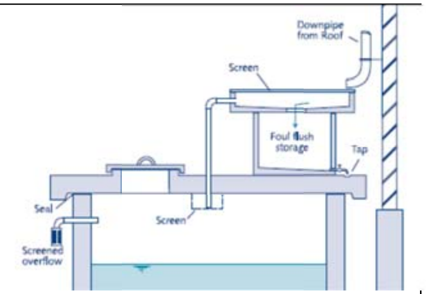


Low cost ground level catchment

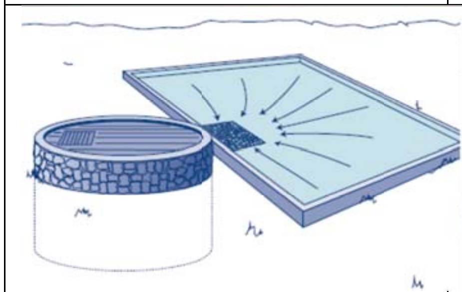
Simple roof catchment and storage



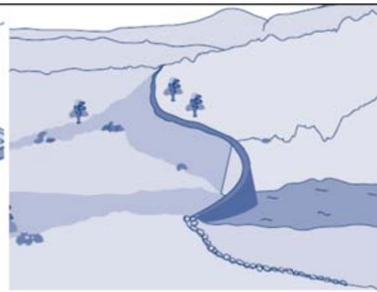
Large ground catchment



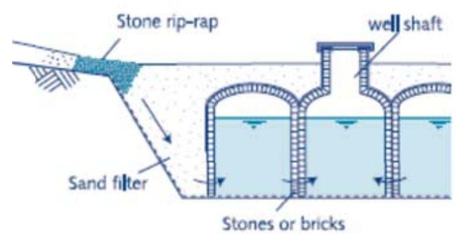
Arrangement for diverting the first foul flush



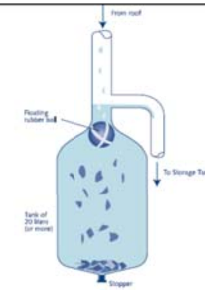
Small ground catchment



Rock catchment



Roof catchment and storage of rainwater (withdrawal by simple handpump)



Simple first flush division

5 Rainfall Data

Precipitation (mm)	January	February	March	April	May	June	July	August	September	October	November	December	Total
1995	116,9	218,5	319,7	99,5	25,2	0	0,2	30,2	4,6	8,9	5,2	45,2	874,1
1996	133,6	335	154,6	64,4	88,7	0	13,1	6,3	0	17,4	24,7	53,5	891,3
1997	55,6	152,7	281	118,4	60,6	38,5	16	0,9	4,4	15,9	125	194,4	1063,4
1998	377,6	89,9	235,9	136,6	40,7	0	0,5	5,9	34,4	15,9	20,3	75,5	1033,2
1999	136,9	213	164,3	234,1	30	32,6	13,4	0,3	37,3	1,1	66,2	115,2	1044,4
2000	96	45,8	349,4	124,5	64,2	31,5	31,1	4,5	19,5	45,4	113,6	233,9	1159,4
2001	313,8	205,3	224,9	139,5	6,9	0	5,1	11,7	3,4	78,8	21,1	146,8	1157,3
2002	314,7	186,4	335,7	170,2	12,8	7,4	10,7	26,6	54,5	7,6	197,3	224,3	1548,2
2003	157	76,7	106,7	60,5	24,1	1,3	0,1	0,6	2,7	0,9	19,9	116,6	567,1
2004	212,5	284,7	106,2	183	37,1	43,7	0	22,8	3,3	85,4	240,2	400,1	1619
2005	161,4	91,4	248,5	84,6	93,5	0,3	0,7	0	12,6	2,9	6,4	27,8	730,1
2006	97	123,7	290,5	277,7	56,1	8,9	38,8	57,5	5,3	33	57	361,8	1407,3
2007	65,2	232,8	124,6	197,6	13,6	5,7	16,7	14,6	11,9	35,5	11,9	67	797,1
2008	308,4	209,3	138	155,6	72,8	11,6	2,6	0	9,2	187,3	60,8	129,7	1285,3
2009	16,8	324,9	116,9	61	56	0,3	0	17,8	0	34,3	39,3	66,2	733,5
average	170,9	186,0	213,1	140,5	45,5	12,1	9,9	13,3	13,5	38,0	67,3	150,5	1060,7
standard deviation	110,0	89,0	88,1	64,3	27,4	15,9	12,0	15,9	16,2	48,9	71,8	113,2	
maximum	377,6	335	349,4	277,7	93,5	43,7	38,8	57,5	54,5	187,3	240,2	400,1	
minimum	16,8	45,8	106,2	60,5	6,9	0	0	0	0	0,9	5,2	27,8	

6 Work Plans

Work plan I Mattijn & Emanuel for week 16 – 20 2010
Visiting villages
Collecting rainfall data
The following villages will be visit

Ward	Village
Mnima	Lipwindi Mtama Kilimahewa
Njengwa	Chiwindi Nang'awanga
Mtiniko	Shaba Malamba Malanje Mtopwa
Nitekela	Niyumba Migombani
Kilomba	Mkahara Nachuma
Chawi	Bandariarusha Ngorongoro

The first visit contains of out of two parts.
Discussion with chairman, village councils and water committees
Village analyses
The discussion will focused on:
Actual water resources

- How many months available
- Quality
- Quantity
- Costs
- Water supply problems
- Risk boreholes
- Complex geology
- Change of not hitting of aquifer, low recharge
- Difficult to maintain + cost
- Possible alternatives

- Which alternatives do they think are suitable

What they think about

- Improving shallow wells, make it protected. Introduce radials
- Roof water catchment
- Hard surface water harvesting/ground level catchment
- Satisfying demand
- Where can it be done?

The analyses of the village will focus on

- Analysing roof potential
- Analyses improvements needed for shallow wells
- Analyses possible places hard surface water harvesting/ground level catchment

The second village visit will be done after a few days to give the village time to discuss. Not much time is needed for the second visit.

Before visiting a village an appointment needs to be made with the village. For this reason there will be only two village-visits per day.
The villages visits are divided in two sections. Section one will be visited in the first two weeks and contains 8 villages. Section two will be visited in the last two weeks and contains 7 villages.
The villages are grouped in pairs which are located close to each other.

Section one
Bandari Arusha (1)
Ngorongoro (1)
Nachuma (2)
Malanje (2)
Mkahara (3)
Malamba (3)
Shaba (4)
Mtopwa (4)

Section two
Lipiwidi (5)
Mtama (5)
Miyumba (6)
Mogombani (6)
Kilimahewa (7)
Chiwindi (7)
Nang'awanga (8)

	Week 1	Week 2
Monday	Appointments Bandariarusha, Ngorongoro, Nachuma, Malanje	Meeting Mkahara, Malamba
Tuesday	Collecting of rainfall data and meeting Bandariarusha, Ngorongoro	Meeting Shaba, Mtopwa
Wednesday	Meeting Nachuma, Malanje	
Thursday		
Friday	Appointments Mkahara, Malamba, Shaba, Mtopwa	Appointments Lipiwidi, Mtama, Niyumba, Migombani
Saterday		
Sunday		

	Week 3	Week 4
Monday	Meeting Lipiwidi, Mtama	Meeting Kilimahewa, Chiwindi
Tuesday	Meeting Miyumba, Mogombani	Meeting Nang'awanga
Wednesday		
Thursday		
Friday	Appointments Kilimahewa, Chiwindi, Nang'awanga	
Saterday		
Sunday		

Midterm discussion

Based on the first work plan we have had a small discussion about the progress of the results. The following list gives an overview of the progress.

Ward	Village	Midterm result
Mnima	Lipwindi Mtama Kilimahewa	Incomplete Incomplete Incomplete
Njengwa	Chiwindi Nang'awanga	Incomplete Incomplete
Mtiniko	Shaba Malamba Malanje Mtopwa	Incomplete Completed Completed Completed
Nitekela	Niyumba Migombani	Incomplete Incomplete
Kilomba	Mkahara Nachuma	Completed Completed
Chawi	Bandariarusha Ngorongoro	Completed Completed

As can be seen from the overview, 7 of the 8 villages are completed. The following villages will be done according to the primary work plan.

From the discussion we concluded that the actual plan (two village visits a day) is not always achieved. The following gives a small overview of the reasons for the delays

- Driver ill, not possible to hire a driver from the district office (2)
- Drivers are in the field (2)
- Car at the garage (1)
- Preparation AMREF Mkuranga staff (1)
- Field trip AMREF Mkuranga staff (2)
- Visit Mister Msola (human resources, AMREF DAR) (5)
- Preparation EU visit (6)

Coming activities

- Finish village's visits, to get an overview of the ideas and opinions of the residents of the villages, to discuss possibilities out of the desk-study and to analyses the potential of the villages.
- Make appointment with constructors and visit the hardware store to obtain an overview of the actual prices of materials. To create a comprehensive overview for the cost-benefit analyses.
- Obtain a socio-economic report about the region Mtwara from regional office to get an overview of the socio-economic aspects of the region. The socio-economic report which is available is from 1997 and out-of-date.
- A follow up is needed to obtain the borehole report and pump tests of phase 1 from the constructor. This is still not provided by the constructor. Those data are needed to analyse the success-rate of the drilled boreholes and setting up of the database.
- Maps of region need to be obtained, from one of the following institutions/persons: DWE/Agricultural office Naliendele/Ruvuma/Regional office.

7 General strategy of village meetings

(for village council, water committee and others)

1. Introduction will be done by village chairman and village executive officer.
2. Introduction of AMREF, our names, nationalities, capabilities
3. We start to tell about the projected planning of the construction of a borehole in this village. The theoretical background of the functioning of a borehole, the pipelines to a tank, to need of a submersible pump by using diesel or electrical pump by using solar energy the drinking points scattered among the village. We make the comparison with previous projects from Finnwater and JICA, we explain that likewise those boreholes it is possible that there is no water due to technical breakdown or lack of maintenance or over pumping by high demand in dry season. In this case, there needs to be alternatives to overcome those periods of breakdown.
4. Give village time to think and let them talk by rising of hand
5. Small hydrology lesson. Explanation of water-cycles
6. Introduction of possible alternatives. Our alternatives are introduced by using of pictures of working systems and sketches of the functioning of the methods. The follow alternatives will be presented:

- Shallow wells, placing of concrete rings, when water is found place permeable rings. Put on a slab with hand pump. With improvements like radials (which can double the recharge of the well) with smaller permeable rings to increase the depth by lowering of groundwater level.
- Subsurface ground catchment is possible in relative flat, sandy areas. Low runoff, high infiltration. Have an impermeable layer subsurface (at a depth of 1-3 metres), this can be concrete/good quality plasic/shelter. Place a drain on the bottom. Drain to a tank for storage, or use sand as storage and create an artificial aquifer for a shallow well (drain will function as radial). By infiltration field of sizes of soccerfield (depth 1.5 metres) a retention area is created for 200 households.
- Hard surface harvesting, by using of hard (concrete/cement) materials on a small slope leading the water to constructed tanks.

- Roof catchment, first of all the introduction of gutters is needed, the introduction of splashguards will be mentioned but has low priority, because there is not yet experience with gutters. Introduction of small tanks made of local materials. The need for a slab (malaria, evaporation).

7. Give village time to think and let them give comments by rising of hand.

8. Conclusion. We are going to look to the mentioned alternatives and going to calculate the potential of those alternatives

8 Minutes Village meetings

Village: **Mtopwa**
Date: 07-05-2010
Location: In village
Attending: Mwalami R Mpota (chairman of subvillage Mtopwa)
Emanuel Fungo
Mattijn van Hoek

General information
Names of subvillages
Mtopwa
Rahaleo
Pachani
Majengo

Actual water resources

Water from the valleys b some streams. 3-4 hours for round trip. Possible for use bicycle, but last part needs to be done by walking.

Dry season no water in the streams. They have option to go to Janjamba where a big swamp is located. This contains water for long period. A round trip is 3 walking hours

Water from streams no smell, but during dry season colours changes to iron. Taste is bitter. Water from swamp is colourless, no smell. Taste is bitter. Bitter like beer. Some sort of salt not like lemon not like beer, hard to explain.

Small swamps of stagnate water fetch water by rains.

Infiltration is very low, water can stay for one day on one place.

All surrounding villages fetch water at the valley no constructions are known in the area.

Summary village meeting

The meeting was attended by 18 men. No chairmen, no village executive officer.

4. Give village time to think and let them talk by rising of hand

Shallow wells in the valley. Some years ago they are dug by hands. Depth of 8ft (2.5 meter). Deeper might be a solution.

Not possible for shallow wells near the villages. Only in the valleys.

They don't trust rainwater. Roofs can be very dirty.

Finding open space for soccer field dig a shallow well next to it. Concrete rings with infiltration which leads to the wells.

7. Give village time to think and let them give comments by rising of hand

All seen as suitable options for the area.

Village: **Nachume**
Date: 30-04-2010 & 04-05-2010
Location: Village office
Attending: Venance Chiamba (village executive officer)
Emanuel Fungo
Mattijn van Hoek

General information
Number of households 255
Population of village 1267
Names of subvillages
- Dohome
- Bwanani
- Chemcheni

Actual income is agriculture. Cash crops are cashew nuts. Food crops are cassava and rice.

