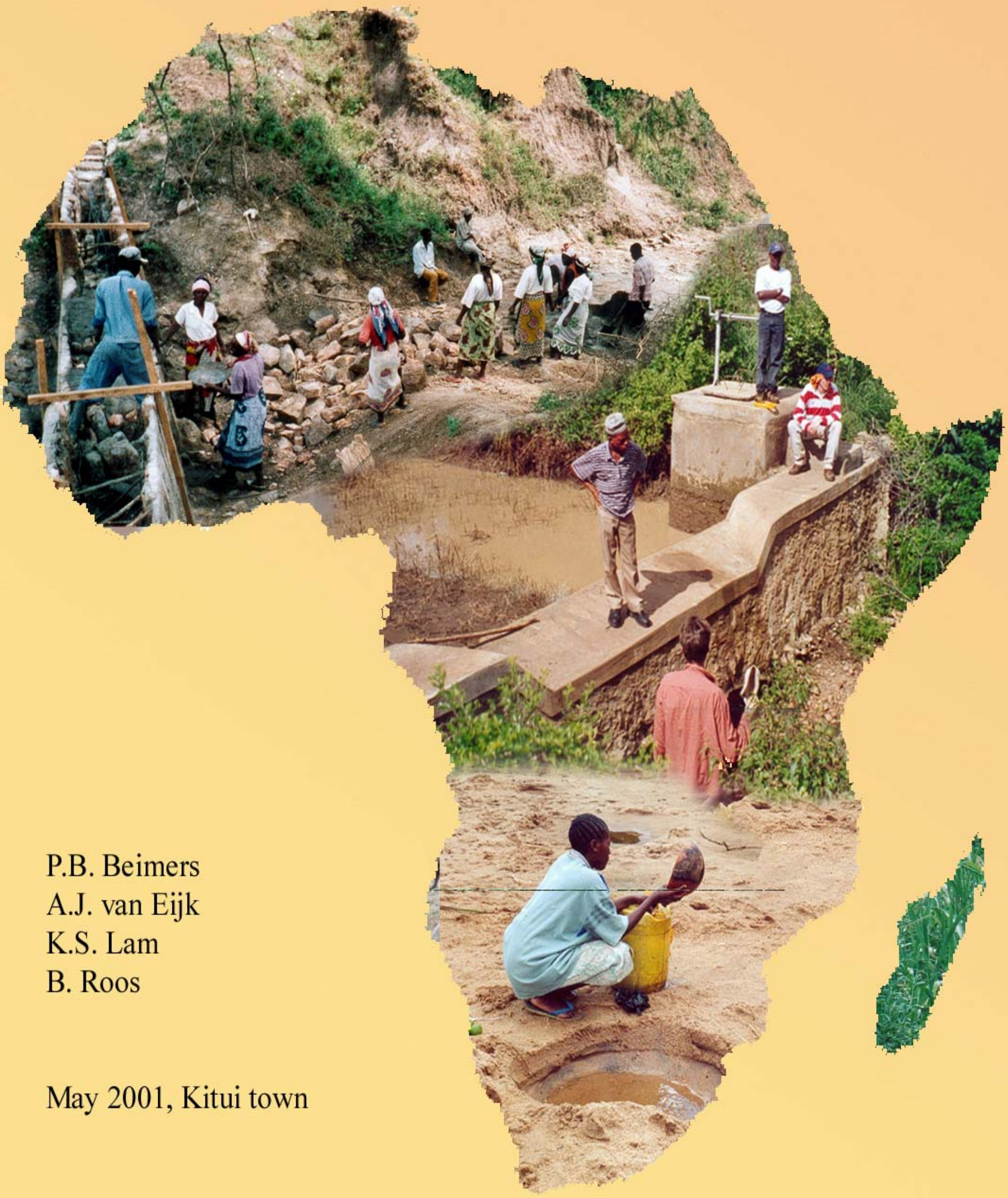
PRACTICAL WORK REPORT

BUILDING SAND-STORAGE DAMS
SASOL FOUNDATION
KITUI DISTRICT, KENYA



P.B. Beimers
A.J. van Eijk
K.S. Lam
B. Roos

May 2001, Kitui town

BUILDING SAND-STORAGE DAMS

SASOL FOUNDATION
KITUI DISTRICT, KENYA

PRACTICAL WORK REPORT

P.B. Beimers	9045221
A.J. van Eijk	9234279
K.S. Lam	9496342
B. Roos	9706128

May 2001, Kitui town

TU Delft
Technische Universiteit Delft

COLOPHON

Delft University of Technology is not responsible for consequences of any kind, resulting from applying data, calculations and conclusions to be found in this report.

Editorship:	P.B. Beimers, A.J. van Eijk, K.S. Lam and B. Roos
Final Editorship:	P.B. Beimers
Lay Out:	K.S. Lam
Authors:	P.B. Beimers
	A.J. van Eijk
	K.S. Lam
	B. Roos
Cover:	B. Roos
Pictures:	P.B. Beimers, A.J. van Eijk, K.S. Lam and B. Roos
Edition:	22 Pieces.

PREFACE

As part of our study, Civil Engineering at Delft University of Technology, we have done practical work in Kitui District, Kenya. We have spent 15 weeks in Kenya (April 1st - July 15th), including six weeks of practical work. This practical work period can be seen as an experiment for Delft University of Technology, faculty of Civil Engineering, because it is combined with a project period (theoretical). The information that has been gained from the practical work is used for the project. Our group consists of four students with different specialisation. One student specialises in water management; the other three specialise in hydraulic engineering.

SASOL, our counterpart was initiated this project. SASOL is trying to know more about the hydrologic impact and possible constructional improvements of the sand-storage dams that are built in Kitui District. This is the first time a group of students of TU Delft has done practical work for SASOL Foundation. SASOL wants to build up a relationship with the University of Nairobi and universities in the Netherlands to gather more scientific knowledge on the issue.

During the period of practical work we stayed in Mangina for five weeks and in Kitui town for one week. Kitui town is the capital of Kitui District. Mangina is a small village in the countryside and a central place from where we could reach several sites.

We would like to thank Ir. W.J. Dijk, Ir. M.W. Ertsen, Prof. ir. R. Brouwer and Prof. ir. L.A.G. Wagemans of Delft University of Technology for having confidence in this special combination of project and practical work. Maartje Westerop of the Westerveld Conservation Trust made arrangements for our stay in Kenya and provided a lot of useful contacts, thanks for this.
David Ngui Kithuku (British), Technical Manager of SASOL, has been a great help to us, he gave us all the necessary information we needed about the design and construction of the dams. We also extend our thanks to Prof. G.C.M. Mutiso, chairman of the SASOL board, for the general co-ordination of the practical work and the connection with Nairobi during our stay in Kitui District. We would also like to thank Milu Muyanga and Mutua wa Isika for revising this report and entertaining us during our stay in Kitui town.

Our special thanks go to Sam Mutiso, Field Manager of SASOL, who managed the residence in Mangina and our stay in Kitui town. He gave us the necessary information concerning the administrative procedures of SASOL. Special thanks to our “mommy” in Mangina too who cooked our meals and looked after us. Stephen Ngei, mason of SASOL, thanks a lot for showing us around Itoleka location and fixing our bikes all the time.

Last but not least we would like to thank our sponsors for their financial support. Without their support this practical work period would not have been possible.

- Advin Consultants & Engineers
- BOB Kennisoverdracht
- Cobouw
- DHV
- Fonds Internationale Stages of the Delft University of Technology
- Fugro
- Gemeentewaterleidingen Amsterdam
- Gerritse IJzerwaren Woerden
- Hoogheemraadschap Uitwaterende Sluizen
- Nuffic Netherlands Organisation for International Cooperation in Higher Education

- Waterleiding Maatschappij Overijssel
- Waterbedrijf Gelderland
- Waterleidingmaatschappij Drenthe
- Waterwinningbedrijf Brabantse Biesbosch
- WSO Fonds, werkgroep Wetenschappelijke Studiereizen Ontwikkelingslanden

Kitui town, May 2001

Benno Beimers
Bart van Eijk
Kin Sun Lam
Bastiaan Roos

TU Delft
Technische Universiteit Delft

DHV

Cobouw

BOB

Advin

FUGRO

water is onze wereld
wmo
DRINKWATER

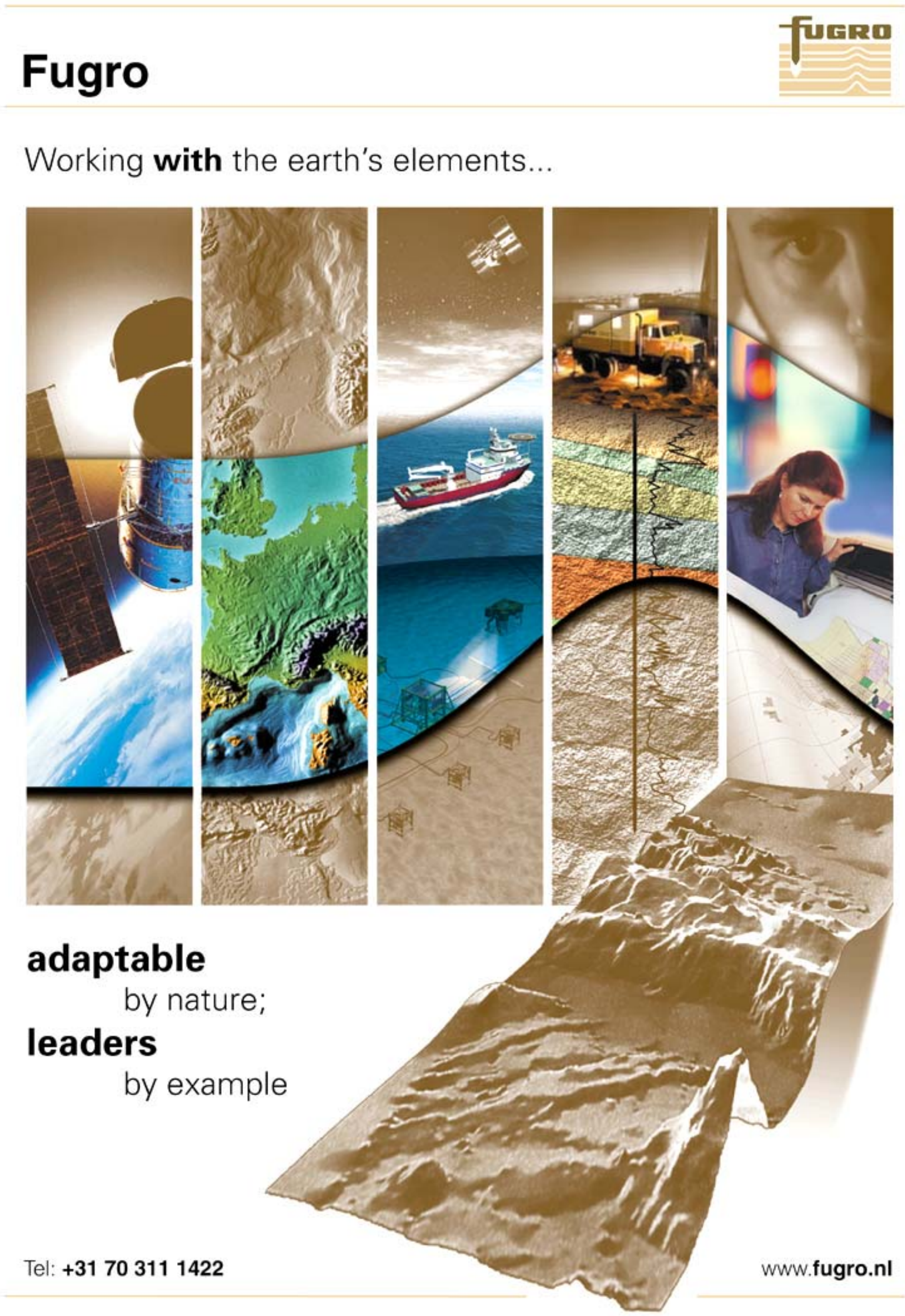
Waterbedrijf
Gelderland

WMD
water

Nuffic
Netherlands organization for international
cooperation in higher education

gerritse
ijzerwaren b.v.

wbb


Fugro
FUGRO
Working with the earth's elements...
adaptable
by nature;
leaders
by example
Tel: +31 70 311 1422
www.fugro.nl


WATER
bron van leven
Nieuwe methoden en technieken,
een veranderende omgeving,
een ander klimaat.
Ook Gemeentewaterleidingen Amsterdam
werkt aan de toekomst
binnen Amsterdam,
maar ook ver over de grenzen.
Meer informatie?
www.gwa.nl
Dit project is mede mogelijk gemaakt door
Gemeentewaterleidingen
Amsterdam

SUMMARY

Kitui District, Kenya is located in Eastern Africa, it is hot and dry and has a semi-arid climate. The main problem in the area is inadequate water for a large part of the population as there are only a few water sources such as rivers and springs. SASOL is an NGO that was founded in 1990. SASOL was established to address water problems in the ASALs, with a special emphasis on sand-storage dams and shallow wells. SASOL uses a community-based approach and has a current work area that covers about 600 km^2.

The objective of the practical work period is to gain experience in building sand-storage dams in Kitui District. During the practical work period the construction process was documented and evaluated in order to get a total overview of the building of sand-storage dams by SASOL.

The main activities during this practical work period consisted of interviewing SASOL staff members and employees, fieldwork in Mangina and office work at SASOL office, Kitui town. The fieldwork concerned: visiting sites, building together with communities and field trips with SASOL's general manager and technical manager.

The office work was meant to give information about: the 50 dams that were visited before the practical work period, the design of the dams, SASOL’s working methods and the building process of the dams. During the office period the design and the construction of the dams was documented and evaluated as well as SASOL's organisation. The office period took two weeks, the fieldwork four weeks.

Before SASOL starts building a dam, the community has to make a request to SASOL, a dam committee is formed and members of the committee are trained by SASOL. The site committee is responsible for the organisation and mobilisation of the community. Rules have to be made pertaining the use of the water behind the dam and SASOL's mason has to be taken care of. The design of the dam is made with some rules of thumb. Dimensions of the dam, foundation issues and reinforcement are described by these rules. The costs of a sand-storage dam are primarily determined by the amount of cement and the labour costs. Compared to other water storing techniques, sand-storage dams are cheap. The materials and equipment that are used to build the dams are simple. The construction of the dams is done by a mason who works together with the community. The community provides the necessary building materials. When the dam has been finished, the community has to take care of inspection and maintenance.

We concluded that the execution method is very suitable for community based building. Attention should be paid to the protection of the dam and its surroundings after completion. The dimensions of the spillway and the stilling basin are weak points in the design of the dam. They are to be improved in the project report. The impact of the dam depends on the way the community uses the dam. Communities have a lot of opportunities once a dam is finished.

The volume of the dam has been related to several constructional and functional aspects of the dam. Comparisons have been made between labour, cost, materials and reservoir volume. The strongest relation that was found is the relation between cost of the dam and dam volume. SASOL can use these relations to make cost-estimates of dams.

In general the opinion about the past practical work is positive. The stay on the countryside has had its impact on all team-members. The period was useful, because a lot of information about the design and the construction process could be found. A disadvantage of the fieldwork was, that except from the interviews, the working days were inactive some times.

The execution method is very suitable for community-based building. The fact that the work is labour intensive, forces the community to organise the labour and the building site properly and efficiently to prevent waste of time and manpower. Attention should be paid to the planting of Napier-grass in the surrounding of the dams. The design of the dams is not based scientifically; especially the design of the spillway and the stilling basin needs to be improved.
The experiment of combining a project and a practical work period has been very successful, from our point of view. We expect that the findings from this practical work period will provide useful information for the project.

TABLE OF CONTENTS

1. Introduction

1.1 Context practical work

Two obligatory subjects in the curriculum of Civil Engineering at Delft University of Technology are the justification of undertaking of the group project CF 599 in Kenya. In the last four months of the fourth year of the curriculum everyone has to execute a six week project and a practical work for a period ranging between six to ten weeks. When the project is done abroad, six weeks is rather a short period to gain good insight into the project. Because of this, group project CF 599 has decided to combine the practical work period and the project.

The objective of the project is: 'drawing up an optimised design for the household and production water dams with a construction plan, a maintenance plan and a user plan that can be used for constructing water dams in the future by SASOL.' To pursue this object 50 dams were visited and evaluated.

The goal of the practical work period was to gain insight into the construction process of sand-storage dams built by SASOL. Construction plays a major role in the design of the dams. The method applied in building has a great influence on costs, quality and planning. In the field a good impression can be gathered about the needs and possibilities of the future dam users and the organisational aspects of counterpart SASOL. The practical part also gives the opportunity to study the 50 dams that already have been visited, in more detail. In other words: the practical work period serves as a period of collecting information that can be used in the project.

Project group CF 599 has worked on a project of building 115 dams in an area of approximately 250 square kilometres. The project is financed by the United Kingdom Department for International Development Eastern Africa and has to be completed within three years. During the fieldwork 20 dams under construction have been visited. The duration of the practical work was 6 weeks.

1.2 Objective practical work period

The objective of the practical work period is to gain experience in building sand-storage dams in Kitui District. During the practical work period the construction process is documented and evaluated in order to get a total overview of the building of sand-storage dams by SASOL.

1.3 Contents practical work report

This report deals with the past practical work period. In the next chapter a description is given about the Kitui District, our counterpart SASOL and the SASOL-project we have worked on last six weeks. The third chapter is about the activities during the practical work as well in the field as in the office. In the fourth chapter the actual construction, organisation and design of the dams is described. The fifth chapter deals with an evaluation of the building process, the organisation and the design of the dams. Chapter six gives the outcome of the comparison on different aspects of the 50 dams that have been visited during the project period. Our own functioning during the practical work project is discussed in chapter 7. In the last chapter final conclusions and recommendations are given.

2. General information practical work Kitui District, Kenya

In this chapter the background of the water problems in Kenya is given in section 2.1. In the next section Kitui District is described. Counterpart SASOL is discussed in section 2.3. This chapter ends with an introduction of the practical work project we have been involved in.

2.1 Background

Only 45% of Kenyans have access to clean water. Generally, households living in the medium and high potential part of the country are considered to have access to safe water if they can get 20 litres of clean drinking water daily from sources within a kilometre away (Kimuyu 1998). Studies show that communities living in arid and semi-arid lands have limitations in accessing sources of water. They use open water sources, more prone to contamination. Closeness to a source of water and opportunities for multiple applications of the source are important considerations in choosing technologies for providing water sources.

Most governments in the developing countries are shifting their roles from 'providers' to 'facilitators'. This has been necessitated by contracting resources, sustainability and the failure of 'top down' (one size fits all) approach to development. This shift is placing more emphasis on water resources management at the lowest appropriate level. It calls for the empowerment of the users and interaction between the users, non-governmental organisations, private sector and the local government.

Major weaknesses and gaps preventing communities from benefiting from their water supply systems have been reported (IRC 1995). These include insufficient capacity building; partial coverage of user populations; lack of effective and equitable financing systems; absence of suitable management tools; environmental degradation of water sheds; and absence of proper gender balance in planning for, contributions to and control over the established water service.

Much can be achieved by building on experience with locally developed management patterns for traditional water sources. Water collection and use are often regulated by explicit agreements (IRC 1995). Women, who have for long played a crucial role in the traditional society, make many of these agreements. Women and men can play decisive and indispensable roles in ensuring the success of water improvement programs, when neither party is overburdened or excluded and then when work, authority and training are divided in a well-balanced way.

Adapted from: *From Rhetoric to Practice: Gender Participation in the Fight for Survival*
The Story of Sand Dams in Kitui

2.2 Kitui District, Kenya

Kitui town is located in Eastern Kenya. It is the administrative centre for Kitui District, which is one of the twelve districts making Eastern Province. The district covers an area of 20,556 km^2, including 6,369 km^2 of the Tsavo National Park inhabited by wildlife. It is divided in eight administrative divisions. An overview map of Kenya, including the location of Kitui District, is shown in figure 2.1.

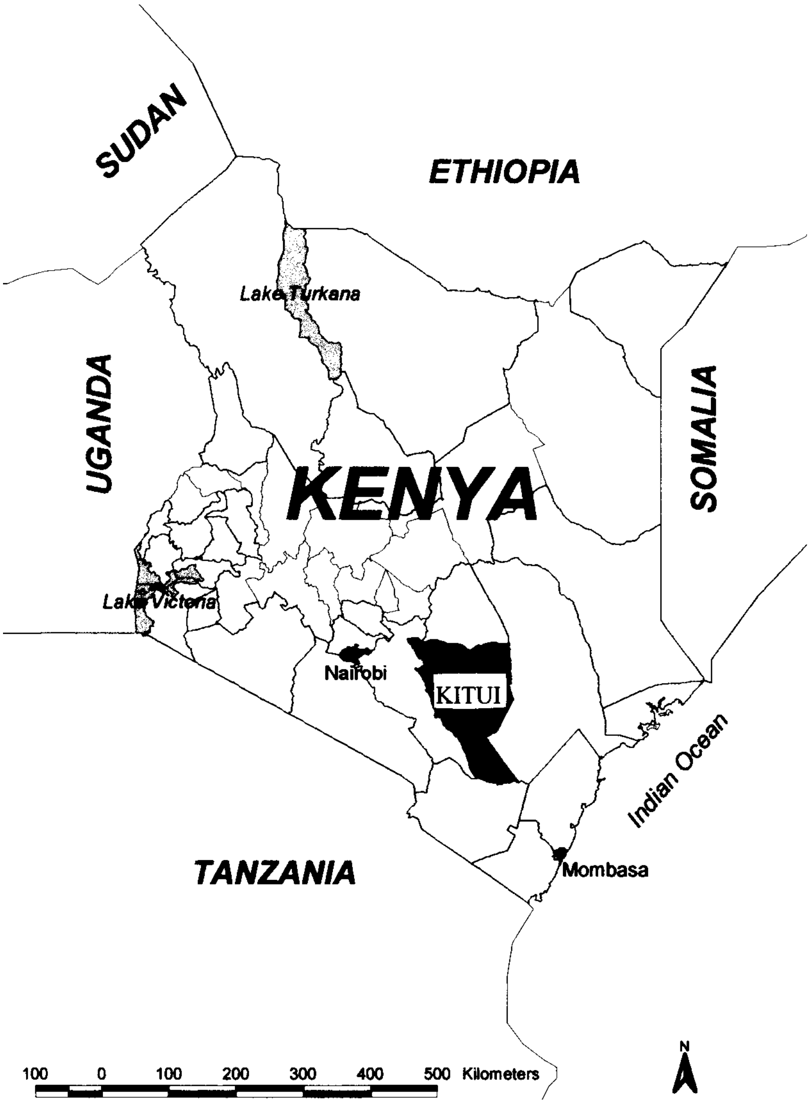


Figure 2.1: Location of Kitui District in Kenya [7]

Kitui District lies between 400 and 1800 m above sea level. At the south-eastern side of the district lies the Yatta Plateau between the rivers Athi and Tiva. The eastern side is almost plain with shallow widely spaced valleys and with some hills. In the higher part of the district there is more rainfall and therefore more productive areas. The main crops in the district are corn and beans. Livestock production is a major economic activity. The majority of the rural households keep cattle either for meat, milk, pulling carts and/or ploughing.

