Irrigation sustainability in rural Amhara, Ethiopia:

Contributions to Deutsche Welthungerhilfe's
"MDG Water and Sanitation Program"

Final Thesis 2010
International Water Management (B. A.)
Van Hall Larenstein University of Applied Sciences, The Netherlands

Student: Christoph Meier zu Biesen
Tutor: Henk van Hoof

The Final Thesis has been compiled during an internship with the INGO Deutsche Welthungerhilfe/German Agro Action (GAA), Office Ethiopia/Horn of Africa

Keywords: Irrigation, Ethiopia, Community-led approach

PREFACE

I would like to take this opportunity to express my thanks and appreciation to *Deutsche Welthungerhilfe* Office Horn of Africa for providing me the chance of this internship. The office has generously supported me in the formulation of my thesis and has allowed me to gain insight into the wide range of interesting topics and subjects of water management. I always enjoyed the welcoming atmosphere, which was created by all the friendly people working in the regional office as well as the program offices. That applies likewise for the offices and staff of the different local organisations I had the chance to work with, which are the *Organisation for Rehabilitation and Development in Amhara* (ORDA) in *Dessie*, the *Bole Bible Baptist Church* (BBBC) in *Arsi Negele* and *Garbet Tehadiso Mahiber* (GTM) in *Butajira*.

In particular I would like to thank Mr. Allemayhue Worku from the *Welthungerhilfe* program office in *Dessie*. He generously shared his experience and impressive knowledge with me, and patiently supported me during the planning and accomplishment of my field survey.

Furthermore I would like to thank Mr. Kumlatschu, who facilitated the fieldtrips, and with his warm humour, exquisite musical taste and best driving skills, turned them into pleasurable events.

At *Van Hall Larenstein University* I want to thank my tutor Mr. Henk van Hoof, who was very committed and patient to respond to my various questions. I very much appreciated his professional advice during the course of my study. I also want to thank my mentor Mr. Bertus Welzen, who introduced me to the course of study *International Water Management* at *Van Hall Larenstein University* and friendly supported me throughout the time.

Arnhem, 2.09.2010

Christoph Meier zu Biesen

EXECUTIVE SUMMARY

The present thesis has been conducted in the context of *Deutsche Welthungerhilfes Millenium Development Goals (MDG) Water and Sanitation – program* in the Amhara region, Ethiopia. The study's main objective was to investigate opportunities and to suggest project activities, which aim on enhanced sustainability of the project activities of the program's irrigation component. With this regard the already approved and partly implemented irrigation projects have been assessed. Problems and needs have been outlined in order to contribute to an optimized implementation. Central assignment of the thesis was the planning of a new irrigation project. The upgrading of a traditional irrigation project has been proposed and designed with the aim to establish a 'model' scheme for best practice (i.e. improved agricultural production). Furthermore options for improved marketing, considered a key success factor for mid- and long term functionality of the irrigation schemes, have been investigated. By this it was intended to contribute to the sustainability of the achievements of the program.

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

AL = Animal labour
AMC = Antecedent Moisture Class
ARF = Areal Reduction Factor
DRF = Design rainfall
EC = European Commission
ETB = Ethiopian Birr, national currency (June 2010: 1 € = 16 ETB)
ETH (+No.) = Project identification number as used at Deutsche Welthungerhilfe Ethiopia, e.g ETH 1064
EU = European Union
HH = Household
HL = Human labour
GAA = German Agro Action, now Deutsche Welthungerhilfe
IWRM = Integrated Water Resource Management
LGP = Length of growing period (days)
LP = Land preparation
LRRD = Linking relief and rehabilitation with development
MDG = Millennium Development Goals
MLVP = Market-led Livelihoods for Vulnerable Populations
(I)NGO = (International) Non Governmental Organisation
ORDA = Organisation for the Rehabilitation and Development of Amhara (National NGO)
O & M = Operation and maintenance
Qtl = 1 quintal = 100 kg
SCS = (US) Soil Conservation Service
USAID = United States Agency for International Development
USDA = United Stated Department of Agriculture
USP = Unit Storm Period
WASH = Water, Sanitation and Hygiene - common term/abbreviation for an integrative program approach in which the three components save drinking water supply, adequate sanitation and hygiene are considered interdependent parameters for improvements in the health sector

1 Introduction

1.1 Framework of the thesis

The formulation of a final thesis accomplishes the course of study *International Water Management* (B.A.) at *Van Hall Larenstein University of Applied Sciences*, The Netherlands. It is part of the last two modules of the second year of the major. The final thesis consists of an individual assignment in the field of land and water management. It is intended to be prepared in conjunction with a placement at an organisation or company active in the field of the study. The present thesis has been compiled during an internship with the International Non-Governmental Organisation (INGO) *Deutsche Welthungerhilfe (German Agro Action)* in Ethiopia, East Africa, in the time from 1st of March to 9th of July 2010[1].

The final thesis intends to develop a subject in the field of land and water management. With respect to the available time for this study, as well as the available capacities of the organisation to support it, the subject needed to be clearly defined with a specific assignment. An internship with an organisation that is active in a variety of working-fields on the other hand offers the opportunity to obtain an insight view into a wide range of themes relevant to land and water management (i.e. irrigation, sanitation and hygiene, rain-water harvesting etc.). In order to include both aspects as well as to set-up and plan my study to possibly be of further use for the organisation, the following framework for my work has been agreed upon:

The final thesis assignment would be prepared in the context of *Deutsche Welthungerhilfe's "MDG Water and Sanitation Program"* (ETH 1064) in the *Amhara-region* in Ethiopia. My assignment has been related to the program's irrigation component. Besides that I have had the opportunity to visit and gain experience in program components concerned with two other important fields of water management: the WASH-program sector, i.e. Water, Sanitation and Hygiene projects in *Arsi Negele* and *Butajira,* and program activities in the arid Afar-region, mainly implementing water harvesting facilities including dissemination of practical knowledge on water harvesting.

In the following I will introduce the current status of the program's irrigation component in the following section and provide a problem analysis. Next, the thesis objective and respective research questions can be formulated.

1.2 Problem analysis and problem statement

In January 2010 the midterm evaluation of ETH 1064 was carried out. As outlined its report, the irrigation activities have - although planned to some extend - not been accomplished in most of the target districts *(woredas)* – except limited activities, which are implemented in 4 schemes: *Kobo* (one diversion & one spring irrigation), *Ambasel* (one spring irrigation) and *Worebabo* (one spring irrigation). These schemes were planned for 954 people (app. 200 households). In order to achieve Result 2.2 of the initial project proposal (intended outcomes of the irrigation component) additional project activities are necessary to address about 900 remaining households.

[1] A description of the organisation is provided in the Plan of Approach (Annex 1)

Taking into account the remaining project time as well as the program's programmatic orientation towards a rather time-consuming community-led approach the evaluators recommended revising and reorganizing the irrigation component. Deep well irrigation and check dam irrigation for example require both high involvement of professionals, long time for study and preparation etc., requirements that make a successful execution at this advanced point of the program rather unlikely. In particular the evaluators recommend that

> *"the activities under this result should be reduced to spring capping irrigation (...) and upgrading traditional irrigation practices. These activities can be managed by program staffs and stakeholders, provided they get trainings on study, design and construction of irrigation facilities".*[2]

As a result of the findings of the mid-term evaluation *ORDA* and *Deutsche Welthungerhilfe* decided to revise and restructure several parts of the program, including the irrigation component.

The community-led approach, practiced in this form for the first time in a *Welthungerhilfe* program has made project implementation far more labour intensive and time-consuming than initially expected. It is likely that a no-cost extension for at least one year has to be requested to enable program staff and communities to successfully complete the projects. This requires respective budget amendments and transfers, which, among others, affect the irrigation component.

Welthungerhilfe's financial administrators and project staff estimated that the number of 1,100 households benefiting from irrigation activities, as proposed under Result 2.2, can be achieved with only 35 % of the original budget. This number results from an extrapolation of the costs of approved project activities in the irritation sector to the total number of target beneficiaries. This means that the original budget for irrigation projects will be reduced by 65%, from 360 000 € to 126 000 € (about 2 260 000 ETB).

After the revision, the remaining projects will have to be completed on the basis of a reduced budget. The budget amendment forces the office to focus on less capital-intensive projects like upgrading of existing small traditional schemes and small river diversions.

In order to formulate a problem statement and corresponding study objectives, two aspects need to be taken into consideration:

- Which problems and needs (in the context of the program's irrigation component) can be identified, and which of these problems can be addressed by my assignment?
- How can my assignment a) address these problems, and b) present an adequate subject for a final thesis assignment (i.e. an assignment by which the contents of the previous studies of the course *International Water Management* can be applied)?

During preliminary discussions with the program staff, concerns about the sustainability of the irrigation projects have been formulated: the establishment or upgrading of some few irrigation schemes might not contribute substantially to productivity-improvements in the area. Thus effectiveness and sustainability of the efforts presents a main problem of this program component.

[2] *Midterm Evaluation of ETH 1064 - MDG Water and Sanitation Program in Rural Amhara*. Temesgen Consultancy Service, Addis Ababa, Ethiopia, p. 40 f.

For the time being, no significant statement can be made regarding the achievements of the four initiated and partly implemented irrigation projects (i.e. improvement of productivity), since irrigated production has not yet started in theses schemes. Therefore it might be helpful to have a look at comparable irrigation projects within the area. Certain common problems can be anticipated and dealt with in future planning.

In the course of a pre-study for an EC Food Facility proposal[3], carried out in June 2009, a number of schemes from previous *Welthungerhilfe* projects in the *Amhara*-region have been assessed. Results of the study show that sustainable improvements of productivity have often been limited due to certain reasons and constraints. These reasons are diverse and vary from scheme to scheme. Nevertheless some basic problems could have been identified:

- The farmers do not consider the project (i.e. the irrigation scheme) as "their property", and consequently do not feel responsible and accountable for it. This often results, among others, in low participation in maintenance work and thus leads to a gradual destruction of the infrastructure.
- The formation of a functional water user association or irrigation cooperative as organisational unit of water management was not successful. The lack of organisational structures regularly leads to poor land and water management and related problems.
- Agronomic practices have not sufficiently been adjusted to irrigated production (improved cropping patterns, crop-scheduling, crop selection etc.). The farmers often lack necessary knowledge and skills to adjust their production to the new conditions. Planning, guidance, trainings and follow-ups have often not been sufficient.
- The marketing component has not been considered sufficiently: when farmers start irrigated production, the need for improved marketing becomes more and more urgent. The products have to be sold at fair/good prices in order to cover increased input costs and to pay off for intensified labour, thus maintain motivation.
- One phenomenon, which is widely referred to as "dependency syndrome" has developed in decades of dependence on foreign relief. This term tries to point out a certain habit among farmers to rely on food aid programs rather than to improve their own production. Farmers who produce irrigated crops are normally excluded from the Productive Safety Net Program (i.e. provision of food-aid). Consequently they may consider irrigation as a "risk" missing a chance of eligibility to food aid. This can undermine motivation and initiative.

The specific program approach of ETH 1064 addresses some of the above-mentioned problems specifically. Poor *"sense of ownership"* as well as poor organisational structures are intended to be improved through the community-led approach. Improvements of agronomic practices through planning and training are part of the capacity building measures, but are not explicate. Improved marketing has not specifically been integrated in the project planning. The "dependency syndrome" can be considered a political issue, since it can easily be observed that provision of food-aid is widely (ab)used for political campaigning, thus solutions for this problem depend on political will.

[3] Pre-study for EC-Food Facility Proposal: *Investigation of the potential for improved agricultural productivity through upgrading of traditional irrigation schemes*. Deutsche Welthungerhilfe/GAA, June 2010.

1.3 Thesis objective and aimed results of the thesis

One possibility to address the above mentioned concerns towards effectiveness and sustainability of the irrigation component is the establishment of model schemes. They can serve as examples of best practice for the farmers and extension workers after the program phases out.

As agreed with *Deutsche Welthungerhilfe* and its partner *ORDA*, the planning of 'model' scheme should be a central component of my assignment and thesis. The design and planning should support the farmers to a) ensure by supplementary irrigation one main crop during poor rainy seasons, b) to produce one additional full crop during the dry season (December – April), and c) to produce a third short-season crop, especially vegetables, during the short rainy season ("Belg"-rain season, February - April).
The scheme design should comprise technical components, e.g. hydrological, hydraulic and agronomical aspects of irrigation. Additionally options for improved marketing will be investigated in order to address the above-formulated problem. In this way the assignment fulfils the above-mentioned requirements: it consists of a technical component, which is relevant to the field of study. Furthermore the outcome can be of practical use for the organisation, as the design can be immediately used within the program.

The *guiding questions* for the assignment can be formulated as follows:
General:
How is the status of the four ongoing irrigation projects, i.e. which lessons from the implementation process can be learnt and benefit further projects so far? Are community proposals available for new projects, and if so, do they fit into the program's irrigation component?

Design:
Which parameters have to be considered for the design? Which data are needed for the scheme design? Which sources of data are available (secondary data)? Which primary data need to be collected, and how can they be collected?

Agronomic component:
After assessing the current agronomic practice, is there room for improvements? What are the components for an improved agronomic practice in an (upgraded) irrigation scheme? How can improved cropping pattern look like?

Marketing component:
How can the marketing component be improved in future projects? Are models for improved marketing available in the area? How did they achieve their improvements?

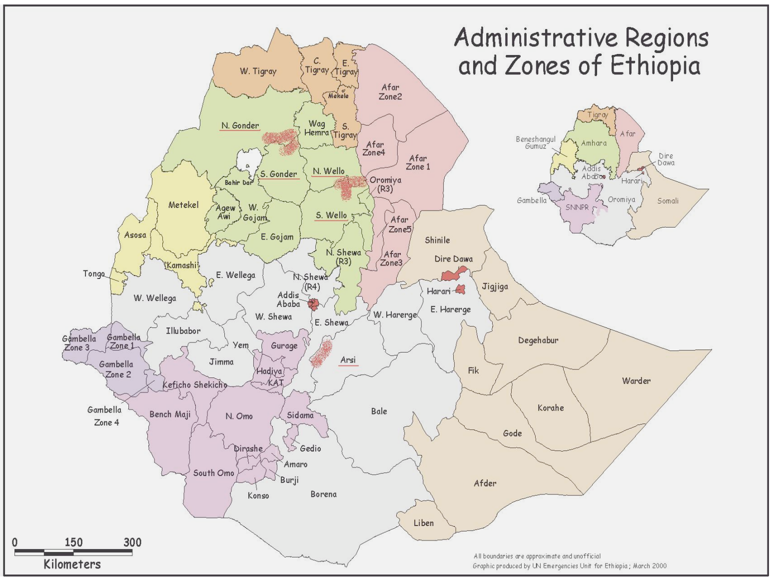
Aimed result of the thesis are
- An evaluation of the status of progress of the irrigation component in the already approved and currently executed projects
- Selection of a new irrigation project on the basis of community proposals
- Scheme design, including improved cropping pattern
- Investigations of opportunities for improved marketing

2. The *MDG Water and Sanitation Program* in Rural Amhara

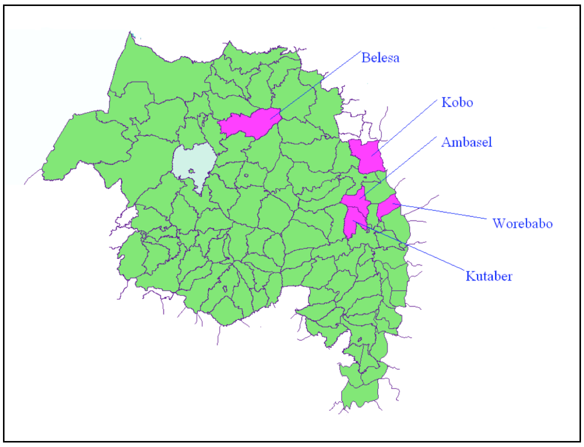
2.1 General information

The *MDG Water and Sanitation Program in Rural Amhara* is an EC funded[4] Water, Sanitation and Hygiene project of *Welthungerhilfe.* The five year program has been launched in December 2006. The total budget amounts to € 3.85 Million[5]. A total of 450 000 people are intended to benefit from the projects. *Welthungerhilfe* in partnership with the *Organization for Rehabilitation and Development in Amhara (ORDA)* is implementing the program in five districts (woredas) of the *Amhara* region: *Kutaber, Ambasel, Worebabo, Kobo* and *East Belessa.*

The *Amhara* region is shown in map 1. Map 2 shows the intervention areas.



Map 1: Administrative Regions and Zones of Ethiopia



Map 2:The Amhara-region with the five intervention-districts ("woredas")

[4] Support of the Ethiopian water sector under the ACP-EU water facility program

[5] It is made up of EU contribution of € 2,8 Million (75%), GAA contribution of € 641,842 (16.67%) and Community contribution of € 320,658 (8.33%)

The overarching development problem in the target districts *(woredas)* is morbidity and child mortality seen as a result of poor access to safe water and inadequate hygiene and sanitation practices. Loss of potential productive time and school days due to illness, care-taking of patients and long walking distances and long-hours queuing to fetch water are problems associated with poor access to safe water and poor hygiene and sanitation practices.

The activities proposed in order to address the problem are:

- Capacity building of the communalities and government offices
- Implementing demand-driven community projects such as: water supply (springs, wells), sanitation (latrines etc.) and small-scale irrigation facilities
- Environmental sustaining interventions (area closure, afforestation and gully rehabilitation)

2.2 Program approach

The program follows a community-led approach. This method is based on two principles: participation and contribution. The communities are intended to participate in at all main stages of the project management, such as

- Identification of a project opportunity („need"), planning and proposal preparation
- Procurement and purchase of materials
- Contracting service providers
- Monitoring and management during implementation
- Operation and maintenance (O&M) management

Furthermore the communities are requested to contribute to the project in terms of

- (Un-)skilled labour
- Collecting and transporting locally available construction materials
- Collecting and saving money to fully cover operation and maintenance cost

The main reason or motivation to implement a program on basis of a community-led approach is the anticipated improvement of sustainability through creation of strong senses of project ownership among the communities. As shown in the flow chart, the identification of project opportunities ("needs") represents the first step in the project cycle. The project initiative needs to come from the communities, while the program "simply" facilitates the process. The establishment of organisational structures for operation and maintenance management at an early stage of the project (i.e. before or simultaneously to the construction works), as another main component of this approach, additionally reflects the attempt to make the communities fully capable in managing the project.

2.3 The program's irrigation component

The objective of the irrigation component is enhanced agricultural production in small-scale irrigation schemes. The proposed outcome this component is formulated under Result 2.2 of the project proposal: "*1,100 households benefit from enhanced agricultural production in pro-poor small-scale irrigation schemes.*"

The designated average area per households amounts to 0,135 ha, giving a total of about 150 ha of irrigated land to be accomplished by the program. The corresponding project activities, as proposed in the initial proposal, comprise improvement of traditional irrigation schemes up to household level runoff harvesting structures. The budget originally allocated for the irrigation component amounts to 360 000 €, thus 9% of the total budget. As outlined above, after the revision the budget for the irrigation component has been reduced to 126 000 €.

3. Assessment of approved and (partly) implemented irrigation components

3.1 Introduction

Four projects within the irrigation component have been approved and implementation is ongoing. In this section I will present the findings of an assessment regarding the status of the sub-projects. It has been conducted to investigate whether problems have occurred in the course of implementation and how they can be solved. Thus the findings can be taken as "lessons learned" for further projects. The findings are presented in the following order:

- General information
- Status of construction
- Water-user organisation
- Agriculture and marketing
- Recommendations

3.2 Methodology

To assess the status of the approved and (partly) implemented irrigation components a solid field study has been carried out. The author has been accompanied and supported (translation, data collection, advice) by the project manager of the *Welthungerhilfe* program office in *Dessie (Mr. Allemauhye Worku)*, and the technical expert from the *ORDA* project office in Kobo (Mr. Abraham). Relevant office documents (i.e. program data-base, design reports and monitoring data) have been reviewed prior to the field visits. Photographs we taken during the visits to document the construction progress. In-depth interviews with farmers and extension workers were conducted with open-ended interview guides as well as semi-structured questionnaires covering mainly the above-mentioned topics. Participant observation was applied throughout. At *Gebereal mesno* irrigation a small survey has been conducted to prepare the design of an improved intake structure, and a pipe to convey the water to a reservoir. The survey consisted of the measurement of the length of the planed canal and the river's cross-sectional profile. Furthermore GPS readings (location and altitude) have been taken.

3.3 Scheme assessments

Basic information such as location, numbers of beneficiaries or project costs are provided for each project in Annex 2.

3.3.1 Gendebash-irrigation in Ambasel

3.3.1.1 General information

Gendebash-irrigation is the upgrading of a traditional irrigation scheme. The source is a spring with a base flow of 8 l/s. The total command comprises an area of about 8 ha. It consists of 3 parcels at close quarter.

The upgrading-project includes three main components:

- Spring capping, i.e. capping of the spring with concrete framing
- Steal pipe connection from the source app. 25 meters downstream, right and left side
- Plastic pipe to the command, following the traditional water course, left and right side

3.3.1.2 Construction

During the field visit the spring capping was almost completed. The steal pipes on both sides had already been connected to the basin and, on the d/s left side, installed on a pillar, on the d/s right side, pierced through a rock. The next step will be the connection with plastic pipes that will convey the water to the fields, following the traditional canal routes.

Following observations regarding the construction have been made:
As shown in picture 1, the steal pipe of the d/s left side was bended during construction. Consequently farmers are concerned that the pipe might not convey as much water as planned.

At the point where the steal pipe will be continued by a plastic pipe on the d/s left side water from an upper catchment flows down a drain. At this part the pipe is in need of extra protection (picture 2).

It is assumed that the intake basin, as shown in picture 3, has not been accurately levelled. This may result in uneven distribution of water to the left and right intake.

Picture 4 documents the right side of the intake (d/s view). The right basin wall is in need of extension in order to prevent further erosion of the back wall.

Picture 1: The steel pipe, d/s view left side

Picture 2: From this point onwards a plastic pipe (HDPP) will convey the water

Picture 3: Spring capping/intake basin

Picture 4: right side (d/s view) of the intake basin

3.3.1.3 Organisation of water-users

The community has shown a strong commitment through contribution of labour and locally available construction materials. The water users already contributed water fees for O&M for the first year of operation, as it was intended in the community led-approach outline.
As stated by water users the community has a "good tradition of water management". Based on oral, traditional bylaws the water distribution and scheduling has been planned and managed in the previous years. The formulation and approval of written bylaws has been requested by program officers, but has not yet been carried out. The farmers consider formally established bylaws a future necessity, specifically to formally regulate and administer the amount and periods of fee collection.