Actual water resources

Nearby is a big valley with several local shallow wells. It will take 1 hour for a return trip. The demand is 4 buckets of 20 litres per household. The people will use more water when it will be available next to the door. Assumes 6 buckets per households.

In the dry period the price will go up to 400SH per 20 litres. While the water cost in the wet season 200 -250 SH. AMREF is paying 8-10000SH per hour. Fetching of water is strenuous and time consuming. When water will come closer to home they will spent more time on the field (and not on sleeping). Go back to the field early before the sun is too hot. By rain buckets outside. There is enough rain, but no facilities to store. The shallow wells in the valleys are used by 4 villages in the dry season, namely Malamba, Kiromba, Mpanyani, Misufini.

According to the village executive officer 13 houses have an iron sheet roof. He assumes that after 10 years 50% of the houses will have iron sheet.

Iron sheets cost 16.500SH, size is 4 * 10 ft (3 meters)

Summary village meeting

04-05-2010

6 women and 5 men of the village council and water committee are attending the meeting. 29 men and 28 children are visitor of the meeting.

4. Give village time to think and let them talk by rising of hand

The better source over here as a lambo. This is a basin what is dug to collect the water

Maybe the lambo should locate in the valley to collect rainwater and surface water

Lambo located near the village, well next to the lambo so water flows to the well

Possibility of tanks by big roofs. Surface rainwater harvesting

What about the thatch roofs, because we have taken measurements of the roofs with iron sheets

Maybe the lambo need to be filled with surface water, but this is dirty how is it possible to clean this before entering the basin?

Is afraid of not digging a borehole because villages nearby already have had a survey.

Bricks and cement are the only materials which can be used to make tanks impermeable. Maybe its possible to construct a tank of makonde clay. Maximum size of 100 litres.

Digging a hole of 1m3 will take 2 hours work and the price will be 4000sh

7. Give village time to think and let them give comments by rising of hand

The people who are attending the meeting are positive about the alternatives. All the alternatives can be feasible in the region.

Village: **Ngorongoro**
Date: 20-04-2010 & 27-04-2010
Location: Village office
Attending: Musa dadi Likulunga (village chairman)
Emanuel Fungo
Mattijn van Hoek

General information
Number of households 243
Population of village 781
Adults
Men 253 Women 278
Children
Men 100 Women 150
Year of data 2009/2010

Actual water resources during rainy season

Stagnate water of small ponds scattered around the village. After July, there is not any water in the ponds due to infiltration/evaporation.

The swamps or local unprotected shallow wells in the valley have a maximum depth of two meters. Digging deeper does not result in an increase of water.

By rain there is collecting of water by pans and pots (placing it on the place where the most water is dripping in one point. By heavy rain 3 buckets of 20 litres and by small rain not even 1 bucket.

Actual water resources during dry season

The source for the collecting of water is the borehole (drilled by JICA in 2000) in Bandariarusha. This is needed from July until March. The distance for walking is 2.5 hours without bucket and around 3 hours with bucket, what result in a total of 5.5 hours. When the pump is not functioning the water is collected from a big pond/swamp fed by the Ruvuma River. According to their interpretation, the borehole is not functioning 3 times monthly. The cost of 1 bucket (20 litres) is TSH 50.

In Ngorongro are 7 houses with a roof of iron sheet.

During dry season 10 litres/ person/ day is a lot.

Follow up

Appointment made for 21-04-2010 (postponed to 27-04-2010) at 10.00am (postponed to 15.30pm) for discussion about alternative water sources.

Attending:
Village chairman
Village executive officer
Village council
8 member's water committee

Summary village meeting

Tuesday 27 March

The meeting is attended by the village council, village chairman, village executive officer, water committees. In total 20 (?) people where attending this meeting in the village office.

The attending women have said that they prefer that the men give comments.

4. Give village time to think and let them talk by rising of hand

Construct shallow wells, comments said that Finnwater has construct 3 20-rings shallow wells with hand pumps, after completion those shallow wells did not provide any water. First thought was not working of pumps, but after removing slabs, no water was founded in the wells.

Construct rambos/lambos (local name) is a underground tank made of concrete, 16 by 9 metres with slab. Sand is removed by using machine.

Using of roof water harvesting. Is seen as good and the most needed option but not sufficient number of roofs

7. Give village time to think and let them give comments by rising of hand

It is hard to give comments on methods that they have never seen in this area.

Shallow wells is not feasible for this village

The soil is very sandy

Near to village are two small streams (editor: circa 0.5L/s) by storing this water you can overcome 3 dry periods (editor: one dry period is 6-7 months).

General personal conclusion/impression

Shallow well not feasible

Roof surface not sufficient for creating coverage

Hard surface harvesting seems useful alternative if the small streams near the village are used. Create two infiltration fields, nearby the two streams. Together with the rainfall seems it to be a suitable option to bring the drinking points closer to the village.

Construction of borehole seems to be useful alternative if the field survey will find an aquifer.

Village:	**Bandariarusha**
Date:	20-04-2010 & 27-04-2010
Location:	Village office
Attending:	Ismael A Mkoba (village executive officer)
	Musa A Mshamu (village chairman)
	Emanuel Fungo
	Mattijn van Hoek

General information
Number of households 382
Population of village 1415
Men 694 Women 721
Year of data 2010
Names of subvillages
Bandariarusha
Arushachini
Arushaju

Actual water resources during rain season

During the rain season, the village relies on two sources, namely the active working JICA borehole and the local shallow wells. The shallow wells are like a small stream with several points with small ponds. It does not dry up in the dry season. During the rain season, it increases, but the stream stay more or less constant.

Actual water resources during dry season

During the dry period, more people use the JICA borehole for fetching water. Local unprotected shallow wells are not used for drinking sources. The big swamp nearby is used as source for water. The money, which is collected by the borehole, is sufficient for maintaining the borehole. Many villages (Ngorongo, Chawi, Nganja, Arushaju) visit the borehole during the dry season.

Responding of DWE is slowly by breakdown of pump, it can take up to 20 days before there is a respond. Opt to use local stream. Borehole is active since 2000. During the dry period there is a high demand. So there occur more breakdowns. Last 3 years more problems occur compare to previous years. The price is still 50TSH for each a 20/litre bucket.

Now the leaking of the tank is a problem. There is only one drinking point, so people need to walk a lot to fetch water. The only drinking point is in Bandariarusha.

Summary village meeting

Tuesday 27 March

The meeting was open for everyone and therefor a high amount of people were attending.

On the left side there are sitting 100 men and on the right side there are sitting 60 women. Everything needs to be explained twice, for the different groups. The input is more or less the same.

The village council, the village chairman and the water committee were attending in the meeting. It was a long, but fruitfully meeting from more than one hour on the middle of the day.

4. Give village time to think and let them talk by rising of hand

Borehole is the best option, but drinking points, which are functioning need to be installed in the subvillage Arushaju to avoid long walking distances.

Construct shallow wells, according to the people is this very good possible, mentioned is the impossibility of shallow wells in Arushaju

Construct a very big house in the middle of the village with iron sheets to collect rainwater; the whole village can fetch water from a big tank, which needs to be constructed.

7. Give village time to think and let them give comments by rising of hand

Question from the audience: There are way more thatched roofs than iron sheets roofs, what about those people, do they need to fetch water at the tanks of the people with iron sheets?

Hard surface harvesting seems to be a good option, because there a lot of areas with small slopes.

Deep borehole is first priority and need to be installed first. After this alternatives can be installed as well and unprotected shallow wells are the best option for this area.

General personal conclusion/impression

Three sub villages. For two is a shallow wells feasible, recharge will come from nearby located swamp, which is fed by Ruvuma river.

For Arushaju shallow well not feasible and hard surface is feasible according to local people, Subsurface storage is very good possible due sandy coarse soil. But is hard to understand for the local people, because they can’t visualize it.

Roof catchment can be introduced, but will create an coverage rate of 0.1% (!, 29 iron roofs on total of 250 households)

Village: **Malamba**
Date: 06-05-2010
Location: Village office
Attending: Twalib Faraji Chinanda (Village executive officer)
Nuran Issa Liyumba (Pump operator)
Emanuel Fungo
Mattijn van Hoek

General information
Number of households 445
Population of village 1708
Men 876 Women 832
Year of data 2010
Names of subvillages
Dodoma
Sokonja
Mkuranga

The source of income is based on agriculture. The cash crop is mainly cashew nut. For increasing the business for the cashew nut the want pesticides. Pesticides needs to be mixed with water. In the dry period the water is not near the fields. One tank (12 litre) is needed to spray 10 cashew nut trees. Spraying tanks needs be filled with 10mL of pesticide and 10Liter of water. The amount of trees owns by a household can go up to 2000. He has 350 trees. Few cashew nut = few profit, but still profitable. If you maintain properly you can get up to 150 kg of cashew nuts. The sell price for cashew nut is at the moment 700Sh/kg and can go up to 1000Sh/kg. The season is from October till January. The pesticides needs to be sprayed 5-6 times seasonally.

Actual water resources during rainy season

Swamps and valleys during rain season. The borehole constructed by JICA has functioned from 2005 to 2008. It has not been functioned for two years. Submersible pump was fallen in the borehole. DWE took the pump for inspection. It took a long time after returning two days functional. The JICA borehole has an depth of 180 metre. JICA placed the pump at 150 metre. Maybe the DWE placed the pump less deep, so recharge of the borehole was not sufficient.

JICA wa able to pump 15 minutes than wait for 45 minutes for recharge. It took 2 days for filling the tank. After returning pump from DWE It was possible to pump for 8 minutes and then wait for 52 minutes for sufficient recharge.

In 8 minutes they were able to fill 6 buckets of 20 litres, 120/8 min (editor: 0.25L/s).

JICA has made two points for survey. The first point is chosen by JICA because the project was almost ended. This one had not sufficient water, but 2nd point was not selected because it was too far. Japanese people have conducted the survey, by making use of VES.

Actual water resources during dry season

During the rainy period rainwater and small sources plus water from stagnate water. During dry season people opt to go to Maranje or Ruvuma river. For a round trip Ruvuma it will take 8 (!) hours by bicycle. For a round trip Maranje 4 hours.

Per bicycle, people are able to transport 4 buckets of water (in total 80 litres). The can sell it for 500 to 700 Sh/bucket. Some families have no boys, so they need to buy. Normally every household take care about themselves.

The JICA borehole was used by people from Malamba, Pjani amd Membasokani.

Summary village meeting

The meeting was attended by 6 men. One of the old members was the founder of the village.

4. Give village time to think and let them talk by rising of hand

Lambo is seen as possible option. Topography has some steep slopes. Surface water is flowing in the valleys. Construct a lambo like a big swimming pool. Valley is flowing full with water.

The better point to locate the lmbo is a big hole. Infiltration rate is high. Shallow well is impossible considering the JICA borehole.

Two options where JICA dit the survey. The other point contains for sure sufficient water.

Both the locations (the option for the lambo, and the option for the borehole) are located quite far. For the option of JICA borehole is 2.5 km and the option for the lambo is 4 km. In July and August there is no water.

20-litre cost in the rain eason 200Sh and in the dry session 500 Sh. In October it cost 1000Sh. No water no money. Therefore, the people offer to work free at the field in change for water. People are opt to go to Nachume

7. Give village time to think and let them give comments by rising of hand

It is difficult to recognize the amount of water, which is evaporating. However, in a tank of 9m3 is a loss of 350 buckets annually.

Subsurface ground catchment is seen as preferred option

Select two - three places with the size of a soccer field dig a two meters deep hole. And create a tank. Place a shallow well

Village:	**Maranje**
Date:	30-04-2010
Location:	In Village
Attending:	Village executive officer
	Emanuel Fungo
	Mattijn van Hoek

Summary village meeting

The meeting is attended by 11 women, 17 men. They represent the village council and the water committee. The village executive officer leads the meeting and the village chairman are not present.

4. Give village time to think and let them talk by rising of hand

If it is possible drill another borehole for the times, JICA borehole is not working.

Another option is to dig a big hole in the valley for entering water. Locally known as lambo.

The shallow wells in the villages will not be sufficient in providing water for whole the village. No shallow wells have been drilled in the village.

We want the new borehole and the new alternatives

This is a big village. Two boreholes will give sufficient water for village. Now it is not sufficient. They are sure about maintenance for two boreholes. In the bank account is 2.5 million TSH. Therefore, there is enough money for maintenance.

7. Give village time to think and let them give comments by rising of hand

Shallow wells will not be sufficient when drilled in the village

It is impossible to get enough water by rainwater; there are too many fetched roofs.

Rain is not enough to fill this infiltration field

Borehole is first priority

General personal conclusion/impression

Difficult meeting, not willing to think about alternatives. District water office has drilled a borehole which contains water, the tank is constructed and 8 drinking points are constructed around the village. The only thing missing is a submersible pump. By renovating this system and installing a pump many costs can be saved.