The climate is hot and dry for most of the year as in arid and semi-arid areas. The rainfall is very erratic and unreliable and the rate of evaporation is high. One in three rainy seasons is a total failure. In the district there are two rain seasons, from April to June and from November to December. Dry periods are between June to September and January to February. The amount of rainfall depends on part of the district and the topography. The higher areas receive 500 - 760 mm per year and the lower part less than 500 mm per year. The minimum temperature is 20 º C and maximum over 30 º C. The climate makes intensive use of land hard. It is important to note that the poor and rich households draw 77 % and 22 % respectively of their incomes from agriculture. Irrigation potential along rivers has been only minimally exploited. With more use of the water in the (seasonal) rivers, a lot of cultivation would be done to increase food production in the district. The district normally experiences food deficit due to recurrent drought episodes. The little harvest is supplemented by relief food from donor agencies.

The population of Kitui District was estimated to be more than 574,000 in 1999 (Census Republic of Kenya, 1999) with a density of 213 persons per square kilometres and is growing at a rate of 3.3 % per year. Sixty per cent of the households in Kitui are female headed and this has impact on the household human capital endowment. This is because of various reasons including men working outside the district, single parenthood and widowhood.

The main problem in the area is inadequate water for a large part of the population as there are only a few water sources such as rivers and springs. Since seepage is slow, there are long waiting hours at the water source to draw enough water. The major sources of water are perennial rivers. To access water, people and animals have to travel for long distances especially during the dry season and drought. In some areas people walk for 25 - 30 kilometres in search to water. Most rainwater is not harnessed. It finds its way to the Indian Ocean. If this rainwater can be stored, it can be used during the dry season and drought.

2.3 Counterpart SASOL

2.3.1 History and founding SASOL

Cyrus Mutiso, Sam Mutiso, Peter van Dongen and Jaap van der Zee founded SASOL Foundation in 1990. The name SASOL stands for Sahelian Solutions and is a non-governmental-organisation (NGO). Sahelian is an Arabic word for Arid and Semi-Arid Lands (ASALs). The population in ASALs all over the world is growing or will be growing in the next decades. The high potential areas cannot supply the needs of the growing populations, so people have to move to less favourable areas. These are the areas where SASOL is focusing on. The major need in these areas is water. If the lack of water in these areas has been solved, opportunities can arise for the population by increasing the productivity. Not only the livestock and crop production, but also the industrial production that is now absent in these areas.

SASOL Foundation has been founded, because the founders have a different vision of development projects than most existing development organisations. They have watched the very little impact of development projects on the lives of people in the past century by donor-driven organisations. In their opinion, development projects should be a great improvement in the lives of people. They think this can be done by simple low-cost projects where the community plays a mayor role in solving their own problems.

Many technologies have been tried to supply water to the communities in the dry periods. Boreholes are expensive to install. Shallow wells also offer an extractive technology, which is not sustainable. Water tanks are expensive and limited by size. Earth dams suffer from extensive losses due to evaporation; they also have a huge potential for contamination and risks to health. When groundwater is recharged, water is stored below the sand reducing evaporative losses. Sand filtration reduces contamination. Isolated sand-storage dams constructed in Kenya during the colonial period in 1940's & 50's by ALDEV are still functional. For SASOL this was proof that the technology is viable.

During the colonial period sand-storage dams were often referred to as sub-surface dams because the water is stored below the surface. However, the term 'sub-surface dam' is used in some countries to refer to a barrier below the surface. It could also be used to refer to an impervious underground barrier in a low-lying area that prevents the lateral flow of groundwater and maintaining or raising the water table. In contrast, a sand-storage dam is made as a concrete or masonry barrier on an ephemeral river. Although the upper side of the wall may be hidden by sand, the lower side is usually exposed, in part due to excavation by water when the river is following.

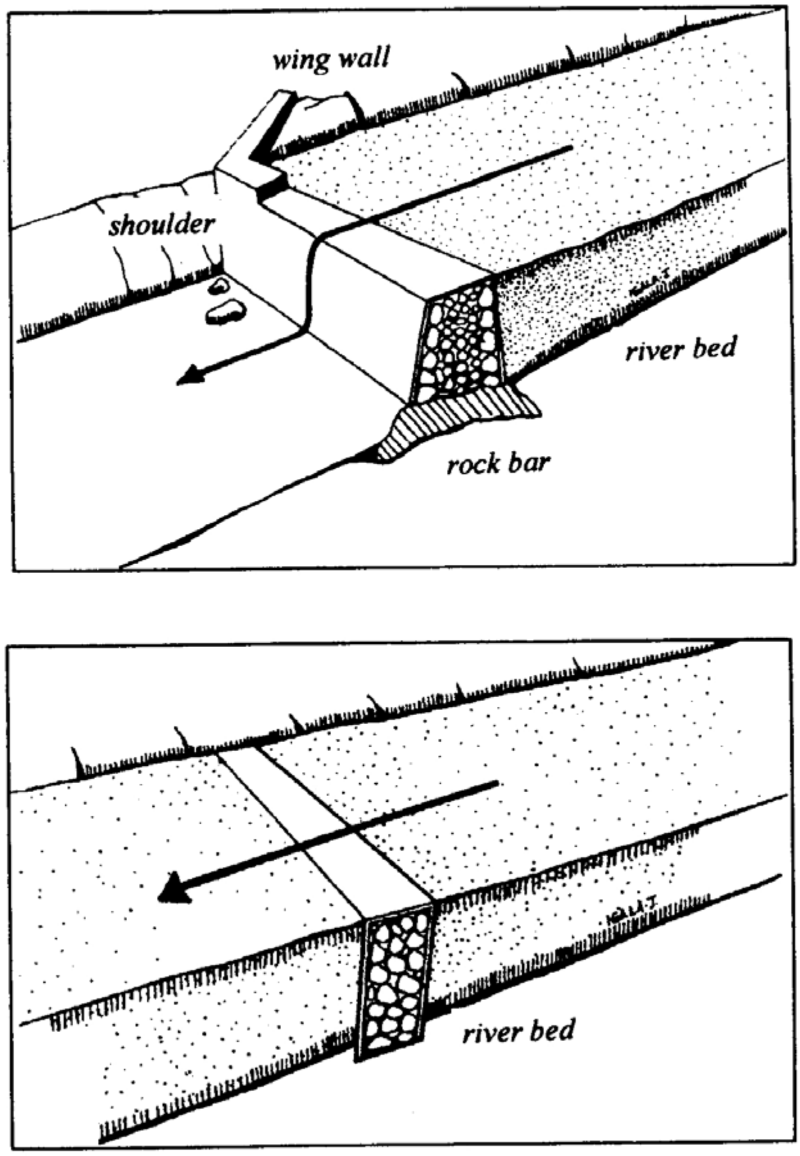


Figure 2.2: Difference between sand-storage dam (upper) and sub-surface dam (lower) [7]

SASOL was established to address water problems in the ASALs, with a special emphasis on sand-storage dams and shallow wells. In the beginning, nobody would fund the dams. So SASOL started a shallow well development with a school-feeding programme. This feeding programme stopped within a few years after starting due to conflicts with donors. The main reason however was the little structural impact on satisfying the basic needs. The school shallow well programme survives to date.

After that, SASOL focused on satisfying the important basic need, water. Both primary and secondary schools in an area of 600 km^2 in the Kitui District have been supplied with water by building shallow wells and rainwater storage tanks. This was a good experience for the future projects, because the approach of this school programme was a bottom-up approach. The community provided most of the labour and materials for the catchments, while SASOL found funding for cement, reinforcement, transport, masons and supervision. The main sponsor for this schools programme was SIMAVI, a Dutch development agency. This programme still continues in Kitui District.

This kind of supplying water for schools, has also been used to supply the local community nearby the schools. The effects on these local communities were substantial, but the supply of water was not sufficient in times of drought. SASOL's focus changed to supply water by building a water network of dams, shallow wells and rainwater catchments.

With the funding from WaterAid, a Non-Governmental Organisation (NGO) from the UK, SASOL started a pilot project on the Kiindu river. This pilot enabled SASOL to test the initial thinking and the practicality of instituting the system. It was also a test of the technology involved and the working systems in community organisation. From March 1995 until August 1995 five dams were built in the Kiindu river. The dams constructed during this period, received water in the October rains that year. SASOL observed an increase of water level at Kamumbuni dams where the scoop holes used to go down to 12 ft, but now the water level after the last long drought was only at 4 ft.

So the concept of building dams for water supply could be approved and the pilot project was followed by "25 sand dams projects" on the same Kiindu river catchment and was funded by WaterAid too. In 1998, WaterAid was wound up in Kenya and ended the funding on dams. In 1994 the Swedish International Development Authority (SIDA) and the United Kingdom Department for International Development, (DFID) (1996) started to fund dams in different rivers in the Kitui District. Every donor finances his own project area, selected by SASOL.
In figure 2.3 an overview map of Kiindu river is shown with the locations of the dams.

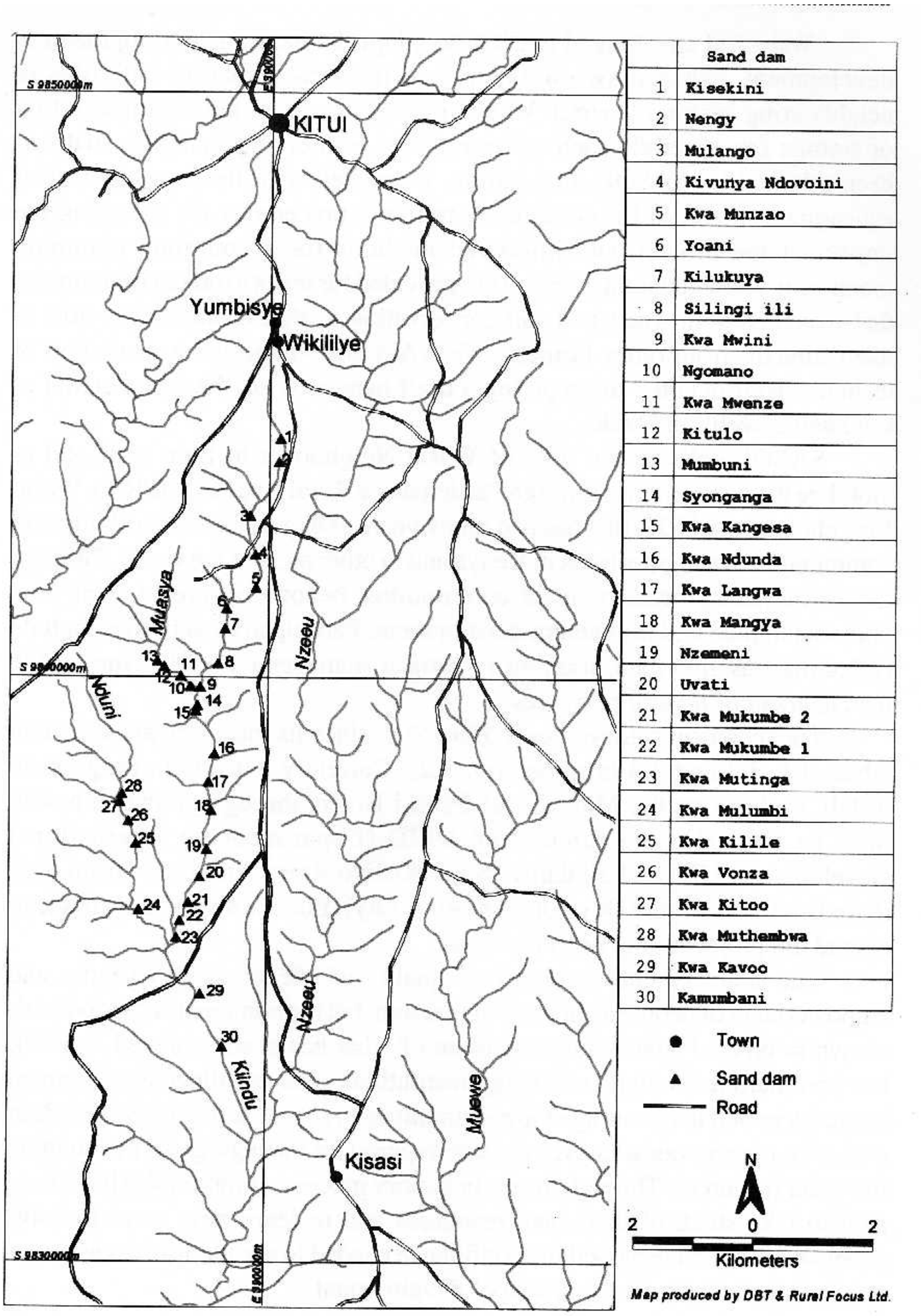


Figure 2.3: Kiindu river and tributaries showing location of sand-storage dams founded by WaterAid [7]

By April 2001, SASOL had already built 216 dams in different rivers in an area of 600 km^2 in the Kitui District. Although not all dams are working (a few collapsed by El Niño in 1997), most dams have a great impact on the local communities.

SASOL's turnover in 1999 was approximately Ksh 9.6 million (about NLG 320.000,-).

2.3.2 Objective SASOL

The main objective of SASOL is to prove that simple, low-cost technology for water infrastructure can improve the lives of people in arid and semi-arid areas, so that other development organisations or governments can copy this technology for water infrastructure.

SASOL's planning is to supply water within 2 kilometres of every home throughout the year in the Kitui District compared to the 10 kilometres women and children were walking to fetch water in the current project area. Progress can be made in satisfying not only the basic needs of the communities, but progress can also be made in life standard by producing high value crops, like mangoes, beans, maize and peas. The general health of the population will increase by this supply. Getting water would not be a negative impact on the health of women and children who used to walk any more, what it used to be by walking more than 10 kilometres for water. By increasing farming activities with more variety in crops, generating more balanced food and higher income, health will also increase. Energy and time expenditure for fetching water in the past can now be used for other activities, like terracing land.

2.3.3 SASOL's approach

The projects of SASOL use the Catchment Development Approach for implementation. The approach of SASOL is to develop a catchment in total. Construction of sand-storage dams is the base on which other activities are built on by the community. The catchment approach depends on the co-operation by the community in developing sequential sand-storage dams in their dry rivers coupled with terracing and tree planting on individual plots. The projects are community driven and managed.

SASOL uses a bottom-up approach when implementing development projects by letting the local community define their own problem, set their own priorities and make their own decisions on how to solve it. SASOL provides the facilities, resources and, if necessary, the required funding. The reason for this approach is first of all the failure of the conventional top-down approach by development organisations in the past and still now. Second, by letting the local community play a major role in solving their own problems, success of the project is more sustained. The community is also encouraged to use and build up their own knowledge, talents, capacities and organisation. Finally, the local community knows their own situation better than outsiders, like natural and human resources and what may or may not work in a given situation.

2.3.4 Work area SASOL

As SASOL is a Kenyan Foundation, activities of SASOL are all in arid or semi-arid areas of Kenya. The main activities of SASOL are in the semi-arid Kitui District. The choice for Kitui District has different reasons.

1. Geography and Morphology.

Kitui District has a great variety of flat and steep places in high and low areas.

2. Production system.

Kitui District used to have a great production of livestock. By growth of the population and more intensive use of the land by livestock, this production became more and more crop agriculture, because of the higher productivity of the cropped land. The fact that Kitui District is a net importer of food, makes the need to be a self-providing in the future more and more important given the growing population.

3. Soil.
Kitui District has a great variety of soils. The behaviour of solutions for the Kitui District on different soils can be reflected on different arid and semi-arid areas.

4. Social organisation.
The nature of social organisations for development in the Kitui district varies from none social organisation to strong organisation of the local communities. It is a challenge to organise communities for solving their problems whether they already are organised or not. This makes the Kitui District a perfect experimental area for the solutions of SASOL for arid and semi-arid areas all over the world.
In figure 2.4 an overview map of SASOL's work area is shown. A larger overview map of that area is given in Appendix 1.

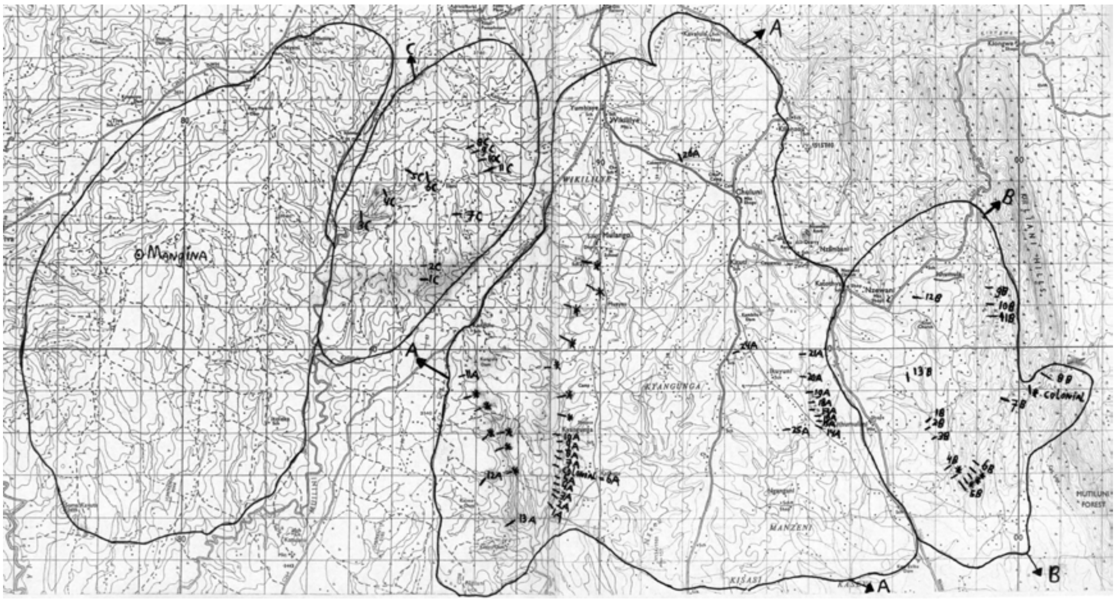


Figure 2.4: SASOL project area

2.3.5 Current organisation

In the period of the school feeding programme and schools programme, the organisation was quite extensive. There were more than 20 managers to do the projects. After starting with the dams, the organisation became smaller to be more effective.

Nowadays, the organisation of SASOL has a small overhead. A board of governors supervises the activities of the organisation. The board has 8 members. The board has four meetings a year. The board has to be complete, by law, at least one time a year. In these full board meetings, the board has to call to account for the activities and the expenditures of the foundation. Policy will be adjusted, made or changed and problems in execution of the foundation will come up for discussions, as other relevant items, like Kenya government policy.

BOARD

Prof. Cyrus Mutiso	Chairman
Peter van Dongen	Treasurer
Francis M. Katua	Vice-Chairman
Evaus Ngava	Member
Catherine Mumo	Member
Maria Mulura	Member
Jennifer Mutia	Member
Makau Kyambo	Member

Under this board, SASOL has an executive board of 5 members. This board is fully authorised to take daily decisions and spend money. The executive board consists of the same members as the board, without the chairman the treasurer and Makau Kyambo, because they are in Nairobi most of the time. The Executive Board chairman is Mr. Francis M. Katua. He is the co-signatory of all the cheques for payments made by SASOL.

EXECUTIVE BOARD

Francis M. Katua	Chairman
Evaus Ngava	Member
Catherine Mumo	Member
Maria Mulwa	Member
Jennifer Mutia	Member

The projects are run by:
- 1 Field Manager (Sam Mutiso)
- 1 Technical Manager (David Ngui Kithuka)
- 1 Community Manager (Matthew Kitema)
- 1 Administration Assistant (R. Mary Maig)
- 2 Group Leaders (Headmen of the masons)
- 16 Masons

In figure 2.5 an organisation chart of the current organisation of SASOL is presented

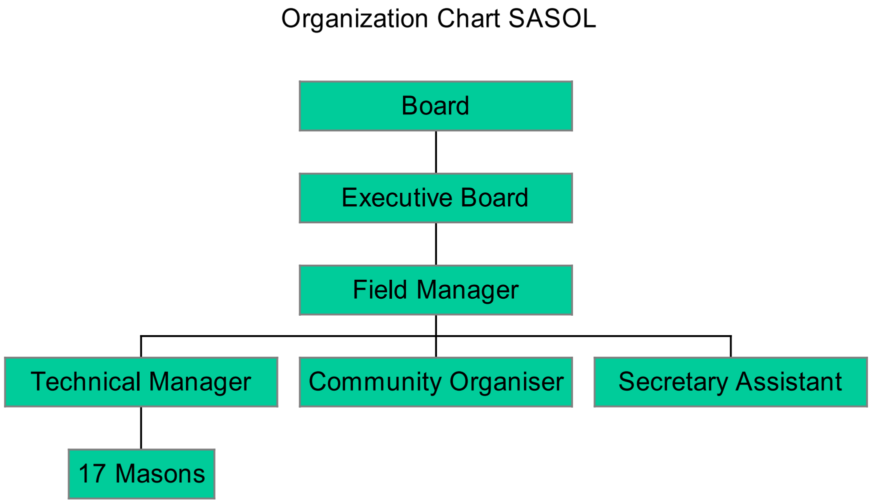


Figure 2.5: Current organisation of SASOL

The tasks and responsibilities of the different staff members and employees are given below.

Tasks Field Manager:

- Managing SASOL-activities
- Fund raising
- Supervising personnel
- Report preparations

Tasks Technical Manager:

- Supervision of the masons
- Location of the dams
- Material management
- Talk with chief, community and site committee
- Transfer the masons
- Check all dams, at least once a year

Tasks Community Manager:

- Making contact with communities
- Training communities
- Participator in community based projects
- Formation committee

Tasks Administration Assistant:

- Looking after accounts
- Data entries
- Managing office

Tasks Group Leaders:

- Co-ordination of work in the field
- Solve small problems
- Intermediate between Technical Manager and Masons

Tasks Mason:

- In charge of the site
- Activate community
- Liaison between community and SASOL
- Training at the site (sanitation)

2.3.6 Future SASOL

In the future, SASOL plans to keep on building dams southwards from the present area to the Tsavo East National Park. The population density in this region is lower and the soil differs from the situation in the present building area, but it is a challenge for SASOL to prove that this technology for water infrastructure can also work in this area. To finance these dams, SASOL has already found funds from the European Union for the coming year. Sourcing for funds for the remaining dams will not be a problem, because of the approved impact of this technology.

Providing water was one part of the objectives. To improve the lives of the population, one has to teach people to use the water efficiently, to maximise their profit. In this view, SASOL will promote:

1. Environmental land protection by terracing land.
2. Agriculture business by cropping high value crops for export and variety in cropping.
3. Organising communities by using the existing organisation in the community for building the dams for other purposes.

To be able to go on with this project, scientific proof of the impact of this water infrastructure is needed. Because little is known about the technology of sand-storage dams, documenting the projects is very important. Organisations that want to use this technology do not struggle with the same problems as SASOL.
Research is needed to asses the impact of this water infrastructure. Not only to ensure funding and support by other organisations or governments, but mainly to optimise this technology by scientific knowledge. How can SASOL optimise the recharge area with the dams, how can the production be optimised by optimal use of the water in the catchments, what is the socio-economic impact of the dams on the lives of the population? Those are some of the many questions SASOL wants to know for the future to optimise the effects of the dams.

SASOL has plans to hire three extra staff members: a health manager, an agriculture-business manager and a research manager. Up till now SASOL did not have the money to employ these people. When a proposal to the European Union is funded, SASOL will implement the planned staff expansion.
The health manager will give health education to the dam users. His work will help to reduce diseases in the project area. The agriculture-business manager can help the population with the crops. 'What is the best strategy for cropping, what are high value crops, what crops are sustainable?' are questions an agriculture-business manager will have to answer. A research manager is intended to co-ordinate the research programs SASOL wants to undertake.