3.3.1.4 Agriculture and marketing

In this scheme mostly perennials such as coffee, oranges and khat are grown. The cultivation of potatoes has recently been tested, but has failed due to a "porcupine plague".
For the time the upgrading is completed some farmers plan to cultivate small vegetables in addition to perennials. This has been tried before but failed due to water shortage, but can now, as the farmers expect, be successful as the irrigation efficiency will increase. The market situation is reported to be good. Most of the production is sold and not consumed. The farmers sell at markets in the area (*Hayk* and *Golbo*), in about 1 to 3 hours walking distance, and in addition at the farm-gate. Current prices are reported to be fair. In particular the cultivation of khat (*Catha edulis*), the mild stimulant widely used ("chewed") in Ethiopia is reported to be very profitable.

3.3.1.5 Recommendations

The community has proven high commitment through eager fulfilment of the required community contributions (labour and money for O&M). As repeatedly stated the farmers are enthusiastically awaiting the completion of the construction works to start the production. In accordance with the observed statues the following recommendations are given:

- Further investigations should consider whether the bended steel pipe (d/s right) negatively affects the flow of water to the right command. If this is the case an artisan should be assigned to recover the original diameter. In case this is not practical, a replacement of the pipe should be considered.
- At the location where the steel pipe is continued by the plastic pipe sufficient protection from the upper catchment drain has to be assured by means of a concrete cover.
- The levelling of the intake basin should be checked and if necessary be adjusted.
- The right basin wall should be heightened in order to prevent further erosion of the earthen back wall.
- The water-users should further be supported to establish and agree upon formal bylaws by regular follow-ups.

3.3.2 Kukumi irrigation in Worebabu

3.3.2.1 General information

The project includes the construction of an intake structure, gully crossings, level crossing, a lined canal of about 500 m length.

3.3.2.2 Construction

The lined canal of about 500 meters is planned to consist of 2 different sections: 130 meters of stone masonry lining, and 370 meters of semi-circular concrete canal. The construction of the first 130 meters has been nearly completed at the time of the visit. Close to the intake a part of the canal is disposed to a drain *(picture 5)*. Due to the steep mountains in the area the flood might be intensive and can gradually destroy the structure.

After the lined canal the water is conveyed by an earthen canal. This canal route crosses the village. As shown in *picture 6*, the seepage water leaks through the porous foundation (weathered rock), and springs up within the house.

Picture 5: Part of canal disposed to drainage water

Picture 6: Seepage water leaks into the houses

3.3.2.3 Organisation of water-users

Kukumi irrigation is a traditional irrigation scheme. Farmers within the community have organised scheme and water management based on oral bylaws in previous years. During the field visit it turned out that a formally approved water user association has not yet been established. As reported by farmers, occasionally conflicts with u/s water-users about water rights occur. An agreement with upstream water users on coordinated rotational irrigation turns has been pre-negotiated by traditional leaders of the community.

3.3.2.4 Agronomy and marketing

Mostly perennial crops like orange, guava, coffee and khat are grown at *Kukumi*. Plans to adjust the production to the improved irrigation facilities and thus improve productivity have not yet been prepared. The market situation is currently satisfying, as farmers report.

3.3.2.5 Recommendations

- A super-passage structure like a slap-top cover should be constructed at the canal section which is exposed to the drain. This could avoid damage to the canal or clogging due to depositions.
- It should be explored how the seepage problem in the village could be solved. Additional lining of short segments should be taken into consideration.
- The formation of a functional water-user association on basis of written bylaws should be further supported. This is of great importance important since conflicts between u/s and d/s water users can develop when irrigation is intensified after the completion of

the upgrading. To successfully face those challenges functional organisational structures are indispensable.
- It should be investigated to what extend agricultural production could be improved after the upgrading has been completed, i.e. introduction of vegetables in addition to perennials, improved varieties etc.

3.3.3 Welyet irrigation in Kobo

3.3.3.1 General information

Some 5 years ago the production at (traditional) *Weilet* irrigation prospered. The farmers grew mostly perennials like banana and sugar cane, and sold them directly at the close main road to transients. Next the abstraction of water from the river by u/s water users increased and water-shortage limited the production. Besides that floods frequently destroyed the traditional irrigation structures.
The upgrading project consists of the construction of an intake structure a gully crossing flume and a stone masonry lined canal of about 290 m length. By this the irrigation efficiency was intended to be improved, and thus mitigate water shortage. The base flow is measured to be 6-7 l/s, the command area comprises approximately 9 ha.

3.3.3.2 Construction

The lining of the canal has been completed. During the field observation it turned out that serious construction failures have to be acknowledged.
As shown in *picture 7* the concrete masonry is loose and already starts to break apart. The used stone material has not been crushed and lacks proper bondage with the mortal. *Picture 8* shows that the canal is already partly washed out. The foundation is obviously insufficient to withstand the forces of the flood stream.


Picture 7: Newly implemented canal section


Picture 8: Insufficient foundation of the canal


Picture 9: Gabion protection washed away


Picture 10: Canal clogged by deposits

The gabion protection presents no adequate protection against the river flood, as shown in *picture 9*.

At a location approximately 100 meters above the intake, famers water their cattle. The cattle drink the water directly from the river. Thus animals loosen the soil while arriving, departing and drinking. This movement increases the sedimentation immensely. *Picture 10* shows a part of the main canal, which is heavily clogged by depositions.

3.3.3.3 Water-user organisation

The farmers of *Weylet* irrigation have not yet established a formal water user association. Due to their experience in irrigation, basic organisational structures are available. However, the collection of the money for O&M for the first year, as requested by the project, has not been accomplished yet.

3.3.3.4 Agronomy and marketing

Due to water shortage in the last years numerous farmers have switched from perennial production to cultivation of eucalyptus. Most of these farmers expressed their wish to revitalise the perennial production as higher profit is expected. As the scheme is closely located to the main road, market options are excellent - especially for perennials like banana or sugar cane, which are commonly bought by transients.

3.3.3.5 Recommendations

- The construction works that have been carried out so far are sub-standard. It can be predicted that future floods will set the scheme out of operation. Therefore it is urgent to take action. As has been outlined long parts of the canal lack proper foundation. The scouring depth has not been investigated properly and a stability assessment has not been carried out. These parts are in dire need of reconstruction, which would cause high additional costs. Therefore cost-effective options to renovate the structures, e.g. improved gabion protection, should be taken into consideration.
- The formation of a functional water user organisation needs further promotion and support. This is an urgent issue since the water-users need to be mobilised and involved in the renovation of the scheme.
- It should be investigated whether a simple cattle trough can be constructed alongside with the intake structure, thus prevent the cattle from loosen the soil and "produce" deposits.
- In particular for those farmers, who want to reintroduce perennials, water shortage will still be a problem in the future. One solution could be the introduction of drip irrigation. Therefore it is recommended to establish a small model plot with drip irrigation. It is also suggested to conduct experience share with the close by *Kobo Girana* irrigation project, which has introduced drip irrigation on a huge scale.

3.3.4 Gebereal mesno irrigation in Kobo

3.3.4.1 General information

Gebereal mesno irrigation is an upgrading of a traditional irrigation scheme. The main feature of this project was the construction of a night storage pond with a capacity of 500m^3 (20m*20m*1,5m including freeboard). The storage pond has been constructed to mitigate water-shortage. The total command area consists of approximately 5 ha, with an average holding of 0,13 ha per household.
The community has proven high commitment and motivation during the construction of the pond, as they contributed locally available construction material, transported additional materials from Kobo town (about 4 hours walking distance), contributed (unskilled) labour and collected the money for the first year's O&M costs.

3.3.4.2 Construction

The construction of the storage pond has been completed. The farmers have mentioned some minor problems such as a broken valve at the pond outlet, altogether the construction seems well handed, and the farmers state to be satisfied.

Picture 11: Storage pond u/s view

Picture 12: Storage pond d/s view

Nevertheless, as the farmers report the problem of water shortage has not been solved completely, although the night storage pond has been constructed.
As *pictures 13* and *14* show, the water flows from the spring through a natural river course of approximately 100 meters d/s where it is guided into an earthen canal. The irrigation efficiency of this section is obviously very poor and considerable amounts of water are lost.

Picture 13: The route of the water from the spring To the earthen canal

Picture 14: Here the water is guided into the earthen canal, leading to the pond

3.3.4.3 Water-user organisation

A water-user association has been established. Members are requested to contribute 10 ETB per year. About 800 ETB have been collected for O&M of the first year. The money for the second year has not been collected so far although it was agreed with the project office.

3.3.4.4 Agriculture and marketing

The farmers of *Gebereal mesno* irrigation cultivate perennials like coffee, mango and guava, and small vegetables such as onions and pepper. The market situation this year is described as being fair. The closest market can be found in about 4 hours walking distance through mountainous areas. The farmers plan to cooperate with other farmers of this area to establish a small market in the proximity.

3.3.4.5 Recommendations

- In order to mitigate the problem of water shortage the following measures are recommended:
    - Construction of a cut-off and a lined canal for the last 20 meters from the source to the earthen canal
    - A pipe connection to replace the earthen canal

Drawings of a proposed cut-off, the canal section, as well as the basic calculations for the pipe (head, diameter) are presented in Annex 3.

- As an additional measure to mitigate water shortage, the introduction of drip irrigation should be considered and discussed with the community. On a model scheme drip irrigation can be introduced to the farmers and respective trainings can be conducted on-site.

3.4 Conclusions

The research question for this chapter, as formulated in the introductory section, was to assess the status of the implementation and to investigate whether already "lessons-learned" can be formulated and thus considered for further planning.

So far the construction works extremely differ in quality. *Weylet*-irrigation in *Kobo* obviously shows serious problems in terms of construction. One of the main findings was that design and implementation have not been carried out appropriately (i.e. poor workmanship, lacking stability assessment etc.). Consequently the scheme's operability is seriously endangered. Considerable parts of the main canal would have to be reconstructed in order to sustainably solve the construction problems. However, budget constraints will most like not allow such comprehensive measures. But even less complex and less costly solutions like the provision of adequate gabion protection will put additional stress on the budget. This example shows the importance of attentive and comprehensive planning and design.

The establishment of functional water user organisations has partly been successful. Since most of the schemes are not yet operational, the phase of formation is currently still on progress.

One component of the community-led approach is the requirement that water-users contribute a certain amount for the yearly O&M costs. As could be observed at *Gebereal mesno* irrigation the farmers readily contributed the first year's share - as it was considered a pre-requirement for the start of the project. After the project was completed (i.e. the construction of the pond), the willingness to pay the yearly share has rapidly diminished. When maintenance work is needed or components need to be replaced - as it is currently the case with a broken valve - no money is available, and the problem remains unsolved.
It is difficult to offer long-term solutions for this situation, as the program' approach (i.e. the community-led approach) has already tried to anticipate these kinds of problems and to address them by certain measures. As some extension workers have stated with regard to this challenge, the community contributions and participation are partly considered "steps" to take in order to receive the support (for the construction of a canal etc.), thus are not experienced as learning processes, by which self-reliance is developed or strengthened.
It should be considered though to intensify follow-up and extend it beyond the first year of operation, as this period must obviously be seen as a critical stage on the way to a self-reliant scheme management.

Agricultural production has not yet been adapted to the altered (improved) conditions after the upgrading in all of the schemes. Plans have partly been made, as it is the case in *Gendebash* irrigation, but comprehensive planning is still missing. With respect to the project goal (improved productivity) the agronomic component should be followed up more seriously, i.e. the farmers should be supported in the development of improved crop patterns, scheduling and the like.

4. Appraisal of community proposals

4.1 Introduction

As described in the introductory section, the implementation of model schemes is considered an effective strategy to improve the sustainability of the achievements of the program's irrigation component. The planning and design of the upgrading of a traditional irrigation scheme, as it is presented here, has been conducted to support this strategy. The selection of the irrigation project has been carried out on basis of available community proposals. Before the scheme design will be presented, the selection of the particular project will be explained.

4.2 Selection of the project

The selection of the new irrigation project was depending on the following factors:

- Availability of community proposals
- Suitability of project for the program

According to internal program consideration the *Deutsche Welthungerhilfe/ORDA*-program office *Dessie* proposed that the new project should be implemented in the district of *Kobo*.
At the project office in *Kobo* three community proposals for an irrigation project have been available:

1. *Tekulesh irrigation I* is a proposed upgrading of a tradition irrigation scheme. About 40 households (200 individuals) share a command area of approximately 20 ha. The water source is a river. Currently the farmers construct temporally intake structures (with stones and wood). The main canal is made from stone and earth. The proposed project components consist of the construction of a solid (concrete) intake structure and a lined canal of about 1 km length, and 4 gully crossing structures (flumes).

2. *Tekulesh irrigation II* is the proposal for a newly constructed irrigation scheme. The farmers are located downstream of *Tekulesh I.* The command would comprise an area of approximately 20 ha, serving a comparable number of beneficiaries as *Tekulesh I.*
3. *Ambunach-Amba* irrigation is the proposed upgrading of a recently established irrigation scheme, with a command area of 7,5 ha, serving about 30 households. The water source is a river. Similar to *Tekulesh I* the upgrading is proposed to comprise a new intake structure and a solid main canal.

To decide which of these three projects should be given priority, an appraisal has been carried out. The appraisal consisted of field observation and discussions with members of the communities.

The field observation at *Tekulesh I* had shown that the intake is located within the bend of the river. The riverbed has a width of nearly 50 meters. During the rainy season this river carries enormous amounts of water, as could be observed from the riverbanks (peak water level). Also the first 100 meters of the main canal are located within the riverbed. Intake and canal are located on the concave side of the bend, thus exposed to maximum forces. At the time of the appraisal the river conveyed very little water. This water (base flow) would have to be guided into the intake, making a complex (with respect to the width of the river) guiding structure necessary. Due to these conditions the complexity and expected costs of the project are assumed to be too high in relation to its benefits.
The farmers of *Tekulesh irrigation II* do not have experiences in irrigation, thus intensive attendance and trainings would be needed. Compared to the farmers of *Ambunach-Amba,* who have shown high commitment as they already constructed a 1,7 km long main canal from stone and earth, the farmers of *Tekulesh II* showed only little initiative. The field observation at *Ambuanch-Amba* had shown that with some few measures (improved intake, lining of main canal) the scheme's efficiency could substantially be improved.

For these reasons priority has been given for the proposal of *Ambuanch-Amba* irrigation.

5 Design for the upgrading of Ambuanch-Amba irrigation

5.1 Methodology

The following data and information have been collected and processed for design and planning of the upgrading of *Ambuanch-Amba*:

Socio-economic data (including agronomy)

- Number / List of beneficiaries / households
- Current agricultural practice
  - Including input rates and output
  - Experience in irrigated agriculture
  - Marketing situation
  - Constraints
- Forms of organisation of the water users
- Future plans
- Needs
- Market data (i.e. current market prices) for cost benefit calculation
- Current material costs for estimation of construction costs

Technical data / design data

- Benchmark location and respective GPS reading (zero-reference)
- Location, size and shape of the command area (GPS)
- Length and course of the traditional irrigation canal
- Water source / base flow of water source
- Longitudinal and cross-sectional profile of the river
- Longitudinal profile of the sensitive part of the river (i.e. the part which is located within the flood river bed)
- Number and form of crossing structures
- Meteorological data (daily rainfall records for the preparation of the complex hydrograph, and class A data for calculation of irrigation duty)
- Topographical maps of the area for delineation of the catchment area

To obtain the basic data for the design comprehensive field work has been carried out. The river's longitudinal and cross-sectional profiles as well as the canal profile have been measured with levelling instrument and measuring tape (i.e. elevation and length).
To delineate the size and shape of the command area as well as the length and course of the traditional canal a GPS track reading has been carried out. The GPS-data have been processed with *Map Source* and *Global Mapper*.
Topographical maps of the area have not been obtainable. The catchment area has been delineated on basis of digital maps of the *Ethiopian Ministry of Transport*. These maps have been processed with the program *Global Mapper*, by which contour lines of a chosen interval can be generated.
Meteorological data were available through the *National Meteorological Institute* in *Kombolcha*. The institute collects data from various stations in the area. The closest station to *Ambuach-Amba* with relative similar geographical attributes is *Muja*. It is located about 35 km (air distance) south-west of the scheme. Its altitude is 2500 m a.m.s.l. At *Muja* station only rainfall data are recorded. These data - daily rainfall over a ten years period, from 1995-2005 – are used for calculation of design rainfall and direct run-off. The peak rainfall data have been checked with standard statistical methods (scew-coefficient).
To calculate crop water requirement and irrigation duty, additional data like minimum and maximum temperature, relative humidity, sunshine hours and wind speed, are needed. These data have been taken from the meteorological station in *Lalibela*, 50 (?) km west of *Ambuanch-Amba* (elevation of 2300 m a.m.s.l.). The crop-water requirements for a proposed crop pattern have been calculated with *CropWat* (FAO).
Socio-economic data and information on agronomic practice have been obtained thorough semi-structured interviews and focus group discussion with the farmers of the scheme as well as community extension workers.
Information on market prices has been acquired through a market price assessment at *Kobo* market. The prices for the most common agricultural products have been enquired, as well as the price range over the last years (i.e. minimum and maximum prices).

5.2 General information

5.2.1 Background information

The *Ambuanch-Amba* irrigation project is an upgrading of a traditional irrigation scheme. It consists of a command area of about 7,5 ha. The total number of beneficiaries accounts to 142, giving 30 households with a mean of 5 (4,7) persons per household (Annex 4). The average area per household is about 0,25 ha.

After the survey at *Ambunach-Amba* has been completed, some farmers from a downstream scheme expressed their interest to be included into the *Ambuanch-Amba* scheme by means of extension of the main canal. Their land-area consists of approximately 2,5 ha. With an extension 8 additional households (40 beneficiaries) could be served with the scheme.
As stated by the technical officer of the ORDA office in Kobo, the extension is desirable and rather easy to implement. But since survey data for the extension (i.e. exact length of extension, location and shape of command etc.) have not been taken, the detailed planning cannot be incorporated in this report. As agreed with the project staff the here conducted calculation of the crop-water requirements and irrigation duty should consider 10 ha. In this way the extension can be prepared (i.e. it can be tested, whether the available water is sufficient), and planning can later easily be adapted.

The upgrading is expected to improve the project efficiency and thus increase productivity. It is intended to reorganise and improve agronomic practices and by this approach an irrigation / cropping intensity of up to 300 %.

The farmers have recently started irrigation, namely in January 2010. After several poor rain seasons - particularly during the small "belg"-rain season - they felt they cannot only depend on rain-fed production. The farmers decided to start to irrigate their lands by utilizing the water of the nearby river. With temporally intake structures, made from stone, earth and wood, the water is guided into an earthen canal with a total length of 1,7 km. Improvised crossing structures (corrugated iron sheets) convey the water over 3 gully-crossings. The farmers have put remarkable efforts and energy into the set-up of their scheme, proving high motivation, commitment and a strong will to improve their means and methods of production.

The following pictures give an impression of the location and the people of *Ambuanch-Amba* irrigation.

Picture 15: The traditional intake

Picture 16: The first ("sensitive") canal section

Picture 17: Traditional earthen canal and parts of the command area

Picture 18: Farmers from Ambuanch-Amba

5.2.2 Location

Administratively *Ambuanch-Amba* irrigation scheme is located in:

Region	Amhara
Zone	North Wollo
District (Woreda)	Kobo
Community (Kebele)	Arbet
Site (Got)	Tsegayebahir

Geographically it is located at:

Latitude	12.13°
Longitude	39.49°
Altitude	2070 m a.s.l.

5.2.3 Climate

Traditionally Ethiopians have divided the country into 5 agro-climatic zones, based on elevation. The highland zones (*Dega* & *Wiena Dega*) contain most of the country's agricultural areas. Livestock in agro-pastoral and pastoral production systems dominate the arid and semi-arid zones (*Behera* & *Kolla*).

Following the description of the traditional classification by the *United Stated Department of Agriculture* (USDA) *Ambuanch-Amba* is located within the ***Weina Dega*** agro-climatic zone, i.e. temperate, cool sub-humid highlands. This zone is characterized as follows:

> *"Areas between 1500 to 2500 meters, where annual rainfall ranges from 800 - 1200 mm. This is where most of the population lives and all regional types of crops are grown, especially teff".*[6]

The actual elevation of *Ambuanch-Amba* is slightly above the here given range of the *Weina Dega*-zone, but the rainfall pattern is in accordance. The "correct" zone in terms of elevation, the *Dega*-zone, with altitudes of 2500–3000 m, is characterized by average rainfalls of 1200 to 2200 mm, and thus represents rather differing conditions.

The area has a bimodal rainfall pattern, with a main rainy season in July to September, and the small rainy season, the so-called *Belg-rain*, from February/March to April.
The closest meteorological stations with relatively similar geographical attributes are *Muja* (daily rainfall), and *Lalibela* (full meteorological data), about 35 and 50 km air distance, respectively. Mean annual rainfall is about 837 mm *(Lalibela)*. Mean maximum and minimum temperature are 13°C and 25°C *(Lalibela)*.