Village:	**Mkahara**
Date:	04-05-2010
Location:	Village office
Attending:	Salum Muhambwev(Village executive officer)
	Mohamedi Adiliki (Village chairman)
	Emanuel Fungo
	Mattijn van Hoek

General information

Number of households		273	
Population of village		1526	
Men	803	Women	723
Year of data	2010		

Actual water resources

Based on spring system, it's a seasonal spring during rain season actively. The spring is more or less 5 km from the village

The village Kyana is visited for fetching water during the dry season. There is also a spring, but for at long distance, around at 8 kilometres.

Households are using 100 litres per household per day.

The residents fetch in the morning an evening. A round trip takes up to 3 hours. During dry period a 20-liter bucket cost 300SH. During rain season a 20 litre bucket cost 100 sh. 4-6 buckets can be carried on a bicycle.

Not sure about good opportunities of his village. Don't have experience with nearby located boreholes.

One brick cost 100SH

Summary village meeting

1 woman, 23 men

4. Give village time to think and let them talk by rising of hand

The need tanks by large roofs, rain, water harvesting. Before AMREF borehole will be drilled

Along the valley there is a spring if they dif a hole it collapse. According to the resident rings can be the solution. The spring contains water all the months of the year. All villagers fetching water at this place.

In the village, there is no possibility of shallow wells

7. Give village time to think and let them give comments by rising of hand

So long there is need for water all the solutions that provide the village water is welcome.

9 Overview List of Elements Training ArcGIS 9.2

ArcCatalog
Content
- Polygon shapefiles
- Polyline shapefiles
- Point shapefiles

Preview
- Geography
- Table

ArcMap
Data View

Add data
- Connect to new folders

Open attribute table
Show All/Selected
Sort Ascending
Sort Descending
Summarize
Options
Select by attributes
- Get unique values
- AND
- OR

Verify
Apply
Clear Selection
Switch Selection
Select All
Add Field
Export

Data
- Export Data

Properties
- Selection
- With this symbol

Display
Transparent
Symbology
- Features
- Single Symbol
- Categories
- Unique values
- Value Field
  - Add all Values
  - Add Values
  - Remove All
  - Group Values
- Quantities
- Graduated colors
- Graduated symbols
- Value
  - Normalization

Symbol Size from x to y
- Labels
- Label features in this layer
- Label Styles
- Placement Properties

Tools
- Zoom in
- Zoom out
- Pan
- Full Extent
- Select Features
- Clear Selected Features
- Identify

ArcToolbox
- Analysis Tools
- Extract
- Clip
- Conversion Tools
  - From Raster
    - Raster to Polygon
  - To dBASE

Table to dBASE (multiple)
Data Management Tools
Generalization
Dissolve
Projections and Transformations
Define Projection
Raster
Mosaic To New Raster
Spatial Analyst Tools
Extraction
Extraction by Mask
Hydrology
Fill
Flow Accumulation
Flow Direction
Snap Pour Point
Stream Link
Stream to Feature
Watershed
Map Algebra
Single Output Map - Algebra
Reclass
Reclassify
Surface
Contour

Editor
Start Editing
Stop Editing
Save Edits

ArcMap Layout View

Insert
Title
Legend
Map Layers
Legend Layers
Number of Columns
Border
Background
North Arrow
Scale Bar
Properties
Number of divisions
Number of subdivisions
Division Units

File
Page and Print Setup
Scale Map Elements
Export Map

10 Delineating Watershed with ArcGIS

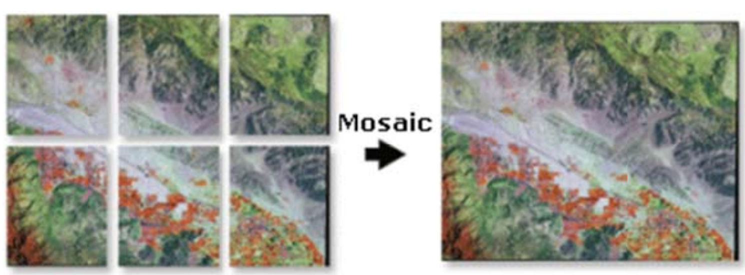
For delineating watersheds and defining stream networks, it is necessary to proceed through a series of steps. With the following process overview, the process of extracting watershed boundaries is explained.

First, the digital elevation map is collected. The source of the elevation data that is used is collected by the Shuttle Radar Topography Mission (SRTM). The Shuttle Radar Topography Mission (SRTM) obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth. SRTM consisted of a specially modified radar system that flew onboard the Space Shuttle Endeavour during an 11-day mission in February of 2000. (Farr, T.G, 2007)

The following data is collected from the NASA ftp server (ftp://e0mss21u.ecs.nasa.gov/srtm/)

S11e038.aux	S11e039.aux	S11e040.aux	S12e038.aux	S12e039.aux
S11e038.bil	S11e039.bil	S11e040.bil	S12e038.bil	S12e039.bil
S11e038.blw	S11e039.blw	S11e040.blw	S12e038.blw	S12e039.blw
S11e038.hdr	S11e039.hdr	S11e040.hdr	S12e038.hdr	S12e039.hdr
S11e038.prj	S11e039.prj	S11e040.prj	S12e038.prj	S12e039.prj
S11e038.rrd	S11e039.rrd	S11e040.rrd	S12e038.rrd	S12e039.rrd
S11e038.stx	S11e039.stx	S11e040.stx	S12e038.stx	S12e039.st

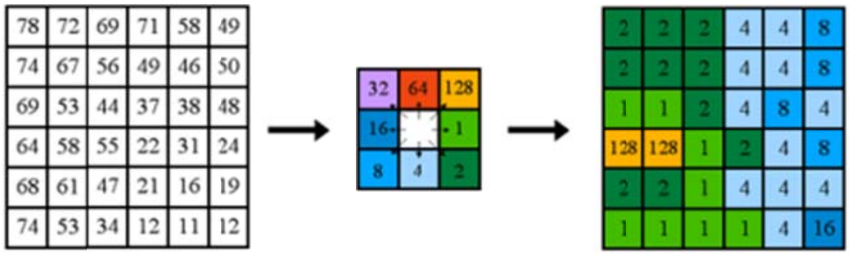
By adding the elevation data into ArcGIS 9.2 it is possible to combine the different raster into one, by making use of the model 'Mosaic to New Raster (Data Management). It allows mosaicking multiple raster datasets into a single raster dataset. The result is called a Digital Elevation Model (DEM)



The next step is analysing the DEM, if there are errors in the elevation model, there may be some cell locations that are lower than the surrounding cells. If this is the case, no water travelling into the cell will travel out. These depressions are called sinks. To fill those sinks the tool 'Fill (Spatial Analyst) is used. If there are still errors in the model the tool 'Reclassify (Spatial Analyst)' are executed and 'NoData' is put on '0' and the previous step ('Fill (Spatial Analyst)') is repeated. The result is a depressionless elevation model.

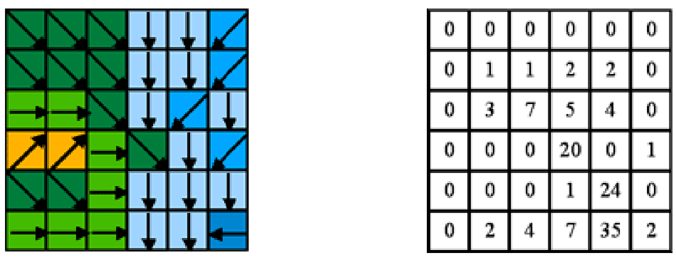
With the depresionless elevation model the flow from every cell in the raster is determined. This is done by the using the 'Flow Direction (Spatial Analyst)'.

For each cell are eight valid output directions relating to the eight neighbouring cells into which flow could travel.



Digital Elevation Model Direction Encoding Flow Direction Raster

When the Flow Direction is determined, the accumulated flow can be calculated by executing the ‘Flow Accumulation (Spatial Analyst)’. This tool will create a raster of accumulated flow to each cell. The result is a raster what shows the number of cells that flows into each cell.



Direction of travel from each cell

Number of cells that flows into each cell – Flow Accumulation Raster

The next step is a decision. What is the number of cells that need to flow into each cell for being a ‘stream’? This is done by making use of the ‘Single Output Map Algebra (Spatial Analyst). The following code is been used to set up a Stream Raster:

‘CON (FlowAcc_flow > 5000, 1)’

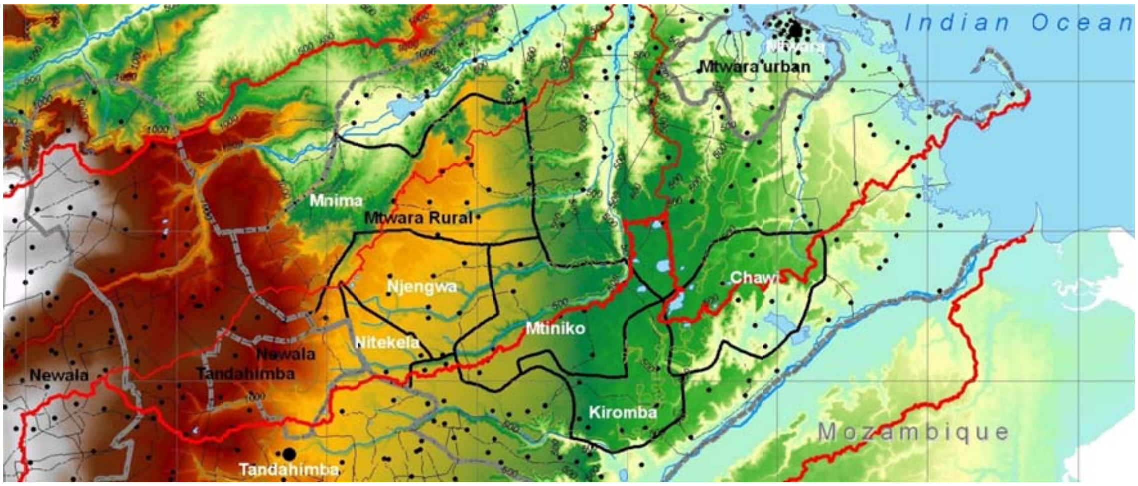
Now there is a Stream Raster created whereby all the cells which contain the flow of more than 5000 others cell is set as 1. This Stream Raster is used as input for creating a Stream Link (‘Stream Link (Spatial Analyst)’), which assigns unique values to sections of a raster linear network between intersections. The Stream Link can be used to find the boundaries of the watershed, those points are selected by ‘Snap Pour Point (Spatial Analyst)’, which will search within a snap distance around the specified pour points for the cell of highest accumulated flow and move the pour point to the cell with the highest flow accumulation.

This is all the information what is needed to determine the boundaries for the watershed. The information about the flow direction of every cell is calculated and the locations are decided above which the contributing catchment will be determined (Flow Direction Raster & Snap Pour Point Raster). Those two raster are given as input in the ‘Watershed (Spatial Analyst)’ tool and the output is a raster with the different watersheds.

This raster is converted to a polygon shapefile by making use of the following command line

‘RasterToPolygon <name raster watershed> <output location> SIMPLIFY VALUE’

Together with the tool 'Stream to Feature (Spatial Analyst)', whereby the streams of the Streams Raster are converted into a polyline shapefile the result can be seen as follow:



In the picture above, the black boundaries are the different watersheds, the small blue lines are small streams, and the normal blue lines are the main streams in the different catchments. The Digital Elevation Model is used as background.