2.4 Practical work project

2.4.1 General

The project, we have been involved in, concerns the construction of 115 sand-storage dams in three years (from January 2000 to December 2002). The United Kingdom Department for International Development (DFID) finances the project. The first co-operation with DFID ended by December 1999. At the end of this project 55 dams with off-take wells had been constructed. DFID has decided to replicate this project along other rivers i.e. Ithimani, Kalikuvu Muthungwe, Ithiiani and Kavou. These catchment areas are located in Itoleka and Kyangwithya West locations. In figure 2.4 the project area is shown.

The total project costs for the construction of 115 dams are Ksh 58 million. The community contribution, labour and stones, is approximately Ksh 17 million. The contribution of DFID is Ksh 41 million (1 Dutch guilder is equivalent to 30 Ksh).

2.4.2 Goal and purpose of the project

The goal of the project is to sustainability increase community water supply in dry areas of Kitui. This could be achieved by increasing the number of available water supply points from say one to ten along 25 - 30 km of the Mwiwe in the dry season.
Purpose of the project is to increase the retention of water in the dry river bed sands for use by the community. The technology exists to retain the water that passes through these seasonal rivers for use in the time of adversity. With support of external resources the community can effectively utilise local resources to supplement their existing water resources.

2.4.3 Output of the project

The main technical output of the project is:

1. Sand-storage dams as a sustainable water harvesting technology in ASALs constructed, used and adapted in Kitui.

It is anticipated the current project and will be centered on the western end of the defined area SASOL has been working on. The project seeks to construct 115 sand-storage dams with off-take wells for use by the community in the area within three years.

2. Improved environmental management of the project area in Kitui.

The management of the environment is critical to the catchment development approach. Construction of sand-storage dams in the river channels is the first step towards retention of water in the catchment. The second step is to control runoff of the land by terracing. The third step is to increase ground vegetative cover. This can go in two stages, one being the protection and maintenance of existing vegetation, which would be followed by additional new trees when the water vase stabilises.

3. Key lessons from the project are documented and disseminated to partners in ASAL water development.

The use of river sands to harvest and store water for communal use has been neglected, as it is poorly understood. Yet this is the source of bulk survival water in the ASALs during droughts. To bring it to the fore and wider usage the project has a duty to circulate it as widely as possible.

2.4.4 Project activities

The main activities of the project are:

1. Community organisation

2. Training to empower the community to:
   - Improve local leadership.
   - Manage their environment.
   - Establish and maintain meaningful records.
   - Institute effective hygiene and sanitation measures in the community.
   - Plan effectively.

3. Construction
   - Establish suitable dam sites to serve the community effectively.
   - Formation of site committees to supervise work at site.
   - Construction of sand-storage dams and wells.

4. Facilitation
   - Terracing for water conservation and management
   - Free seedling to improve the planting

We have mainly been involved in activity 3, Construction of sand-storage dams.

3. Activities during practical work

Our practical work consisted of fieldwork, interviewing and office work. The fieldwork took four weeks of our practical work period, the office work two. The interviews have been done in the meantime. Our activities and circumstances during the fieldwork are specified in section 3.1. In section 3.2 the interviews and the interviewed persons are described. This chapter ends with a description of our activities during the office period (section 3.3).

3.1 Fieldwork

3.1.1 Activities during fieldwork

The fieldwork consisted of the following activities:

- Visiting sites.
- Building together with communities.
- Field trips with general manager and technical manager.

These activities are reflected in the next three sub- sections. The fieldwork gives information for drawing up the description of the building process of the dams (see section 3.3.5) and for making an evaluation of the building process (see section 3.3.6).

3.1.2 Visiting sites

Observations of the construction process have been made during the visits we paid to the different sites (23). 11 of these sites were still under construction, 12 had just been finished. We visited different sites instead of staying at one site all the time, because of two reasons:

First of all we wanted to see all aspects of construction, it was not possible to see these aspects on one site. The foundation of the dams was different. Some were rock based, while others were founded on clay. Some dams were small, while others are big. At some sites the necessary materials (water, sand etceteras) were not available in the surroundings of the site, and had a great influence on the building process.
Furthermore the community organisation differed from place to place and all dams had different masons who could give additional information about design aspects.

During the field visits we have undertaken the following activities:

- We interviewed the chairmen/ladies and other committee members of the different sites. Most of the time these people were able to give us specific information about the construction, the building process, the community, the necessity of the dam, problems and the progress at their dam site. Because the committee is also responsible for the regulations about the water use of the dam, also some interesting matters about legal aspects were brought up.
- We observed the organisation of different communities. The nature of organisation strongly differed from place to place. We saw some fierce discussions between community members and committees. Sometimes even an evaluation talk took place at the end of the day. It was also interesting to see how communities make their own laws and regulations. Organisations made visible progress during our practical work period.

Figure 3.1: Committee chairlady of Kya Munua A dam site, Mrs. Rose Harrison Kilului

- We also studied the design of the dams and discussed the design and construction with the masons we met at the different sites. It was necessary to study the design of the dams, because it was not clear what the current dam design of SASOL was like. Documentation about the current SASOL design was not available.
- We accompanied the head mason at a journey along some dams. He was able to tell us about the design and some organisational aspects of SASOL.
- Because we have been at so many different places, we were able to study all relevant aspects of the construction; from digging foundation to finishing the dams.
- We visited 12 dams that had been finished recently (March 2001). These dams were interesting, because there were some experiments on the dimensions of the spillway. By means of a trial and error system SASOL tries to find out whether the design of the spillway can be improved.

We chose to stay together with the group, instead of splitting up. We found that we could make better observations when we were together. Apart from that, we had only one guide who could show us the way to the different sites, which were very inaccessible sometimes. Safety also played a role in the decision to stay together.

Our guide during the field work in Mangina was Stephen Ngei, who showed us many building sites, and took time to explain all about the current SASOL dam design. Stephen Ngei is an experienced mason who has been working for SASOL, right from its initiation.

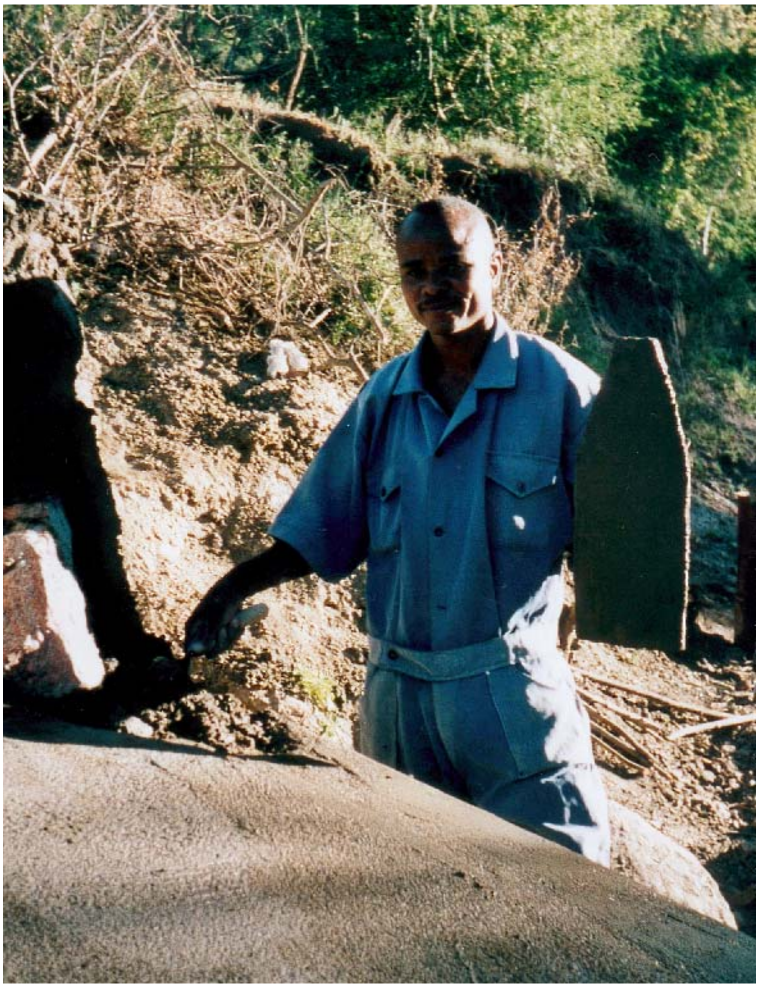


Figure 3.2: Stephen Ngei, SASOL mason, guide and bicycle repair man

In Appendix 2, an overview is given of the different sites under construction, we have visited. Some general features and comments about design and construction process are brought up.

3.1.3 Building together with communities

During the dam visits, there was usually some time to work with the people and help them with the construction. Activities like breaking and carrying stones, mixing cement, and carrying sand have one thing in common: They will cause blisters everywhere! The work on the site was heavy and the hot and humid climate did not make it easier.

Figure 3.3: Building together with communities

3.1.4 Field work with general manager and technical manager

In the field trips we were accompanied by SASOL's general manager and SASOL's technical manager. We have seen what kind of work they do when they are in the field. The location of good building sites, instruction of the masons and interaction with the community, are among their activities. In the end the technical manager is responsible for the dams that are built. Because of this the technical manager normally travels around on his motorcycle to keep in touch with the masons and the communities.

3.1.5 Working hours and residence

The construction of the dams usually started at 9 a.m. The masons had to be at the site at 8 a.m., but most of the time they arrived together with the community. The construction ended at about 5 a.m. During the practical work period in the field, our working hours were the same as those of the masons. Sunset was already at 6:30 p.m., so there was not really much to do, after working hours.

Our residence during the field period was in Mangina. The work area was too far away from Kitui town to commute every day. So it was really good that we had a central place to stay from where we could reach most sites. We stayed in two small rooms (9 m^2 and 12 m^2) that were situated behind a local shop on the central square of Mangina. SASOL had hired a lady who cooked our meals and looked after us during our stay in the field. There was no electricity, flowing water or telephone, so the circumstances were quite primitive, according to our western standards. Mangina town was not really exciting, except from the Gospel Road Show that came by twice during our stay and not to be forgotten the football games with the local schoolchildren.

Figure 3.4: Our residence in Mangina

Figure 3.5: Gospel Road Show

3.1.6 Transport

There were only three dam sites we could walk to in a reasonable time; the others were just too far away. Because we could not see all phases of the building process at these sites, we have decided to purchase bicycles. After the first week, we got the bicycles, so we could travel longer distances and thus see more dam sites. We also used the bikes to travel from Mangina to Kitui Town and vice versa.

Figure 3.6: Cycling around Itoleka location

3.2 Interviewing SASOL staff and board members

During the period of practical work some SASOL staff and board members of SASOL have been interviewed. Most interviews took about three to four hours. The interviews give information for drawing up the description of the building process of the dams (see section 3.3.5). We also gathered general information about SASOL and our practical work project (see chapter 2.4).

The first person that was interviewed, was Prof. C.M.G. Mutiso, Chairman of SASOL Foundation. As Mutiso is one of the founders of SASOL, he was able to tell us all about the history of SASOL. Because he is very devoted to the work, also the current activities and future plans were discussed. The organisation and the objectives of SASOL were discussed.

The next person to interview was David Kithuku, better known as ‘British’. British is the technical manager of SASOL. He is responsible for the design and construction of the dams. These matters were raised with him, since they are most interesting for us, civil engineers. Also the evolution of the design of the dams during the past five years was subject of discussion. Alternatives for dam construction have been proposed and discussed. Future developments, general information about SASOL and constructing together with communities are among the many other things that have been mentioned.

The third person to interview was Sam Mutiso. Sam is SASOL’s field manager. He is responsible for the whole process of building dams. He plans, raises funds, supervises and writes reports for donors. Matters that were discussed are: organisation, objectives of SASOL, future improvements, donors, relationship with the local government, the construction process and the question if sand-storage dams are a suitable solution for other areas of Kenya.

The fourth person, who has been interviewed, was Stephen Ngei, an experienced mason of SASOL, who has worked with SASOL right from the start. He was able to tell us a lot about design, guidelines for construction of the dams, general aspects of the building process and working together with the communities. Ngei has seen the dam designs change during the years.

We also had a meeting with the chairman of the executive board, Mr. Francis Mkuta. This was not really an interview since the atmosphere during the meeting was quite informal. The main subject of conversation was our work in Kitui District.

Unfortunately we have not had the time to arrange an interview with SASOL's community mobiliser. Although we have met him several times, there was no time or opportunity to interview him. His tasks and responsibilities are described in chapter 2.3.5

3.3 Office work

3.3.1 Activities during office work

The office work consisted of the following activities:

- Input data for evaluation and comparison between 50 dams
- Studying the design of the dams
- Studying SASOL’s working methods
- Drawing up a description of the building process of the dams
- Making an evaluation of the building process of the dams

These activities are described in the following five sections.

3.3.2 Input data 50 dams

In the two weeks before the period of practical work, we paid visits to 50 dams built by SASOL and filled in an evaluation form for each dam. In the evaluation form different characteristics and dimensions of the dam, the river and the surroundings of the dam were recorded. More information about the evaluation of the dams can be found in the project report that will be published 25th June 2001. SASOL also keeps records of all the dams that are built. In these small booklets, information about the construction process can be found. These data, together with the data collected during our visits, has been put in a spreadsheet. The booklets provided information about the number of people that had worked at the dam, subdivided in men and women, the amount of materials used, and the various construction activities. The booklets also contain a detailed longitudinal section, which enabled us to calculate the volume of the dams.

The outcome of these comparisons between the 50 dams can be used for our project. The comparisons are given in chapter 6.

3.3.3 Studying designs dams

Except from the information about the construction process, the small booklets also contained a drawing and information about the dam design. We have studied these designs to draw up the design of the dams for the description of the building process of the dams (see section 3.3.5).

3.3.4 Studying SASOL's working methods

We gathered information about SASOL at the office. This information concerned:

- Construction records
- Organisation
- Planning
- Community training
- Work areas
- Financial Statements
- Project proposals
- Literature about dam design

Sam Mutiso and British helped us to find the information in the office, and answered our questions about matters like organisation, design and planning. All this information has been used to draw up a description of the building process of the dams (see section 3.3.5) and to gather general information about SASOL and our practical work (see chapter 2).

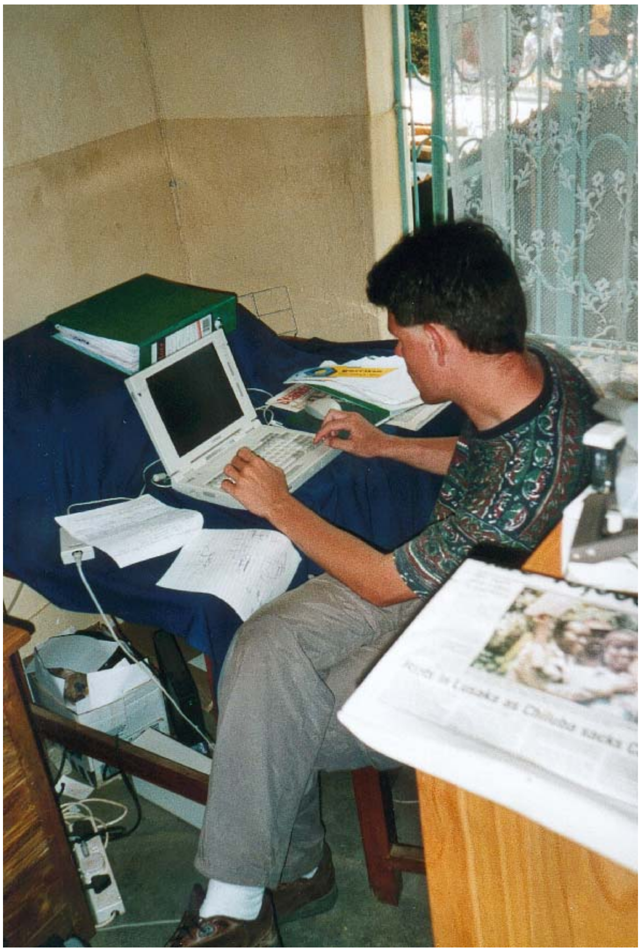


Figure 3.7: SASOL office, Kitui Town

3.3.5 Drawing up description building process dams

Part of our office work was to draw up a description of the building process of the dams made by SASOL. We have tried to give a total overview of the building process from the beginning to the moment the dam is brought into use by the community. There are two reasons to draw up a description of the building process:

1. To gather information that can be used in the project. The objective of the project is: ‘drawing up an optimised design for the household and production water dams with a construction plan, a maintenance plan and a user plan that can be used for constructing water dams in the future by SASOL. The information from the description of the building process of the dams plays a major role to carry out the objective of our project. Construction plays a major role in the design of the dams. The way of building has a great influence on costs, quality and planning.
2. To make an evaluation of the building process (see section 3.3.6). SASOL asked us to give a critical refection of the building process. The past years they have spent most of their time to set up SASOL and to prove that their concept of the sand-storage dams is working (for donors and government). At this moment SASOL is running well and there is time to improve their building process and working methods.

The description of the building process of the dams is given in chapter 4.

3.3.6 Evaluation of the building process of the dams

On the basis of the description of the building process of the dams we made an evaluation of the building process. In this evaluation we give our reflections on the current building process and give some recommendations to improve the current building process. The evaluation of the building process of the dams is given in chapter 5.

3.3.7 Working hours and residence

At the office we started at about 9 a.m., lunch from 1 till 2 and finished at about 6 p.m. The office of SASOL is located in Kitui town and is also the residence of the field manager. Our residence during the office period was in ‘Kitui Tourist Hotel’. This hotel was nearby the office of SASOL (100 metres). This residence was more luxurious than our residence in Mangina. We could use flowing water, there was a toilet, electricity and the food was relatively good.

We took breakfast at a small teahouse at 500 metres from the hotel. Kitui town was more exciting than Mangina. There was a disco (Reflections, the place to be) and there were much more shops. Most products are available in Kitui town.

4. Practical work: Description building process

In this chapter the outcome of interviews and observations is presented. The building process of the dams was studied at the different sites that were visited during the practical work period. First the preparations SASOL undertakes before starting construction are discussed. In section 4.2 the organisation at the building site is presented. Section 4.3 shows the guidelines that are used by SASOL to design and build the dams. The financing of the dams is discussed in section 4.4. The materials, equipment and planning needed for building the dams are brought up in respectively section 4.5 and 4.6. In section 4.7 a presentation of all construction of the dams from the beginning to the end is given. This chapter ends with the sections 'completion and inspection' (section 4.8) and 'in use' (section 4.9).

4.1 Preparations

4.1.1 Legal aspects

To be allowed to operate as a non-governmental organisation in Kitui District, one has to be incorporated in the District Development Committee (DDC). All organisations need their approval to operate in the district. Before starting their activities, SASOL has submitted a proposal to the DDC. When an organisation undertakes useful activities for the community (like building dams), getting permission is usually no problem and the organisation can become a member of the DDC.

SASOL always selects seasonal rivers to build its dams in. In seasonal rivers permission of the government is not necessary. Only the landowners, whose land is next to the river, have to agree. Most of the time that is no problem, because the dams improve their land nearby the rivers and they can use the water too. A building licence is not required for building the dams on own property.

4.1.2 Authorities

SASOL focuses on an area of about 600 km^2 (Central Division) of the 20,566 km^2 of Kitui District, because Central Division has the highest population density of all divisions. The intention is to build around 300 dams in this area. Every year SASOL selects sub-areas to work in.

SASOL presents itself formally to the community in the project area. This is done through the Chief's Office. The local chief will organise a public meeting or 'baraza' to introduce SASOL and its intended projects, in the area. The chief is the administrative head of a location and the Chief's Office is the administration level closest to local communities. In total there are 60 locations in Kitui District. The following table illustrates the existing administrative structure of the Kitui District.

Table 4.1: Administrative structure Kitui District

Level	Administrator	Government development agency
District	District Commissioner	District Development Committee (DDC)
Division	District Officer	Sub-District Development Committee (Sub- DDC)
Location	Chief	Location Development Committee (LDC)
Sub-location	Assistant Chief	Sub-Location Development Committee (SLDC)
Village (Utui)	Headman (Mutui)	Village Development Committee (VDC) (Nzama ya Utui)

There are three reasons to involve the chief in the intended projects:
1. The chief has to give his authority to work in the area. Without authority serious problems can arise.
2. The people are brought together. There is no other forum to get the different people and communities of an area together.
3. The administration plays a major role in legitimising the rules the community makes.

The following persons are present at the meeting:
1. Field manager (SASOL)
2. Technical manager (SASOL)
3. Local chief
4. Local Assistant-chiefs (sub-chiefs)
5. Representatives of the different communities (headmen of the villages)

The subjects of discussion are:
1. Problems of the communities with water in their area. Most common problems are:
   - Not enough water for cattle
   - Not enough water to crop vegetables
   - Not enough rain
2. Concept of the dams
3. Technical aspects
4. Kind of organisation
5. The kind of work involved

4.1.3 Community request

Once the chief has introduced SASOL, he usually quits the scene. The sub-locations, which are interested in the intended project, then, approach SASOL, so that intervention might be effected. Typically a sub-location covers an area of 30 km^2 and has a population of around 6000 people. With a formal approach through the sub-location, deliberations with the community can start. Nowadays SASOL gets more requests for their approach than they can handle. Before the community can start building, it has to form a committee. Committee training is part of the preparations.

SASOL used to train the whole community in the selected area. Problem of this approach was that a great part of the community that had got training was not involved in the committees. A lot of people who had got the training did not apply their knowledge, so that the money was wasted. Nowadays only committee members are trained.

4.1.4 SASOL requirements

1. SASOL makes demands on the community before honouring a request. There have to be enough people (households) to build the dam. If there are not enough people, the work will go to slow and becomes too expensive.
2. The community has to be strong enough (enough men), because a part of the work is heavy.
3. Organisation and mobilisation of the people is very important. If the community has not been organised very well and some people do not work, or work less, other people will lose their motivation as well. In the end this will give problems.
4. The community members have to provide labour and local materials. The basic idea behind the approach is to ensure ownership and sustainability.

4.1.5 Community location choice

After the SASOL committee training, representatives of the community walk with two SASOL representatives (mostly the technical manager and a mason, sometimes the field manager) along the river and show them what they think is the best place to build a dam. Before this walk the community has already discussed what they think is the best location for the dam. Both women and men are involved in site selection. Women play a major role as water managers and drawers in the household. As the project is mainly on water, they play a major role in it.
They know which areas are most convenient to obtain water from and the distribution of these points for maximum coverage. In the community meetings the women's voice is heard loud and clear. The community has picked out the sites in accordance to user suitability and their knowledge of the area.

Important factors to determine the best location are:
- Accessibility for the community
- Existing water collection point
- Presence of a road. When there is a road the community does not need permission of the landowners to build the dam, otherwise she does.

Together with SASOL staff the technical suitability of the selected site is assessed and reviewed as necessary.