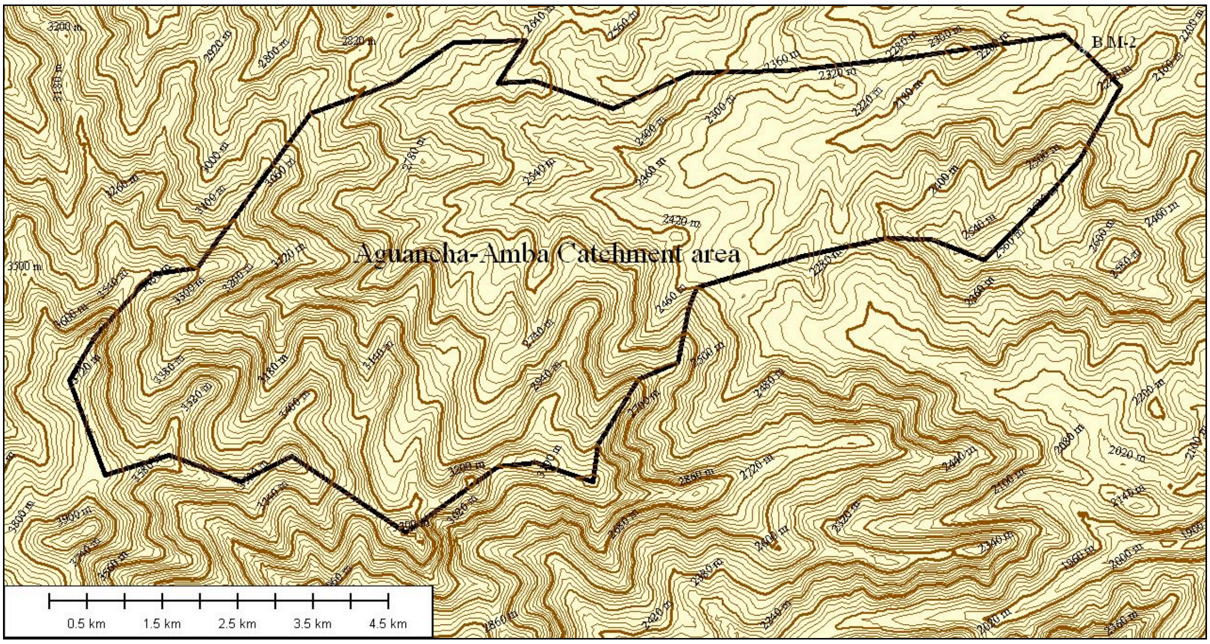
[6]http://www.fas.usda.gov/pecad2/highlights/2002/10/ethiopia/baseline/Eth_Agroeco_Zones.htm (Status 1.7.2010)

5.3 Hydrology

5.3.1 The catchment area

As mentioned earlier, detailed topographical maps for the area have not been obtainable. Therefore other means and sources had to be found to identify the catchment area.

The catchment area has been delineated on basis of digital topographic maps from the *Ethiopian Ministry of Transport*. These maps can be processed with the program *Global Mapper*. On basis of digital maps this program generates contour lines of different intervals, whereby 1 m elevation difference represent the maximal detailedness. For application of the program it has to be considered that the smaller the chosen interval, the more complex the computation will be. For the delineation of the catchment area, where a rather huge clipping was needed, contour intervals of 20 meters have been chosen. This represents a compromise between accuracy and technical practicability.



Map 3: The catchment area of Abuanch-Amba irrigation scheme. The intake is located at the point BM 2 (benchmark 2).

After defining the boundaries the total catchment area could be measured with *Global Mapper* measuring tools (Map 3). The catchment of *Abuanch-Amba* irrigation scheme comprises a total area of **46,6 km^2**.

The catchment's boundaries as set in *Global Mapper* and the survey benchmarks have been transferred to *Google Earth*. Now the reasonability of the catchment's delineation could once more be checked applying a 3D view of the catchment. Furthermore the satellite images of Google Earth are used to identify land-use and land cover of the catchment area. This process will be presented later in the report.

5.3.2 Available Hydro-Meteorological data

In this section the available hydro-meteorological data will be presented. On basis of these data the hydrological analysis will be conducted

5.3.2.1 Base flow of the water source

The base flow has been estimated on the basis of the farmers' reports.
During the survey, which was conducted in May, i.e. after the small rainy season (belg), the river flow was estimated to be about 50 l/s. During dry season the river flow was assumed to be around 1/5 of this flow. Therefore a **base flow of 10 l/s** can be assumed.

5.3.2.2 Available meteorological data

Maximum monthly rainfall
For peak flow estimation, maximum daily rainfall data from *Muja* Station are used. The recordings cover a period of 10 years (1995-2005). From daily recordings monthly averages are taken.

Year	**Max (mm)**
1995	52,7
1996	47
1997	25,6
1998	48,3
1999	41,7
2000	33,3
2001	42,7
2002	37
2003	51,9
2004	51
2005	49,5
Sum	480,7
Average	**43,7**

Table 1: Maximum monthly rainfall 1995-2005, Muja Station

Full meteorological data
The following table presents the full meteorological data, i.e. averages of 10 and 13 years periods, as obtained through *Kombolcha National Meteorological Office*:

Element	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**Average**	**Remark**
Mean monthly rainfall (mm)	28,8	40,4	32,7	29,4	127,9	272,6	180,6	74,3	29,3	8,9	9,5	2,9	837,3	69,8	Lalibela Station (1994-2007)
Mean monthly max. temperature (°C)	30,3	27,4	27,0	26,7	26,7	25,0	19,9	19,8	22,6	25,2	25,1	26,2	301,8	25,2	
Mean monthly min. temperature (°C)	13,0	14,0	14,3	14,5	15,4	14,2	12,1	11,7	13,0	12,9	12,5	12,9	160,6	13,4	
Mean monthly RH (%)	37,9	32,8	41,5	43,1	45,0	50,8	80,3	83,8	64,2	49,2	43,4	40,0	612,2	51,0	Lalibela station (1995-2007)
Mean monthly wind speed (m/s)	1,3	1,4	1,4	1,6	1,8	1,5	1,0	0,8	1,1	1,6	1,1	1,2	15,7	1,3	
Mean monthly sunshine (h)	9,9	9,4	8,3	7,9	7,7	6,2	3,3	4,4	6,1	7,8	8,5	9,5	89,0	7,4	

Table 2: Meteorological data from the meteorological stations in Muja and Lalibela (Source: Kombolcha National Meteorological Office)

5.3.3 Direct runoff

For the stability assessment[7] of the intake structures and the (sensitive) canal section, i.e. the part that is located within the flood bed, as well as to determine the scouring depths the direct run-off value of the *Ambuanch-Amba* catchment is required.

During the survey solid rock formations have been detected in about 3 meters depths. Scouring depths in the range of 0 to 3 meters will therefore determine the depth of the structures. In case the scouring depth exceeds 3 meters the structures will be fixed on the solid rock formation (hard stratum).

For the *Ambuanch-Amba* catchment, run-off data are not obtainable. In this case the Curve Number Method can be applied to *"estimate the depth of direct runoff from rainfall depth, given an index describing runoff response characteristics"*[8].
In this section the direct runoff represents a depth uniformly distributed over the drainage basin ("excess rainfall"). In order to estimate the time distribution of the runoff rate at a specific point of the catchment, i.e. the intake of the irrigation scheme, the Unit Hydrograph Method will be applied.

5.3.3.1 Design rainfall (DRF)
The design rainfall (DRF) will be calculated by applying the *Gumble extreme value method*, as described in the Ethiopian textbook for extension workers. The technical expert of *Welthungerhilfe Dessie* has proposed this procedure, as it is the standard method used in the projects. For the design of structures in a small-scale irrigation scheme commonly return periods of 25 – 50 years are used. To be on the safe side, a return period of 50 years has been chosen for this project.

The design rainfall will be calculated as follows:

Design rainfall (DRF) = R_{av} + S (0,78y-0,45)

Where
R_{av} = Mean 24 h peak rainfall
S= Sample Standard deviation (= 8, 6769 = 8,7)
$y = -\ln(-\ln(1 - \frac{1}{T})$
T= return period

For R_{av} the average of maximum monthly rainfall of the years 1995 – 2005 has been taken, giving a value of **43,7 mm** (see table XX).

For a return period of 50 years (T=50) y will be:
$y = -\ln(-\ln(1 - \frac{1}{50}) = 3,9$

7 The stability assessment will not be part of this report. It will be conducted by the *Welthungerhilfe* program-office *Dessie.*

8 J. Boonstra, LRI (International Institute for land reclamation and improvement) Wageningen, The Netherlands. Publication 16, Chapter 4.2: The Curve Number Method, p.121

Now the design rainfall can be calculated:
43,7+8,7(0,78*3,9-0,45) = 66,2 mm
→ take 67 (mm/24h, T=50).

Point rainfall to areal rainfall
The meteorological data represent point rainfall recordings. Now point rainfall needs to be converted to areal rainfall by applying an Areal Reduction Factor (ARF). The ARF is calculated with the following formula:

$$ARF = 1 - 0{,}044 \times A^{0{,}275}$$

where:
A (catchment area, km^2) = 46,6
giving:
ARF = 0,872

Now point rainfall can be transferred to areal rainfall:
ARF*DRF = 0,872*67 = 58,5 mm

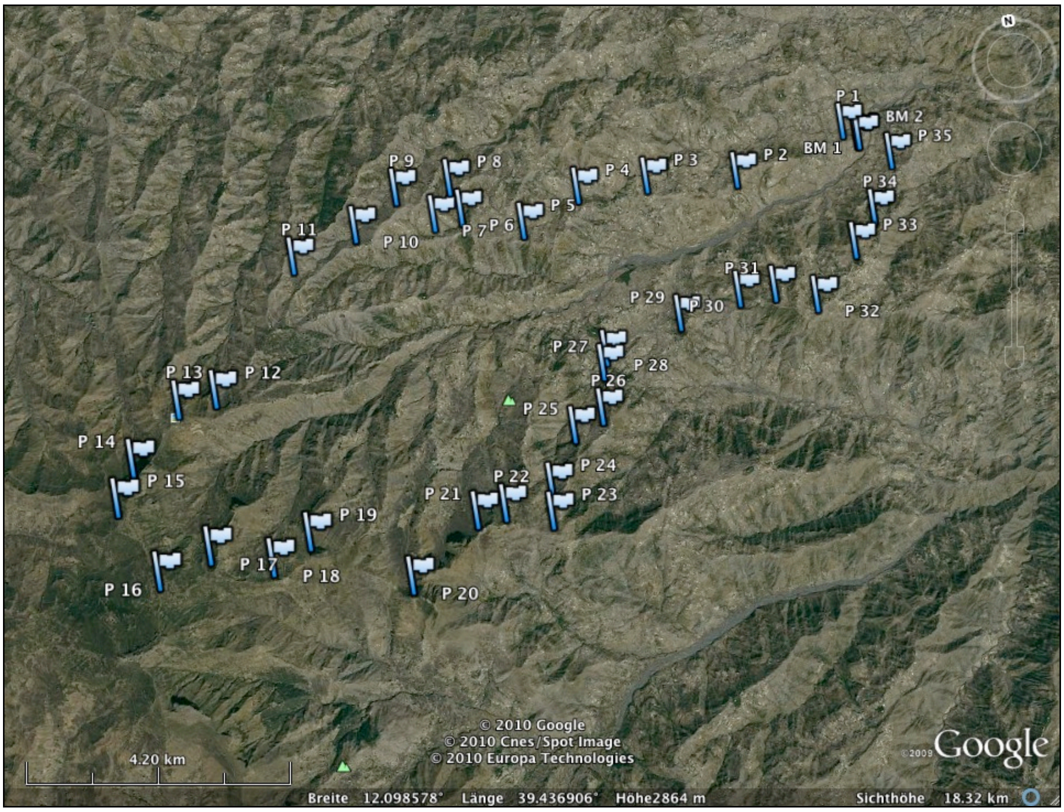
So the final DRF has been calculated to be **58,5 mm / 24 hours, for a return period of 50 years.**

5.3.3.2 Determination of Curve Number (CN) of the catchment area

Next a Curve Number (CN) for the catchment area will be determined. I will make use of the procedure and tables developed by the *US Soil Conservation Service (SCS).*

The factors that determine the Curve Number are:
- Land-cover / land-use
- Slope
- Hydrological soil group
- Treatment of practice in relation to hydrological condition
- Antecedent Moisture Condition

Land-use and land-cover
In order to identify the catchment's land use and land-cover, the basin boundaries delineated with *Global Mapper* have been transferred to *Google Earth* (Map 4). In this way information gained through observation and questioning of farmers and extension workers have been checked, adjusted and extended.



Map 4: Google Earth image of the catchment area

The following proportional distribution has been prepared:

Land-use	% of catchment area	Area (km^2)
Cultivated land	35	16,3
Settlement	15	7,0
Bushland	25	11,7
Forest	5	2,3
Grazing	5	2,3
Bareland	15	7,0
Total	*100*	*46,6*

Table 3: Proportional distribution of land-use and land cover

Slope

The catchment can broadly be divided into 2 main areas with a different average slopes, giving a slope of 35 % (area 1) and 14% (area 2), respectively. (Annex 5)

These areas can now be assigned to a corresponding slope class:
Area 1 → 35% → very steep (>20%) → slope class V
Area 2 → 14 % → steep (10-20%) → slope class IV

According to their appearance, forms of land-use/land-cover can assigned to a slope class, giving the following table:

Area	Landuse	Slope class	% of total area	Area (km^2)
Area 1	Bareland	V	75	30,3
	Forest			
	Bushland			
	Settlement			
	Grazing land			
Area 2	Cultivated land	IV	35	16,3

Table 4: Land-use and corresponding spatial expansion assigned to slope classes

Now *soil group*, *treatment* and respective *hydrological condition* can be defined.
The *bare lands*, consisting of weathered rocks with shallow soil depths are assigned to soil group D and poor hydrological condition (CN of 94).
The *cultivated land* is divided into small grains (75%) and row crops (25%), representing the traditional agricultural practice in the area. The soils can be described as sandy-loam, the fields are countered, and the hydrological condition is good (CN of 71).
Bush land and *forest* are assigned to soil group C and B, expressing the fact that soils in the bush land are more prone to erosion and consist of more shallow soil depths compared to forests. The hydrological condition can bee characterised as fair (CN of 77 and 60).
Settlements have been assigned to soil group D, as corrugated iron roofs produce a run-off of 100%. The hydrological condition is assumed to be poor (CN of 91).
Finally *grazing land* has been assigned to soil group C with poor hydrological condition, thus representing the commonly practiced overgrazing and resultant high run-off rates (CN of 81).

A valued, i.e. proportionate curve number has been prepared as shown in table 4:

Land-use		Soiltype/ cover	Soil group	Treat-ment or practice	Hydrol. Cond-ition	CN 1	Slope %	Slope class	CN 2 (acc. to slope)	CN final	% of area	% CN
Bareland		weathered rock, shallow depths	D		poor	94	38	V	95	95	15	14,2
Culti-vated land	small grains (75%)	sandy-loam	B	cont./ terraced	good	70	14	IV	66	68	26,25	17,9
	row crops (25%)	sandy-loam	B	cont./ terraced	good	71	14	IV	66	69	8,75	6,0
Bush-land		sandy-loam	C		fair	77	38	V	86	82	25	20,4
Forest		sandy-loam	B		fair	60	38	V	75	68	5	3,4
Settle-ment		(corrogated iron)	D		poor	94	38	V	95	95	15	14,2
Grazing land			C	count-oured	poor	81	38	V	92	87	5	4,3
											weigthed CN	**80,3**

Table 5: Valued Curve Number for Ambuanch-Amba catchment for AMC II

For average conditions a weighted Curve Number of 81 seems a realistic estimate. Now the final step will be to determine which Antecedent Moisture Class (AMC) is the most appropriate for the *Ambuanch-Amba* catchment.

In order to decide which AMC class is appropriate, the *US Soil Conservation Service* proposes to determine the mean of a total 5-day antecedent rainfall value of the two historical rainfall events that proceed and follow the selected design rainfall.

As the DRF has been determined in this design was not selected on basis of a frequency analysis but by applying the *Gumble extreme value method* on values of daily maximum rainfall of the year 1995-2005, we have to adapt the method.

A total of five days antecedent rainfall prior to the yearly maximum value will therefore be taken from each year. The average of the years than will then be taken as value for 5 days antecedent rainfall. Afterwards this value will be applied to the SCS table of "Seasonal rainfall limits for AMC classes".

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Total	Average
5 days total antecedent rainfall (mm)	56	0,0	47,9	71,2	45,8	33,2	49,1	9,0	46,7	15,8	6,5	381,2	34,65

Table 6: 5 days antecedent rainfall prior to each years maximum rainfall, the including average of 11 years

As shown in table 6, the average of the total 5 days antecedent rainfall prior to the maximum 24-h rainfall is 34,65 mm.

The table of seasonal rainfall limits for AMC classes[9] provided by the SCS Service comprises values for East African conditions:

Antecedent Moisture Condition Class	5-day antecedent rainfall (mm)
I	< 23
II	23 - 40
III	> 40

According to the table AMC II is appropriate for the *Ambuanch-Amba* catchment, and the above calculated CN of 81 would present the appropriate and final curve number.
Since the determination of the AMC class was based on 24 hours rainfall data, this estimation might not be totally correct. Besides that it can be seen from table 6 that during 6 of the 11 years the values exceed the rainfall limits of the SCS table, partly to a considerable amount. Therefore I decide to calculate the run-off data for both AMC classes, giving CNs of 81 (AMC II) a CN of 91 (change from AMC II to AMC III) in order to allow the technical expert who carries out the stability assessment, in order to decide what is appropriate. In this report I will use the CN for AMC III (i.e. 91) for calculation of peak runoff rates. Additionally the results of peak run off for a CN of 81 will be presented.

5.3.3.3 Direct runoff values

In order to determine peak run off rates, first values of direct runoff have to be determined. Then a dimensional Unit Hydrograph for the *Ambuanch-Amba* catchment can be prepared on basis of the parametric unit hydrograph as developed by the Soil Conservation Service. Finally a composite hydrograph can be prepared, by which peak run-off rates at the specific location within the catchment (i.e. the intake) can be determined.

[9] The Curve Number method, p.128

Maximum Potential Retention (S) and Initial abstraction (I_a)

Having determined the Curve Number, the *Maximum Potential Retention* (S) and *Initial abstraction* (I_a) can be calculated.

From the *SCS* empirical relation

$$CN = \frac{25400}{254 + S}$$

the maximum potential retention (S) can be calculated as follows:

$$S = (\frac{25400}{CN}) - 254$$

for a CN of 91 this will be:
S = (25400/91)-254= **25,12 (mm)**

The *Initial Abstraction* (I_a) is calculated as follows:

$$I_a = 0.2 \times S$$

giving:
I_a= 0.2*25.12 = **5,02 (mm)**

Rainfall profile
A rainfall profile is the plot of cumulative depth of rainfall versus time. For this case, a generalised rainfall profile developed on the basis of rainfall profiles observed at 17 rain gauges located in the highland of Ethiopia is being used. This profile is published in a working manual for extension workers.

The following formula has been derived from the rainfall profile (i.e. from the graph), and is used to calculate the rainfall distribution:

44.365+19.443*(ln (Duration))

As shown in table 7, the rainfall profile is distributed over the intervals of 0,25 h (row II). Now the above-calculated DRF of 58,5 mm is distributed according to the profile (row IV). Next, excess rainfall can be calculated (row V). Then the SCS empirical relation for Q (direct run-off accumulated) can be applied:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \text{ (for P > 0.2 S)}$$

Now Q incremental can be calculated and finally direct runoff depths (row VI and VII).

I	II	III	IV	V	VI	VII
Duration (h)	**DRF (%)**	**DRF (mm)=P**	**Incremental rainfall**	**Direct runoff accumulated = excess rainfall (mm)**	**Q incremental (mm)**	**Q (direct runoff depths) (mm)**
0	0	0,0	0	0,0	0	
0,25	17,4	10,2	10,2	0,9	0	0,0
0,5	30,9	18,1	7,9	4,5	3,6	3,6
0,75	38,8	22,7	4,6	7,3	2,8	6,4
1	44,4	26,0	3,3	9,5	2,2	5,1
1,25	48,7	28,5	2,5	11,3	1,8	4,0
1,5	52,2	30,6	2,1	12,9	1,5	3,4
1,75	55,2	32,3	1,8	14,2	1,3	2,9
2	57,8	33,8	1,5	15,4	1,2	2,5
2,25	60,1	35,2	1,3	16,4	1,1	2,2
2,5	62,2	36,4	1,2	17,4	1,0	2,0
2,75	64,0	37,5	1,1	18,3	0,9	1,8
3	65,7	38,4	1,0	19,1	0,8	1,7
6	79,2	46,3	7,9	25,7	6,6	7,4
12	87	50,9	4,6	29,6	4,0	10,6
24	100	58,5	7,6	36,4	6,7	10,7

Table 7: Values of rainfall depth and corresponding depth of direct runoff for a rainfall of 58,5 mm and a duration of 24 hours for a design period of 50 years

5.3.4 Complex Hydrograph

5.3.4.1 Parametric Unit Hydrograph

To estimate the time distribution of the direct runoff rate at a specific location in the drainage basin, i.e. the intake of the scheme, the Unit Hydrograph Method will be applied. For *Ambuanch-Amba* catchment, where no runoff has been measured, the Unit Hydrograph is based on a parametric hydrograph shape.

t/T_p	q_t/q_p	t/T_p	q_t/q_p	t/T_p	q_t/q_p
0	0	1,75	0,45	3,5	0,036
0,25	0,12	2	0,32	3,75	0,026
0,5	0,43	2,25	0,22	4	0,018
0,75	0,83	2,5	0,15	4,25	0,012
1	1	2,75	0,105	4,5	0,009
1,25	0,88	3	0,075	4,75	0,006
1,5	0,66	3,25	0,053	5	0,004

Table 8: Dimensionless time and runoff ratios of the SCS parametric unity hydrograph

Time of concentration (Tc) and Time to peak (Tp)

First the length of the so-called *Unit Storm Periods (USP)* will be defined. To do so we have to know the *Time of concentration* (T_c) and *Time to peak* (T_p), respectively.

Kirpich formula for time of concentration (h):

$$T_c = 0.002 \times L^{0.77} \times s^{-0.385}$$

where
T_c = Time of concentration (min)
L = max. length of travel (m)
s = slope (H/L, where H difference in elevation between most remote point in the basin and outlet)

given
L = 14700 m (as measured with *Global Mapper*)
H = 1564 m
s = 0.1064

T_c = 77,6 min = 1,3 h
T_p= 0,7*T_c
T_p = 0,91 h

Length Unit Storm Periods (USP)
Now the length of the Unit Storm period can be defined:
USP = Tc/5
USP = 1,3/5 = 0,26 → take **0,25 h**

Peak runoff rate unit hydrograph (qp)
Now the peak runoff rate for the unit hydrograph (unit =1 mm) will be calculated:

$$q_p = 0,208 \times \frac{AQ}{T_p}$$

where
q_p = peak runoff rate unit hydrograph (m^3/s)
A = Area of drainage basin / catchment (km^2)
Q = excess rainfall (mm) = 1 mm
T_p = time to peak runoff unit hydrograph (h)
giving

$$qp = 0,208 \times \frac{46,6 \times 1}{0,91}$$

qp = 10,7 m^3/s

The peak runoff rate for an excess rainfall of 1 mm is **10,7 m^3/s**.