11 Maps of Area

Density Wards Mtwara Rural

Elevation Mtwara region

Land use Mtwara Rural

Geological Formations Mtwara Rural

Project Wards Mtwara Rural

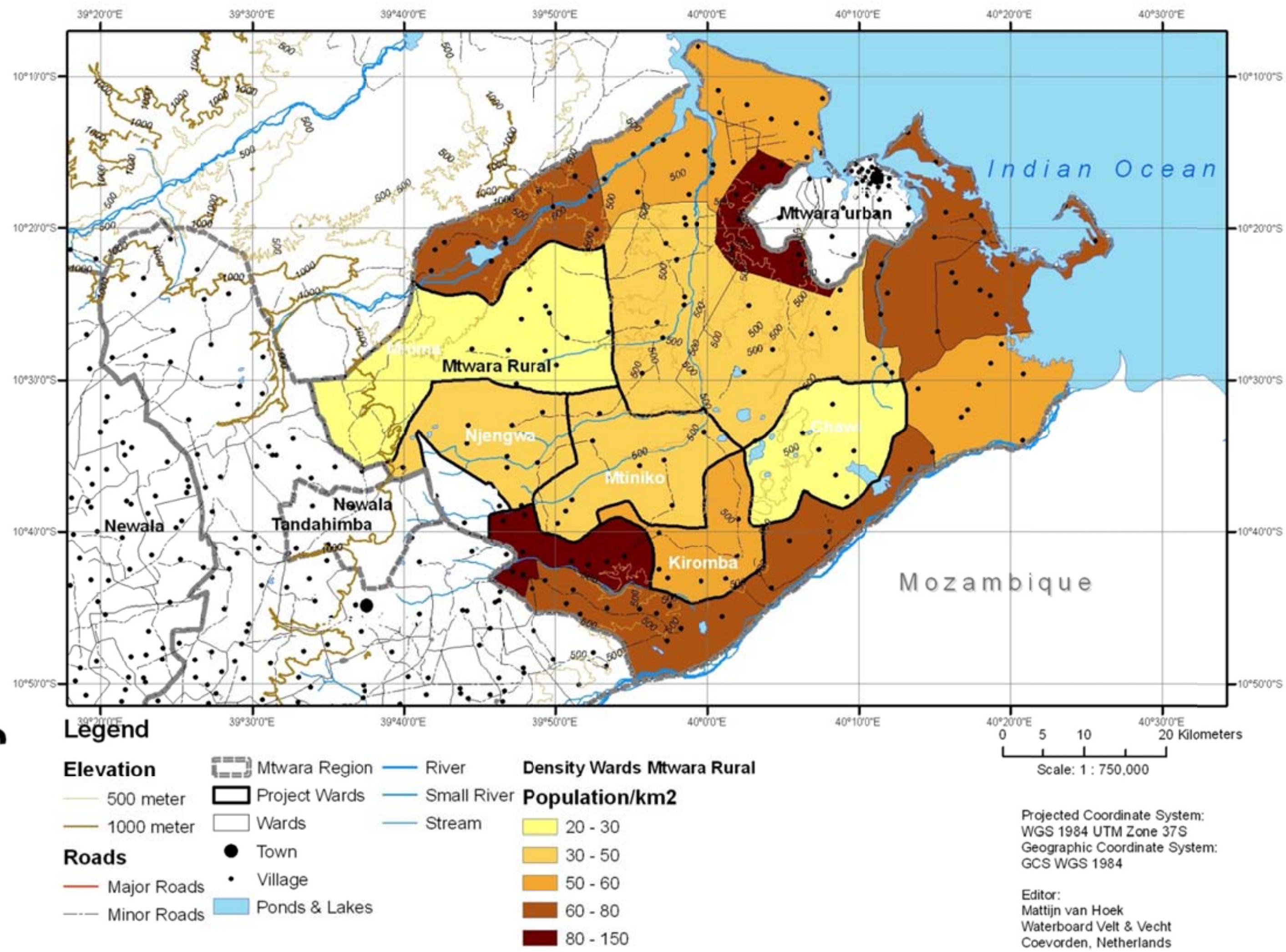
Pump Capacity Deep Boreholes (stretched elevation)

Pump Capacity Deep Boreholes (classified elevation)

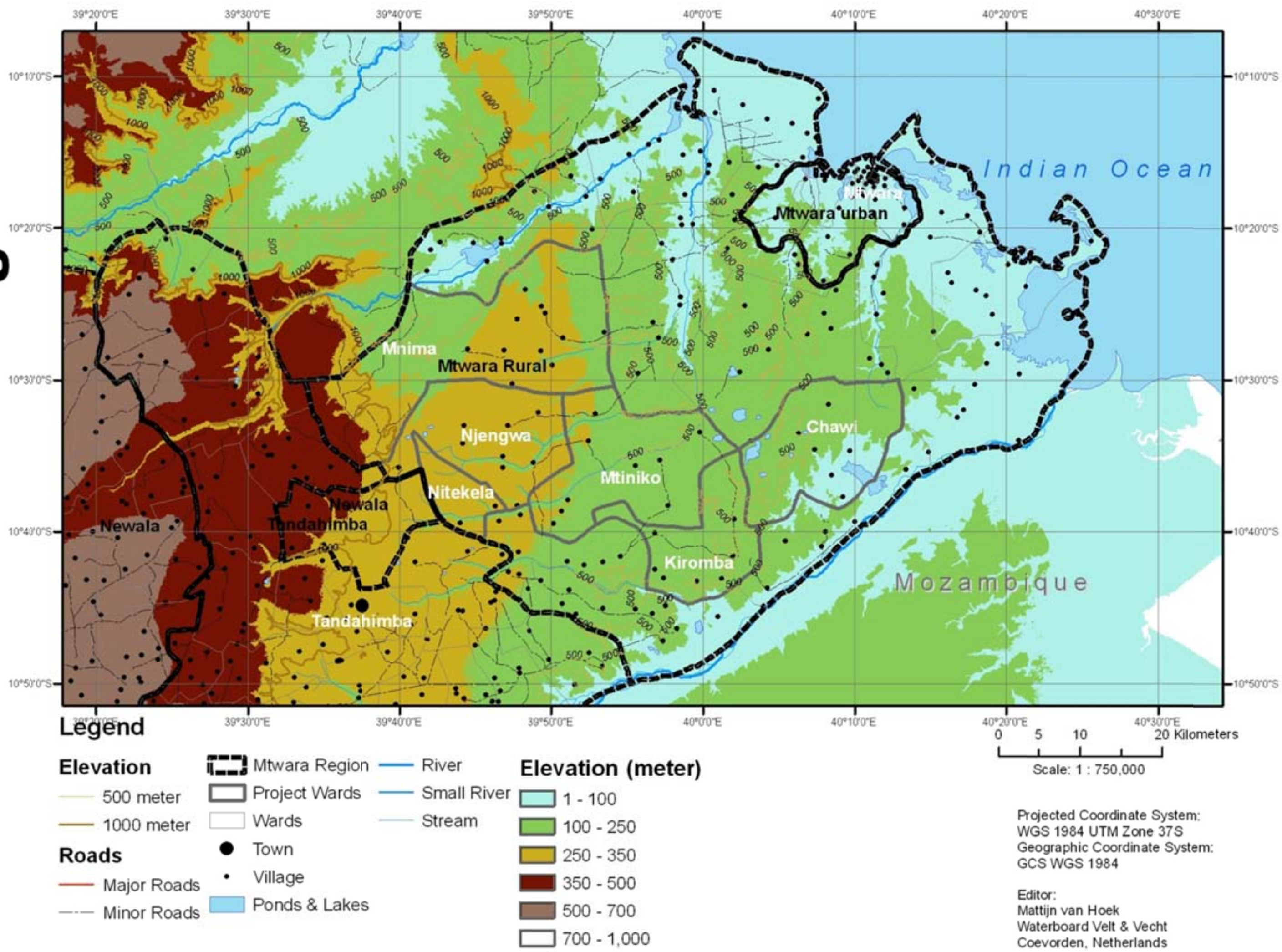
Pump Capacity Deep Boreholes (geological formation)