4.1.6 Final location choice

The SASOL representatives look from a technical point of view whether there is a location to build the dam. If so, SASOL's technical manager will try to convince the community this is the best location. Criteria of the technical manager for a good dam location are:
1. Storage capacity (is water storage adequate)
2. Soil characteristics at the location
3. Is it a good place to work?
4. Is the river at this location naturally confined between banks, even during flooding?
5. Is the river straight? Locations near a bend are unfavourable.
6. Is there a rock bar across the riverbed? - Possibly without a fracture (as far as can be ascertained by probing with an iron rod). Such rock bars are the best foundation and occur quite frequently in the project areas.
7. Are there enough materials in the surroundings (clean sand, stones and water)? It is time-consuming and expensive when stones, water or sand have to be imported from other places.
8. Distance between previous dam and new dam (recommendation is 1/2 kilometre for steep rivers and 1 kilometre for gentle rivers). Another important issue is the height of the previous dams (series).

Sometimes water may be needed at a location where the favourable conditions are absent. In such cases, risk of failure is high.

When the community agrees with the proposed location for the dam, the technical manager discusses his findings with SASOL's general manager. Each approved site elects a site committee (see section 4.2), which will supervise the implementation, operation and maintenance of the site.

4.1.7 Community training

Using participatory methodologies, SASOL helps communities to organise their knowledge, establish records, fill in any gaps in knowledge that the community might have and input new ideas, knowledge and information. Community participation is a strategy that encompasses beneficiaries sharing project costs, assisting in the design, implementation, operation, maintenance and management of water resources. Before communities can be mobilised, people must be trained. Major areas of concern in the training are:
1. Maintenance
2. Leadership
3. Community organisation
4. Natural resource management

SASOL has found that training can best be done at the level of sub-location, because people from the same locality are brought together. This locality is small enough for matters of common concern. SASOL gives the following training:

1. Initial Participatory Rural Appraisal (PRA) training

As a first step of intervention in the community, a small representative group is selected by the community for training, both men and women (committee members). To establish understanding and to foster close co-operation, the artisan (allocated to the group by SASOL) attends these sessions too. The basic idea is that the representatives will carry the message and their deliberations back to the community. The community must define its own problems, set priorities and make decisions on how to solve them (bottom-up strategy). The community provides solutions to problems through use of local knowledge and talents and plans appropriate actions to invoke the solutions.
The key problem identified by the ASAL (Arid and Semi-Arid Land) communities is the lack of water for human, livestock consumption and production. This is always the first problem to be tackled as it is at the root of the poverty in the ASALs.

2. Project Management Training

The purpose for this training is to enable the community to identify factors, which have been helpful and hindering the completion and sustainability of development projects. It should also facilitate the removal of the hindering factors and promote the helping factors of development. The training is aimed to the members of the village development committees; community based organisation leaders and other community leaders.

3. Natural resource management training

The catchment development approach training and understanding soils, the role of manure, seasons, trees, water management, terracing and conservation on land, crop production and water cycle, helps the community to increase the productivity of their land. In many ASALs the problem is not the absolute lack of water, but rather the loss of received precipitation.

4. Sanitation and hygiene training

The purpose for this training is to enable the community to identify possible diseases and teach them ways how to prevent them.

Most of the community training takes place before building. This is not always possible, because of the limited capacity of the training. The organisation of the community training is the work of the field manager. Training is given in co-operation with another NGO. This is the organisation World Neighbours. SASOL's field manager is one of the teachers. The training takes place in a centre (for example a school) in the surroundings of the new dam.

4.2 Organisation

4.2.1 Site committee composition

The projects are designed to give the community responsibility in running its own water projects. After SASOL's approval to build a dam, the community has to select a site committee. SASOL demands that the committee must consist of young and old people. This is done, because of the continuity of the committee in the future and because of the fact that young people are generally more educated, which is useful for the committee tasks (writing, recording, reading). Women also play a major role. In the Kiindu river project, more than half of the sites was overseen by chair-ladies.

The site committee exists of about 13 members.
The officials are:
- one chairman (or chair-lady)
- one vice chairman
- one secretary
- one vice secretary (optional)
- one treasurer

The committee is trained on site management.

4.2.2 Site committee tasks

The most important tasks of the site community are:
- Make regulations and rules to duties for the community for the construction.
- Make sure that the people of the community follow these regulations and rules.
- Mobilise community to collect resources (sand, stones and water) and to dig the foundation trench.
- Arrange storage for the cement, round bars and equipment.
- Make arrangement for housing and feeding of the mason.
- Collecting money from the community to finance the community tasks (feeding, housing for mason and storage of materials)
- Plan the work
- Divide the community in work teams.
- Make a time-schedule for the work teams.
- Stock management and keep records.
- Make the regulations and rules for the use of the dam
- Look at maintenance and follow up projects.

4.2.3 Site organisation

The construction can be divided in two phases. In the first phase of the construction, when the community collects materials as stones, water and sand and digs the foundation trench, the local headman of the village and the chairman of the site committee have leadership. They assign duties during the construction of the dam.

The site committee divides the able-bodied members of the community in work teams. The teams rotate from day to day so that the task at home or in the fields is not neglected. The tasks of the different teams are:
1. Digging the foundation trench (men)
2. Breaking and collecting stones (men)
3. Collecting sand, if not presented in river bed (men and women)
4. Cooking (women)
5. Day nursery (women)

Most of the time men carry out the heavier tasks as digging foundation and breaking stones and the women fulfil the lighter tasks. When a lot of young men work outside the district, women have to carry out some heavier tasks.

At this stage, the mason is present at the site most of the days. He gives instructions and checks the quality and the quantities of the materials. The masons all have had basic training in building at various technical institutions. Many of them have also gained experience in water-resource development while working in Mutomo Division, southern Kitui. Further training in sand-storage dam construction took place under the supervision of David Kithuku, technical manager of SASOL.

When the community has collected enough materials and has dug the foundation trench, the actual construction of the dam can start. From this moment the mason leads the building process and urges the community that there are enough stones and mortar. The site committee remains responsible for the organisation and all tasks of the building process. The mason builds the dam together with the community, with a small power distance between mason and community, which encourages the team spirit and the co-operation.

4.2.4 Committee rules

One of the tasks of the site committee is to make legislation for the site organisation and for the use of the water when the dam has been finished. A copy of these rules is sent to:
1. The Chief of the location
2. The Sub-Chief of the location
3. The mason(s) of SASOL

The sub-chief of the location signs these rules when he has no objection about these rules. The sub-chief plays a major role in legitimising the rules the community makes.

The site committee keeps records of those who attend and fines those who are late or fail to appear.

1.	Punishment for using the water behind the dam, without building:	3000	Ksh.
2.	Punishment for stealing the water behind the dam:	3000	Ksh.
3.	Punishment if a member of the community is absents for work:	50	Ksh.
4.	Punishment if a member of the community is late:	10	Ksh.
5.	A man who is working out of town during the building and wants to use the water has to pay the committee:	250	Ksh.
6.	The final responsibility for the construction of the three dams is for the Sub-Chief and the two headmen of the villages		

Figure 4.1: Example of committee rules for Muteto Site

4.2.5 Building process records

Every working day the mason keeps up records of the building process on behalf of SASOL. He keeps up a SASOL record, a community record and a list of the members of the site committee and their tasks. The secretary of the site committee keeps a parallel independent record. The SASOL record consists of the following items:

1. Date
2. Cement received
3. Cement in store
4. Cement used
5. Total cement used
6. Cement balance
7. Work done by mason
8. Arrival time
9. Departure time
10. Problems

The community record consists of the following items:

1. Date
2. Number of men (who have worked that day)
3. Number of women (who have worked that day)
4. Total number of people (who have worked that day)
5. Work done by men
6. Work done by women
7. Arrival time
8. Departure time
9. Materials record

At the end of the construction SASOL knows how many working days have been spent and how many materials have been used to build the dam.

4.2.6 Supervision

The technical manager supervises the construction sites and the work of the masons every week. SASOL plans more dams near to each other, which makes this supervision easier and cheaper.

Once a month there is a staff meeting at which the mason reports on progress and gives an account of the materials used. Once a quarter there is a meeting of all masons to review progress and to discuss any problem that may have risen. At the end of the year in November (in December the masons are on holiday) the masons visit all the project sites as a group and evaluate each other’s work. In this way, they maintain a high standard and every mason who fails this standard is discharged.

4.3 Description realisation constructive design dams

4.3.1 General

The procedures for the design and construction of the sand-storage dams are variable. Each site is different and the design has to be modified accordingly. David Kithuku (Nickname ’British’), technical manager of SASOL, and the mason, who will build the dam, together make the design of the dam. The design is made on the basis of some rules of thumb. These rules are based on practical experience, information from congresses and the following literature:

- Nissen-Petersen, Erik - *Rain Catchment and Water Supply in Rural Africa: A Manual* - Hodder and Stoughton - 1982
- Nissen-Petersen, Erik; Lee, Dr. Michael - *Harvesting rainwater in semi-arid Africa, sub-surface and sand-storage dams* - Nairobi - 1990
- Nissen-Petersen, Erik - *Groundwater dams in sand-rivers, a manual on survey, design, construction and maintenance* - Nairobi - 1996
- Nissen-Petersen, Erik - *Affordable water, a series of manuals for designers and builders* - Kibwezi - 1999

SASOL's technical manager has worked together with Erik Nissen-Petersen from 1980 until 1991. Together they have built several dams in Kenya.

After completion a plan of the dam is drawn with all its dimensions.

In literature suggestions are sometimes made to build the dam in stages. The reason to build the dam in stages is that the reservoir can gradually fill up with sediment. Only coarse sediment will settle behind the dam because of the higher flowing velocities. Fine particles will just flow across the dam. The coarse sediments increase the storage possibility of the dam because coarse sediment has a higher porosity. Furthermore the abstraction of water from the reservoir is easier in case of coarse material. Nevertheless SASOL has chosen not to build the dam in stages, because it is very difficult to mobilise communities for the second time. Most dams that we have seen do not have problems concerning the sediment behind the dam. In general the sediment that has settled is coarse.

4.3.2 Length and crest level determination

The lowest bank of the river determines the final height of the crest of the dam. The level of the lowest bank is called the 'building line' of the dam. The crest level of the dam is the distance between the crest of the dam and the lowest point of the river bottom. The crest level of the dam depends on the height of the spillway above the river bottom (see section 4.3.5) and the gross freeboard of the spillway (distance between the crest of the dam and the top of the spillway).

Crest level dam =

height of spillway at lowest point above river bottom + gross freeboard

The length between the two points where the crest level of the dam intersects both banks becomes the final length of dam (see figure 4.2).

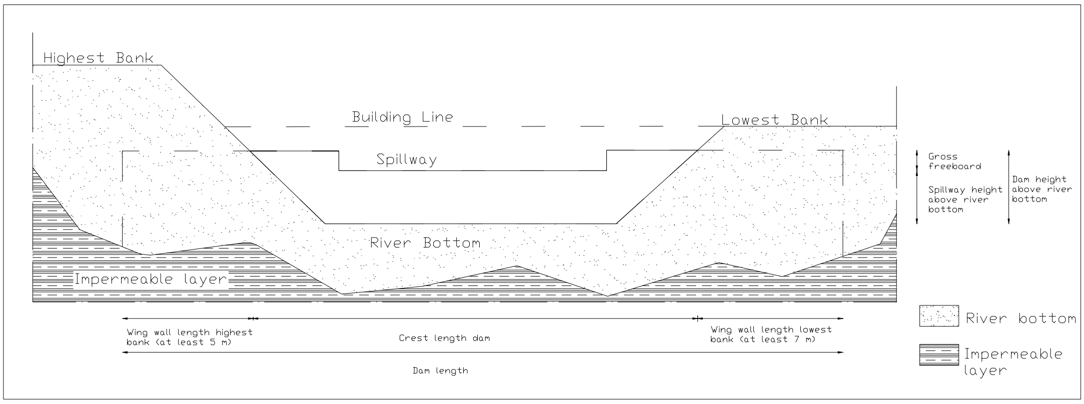


Figure 4.2: Final length of the dam between both banks

Where the riverbanks are flat or consist of bad soil, wing walls are added to the main dam to prevent the river cutting round during a flood. After finishing the dam the banks above the wing walls will be covered with soil. The wing wall on the highest bank is at least five meters long, and the wing wall on the lowest bank is at least seven metres long. The length of the wing walls depends on the kind of soil of the banks.

Crest length dam = length between the two points where the crest level of the dam intersects the banks
Wing walls length = at least 5 metres (if the banks do not consist of base rock)

In the rest of this chapter we consider the dams as if they only consist of a spillway and two wing walls at both sides of the spillway. In the next sections the length of the wing walls includes the distance between the real wing wall and the spillway.

Dam length = spillway length + length both wing walls

4.3.3 Foundation depth determination

The final foundation depth depends on the fact whether and on which level base rock, clay or murram (soil with small stones) is found. The base rock is the best foundation for the dam. Clay is the second best foundation. The clay in Kitui District is very compact and will not settle.

Foundation depth = depending on depth base rock, clay or murram

4.3.4 Width determination

The width of the dam depends on the size of the river. The width of the dam is determined according table 4.2.

Table 4.2:Width of the dam

		Spillway/dam			**Wings**	
Kind of river	**Width river bottom**	**Base width (m)**	**Width river bottom (m)**	**Top width (m)**	**Base width (m)**	**Top width (m)**
Small	< 5 m	2.0	1.0	0.75	0.60	0.60
Medium	5-10 m	2.0	1.0	0.75	0.60	0.60
Large	> 10 m	2.0	1.5	0.75	0.60	0.60

These dimensions arise out of practical experience. The upstream side of the spillway is straight and the downstream side is oblique. The downstream side is oblique, because of the stability of the dam (see figure 4.3). Both sides of the wing walls are straight.

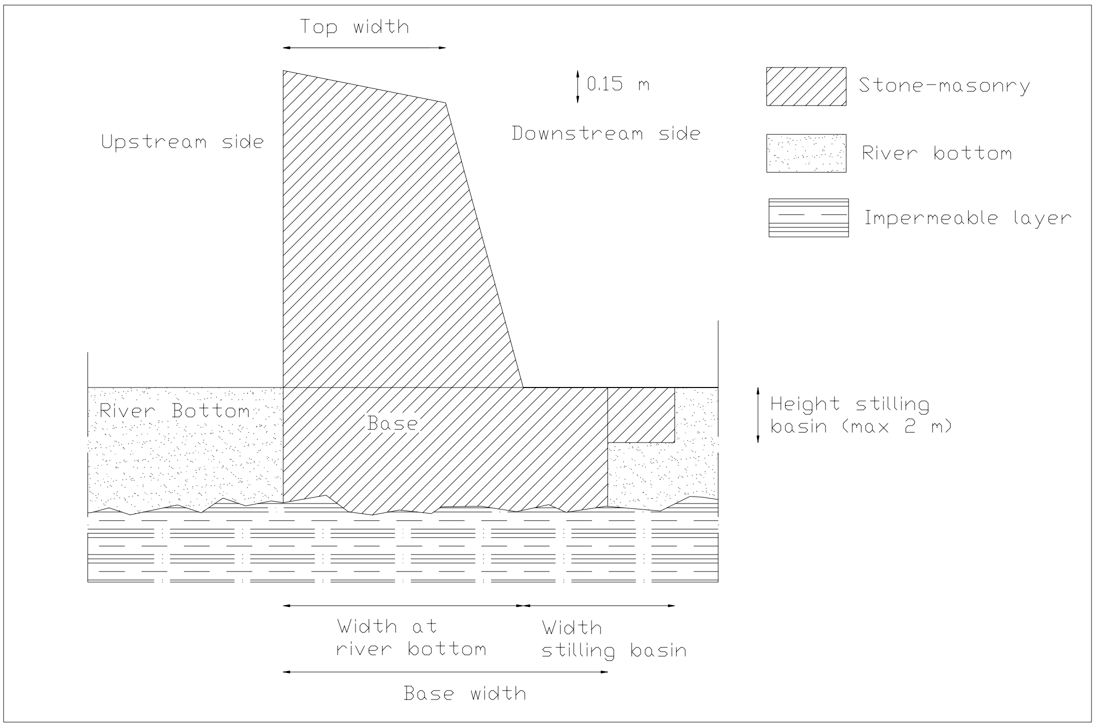


Figure 4.3: Cross-section spillway sand-storage dam

4.3.5 Spillway dimensions determination

Whether a dam is built with a spillway depends on the kind of river. When the river has a big discharge during the rainy season, a spillway is not applied at the dam. In SASOL's opinion it makes no sense to construct a spillway when a lot of water flows across the spillway and the dam.

At this moment SASOL builds two types of spillways:
1. A rectangle cross-section
2. A trapezium cross-section

The length of the spillway depends on the kind of river. The downstream length of the spillway is smaller than the upstream length. The length of the upstream side of the spillway is determined by the width of the river bottom minus two times a certain distance from the banks. The length of the downstream side of the spillway is determined with the width of the river bottom minus two times a certain distance from the banks minus two times 0.15 metres (½ ft). So the width of the spillway downstream is 0.3 metres (1 ft) smaller than upstream (see figure 4.4 and table 4.3). The reason for this is to direct the flow more to the centre of the river, thus preventing erosion of the downstream banks and the downstream side of the dam.

Table 4.3: Rectangle spillway dimensions

Kind of river	Width river bottom	Downstream spillway length	Upstream spillway length
Small	< 5 m	Width river bottom - 2 * 0.6 m (2 ft) - 2 * 0.15 m (0,5 ft)	Width river bottom - 2 * 0.6 m (2 ft)
Medium	5-10 m	Width river bottom - 2 * 0.6 m (2 ft) - 2 * 0.15 m (0,5 ft)	Width river bottom - 2 * 0.6 m (2 ft)
Large	> 10 m	Width river bottom - 2 * 2.0 m - 2 * 0.15 m (0,5 ft)	Width river bottom - 2 * 2.0 m

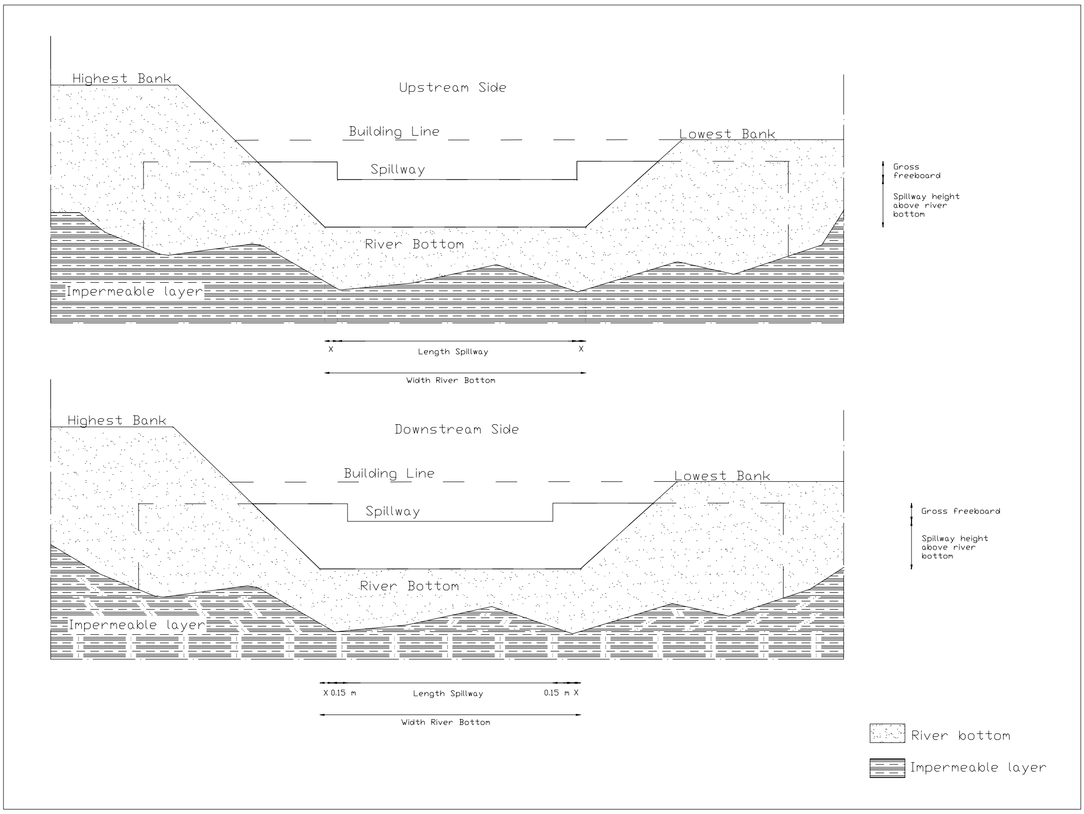


Figure 4.4: Rectangle spillway dimensions

For the spillway with a trapezium cross-section two lengths are important. One at the top level of the spillway and one at the crest level of the dam (see figure 4.5). The length of the spillway at the crest level of the dam is the same as the width of the river bottom. The length of the spillway at the top level of the spillway is determined by the width of the river bottom minus two times a certain distance from the banks (see table 4.4).

Table 4.4: Trapezium spillway dimensions

Kind of river	Width river Bottom	Spillway length at crest level dam	Spillway length at top level spillway
Small	0-5 m	Width river bottom	Width river bottom - 2 * 0.6 m (2 ft)
Medium	5-10 m	Width river bottom	Width river bottom - 2 * 0.6 m (2 ft)
Big	> 10 m	Width river bottom	Width river bottom - 2 * 2.0 m

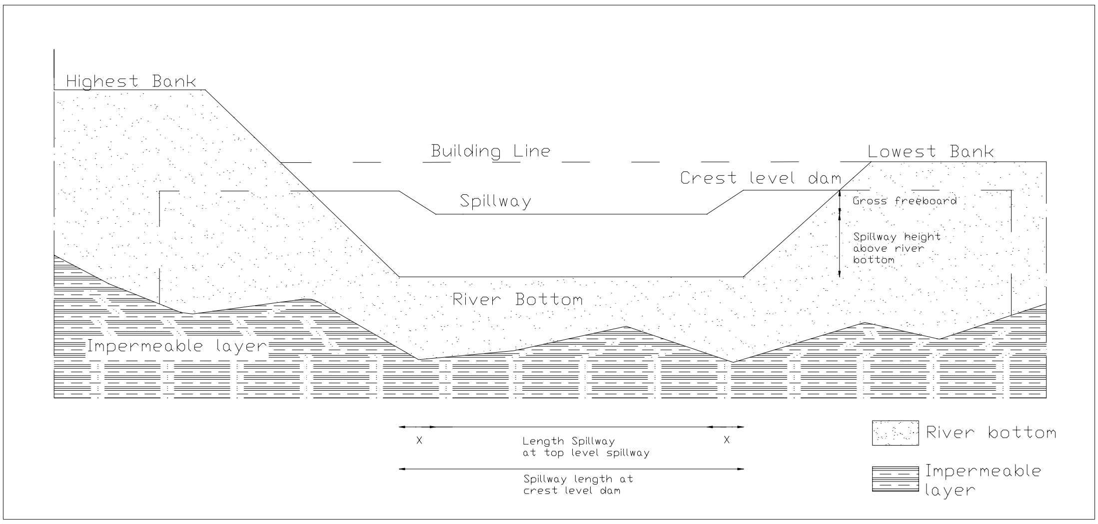


Figure 4.5: Trapezium spillway dimensions

The slopes of the trapezium cross-section are determined on the basis of the width of the river (see table 4.5).