5.3.4.2 Dimensional Unit Hydrograph for the Ambuanch-Amba catchment

Now the *SCS parametric curve linear unit hydrograph* will be converted into a *dimensional unit hydrograph* of the *Ambuanch-Amba* catchment.

By substituting values of T_p and q_p into table 8 (SCS parametric hydrograph) we get the runoff values for this hydrograph.

t/Tp	qt/qp	t	t/Tp	qt/qp	qt
0	0	0	0,00	0,0	0,00
0,25	0,12	0,25	0,27	0,14	1,50
0,5	0,43	0,5	0,55	0,53	5,67
0,75	0,83	0,75	0,82	0,88	9,42
		0,91	1,00	1,00	10,70
1	1	1	1,10	0,95	10,17
1,25	0,88	1,25	1,37	0,82	8,77
1,5	0,66	1,5	1,65	0,53	5,65
1,75	0,45	1,75	1,92	0,36	3,80
2	0,32	2	2,20	0,24	2,56
2,25	0,22	2,25	2,47	0,16	1,72
2,5	0,15	2,5	2,75	0,11	1,16
2,75	0,105	2,75	3,02	0,07	0,78
3	0,075	3	3,30	0,049	0,53
3,25	0,053	3,25	3,57	0,033	0,35
3,5	0,036	3,5	3,85	0,022	0,24
3,75	0,026	3,75	4,12	0,015	0,16
4	0,018	4	4,40	0,010	0,11
4,25	0,012	4,25	4,67	0,007	0,07
4,5	0,009	4,5	4,95	0,005	0,05
4,75	0,006	4,75	5,22	0,003	0,03
5	0,004	5	5,49	0,002	0,02

Table 9: Dimensional time and runoff of the unit hydrograph

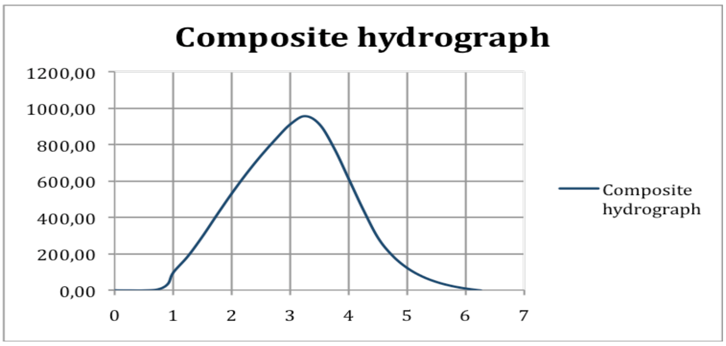
5.3.4.3 Composite hydrograph

Now the composite hydrograph of direct runoff can be developed:

Unit Storm Periods		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	
Excess rainfall (mm)		**0,00**	**0,90**	**4,46**	**7,29**	**9,51**	**11,33**	**12,88**	**14,21**	**15,39**	**16,45**	**17,41**	**18,28**	**19,08**	
Time (h)	**Unit Hydrograph (m3/s)**														**Composite hydrograph (m3/s)**
		Hydrographs of unit storm period													
		1	2	3	4	5	6	7	8	9	10	11	12	13	
0	0,00	0	0												0,00
0,25	1,50	0	0												0,00
0,5	5,67	0	0	0,00											0,00
0,75	9,42	0	0	6,68	0,00										6,68
0,91	10,70	0	0	25,30	10,93	0,00									36,22
1	10,17	0	0	42,01	41,35	14,26	0,00								97,62
1,25	8,77	0	0	47,71	68,66	53,97	16,99	0,00							187,33
1,5	5,65	0	0	45,33	77,98	89,61	64,30	19,30	0,00						296,53
1,75	3,80	0	0	39,12	74,08	101,78	106,78	73,05	21,31	0,00					416,13
2	2,56	0	0	25,18	63,95	96,69	121,28	121,31	80,64	23,08	0,00				532,12
2,25	1,72	0	0	16,96	41,16	83,46	115,21	137,78	133,90	87,33	24,66	0,00			640,46
2,5	1,16	0	0	11,42	27,72	53,73	99,45	130,89	152,08	145,01	93,32	26,09	0,00		739,70
2,75	0,78	0	0	7,69	18,66	36,17	64,02	112,98	144,48	164,70	154,96	98,75	27,40	0,00	829,81
3	0,53	0	0	5,18	12,56	24,35	43,10	72,73	124,71	156,47	176,00	163,97	103,70	28,61	911,38
		0	0	3,48	8,46	16,40	29,02	48,97	80,28	135,06	167,20	186,24	172,20	108,27	955,56
			0	2,35	5,69	11,04	19,54	32,97	54,05	86,94	144,32	176,92	195,58	179,78	909,18
				0,00	3,83	7,43	13,15	22,20	36,39	58,54	92,91	152,71	185,80	204,19	777,15
					0,00	5,00	8,86	14,94	24,50	39,41	62,55	98,31	160,38	193,98	607,93
						0,00	5,96	10,06	16,50	26,53	42,11	66,19	103,24	167,44	438,03
							0,00	6,77	11,11	17,86	28,35	44,56	69,51	107,78	285,95
								0,00	7,48	12,03	19,09	30,00	46,80	72,57	187,97
									0,00	8,10	12,85	20,20	31,51	48,86	121,52
										0,00	8,65	13,60	21,21	32,90	76,36
											0,00	9,16	14,28	22,15	45,59
												0,00	9,62	14,91	24,53
													0,00	10,04	10,04
														0,00	0,00

Table 10: Composite hydrograph of direct runoff

From the composite hydrograph a **peak run-off of 956 m^3/s** after 3,25 hours has been estimated. For a Curve Number of 81 the peak run-off is 375 m^3/s.



Graph 1: Composite hydrograph for Ambuanch-Amba

5.4 Irrigation infrastructure

In this section the design of the irrigation infrastructure will be presented. The basic idea for the canal layout is to follow the traditional canal route for the main canal. The fields immediately start below the main canal; therefore no secondary canals are needed. The water will be taken from the main canals with siphons. The farmers dig field canals to distribute the water over the fields as they need. The lower part of the fields borders the river. Superfluous water will naturally be drained into the river.

The main canal is divided into two sections: the first 107,1 meters from the intake are considered a “sensitive” canal section, i.e. this part of the canal which is located within the potential flood river bed. This part of the canal is intended to be lined with concrete-stone masonry. The remaining part is intended to be constructed in form of a semi-circular canal section. A semi-circular canal saves considerable amounts of construction material. It will be prepared by making use of a mould, which has already been used for other projects.

The intake is intended to consist of a partition wall, which will guide the flow to the intake. It is intended to make use of removable gates, as it can be removed during river-floods and damage can be prevented.

Three gully crossings are needed. It is planned to construct them from sheet metal and steel pipes. The following picture presents a comparable construction, as found at *Weylet* irrigation.

Picture 19: Simple crossing structure made form sheet metal and steel pipes, as found at Weylet irrigation

The components of the following design are

- Canal section for the first 107,1 (200) meters (sensitive part)
- Intake structure, i.e. partition wall to guide the river flow, removable shutters, and intake

The drawings of the canal section and the intake are presented in Annex 6.

Prior to the design the scouring depth will be presented. It has been calculated on basis of the determined peak flood value. The value of the scouring depths is needed to determine the required depths of the intake structures.

5.4.1 Scouring depth

The scouring depth (R) has been calculated to be **10 m** (Annex 7). As mentioned above, the rock-level within the riverbed has been detected at a maximum depth of 3 meters during the survey. The scouring depth of 10 meters will make it necessary to fix the structures on the rock formation. The depths of 3 meters will be used for the design.

5.4.2 Design of canal section

In order to find the most economical solution, i.e. to keep the height if the shutter crest as small as possible, we investigate how far we can extend the canal - head relation and thus receive smaller values for the height of the shutter crest.

From the survey we know that up to a length of 200 m the canal is ideal, i.e the slope is moderate and regular. The survey reading extents only to a length of 107,1 m (as the part, which is "sensitive", i.e. placed within potential flood bed). Therefore we will use the GPS reading which has simultaneously been taken, and bring it in step with the survey readings. The GPS reading can be used in spite of its low accuracy in determining absolute values of the elevation. Here we need to identify the relative value of the difference in elevation as recorded by track reading. The GPS track readings are accurate enough to determine these relative values. As reference point we use the survey intake reading.

	(m a.s.l.)	Adjusted to topomap/survey (m a.s.l.)
"Flume"	GPS reading 2056	2065,45
Intake	(Interpolation) 2062	2071,45

Giving an elevation difference of 6 meters.

The elevation of the existing canal bed at the end point of the canal (L=200 m) is then: 2065,45 m a.s.l.

Therefore we trace back and get the intake point at:
2065,45+(200*0,002)=2065,85 m.

now
2065,85 - 2071,45 = -5,6 m

This means enough difference of elevation is available for an extension. Hence, it is possible to fix the designed canal bed level to the river-bed level. Then only the head causing flow has to be fixed with the shutter.

5.4.2.1 Canal dimensions

The base flow is 10 l/s. For the design of the canal section we take Q = 20 l/s, in order to provide a certain range of flexibility.

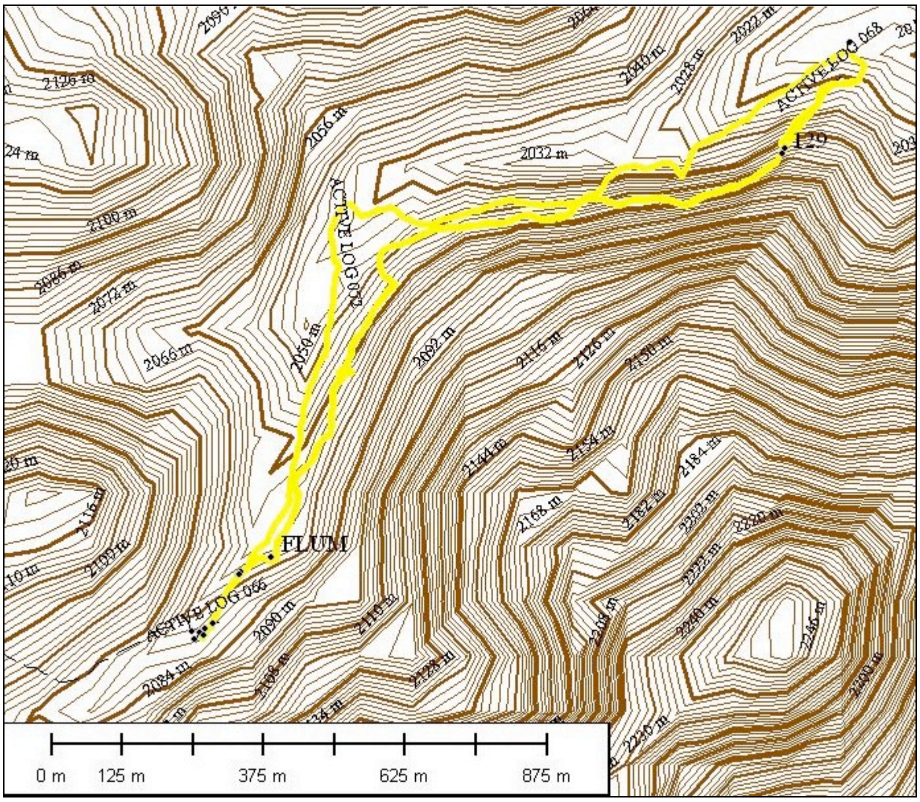
From the calculations (Annex 8) we find that b = 0,30 and d = 0,15 will have a capacity of app. 20 l/s. We have a velocity (v) of 0,4 m/s, which is acceptable.

5.4.2.2 Intake

Now the intake section can be designed. For the shutter crest level we find a height of 0,15 meters. The length of the partition wall is calculated to be 10 meters. (Annex 9)

5.4.3 Command area and canal profile

The command area and the canal course have been delineated by GPS track-reading, giving a command area of 7,5 ha and a length of the main canal of 1,7 km.



Map 5: The command area as determined by GPS track-reading and transferred to a digital topographical map

The indicated command area (Map 5) is divided into fields of different sizes. The fields immediately start below the main canal; therefore no secondary canals are needed. The water will be taken from the main canals with siphons. The farmers will dig field canals to distribute the water over the fields, as they need. The lower part of the fields borders the river; therefore excessive water can directly be drained into the river.

Map 6 present the layout of the main canal and indicates the river course (dotted line) to where the excessive water is drained.

Map 6: Main canal (solid line) and drain (dotted line)

The sensitive part has been measured (lengths, bends) during the field survey. The detailed drawing is presented in Annex 10.

5.5 Agronomy

5.5.1 Present cropping pattern and productivity

The farmers could not give full information on the cropping pattern of the main rainy season. The information for a total area of 2,8 ha only has been obtainable (Annex 11). For the current season, information for the total command of 7,5 ha are given, but obviously data on average yields could not be provided since this is the first irrigation season for *Ambuanch-Amba*, and at the time of the interviews harvest was still to come. In order to complete the above table some estimation and assumptions need to be made.

The crop selection and pattern of rainy season crops will be extended for the total command according to the proportions given for 2,8 ha.
Furthermore some of the farmers' statements needed to be checked and adjusted. This is the case for the statement of an average yield of 45 quintal per ha for sorghum. This value seems rather exaggerated, especially as no chemical fertilizers are being used. From experience of extension workers this value should realistically be in the range of 20-30 quintal. So 25 quintal seems a realistic estimate.
The yield of pepper on the other hand, with 9 quintal per ha, seems rather understated. Values of small-scale irrigation projects with comparable conditions are in the range of 30-40 quintal

per ha[10]. Therewith 35 quintal per ha seems a more realistic estimate. For average yields of maize the *Ambuanch-Amba* farmers had no information. As the mean yield of comparable projects is in the range of 20-30 quintal per ha, again 25 quintal seems realistic estimate. Average onion yields per ha at comparable sites are in the range of 60 – 120 quintal per ha. We can take the mean of 90 quintal per ha as an estimate.

The following table presents the present cropping pattern and gross return rates after the above-mentioned adjustments have been applied:

Sea-son	#	Crop type	LP	Plant.	Harvest	Area			Aver. yield (quintal /ha)	Aver. price (ETB/ quintal)	Gross return (ETB/ ha)	Gross return (ETB/crop /year)
						Ha	H Hs	% of total				
Main rainy reason	1	Sorgh	Jan-Mar	Apr/ May	Nov	1,32		17,65	25	590	14750	19522,06
	2	Whe-at	Feb-Apr	Jun	Nov	1,32		17,65	10	550	5500	7279,41
	3	Bar-ley	Jan-Mar	Jun	Nov	1,32		17,65	12	550	6600	8735,29
	4	Teff	Mar-May	Jun	Oct	1,32		17,65	8	670	5360	7094,12
	5	Local pea	-	Jun	Oct	1,32		17,65	13	400	5200	6882,35
	6	Lintel	-	Jun/Jul	Oct	0,66		8,82	7	770	5390	3566,91
	7	Pep-per	Jan	Apr	Sep	0,22		2,94	35	930	32550	7180,15
Sub-Total						7,5		100,00			75350	60260,29
IRR	1	Onion	Nov	Dec	May	1,5	6	20	90	300	27000	40500,00
	2	Maize	Nov	Feb	Jun	3,75	8	50,00	25	380	9500	35625,00
	3	Teff	Jan	Mar	Jun	1,75	7	23,33	8	670	5360	9380,00
	4	Lintel	-	Dec	Apr (failed)	0,5	1	6,67	7	770	0	0,00
Sub-Total						7,5		100			41860	85505,00
Total						15		200,00			117210	**145765,29**

Table 11: Adjusted Crop pattern and gross return rates

5.5.2 Crop budget of present cropping pattern

For the calculation of a crop budget, the production costs need to be known. Since the farmers do not make use of chemical fertilizers or pesticides the input costs are composed of labour costs (animal and human labour) and costs for seeds. (Annex 12) Table 12 presents the crop budget of the current crop pattern. It includes this year's (first) irrigated production on basis of yield estimations. Land taxes are taken to be 20 ETB per year.

[10] ETH 1052 *Study on the Design of appropriate cropping pattern at three irrigation sides – Jare, Gedeo Ulaula and Derek Woha (Amhara, North Wollo)*. GAA/ORDA 2006

Crop	Total area (ha)	Production costs + land tax (ETB)	Gross return (ETB)	Gross return/man day (ETB)	Net return (ETB)	B/C
Maize	3,75	5305,00	35625,00	139,71	30320,00	5,7
Sorghum	1,32	3020,59	19522,06	136,57	16501,47	5,5
Wheat	1,32	3048,24	7279,41	52,88	4231,18	1,4
Barley	1,32	2907,06	8735,29	68,75	5828,24	2,0
Teff	3,07	7158,78	16474,12	51,54	9315,33	1,3
Local peas	1,32	1565,88	6882,35	162,50	5316,47	3,4
Lintel	1,16	1056,81	3566,91	95,95	2510,10	2,4
Pepper	0,22	433,59	7180,15	290,63	6746,55	15,6
Onion	1,50	3664,88	40500,00	177,63	36835,12	10,1
Total	15,00	28160,83	145765,29		117604,46	
Average						5,3

Table 12: Crop budget of current production at Ambuanch-Amba.

The highest return rates are achieved through production of onions and pepper. Teff *(Eragrostis tef)*, the widely cultivated traditional Ethiopian cereal, with its general low overall-productivity (kg/ha), high labour intensity and long growing period achieves the lowest net return of all produced crops

As mentioned above, for the proposed crop-pattern a cultivated area of 10 ha has been assumed. To compare the net return rates of the current and the proposed patterns we have to extrapolate the net return of 7,5 to those of 10 ha. Therefore we can apply a factor of 1,3 to the net return of 7,5 ha, giving a net return for 10 ha of 156805,95 ETB.

5.5.3 Proposed crop pattern

5.5.3.1 Crop selection

To develop an improved cropping pattern different criteria for crop selection have to be taken into consideration.

Market outlet
The main market for these farmers is found at Kobo town, approximately 3 hours walking distance. The products are transported by men, with donkeys and camels. This market is the main market for staple crops. An additional market, closer to the site but smaller, is found at *Tekulesh*, in approximately 1 hour walking distance.

Marketing of agricultural products will become a more important issue as production is intensified. As mentioned, this year is the first year of irrigated production for these farmers.

The farmers report that market prices are currently satisfying. Nevertheless it is known that prices for agricultural products are highly fluctuating, and the farmers' market position is rather weak. In specific the vegetable/horticulture market is tightly controlled by traders with the capacities and respective information to move products to more profitable markets - the farmers being price takers. One cause of this situation is the uncoordinated production, meaning that farmers produce at the same time the same crop, thus increase competition.

Marketing conditions for the farmers can hardly be improved substantially on imitative or by the efforts of one (small) irrigation scheme only. One promising approach can be found in the coordination of activities through marketing cooperatives, as seen in the Ankerka Vegetable Producers Cooperative. In order to improve marketing, i.e. to gain a more powerful market position by means of coordinated production and sales, a certain number of farmers need to come together and work together.

Climatic condition of the area
As described earlier the climatic condition of the area allows the cultivation of a diversity of crops.

Availability of water
Availability of water can be considered as major constraint for production in this area. From October/November to February/March, when nearly no rain can be expected, production exclusively depends on irrigation. The second, small rainy season, the so-called belg-rain season, starting around February/March, is in some areas used for a second crop. This season is unreliable in terms of quantity of rain as well as timely distribution, therefore supplementary irrigation is an important mean to ensure this crop.

Soils
In the command area soils consist of sandy clay loam, with a fair to good natural fertility. Fertilizers are not being used. Intensified production will challenge the balance of nutrient production and outtake. Both, informed crop rotation as well as advisedly application of fertilizers will become important matters of sustainable production.

Client preferences and traditional agricultural knowledge
The farmers of *Ambuanch-Amba* are, as mentioned, new to irrigation. From their expressed self-assessment they need trainings and advice in agronomy and water management in order to establish a profitable irrigation production. Traditionally these farmers produce some vegetables (onions) and small grains like teff. For this year’s first irrigation season most of the command is planted with maize.
In general it can be said, that with adequate advice and trainings these farmers are willing and able to adjust their practice to an improved crop pattern. This has been the experience in many other schemes of *ORDA* and *Welthungerhilfe* in Ethiopia.

Economic advantage of crop
As we could see from the above presented crop budget of the present crop pattern, different crops achieve considerable differences in net return rates.
In general an improved cropping pattern should find a balance between the need of producing staple crops and high value crops. Since irrigation is costly, the need for producing high value crops at a substantial rate is obvious. Therefore preference is made for onion and pepper. For this scheme it will be recommended to exclude teff from production, because of its low overall productivity. It will be suggested to replace it by sorghum and maize. Both sorghum and maize achieve higher net return rates, and with a growing period (LGP) of 125 days, which is 40 days less than teff (LGP minimum 165 days), fit much better into a 3 crops per year scheduling.

Dietary habit and nutritional requirement of the local people
In the area sorghum is the main staple food, followed by teff and maize. The selection of wet-season crops takes this into consideration. Cereals are highly valued by the farmers not only

for their consumption but also for livestock feed. In order to shift from cereals production to production of more profitable crops, forage development should be accordingly promoted.

5.5.3.2 Crop rotation

Sustainability has to be a central concern for the proposal of a cropping pattern. As mentioned, intensified production - a shift from 1 (or 2) to 3 crops a year - puts considerable stress on natural resources. The farmers at *Ambuanch-Amba* do not make use of any of the common chemical fertilizers like Diammonium-Phosphate (DAP) or Urea. But few use of compost as natural fertilizer. In the absence of chemical fertilizers soil depletion can be conquered / mitigated by introducing managed crop rotation, balancing nutritional abstraction and retrieval. To enhance availability of nitrogen leguminous should be planted at least in one of the seasons on every plot.

5.5.3.3 Improved cropping pattern

To develop an improved crop pattern the above-mentioned considerations have to be taken into consideration. In order to find a balance between production of staple food and high value crops sorghum and maize are included during both rainy seasons. To assure profitability of the scheme preference is given to high value crops. This means during irrigation season it will be recommended to produce vegetables and pulses only, and during the rainy seasons to produce additional vegetables and pulses, besides cereals. Due to the above-mentioned consideration concerning soil fertility, a sequence of grains – vegetables – pulse-crops is proposed for every plot of the scheme.

A crop ratio for cereals, vegetables and pulse-crops of 1:2:1 is proposed for the improved pattern and presented in table 13. Under vegetables onion and pepper are subsumed. Pulse stand for lentil and local peas. Cereals are partitioned into sorghum and maize, with a ratio of 2:1.