Tanzania – Mtwara – Mtwara Rural

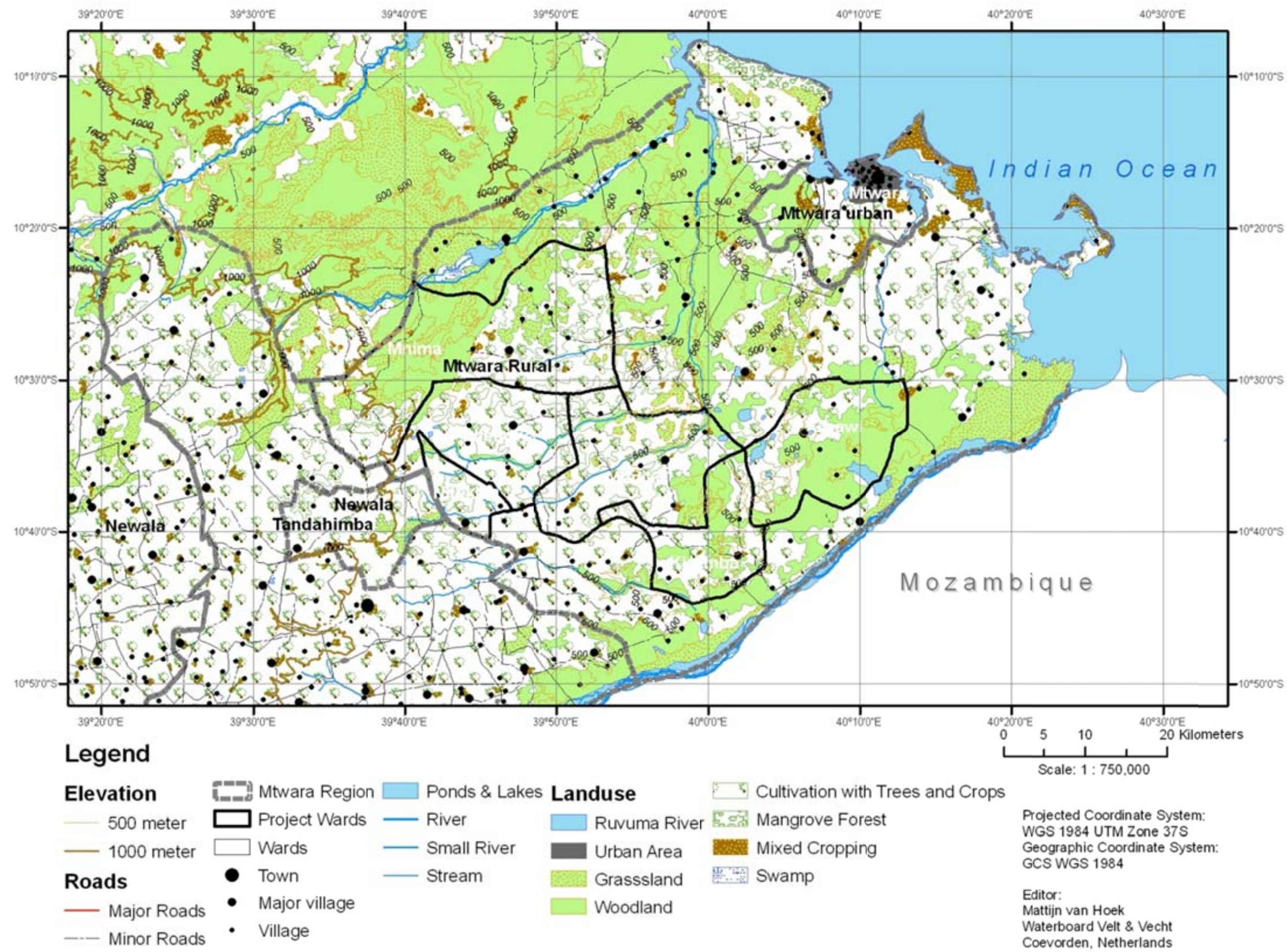
Density Wards Mtwara Rural



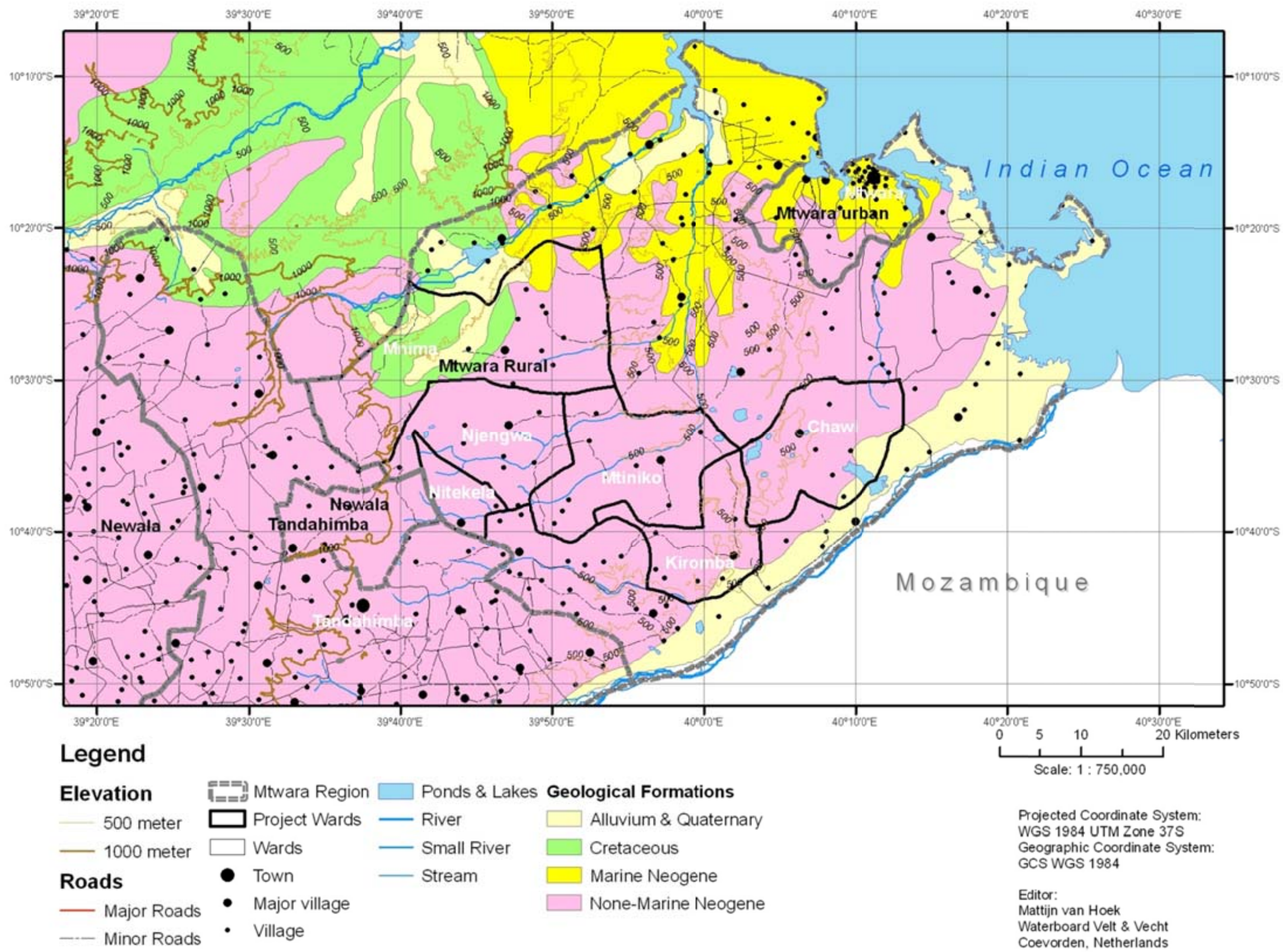
Elevation Mtwara Region



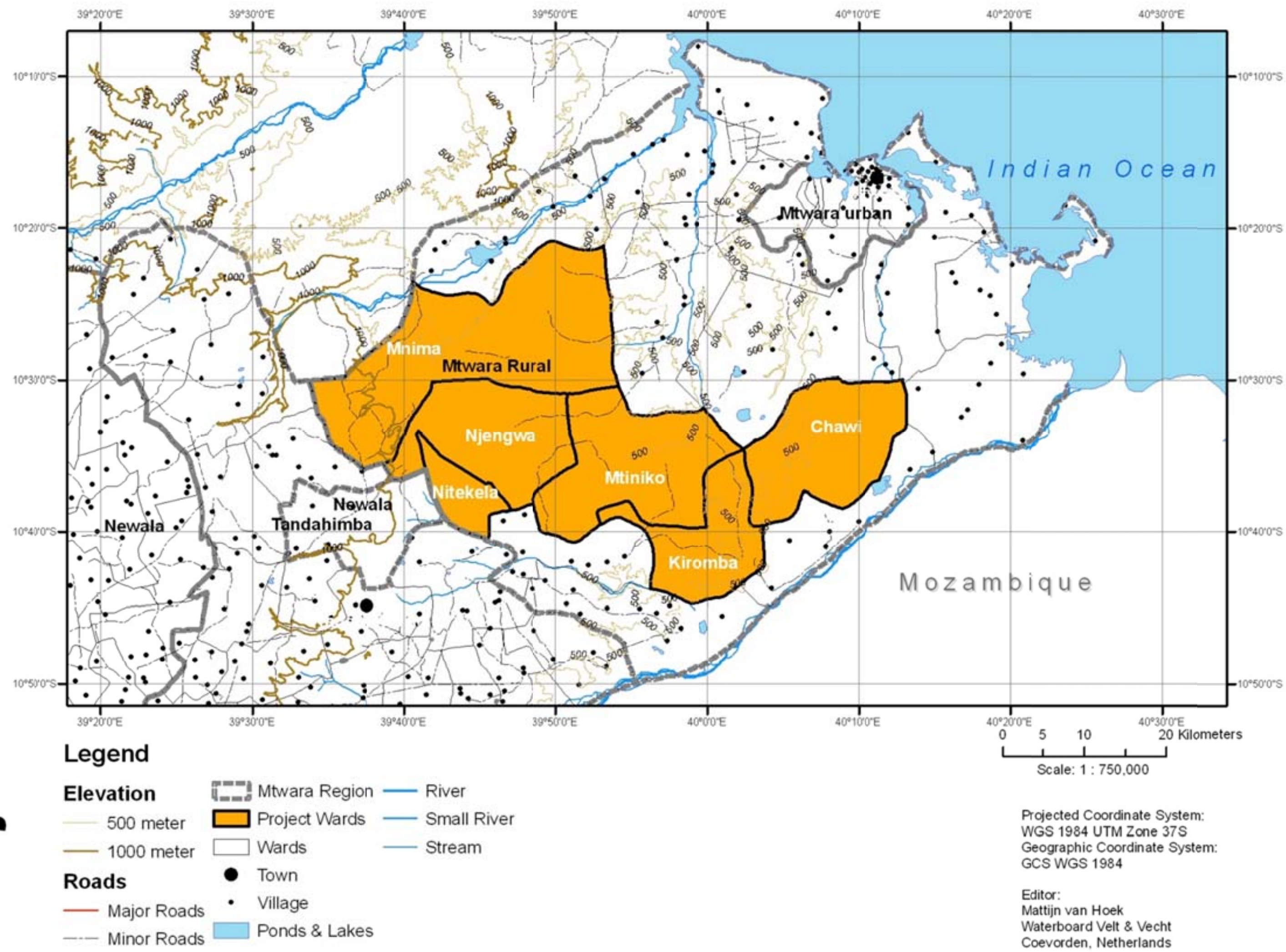
Landuse Mtwara Rural



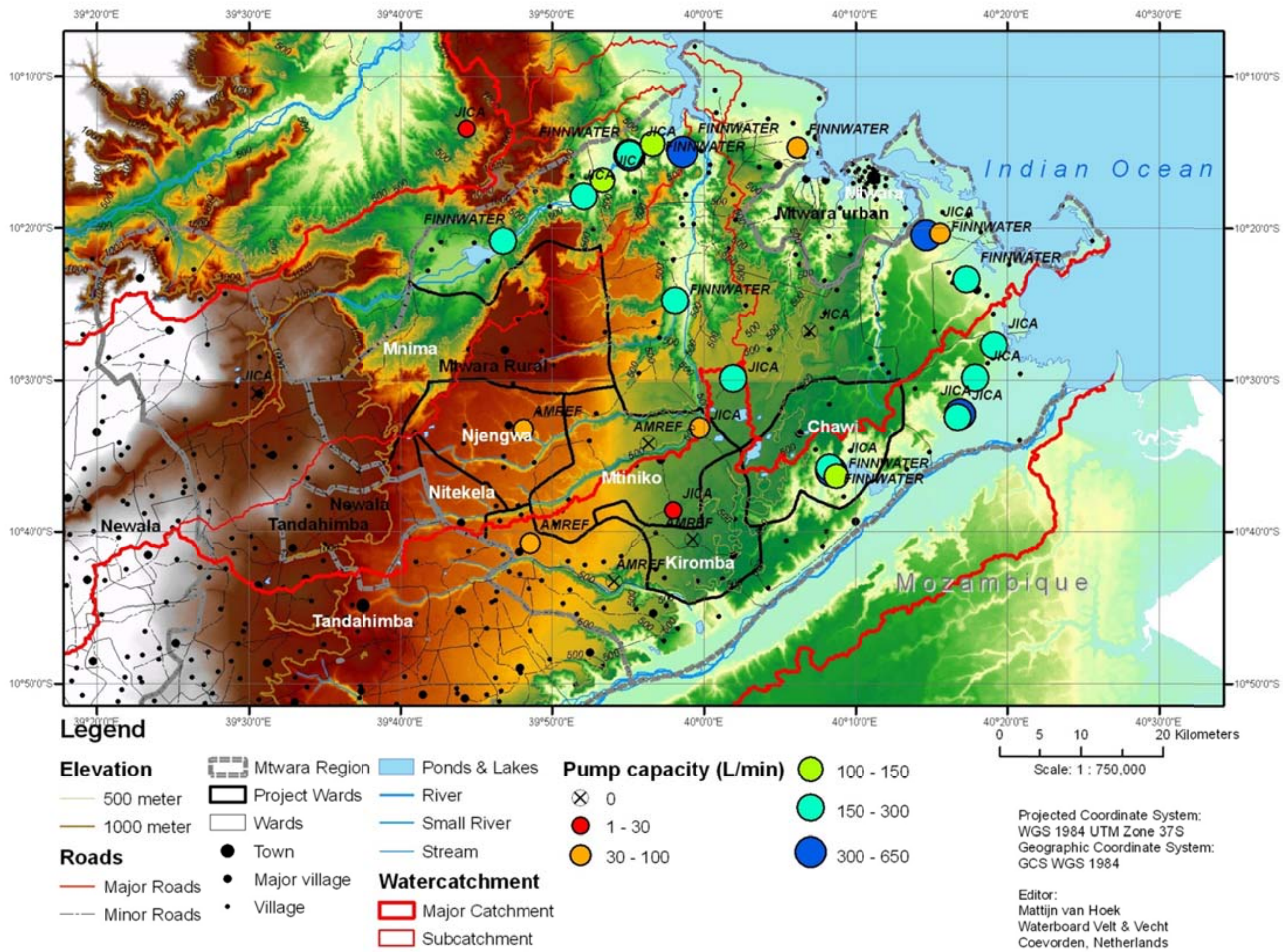
Geological Formations Mtwara Rural



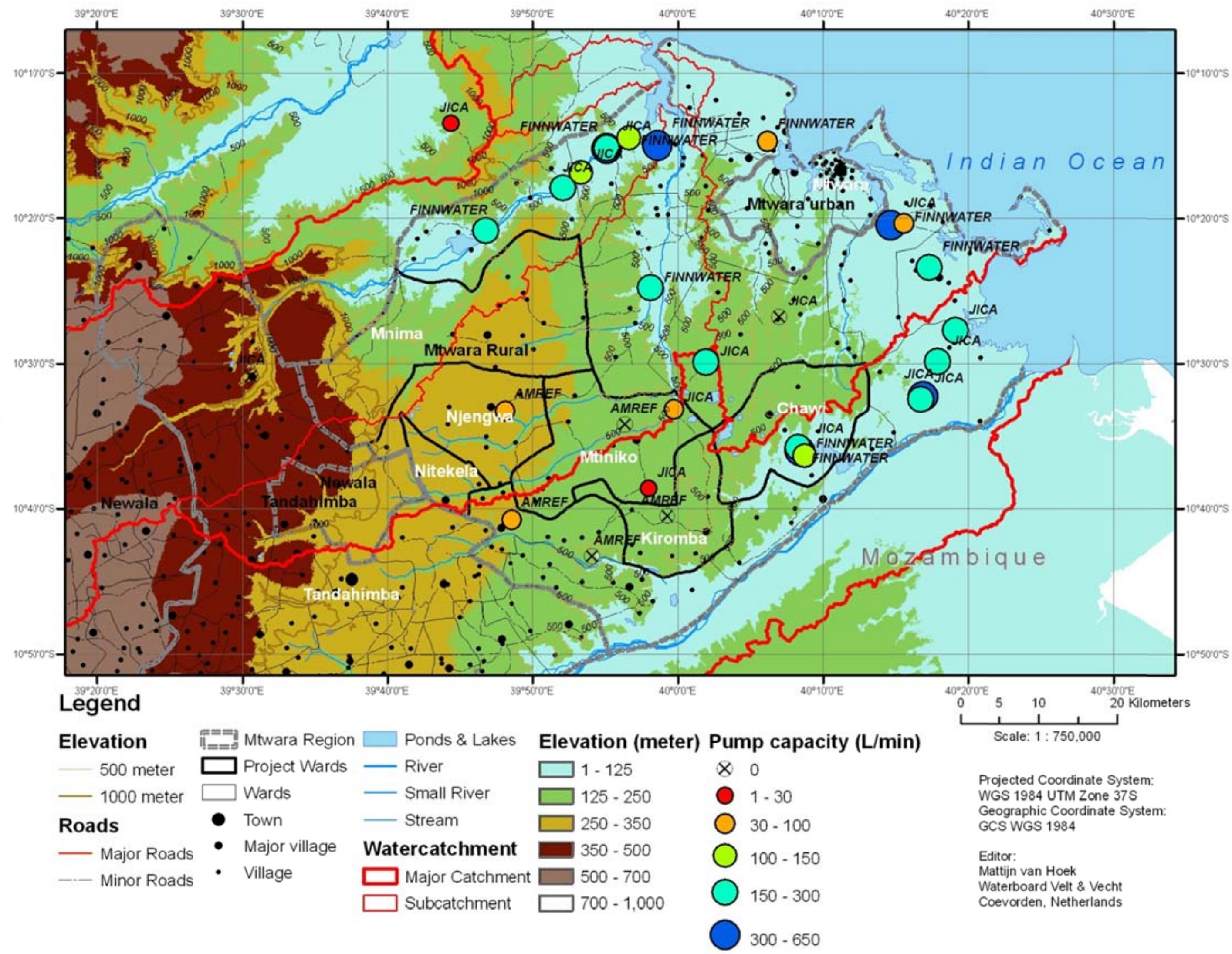
Project Wards Mtwara Rural



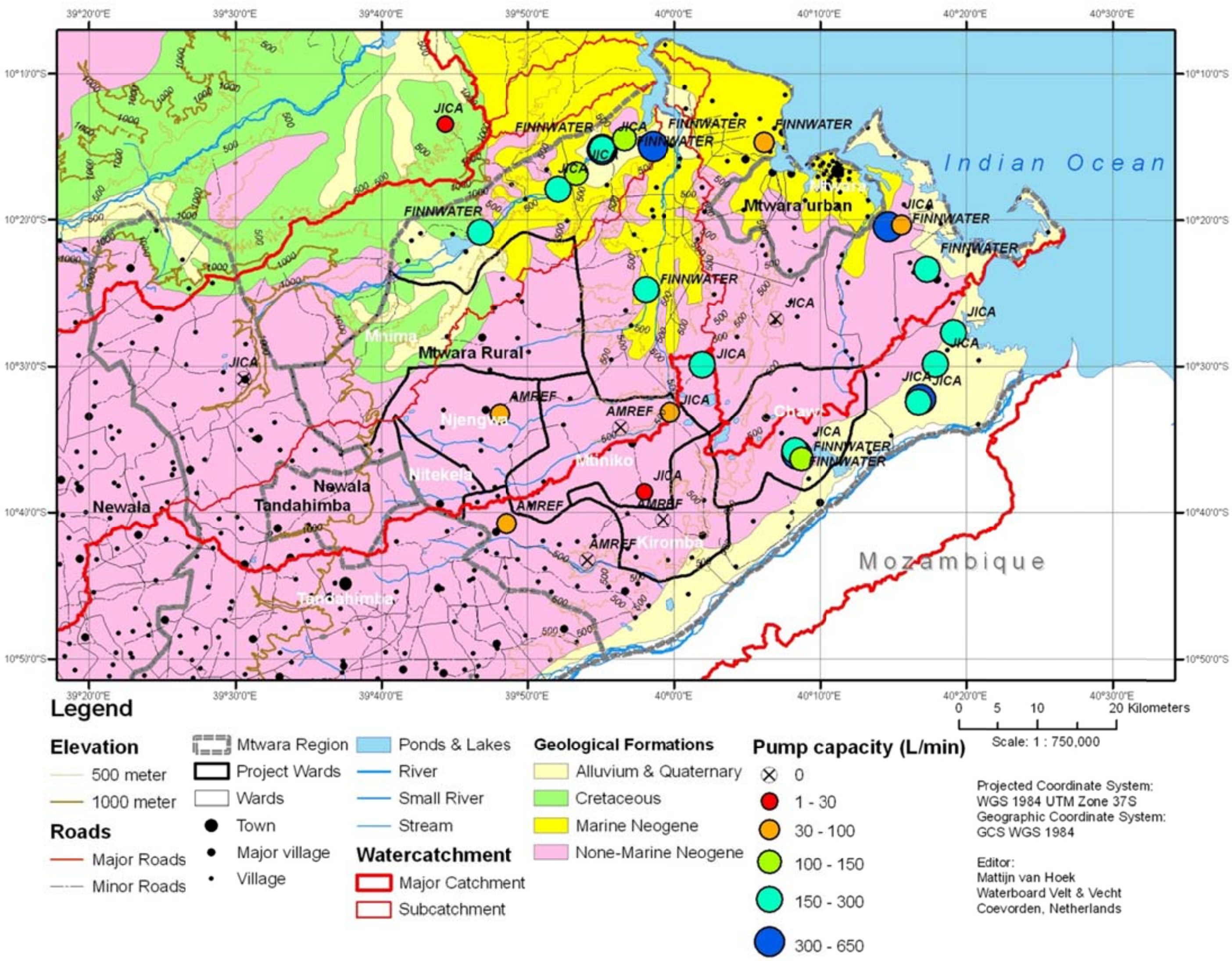
Pump capacity Deep Boreholes



Pump capacity Deep Boreholes

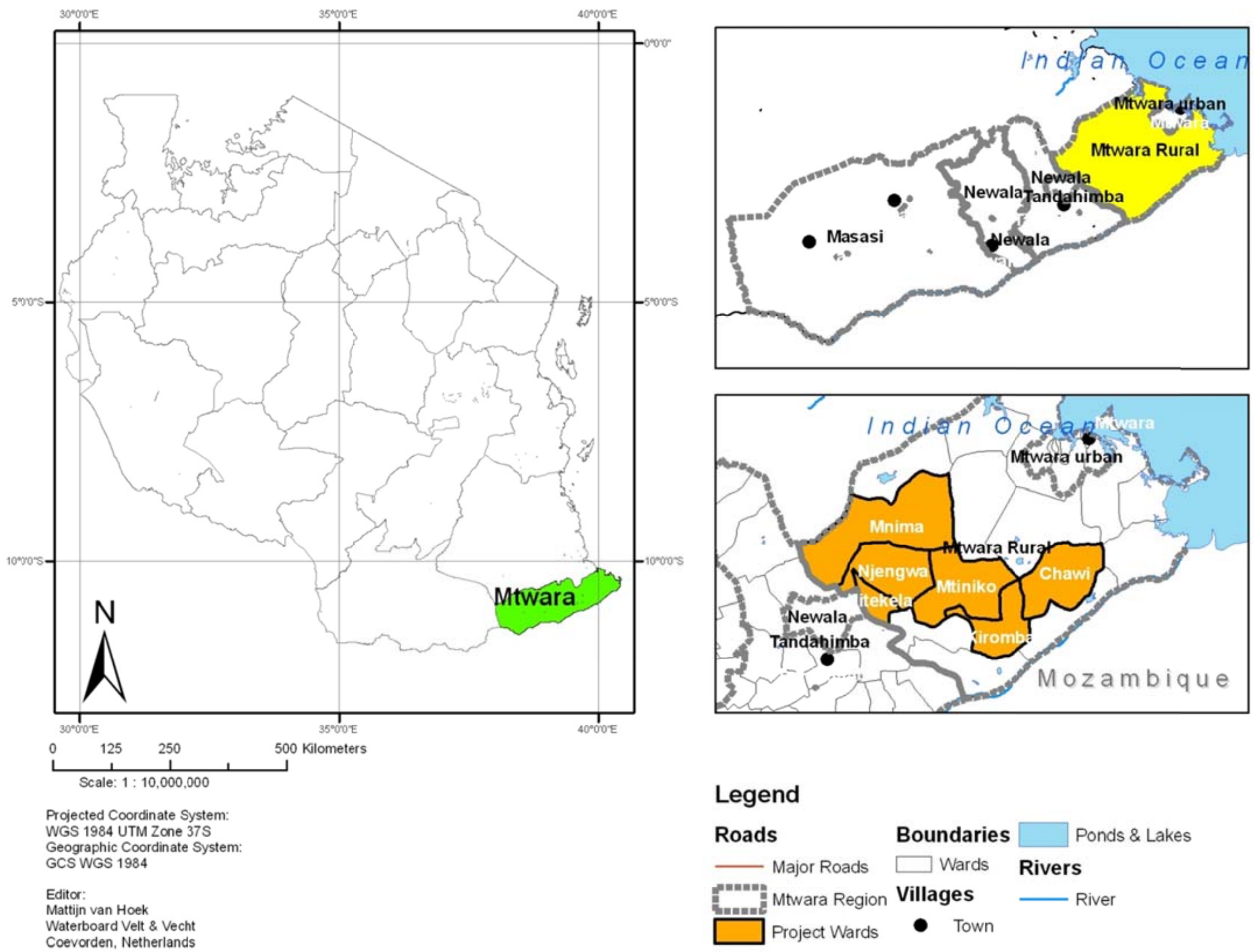


Pump capacity Deep Boreholes



XL

Tanzania - Mtwara - Mtwara Rural



12 Explanation Models

Model 1. Roof catchment with storage tank

The model is based on different aspects. The main aspects are the roof surface, the storage capacity of the tank, the annual precipitation, the material of the tank, the number of people in one household and the demand in litres per capita for each day.

The assumptions are based on the value of water (20-litre bucket) the efficiency of the roof surface.

The annual roof run-off is calculated on base of the annual precipitation the dimensions of the roof surface and the efficiency of the roof. On base of this figure, it is possible to calculate the average daily roof run-off. In the model, it is calculated in litres and buckets (20-litre).

The demand is calculated on base of two different viewpoints, namely standard demand and adaptive demand. The standard demand is based on the number of population of the household and the daily demand per capita. It is the same year round.

Adaptive demand is based on the volume of the storage facility. If the storage facility is full of water, the demand is higher than normal. When the storage capacity is decreasing, the demand is also decreasing. If the storage capacity is below 1/3 of the maximum capacity, the demand is 2/3 of the selected standard daily demand.

In the two graphs of the main page of the model there are shown the two graphs of the adaptive and standard demand are shown. The blue line is the fluctuation of the storage of the tank. This line is based on the daily water demand, the monthly precipitation and the selected storage capacity of the tank. Usually the graph of the adaptive demand is smooth when the volume of the tank is low and the graph is decreasing faster if the storage capacity is more than 2/3 of the maximum capacity if it is compared with the graph with a standard demand.

The red line shows the overflow. If the monthly precipitation is delivering more water to the tank than the maximum storage capacity there is a overflow. To increase the efficiency of the model the overflow should be as low as possible.

On the following two pages an example of the input, the assumptions, the results, the performance indicators and the bill of quantities is shown.

Input Subsurface Soil Storage

Name of ward	Average ward	**Name of village**	Average village

Select from list repetition time of annual rainfall: Propability 80% (Repetition time 1 in 5 years)

Annual rainfall: 797.1 mm

Dry months *(less or equal to 50 mm monthly precipitation)*: 7

Set Population	Set Households	Select from list the surface	Length (meter)	Width (meter)