Table 4.5: Slope of trapezium cross-section

Kind of river	Width river bottom	Slope of trapezium cross-section
Small	0-5 m	gross freeboard/0.6 m (2 ft)
Medium	5-10 m	gross freeboard/0.6 m (2 ft)
Big	> 10 m	gross freeboard/2.0 m

The gross freeboard (distance between the top of the spillway and the crest of the dam) depends on the width of the river, for both types of spillways. For all the dams SASOL is building at this moment, the gross freeboard is between 0.6 m (2 ft) and 0.75 m (2.5 ft). A general rule does not exist however. SASOL's technical manager estimates the average water level in the river during the rainy seasons and determines the final height of the gross freeboard.
When the discharge of the river is big in the rainy seasons the gross freeboard of the spillway will be high. A low discharge will result in a low gross freeboard.

The height of the spillway above the river bottom in the centre point (most of the time the lowest point) of the dam is determined by multiplying the distance between the river bottom and the building line (see section 4.3.2) with ¼ or ½ depending on the width of the river (see table 4.6). The height of the spillway is usually about 1.5 to 2 metres above the river bottom, but dams up to 4 metres have been constructed.

Table 4.6: Height of spillway above river bottom

Kind of river	River width	Height of spillway above river bottom in centre point
Small	0-5 m	½ * distance between river bottom and lowest bank
Medium	5-10 m	½ * distance between river bottom and lowest bank
Big	> 10 m	¼ * distance between river bottom and lowest bank

The downstream side of the spillway is 15 centimetres (6 inches) lower than the upstream side (see figure 4.3). Because of this the crest of the spillway gets a slope down to the downstream side. The slope will accelerate the water and this will prevent the water from eating the plaster layer at the downstream side of the spillway. Another reason for the slope is to prevent people walking over the spillway and damaging the dam (see section 4.3.2 and figures 4.4 and 4.5).

The choice of the kind of spillway rests on discretion of the technical manager. Both cross-sections satisfy. The masons prefer a trapezium cross-section, because they give less erosion.

4.3.6 Stilling basin design

The downstream part of the base of the spillway (width = 2 metres) serves partly as stilling basin too (see figure 4.3). The width of the stilling basin for all kind of rivers is about 2 metres (see table 4.7 and figure 4.3). The height of the stilling basin is at most 2 metres, depending on the foundation depth.

Table 4.7: Stilling basin dimensions

Kind of river	Spillway/dam Base width (m)	Width at river bottom (m)	Width stilling basin (m)
Small	2.0	1.0	2.0
Medium	2.0	1.0	2.0
Large	2.0	1.5	2.0

The first one metre of the stilling basin consists only of hardcore. The top of the stilling basin consists of hardcore with mortar.

4.3.7 Dam construction

The dam is constructed out of the following components:

1. Reinforcing columns

Reinforcing columns are placed at intervals of about 2-3 metres across the length of the dam (wing walls and spillway). The reinforcing columns consists of:

- 4 vertical round iron bars in the corners of the column
  Diameter: 12,5 millimetres (½ inch)
  Length: depending on height dam (foundation depth)
- Square bent iron bars (horizontal placed) every 0,45 metre (18 inches) - 0,6 metre (2 ft). This distance depends on the preferences of the mason for filling the wall with hardcore and the quantity available iron bars.
  Diameter: 6,3 millimetres (¼ inch)
  Length sides square at the base of the spillway: 0,75 m (30 inches) (depending on depth of dam)
  Length sides square at the base of the wing walls: 0,40 m (16 inches)
  Length sides square at the top of the spillway: 0,45 m (18 inches)
  Length sides square at the top of the wing walls: 0,40 m (16 inches)

The round iron bars of the columns are firmly grouted into holes of 5 centimetres deep (2 inches) that have been cut with a chisel into the foundation rock.

2. First mortar layer

A layer of cement sand mortar (1:3 mix) is spread on the foundation to a depth of 5 centimetres (2 inches). When there is no foundation rock the vertical iron bars are only placed in the mortar layer.

3. First horizontal reinforcement layer

After the mortar layer is spread 12 strands of barbed wire, evenly divided over the width of the wing walls and the spillway, are laid lengthways along it.

4. Second mortar layer

The wires are covered by a further 5 centimetres (2 inches) of mortar. The function of the barbed wire is to make the dam stronger.

5. Masonry comprising hardcore and mortar

Building proceeds in stages by constructing the wall faces to a height of about 1 metre and then filling the middle with masonry comprising clean hardcore (broken stone) and mortar (mostly 1:4 mix depending on quantity of clay in sand). The joints between the rocks are filled with about 25 millimetres of mortar (1:3 mix). The mortar for filling contains much more water to prevent seepage through the dam. The rocks are sometimes permeable. That is why the dam is not constructed with only masonry. The mortar will fill up the space between the stones.

6. Horizontal reinforcement layers.

After each 0.45 metre (18 inches)- 0,60 metre (2ft) stands of barbed wire, evenly divided over the width of the wing walls and the spillway, are laid lengthways as before. Number of stands of barbed wire reduces with two stands every layer, starting with 12 stands of barbed wire. The function of the barbed wire is to make the dam stronger.

7. Plaster layer.

The top of the dam is covered with a layer of plaster, around 1.5 centimetres thick, rounded at the downstream edge to prevent cavitation. The wall on the upper side is also plastered to ensure that the dam is watertight, and an extra thickness of plaster is laid at the foot of the wall on either side for the same purpose (only for rock foundation). The wall on the downstream side is plastered for only 15 centimetres (6 inches) below the top of the spillway and the wing walls (see figure 4.6). The plastering of the downstream side is only to make the dam look nice, but it has no function.

Figure 4.6: Plastering the dam

4.4 Financing

4.4.1 Total dam cost

The total cost of a dam depend on the following:

	Unit cost (1998):	Unit cost (2001)
Materials:		
Cement 50 kg	530 Ksh./bag	560 Ksh./bag
Barbed wire 25kg (16 g/m)	2,250 Ksh./roll	2,200 Ksh./roll
Round bars 12.5 mm (½ inch), 12 m (40 ft)	450 Ksh./piece	350 Ksh./piece
Round bars 6.25 mm (¼ inch), 12m (40 ft)	290 Ksh./piece	120 Ksh./piece
Cypress timber 2" x 2"	23 Ksh./metre	23 Ksh/metre
Nails 4"	70 Ksh./kg	60 Ksh./kg
Labour:		
Mason	5,000 Ksh./month	6,000 Ksh./month
Supervision and monitoring	30,000 Ksh./dam	30,000 Ksh./dam
Community organisation and mobilisation	40,000 Ksh./dam	40,000 Ksh./dam

Community contribution:		
Labour	100 Ksh./pp/day	100 Ksh./pp/day
Support mason	6,000 Ksh./dam	6,000 Ksh./dam

Sand-storage dam technology is relatively cheap. A typical sand-storage dam will cost around 230,000 Ksh. and retains about 2650 m^3 (unit prices 2001, see section 6.3). 165,000 Ksh. is used for materials and labour. The rest (65,000 Ksh.) is contributed by the community. Maintenance costs of sand-storage dams are quite low.

4.4.2 Costs sand-storage dam technology compared with other technologies

Water tanks are also a relatively cheap technology. However they are limited in size. A 45 m^3 tank in Kitui would cost Ksh 90,000 to construct (1999) [6].

Shallow wells and boreholes are both relatively expensive technologies. These solutions are not sustainable in ASALs, if not coupled with retentive measures like preservation of water catchment areas. Depletion of the aquifers shortens the lifetime of boreholes and wells.

Furthermore the cost of sinking a 30 m (100 ft) deep borehole in Kitui is approximately 700,000 (1999) [6] and it has a tendency to become saline with time.

A 15-20 m deep shallow well in Kitui would cost Ksh. 60,000 to construct (1999) [6]. There is little maintenance required for the shallow well when properly utilised. One has to ensure however that conservation on the upstream side is maintained to keep the well recharged.

Survey cost different technologies:

Water tank (45 m^3):	Ksh.	90,000
Shallow well (15 - 20 m):	Ksh.	60,000
Borehole (30 m):	Ksh.	700,000 + cost of pump and lining
Sand-storage dam (4000 m^3):	Ksh.	225,000

4.4.3 Financial contribution SASOL

SASOL finances:
- Cement, barbed wire, round bars, cypress timber and nails
- Equipment
- Mason
- Supervision and monitoring
- Community organisation and mobilisation (part of the training)
- Training

4.4.4 Financial contribution community

The community members are not paid. They provide sand, stones and water, which are difficult to value. The figure for labour is simply shown for the purpose of indicating the proportion of cost borne by the community. The time invested by the community in the organisation and training, which is essential for the sustainability of the project and future development is not valued in monetary units. The community finances housing and feeding of the mason and storage of the materials.

4.5 Materials and equipment

4.5.1 Materials

After the digging and measuring, the dam design is made. On the basis of the dimensions of the dam the technical manager estimates how many materials are needed to build the dam. It is not possible to determine the exact quantities of materials, since they depend on the quality of the sand for the mortal, the quality of the rocks, the skill of the mason and other facts like the community who builds the dam.

Materials used for setting are:
- Mortar (to fix wooden frames)
- Cypress timbers 2x2 (inches) (to make wooden frames)
- Nails 4” (inches) (to make wooden frames)

Materials used for building the dam are:
- Cement (for the mortar)
- Water (for the mortar, for cleaning stones and masonry and for wetting the masonry)
- Sand (for the mortar)
- Hard-core (for the masonry)
- Barbed wire (reinforcement)
- Round bars 12.5 mm (½ inch) and 6.25 mm (¼ inch) (reinforcement)

4.5.2 Supply materials

SASOL orders cement, barbed wire, round bars (½ inch and ¼ inch), cypress timber and nails at the nearest supplier in the area of the new dam. Because the project is run on fully participatory basis, the community picks the store where the materials are going to be kept. The supplier transports the materials to the building site. At the building site the community and the SASOL staff (mason) check the delivery and when the delivery is all right, the chairman signs the receipt of the driver for good delivery. This method ensures that the community creates a sense of ownership and creates an interest in protection of the received assets. Under these circumstances it is difficult to tamper with the supplies, as there is collective responsibility for the material. SASOL pays only directly to the supplier (cash) when they have got a receipt for the delivery signed by the chairman of the committee.

Since material delivered to a community is for a specific purpose, it cannot be diverted into any other use. Any residual material is transferred to the next site by local arrangement. The materials are brought to the new site following the same procedure as if it came from the supplier.

The system is designed to educate the communities to take responsibility of public goods. This should eliminate the highly destructive notion that the public goods are not theirs and can therefore be plundered.

4.5.3 Store issues

All material (cement, reinforcement bars, etceteras), that is delivered at the site, is received and stored by the community who is responsible for it. Normally stores are established at one of the community homesteads near the site. Sometimes the Sub-Chief of the location offers a part of his house to store the materials. One member of the site committee together with the owner of the store is responsible for all store issues. The community and the masons keep records of the materials used.

4.5.4 Equipment

For the construction of the dams the mason and the community use the following tools:

Tools used for digging and collecting materials are:
- Shovels (to dig)
- Mattock (to dig)
- Pinch bar (to make stones free)
- Sledgehammer (to break stones and rock into hardcore)
- Plates (Karais, basins to carry sand and mortar)
- Plastic (rice)bags (to carry stones)
- Oil barrow (to store water at the site)
- Little jugs (to abstract water)
- 20-litre barrels(to transport water to the site)
- Hack saw (to make steels for the mattocks)
- Wheelbarrow (not available at every site)

Tools used for setting are:
- Building line
- Spirit level
- Tape measure 2 metres
- Tape measure 50 metres
- Claw hammer
- Hand saw
- Building trowel

Mason tools:
- Cold chisels
- Dressing chisels
- Steel trowel (building trowel)
- Wooden float
- Mason square
- Steel square
- Building line
- Plumb bob
- Spirit level
- Lining level
- Claw hammer

SASOL has its own equipment and takes care for it. When a work is finished at one location, the equipment is taken to another location. When equipment is broken, SASOL arranges new equipment.

4.6 Planning

4.6.1 General

Planning is the task of the committee of the community. The mason only gives recommendations and incentives when he can not continue his work. Sometimes digging is not finished in time, there is a lack of stones or mortar etceteras.

4.6.2 Working days

The community usually works from Monday till Friday. The 17 masons do not work continuously at one site. At this moment SASOL operates at 30 new sites and 6 sites, which have not been finished last year. The masons work alternately on these dam sites. Officially working days start at 8 a.m. and finish at 5 p.m. In the afternoon there is a lunch break of about one hour. Because the mason is dependent on the community he works with, the construction can start, when the majority of the community has arrived. Most of the time the actual work starts at about 10 a.m. In the afternoon the work finishes when the pile of mortar has been finished. Sometimes this is earlier than 5 p.m., sometimes later. When the work finishes earlier than 5 p.m., it makes no sense to mix a new pile of mortar, because the most important materials (water, cement) have to come from far. Besides this the mixing of mortar takes a lot of time. It is important that the mason makes a good estimate of the quantity of mortar he will use that day

4.6.3 Execution order and duration

The time-schedule for the building process of the dam is stated below. The exact time-schedule depends on the dimensions of the dam, the ground characteristics, the community, the skill of the mason etceteras.

Table 4.8: Time-schedule building process

Activity	Duration
Talking with the (sub-)chief and the community	1 week
Selecting dam location	1 week
Selecting committee	1 week
Digging and making design	2-6 weeks
Collecting stones	4-6 weeks (depends on availability rock)
Construction (including collecting sand and water)	3-6 weeks

A well-organised community should be able to build a dam within one month. This is possible when there is a well organised community with a strong committee that plans the building process well and plans activities simultaneously. For example one group is building and filling one wing wall, while another group is digging the other wing wall and a third group is collecting stones. This is only possible when many people are available. Building this way will not be possible for all communities, because some of them are too small. For poor organised communities or small communities it can take up to 3 months to build a dam.

4.7 Construction

4.7.1 Marking

The mason places two pegs of 0.60 metre (two feet) at the end of the wing walls on each bank of the river. These four pegs form a rectangle. The length of the long sides of the rectangle is equivalent to the total length of the dam and the wing walls. The length of the short sides of the rectangle is 0.60 meters (see figure 4.7). At the place where the spillway is planned, the length of the short side is increased to 2.0 meters. The mason does not place new pegs to mark the spillway.

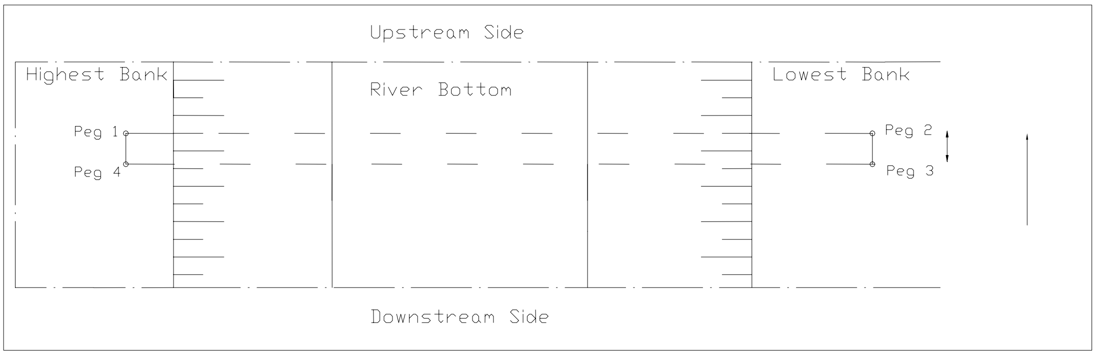


Figure 4.7: Marking a dam site

4.7.2 Digging

The community digs out the rectangle until clay or 'murram' (soil with stones) is reached. When none of these soils are found, the digging continues until a depth of 10 ft is reached.

The trench for the wing walls is dug first. An earth or a stone-cement wall prevents the foundation trench of the wing walls to prevent water flowing into the trench in the rainy season. After building the wing walls, the foundation in the river is dug out.

The time needed for digging the trench strongly depends on the kind of soil. In general the soils in the project area are pretty difficult to dig, but fortunately they have enough cohesion to make the trench walls straight.

4.7.3 Setting

When the foundation trench has been dug the wing walls and the base (see figure 4.8) of the dam are built with hardcore and mortar (see section 4.3.7). The base is the part of the dam under the river bottom.

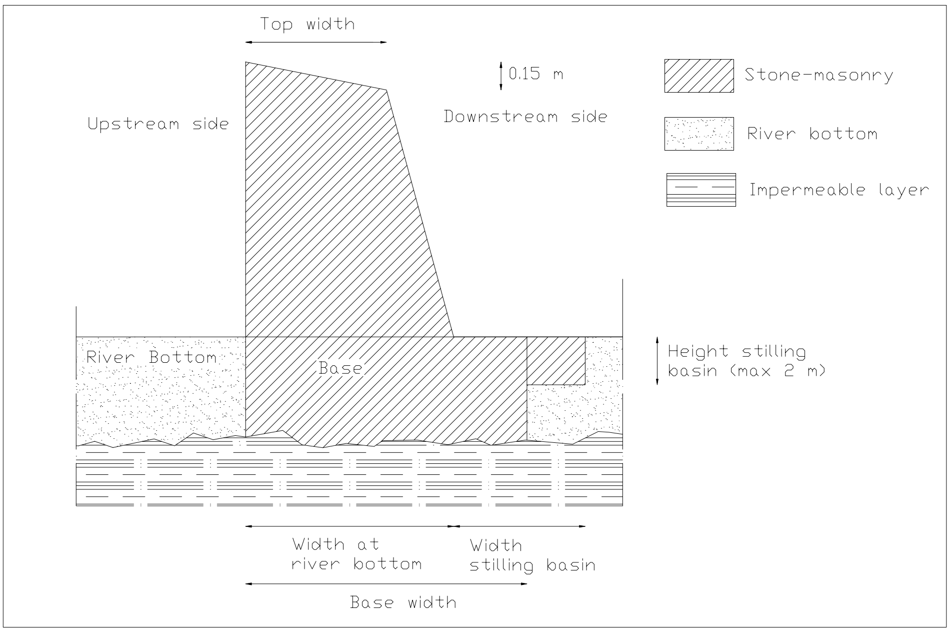


Figure 4.8: Base of the dam

After building the wing walls, the base and the stilling basin the mason sets two wooden frames, that mark the contours of the spillway, above the river bottom (see figure 4.8). The mason starts to tie a level line between the pegs, using a spirit level that mark the crest level at both banks of the dam to get the height of the timber for setting. The mason joints the timber with a base of 1.0 or 1.5 metres and a top width of 0.75 metres and takes it to the both marked edges of the spillway (see section 4.3.4). He supports it with hard-core and mortar (proportion 1 cement and 4 sand). When the walls are built, level lines between the frames give the right level and direction to build.

Figure 4.9: Setting wooden frames

4.7.4 Collecting materials

The most important material at the building site is water. It is used for many activities like mixing cement, cleaning and wetting the fresh masonry. Because a lot of water is needed, fetching enough water can become a bottleneck for the building process. Water is fetched at the main permanent river that can be located about 1 km to 7 km away from the building site. Generally women and children fetch water with donkeys. Each donkey carries 2 or 4 20 litre-barrels. Water is collected from scoop holes with a little jug. This makes fetching water a time-consuming activity. At the building site water is stored in an oil barrel.

Stones for the filling of the dam and construction of the walls are collected from big rock parts on the hills or from the riverbed. The stones are cut or broken off from the rocks in smaller rough parts. The mason shows the community how to break stones. Limestone is easy to break, but breaking harder stones is tough. After breaking, the stones are carried to the building site one by one. Often the site is near, but sometimes it can be up to 1 km away. The heavier stones are carried in plastic (rice-) bags. Occasionally bulls are used to drag the stones to the construction site.

Sand is collected in the river next to the building site. Ideally the sand is collected upstream, so that the riverbed downstream will not be damaged. This is not always possible, because of the quality of the sand. Generally the quality of the sand that is used for construction is poor. The riverbed contains a lot of clay, silt and humus. Often there is no other option to collect better sand in the surroundings. Importing sand from somewhere else is very expensive and therefore not attractive. The sand is brought to the mixing place with plates (Karais, basins to carry mortar, sand and things like that).

Cement, reinforcement bars, barbed wire and other small items are stored in a building near by the building site. Generally collecting materials costs a lot of time and manpower. The roads are steep and hard to walk. Vehicles are rare and cannot reach most places. The only relieve is to use donkeys. Every workday the community collects materials as much as needed for that day.

Firewood for cooking is collected by women.

4.7.5 Positioning reinforcing columns

The mason cuts iron bars of ½ inch according to the depth and folds ¼ inch round bars. He ties them with binding wires and takes them to their position. Reinforcing columns are placed at intervals of about 2-4 metres across the length of the dam (wing walls and spillway) (see for dimensions of the reinforcing columns section 4.3.7). Figure 4.10 shows reinforcement bars being placed in the construction.
The vertical round iron bars of ½ inch of the columns are firmly grouted into small holes of 5 centimetres deep (2 inches) that have been cut into the foundation rock with a chisel. When there is no foundation rock the vertical iron bars are placed in the first mortar layer.

Figure 4.10: Reinforcement columns

4.7.6 Foundation

The foundation is constructed with two mortar layers and a horizontal reinforcement layer. First a layer of cement sand mortar (1:3 mix) is spread on the foundation to a depth of 5 centimetres (2 inches). After that a horizontal reinforcement layer of 12 strands of barbed wire is laid lengthways, evenly divided over the width of the wing walls and the spillway (figure 4.11). This is also the first horizontal reinforcement layer. A second layer of 5 centimetres (2 inches) covers the reinforcement layer.

Figure 4.11: Horizontal reinforcement using barbed wire

4.7.7 Building dam

First of all the wing walls are constructed at both sides. This prevents water to leak in the foundation trench of the wing walls during the rainy season, but there is also a psychological advantage. People can see the gap in the dam become smaller and smaller and this will encourage them to finish construction. Finally the spillway is constructed.

The parts of the wing walls under the surface of the banks are built by filling the foundation trench with masonry comprising hardcore (broken stone) and mortar (mostly 1:4 mix depending on quantity of clay in sand). The mortar used for filling contains more water than the mortar for masonry. This is done to prevent seepage through the dam. Rocks can be permeable sometimes.

Building of the parts of the wing walls above the bank surface and the spillway proceeds in stages by constructing the wall to a height of about 1 metre and then filling the middle with masonry comprising hardcore and mortar. The mason builds a wall face at the upstream side first. After that he builds a wall face at the downstream side. The masonry comprises clean hardcore and mortar. The joints between the rocks are filled with about 25 millimetres of mortar (1:3 mix). At the level of the river bottom, a small hole is left open in the middle of the future spillway (in the middle of the river), so water can go through when it rains. This is done because the pressure at the masonry can become too high causing the new wall to collapse.

The space between both wall faces is filled with masonry comprising hardcore (broken stone) and mortar. This process of building in stages continues until the final height of the dam is reached.
After each 0.45 metre (18 inches)- 0.60 metre (2ft) horizontal reinforcement (made of barbed wire) is laid. The number of stands of barbed wire that is used per layer reduces with two stands every layer, starting with 10 stands of barbed wire.

The mason takes care of the masonry of the dam. The community takes care of supplying mortar and handing stones to the mason. The community mixes the cement at a mixing place (rock or work floor) near by the construction place. To make a work floor the mixing starts on the ground and after some time, the remaining mortar will form a work floor.