Season	Crop	LGP	%	Area (ha)	SW-date	HV-date
Main rain season	Maize	125	25	2,5	1.6.	3.10.
	Sorghum	125	25	2,5	1.6.	3.10.
	VEG	95	50	5	10.6.	12.9.
	Sub-total		100	10		
IRR (dry season)	VEG	95	50	5	20.10.	22.1.
	Pulses	110	50	5	1.10.	18.1.
	Sub-total		100	10		
Belg rain / supplementary IRR	Sorghum	125	25	2,5	1.2.	5.6.
	VEG	95	50	5	10.2.	15.5.
	Pulses	110	25	2,5	10.2.	30.5.
	Sub-total		100	10		
	Total		300	30		
	Irrigation/cropping intensity (%)		300			

Table 13: Proposed crop pattern

5.5.3.4 Crop budget of the proposed crop pattern

The following table presents the crop budget of the proposed crop pattern:

Crop	Area (ha)	Aver. yield (Q/ha)	Aver. market price (ETB/Q)	Gross return / year (ETB)	HL & AL / ha (ETB)	HL & AL value (ETB)	Seed costs / ha (ETB)	Seed costs value (ETB)	Prod. costs & land tax (ETB)	Net return (ETB)	B/C
Maize	2,5	25	380	23750	1356	3390	53,33	133,33	3543,33	20206,67	5,7
Sorgh	5	25	590	73750	2196	10980	71,11	355,56	11355,56	62394,44	5,5
Onion	7,5	90	300	202500	2424	18180	5,92	44,40	18244,40	184255,60	10,1
Pepper	7,5	35	930	244125	1872	14040	2,96	22,22	14082,22	230042,78	16,3
Peas	3,75	7	400	10500	768	2880	400,00	1500,00	4400,00	6100,00	1,4
Lintel	3,75	13	770	37537,5	768	2880	124,44	466,67	3366,67	34170,83	10,1
Total	30									537170,32	8,2

Table 14: Crop budget of the proposed cropping pattern (HL=Human labour; AL=Animal labour)

5.5.4 Comparison of the crop budgets

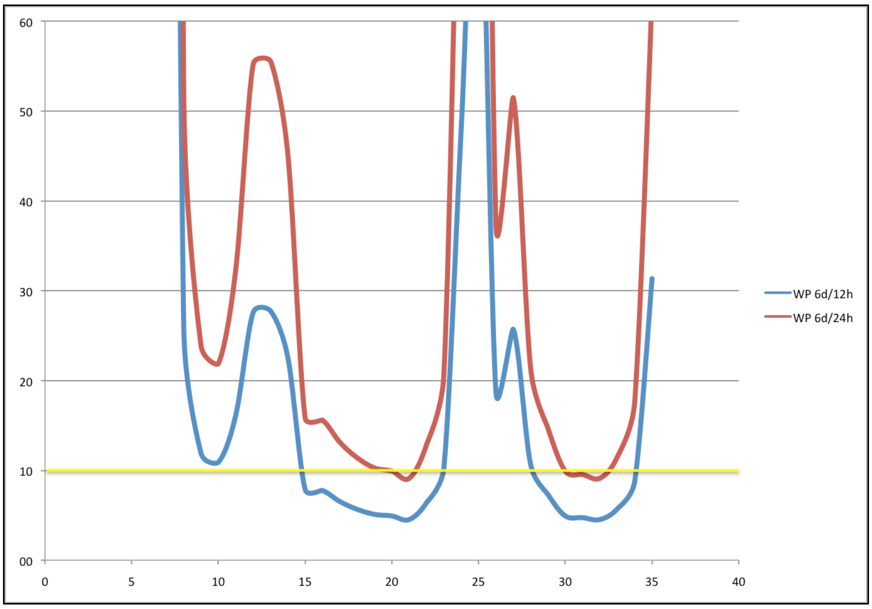
From the crop budgets of the present and the proposed cropping pattern we can see that the improved pattern - with its main focus on high value crops - achieves a net return of 537 170 ETB, this being more than three times the current net return of 156 805 ETB. For this calculation increased productivity as a result of trainings and use of fertilizers has not even been considered.

5.5.5 Crop water requirement and water potential

On the basis of the proposed crop pattern the crop water requirement and respective irrigation duty can be calculated. Effective rainfall and overall evapotranspiration (ETo) have been calculated with CropWat (Annex 13).
The water potential for an irrigation scheduling of *6 days per week and 12 hours per day*, and *6 days per week and 24 hours per day* has been considered. These calculations are provided in Annex 14.

The *irrigation efficiency* has been calculated as follows:
$Eff_{overal} = Eff_{convayance} * Eff_{distribution} * Eff_{application}$
The conveyance efficiency is estimated to be 90% (lined canal). The distribution efficiency will not be considered since the water will be applied directly from the main canal to the fields, thus secondary canals are not required. The application efficiency (surface/furrows) is estimated to be 60%. Therefore the overall irrigation efficiency is considered to be 54%.

As shown in *graph 2*, in order to follow the crop pattern and serve the total of 10 ha a shift from a 12 h to 24 h irrigation interval would be necessary during certain periods of the year. During few decades the water potential would still not be sufficient (December, March/April). Since the water potential is only slightly below 10 ha, a temporary shift to 7 days a week might be a practical solution to avoid stress to plant growth. Out of experience in other schemes, farmers can easily adjust their operations and work-times to urgent needs.



Graph 2: Water potential for different irrigation-intervals in relation to total command area of 10 ha

Therefore we can conclude that the above-proposed cropping pattern can be realised in terms of water-availability in an upgraded scheme.

5.6 Total costs and financial analysis

The material costs have been calculated in a material breakdown and the Bill of quantity (Annex 15). The following budget items have been estimated:

Total costs	ETB	€
Intake and canal	348374,50	21773,41
Crossing structures	6855	428
Shutter	1500	94
Total	356 729,50	22 296

Table 15: Total material costs of the irrigation infrastructure

The total material costs for intake, canal and crossing structures amount to **356 730 ETB or 22 296 €.**

After the revision of the budget of 2 260 000 ETB is available for the irrigation component, if we assume a total of 150 ha of irrigated area we receive an available budget of 15 066,00 ETB per ha, thus 150 666,00 for 10 ha. The costs for *Ambuanch-Amba* irrigation according to this design are two times higher.

It now has to be decided whether this amount of money can be spend on *Ambunach-Amba.* As this scheme is intended to serve as a model, a special arrangement might be appropriate. Other projects would then have to be implemented with a further reduced budget, i.e. less complex projects must be chosen.

Another option would be to reduce the length of the main canal. Here a length of 2 km has been assumed, thus the extension to the additional households has been considered. If the length of the canal will be reduced, the irrigation efficiency will become lower. This can be mitigated by changing to 7 days per week irrigation during peak times.

The economic indicator analysis (Annex 16) shows, that assuming a yearly net return of 537170,32 ETB (as calculated for the proposed crop pattern) and implementation costs of 356 730 ETB the Net Present Value would amount to 2,7, and the benefit cost ration would amount to 2,6, thus both values indicate a profitable project.

6. Improved marketing

6.1 Introduction

Poor marketing of farmers has been described as a major constraint for a sustainable functionality of irrigation schemes. In this last chapter, I will analyse which role marketing plays for the establishment of functional water-user organisations, and thus scheme management. Accordingly, I will present the findings of the enquiry on improved marketing strategies. With this regard experiences of farmers from the Ankerka marketing cooperative will be presented.

6.2 Bottleneck "marketing"

In the course of a pre-study for an EC-Food Facility proposal, carried out by *Deutsche Welthungerhilfe* in June 2009, about 20 irrigation schemes, which have been implemented by *Welthungerhilfe* and *ORDA* in previous years in the *Amhara*-region, have been assessed. The objective of the study was to identify further project opportunities on basis of a status analysis of the schemes and impact assessment.

One central finding of the study was that in a large number of the schemes the productivity has not been improved to the extent initially expected after the program phased-out. Furthermore poor scheme management (i.e. irregular maintenance) has often led to a gradual destruction of the physical structures (head work, canals etc.).

The study shows that the establishment of functional water user associations or irrigation cooperatives has not been successful. Although in most of the schemes respective organisations have formally been established (on basis of commonly agreed bylaws, legally approved by governmental institutions), the majority of the farmers did not actively participate in these organisations.

The reasons for this development are diverse. To some extend the establishment of functional water-user organisations has been neglected in the course of the program. Though the formation of these institutions was intended, respective trainings and follow-ups have probably not been sufficient. Additionally the support for the farmers through respective governmental institutions was very limited. Recently a reorganisation of the legislation of cooperatives was conducted. A *Cooperative Promotion Office* has been established (on regional, district and community level), with the objective to enhance the support for farmers, women-groups etc. during the formation of cooperatives. But the office has proven to work rather inefficiently, and ongoing conflicts about competences and responsibilities with other offices (e.g. Agricultural Office) have complicated the work.

Despite these problems cooperatives or water-user associations have finally been established in mist of the schemes, at least formally. Since participation of the farmers was rather poor at any time the functionality of the units is very limited. The main reason why farmers refused to participate in these organisations was the understanding and expectation not to benefit from their involvement. Although the production methods have been improved in the course of the project, the results in respect to the returns and profits are equally poor. The cooperative-formation has not been set up in tandem with the establishment of innovative and profitable marketing strategies – which can be considered as a key to success.

The prices for agricultural products are highly fluctuating. Particularly the vegetable/horticulture market is tightly controlled by traders with the capacities and respective information to move products to more profitable markets - the farmers being price takers. Since the farmers themselves normally do not own or have access to transportation facilities others than donkeys or camels, they can hardly access alternative markets. Lacking adequate storage capacities - especially for perishables - is another disadvantage for farmers as they cannot simply wait for better prices. This situation is often aggravated by uncoordinated production of farmers of one site or area: many farmers produce the same crop at the same time, which has a negative impact on the competitive capacity.

It has become obvious that the lack of successful marketing strategies is one of the key problems cooperatives have to deal with: low membership and participation due to lack of incentives, weak management structures as a result of lack of support for committees and in consequence substandard scheme and water management. Furthermore, improvements of agricultural practice (introduction of improved varieties, agronomic skills etc.) are only then likely to be sustainable when farmers are linked to reliable and profitable markets, which enable them to earn the capital needed for the regular investments. This is particularly important for irrigated production where in addition for regular costs for agricultural inputs, costs for repair and maintenance have to be covered as well.

It is obvious that improved marketing has to be considered a prerequisite of sustainable achievements (i.e. improved productivity) of irrigation projects. In this sense it seems important to look out for improved marketing strategies. How can marketing for smallholders be substantially improved? Are models for improved marketing developed and available in the area?

6.3 The Ankerka Vegetable Producers' Cooperative

6.3.1 Background information

Some 5 years ago the *Ankerka Vegetable Producers' Cooperative* was founded in the Tehuledere district, which was supported through the *Market-led Livelihoods for Vulnerable Populations* (MLVP) program. The program was launched and financed by the *United States Agency for International Development* (USAID) and has been implemented at *Ankerka* through the *Organisation for Rehabilitation and Development in Amhara* (ORDA) with the main objective to support farmers in improved marketing of their products.

Currently the cooperative has 270 members from 4 communities (*Tigu, Ankarka, Gidu, Estenna*) selling their products through the cooperative. About 1100 additional non-member farmers are freely associated to the cooperative without formal membership and sell parts of their production through it. In 2009 281 tons, mostly vegetables, have been produced on 35 ha of land. The data provided by the office regarding return rates of the cooperative are not very

clear since the actual number of farmers who sold their products to the cooperative is not outlined.
At present carrots, cabbage, potatoes, tomatoes and onions are produced. This year (2010) additionally cereals have been included in the agronomic planning, as a mixed production would better protect farmers from market failure.
To become a member farmers have to pay a registration fee of 10 ETB and a share of 50 ETB. The current savings (capital) of the cooperative is about 47,000 ETB. The cooperative is involved in the management of the nearby *Tigu*-irrigation scheme, as the farmers of this scheme have been the founders of the cooperative. The water-users contribute a water-fee of 4 ETB per water gift. In return costs for maintenance are covered through the cooperative.
The cooperative owns a storage house and a small office in *Tigu*. These buildings have been funded by the MLVP-program.

The cooperative is involved in the following activities:

- *Storage of products*: the associative farmers deliver their products to the storage house, where they can adequately be stored
- *Market assessment:* a market assessment committee carries out market analyses via telephone or by travelling to marketplaces. Pre-negotiations with merchants about quantities, quality and prices are conducted.
- *Improving agronomic practice:* in accordance with market demands the farmers are advised to produce certain crops. Trainings for improved agronomy are regularly provided to cooperative members. These trainings are designed in relation to previously conducted market assessments (market driven production). For members, the production is partly coordinated and centrally scheduled. Non-members deliver whenever and whatever (predominantly vegetables) they produce.
- *Contact wholesalers*: wholesalers are contacted and invited to the warehouse compound, where agricultural auctions take place.
- *Organising transports to alternative markets:* trucks are regularly rented to transport products to more profitable markets (i.e. big city markets in *Dessie, Bahir-Dar, Addis-Ababa, Gondar* etc.). Before conducted market assessments prepare and allow a strategic market selection.
- *Provision of fertilizers*: fertilizers are purchased through the Agricultural Office, thereafter re-sold to the members. This procedure is advantageous for the farmers as they save time and money for travelling and transport. Additionally the prices can be reduced since large quantities are being purchased.
- *Provision of credits:* other agricultural inputs like seeds are provided to the farmers on credit basis. The credits are paid back after the final products have been sold.

Picture 20: The cooperative's storehouse in Tigu, Tehuledere

6.3.2 Life before and after founding of the cooperative: farmers' perspective

6.3.2.1 Diversification

Before the cooperative has been established, farmers of the area mostly grew carrots and onions. The production has been diversified in the last years (with respect to crops as well as varieties) as a result of market demand analysis and trainings. Farmers have appreciated new impulses through the cooperative as benefits could have been immediately experienced.

6.3.2.2 Income

One farmer reported that his income has increased from 1000 / 2000 ETB per year to 5000 / 6000 ETB in the last 5 years. These figures have been confirmed by the Development Agents; numerous farmers have confirmed similar experiences.
Before the cooperative was established, this farmer like most of his colleges transported his vegetables to the local market with a donkey. The long transportation time often reduced the quality of the products significantly, and decreased the income gained on the market. Furthermore, he was totally dependant on the existing prices on the local markets. Due to lack of information on current price levels the farmers had to accept the prices offered by local merchants/brokers.

6.3.2.3 Living standard

An improvement of the living standards due to higher income is obvious in the project area. Newly, professionally constructed houses with corrugated iron roofs replace traditional Tukul houses. Electricity has been introduced in the villages around *Tigu*-irrigation (as first and currently the only village in the area). And, as stated by the Development Agents, the percentage of children attending school has increased substantially.

6.3.2.4 Reaction of local merchants and brokers to the new marketing strategy:

As stated by the community Development Agents local merchants and brokers were not happy about the cooperative's initiatives and activities. But it was not a matter of serious conflicts as this group has enough alternatives in the area to buy products to their own conditions.

6.3.3 Conclusions

The activities of the cooperative address exactly the problems being identified by the EC-pre study: provision of sufficient storage and transportation capacity, as well as provision of adequate market-information based on market assessment data. Since the establishment of the cooperative the farmers present themselves as a team to the competitors on the market, and thus attain a far stronger market position than an individually acting farmer could ever have. Furthermore agronomic planning can be coordinated among the community members according to profound assessment of market demands and developments.

As a result of the cooperative's activities - namely improved marketing strategies and demand oriented agricultural production - farmers' income has increased substantially during the last five years. Although the cooperative did not provide reliable and detailed data of the revenues the livelihood improvements are obvious and have repeatedly been stated by interviewed farmers and during focus group discussions. Furthermore, the scheme management of *Tigu*-irrigation, which is partly coordinated by the cooperative, can be described as a model scheme. The structures are in a good condition and well maintained. The water-users actively participate in operation, management and maintenance since they experienced immediate benefits. That draws a distinction between other schemes in the area, where farmers do not experience noticeable benefits from irrigated production.

Most of the cooperatives assessed during the pre-study have been established as genuine irrigation cooperatives. Their main purpose is scheme and water management. Altered conditions of agricultural production in an irrigation scheme, i.e. the need to cover costs for operation and maintenance as well as probably increased input-costs, the need for adapted agronomic practice, the often intensified labour etc., has to be compensated, i.e. benefits need to be substantially adjusted.
The *Ankerka* cooperative on the other side has been established as a marketing cooperative for several sites and schemes. With newly established structures like a storage house, improved information flow through market assessments, increased yields which raises the interest of merchants and farmers to pay for transportation of their products to more profitable markets.

The project proves that it is more advisable to establish central marketing cooperative rather than cooperatives within individual small-scale schemes.

7. Conclusions and recommendations

In order to specify the objectives of the present thesis two problem aspects had been analysed: the problem statement concerning the irrigation component of the *Deutsche Welthungerhilfe* program ETH 1064, and the problem statement concerning irrigation projects in general, as derived from impact assessments of previous projects. Both problem statements share the core concern for sustainability of the project activities. With this regard, the present study presents an attempt to contribute to the sustainability of the achievements of the irrigation component of the *MDG Water and Sanitation program*.

To address the needs of the program and its irrigation component in particular, namely the apprehended lack of sustainability of the project activities, the establishment of model schemes was considered an adequate action. With this regard the upgrading of *Ambunach-Amba* irrigation has been carried out. The design and planning is intended to support the farmers to a) ensure by supplementary irrigation one main crop during poor rain seasons, b) to produce one additional full crop during the dry season (December – April), and c) to produce a third short-season crop, especially vegetables, during the so called belg-rain season (February - April).

Preceding the scheme design, an assessment of the four approved and partly implemented irrigation projects has been carried out, with the objective to identify problems and opportunities for further projects (“lessons-learned”).
The findings can be used by program staff to optimize the implementation. Some of the findings have been integrated into the planning and design of the model scheme, e.g. the importance of adequate stability assessments (i.e. preparation of stability assessment through comprehensive hydrological analysis), and the need of planning of an improved crop-pattern.

In addition to this, options for improved marketing, considered as one of they key-success factors of sustainable functionality, have been investigated. The main finding of this chapter was that through cooperation farmers can gain a stronger market position, improve their income and thus their livelihoods. As a result of this farmers are intrinsically motivated to participate in the scheme management.

With this regard it is recommended to

Review the findings and recommendations of the assessment of the ongoing irrigation projects: In particular the construction works at *Weylet* irrigation are urgently in need of supervision and follow up, as outlined in the respective section. Furthermore the formation of functional water-user association, which is intended to be accomplished alongside with the construction works, is in need of follow-up and support. As outlined in the respective chapters, functional units of water management must be considered a key-success factor for sustainable operability of the schemes. As agricultural practices have not yet been adapted to the conditions of irrigation, the planning of adjusted cropping patterns, as shown at *Ambuanch-Amba* irrigation, should be advanced.

Implementation of design and planning of Ambuanch-Amba: As agreed with the program office, the upgrading of *Ambuanch-Amba* irrigation will start to be executed after the main rainy season (i.e. October/November 2010). Until then the office’s technical staff should review the design. Based on their experience some items of the design can further be adjusted to the particular Ethiopian setting, i.e. estimation of the appropriate Antecedent Moisture Condition and respective Curve Number. Furthermore, based on the hydrological analysis, the stability assessment should be carried out. Additionally it is recommended to discuss the

improved cropping pattern, as proposed in the report, with the farmers. The pattern should be considered as one option, by which a cropping intensity of 300 % can be approximated. As expected it needs to be adjusted to the farmers demands and preferences. Additional options to improve the agricultural practice, e.g. the introduction of improved varieties, or intensified use of chemical fertilizers should be investigated.
Once the upgrading has been accomplished and an improved cropping pattern is practiced, experience share activities with farmers of the area should be conducted.

To consider of the establishment of a marketing cooperative: It is recommended to establish central marketing cooperatives alongside with irrigation projects, for this or for any other program in this sector. It has become obvious that the marketing conditions can hardly be improved by the farmers of one (small-scale) irrigation scheme only. Therefore cooperation is needed. A model for cooperation and improved marketing can be found at the *Ankerka Marketing Cooperative*, as described in an earlier section. Since about 20 irrigation schemes already exist in the area, which have been implemented or upgraded in previous years by *Deutsche Welthungerhilfe* and *ORDA*, and additional schemes will be added in the course of this program, numerous schemes are available to be integrated into the activities of a central marketing cooperative.
Since the formation of a marketing cooperative has not been considered in the initial program proposal, human and budget resources are limiting factors. The importance of improved marketing for the sustainability of the schemes should nevertheless be taken seriously, and be considered in the coming projects and programs right from the beginning.

References

ETH 1052 Study on the Design of appropriate cropping pattern at three irrigation sides – Jare, Gedeo Ulaula and Derek Woha (Amhara, North Wollo), GAA/ORDA 2006.

J. Boonstra, LRI (International Institute for land reclamation and improvement) Wageningen, The Netherlands. Publication 16; completely revised edition 1995, Chapter 4, Estimating peak runoff rates.

Lecture notes Internationale Agrarische Hogeschool Larenstein: Introduction to irrigation I & II. Vakgroep international land en watermanagement. First revised edition, October 1992.

Midterm Evaluation of ETH 1064 - MDG Water and Sanitation Program in Rural Amhara. Temesgen Consultancy Service, Addis Ababa, Ethiopia, p. 40 f.

Pre-study for EC-Food Facility Proposal: Investigation of the potential for improved agricultural productivity through upgrading of traditional irrigation schemes. Deutsche Welthungerhilfe/GAA, June 2010.

Working manual for extension workers: Hydrology. Ministry of Agriculture, Addis Ababa, 1996.

ANNEXES

ANNEX 1: Plan of approach

Plan of approach

Planning and design of an upgrading of an irrigation scheme in the context of Deutsche Welthungerhilfe's "MDG Water and Sanitation Program" in the Amhara region.

Final Thesis 2010
International Water Management (BA)
Van Hall Larenstein University of Applied Sciences, The Netherlands

Student: Christoph Meier zu Biesen
Tutor: Henk van Hoof

The Final Thesis will be compiled during an internship with the INGO Deutsche Welthungerhilfe / German Agro Action (GAA), Office Ethiopia/Horn of Africa

1. Description of framework of the assignment

The formulation of a final thesis accomplishes the course of study *International Water Management* (B.A.) at *Van Hall Larenstein University of Applied Sciences*, The Netherlands.