1918	383	Soccerfield	100	60

Select from list the Material for Ground Catchment	Select from list the Depth of Field (meter)	Number of Fields	Offset (meter)
EPDM Rubber Sheet	1.5	2.0	25

Select from list where Daily Water Demand will be based on:	Liters/Capita/Day
Baseline Survey Mtwara	15

Assumptions

Value of bucket water (20 liters) TZS	*Soil Storage Capacity is based on Sandy Soil*	*Efficiency offset (%)*	*Efficiency storage (%)*	*Efficiency fetching (%)*	*Currency rate TZS : EURO*
TZS 50.00	0.34	60%	95%	95%	1722

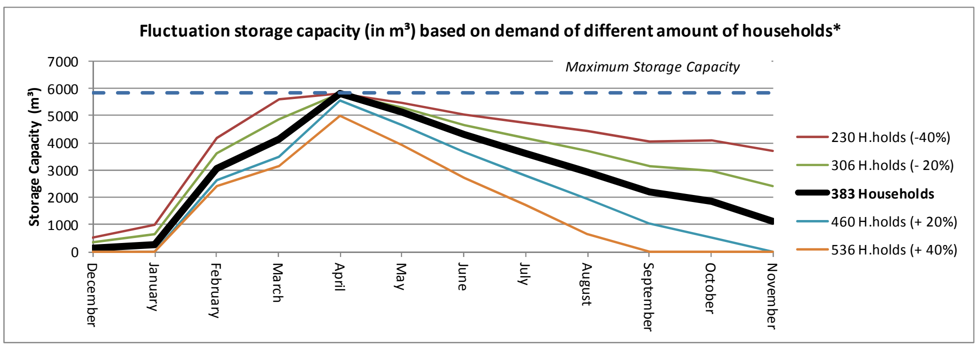
Demand, Storage Capacity & Overflow

Water Demand Village

28.8 m3/day	875 m3/month	10501 m3/year

Annual Overflow

560 m3/year



* *Based on precipitation with repetition time of 1 in 5 years (propability 80%)*

Performance Indicators

Demand satisfaction	116%		*Annual water delivered (excluded overflow) in relation to the Annual water demand*
Efficiency	96%		*Annual water delivered (excluded overflow) in relation to the Annual Catched Precipitation*
Reliability of supply	100%		*Percentages of days whereby the subsurface ground catchment contains water*
Payback time			*Value of water (based on the Annual Water Demand) divided by the construction costs*
Total months	28		
Which is equal to			
Years	*2*		
Months	*4*		
	TZS	Euro	
Equivalent Unit Cost	830,580.02	482.33	*The costs divided by the water storage of the tank (costs for every cubic meter)*
EUC/Water user	433.04	0.25	*Equivalent Unit Costs divided by the number of people who will use the tank (costs for every cubic meter/wateruser)*
Total Costs	63,331,386.40	36,777.81	*Total costs as given in the BIQ*

Bill of Quantities

N° of infiltration fields	2		Ward	Average ward
Length	100 meter		Village	Average village
Width	60 meter		Population	1918
Depth	1.5 meter			

Description of components

Labour Cost	**People**	**Days**	**Cost/day (TZS)**	**Total cost (TZS)**
Technicians	2	55	7,000.00	770,000.00
Labourers	95	162	2,500.00	38,571,428.57
	5%	*of population*		----------------
Total Labour Costs				39,341,428.57
Materials	**Unit**	**Quantity**	**Unit cost (TZS)**	**Total Cost (TZS)**
Wheelbarrow	Pieces	12	10,000.00	120,000.00
Handpump	Units	2	1,000,000.00	2,000,000.00
Drains	Metres	240	5,000.00	1,200,000.00
Concrete ring (depth 0.5 meter)	Units	10	50,000.00	500,000.00
Shovels	Pieces	23	5,000.00	115,000.00
EPDM Rubber Sheet	Sq.m	3123	6,390.00	19,954,957.82
-	-	-	-	-
-	-	-	-	-

Total material costs				23,889,957.82
Transport of Materials	Tonnes	Loads		
Hardware lorries	7	1	100,000.00	100,000.00
Total costs				
Labour costs				39,341,428.57
Materials				23,889,957.82
Transport of Materials				100,000.00
Total costs			**TZS**	**63,331,386.40**
			EURO	**36,777.81**

Model 2. Surface catchment with subsurface soil storage

This model is based on the system whereby the water is stored in the soil. This is possible by the porosity of the soil. Different soil types have different porosity characteristics. The project area is located in area with sandy coarse soil. The porosity of this type of soil is 0.34. In a bucket of 20 liters filled with sand it is still possible to add 8 liters of water.