For the mixing process the number of sand plates that fill a bag of cement, is determined. The number of plates multiplied by three gives the number of plates that have to be mixed with one bag of cement. This method is not applied at every site. Most of the time the quantity of sand is roughly estimated on the pile. Before the start of construction, the mason shows the community how to mix the cement.

Figure 4.12: Mixing cement

The sand and the cement are mixed by shuffling and moving it from pile to pile two times. The water is added on top of the pile and the sand-cement mix is carefully mixed with water. If necessary, extra water is added. A line of people passes on the cement mixture on iron plates to the mason.

Building the upstream and downstream wall faces has to be done accurately. The hardcore for building the wall faces is cleaned and passed on to the mason. He makes the stones fit and places them. Filling the space between the walls can be done less accurately. The mason pours a lot of mortar together with the hardcore in the space between the two wall faces.

4.7.8 Finishing

After filling the dam with hardcore and mortar, grooves are made in the top mortar layer. These grooves form a rough surface on which can be plastered. Plastering the dam is the last part of the execution. The top and the upstream side of the dam are covered with a layer of plaster, (around 1.5 centimetres). This layer of plaster is applied to prevent seepage through the wall. An extra layer of plaster is laid at the foot of the wall on either side for the same purpose. The wall on the downstream side is plastered for only 15 centimetres (6 inches) below the top of the spillway and the wing walls (see figure 4.13).

Figure 4.13: Plastering the dam is the final part of construction

The mason wets the surface that has to be plastered. After that he applies dry cement on the wall. Then he puts on a layer of wet plaster (sand-cement mix) on the surface. After a few moments he puts on a second layer of wet cement and smoothes it.

4.7.9 Other activities

Cooking food

Food is arranged at the building site. One person is in charge of cooking food for all the workers. Every worker pays a sum for the food and brings his/her own plate and spoon. Lunch is served at around 2 p.m. till 3 p.m. and exists of beans and maize, called 'Muthikoi', a Kenyan dish.

Figure 4.14: Eating Muthikoi at the building site

Clearing the site

After a day of working, all equipment is cleaned and washed. Tools and remaining materials are returned to the storage. The mix-plate is cleaned, so that the plate remains smooth.
The dam in construction will be protected after work with a hedge of thorn-branches, so animals like goats, cows and donkeys cannot damage the dam. Water is pored on the masonry work every day to keep it wet. This prevents the masonry from drying too fast. The wetting of the dam continues for three weeks after completion of the dam.

4.8 Completion and inspection

During the building process the technical manager visits the building site several times to check the building progress. When the dam is finished the technical manager checks the dam and discusses possible faults or weak points with the mason.

Every November the technical manager and the masons evaluate the dams that have been made that year. They discuss the problems and adapt the guidelines for building the dams to their findings.

4.9 In use

4.9.1 Recommendations for committee

When the construction is finished, the mason and the technical manager talk with the committee and give them some recommendations:

1. Plant Napier-grass and associated plants at the up- and downstream riverbanks. Napier grasses and associated plants can survive throughout the year to protect the riverbanks. At the same time Napier-grass provides fodder for animals during the dry season.

2. Keep an eye on the dam, especially in the rain seasons.
3. Separate livestock watering areas and domestic water points.
4. Fence the reservoir or river (domestic water points) because of pollution by cattle.
5. Maintain the dam.
6. Build terraces to control run-off

It is the responsibility of the committee to fill in these recommendations.

4.9.2 Water abstraction

Usually water is abstracted from the sand-storage dams by using scoop-holes. Often a offtake well is constructed near the dam. This shallow well is said to give the best water quality, but people still tend to use scoop-holes to get water. Sometimes wells are polluted, due to dead animals or vegetation inside the well. Some attempts have been made to draw water from the dams by using an outlet pipe, but this system has failed many times. The tap was left open, broke down or the intake was blocked. Because of these failures SASOL does not apply this way of abstracting water from sand-storage dams.

Figure 4.15: Construction of an off take well nearby a sand-storage dam

SASOL rewards the best-organised community with an India Mark 2 water pump. The pump is known for it reliability. A total of about 25 pumps have been placed all ready.

4.9.3 Maintenance

When the dam is finished, the dam is under the responsibility of the community. If the dam is constructed well, there should be little or no maintenance. The dams are checked by SASOL every year and also after exceptional floods. Communities do not always report damage to SASOL. Sometimes, however they do, and a quick repair is possible.

4.9.4 Legal aspects

Most of the time the committee has made rules for using the water (see section 4.2.4). It is not a case of SASOL, because the dam belongs to the community.

4.9.5 Immediate impact

The sand-storage dams reduce the distance for fetching water to the households of ASAL communities. Women and children will gain maximum benefits because they are in charge of fetching water. In some areas time for fetching is shortened from about 12 hours in dry season to a maximum of 2 hours for those who live most distant from the river.
The greatest impact of the dams is therefore in the cost of water transport both in time, animals and equipment. SASOL estimates that 50 % of the population will use the facilities throughout the year, while in drought periods more than 100 % will make use of the water, as people from outside these areas will come to fetch water.

The main function of the dams is the retention of precipitation on the catchment where it is received. The direct consequence of this is that the groundwater level will rise both on the riverbeds and the adjacent land. Raised water table will mean that shallow wells have water nearer to the surface and scoop holes on sandy riverbeds are shallower.

4.9.6 Long term impact

When the dams are finished, people can begin using the water, irrigating the land, building terraces, etceteras. A raised water table will facilitate new colonising plants, which could not grow before. On the other hand some plants will die due to water logging.
Overall ground cover will improve and evapo-transpiration will increase. Increased ground cover will also reduce runoff and facilitate percolation.

As a consequence of terracing, water is held on higher grounds of the catchment for longer periods. The soil will remain humid for longer periods, facilitating a longer cropping period. Some of the water held in the higher grounds eventually recharges into the river channels. This phenomenon ensures adequate supply of water even in extended droughts.

In the long run the whole community gains because the land productivity improves. The sale of vegetables and farm products coupled with water related economic activities such as brick making improve income. There are some examples of places where community organisation is well developed, and communities start other projects, such as building schools, houses and hospitals. Sometimes even family planning is discussed.

4.9.7 General evaluation

When all dams in a project area are finished there will be an evaluation by SASOL, the donor and the different communities. Every project area has only one donor (see 2.3.1).
The evaluation is an important criterion for the donor to decide to continue financing the projects of SASOL. The evaluation deals with the impacts and effects of the sand-storage dams on the communities and the environment.

5. Practical work: Evaluation building process dams

In chapter 4 the description of the building process of the dams has been given. In this chapter the evaluation of this same building process is given. First the preparations SASOL undertakes before starting construction are evaluated. In section 5.2 the organisation at the building site is reflected. Section 5.3 evaluates the guidelines that are used by SASOL to design and build the dams. The financing of the dams is discussed in section 5.4. The materials, equipment and planning needed for building the dams are brought up in respectively section 5.5 and 5.6. In section 5.7 an evaluation of all construction of the dams from the beginning to the end is given. This chapter ends with the sections ‘completion and inspection’ (section 5.8) and ‘in use’ (section 5.9).

5.1 Preparations

Legal aspects
The whole project of building dams is made possible by the fact that building on seasonal rivers is legal without permission. Agreements with the landowners at both sides of the river where the dam is built, should be drawn up carefully and completely, so that it is guaranteed that the community always can use the water behind the dam. Strict rules have to be made about ownership of the dams (selling the land, the dam is built on or death of the landowner who has signed the agreements with SASOL and the community). We recommend to let the (sub-) chief of the (sub) location sign these agreements too. By doing this discussions about ownership and water use are not possible anymore, in the future. In contrast to the Netherlands a building licence is not required for building something on your own property. This makes the building process much easier.

Authorities
Keeping the authorities involved in the development work that SASOL does, is important. Not only because of the legal aspects, but also because of possible support and co-operation. In the area we worked in, the sub-chief offered a part of his house to store materials. He visited the dams in his sub-location several times and motivated the people. In our opinion this makes sense, because he has more power than SASOL in the sub-location. We think this a very good example how authorities and communities can work together to improve their circumstances.

Community request
As long as the community requests for the dams, there is need for dams and the activities of SASOL can continue. The fact that SASOL cannot handle the requests proves that their approach is working. The request of the community is important because of the motivation of the community. In this way, co-operation from the local community is assured and the chance that the project will work increases. When the request to build a dam comes from the community, they are motivated already. In the field we have seen that motivation influences the construction time, the quality of the dam, etceteras. Motivation is the most important input to let the project succeed (see also section 5.2).

SASOL requirements
By the demands on the local community, SASOL is assured that almost all the money that is put into the project is used effectively. This becomes more and more important, because SASOL gets more requests than they can handle at this moment. Their demands could be stricter and they could help the best-motivated communities only.

Community location choice and final location choice
Location choice on technical grounds is done on the basis of a field trip, a very simple and cheap investigation method. Because dam technology is low-tech, low budget and the location choice depends on community preconditions, the field trip seems to be more suitable than systematic studies that are expensive and time-consuming. More extensive investigation methods, as test drillings were done in the past to find foundation rocks, but they were unreliable, because they stranded prematurely on rocks or hard soils

Community training
Community training will improve organisation skills. The use of water behind the dam can also be optimised by training communities. SASOL could pay more attention to the construction of the dams during the training. For example: explaining how to mix mortar, the importance of using clean hardcore and sand and how to save time with a good organisation. Also the results of not doing so, have to be explained.

5.2 Organisation

Site committee composition
It is a good matter that women are involved in the building process and sometimes even direct this process. So construction does not become a male affair, as it is in the Netherlands.

Site committee tasks
The site committee has a lot of different tasks and responsibilities. It is important that the tasks are divided between all committee members. This makes the organisation run better, because a few members do not have to arrange everything. Intensive communication between the members is required to do the committee work. Continuity is a weak point in volunteer work, also at these site committees. Taking over the tasks of a quitting member is hard. Assigning two persons can solve this problem, as they can help and complement each other.

Site organisation
The efficiency of the site organisation depends on the community and their committee. Community members do not show too much initiative. It is important the committee takes its responsibilities and motivates the other members of the community. Because this is not always the case, SASOL should emphasise this at the training of the committee members.

The community is not paid so it is important to keep them motivated. A good progress is important. Letting the site committee organise the building process is good and has its own advantages according to us.
First the committee has good contact with the rest of the community members (the workers), they know what the specialities of the committee members are and can divide the work and tasks better than a mason can. Second advantage is that they learn to organise themselves and learn through experience how to organise efficient.

Nevertheless more intervention of the mason by guiding the committee in their organisation tasks can make the building process more efficient and will show the committee how to organise well. This can accelerate the learning process. At this moment the mason only gives indications about the construction and not about the organisation.

When the committee has good organisation skills, the building process can be very efficient. If not, the work process can be very inefficient, because many people will do nothing.

Committee rules
For organising and motivating the local community, it is positive that the committee makes rules about presence during construction and using the stored water behind the dam after completion. By confirming these rules by the (sub-) chief, the rules become legal and accordingly effective.

Building process records
It is very good to record the building process, not only by the masons or SASOL but also by the committee. If there are records, things can be traced and the process can be evaluated, so that future organised work can improve by learning from the past. Furthermore recording is a basic organisation skill that can put the organisation on a higher level and it involves the community in the building process.

For the evaluation of the building process, records of the dams should contain the same items. To make the process of recording easier, it is possible to give all the record books the same contents and layout. The items that have to be recorded by the masons can be determined by SASOL, so that recording the building process becomes a standard procedure in the organisation system. The information can be used in spreadsheet programs very easy, when the information is uniform.
SASOL can give a helping hand in organising skills by giving some standard layout and contents for the recordings in the community training.

Supervision
An optimal system has been set up for the supervision of the masons and guarantees the quality of the mason's work. If a mason fails, he can be charge for it. Especially the yearly visits to the dams, made in the preceding months work out very well for the quality of the dams. The Technical Manager and his masons evaluate the dams they have made and on the basis of that they adapt the design and the guidelines.

In the case of the workers from the community it is hard to charge them for their part. They are not paid for their work and there is no boss. The committee rules give some relieve in a situation a worker does not show up or is late. Only the committee can pressure the other members of the community to do something. The relations in a community and between the committee and the community can affect the functioning of the whole community during the building process a lot. This is a general problem in community work. It is important to have strong community members in the committees.

5.3 Evaluation realisation constructive design dams

General
The way of designing the dams and the scientific background use for the design is good, but there is no proper documentation of the guidelines and the design of the dams. For us it was difficult to fix the complete design and the guidelines. By interviewing the field manager, the technical manager, different masons and visiting the different sites, which SASOL was building, we have succeeded. By documenting the design and the building guidelines it becomes possible for staff members, employees of SASOL and outsiders to find the right information and to work with it. To keep this information up to date, SASOL has to adapt their changes in the design and the guidelines in this documentation. Especially the changes they make every year during the evaluation of all the dams, have to be adapted.

Length and crest level determination
SASOL has problems determining the height of the spillway above the river bottom and the height of the gross freeboard. Because the crest level of the dam is determined by these two dimensions (crest level dam = height of spillway in lowest point above river bottom + gross

freeboard), SASOL can also not determine the crest level of the dam adequately. The height of the spillway above the river bottom and the gross freeboard do depend on the width of the river and the quantity of water flowing through it during the rainy season. So the crest level depends solely on the dimensions of the spillway and not on the quantity of water SASOL wants to store behind the dam (height of the reservoir). Of course SASOL wants to maximise this quantity, but therefore SASOL needs guidelines to determine the dimensions of the spillway more precisely. After that the crest level of the dam can be determined more precisely too. SASOL knows that the river needs enough space, otherwise the flow will go over the banks when there is a large discharge. At this moment SASOL uses a guideline that is based on practical experience (trial and error). This guideline does not always work efficiently. The relations between spillway dimensions, height of the spillway above the river bottom, crest level of the dam and the height of the reservoir behind the dam will be considered closer in our project report. We will try to give a more scientific approach to determine these parameters.

After some problems in the past with water flowing round the dams, the length of the wing walls is extended. The present design length seems to be long enough to prevent water flowing around.

Determination foundation depth
After some problems in the past SASOL determines the final foundation depth on the fact at which level base rock, clay or murram is found. This is done both for the spillway and the wing walls. In our opinion this is a good way of determining the foundation depth of the dam, because of the following three reasons:
1. Good base to found
2. Preventing seepage
3. Preventing piping

When founded on rock, the foundation trench is dug until the rock. To prevent seepage, it is sensible to cut a groove along the length of the dam and make the rock-base rough enough for a good connection with the mortar and the rest of the dam, especially when the rock base is not deep. In case of permeable rock, the dam should be built against the rock to prevent seepage through the rock-base. The rock-base will also support the dam, so the width of the dam can eventually be adapted.

Width determination
The width of the dam is based on practical experience. The materials used have a wide variation in strength (see section 5.5) and the construction is not very strict. The minimal possible width of the dam depends on these facts. This makes it difficult to say something about the width. At first the width of the dams is right, because of the quality of the hardcore, the mortar and the way of building. The width base of 2.0 meters seems to be very wide for us. Nevertheless the weakest point is the connection between the base and the spillway at the river bottom level. In our project report, a closer look will be taken at the width of the spillway for different heights above the river bottom. We will also look to the sense of the oblique downstream side of the spillway, because this complicates the masonry.

The minimal width of the wing walls is determined by construction. Because of this the minimal width of the wing walls is 0.60 metre. Making the wing walls thicker makes no sense because the wing walls only have to change the direction of the water and the wing walls have no constructional function. Making the wing walls thinner is not possible, because the workers can not dig the foundation trench adequately. Other possibilities for the wing walls will be considered in our project report.

Spillway dimensions determination
The dimension of the spillway is a weak point in the design, which is also indicated by SASOL. SASOL finds it difficult to find a good way to determine these dimensions and want to know more about it. Recommendation about these dimensions shall be worked out in our project report (see also "length and crest level dam determination").

Design stilling basin
The length of the stilling basin is 2.0 meters and the same for all kind of rivers. According to us this is too short for large rivers. It is likely that the water will cause erosion immediately after the stilling basin. In our project report we will give some recommendations about the needed length of the stilling basin and the kind materials that are suitable for it.

Dam construction
The anchoring of the reinforcement bars could be deeper, especially when the dam is founded on rock, that is located at a very short distance beneath or at the original river bottom level. In that case the dam is not clamped into the river bottom. Critical point is the connection between rock base and dam. A deeper anchoring of the reinforcement into the rock base increases the strength of the connection.

The reinforcement columns in the spillway are useful for the spillways. According to us the reinforcement columns in the wing walls are not useful, because the wing walls are clamped in the bottom. Besides this rough iron bars for the reinforcement columns are better, but these may be more expensive or not available. Rough iron bars form a better connection with the mortar then the smooth bars SASOL uses at this moment.

The barbed wire that SASOL uses as horizontal reinforcement is not useful in our opinion. It does give the construction some more coherence and has a physical effect for the communities, but it is too weak to have sense in a constructive way. We will look closer to these points in our project report in combination with the width and the height of the dam.

SASOL has also asked us to give some recommendations about other materials that can be used for the dams. We will do this in our project report too.

5.4 Financing

SASOL supports the community with knowledge and materials for the dam. The communities take care for the labour, the storage of the materials and the housing and living costs for the mason.

This partition of finance has some advantages:
- The cost of every dam is minimised for SASOL.
- Community takes care of things, which they can arrange easier, than SASOL can.
- It involves the community in the building process.
- When they do nothing, they also waste their own time and money. It gives a kind of motivation to work more efficient.
- It is a kind of compensation for the fact the community wants a dam. The community has to do something by themselves (according to us, this is very good).

SASOL contribution mainly consists of cost that do not depend on the execution speed, except the wages of the mason. The contribution of the community depends on the execution speed, which will encourage the community to build faster. Good mobilisation (and organisation) of the community has to keep an important point, so that the mason costs will not rise too high.

5.5 Materials and equipment

Materials
The quality and strength of the materials have a wide variation and this has to be kept in mind, making the design and the guidelines. An estimate of the strength of the dam can not be made without knowledge about the quality of materials.

Using hardcore and mortar in combination with some reinforcement seems to be a good and cheap way for the sand-storage dams, when:
- The constructions are relative small.
- Construction failures (through weak materials) have no big consequences downstream (torrents).
- Labour is cheap.
- Hardcore, sand and water are available in the surroundings of the dam.

The SASOL dams satisfy at these points. Searching to other constructions and materials may be needed, when SASOL moves to other project areas or bigger dams (see also section 5.3 “Dam construction”).

The sand used is sediment from the riverbed, next to the construction site. The rivers are seasonal and the sediment therefore has a wide gradation, with mostly silt, clay or organic materials. Mortar made with this sand is less strong. Getting better sand from elsewhere is very expensive, but the quality of sand can also be improved by filtering the sediment. A rough filter will remove the most serious pollution as pieces of clay and organic materials. Filtering will ask for more work, but will improve the quality of the mortar.

The quality of the stones varies from very hard stones to limestone. Limestone is common in Kitui and is easy to break and permeable. The best way is to look for impermeable and harder hardcore near by the site, this may not always be available, but it improves the quality. Often the stones for filling the dam are not cleaned. When the stones are clean, the rough surfaces have a better coherence with the mortar.

The used iron bars are smooth. This makes that the iron bars have less coherence with the mortar (see also section 5.3 “Dam construction”).

Store issues
The stock management is well organised. There is a good administration, which is checked by different persons. Giving the materials to the community and make it their responsibility encourages social control and makes it hard to commit fraud. Nevertheless, a good supervision is needed. Several masons have been fired in the past, because they used SASOL's cement for other work, which was the cause of too little supervision of SASOL's management.

The storage places are generally not very far from the building site (about 500 metre). Storing the materials in a homestead of one of the community members seems to be a good choice, because it makes it easier to control and secures the materials.

Equipment
Equipment is simple and easy to use. Most people know how to use them, because they use it for agriculture and building houses. Some tasks as breaking stones and digging the foundation trench are very hard. Using improved technologies to dig and break stones would speed up the work, but they are more expensive and ask for more craftsmanship. Because the low wages, better equipment is not cost-effective and it reduces the community involvement, because more craftsmen are needed.

Sometimes not enough equipment is available at the sites. In these cases the communities could not work efficient, because they had to wait for each other. At some sites the committees indicated this as a problem. A possibility is that the members of the community use their own equipment. The reason for not doing this, is probably that when equipment breaks they have to repair it at their own cost. It is important SASOL takes care for enough equipment at the different sites.

5.6 Planning

Working days
The Kenyan culture is not strict about being on time. Especially for work that is not to paid it is hard to motivate people to be strict on time. People who are on time cannot start the work and waste their time by waiting for others. People are discouraged to be on time. The better the organisation of the community (see also section 5.2), the fewer people are too late.

Execution order and duration
It is important that the activities that can be done without a mason are done before the mason comes. Collecting stones and sand and digging the trenches. When the mason comes, he can start immediately with building the wall faces and filling the dam. Nowadays the mason often wastes his time by waiting for the community.
This is very inefficient because the mason cannot work continuously. SASOL could employ one person who keeps an eye on the digging process and the collection of stones at different sites. He can also teach the communities how to break the stones and how to dig.

The duration of the execution depends on the level of organisation of the community. If the community is well organised, work can be planned tight and divided in tasks. Members of the community have to be responsible for their own instructed task to be carried out.

5.7 Execution

General
The building of the dam is very labour-intensive. Most tasks call for little craftsmanship. This enables the community to build the dam with only one mason.

The quality of the final result mainly depends on the work of the mason. The mason is the only person with building expertise. The mason should give recommendations about the mortar and hardcore and should supervise the quality of the construction. It is therefore important that SASOL maintains a high standard of the work of the masons.

Collecting materials
Collecting the stones and sand before starting the building process makes that the building process can proceed, without hinderance through shortage of these materials (see section 5.6). Collecting cement and water are time consuming activities during the construction. Water is one of the critical points, because it is fetched at the beginning of every working day and the people, who fetch the water, start at the same time as the rest of the community. The other people have to wait until these materials are collected and this makes that the construction usually starts at 10-11 a.m. We recommend that the groups that collect water and cement start earlier.

Mixing mortar
One of the things that is done badly at the sites is the mixing of the mortar. First of all, most of the time, there is no clean flat mixing place. A rock floor is recommended, but a mixing place can also be made with some cement and water. A good flat mixing place prevents the mortar from other materials.

Secondly, the estimation of the quantity of sand that has to be mixed with the cement is very rough. We recommend determining the exact quantity of sand by using plates or buckets. SASOL advises this too, but on many sites these guidelines are not followed. On these sites the quantities are roughly estimated on the size of the sand pile. The proportion cement/sand is therefore not accurate. It is the task of the mason to check this process.

Finally, the sand and the cement are not mixed very well. Sometimes the pile is only moved twice (one time dry and one time wet). This results in bad mortar. It is better to mix the mortar two times dry and after that two times wet.

The mortar for filling the dam contains more water then the mortar for building, so it can fill up all the spaces between the hardcore, but it is often too watery. The community members have not the skills to check the right proportions. It is therefore the task of the mason to check this proportion and to give comments to the community.

It is important that the mason makes a good estimate of the needed quantity of cement at the beginning of the day, so the working day can be fully utilised. Sometimes the construction ends at 3:30 p.m., because the mortar has been finished. Mixing new mortar makes no sense, because it takes too long to collect cement and water for the mortar.