It takes place during the last two modules of the 2nd year of the major. The final thesis consists of an individual assignment in the field of land and water management. As intended, it will be prepared in conjunction with a placement at an organisation or company active in the field of the study. The results will be presented in the form of a report, and a presentation at a final thesis colloquium.

The present thesis will be compiled during an internship with the International Non-Governmental Organisation (INGO) *Deutsche Welthungerhilfe (German Agro Action)* in Ethiopia, East Africa, in the time from 1.3. to 9.7. 2010.

The organisation: *Deutsche Welthungerhilfe (German Agro Action)*

Deutsche Welthungerhilfe is an international humanitarian NGO, founded in 1962. The organisation's headquarter is in Bonn, Germany. *Deutsche Welthungerhilfe* is currently working in 45 countries with about 321 running projects (2008). The total budget amounts to ca. 140 Mio € in 2008, of which 115 Mio € are project turnover

Welthungerhilfe translates into "world-hunger-help", which was the main operational feature during the first decades since start of operation and is still partly, e.g. in Darfur/Sudan.

Deutsche Welthungerhilfe is active in Ethiopia for 32 years. The accumulated budget for this period amounts to 120 Mio €. In 2008 16 projects were operational, aiming at 1,400,000 beneficiaries in 6 regions (24 districts). The annual turnover is ca. 5 Mio € for about 400,000 needy persons per year.

Deutsche Welthungerhilfe is cooperating with 10 Ethiopian partner NGOs. Most of the program activities are carried out through these local partner organisations, while GAA closely supervises and monitors the projects.

The main fields of work *Deutsche Welthungerhilfe* and its partner organisations are involved are:

- Water, sanitation and hygiene
- Food security and rural development, including natural resource management and agricultural development
- Social development and capacity building at all levels (including rural health)
- Pastoral development (Afar/Somali-region)
- Relief and rehabilitation

The specific program approach of *Deutsche Welthungerhilfe* in Ethiopia can be characterised by the following working principles:

- Participatory and community-led methods and approaches
- Partnership with local NGOs
- Strong and strict gender approach
- Secular / non-religious / non-political approach
- LRRD: linking relief and rehabilitation with development

- Integrated, holistic analyses and views
- Strengthening of the civil society

The framework of the final thesis assignment in the context of the activities of *Deutsche Welthungerhilfe* in Ethiopia

The final thesis is intended to develop a subject in the field of land and water management. With respect to the available time for this study as well as the available capacities of the organisation to support my study, the subject needs to be limited to a specific assignment. An internship with an organisation active in a variety of working-fields on the other hand offers the opportunity to gain insight into a wide range of themes relevant to land and water management (i.e. irrigation, sanitation and hygiene, rain-water harvesting etc.). In order to answer both purposes as well as to set-up and plan my study to possibly be of further use for the organisation, the following framework for my work has been agreed upon:

The final thesis assignment will be prepared in the context of *Deutsche Welthungerhilfe's "MDG Water and Sanitation Program"* (ETH 1064) in the Amhara-region in Ethiopia. My assignment will be related to the program's irrigation component. Details on the program as well as on my study objectives will be given in the following.

Besides that I will be given the opportunity to visit and experience program components concerned with two other important fields of water management: the WASH-program sector, i.e. Water, Sanitation and Hygiene projects in Arsi Negele and Butajira (ETH 1070 & ETH 1080), and program activities in the arid Afar-region, mainly concerned with the implementation of water harvesting facilities and the dissemination of practical knowledge on water harvesting (ETH 1081).

An outline of my activities will be presented in a draft time frame for the internship at the end of this Plan of Approach.

The "*MDG Water and Sanitation Program in Rural Amhara" – Deutsche Welthungerhilfe* - Program ETH 1064

As mentioned, the thesis assignment will be compiled in the context of the *Welthungerhilfe* program ETH 1064 in the *Amhara*-region. I will now briefly introduce the program and the program's irrigation component in particular. Then, leading over to the problem analysis and the respective problem statement, the current status of the program will be outlined.

General information

The *MDG Water and Sanitation Program in Rural Amhara* is an EC funded[11] Water, Sanitation and Hygiene project of *Welthungerhilfe*. The program has been launched for five years, starting in December 2006. *Welthungerhilfe* in partnership with the *Organization for Rehabilitation and Development in Amhara* (ORDA) is implementing the program in five districts (woredas) of the *Amhara* region: *Kutaber, Ambasel, Worebabo, Kobo* and *East Belessa.*

The overarching development problem to be addressed by the program is morbidity and child mortality in the target woredas, seen as a result of poor access to safe water and inadequate

[11] Support of the Ethiopian water sector under the ACP-EU water facility program

hygiene & sanitation practices. Loss of potential productive time and school days due to illness, taking care of patients and long walking distances and long-hours queuing to fetch water are problems associated with/to poor access to safe water and poor hygiene & sanitation practices.

The activities proposed to address the problem are:

- Capacity building of the communalities and government offices;
- Implementing demand-driven community projects such as: water supply (springs, wells), sanitation (latrines etc.) and small-scale irrigation facilities;
- Environmental sustaining interventions such as: area closure, afforestation and gully rehabilitation.

The total budget amounts to € 3.85 Million. It is made up of

- EU contribution: € 2,8 Million (75%)
- GAA contribution: € 641,842 (16.67%)
- Community contribution: € 320,658 (8.33%)

About 40 % of the budget is allocated for projects concerned with save drinking water supply (SWS), thus representing the program's main feature. It is intended to raise the save water coverage from 25% to 57% in the course of the program, thus benefiting about 281,000 individuals.

The Program's approach

The program follows a *community-led approach*. *Image 1* visualises the six-phased *Participatory Community Projects Management Cycle,* as used in the program. It includes all basic management steps during a project, from project identification to evaluation.

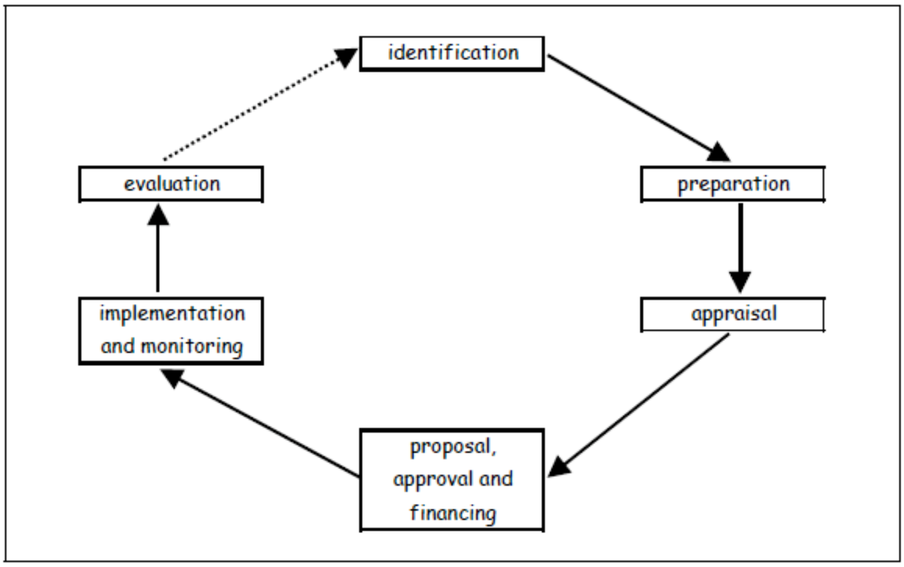


Image 1: Visualisation of the six-phased Participatory Community Project Management Cycle

The community-led approach is based on two principles: participation and contribution.
The communities are intended to participate in at all main stages of the project management, which are:

- Identification of a project opportunity („need"), planning & proposal preparation;

- Procurement & purchase of materials;
- Contracting service providers;
- Monitoring & management during implementation;
- Operation and maintenance (O&M) management.

Furthermore the communities are requested to contribute to the project in terms of
- (Un-)skilled labour
- Collection and transportation of locally available construction materials
- Collect and save money to fully cover operation and maintenance cost.

The main reason or motivation to implement a program on basis of a community-led approach is the anticipated improvement of sustainability through creation of strong senses of project ownership among the communities. As shown in the flow chart, the identification of project opportunities (“needs”) represents the first step in the project cycle. With other words, the initiative needs to come from the communities, while the program “only” facilitates the process.

The establishment of organisational structures for operation and maintenance management at an early stage of the project (i.e. before or simultaneously to the construction works), as another main component of this approach, also reflects the attempt to make the communities fully capable to manage the project.

The program’s irrigation component

As mentioned above and agreed with *Deutsche Welthungerhilfe*, my thesis assignment will be formulated in the context of the irrigation sector of ETH 1064. The activities in this sector aim on enhanced agricultural production in small-scale irrigation schemes.

The proposed outcome of the program’s irrigation component is formulated under Result 2.2 of the project proposal*: 1,100 households benefit from enhanced agricultural production in pro-poor small-scale irrigation schemes*.

The corresponding project activities, as proposed in the initial proposal, include
- Improvement of traditional irrigation schemes
- Spring capping irrigation
- River diversion irrigation
- Deep well irrigation
- Check dam irrigation
- Runoff harvesting check dams
- Household level runoff harvesting structures

The budget originally allocated for the irrigation component amounts to 360,000 €, thus 9% of the total budget.

2. Problem analysis and problem statement

In this section I will give a short overview of the current status of the program’s irrigation component. Against this background a problem analysis and a problem statement can be formulated.

Current situation of the irrigation component of ETH 1064

Mid-term evaluation

In January 2010 the midterm evaluation of ETH 1064 was carried out. As outlined in the report, the irrigation activities have - although planned to some extend - not been accomplished in most of the target Woredas – except limited activities, which are on implementation in 4 schemes: *Kobo* (1 diversion & 1 spring irrigation), *Ambasel* (1 spring irrigation) and *Worebabo* (1 spring irrigation). These schemes are intended to benefit 954 people (app. 200 HHs). This means additional project activities in the irrigation sector will have to address about 900 more HHs in order to achieve Result 2.2.

Taking into account the remaining project time as well as the program's programmatic orientation towards a rather time-consuming community-led approach the evaluators recommend to revise and reorganize the irrigation component. Deep well irrigation and check dam irrigation for example require both high involvement of professionals, long time for study and preparation etc., requirements that make a successful execution at this advanced point of the program rather unlikely. In this sense the evaluators recommend that

> *"the activities under this result should be reduced to spring capping irrigation (...) and upgrading traditional irrigation practices. These activities can be managed by program staffs and stakeholders, provided they get trainings on study, design and construction of irrigation facilities".*[12]

GAA and ORDA: Revision of budget and strategy of the irrigation component

As a result of the findings of the mid-term evaluation *ORDA* and *Deutsche Welthungerhilfe* decided to revise and restructure several parts of the program, including the irrigation component.

The community-led approach, practiced in this form for the first time in a *Welthungerhilfe* program has made project implementation far more laborious and time-consuming than initially expected. It is likely that a no-cost extension for at least one year has to be requested to enable program staff and communities to successfully complete the projects. This requires respective budget amendments and transfers, which, among others, affect the irrigation component.

Welthungerhilfe's financial administrators and project staff estimated that the number of 1,100 households benefiting from irrigation activities, as proposed under Result 2.2, can be achieved with only 35 % of the original budget. This number results from an extrapolation of the costs of accomplished / ongoing project activities in the irritation sector to the total number of target beneficiaries. This means the original budget for irrigation projects will be reduced by 65%, from 360,000 € to 126,000 € (about 2,260,000 ETB).

After the revision, the remaining projects will have to be completed on basis of a reduced budget. The budget amendment forces the office to focus on less capital-intensive projects like upgrading of existing small traditional schemes and small river diversions.

---

[12] *Midterm Evaluation of ETH 1064 - MDG Water and Sanitation Program in Rural Amhara*. Temesgen Consultancy Service, Addis Ababa, Ethiopia, p. 40 f.

As stated in the original project proposal, in order to achieve Result 2.2 (1,100 HHs) a total area of 150 ha of irrigated land has to be realised. This means an average size of 0,136 ha per household. The number of households benefitting from the already approved and (partly) implemented schemes accounts to approximately 200. With an estimated irrigated area of 30 – 40 ha in the 4 projects this number seems reasonable. About 200 to 250 more beneficiaries are expected from a proposed and approved project in *East-Belessa* (ca. 60 ha). Here construction has not started yet and at the moment the status of the sub-project is rather unclear. Given that the already approved irrigation projects cover a total area of 30 – 40 ha, and including *East Belessa* 100 ha, some 50 ha have to be realised during the phase 2010 – 2012 (assuming a 1-year no-cost extension).

Problem analysis and problem statement

In order to formulate a problem statement and corresponding study objectives, two aspects need to be taken into consideration:

1. What problems and needs (in the context of the program's irrigation component) can be identified, and which of these problems can be addressed by my assignment?
2. How can my assignment be planned to a) address these problems, and b) present an adequate subject for a final thesis assignment (i.e. an assignment by which the contents of the previous studies of the course International Water Management can be applied)?

During preliminary discussions with the program staff, concerns about the sustainability of the irrigation projects have been formulated: the establishment or upgrading of a few irrigation schemes might not contribute substantially to productivity-improvements in the area. In this sense effectiveness and sustainability of the efforts presents a main problem of this program component.

For the time being, nothing significant can be said about the achievements of the five initiated and partly implemented irrigation projects (i.e. improvement of productivity), since irrigated production has not yet started in theses schemes.

In order to provide a preparatory problem analysis it might be helpful to have a look at comparable irrigation projects in the area. In this way certain common problems can be anticipated and dealt with in future planning.

In the course of a pre-study for an EC Food Facility proposal[13], carried out in June 2009, a number of schemes from previous *Welthungerhilfe* projects in the *Amhara*-region have been assessed. The study shows that sustainable improvements of productivity have often been limited by certain reasons. These reasons are diverse and of course vary from scheme to scheme. Nevertheless some basic problems could be identified:

- The farmers do not consider the project (i.e. the irrigation scheme) "their property", and consequently do not feel responsible and accountable for it. This often results, among other things, in low participation in maintenance and thus a gradual destruction of the infrastructure.

[13] Pre-study for EC-Food Facility Proposal: *Investigation of the potential for improved agricultural productivity through upgrading of traditional irrigation schemes*. Deutsche Welthungerhilfe/GAA, June 2010.

- The formation of a functional water user association or irrigation cooperative as organisational unit of water management was not successful. The lack of organisational structures regularly leads to poor land and water management and related problems.
- Agronomic practices have not sufficiently been adjusted to irrigated production (improved cropping patterns, crop-scheduling, crop selection etc.). The farmers often lack necessary knowledge and skills to adjust their production to the new circumstances. Planning, guidance, trainings and follow-ups have often not been sufficient.
- The marketing component has not been considered sufficiently: when farmers start irrigated production, the need for good marketing becomes more and more urgent. The products have to be sold at fair/good prices in order to cover increased input costs and pay off for intensified labour, thus maintain motivation.
- A phenomenon, which is widely referred to as "dependency syndrome" has developed in decades of dependence on foreign relief. This term tries to point out a certain habit among farmers to rely on food aid programs rather than to improve their own production. Farmers who produce irrigated crops are normally excluded from this so-called Productive Safety Net Program (i.e. provision of food-aid). In this sense irrigation can be considered as a "risk" by these farmers and can undermine motivation and initiative.

The specific program approach of ETH 1064 addresses some of the before mentioned problems explicitly. Poor "sense of ownership" as well as poor organisational structures are intended to be improved through the community-led approach, as described in an earlier section. Improvements of agronomic practices through planning and training ranges under capacity building measures, but are not explicate. Improved marketing has not specifically been integrated in the project planning.

3. Thesis objective

On basis of the problem analysis and problem statement, the study objectives can be formulated.

One possibility to address the above mentioned concerns towards effectiveness and sustainability of the irrigation component is the establishment of model schemes. These models can serve as examples of good practice for the farmers and extension workers after the program phases out.

The planning of an upgrading of an irrigation scheme, which can serve as a model, will therefore be considered to be the assignment of the present thesis. The design and planning should support the farmers to **a)** ensure by supplementary irrigation one main crop during poor rain seasons, **b)** to produce one additional full crop during the dry season (December – April), and **c)** to produce a 3rd short-season crop, especially vegetables, during the so called Belg-rain season (February - April).

The scheme design should comprise the hydrological and agronomical aspects of irrigation as well as recommendations for improved marketing. In this way the assignment fullfills the above-mentioned requirements: it consists of a technical component, which is relevant to the field of study. Furthermore the outcome can be of practical use for the organisation, as the design can be immediately used in the program.

The *guiding questions* for the assignment can be formulated as follows:

General:
How is the status of the 5 ongoing irrigation projects, i.e. can anything for further projects be learned from the implementation process so far?
Are community proposals for new projects available, and which of these fit into the program's irrigation component?

Design:
What parameters have to be considered for the design?
What data are needed for the scheme design?
Which sources of data are available?
If relevant data are missing, how can they be collected?

Agronomic component:
How is the current agronomic practice like, and is there room for improvements? What are the components for an improved agronomic practice in an (upgraded) irrigation scheme? How can improved cropping pattern look like? What other factors should be taken into consideration?

Marketing component:
How can the marketing component be improved in future projects? Are models for improved marketing available in the area? How did they achieve their improvements?

In accordance with the thesis objective the activities can now be planned as follows:
- Review of program documents, mid-term evaluation, monitoring documents, etc.
- Discussion of recommendations / revised strategy towards result 2.2 with program office Dessie (ORDA, GAA)
- Brief Evaluation of the 4 implemented irrigation schemes
- Investigation of potential sites for further irrigation activities under revised strategy
- Design for the upgrading of a additional scheme
- Investigations of options/strategies for improved marketing

4. Aimed results of the thesis

Aimed result of the thesis is a report (and a presentation) covering the following issues:
- Brief evaluation of the current status of progress of the already approved and currently executed project activities of the program's irrigation component
- On basis of community proposals and a rapid appraisal procedure selection of a new irrigation project
- Scheme design, including improved cropping pattern
- Recommendations for improved marketing

By this the thesis-report is meant to support the achievement of Result 2.2.

5. Methodology and necessary means

Methodology

The following methods will be applied to achieve the study objectives:
(Desk-)Study of relevant office and program documents as well as other relevant literature presents the first working step.

For interviews with farmers, extension workers (on agronomic practices etc.) semi-structures questionnaires will be prepared and used.

In order to collect primary data for scheme design a field survey will be conducted, including field observation, measurements, GPS reading.

Necessary means
Support of and cooperation with ORDA/GAA office staff is obviously crucial for a successful completion of the study. Monitoring data bases of the project offices as well as of the regional and zonal district will be important sources of information. For the field survey, car, driver, translator, GPS device, and digital camera are further necessary means. For the procession of data and the scheme design a number of computer programs will be applied (Microsoft Office Word and Excel, AutoCAD, MapSource and Global Mapper).

6. Timeframe

Working step	Procedural method	Date/Duration
Review of documents Preparation of office questionnaire Preparation of Rapid Appraisal forms/data sheets	Detailed revision on all efforts, papers, documents of ETH 1064;	Weeks 1.3 -9.4 2010
Field Survey in the ETH 1064 program area in Amhara	Solid field-survey / Rapid Appraisal; review of office documents, interviews and group-discussions, data collection, field observation	Weeks 12.4 - 11.5 2010 (capable of being adapted)
Elaboration of collected data	Transcription and elaboration of the field study; elaboration of all interviews and notes; Consultation and discussion with GAA/ORDA staff members	Weeks 12.5-13.6 (prolongable)
Field trip/Visit of 2 WASH programs (ETH 1071, 1080)	Comparison of the approaches/strategy/contents of the two Programs	Flexible timeframe (14.6.-20.6.)
Field trips/Visit of project in Affar		Flexible time frame (30.6 - 7.7 2010)
Composition of final thesis report	Writing down of report following the above listed draft structure	Starting 15.7

Handing in of final thesis report		2.9.2010
Presentation of thesis		20.9.2010

7. Preliminary table of content of the thesis report

Introduction (study background, thesis objective etc.)