In the input of the model there are different main aspects.

The minimum annual rainfall, by selecting the repetition time of annual rainfall. It is possible to select a repetition time 1 in 10 years, 1 in 5 years and 1 in 2 years.

The population of the village should be entered.

The dimensions of the infiltration area need to be selected by choosing the dimensions of a basketball field, a half soccer field or a whole soccer field.

The depth of the infiltration field is selected by making choice between 1 and 5 meters below the surface level.

The offset is the radius around the infiltration field, which is also part of the catchment area. If the offset is increasing the catchment area around the infiltration field is also increasing.

The assumptions are the value of bucket water (20 liters), the porosity of the soil, or in other words the soil storage capacity. The efficiency of the storage and the efficiency of fetching. For calculating the costs from shilling to euro there is made use of the currency rate of 20 may 2010.

In the input, it is also possible to select the material for the impervious layer. The possible options are EPDM rubber, LPDE plastic and concrete.

The demand of the village is calculated in days, month and for every year as well as the total sum of the overflow.

The storage capacity is based on the monthly precipitation, the monthly demand the total size of the catchment area.

In the graph, the fluctuation of the storage capacity is shown. It is based on the demand of different number of households. The households, which are shown, are the number of households what is calculated on bases of the selected population and the number of households by an increase of 20 and 40% and a reduction of 20 and 40%.

With the dotted blue line the maximum storage capacity is shown. This is the maximum storage capacity of water and not the volume of the infiltration field. It is based on the dimensions of the infiltration field and the porosity of the soil.

If the lines are reaching the dotted blue line of the maximum storage capacity it means that the infiltration field is full with water and if the lines are reaching the x-as it means that the storage capacity is 0, so there will not be sufficient water to overcome the whole dry period.

On the following two pages is shown an example of the input, the assumptions, the results, the performance indicators and the bill of quantities.

Input Surface Catchment

Name of village	Average ward	**Name of family**	Average household
Select from list repetition time of annual rainfall	Propability 80% (Repetition time 1 in 5 years)	**Annual rainfall** 797.1 mm	**Dry months** *(less or equal to 50 mm monthly precipitation)* 7

Set Population	**Set Households**	**Diameter (meter)**	*Capacity tank*
50	10	8.0	121 m^3

Select from list the Material for Ground Catchment	**Select Depth of Subsurface tank (meter)**	**Number of Fields**	**Offset (meter)**
LPDE Plastic Sheet	3	1.0	25

Select from list where Daily Water Demand will be based on:	**Liters/Capita/Day**
Baseline Survey Mtwara	15

Assumptions

Value of bucket water (20 liters) TZS	*Efficiency offset (%)*	*Efficiency storage (%)*	*Efficiency fetching (%)*	*Currency rate TZS : EURO*
TZS 50.00	60%	95%	95%	1722

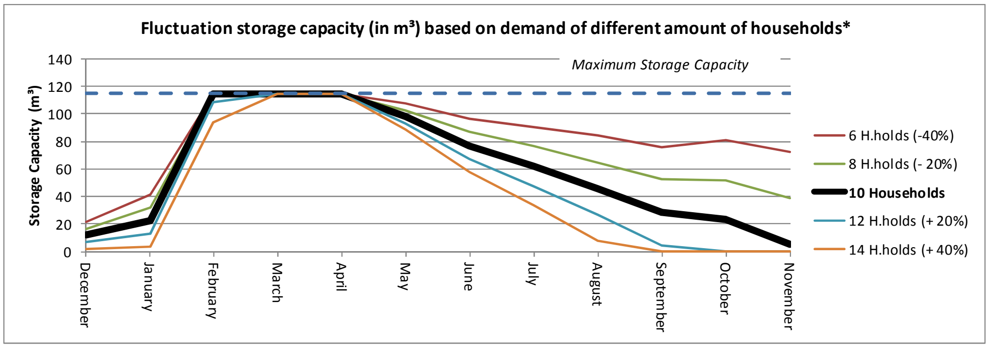
Demand, Storage Capacity & Overflow

Water Demand Village

0.8 m3/day   23 m3/month   274 m3/year

Annual Overflow

132 m3/year



* *Based on precipitation with repetition time of 1 in 5 years (propability 80%)*

Performance measures

Demand satisfaction	107%		*Annual water delivered (excluded overflow) in relation to the Annual water demand*
Efficiency	69%		*Annual water delivered (excluded overflow) in relation to the Annual Catched Precipitation*
Reliability of supply	100%		*Percentages of days whereby the subsurface ground catchment contains water*
Payback time			*Value of water (based on the Annual Water Demand) divided by the construction costs*
Total months	40		
Which is equal to			
Years	*3*		
Months	*4*		
	TZS	Euro	
Equivalent Unit Cost	213,743.25	124.12	*The costs divided by the water storage of the tank (costs for every cubic meter)*
EUC/Water user	4,274.86	2.48	*Equivalent Unit Costs divided by the number of people who will use the tank (corsts for every cubic meter/wateruser)*
Total Costs	2,288,204.09	1,328.81	*Total costs as given in the BIQ*

Bill of Quantities

N° of reservoirs	1	Ward	Average ward
Diameter	8 meter	Village	Average household
Depth	3 meter	Population	50
Type of Tank	LPDE Plastic Sheet		

Description of components

Labour Cost	**People**	**Days**	**Cost/day (TZS)**	**Total cost (TZS)**
Technicians	0	0	7,000.00	-
Labourers	8	9	5,000.00	344,677.59
	15%	*of population*		----------------
Total Labour Costs				344,677.59
Materials	**Unit**	**Quantity**	**Unit cost (TZS)**	**Total Cost (TZS)**
Handpump	Units	1	1,000,000.00	1,000,000.00
Wheelbarrow	Pieces	1	10,000.00	10,000.00
Fence (barbed wire)	Metres	2320	100.00	232,000.00
Fence (poles)	Units	29	5,000.00	145,000.00
Cover	Sq.m	50	10,000.00	502,654.82
Shovels	Pieces	2	5,000.00	10,000.00
LPDE Plastic Sheet	Sq.m	40	600.00	23,871.67
-	-	-	-	-
-	-	-	-	-
-	-	-	-	-

Total material costs				1,923,526.50
Transport of Materials	Tonnes	Loads		
Hardware lorries	7	0.2	100,000.00	20,000.00
Total costs				
Labour costs				344,677.59
Materials				1,923,526.50
Transport of Materials				20,000.00
Total costs			**TZS**	**2,288,204.09**
			EURO	**1,328.81**

Model 3. Surface catchment with subsurface tank storage

This model is based on a subsurface ground tank with a catchment area around the ground tank. The main inputs are the repetition time of the annual rainfall, the number of people and the number of households.

The subsurface tank is a circular tank with a selected diameter. The depth of the subsurface tank needs to be selected. In the model it is possible to select a depth up to 5 metres below surface level. Practically, exceeding a depth of 3 metre is hardly possible.

The offset is the radius around the subsurface ground tank. There are losses for the offset and for this; it is possible to set efficiency for the offset. The loses include evaporation, infiltration.

The daily water demand can be selected on the base of different options. The baseline survey Mtwara, the water policy Tanzania and according to the world health organization. the daily water demand are for these representative 15, 25 and 20 litres of water for every capita for every day.

The demand is calculated on the base of the selected daily water demand and the number of population. The storage is based on the precipitation on the catchment area minus the losses and on the area of the surface of the tank, for this part there are no loses calculated.

In the graph the fluctuation of the storage capacity is shown. It can be seen that the maximal storage is only reached once a year during the wet season. During the dry season the storage capacity is slowly decreasing. This is because of the minimum amount of precipitation during the dry period versus the daily water demand of the selected population. The black line is shown the number of household what is selected and the other lines are calculated on the base of a decrease or increase of water users.

On the base of the selected material for the subsurface ground tank and the storage capacity of the tank is calculated and shown in the bill of quantities.

On the following two pages is shown an example of the input, the assumptions, the results, the performance indicators and the bill of quantities.

Select Roof Surface & Tank size

Input surface (m²)	Number of people in Household	Select from list the Daily Water Demand	Liters/Capita/Day
50.9	5	Baseline Survey Mtwara	15

Select from the list the Tank Storage Capaciy (m³)	Select Material	Select from list repetition time of annual rainfall
15	Ferro - Cement	Propability 80% (Repetition time 1 in 5 years)

[1] List is formed by Analyse of Roof distribution *[2] Based on houses with iron sheet* *[3] Recommended*

Assumptions

Value of bucket water (20 liters) TZS	*Percentage of Annual Average what will fill the tank*	*Currency rate TZS : EURO*
TZS 50.00	90%	1722

Roof Run-off & Demand

Annual Roof Run-Off

36515 L/year

36.5 m3/year

Average Daily Roof Run-off

100.04 L/day

5.0 Buckets of 20 Liter

Standard Demand is

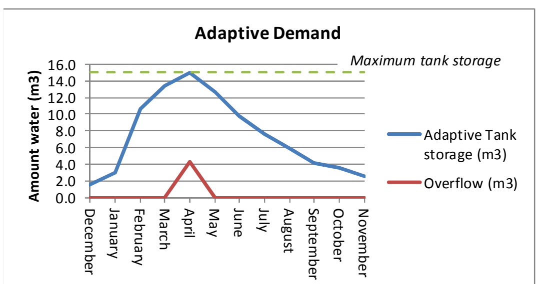
75 L/day

2.3 m3/month

Adaptive demand is

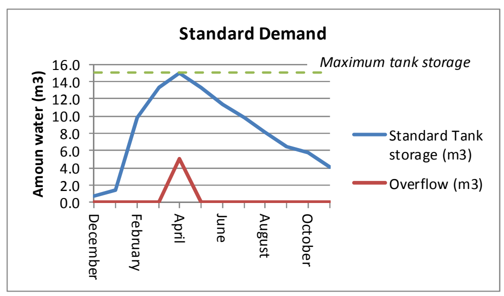
Tank > 2/3	100.0 L/day	3.0 m3/month
1/3<Tank<2/3	75.0 L/day	2.3 m3/month
Tank > 1/3	50.0 L/day	1.5 m3/month

Tank storage & Overflow



Annual Water Demand 29.7 m3

Annual Overflow 4.3 m3



Annual Water Demand 27.4 m3

Annual Overflow 5.1 m3

Performance measures

	Adaptive demand	Standard demand	
Demand satisfaction	109%	118%	*Annual water delivered to the household (excluded overflow) in relation to the Annual water demand*
Efficiency	88%	86%	*Annual water delivered to the household (excluded overflow) in relation to the Annual roof run-off*
Reliability of supply	100%	100%	*Percentages of days whereby the tank contains water*
Payback time			*Value of water (based on the Annual Water Demand) divided by the construction costs*
Total months	138	150	
Which is equal to:			
Year(s)	*11*	*12*	
Months	*6*	*6*	
	TZS	Euro	
Equivalent Unit Cost	221,164.27	128.43	*The costs divided by the water storage of the tank (costs for every cubic meter)*
			Costs for every cubic meter divided by the water users (cost cubic meter
EUC/Water user	44,232.85	25.69	*Equivalent Unit Costs divided by the number of people who will use the tank (corsts for every cubic meter/wateruser)*
Total Costs	856,565.52	497.42	*Total costs as given in the BIQ*

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Bill of Quantities

Type of tank	Ferro - Cement		Name village	
Volume	15 m3		Households	1
Minimum roof surface	51 m2		P.p. Households	5

Description of components

Labour Cost	**People**	**Days**	**Cost/day (TZS)**	**Total cost (TZS)**
Technicians	2	8	7,000.00	112,000.00
Labourers	4	8	5,000.00	160,000.00

Total Labour Costs				272,000.00
Materials	**Unit**	**Quantity**	**Unit cost (TZS)**	**Total Cost (TZS)**
Cement	50 kg bags	26	15,000.00	391,379.57
Lime (Lihno)	25 kg bags	1	7,500.00	8,894.99
Pole	Metres	6	3,000.00	17,789.98
Aggregate	Tonnes	2	34,285.71	81,325.63
Hardcore	Tonnes	1	1,142.86	1,355.43
Burnt bricks	Units	59	600.00	35,579.96
Water	Liter	18	20.00	355.80
BRC mesh	Sq.m	47	800.00	37,951.96
Twisted bars, Y12	Metres	4	12,800.00	45,542.35
uPVC, 4" sewage pipe	Metres	4	4,000.00	14,231.98
G.I pipe, ½"	Metres	1	12,000.00	14,231.98
Timber, 2"x3"	Metres	19	3,250.00	61,671.93
Pole	Metres	9	3,000.00	28,463.97

Total material costs				738,775.54
Transport of Materials	Tonnes	Loads		
Hardware lorries	7	1	100,000.00	100,000.00
Total costs				
Labour costs				17,789.98
Materials				738,775.54
Transport of Materials				100,000.00
Total costs			**TZS**	**856,565.52**
			EURO	**497.42**