5.8 Completion and inspection

The fact that the community builds their own dam makes the completion difficult. In general, the client who gives an assignment checks the construction at the completion and gives closer assignments or accepts the work. In the case of building these sand-storage dams, the community should check their own job during the completion. But because they do not have the knowledge to do this and they are not independent, the technical manager of SASOL inspects the dam after finishing. The technical manager, who cannot be totally neutral, checks the work of his own masons. There is not an independent person from outside the organisation to inspect the construction.

Appointing an independent person to do the inspection will be a better base to improve the whole building process, but it is very difficult and too expensive to realise.

So it is important that the technical manager stays neutral and is open to faults in his own design. Clearly this is the case with SASOL, because of the many adaptations of the design during the last five years.
The technical manager arranges monthly meetings with the mason. During these meetings problems that have arisen the past month are discussed. The quality level of the execution and the construction is guaranteed well.

5.9 In use

Recommendations for committee
The recommendations to the committee by the mason and the technical manager do not have a broad follow up. Most of the recommendations are essential for a good functioning of the water storage and the water supply by the dam.
Especially the tasks directly related to the dam, like planting Napier-grass at the most important places close to the dam, could be done by SASOL. More important is to emphasise the importance of the recommendations during the training.

Water abstraction
Because fences do not protect the water basins in general, cattle can walk on the basin surface and drink water from scoop-holes. Part of this problem is that the rivers are often main roads for cattle and that donkeys are used for transporting the water. Because the domestic and livestock water points are badly separated, the water-quality is affected especially when the water is harvested from scoop-holes in the reservoir. It is important to protect the reservoirs.

When there is a well, the water-quality is better, because the sand filters the water. Some wells are not used, because people think it is not hygienic that all people use their own buckets. This makes it that the well is only used in the very dry seasons. Another problem with the well is that they become polluted, because the well lit is removed.

Maintenance
Generally the dams only wear out a little bit at the spillway and this wear has not asked for maintenance up till now. A few years ago, during heavy rains, the water passed along some dams, because they had too short wing walls. Some of these dams have been repaired by extending the dam, but a few dams kept damaged, because SASOL could not mobilise the communities again. They have very less confidence in the quality and the utility of the dam. This shows that it is important that the dam requires little to no maintenance and that it is built well at once, because it is difficult to mobilise the community for a second time.

Impact
Although the sand-storage dams bring al lot of benefits, ASAL communities should cash in maximally on the opportunities that the dams offer to improve their life standard. To live the same way as before building the dam is a waste of the possibilities the dams can offer. With more water available, communities can undertake new activities to enlarge their economic capacity and their physical conditions.

We recommend showing the communities some good examples of good working and well-organised communities. Let them see how they have succeeded and how they have improved their life by terracing, increasing crops etceteras. When you show them, preferably with pictures or drawings, it has a bigger impact on them. People are afraid to change their life. SASOL plays an important role to convince the communities in this.

General evaluation
The evaluation of the project by the donor is eminent. The donor decides after the evaluation if the sand-storage dams have obtained their objectives or not. This evaluation is unprejudiced and is done by an outsider, so a good sign for SASOL if they reach their targets (see also section 5.8).

6. Practical work: Comparisons data 50 dams

In this chapter data of the 50 dams we have visited during the first two weeks of our project period are compared on several aspects. Statistic data, correlation and relations of and between the different dams, are determined. In section 6.1 general information is given about the input of the data in a spreadsheet, the assumptions and points of departure. In section 6.2 comparisons with workforce, duration and execution speed are made. The comparisons with material use and costs are described in section 6.3 and the comparisons with the reservoir volume in section 6.4. This chapter ends with conclusions and recommendations of the comparisons and the relation between the different aspects.

6.1 General

The input of the data in the spreadsheet concerns the duration of construction, workforce, used materials, and dimensions of the dam and the reservoir. On one dam, built in the colonial period, no useful data could be found. The documentation of some dams, built in the earlier years of SASOL, is not as detailed as it is now. This blank data is replaced by data collected during our visits of the dams.

For the comparison of the costs, prices for the material and labour are derived from year 1998 and year 2001 (see section 4.4.1). These prices have changed slightly in past years. The documentation of the evaluated dams can be found in Appendix 3. Besides this data, also some statistical calculations (average, extreme values and variance) of the dams are presented in Appendix 3. An overview is shown in table 6.2.

Table 6.1: Statistical calculations of input data

	length	length wing		length spillway			width		heigth	average height
	overall	left	right	base	left	right	base	top	spillway	
	m	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*
Average	28,3	5,7	6,7	11,1	2,6	2,3	1,05	0,83	0,58	1,96
Median	27,0	6,0	6,1	6,6	2,1	2,0	1,00	0,75	0,56	1,86
Minimum value	10,0	0,0	0,0	1,5	0,0	0,0	0,75	0,60	0,00	0,46
Maximum value	52,0	19,0	24,8	52,0	20,0	8,1	2,00	1,50	2,02	4,64
Variance	99,1	18,1	33,4	102,9	9,7	3,6	0,05	0,03	0,24	1,00
Standard Deviation	10,0	4,3	5,8	10,1	3,1	1,9	0,23	0,16	0,49	1,00
Standard Deviation/Average	35%	75%	86%	91%	119%	84%	22%	20%	86%	51%

	duration	work force				materials
		men	women	artisans	total	cement
	workdays	*human workday*	*human workday*	*human workday*	*human workday*	*bag (50 kg)*
Average	46	252	346	50	634	134,8
Median	36	209	259	36	503	121
Minimum value	8	21	0	8	0	25
Maximum value	162	1074	1123	192	2014	374
Variance	1128	36242	68203	1310	190079	4743
Standard Deviation	34	190	261	36	436	69
Standard Deviation/Average	73%	76%	75%	73%	69%	51%

	volume of dam	reservoir	cost 2001	cost 1998
		volume	total	total
	m3	*m3*	*Ksh*	*Ksh*
Average	53,1	2658	156.476	151.281
Median	41	642	134.775	130.700
Minimum value	5	58	42.110	41.280
Maximum value	188	24500	431.400	414.360
Variance	1370	25197648	7.012.783.694	6.487.253.341
Standard Deviation	37	5020	83.742	80.543
Standard Deviation/Average	70%	189%	54%	53%

The dam volume, the reservoir volume and the costs of the dam can be calculated, using the input data. The formulas that are used for these calculations are enclosed in Appendix 4. With these results the different aspects can be related. Statistical calculations about the spread of the data and correlation between different data have been made. The relations, correlation between different data and the costs of the evaluated dams can be found in Appendix 5. Note that the given costs do not represent the real costs of the dams. By means of unit prices for materials and labour, the cost of the dam is determined in 1998 and 2001. Because the data about used materials and labour is known, it is possible to compare the different dams.

The dam volume is a good unit of measurement to compare with the labour, the used materials and the estimated reservoir volume. Only looking at the dam volume, some aspects are not taken into account, like the accessibility of the site, the foundation and many other things. Since these matters are very difficult to quantify, we have still chosen to calculate the dam volume and use this as a basis for the comparison between the 50 dams.

In the next sections the comparisons of the main aspects and findings will be discussed.

6.2 Comparison with workforce, duration and execution speed

First some statistical information about the number of male and female workers and masons is given for the 50 different sites. After that, comparisons with workforce, duration and execution speed are made, see table 6.2.

Table 6.2: Comparisons with workforce, duration and execution speed

	workforce					working days
	men/total	women/total	artisan/total	total/days	workforce	execution speed
	%	%	%	workmen/day	workmen/m3	days/m3
Average	40,4%	51,2%	8,4%	16,7	15,2	1,0
Median	41%	52%	7%	15	12	0,9
Minimum value	7%	0%	2%	4	2	0,3
Maximum value	89%	81%	26%	54	52	4,7
Variance	3%	3%	0,2%	86	95	0,5
Standard Deviation	16%	17%	5%	9	10	0,7
Standard Deviation/Average	40%	32%	56%	55%	64%	68%
Correlation	0,60	0,60	0,73	0,76	0,66	0,62
Covariance	29195	5803	11142	10749	10362	766

There are slightly more female workers than male workers, as SASOL claims. The masons fill in almost 10 percent of the total number of working days of the dam. The female workers fill in 50 percent and the male workers fill in 40 percent of the total number of working days. These percentages can differ considerably.

The average number of labour needed for a cubic metre dam is about 15 persons. This amount depends on the work efficiency and the level of community organisation. The average number of construction days needed for a cubic metre dam is 1 day. This amount also depends on the community. Note that the characteristics of the site and the distance of material supply also affect the work efficiency. The average number of labour a day at a building site is almost 16 persons. This amount is different every day, because the building process demands a different amount of persons every day.

6.3 Comparisons for material uses and costs

In this section comparisons with the material use and costs are made, see table 6.3.

Table 6.3: Comparison material use and costs

	materials	cost comparison 2001	cost comparison 1998
	cement use	cost/volume	cost/volume
	bags/m3	*Ksh/m3*	*Ksh/m3*
Average	3,1	3.668	3.545
Median	2,9	3.206	3.137
Minimum value	1,1	1.093	1.056
Maximum value	8,2	9.154	8.974
Variance	2,4	3.390.757	3.140.659
Standard Deviation	1,5	1.841	1.772
Standard Deviation/Average	49%	50%	50%
Correlation	0,65	0,70	0,70
Covariance	1636	2140437	2066546

Only the relation between the amount of used cement and the dam volume is considered, because cement is the most important cost item of all used materials. The cost of cement is around 90 % of the total material costs.

The average use of cement per cubic metre dam is 150 kg (3 bags). The differences can be explained by the fact that cement is not only used to fill up the dam but also for plastering the dam, for a possibly drift, stilling basin or erosion protection. The ratios between the aggregates and cement can also vary per dam.

Since the prices for materials and labour have increased from 1998 to 2001, the cost of the total dam has also increased (average 3 percent). To compare the cost of the dams we have related a cubic metre dam and the cost of it. In 2001 over 3,600 Ksh. was paid per cubic metre dam and in 1998 3,500 Ksh. A note has to be made about this calculation. If the information about the used materials was not available, no cost could be applied to those materials. Only the cement use and labour are available for all dams that SASOL has built. Besides this, a few extreme long dams (length of more than 40 m) influence the average cost of the dams notably.

Although this disruptions in the calculations, the correlation between volume of the dam and the cost is quite strong. Using the average materials use and labour and the average volume of the dam, the direct cost per cubic metre dam can be determined quite exact. For 2001 this is 2,850 Ksh. per cubic metre dam. The average direct costs of a dam are around 151,000 Ksh. The direct costs include all material cost, labour cost of the mason and the community. The indirect costs are around 76,000 Ksh. The indirect costs include the cost of the community organisation and mobilisation, the cost of supervision and monitoring and the cost of support of the mason. The average community contribution is 65,000 Ksh. and the average contribution of SASOL is 165,000 Ksh. The average total cost of the dams is 230,000 Ksh.

6.4 Comparisons with reservoir volume

The comparisons with the reservoir volume are reflected in table 6.4.

Table 6.4: Comparisons reservoir volume

	reservoir	cost comparison 2001	cost comparison 1998
	efficiency	cost/reservoir capacity	cost/reservoir capacity
	m3/m3	*Ksh/m3*	*Ksh/m3*
Average	59,9	325	315
Median	15,8	231	224
Minimum value	1,5	3	3
Maximum value	470,8	1.656	1.593
Variance	9702,1	121.650	114.059
Standard Deviation	98,5	349	338
Standard Deviation/Average	164%	107%	107%
Correlation	0,38	0,24	0,23
Covariance	69537	97741887	92761914

Referring to appendix 5 of the calculation of the reservoir behind the sand-storage dam, it can be concluded that the estimate of the reservoir is inaccurate. So the comparisons with the volume of the reservoir are also inaccurate. Nevertheless, we have made some comparisons with the reservoir volume, because the volume of stored water determines the efficiency of the dams.

First of all, we searched for a relation between the dimensions of the dam and the reservoir volume. The ratio between the dam volume and the reservoir volume is 60 cubic metre water storage per cubic metre dam. Unfortunately, the correlation of this ratio is very weak and the variance is high. These two aspects cannot be related.

After that, a relation between the cost of the dam and the volume of the water storage has been searched. One cubic metre of water storage costs approximately 325 Ksh. Also this correlation is very weak and the variance is high. Dams in width, big rivers with a long throwback can store much water with slightly more cost than an average dam. On the other hand, dams in small, narrow rivers with a low crest height have a smaller storage than average, while the cost of the dam is not dropping down that hard. This explains the huge difference between cost per cubic metre stored water per dam.

6.5 Conclusions and recommendations

Although the difference between the dams is notable and the calculations have some disruption, relations between the dams can be made. The strongest relation that can be found is the relation between the cost of the dam and the volume of the dam. The correlation between these two aspects is 0.7. For the future, multiplying the dam volume with the direct costs per cubic metre dam can give an estimate for the direct costs of a dam. The direct costs do not include the cost of community organisation and mobilisation, the cost of supervision and monitoring and the cost of support of the mason.

$$\text{Estimated direct costs dam} = \text{Dam volume} \cdot \text{Direct cost per cubic metre dam}$$

For 2001, the cost per cubic metre dam is 2,850 Ksh. When the prices will change, the direct cost per cubic metre dam can be calculated by multiplying the average quantity of used materials and labour with the actual prices and then divide it by the average volume of the dam. The formula is:

$$\text{Direct cost per cubic metre dam} = \frac{\sum(\text{Average working days quantity} \cdot \text{labour costs}) + \sum(\text{Average quantity of used materials} \cdot \text{material costs})}{\text{Average dam volume}}$$

The cost per cubic metre dam can also be calculated using the workforce and the cement needed for a cubic metre dam. This is even a better estimate, because the correlation between the workforce and used cement with the volume of the dam is strong. The formula is:

$$\text{Direct costs per cubic metre dam} = W \cdot \frac{A}{100} \cdot Pa + W \cdot \frac{L}{100} \cdot Pl + \frac{M}{C/100} \cdot Pc$$

W	=	Working days per cubic metre dam
M	=	Cement used per cubic metre dam
A	=	Percentage artisans of the total workforce (8 % in 2001)
L	=	Percentage labour of the total workforce (92 % in 2001)
C	=	Percentage cement of the total material cost (90 % in 2001)
Pa	=	Mason cost
Pl	=	Labour cost
Pc	=	Cement price

The other relations between the aspects are less strong, but can be used for rough calculations to give some impressions about the characteristics of the dam. Most relations have a standard deviation round 50 % of the average amount and a correlation above 0.6.

The relation between the cost of the dam and the volume of the stored water in the reservoir is very weak, but we can use the range of the direct cost per cubic metre stored water to compare this water storage system with other systems. The range of the direct cost of a cubic metre stored water for a sand-storage dam in 2001 is 1,000 Ksh. for a small narrow river and less than 100 Ksh. for a big, width river.

In fact the costs for sand-storage dams are lower because the reservoir will also be recharged after every rainy season by groundwater flow from higher located areas. So the reservoir gives more water during the year then the quantity of water storage in the reservoir during the rainy seasons. Anyway this quantity is reduced by evaporation and seepage to other areas (groundwater flows). The upstream banks and land near by the dam are also storage for water, when they do not consist of rock or clay. Although the estimate of the reservoir volume is rough, the range of the cost of the stored water is quite secure.

The direct cost of a rainwater-storage tank is approximately 2,000 Ksh. per cubic metre stored water. Compared with this the sand-dam is much cheaper, making it a better alternative. From the studied data we can conclude that using sand-storage dams is an efficient method to collect and store water. Benefits are higher as the river is bigger and wider.

7. Impressions Practical Work

In this chapter the expectation and outcome of our practical work is described in section 7.1. Critical reflections are given in section 7.2. In section 7.3 our personal view and conclusions about our own functioning are discussed. This chapter ends with recommendations to the sub-faculty of Civil Engineering.

7.1 Expectation and outcome

Before going to work in a country one does not know at all, there are some expectations, questions and mysteries about the country, the culture, the work and the organisation at the site. Some differences between expectation and outcome are presented in this section as well as differences between the Netherlands, Kenya and Nepal. Because two of us have been in Nepal to build a bridge, last year, we think it is interesting to compare these two developing countries.

Working in a developing country:

- Building together with communities.
  We built dams together with communities. We had expected a tough working day. Although working days were short most of the time, the hot and humid climate made it tiring. It was striking to see that the community did not work efficiently at all. People sat down most of the time and were chatting and not working too much.
- Simple techniques.
  The techniques used in Kenya are very simple most of the time. People are inventive in finding solutions for building or repairing things. Sometimes we were surprised to see briars serve as a fence. Worn tires are used to make sandals etceteras.
- More labour.
  Because of the absence of equipment, most of the work had to be carried out by hand. We had not expected to see bulldozers and so on, but there is really nothing at the construction site that is carried out mechanically. Reason for this is the low cost of labour.
- Primitive circumstances.
  Before we left to Mangina we dreaded the period of fieldwork because of the primitive circumstances we thought we were going to face. But when we arrived at our residence, we found beds, a kitchen and somebody to prepare our meals. So the circumstances were not so bad after all.
- Different problems.
  Problems we faced in Kenya are different of the problems in the Netherlands. For example: The death of a community member will stop the construction of a dam for a whole day.
- Different solutions.
  The different solutions that are used are mentioned under simple techniques. The solutions that are used often are ad-hoc solutions to a problem. When something breaks down in the Netherlands, the broken part is replaced and thrown away. In Kenya almost everything is recycled.
- Different materials.
  The materials that are used during construction depend to a large extent on the availability. Buying materials is almost never feasible. In Delft University we have learned to construct economically. Economically has got a different meaning: Just construct with materials that are available locally and free.

- Different setting.
  Off course almost everything is different working in Kenya. The most striking differences were: work is not very structured, the work tempo is low, the climate is totally different, work with people who have had no education, language problems, low-tech.
- Mean something to local communities.
  Before we came to Kenya we thought we could really mean something to the local communities. Looking back on the past practical work period, the influence we could exert was limited. Just building together with the community is not very helpful to them. What might help the communities, in an indirect way, is the evaluation of the design and construction process. This will eventually help the local communities.
- Language.
  Our assumption was that most people in Kenya speak English, because English is the official language of Kenya. In Mangina we found out that only few people speak English very well. Most people know a little English, but the mother tongue in most parts of Kitui is Kikamba, a language we didn't know at all. This made communication difficult. Fortunately SASOL staff and masons speak English.

Difference between working in Kenya and Nepal.

The climate in Nepal was of great influence on the work tempo, in Kenya this influence is less (as far as we could see). The people who worked at the construction of the bridge were paid, while the SASOL communities are not paid for the work they do. This resulted in higher productivity and reliability of the labour force in Nepal. When somebody did not show up in Nepal, just another person could be hired. In Nepal two of us were in charge of the construction process, while in Kenya the masons together with the dam committees are in charge. In Kenya it was more difficult to exert an influence on the construction process and the design. Transport was more complicated in the mountains of Nepal than in Kitui (we cannot speak for other parts of Kenya)

Organisation:

- Encouraging local community.
  We wondered how it would be to encourage communities to build dams. During the practical work period we did not really have opportunities to do so. We have visited sites where construction already had started or was to begin. This people had already been mobilised to build dams and improve their own situation. To really encourage people one has to be able to communicate with the communities very well. In fact SASOL even has its own community mobiliser. Furthermore SASOL has no problems finding locations and communities to build the dams. More people apply for a dam per year than SASOL can build. SASOL's philosophy is not really to encourage the people themselves; SASOL only provides the materials and knowledge to build the dams. The community has to organise itself and benefit from this.
- Community based organisation.
  We were very curious to find out how and if a community based organisation would work. We have seen some examples of communities that were very well organised. On the other hand some communities have a very poor organisation, such that construction takes a very long time. Before we went to Kitui we have also visited some dams in Utooni. We saw a classic example of how communities can be organised. SASOL faces a challenge to reach this level of organisation.

- Site organisation.
  We had no expectations about the site organisation. The site organisation we have seen during the practical work period was different from place to place. Sometimes we found it difficult not to interfere in the construction process. For example: In one place a community wanted to build three dams. When the first dam was about to finish, there was only work available for about ten people. That day about forty people came to work, ten were working, the rest was just sitting around, while there were two other sites that had to be dug out. In the Netherlands we are used to use labour as efficiently as possible. The mason, who has a lot of experience with building dams, encouraged the committee to start with the other sites, but this advice was not taken.
- Working hours. We had expected long working days, but the working hours were about the same as in the Netherlands or sometimes even shorter.

Culture:

- Difference between Dutch and Kenyan culture.
  Time is for free (African time); people are communally tied together, while Dutch people are more individualistic. Ties between community members are strong, as well as family ties. People tend to be less organised and live day by day. People are more fatalistic and do not try very hard to improve their own situation. Religion takes an important place in Kenyan culture. Women are emancipated just like in the Netherlands, although the tasks of men and women are strictly separated.
- Learn more about Kenyan culture.
  We had expected to get to know more about Kenyan culture. We think we have succeeded in this. Because we lived very close to the people of Mangina and worked together with the communities, we were able to integrate to some extent. One will always be a foreigner, but we think we came as close to the people of Kitui as we could get.

Difference between Nepalese and Kenyan culture.

In Nepal religion takes a more important place in society. As well as in Kenya family ties are very important, also because of the absence of a social security system. Education in Kenya is better than in Nepal, more people can attend primary and secondary school. People in Nepal are more open to foreigners than people in Kenya. Women are more equal to men in Kenya than in Nepal, in Kenya women even hold leading positions.

7.2 Critical reflections

On the construction site we could not do much more than just making observations and helping the community with digging, carrying stones and passing through plates with cement. We tried to make the best of it by interviewing masons and trying to understand the philosophy of the design. To be able to see as many dams as possible we bought bicycles and visited most of the dams that were under construction. Nevertheless the fieldwork was not what we had expected.

In our project proposal we stated that we would try to make changes in the design during construction. This appeared not to be possible at all. At the site, the mason is responsible for the construction of the dam and the communication with the community. SASOL's approach is community based, this means that the community has to find out for itself when the efficiency is low. In the Netherlands we have learned to work as efficiently as possible. 'Time is money' we say in Holland. It was difficult to remain motivated, during long, inactive days of construction.

Even the mason does not involve himself in the construction process all the time. He only gives the community recommendations and gives some indications when his duties stagnate. Although it was frustrating for us to see people doing nothing, not working adequately and wasting a lot of time only because of a bad organisation, we still think it is one of the best methods to organise and mobilise the communities.

We have seen that by letting the local community play a role in solving their own problems the community is encouraged to build up their own organisation. At some sites we have heard heated discussions about the work. Some communities organised evaluation discussions at the end of day.

We have concluded that the only thing that might help the communities, in an indirect way, is the evaluation of the design and construction process. If weak points are approved and some recommendations are adopted, the process as a whole can become more efficient, this will eventually help SASOL and the local communities. This became our main objective during our practical work.

7.3 Personal view and conclusions own functioning

7.3.1 P.B. Beimers

I found the past period of practical work very interesting and useful for my development as a civil engineer and as a person. My mainspring to go to Kenya was to see how it would be like to live and work in a developing country. I liked the working and living, but there are some cons. The work we have done was very practical. In the future I would like to be involved in projects where planning plays a more important role. Of course SASOL plans its activities but the projects are small scale and during the practical work we have not been involved in planning.
I thought it would be easier to integrate in the community than it turned out to be. We remained 'British' all the time. I found it very interesting to learn about the African way of living and culture and I think I have also changed as a person. Things, like water, communication and electricity that are very normal to me in the Netherlands, are not so obvious in Kenya.