1. Background information: The MDG Drinking Water and Sanitation Program in Amhara (ETH 1064)
    1.2 Program's approach
    1.3 Program actors and their roles
    1.4 Target group
    1.5 Mid term evaluation findings
    1.6 Revision of irrigation component: framework for future activities

2. Assessment of implemented components
    2.1 Methodology
    2.2 Findings
    (2.2.1 Kobo River diversion
    2.2.2 Kobo Spring irrigation
    2.2.3 Ambasel Spring irrigation
    2.2.4 Worebabu Spring irrigation
    2.1.3 Conclusion

3 Evaluation/appraisal of potential future irrigation components / sites
    3.1 Methodology
    3.2 Findings
    (…)
    3.3 Conclusion

4. Scheme Design

5. Marketing

6. Conclusions

ANNEX 2: General project information for the four schemes Gendebash, Kukumi, Weylet and Gebereal mesno

Location	District (woreda)	Ambasel
	Community(kebele)	04&05 Chefie
	Site (got)	Abalbu
	Scheme name	Gendebash irrigation
	Latitude (UTM)	1260721
	Longitude (UTM)	37566896
	Altitude (m a.m.s.l.)	1896
Sub-project	Type	Spring - improved traditional
	Component	Irrigation
Time	Start	03/2010
	Completion	In progress
Target group	Beneficiaries (male)	-
	Beneficiaries (female)	-
	Beneficiaries total	210
Costs (ETB)	Total	153 114,11
	Community contribution	22 967,11
	O & M	800

Location	District (woreda)	Worebabo
	Community(kebele)	Gubisa
	Site (got)	
	Scheme name	Kukumi Mesno
	Latitude (UTM)	1253755
	Longitude (UTM)	37588634
	Altitude (m a.m.s.l.)	1931
Sub-project	Type	New scheme
	Component	Irrigation
Time	Start	01 2010
	Completion	In progress
Target group	Beneficiaries (male)	213
	Beneficiaries (female)	215
	Beneficiaries total	428
Costs (ETB)	Total	196 058,00 (per plan)
	Community contribution	29 408,00
	O & M	600,00

Location	District (woreda)	Kobo
	Community(kebele)	036 Menjelo
	Site (got)	Weylet
	Scheme name	Weylet irrigation
	Latitude (UTM)	1327645
	Longitude (UTM)	37567078
	Altitude (m a.m.s.l.)	1654
Sub-project	Type	Improved traditional
	Component	Irrigation
Time	Start	04/2009
	Completion	In progress
Target group	Beneficiaries (male)	180
	Beneficiaries (female)	156
	Beneficiaries total	336
Costs (ETB)	Total	15 180,00
	Community contribution	15 180,00
	O & M	700

Location	District (woreda)	Kobo
	Community(kebele)	027 Arebete
	Site (got)	Gebereal mesno
	Scheme name	Gebereal mesno irrigation
	Latitude (UTM)	1336940
	Longitude (UTM)	37556750
	Altitude (m a.m.s.l.)	1654
Sub-project	Type	Spring - improved traditional
	Component	Irrigation
Time	Start	05/2009
	Completion	08/2009
Target group	Beneficiaries (male)	112
	Beneficiaries (female)	78
	Beneficiaries total	190
Costs (ETB)	Total	14 230,00
	Community contribution	14 230,00
	O & M	700

ANNEX 3: Calculation and drawings for pipe construction at Gebereal irrigation

1. Rough in-field estimation of required head:

$$h_f = \frac{fLv^2}{2gd}$$

(h_F= elevation difference / required head)

with:
Q = 2 l/s
L = 500 m
2" pipe (=5,08 cm = 0,0508 m)
F= 0,018 for plastic pipe (HDPP)

$$A = \frac{\pi d^2}{4} = 0{,}0020258 m^2$$

$$v = \frac{Q}{A} = \frac{0{,}002 m^3/s}{0{,}0020258 m^2} = 0{,}99 m/s$$

$$h_F = \frac{0{,}018 \times 500m \times 0{,}99m2}{2 \times 9{,}81 \times 0{,}0508} = 8{,}85m$$

minor losses 10 %
8,85 * 1.1 = 9,7 = **<u>10 m</u>**

From GPS reading, available head:
Intake altitude: 2075 m a.m.s.l.
Storage altitude: 2056m a.m.s.l.
$\Delta h = 19m$

Conveyance via pipe seems possible! Taking into account that the GPS reading is not very accurate (+-9m), the available head will still be sufficient. After survey the total pipe length has been defined as 300 meters (minus 200 meters from first estimation), thus increasing the gradient.

2. Detail calculation: suitable pipe diameter

Total length (L) now: 300 m
Q= 3 l/s
New Q:
Cutoff, max flow; also: to be on the save side

Energy equation

$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_F$$

z_1, z_2= altitude

hF= headloss between z_1 and z_2
$\Delta h = z_1 - z_2$
gamma=density of water * gravitational acceleration

$\frac{P_1}{\gamma};\frac{P_2}{\gamma}$ → atmospheric
v_1 → =0 (stagnant water)

then:

$$\Delta h = \frac{v_2^{\ 2}}{2g} + h_F$$

$$hF = 1.1\frac{FLv2}{2gd}$$

$$\Delta h = \frac{v_2^{\ 2}}{2g} + 1.1\frac{FLv^2}{2gd}$$

Q= Av
v= Q/A = 4Q/Pid^2
v^2= Q^2/A^2

$$v^2 = \frac{16Q^2}{\pi^2 d^4}$$

into:

$$\Delta h = \frac{v2}{2g}(1 + \frac{1.1FL}{d})$$

gives:

$$\Delta h = \frac{16Q^2}{\pi^2 d^4 2g}(1 + \frac{1.1FL}{d})$$

$$19 = \frac{0{,}00000074}{d^4}(1 + \frac{5{,}94}{d})$$

$$19 = \frac{0{,}00000074}{d^4} + \frac{0{,}00000442}{d^5}$$

$19d^5$ – 0,00000074d – 0,00000442 = 0

solve for d with trail and error (goal seek excel)

2 “ pipe d = 0,0508
F(d) = 0,00000197

Velocity (permissible: 2m/s)

$$v^2 = \frac{16Q^2}{\pi^2 d^4}$$

$v^2 = 16*0{,}003^2 = 0{,}000144$
$v^2 = 0{,}000144/(Pi^2*0{,}0508^4) = 2{,}1908261$
v = 1,4802 m/s → acceptable

3. Sump
At the end of the lined canal the water will flow into a sump. The sump consists of 2 chambers. The first chamber will be equipped with a trash rack. Therefore only relatively clean water will enter the second chamber, in which the pipe outlet is fixed. The second chamber will be covered with a manhole cover fixed with weak mortal for regular cleaning.

Q=vA
$$v = \sqrt{2gd}$$
$$Q = c_d\sqrt{2gh}A$$
$$Q = 0.6\sqrt{2gh}A$$

A=bH → H=2h
b= 0.5 (fixed)
A=0.5*2h=h

$$Q = 0.6\sqrt{2gd}h$$
$$Q = 0.6\sqrt{2g}\sqrt{h}h$$
$$Q = 0.6\sqrt{2g}h^{3/2}$$
$$h = (\frac{Q}{0.6\sqrt{2g}})^{2/3} = (\frac{0{,}003}{0.6\sqrt{2\times 9.81}})^{2/3}$$

h= 0,011
H= 2h =0,022

From practical point of view take H= 0,10 m

4. Canal

Q= 0,003 m3/s
L= 20 m
s= 0,001
n=0,018

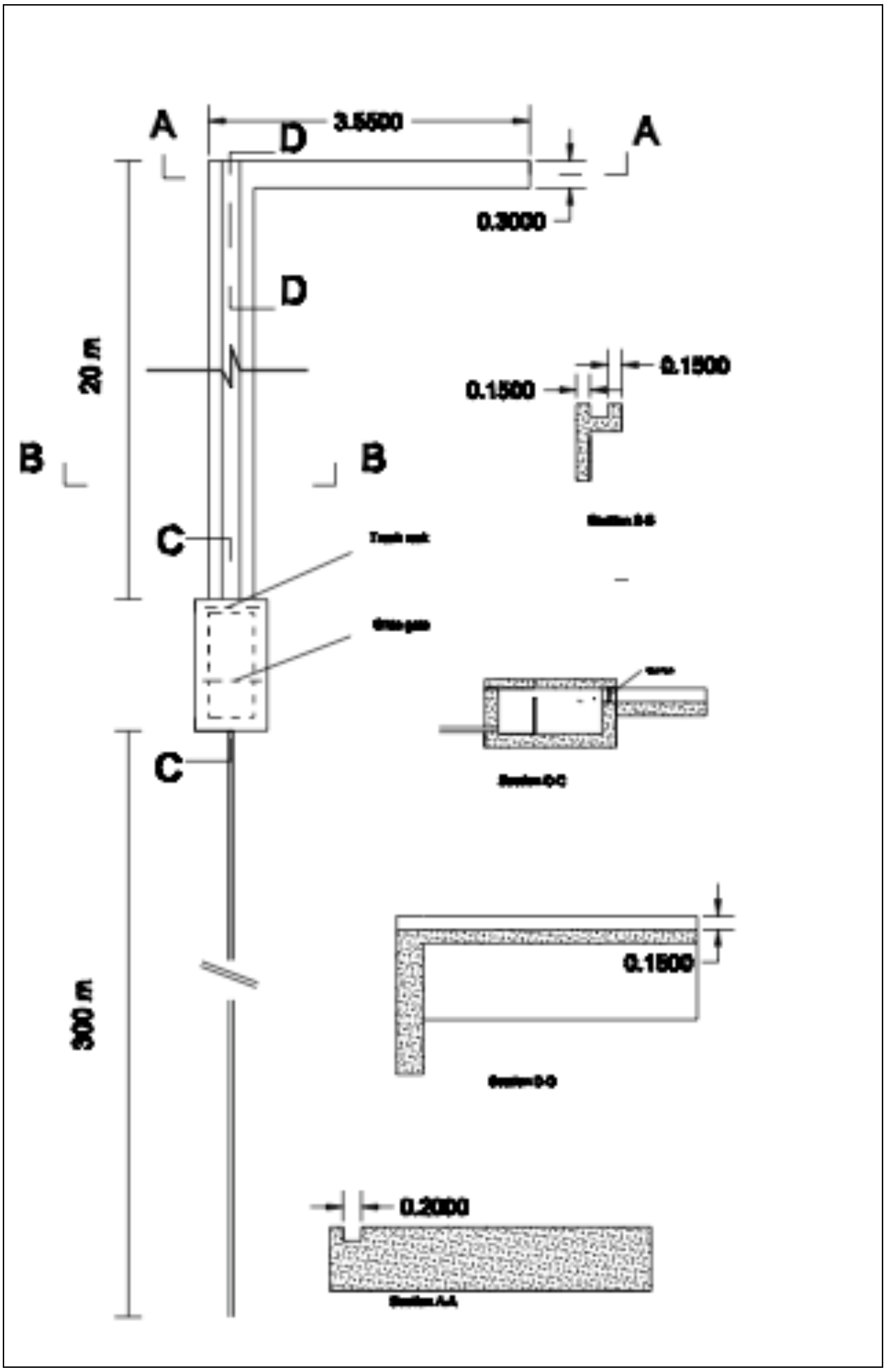
For best economical rectangular canal section b/d=2 → b=2d
A= b*d →$2d^2$
P=b+2d → 4d
R=A/P → d/2

Q=AV → $1/n*A*R^{2/3}S^{1/2}$
$0.003 = 1/0.018*2d^2(d/2)^{2/3}*0.001^{1/2}$

From which d = 0.088 m, then b = 2d ➔ 0.176 m

But from practical point of view take **d = 0.15 m** and **b = 0.20 m.**

Drawing of canal segment and intake



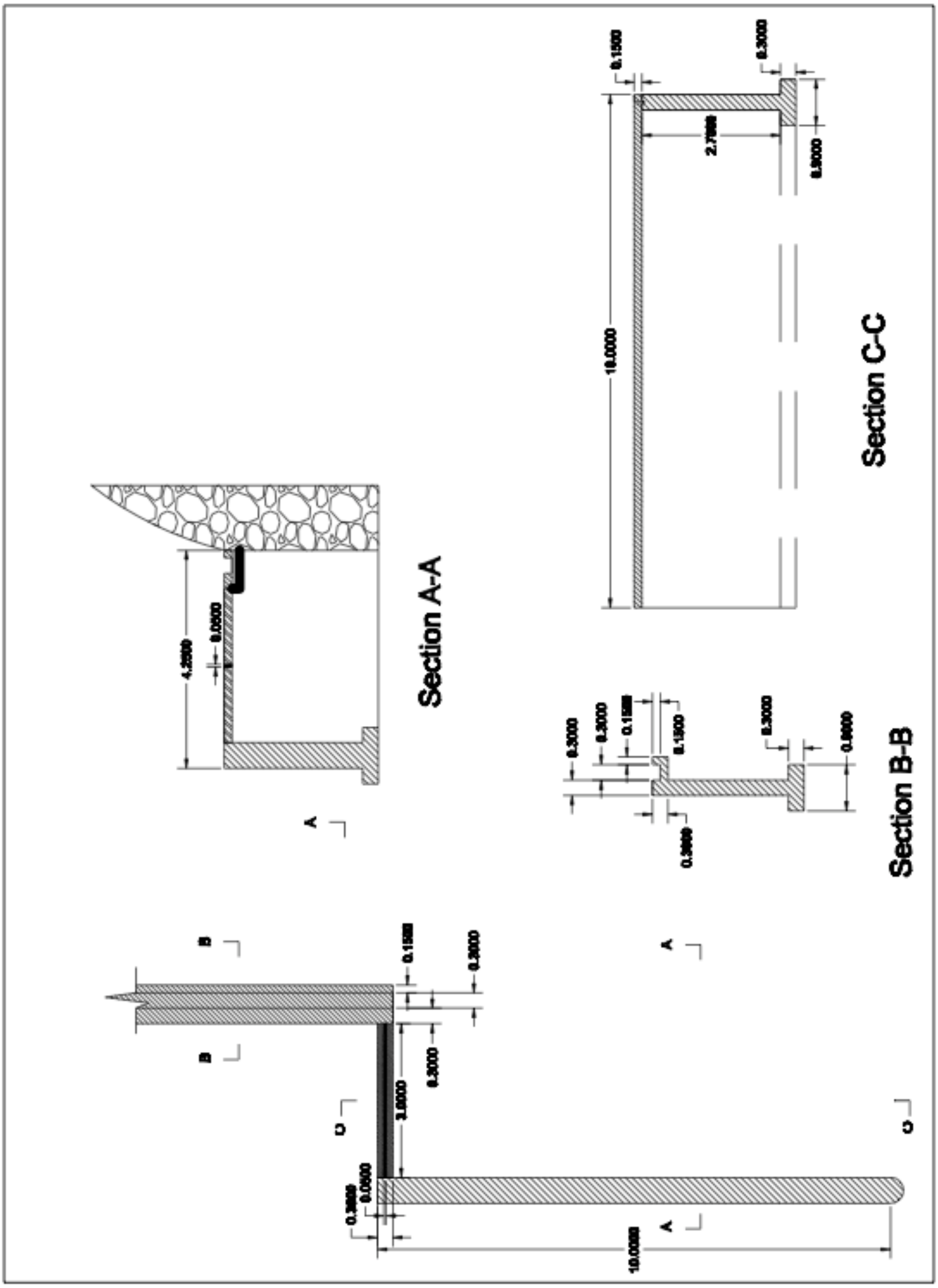
ANNEX 4: List of beneficiaries of Ambuanch-Amba

		members of the HH		
No.	Name (head of the HH)	male	femal	total
1	Aley Beleynah	2	4	6
2	Fantau Crobaze	6	2	8
3	Mekonen Y/man	2	1	3
4	Mofes Adanew	2	1	3
5	Tadese Lesay	3	3	6
6	Mesefan Molla	3	4	7
7	Sisan Meyesta	4	4	8
8	Mekonen	3	3	6
9	M/Geta Leneba Haile	2	2	4
10	Ayalew Haile	1	0	1
11	Yelifine Haile	0	1	1
12	Zenebech Fentao	0	1	1
13	Megose Wedefo	2	2	4
14	Baya Tebefa	3	4	7
15	Fesha Temesgen	3	4	7
16	Pesala Negese	2	3	5
17	K/s Tabefe Negese	2	1	3
18	Desta Sisan	3	4	7
19	Cefachew Fantao	1	2	3
20	Tekeluess Asefaw	1	3	4
21	Sisay Ababa	3	3	6
22	Mollu Sisay	1	4	5
23	K/s G/yasus Mesela	2	0	2
24	Tadessa Kassay	1	2	3
25	Ayalnesu Fantao	3	4	7
26	Devashot Menfaw	1	2	3
27	Sisan Denba	3	3	6
28	Yanomnesu Dessalen	2	2	4
29	Yenga Thefara	5	2	7
30	Ashenaf Tebu	2	3	5
	Sub-total	68	74	142
	average Bs/HH			4,7
	add. 8 HHs d/s (40 Bf.)			40
	Total beneficaries			182
	Total HHs			38

Annex 5: Determination of different slope classes

		Altitude 1 (m a.m.s.l.)	**Altitude 2 (m a.m.s.l.)**	**Length (m)**	**Slope**	**Slope class**
Area 1	Measurm. 1	3301	3792	1223	0,401471791	
	Measurm. 2	3181	3495	882	0,35600907	
Average slope Area 1					**0,37874043**	V (very steep)
Area 2	Measurm. 3	2211	2364	968	0,158057851	
	Measurm. 4	2227	2393	1264	0,131329114	
Average slope Area 2					**0,144693483**	VI (steep)
Average total slope					0,261716957	

Annex 6: Drawings of intake and canal section for Ambuanch-Amba



Annex 7: Calculation of the scouring depth

Water level at peak flood

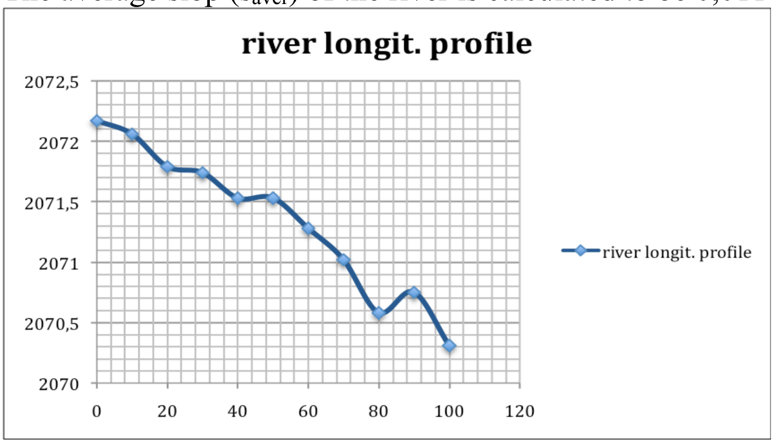
Having estimated the peak runoff rate the corresponding water level in the river can be calculated. Now the discharge (Q) for different water levels (elevations) will be calculated, until the design peak flood of 956 m^3/s is reached.

Before we can calculate the discharge we need to know the average slope of the river. The slope can be determined on basis of the longitudinal river profile taken during the survey.

No.	Station No.	Distance L (m)	Elevation H (m)	Accumul. height H(m)	Total area A (m^2)
0	0+00	0	2070,31	0	
1	0+10	10	2070,75	0,44	
2	0+20	10	2070,58	0,27	
3	0+30	10	2071,02	0,71	
4	0+40	10	2071,28	0,97	
5	0+50	10	2071,53	1,22	
6	0+60	10	2071,53	1,22	
7	0+70	10	2071,74	1,43	
8	0+80	10	2071,79	1,48	
9	0+90	10	2072,06	1,75	
10	0+100	10	2072,17	1,86	
					56,75
				H_{aver}	1,135
				$S_{average}$	0,01135

Longitudinal river profile and average river slope

The average slop (s_{aver}) of the river is calculated to be 0,0114.



Longitudinal profile of the river (Source: Field survey)

On the basis of the river's cross-sectional profile now the discharge for different H's can be calculated.

Cross-sectional river profile
The table presents the readings taken during the survey.

Chainage	Elevation	Remark
0	2076,94	Extended point beyond B.M.1
5	2073,82	B.M. 1 (left side)
7,8	2071,74	
8,7	2071,7	left river edge
13,8	2071,77	
16	2071,83	
18,4	2071,66	
21,7	2071,55	
24,6	2071,69	River edge
26,75	2075	B.M.2 (GPS reading)

Table XX: Survey readings of the river's cross-sectional profile

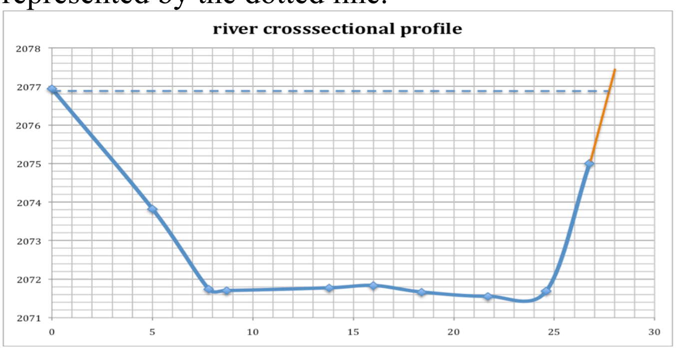
Now the discharge for different water levels can be determined using the Manning-formula. N will be 0,035 (natural stream).

Elevation	**Depth d (m)**	**A (m^2)**	**P (m)**	**R (m)**	**v (m/s)**	**n**	**Q (m^3/s)**
2071,55	0	0	0	0	0	0,035	0,00
2072	0,45	5,19	18,09	0,29	1,3240	0,035	6,87
2072,5	0,95	14,7	19,35	0,76	2,5340	0,035	37,25
2073	1,45	23,98	20,24	1,18	3,4079	0,035	81,72
2073,5	1,95	33,91	21,36	1,59	4,1419	0,035	140,45
2074	2,45	44,24	22,41	1,97	4,7899	0,035	211,91
2074,5	2,95	55,53	23,54	2,36	5,3937	0,035	299,51
2075	3,45	67,09	24,95	2,69	5,8858	0,035	394,88
2075,5	3,95	81,44	26,38	3,09	6,4532	0,035	525,55
2076	4,45	110,55	27,52	4,02	7,6917	0,035	850,31
2076,5	4,95	117,95	28,78	4,10	7,7960	0,035	919,54
2077	5,45	125,25	29,75	4,21	7,9361	0,035	993,99

Table XXX: Water level for different Qs

For the design peak flood of 956 m^3/s the water level will reach an elevation of 2076,85 m a.m.s.l.

The following graph presents the cross-sectional profile and the water-level of peak flood is represented by the dotted line.



Scouring depths
On the basis of the design peak flood value of the composite hydrograph, the scouring depths can be calculated.

The particle size of bed material is defined as bolder stage and fine particles, with an average particle size of 0,5 – 1 cm.

The silt factor will be calculated as follows:

$$f = 1{,}76 \times \sqrt{mv}$$

where
f=silt factor
mv = particle size (mm) = 10 mm

giving
f= 5,57

Then the scouring depths can be calculated:

$$R = 1{,}35 \times \left(\frac{q^2}{f}\right)^{1/3}$$

where
R = scouring depths (m)
q (discharge intensity) = Q/L
Q = design peak flood = 956 m^3/s
L = average river cross section = 20,1 m

Giving:
Scouring depths R = 10 m

Annex 8: Calculation of canal dimensions

The design parameters for the canal section therefore are:

$$Q = A \times v = \frac{1}{n} \times A \times R^{2/3} \times s^{1/2}$$

with
Q_{design} = 20 l/s
Manning coefficient (n) for concrete canal = 0,018
b/d (ideal/economical canal section) = 2
Wetted parameter (P) = b+2d = 4d (m)
Hydraulic radius (R) = A/P = d/2 (m)

giving
$0{,}02\ m^3/s = 1/0{,}018*2d^2(d/2)^{2/3}*0{,}004^{1/2}$

As minimum width in terms of workability we assume 0,3 m for b. Therefore:

A = 0,3d
P = 0,3+2d
R = 0,3d/0,3+2d
$0{,}002 = 0{,}3d(0{,}3d/(0{,}3+2d)^{2/3}*0{,}002^{1/2}$

From excel goal seek we can determine d for Q=20 l., giving b of 0,15 m.

b (m)	d (m)	A (m^2)	P (m)	R (m)	s	n	v (m/s)	Q (m^3/s)
0,3000	0,1513	0,0454	0,6026	0,0753	0,0020	0,0180	0,4431	0,0201
0,3000	0,1500	0,0450	0,6000	0,0750	0,0020	0,0180	0,4419	0,0199

Therefore b = 0,30 and d = 0,15 will have a capacity of app. 20 l/s. We have a velocity (v) of 0,4 m/s, which is acceptable.