Costs of the different materials in Mtwara

List of Materials	**Kiswahili**	**Units**	**Unit cost TZS**		Labour costs	Cost/day	
Aggregate	Kokoto	Tonnes	34,285.71		Artesians	7000	
Angle iron 25x25mm		Units	12,800.00		Labourers	5000	
Barbed wire g.12.5		25 Kg	60,000.00				
Binding wire g.8	Bending wire	Kg	2,500.00				
Bolts 6mmx100mm	Bolts	Number	1,000.00		Transport	Cost/tonnes	Tonnes
BRC mesh No 65		Metres	800.00		Hardware lorries	100000	7
Burnt bricks, 10"x12"x20"	Tofali lakuchoma	Units	1,200.00			250000	15
Burnt bricks, 3"x5"x8"		Units	400.00				
Burnt bricks, 4"x6"x10"		Units	600.00				
Canvas 1.2 m	Turubai	Metres	16,000.00				
Cement	Cement	50 kg bags	15,000.00				
Chicken mesh 25mm 0.9mm	Wavu wa kuku	Metres	45,000.00		Movement of sand	Hours	
Circular bolts, 6mmx25mm	Bolts	Units	1,000.00		1m2	2	
Circular metal ring		Centimetres	1,000.00		Digging		
G.I elbow, ½"	G.I Elboq	Units	600.00		1m2	3	
G.I pipe, ½"		Metres	24,000.00				
G.I pipe, ¾"		Metres	30,000.00				
G.I Sheet		Units					
G.I tap		Units	6,000.00				
G.I wire, 3mm		Kg					
Galvanised coffee mesh		Sq.m	130,000.00				
Galvanized ceiling nails	Misumari ya dari	Kg	3,500.00				
Hardcore, 4"x6"	Mawe	Tonnes	1,142.86				
Lime (Lihno)	Chokaa	25 kg bags	7,500.00				
Mosquito mesh	Wavu wa Mbu	Sq.m	1,700.00				
Nails 3"	Misumari inch tatu	Kg	2,500.00				
Nails, 2"	Misumari inch mbili	Kg	2,500.00				
Oil-drums, discharged	Pipa	Number					
Plastic bag		Number					
Plastic basin	Baseni	Number	2,000.00				
Pole	Nguzo	Lenghts					
River Sand	Mchanga	Tonnes	17,142.86				
Rubble stones blocks, 5"x8"x15"		Units					
Sisal twine	Kamba ya katani	Roll	2,000.00				
Soil compressed blocks, 4"x5"x12"		Units	200.00				
Timber, 2"x3"	Mbao 2"x3"	Metres	3,250.00				
Timber, 6"x1"	Mbao 6"x1"	Metres	7,500.00				
Twisted bars, Y12	Nondo mm 12	Metres	12,800.00				
uPVC, 2" sewage pipe		Metres	12,000.00				
uPVC, 4" sewage pipe		Metres	16,000.00				
Water	Maji	Liter	20.00				
Weld mesh 2.4x1.2 gr.8	Wavu	Metres	800.00				
G.I socket, ¾"		Units	1,000.00				
G.I nipple, ¾"		Units	1,000.00				
LPDE Plastic Sheet		Sq.m	750.00				
EPDM Rubber Sheet		Sq.m	6,390.00				
Handpump		Units	1,000,000.00				
Drains		Metres	5,000.00				
Concrete ring (depth 0.5 meter)		Units	50,000.00				
Shovels		Pieces	5,000.00				
Wheelbarrow		Pieces	10,000.00				

13 Budget for each system

Actual Used System	Borehole + Water Storage Tank + Distribution Network						
Number of Villagers	**Daily water demand per capita**				**Currency (18/5/2010 quoted rate)**		
1918	15	L/c/d					1.722,00
	422,96	m³/month/village (average)					
Description of Components	**Cost of fixed asset**		**Residual value**		**Useful life of**	**Cost/month**	**Cost/month**
	Euro	Shilling	Euro	Shilling	**asset (years)**	**(Euro)**	**(Shilling)**
Water storage tank	16.352	28.158.144,00		-	20	68,13	117.325,60
Distribution network	13.081	22.525.482,00		-	15	72,67	125.141,57
Borehole	11.119	19.146.918,00		-	20	46,33	79.778,83
Pumphouse	5.000	8.610.000,00		-	15	27,78	47.833,33
Solar panels	30.000	51.660.000,00		-	20	125,00	215.250,00
Pump	9.811	16.894.542,00		-	8	102,20	175.984,81
Total	**85.363**	**146.995.086,00**				**442,11**	**761.314,14**
Operation and Maintenance						**Cost/month (Euro)**	**Cost/month (Shilling)**
Maintenance and repair						100,00	172.200,00
Salary administrator						70,00	120.540,00
Salary operator						50,00	86.100,00
Total						**220,00**	**378.840,00**
Calculation of Costs per m³ consumed	*85%*	*of production*				**Per m³ (Euro)**	**Per m³ (Shilling)**
Investments						1,23	2.117,61
Operation and Maintenance	Maintenance and repair					0,28	478,98
	Salary					0,33	574,77
Total						**1,84**	**3.171,37**
Price/bucket (20-Litre)						**0,037**	**63,43**
Monthly Income						521,94	898.787,79
Monthly Costs						662,11	1.140.154,14
Difference income costs / month						**140,17-**	**241.366,35-**
Annually Income						6.263,33	10.785.453,44
Anually Costs						7.945,33	13.681.849,65
Difference income costs / year						**1.682,00-**	**2.896.396,21-**

Possible Alternative (1)	**Subsurface Soil Storage + Surface Catchment**						
Number of Villagers	**Daily water demand per capita**						**Currency (18/5/2010 quoted rate)**
1918	15	L/c/d					1.722,00
	422,96	m³/month/village (average)			N° of infiltration fields	2	
					Length	100	meter
					Width	60	meter
					Depth	1,5	meter
Labour costs	**Days**		**Euro/day**	**Shilling/day**	**Depreciation**	**Cost/month**	**Total cost**
			2,90	5.000,00	**(years)**	**(Euro)**	**(Shilling)**
Sand excavation	7695		22.343,20	38.474.993,84	15	124,13	213.749,97
Construction drains	10		29,04	49.999,99	15	0,16	277,78
Installation impervious layer	6		17,42	30.000,00	15	0,10	166,67
Constructing fence	20		58,07	99.999,98	5	0,97	1.666,67
Constructing well	10		29,04	49.999,99	15	0,16	277,78
Total	**7741**		**22.476,77**	**38.704.993,81**		**125,52**	**216.138,85**
Description of Components	**Cost of fixed asset**		**Residual value**		**Useful life of**	**Cost/month**	**Cost/month**
	Euro	Shilling	Euro	Shilling	**asset (years)**	**(Euro)**	**(Shilling)**
Drainage network	696,86	1.199.992,92		-	15	3,87	6.666,63
Hand pump	1.161,44	1.999.999,68		-	8	12,10	20.833,33
Impervious layer (EPDM Rubber)	11.588,24	19.954.949,28		-	15	64,38	110.860,83
Fence	100,00	172.200,00		-	5	1,67	2.870,00
Shallow Well	290,36	499.999,92		-	15	1,61	2.777,78
Total	**13.837**	**23.827.141,80**				**83,63**	**144.008,56**
Operation and Maintenance						**Cost/month (Euro)**	**Cost/month (Shilling)**
Maintenance and repair						20,00	34.440,00
Salary administrator						70,00	120.540,00
Salary operator						50,00	86.100,00
Total						**140,00**	**241.080,00**
Calculation of Costs per m³ consumed	*85%*	*of production*				**Per m³ (Euro)**	**Per m³ (Shilling)**
Investments						0,23	400,56
Labour cost						0,35	601,20
Operation and Maintenance	Maintenance and repair					0,06	95,80
	Salary					0,33	574,77
Total						**0,97**	**1.672,33**
Price/bucket (20-Litre)						**0,019**	**33,45**
Monthly Income						521,94	898.787,79
Monthly Costs						349,14	601.227,42
Difference income costs / month						**172,80**	**297.560,37**
Annually Income						6.263,33	10.785.453,44
Anually Costs						4.189,74	7.214.729,02
Difference income costs / year						**2.073,59**	**3.570.724,42**

Possible Alternative (2)	**Subsurface Reservoir + Surface Catchment**						
Number of Villagers	**Daily water demand per capita**						**Currency (18/5/2010 quoted rate)**
1918	15	L/c/d					1.722,00
	422,96	m^3/month/village (average)			N° of reservoirs	38	
					Diameter	8	meter
					Depth	3	meter
					Type of Tank	EPDM Rubber Sheet	
Labour costs	**Days**		**Euro/day**	**Shilling/day**	**Depreciation**	**Cost/month**	**Total cost**
			2,90	5.000,00	**(years)**	**(Euro)**	**(Shilling)**
Sand excavation	2622		7.613,24	13.109.997,90	15	42,30	72.833,32
Construction reservoir	380		1.103,37	1.899.999,70	15	6,13	10.555,55
Constructing cover	760		2.206,74	3.799.999,39	5	36,78	63.333,32
Constructing fence	380		1.103,37	1.899.999,70	15	6,13	10.555,55
Total	**4142**		**12.026,71**	**20.709.996,69**		**91,33**	**157.277,75**
Description of Components	**Cost of fixed asset**		**Residual value**		**Useful life of**	**Cost/month**	**Cost/month**
	Euro	Shilling	Euro	Shilling	**asset (years)**	**(Euro)**	**(Shilling)**
Cover	291,90	502.654,84		-	10	2,43	4.188,79
Hand pump	22.067,36	38.000.000,00		-	8	229,87	395.833,33
Impervious layer (EPDM Rubber)	5.610,26	9.660.865,57		-	15	31,17	53.671,48
Fence	218,93	377.000,00		-	5	3,65	6.283,33
Total	**28.188**	**48.540.520,41**				**267,12**	**459.976,93**
Operation and Maintenance						**Cost/month (Euro)**	**Cost/month (Shilling)**
Maintenance and repair						50,00	86.100,00
Salary administrator						70,00	120.540,00
Salary operator						50,00	86.100,00
Total						**170,00**	**292.740,00**
Calculation of Costs per m^3 consumed	*85%*	*of production*				**Per m^3 (Euro)**	**Per m^3 (Shilling)**
Investments						0,74	1.279,44
Labour cost						0,25	437,47
Operation and Maintenance	Maintenance and repair					0,14	239,49
	Salary					0,33	574,77
Total						**1,47**	**2.531,17**
Price/bucket (20-Litre)						**0,029**	**50,62**
Monthly Income						521,94	898.787,79
Monthly Costs						528,45	909.994,69
Difference income costs / month						**6,51-**	**11.206,90-**
Annually Income						6.263,33	10.785.453,44
Anually Costs						6.341,43	10.919.936,22
Difference income costs / year						**78,10-**	**134.482,78-**

Possible Alternative (3)	Tank storage + Roof catchment						
Number of Villagers	**Daily water demand per capita**				**Currency (18/5/2010 quoted rate)**		
1918	15	L/c/d					1,722.00
	422.96	m^3/month/village (average)			N° of tanks	383	
					Type of tank	Ferro - Cement	
					Volume	15	m3
				Minimum roof surface		51	m2
Labour costs	**Days**		**Euro/day**	**Shilling/day**	**Depreciation**	**Cost/month**	**Total cost**
			2.90	5,000.00	**(years)**	**(Euro)**	**(Shilling)**
Construction tank	12256		35,586.52	61,279,990.20	15	197.70	340,444.39
Constructing gutters	766		2,224.16	3,829,999.39	5	37.07	63,833.32
Total	**13022**		**37,810.68**	**65,109,989.58**		**234.77**	**404,277.71**
Description of Components	**Cost of fixed asset**		**Residual value**		**Useful life of**	**Cost/month**	**Cost/month**
	Euro	Shilling	Euro	Shilling	**asset (years)**	**(Euro)**	**(Shilling)**
Tank	164,315.35	282,951,030.90		-	10	1,369.29	2,357,925.26
Gutters	10,675.96	18,384,000.00		-	8	111.21	191,500.00
Total	**174,991**	**301,335,030.90**				**1,480.50**	**2,549,425.26**
Operation and Maintenance						**Cost/month (Euro)**	**Cost/month (Shilling)**
Maintenance and repair						20.00	34,440.00
Total						**20.00**	**34,440.00**
Calculation of Costs per m^3 consumed	*85%*	*of production*				**Per m^3 (Euro)**	**Per m^3 (Shilling)**
Investments						4.12	7,091.29
Labour cost						0.65	1,124.51
Operation and Maintenance	Maintenance and repair					0.06	95.80
Total						**4.83**	**8,311.59**
Price/bucket (20-Litre)						**0.097**	**166.23**
Monthly Income						521.94	898,787.79
Monthly Costs						1,735.27	2,988,142.97
Difference income costs / month						**978.56-**	**1,685,077.47-**
Annually Income						6,263.33	10,785,453.44
Anually Costs						20,823.30	35,857,715.65
Difference income costs / year						**14,559.97-**	**25,072,262.21-**