Annex 9: Calculation of intake dimensions

Orifice

$$Q = c \times A \times \sqrt{2gH}$$

where
Q = design discharge
c = orifice coefficient = 0,7
A = area (m^2)
g = gravitational force = 9,81
H = Head / Height

$$0{,}02 = 0{,}7 \times 0{,}3H \times \sqrt{2g} \times \sqrt{\frac{H}{2}}$$

$$0{,}02 = \frac{(0{,}7 \times 0{,}3H \times \sqrt{2g}H^{3/2}}{\sqrt{2}}$$

Excel goal seek gives H of 0,09 for Q = 0,02:

b (m)	d (m)	A (m^2)	c	g	H (m)	Q (m^3/s)
0,3	0,1	0,03	0,7	9,81	0,0996	0,029

With respect to workability it seems reasonable to take 0,15 m for H, as this is the same level as the canal section.

Therefore the height of the shutter crest is to be 0,15 m. The shutter will be fixed in form of a removable gate. The gate will be fixed in the concrete floor my means of a grove.

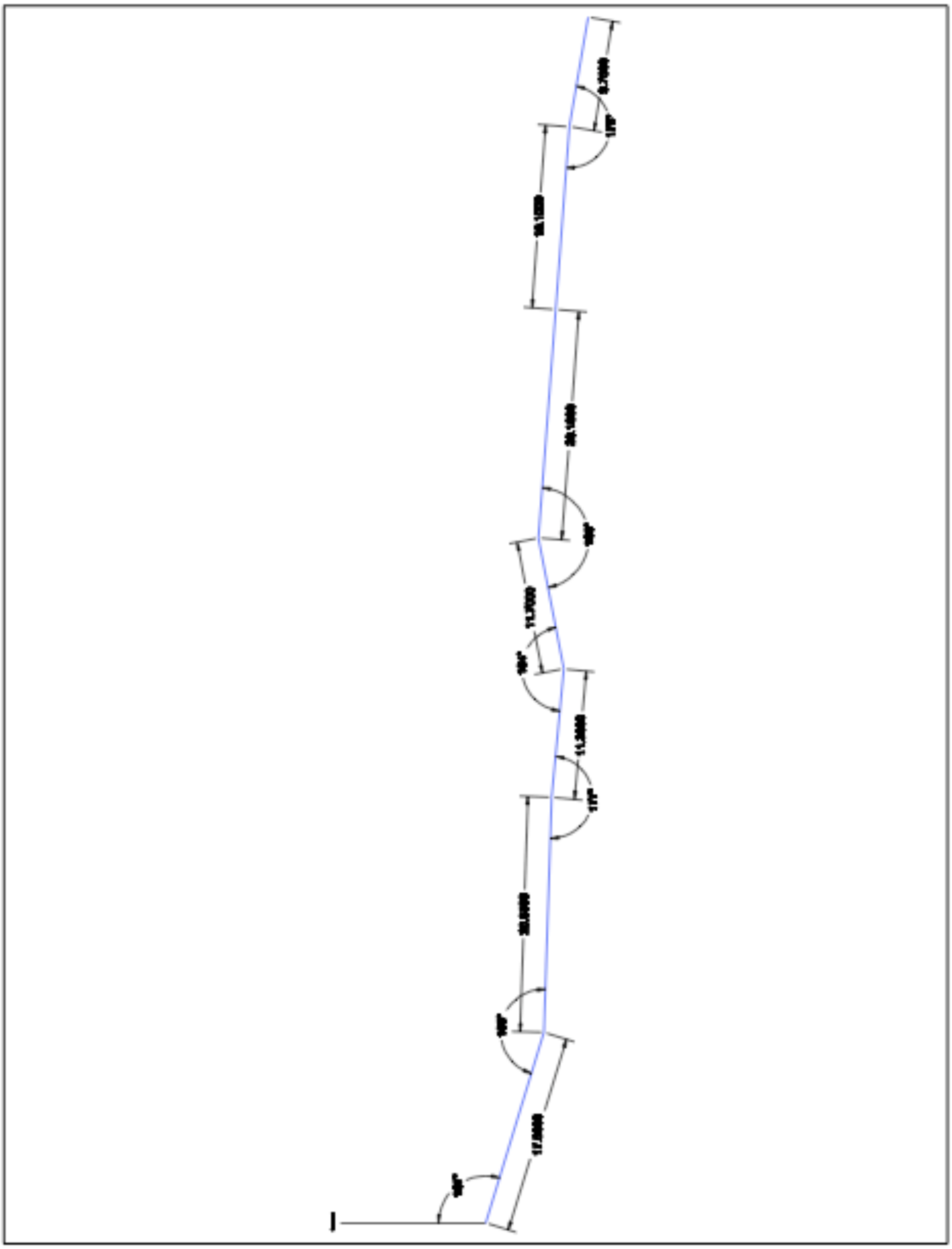
Partition wall
In order to define the require length of the partition wall, we can calculate:

$$L = \frac{\Delta h}{s} = \frac{0{,}15m}{0{,}011} = 13{,}63m$$

where s = 0,011 presents the average slope of the river as measured during the survey.

Therefore the partition wall would have a length of 13 meters. It has been recommended by the technical officer to reduce the length to 10 meters, since the d of the canal section has been calculated for Q=20m^3/s, while the actual base flow is Q=10 m^3/s (freeboard).

Annex 10: Layout of the "Sensitive" canal section



Annex 11: The current crop pattern and corresponding gross-return rates, as obtained through farmer interviews and focus group discussion.

Season	#	Crop	LP	Planting	Harvest	Area			Aver. yield (quintal / ha)	Aver. price (ETB/ quintal)	Gross return / ha	Gross return / HH (0,5ha)
						Ha	(HHs)	% of total				
Main rainy reason	1	Sorgh	Jan-Mar	Apr/May	Nov	0,5		17,65	45	590	26550	13275
	2	Wheat	Feb-Apr	June	Nov	0,5		17,65	10	550	5500	2750
	3	Barley	Jan-Mar	June	Nov	0,5		17,65	12			
	4	local Pea	-	June	Oct	0,5		17,65	13			
	5	Teff	Mar-May	June	Oct	0,5		17,65	8	670	5360	2680
	6	Lintel	-	Jun/Jul	Oct	0,25		8,82	7	770	5390	2695
	7	Pepper	Jan	Apr	Sep	0,08		2,94	9	930	8370	4185
	Total					*2,83*		*100*				
IRR	1	Onion	Nov	Dec	May	1,5	6	20		300		
	2	Teff	Jan	Mar	Jun	1,75	7	23,33		670		
	3	Maize	Nov	Feb	Jun	2	8	26,67		380		
	4	Lintel	-	end of Dec	Apr (failed)	2,25	9	30		770		
	Total					*7,5*		*100*				

Annex 12: Input rates for current cropping pattern

The following tables presents the current input rates. Since at present the farmers of *Ambuach-Amba* do not make use of fertilizers and pesticides, input costs comprise seeds, labour costs and land tax only.

The table presents the seed rates, unit costs per ha, and finally the values for the total production during one year:

Crop	Seed rate (kg/ha)	Unit costs (ETB/Quintal)	Value/ha	For total area per year (ETB)
Maize	13,33	400,00	53,33	200,00
Sorghum	10,67	666,67	71,11	94,12
Wheat	40,00	500,00	200,00	264,71
Barley	53,33	400,00	213,33	282,35
Teff	58,67	400,00	234,67	721,25
Local peas	40,00	1000,00	400,00	529,41
Lintel	18,67	666,67	124,44	144,58
Pepper	0,89	333,33	2,96	0,65
Onion	4,00	148,00	5,92	8,88

Table XXX: Currently practiced seed rates and corresponding value (Source: Farmer interviews)

The table presents the costs for human labour (man-days) and animal labour (oxen-days). The last row shows the total costs for one year production:

Crop	Man-days					Oxendays					Total cost / ha (ETB)	For total area per year (ETB)
	Intervalls/ oxen-day	Days / oxen day (0.25 ha)	Days /ha	Wage/ day (ETB)	Labour cost/ha (ETB)	Intervalls/ oxen-day	Days/ oxen-day	Days / ha	Cost/ day (ETB)	Cost/ ha/ season (ETB)		
Maize	3+4+3+5+2	17	68	15	1020	3+1+3	7	28	12	336	1356	5085,00
Sorgh	3+15+1+5+3	27	108	15	1620	3+1+8	12	48	12	576	2196	2906,47
Wheat	3+15+5+3	26	104	15	1560	3+8	11	44	12	528	2088	2763,53
Barley	3+15+3+3	24	96	15	1440	3+8	11	44	12	528	1968	2604,71
Teff	3+12+8+3	26	104	15	1560	3+8	11	44	12	528	2088	6417,53
Local pea	1+5+2	8	32	15	480	1+5	6	24	12	288	768	1016,47
Lintel	1+5+2	8	32	15	480	1+5	6	24	12	288	768	892,24
Pepper	4+7+12+5	28	112	15	1680	4	4	16	12	192	1872	412,94
Onion	3+10+15+10	38	152	15	2280	3	3	12	12	144	2424	3636,00

Table XXX: Costs for human labour (man-days) and animal labour (oxen-days) (Source: Farmer interviews)

Annex 13: Effective rainfall and overall evapotranspiration

Effective Rainfall

For the calculation of crop water requirements for the proposed crop pattern full meteorological data of *Lalibela* meteorological station are used. These records cover a period of 15 years (1994 to 2007). In order to calculate crop water requirement and respective irrigation duty the data have been processed with *CropWat*. For mean monthly rainfall the average of the years 1994 to 2007 has been taken. Then effective rainfall then has been calculated with *CropWat*, making use of the *USDA Soil conservation method*.

Month	Rain (mm)	Eff. Rain (mm)
January	28.8	27.5
February	40.4	37.8
March	32.7	31
April	29.4	28
May	127.9	101.7
June	272.6	152.3
July	180.6	128.4
August	74.3	65.5
September	29.3	27.9
October	8.9	8.8
November	9.5	9.4
December	2.9	2.9
Total	**837.3**	**621.1**

Overall evapotranspiration (ET_o)

On the basis of full meteorological data (minimum and maximum temperature, relative humidity, wind speed, sunshine hours) an average monthly Et_o (mm/day) can be calculated (Et_o Penman / CropWat):

Month	Min Temp	Max Temp	Humidity	Wind	Sunshine	Radiation	ET_o
Unit	°C	°C	%	km/day	hours	MJ/m²/day	**mm/day**
January	13	30.3	38	111	9.9	21.2	**4.21**
February	14	27.4	33	121	9.4	22.1	**4.58**
March	14.3	27	42	124	8.3	21.8	**4.64**
April	14.5	26.7	43	134	7.9	21.7	**4.74**
May	15.4	26.7	45	151	7.7	21.1	**4.82**
June	14.2	25	51	126	6.2	18.6	**4.17**
July	12.1	19.9	80	84	3.3	14.3	**2.75**
August	11.7	19.8	84	72	4.4	16.1	**2.83**
September	13	22.6	64	97	6.1	18.5	**3.49**
October	12.9	25.2	49	136	7.8	20	**4.11**
November	12.5	25.1	43	98	8.5	19.6	**3.71**
December	12.9	26.2	40	101	9.5	20.1	**3.72**
Average	13.4	25.2	51	113	7.4	19.6	**3.98**

Average monthly ET_o as calculated with CropWat (ETo Penman)

Annex 14: Crop water requirement, irrigation duty and water potential for different intervals

Crop water requirement									***Water potential 6 d/12 h***		***Water potential 6 d/24 h***	
Hydrol. Year (Dec.)	Mth	Veg	Pul-ses	Mai-ze	Sorg.	Weigthed av. NET IRR Req (mm/dec)	Gross IRR Req (mm/dec)	Duty (l/s/ha) (CF)	Duty (6d/12h)	WP (ha)	Duty (6d/24h)	WP (ha)
1	JUN	3,1		0	0	1,55	2,87	0,03	0,08	129,0	0,04	258,0
2	JUN	0		0	0	0	0,00	0,00	0,00		0,00	
3	JUN	0		0	0	0	0,00	0,00	0,00		0,00	
4	JUL	0		0	0	0	0,00	0,00	0,00		0,00	
5	JUL	0		0	0	0	0,00	0,00	0,00		0,00	
6	JUL	0		0	0	0	0,00	0,00	0,00		0,00	
7	AUG	0		3	0	0,75	1,39	0,02	0,04	266,6	0,02	533,2
8	AUG	7,5		10,7	5,2	7,725	14,31	0,17	0,39	25,9	0,19	51,8
9	AUG	16,5		20,3	13,9	16,8	31,11	0,36	0,84	11,9	0,42	23,8
10	SEP	18,1		21,1	15,8	18,275	33,84	0,39	0,91	10,9	0,46	21,9
11	SEP	6,4		19,2	17,4	12,35	22,87	0,26	0,62	16,2	0,31	32,4
12	SEP			13,4	15,6	7,25	13,43	0,16	0,36	27,6	0,18	55,2
13	OCT		11,4	2,2	3,8	7,2	13,33	0,15	0,36	27,8	0,18	55,5
14	OCT	2,9	14,8			8,85	16,39	0,19	0,44	22,6	0,22	45,2
15	OCT	28,7	21,9			25,3	46,85	0,54	1,27	7,9	0,63	15,8
16	NOV	23,8	27,6			25,7	47,59	0,55	1,29	7,8	0,64	15,6
17	NOV	25,7	35,3			30,5	56,48	0,65	1,53	6,6	0,76	13,1
18	NOV	30,8	39,5			35,15	65,09	0,75	1,76	5,7	0,88	11,4
19	DEC	36,7	41,3			39	72,22	0,84	1,95	5,1	0,98	10,3
20	DEC	38,7	42,1			40,4	74,81	0,87	2,02	4,9	1,01	9,9
21	DEC	42,2	45,7			43,95	81,39	0,94	2,20	4,5	1,10	9,1
22	JAN	35,1	27,1			31,1	57,59	0,67	1,56	6,4	0,78	12,9
23	JAN	32	6,6			19,3	35,74	0,41	0,97	10,4	0,48	20,7
24	JAN	8,3				4,15	7,69	0,09	0,21	48,2	0,10	96,4
25	FEB	3,1	1,8		1,4	2,35	4,35	0,05	0,12	85,1	0,06	170,2
26	FEB	18,7	4,9		0,4	10,675	19,77	0,23	0,53	18,7	0,27	37,5
27	FEB	13,4	2,4		1,9	7,775	14,40	0,17	0,39	25,7	0,19	51,4
28	MAR	23,7	12,6		15	18,75	34,72	0,40	0,94	10,7	0,47	21,3
29	MAR	29,8	24,8		24,8	27,3	50,56	0,59	1,37	7,3	0,68	14,6
30	MAR	40,5	42,1		38,5	40,4	74,81	0,87	2,02	4,9	1,01	9,9
31	APR	41,5	46,2		38,8	42	77,78	0,90	2,10	4,8	1,05	9,5
32	APR	43,4	48,1		40,7	43,9	81,30	0,94	2,20	4,6	1,10	9,1
33	APR	34,3	39		31,5	34,775	64,40	0,75	1,74	5,7	0,87	11,5
34	MAY	21,5	28		19,8	22,7	42,04	0,49	1,14	8,8	0,57	17,6
35	MAY	5,4	9,4		5,3	6,375	11,81	0,14	0,32	31,4	0,16	62,7
36	MAY		0		0						0,00	
37	JUN				0						0,00	
	TL	*631,8*	*572,6*	*89,9*	*289,8*	*632,3*	*1170,93*					

Annex 15: Material breakdown and Bill of quantity

Bill of quantity

1. **Current material costs** (as in May 2010; 1€ =16 ETB)

Canal

- Current *cement* prices, including transport, loading: **3500 ETB/m^3**
- Stone/Gravel *crashing* costs: 20 ETB/barrel = **100 ETB/m^3**

Crossing structures

- *Sheet metal* for flume construction: 1 sheet = 1m*2m = **250 ETB**
- *2" steel pipe*: 1 pipe = 6 m = 600 ETB = **100 ETB/m**
- Costs for *welding* assumed as 20 % of total costs

2. Intake and canal

Volumen

Stone masonry (Mix-ratio: Cement : Sand = 1:2)

a) Partition wall
For L= 10 m
V = ((2.85*0,5)+(1.1*0.3))*10 = **17.55 m^3**

b) Cut-off
For L=3 m
V = (2.7*0.3)+(0.9*0.3)*3 = **3.24 m^3**

c) Canal: sensitive part
For L=200 m
V = ((0,15*0,75)+(0,15*0,15)+(0,3*0,15)+(2,35*0,3)+(0,9*0,3))*200 = **231 m^3**

Concrete (Mix-ratio: Cement : Sand : Gravel = 1:2:3)

d) canal section: semi-circular
L = 2000 m

for Q_{design} = 0.02 m^3/s
d = 0.33 m

use d = 0.6 m (available mould)
thickness = 0.05 m

$$V = (\frac{\pi D^2}{8} - \frac{\pi d^2}{8}) \times L$$

where
D = external diameter
d = internal diameter

V= 102,10 m^3

Material breakdown and costs

Component	Volumen	Material breakdown				Costs		Total costs (ETB)
	(m^3)	Cement (m^3)	Sand (m^3)	Gravel (m^3)	Stone (m^3)	Cement cost (ETB)	Stone crashing (ETB)	
Partition wall	17,55	4,259	6,07	-	10,5	14906,5	1050	15956,50
Cut off	3,24	0,786	1,12	-	1,94	2751	194	2945,00
Canal (sensitive)	231	56,056	80,08	-	138,6	196196	13860	210056,00
Semi-circular	102,10	32,15	45,95	68,92		112525	6892	119417,00
Total (ETB)								348374,50
Total (€)								21773,41

Table XXX: Material breakdown and costs for intake and canal

So total material costs for the intake and canal parts amount to **348,375 ETB or 21,773 €.**

3. Flumes / crossing structures

General information of current prices and sizes available on the Ethiopian market

Sheet metal for flume construction:
- 1 sheet = 1m*2m = 250 ETB
- to use economically take: b = 0.25 and d = 0.125
- so per meter flume ¼ sheet = 62.5 ETB

Support structures:
- for support use of 2” steel pipe
- 1 pipe = 6 m = 600 ETB = 100 ETB/m

Welding
Costs for welding assumed as 20% of total costs, giving:
*Costs for sheet metal + costs for pipe + (Costs for sheet metal + costs for pipe * 0.2) = total*

Dimensions

Crossing structure No. 1
L= 7.2 m
H=2.10 m

One support structure with crossbars every 0.5 m
Giving total L of
(2.10 * 2)+ (4*0.25)= 5.2 m = 6 m

Crossing structure No. 2
L=15 m
H=3.6 m

2 support structures with crossbars every 0.5 m
(3.6*4)+(14*0.25) = 17.9 = 18 m

Crossing structure No. 3
L= 10 m
H: 5 m

1 support structure with crossbars every 0.5 m
(5*2)+(10*0.25) = 12.5 m

Material breakdown and costs

Component	Rounded L sheet metal (m)	Rounded L pipe (m)	Costs sheet metal (ETB)	Costs steel pipe (ETB)	Total material costs (ETB)	20 % Welding costs (ETB)	Total costs (ETB)
Flume 1	8	6	500	600	1100	220	1320
Flume 2	15	18	937,5	1800	2737,5	547,5	3285
Flume 3	10	12,5	625	1250	1875	375	2250
Total							6855
Total (€)							428

Table XXX: Material breakdown and costs for 3 crossing structures

Total costs for 3 crossing structures / flumes, incl. sheet metal, steel pipes and welding costs amount to **6855 ETB or 428 €.**

Annex 16: Economic efficiency indicators analysis

For a design period of 15 years we assume following budget items and costs:

Budget item	Costs (ETB)
Investment costs	356729,50
Yearly operation costs	54992,18
Yearly maintenance (0,3 % of investment)	107018,85
Yearly O & M	162011,03
Flume replacement (every 5 years)	6855,00
Schutter replacement (every 3 years)	1500,00

Assuming a yearly net return of 537170,32 ETB as calculated for the proposed crop pattern, we receive the following results for the economic indicators Net Present Value (NPV) and benefit-cost ratio B/C:

Ye-ar	Investment cost	Replace ment	Operation and Maintenan ce	Total project cost	Total return	Net cash flow	Total dis. return at 8.5% D.R	Total dis. cost at 8.5% D.R
0	356.729,50	-	-	356.729,50	4.000,00	(352.729,50)	4.000,00	356.729,50
1			162.011,03	162.011,03	537.170,32	375.159,29	495.087,85	149.318,92
2			162.011,03	162.011,03	537.170,32	375.159,29	456.302,17	137.621,12
3		1.500,00	162.011,03	163.511,03	537.170,32	373.659,29	420.555,00	128.014,11
4			162.011,03	162.011,03	537.170,32	375.159,29	387.608,29	116.902,99
5		6.850,00	162.011,03	168.861,03	537.170,32	368.309,29	357.242,66	112.300,25
6		1.500,00	162.011,03	163.511,03	537.170,32	373.659,29	329.255,91	100.223,28
7			162.011,03	162.011,03	537.170,32	375.159,29	303.461,67	91.524,30
8			162.011,03	162.011,03	537.170,32	375.159,29	279.688,18	84.354,19
9		1.500,00	162.011,03	163.511,03	537.170,32	373.659,29	257.777,12	78.465,62
10		6.850,00	162.011,03	168.861,03	537.170,32	368.309,29	237.582,60	74.684,77
11			162.011,03	162.011,03	537.170,32	375.159,29	218.970,14	66.041,58
12		1.500,00	162.011,03	163.511,03	537.170,32	373.659,29	201.815,79	61.431,37
13			162.011,03	162.011,03	537.170,32	375.159,29	186.005,34	56.099,37
14			162.011,03	162.011,03	537.170,32	375.159,29	171.433,49	51.704,49
15		8.350,00	162.011,03	170.361,03	537.170,32	366.809,29	158.003,22	50.109,97
Total				**2.814.944,92**		**5.246.609,92**	**4.464.789,44**	**1.715.525,84**
	NPV	**2.749.263,60**		**B/C**	**2,602577785**			