After all, I think we did a good job in the field although the communities will only benefit from our work in a very indirect way. Carrying stones is not exactly what we have learned at TU Delft, but I regard this practical work as successful, because the results can really be used in the project.

7.3.2 A.J. van Eijk

The practical work period in Kitui District, Kenya, has been very interesting for me, especially because I have done practical work in Nepal last year. It was possible to compare the way of building with communities in two different developing countries to each other. It is nice to see that, people without a technical background and little or no education, learn to construct. During the work the people learn to make mortar, break stones and they see how the mason builds the dam. The mason will tell them what to do. In Kenya it is the mason who teaches the people these things in Nepal we did this ourselves. It is satisfying for me to see people learn to make mortar and things like that and make progress during the construction.

For me it would be nice to teach the people how to build, but this is the task of the mason. We had no other medium than our report, where we could give some recommendations and suggestions about the building process. Disadvantage of this was that there was a distance between the workers and myself than in Nepal. In Nepal we built together with the workers (derived from the local community) and learned from each other. We taught them how to make mortar, concrete, iron frames etceteras and they taught us how to remove a big tree out of the river, how to plaster, how to make scaffolds with limited resources. Because of that we got a better relation with the local community. I hoped this would be the same during our practical work in Kenya, but unfortunately this was not the case.

The practical work in Nepal, the construction and design of a bridge, was a bigger challenge for me. I could be more creative and could give practical solutions for problems that arose during the building of the bridge. The most important thing I have learnt is that I need challenges in my future job.

No matter how the practical work in Kenya has been a success. I have seen how people live and build constructions in a non-western society in Africa, which was my mainspring to go to Kenya. Apart from the impact that the practical work had on me as a civil engineer it had the greatest impact on my self-development. Finally it was very nice to get to know the Kenyan culture and people.

7.3.3 K.S. Lam

My practical work for SASOL in Kenya was quite fascinating. There were a lot of good things about my stay in this African country. I am interested in learning about other cultures, climates, life-styles, approaches and knowledge especially in developing countries, because the differences with the well-developed Netherlands are immense. People work with restricted resources, materials and equipment. Often they have little education and not the technical knowledge we have. Most people have a low standard of living, so struggle for life is their main duty. Their solutions for the problems are so obvious that we, from the developed West, can even hit on the idea.
I already have some experience with developing countries. Especially my last year experience when I did practical work in Nepal has been very useful. In Nepal we designed a bridge and built it afterwards with the local community. This enables me to compare the two practical works.
First, in Nepal I had to do and think the easy way to design and construct a total bridge. Our task in Kenya was, to document and evaluate the construction process of SASOL's sand-storage dams. Other people did the execution and thinking. It was the difference between being an active or a passive actor. Being an active actor was more exciting, challenging and joyful.
Secondly, at both practical works I worked for a development organisation. Doing a job for a real client, especially a non-profit organisation, and working on a real project, still challenges me more than making exercises at the university.
Finally, both in Nepal and Kenya I have done work for the local community. Work that makes the lives of the people a little bit less hard. The local people are grateful for our job and happy we help them and teach them things as they have also taught me a lot. This pleases me. The community in Nepal profited in a direct way by building a bridge for them. Our work in Kenya does not have that direct impact. Still I am glad my work can eventually help the local community.

This practical work was arranged to collect data for another project. I think that we have done a good job. Not only for the university, but I hope our work can be used by SASOL too. The documentation and evaluation of the dams can be useful to put their organisation on a higher level.

With all things there are also some less good things, like our work at the building site. I grew up in a western society where speed is a must, so it was hard for me not to intervene and to sit down and see them work their own way.
The execution was simple and the work we could do was also quite simple, like passing

materials. The job we did was not senseless, but it is not as scientific as it would be on many other practical works. Since in developing countries this simplicity is the key to the solution, we had no choice.
Yet I am sure that I have learned a lot at my practical work in Kenya not only on technical field but also as a person.

7.3.4 B. Roos

For a long time I have been interested in working in developing countries. This practical work period gave me the opportunity to experience how it is to work and live in a developing country. I have enjoyed the stay in Kenya, but I have noticed that this kind of small-scale projects is too practical for me. I am interested in work that is more theoretical.
It was nice to stay and work with the local people, but integration with the local community was more difficult than I had expected. There are many differences in culture, their and our experience, humour, etceteras, which would make it difficult for me to stay in a developing country for a longer time.

I have experienced how it is to live in the countryside of Kenya. It really increased my understanding of the way they live, their culture and their problems. These are things, one can read about, but seeing it from nearby gives a good understanding of their situation.
One of the most interesting points of SASOL was the bottom up approach; working together with communities, using simple techniques and using materials that can be found in the surrounding. All very simple and small-scale, but it works and it enables the community to improve their lives.
After all, it was a pleasant, interesting and very instructive period, as well for my study as for my personal development.

7.4 Recommendations sub-faculty Civil Engineering

The combination of practical work and project seems to be very successful. Although the project is not finished yet we expect that the loads of information we have gathered during this period of practical work period will be very useful during the project. Without the practical work period we would not have known as much about SASOL, sand-storage dams, construction and design as we do now. This knowledge will eventually help us to make better recommendations for the design. During an 'ordinary' project abroad, shortage of time is a problem most of the time. By combining project and practical work time can be used more efficiently.

We recommend the combination of project and practical work when the practical work can give useful information or practical information for the project.

Another possibility could be to give the students, who do a project in a foreign country, the opportunity to increase the number of weeks required for the project from six weeks to eight or ten weeks, depending on the kind of project. In these two or four extra weeks the students can become more familiar with the subject matter and more research or fieldwork can be done. The fieldwork can give a lot of interesting information, so that the outcome of the project can improve for both the students and the counterpart. It seems to be reasonable to reward these extra weeks of work (more 'studiepunten'), like it is the case with practical work right now.

8. Final conclusions and recommendations

After six weeks of working at our practical work project, we have seen the execution of many dams built by SASOL. We have collected and documented much data about SASOL, the design and execution of sand-storage dams. The design and the execution of the dam have also been evaluated. Although the fieldwork had his dispirited moments, both the office work and fieldwork gave us a lot of useful information.

We can conclude the execution method is very suitable for community-based building. No heavy equipment is necessary, the materials used are common and available everywhere, the technique is quite simple and technical advice can be gained from the mason. The fact that the work is labour intensive, forces the community to organise the labour and the building site properly and efficiently to prevent waste of time and manpower.
About the execution of the dams we recommend SASOL not only to take care of the building, but also to take care of all the tasks that involve the functionality of the dams directly, like planting Napier-grass at the banks near by the dam. This lack of implementing those tasks can have a major effect on the functionality of the dam and can cause erosion nearby the dam.

SASOL has improved the design of the dam in recent years. A dam that is constructed the right way can have a life span of many years and little maintenance will be needed. Although the actual design has proved his functionality, some aspects of the design of the sand-storage dam are not optimal or not based scientifically. Especially the spillway is a weak point in the design of the dam. Since wrong dimensions of the spillway can cause major erosion around the dam, optimisation of the spillway is necessary.
The same comment can be given on the stilling basin. In combination with the spillway, these parts of the dam should prevent the erosion of the soil in the surroundings of the dam.
A third point of comment can be made on the width of the dam in relation to the height of the dam. All dams have the same width; high dams as well as low dams. This can be optimised by varying the width of the dam with the height of the dam. Doing so, will reduce the cost of the dam.
The last comment on the design concerns the use of barbed wire and reinforcements bars in the dam. The way these materials are placed in the construction has practically no effect on the strength of the dam. The use of reinforcement bars and barbed wire can be optimised by reducing or relocating these materials. This can save costs.
All this comments about the design will be worked out in the project report of CF599. In that report recommendations about these aspects of the dams will be made. For the outcome of our investigation of the design of sand-storage dams built by SASOL, we refer to our project report.

Though the evaluation on the technical field is our main focus, we want to make some comments about the organisation of this sand-storage dam project.
First of all, we want to make a comment about the organisation of SASOL. SASOL is well organised and the structure is clear. Small overhead organisations have to deal with a shortage of manpower. In case of SASOL, the documentation is often present, but it is not always even structured or complete. This makes it hard to find the right information. This information becomes important when SASOL wants to co-operate, exchange knowledge or provide information to other organisations that also want to tackle the water problem in ASALs. If SASOL wants to be an example of how the water problem can be tackled in ASALs, the documentation has to be complete, structured and proper.

Another point of interest is the organisation of the community. The success of the sand-storage dam projects depends on the way the community is organised. The impact or effects of the dam depend on the way the community uses the dam and what kind of investments is made. SASOL has to encourage the community to organise and provide them with knowledge on both technical as organisation field.
For example how to benefits from cropping and agriculture? On organisational field: how to plan, how to use time and money on the efficient way, how to control the quality or how to set up a sharp organisation? It is SASOL's target to get communities organised and let them take care of their own problems. In that way, we think that providing knowledge and encouraging communities are the major activities of SASOL. Building a dam to solve their water problem is a good exercise.

Finally we want to make some comments about the organisation of our practical work. This practical work is combined with a project. In our case the combination has had a lot of benefits. In this practical work we have collected data and gained experience on the execution of sand-storage dams for our project.
We gladly recommend our faculty to let the possibility of combining practical work and project exist in case the practical work can provide useful data or practical experience can be gained about the subject.
Since the practical work is there to gain useful data and experience for execution of the project, the supervision is very important. The group has to prove itself by gaining the needed data and experience, otherwise the following project makes no sense, especially the combination of project and practical work in a foreign country with a foreign counterpart. The supervision has to be arranged properly from the university as well as from the counterpart. In our case both university and counterpart have arranged well-experienced supervision. We are sure that this has been to the advantage of our practical work.

LITERATURE REFERENCES

Literature

1. Isika, M.; Muyanga, M., Sahelian Solutions Foundation - *The Story of Sand Dams in Kitui District* - Delft - 2000

2. Isika, M.; Muyanga, M. - *From rhetoric to practice: gender participation in the fight for survival* - Delft - 2000

3. Muthoka, Sam; Mutiso, Prof. C.G.M. - *SASOL dams: Social and economic impact study* - Nairobi - 2000

4. Mutiso, S.M. - *PRA training* -SASOL Foundation - Kitui - 1997

5. Office of the vice-president and ministry of planning and national development - *Kitui District Development Plan 1997 - 2001* - Nairobi

6. SASOL (Sahelian Solutions Foundation) - *Kitui water retention sand dams, a three year proposal for the United Kingdom Department of International Development* - Nairobi - 1999

7. SASOL (Sahelian Solutions Foundation) and Maji na Ufanisi (Water and Development), Thomas, Donald B. - *Where there is no water, A story of community water development and sand dams in Kitui District, Kenya* - Nairobi - 1999

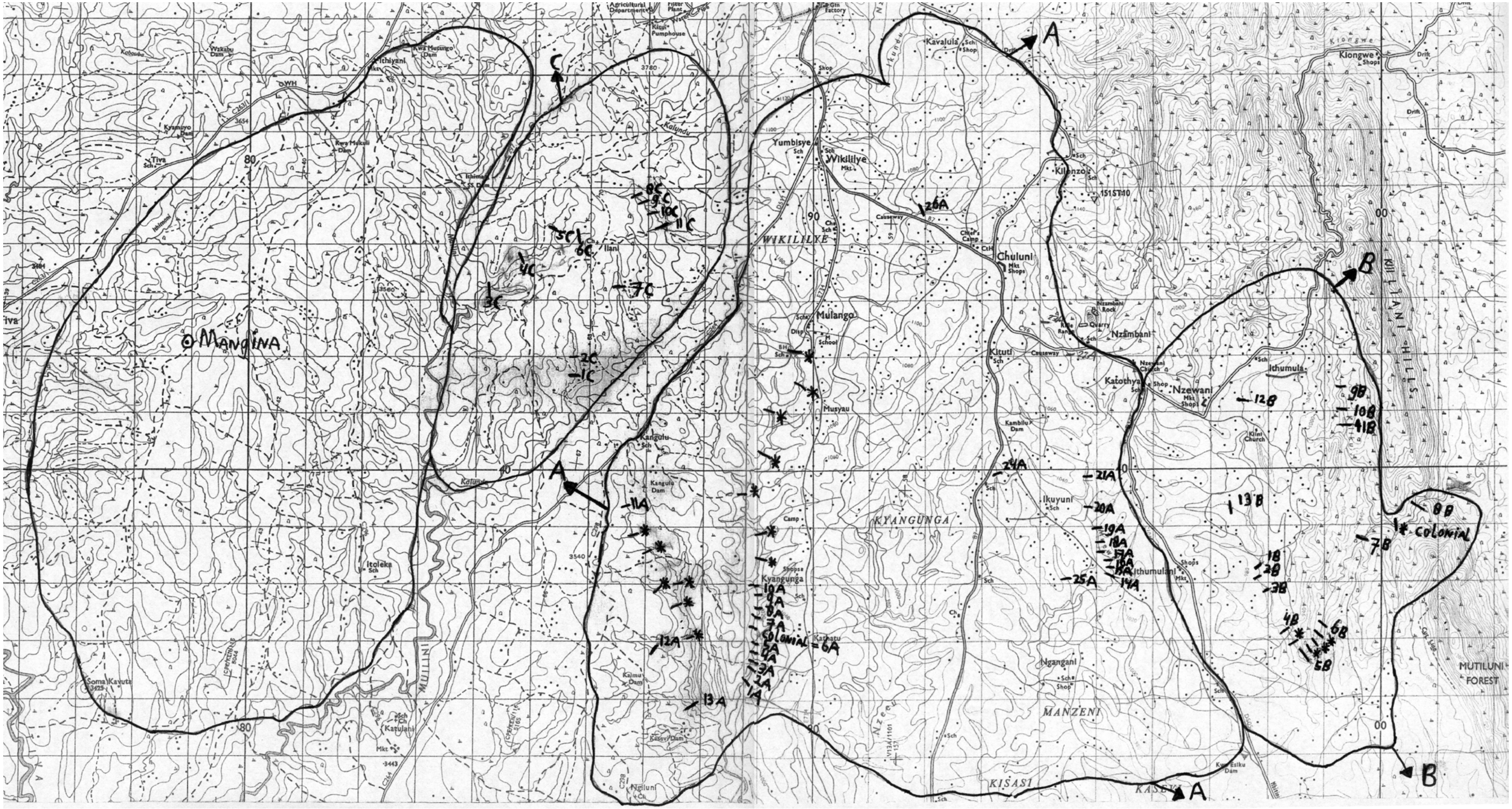
8. Stephens, Tim - *Handbook on small earth dams and weirs, a guide to siting and construction* - Cranfield Press - 1991

Interviews

The following persons have been interviewed during the practical work period:

- Katua, Francis M. - Executive board chairman - April, 20th - Kitui
- Kithuku, David (British) - Technical manager SASOL - April, 20th - Kitui
- Mutiso, Prof. C.M.G. - Chairman SASOL - April, 19th - Kitui
- Mutiso, S.M. - Field manager SASOL - April, 21st - Kitui
- Stephen Ngei - Mason SASOL - April, 25th - Mangina

APPENDIX 1: SASOL PROJECT AREA



MANGINA
WIKILILYE
KYANGUNGA
MANZENI
KISASI
KILUNGU
KILIMANI HILLS
MUTILUNI FOREST
Yumbisye
Wikililye
Chuluni
Mulango
Musyau
Kituti
Nzambani
Nzewani
Katothya
Ithumula
Ikuyuni
Ithumulani
Kavalula
Kilonzo
Kiongwe
Itoleka
Katulani
Kangulu
Kyangunga
Nganganl
Ilani
COLONIAL

APPENDIX 2: INFORMATION DAMS UNDER CONSTRUCTION

Dams under construction:

1.

Dam:	Kwa Maleue
River:	Kithiano
Location:	Kyangwithya
Chairman/Headman:	Manygagi
Mason:	Mulu
Sub-Chief:	Mr. Mweke
Number of households:	39
Average number of workers/day:	40
Distance water:	4 km
Distance sand:	-
Distance stones:	200 m
Distance storage:	400 m
Start construction:	1/4
Visited:	3/5,
Problems:	No oil barrels, shovels and tools. Committee has not been elected yet Foundation very deep, no basement rock
Other dams in same river?	Upstream, already 8 dams have been built.

2.

Dam:	Ituli A
River:	Itulya Mbui
Location:	Itoleka
Chairman:	Mr. Mwongela
Mason:	Mr. Mulu Musembi
Sub-Chief:	Mr. Mweke
Number of households:	25 members
Average number of workers/day:	18
Distance water:	5 km
Distance sand:	200 m
Distance stones:	-
Distance storage:	5 minutes walk
Start construction:	
Visited:	2/5
Problems:	
Other dams in same river?	

3.

Dam:	Ituli B
River:	Itulya Mbui
Location:	Itoleka
Chairman:	Mr. Mwongela
Mason:	Mr. Mulu Musembi
Sub-Chief:	Mr. Mweke
Number of households:	25 members
Average number of workers/day:	18
Distance water:	5 km
Distance sand:	200 m

Distance stones:	-
Distance storage:	5 minutes walk
Start construction:	
Visited:	2/5
Problems:	
Other dams in same river?	

4.

Dam:	Muteto
River:	Kyanzengwa
Location:	Sooma
Chairman:	Mr. Kakuli
Mason:	Mr. Stephen Ngei, Mr. Mwanzu
Sub-Chief:	Mr. Mweke
Number of households:	50
Average number of workers/day:	40
Distance water:	2 km
Distance sand:	-
Distance stones:	-
Distance storage:	500 m
Start construction:	?, finished 8/5
Visited:	24/4, 26/4, 2/5, 4/5, 7/5
Problems:	Community does not work efficiently at all
Other dams in same river?	Three dams are being built in this river

5.

Dam:	Kya Munua A
River:	Kyanzengwa
Location:	Sooma
Chairman:	Mr. Kakuli
Mason:	Mr. Stephen Ngei, Mr. Mwanzu
Sub-Chief:	Mr. Mweke
Number of households:	50
Average number of workers/day:	40
Distance water:	2 km
Distance sand:	-
Distance stones:	-
Distance storage:	500 m
Start construction:	
Visited:	24/4, 26/4, 2/5, 4/5, 7/5, 9/5
Problems:	-
Other dams in same river?	Three dams are being built in this river

6.

Dam:	Kya Munua B
River:	Kyanzengwa
Location:	Sooma
Chairman:	Mr. Kakuli
Mason:	Mr. Stephen Ngei, Mr. Mwanzu
Sub-Chief:	Mr. Mweke
Number of households:	
Average number of workers/day:	40
Distance water:	2 km
Distance sand:	-

Distance stones:	-
Distance storage:	500 m
Start construction:	9/5
Visited:	24/4, 26/4, 2/5, 4/5, 9/5
Problems:	
Other dams in same river?	3

7.

Dam:	Momboni
River:	Katitika stream
Location:	Itoleka
Chairman:	Mr. Kamosu
Mason:	Mr. Mutinoa
Sub-Chief:	Mr. Musumbi
Number of households:	50
Average number of workers/day:	42
Distance water:	1 km
Distance sand:	-
Distance stones:	-
Distance storage:	1 km
Start construction:	16/4
Visited:	25/4, 8/5
Problems:	Foundation very deep (clay)
Other dams in same river?	No

8.

Dam:	Muthunguwe A
River:	Muthunguwe
Location:	Itoleka
Chairman/Headman:	Mr. Musembi
Mason:	Mr. Mwambu
Sub-Chief:	Mr. Mweke
Number of households:	30
Average number of workers/day:	30
Distance water:	3 km
Distance sand:	-
Distance stones:	100 m
Distance storage:	200 m
Start construction:	24/4
Visited:	25/4, 8/5
Problems:	Hakuna matata (no problems)
Other dams in same river?	2

9.

Dam:	Muthunguwe B
River:	Muthunguwe
Location:	Itoleka
Chairman/Headman:	Mr. Kaveli Ngulo
Mason:	Mr. Joseph Kivungu Musyoke
Sub-Chief:	Mr. Mweke
Number of households:	15
Average number of workers/day:	14
Distance water:	4 km
Distance sand:	-
Distance stones:	300 m

Distance storage:	300 m
Start construction:	26/4
Visited:	25/4, 8/5
Problems:	Only ladies for digging
Other dams in same river?	2

10.

Dam:	Muthunguwe C
River:	Muthunguwe
Location:	Itoleka
Chairman/Headman:	Ms. Christine Nuyoki
Mason:	Mr. Mwanza
Sub-Chief:	Mr. Mweke
Number of households:	21
Average number of workers/day:	22
Distance water:	7 km
Distance sand:	-
Distance stones:	200 m
Distance storage:	150 m
Start construction:	5/4
Visited:	25/4, 8/5
Problems:	Few people
Other dams in same river?	2

APPENDIX 3: DOCUMENTATION OF THE EVALUATED DAMS

Evaluation Sand-Storage Dams, Kitui District

DATA AND PRIMARY CALCULATIONS
Date: April 2001
by Projectgroup CF599, TU Delft

no.	code	name dam	river	duration	work force				materials					
					men	women	artisans	total	cement	round bar		barbed wire	timber	nails
				days	*human workday*	*human workday*	*human workday*	*human workday*	*bag (50 kg)*	*1/4 inch/40 ft*	*1/2 inch/40 ft*	*rolls (25 kg)*	*ft of 2 *2*	*kg*
1	1A	Kamumbuni	Kiindu river	27	155	579	96	830	115	0	1	0,5	0	0
2	2A	Kwa Kavoo	Kiindu river	16	21	233	32	286	68	0	1	1	50	1
3	3A	Kwa Mutinga	Kiindu river	30	156	614	87	857	120	N/A	N/A	N/A	N/A	N/A
4	4A	Kwa Mukumbe 1	Kiindu river	21	59	156	76	291	64	0	1	0,5	0	0
5	5A	Kwa Mukumbe 2	Kiindu river	24	96	318	88	502	83	0	0	0,5	0	0
6	6A	Uvalti (colonial dam)	Kiindu river	N/A	N/A	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A
7	7A	Nzemeini	Kiindu river	26	44	294	40	378	95	0	2	1	N/A	1
8	8A	Kwa Langwa	Kiindu river	45	333	1097	35	1465	150	5	5	2	50	1
9	9A	Kwa Mangya	Kiindu river	17	163	720	32	915	72	1	7	7	N/A	N/A
10	10A	Kwa Ndunda	Kiindu river	32	175	237	55	467	80	2	6	1	N/A	1
11	11A	Kwa Tito	Katili	42	222	5	23	250	161	6	4	1,75	50	0,5
12	12A	Kwa Mutia	Katili	24	209	557	23	789	100	4	4	2	0	0
13	13A	Kwa Wambua	Kwa Ngoo	28	119	312	33	464	155	4	3	2	50	1
14	14A	Kathini	Mwewe	91	1074	701	105	1880	212	4	4	2,75	100	2
15	15A	Ndia Aimu	Mwewe	162	589	839	192	1620	371	8	8	4	100	1
16	16A	Kwa Milu	Mwewe	127	893	1003	118	2014	325	5	3,5	4	100	1
17	17A	Tendelya	Mwewe	86	292	274	47	613	126	6	6	1	100	1
18	18A	Kyanguni	Mwewe	162	561	1123	152	1836	374	6	6	3	200	3
19	19A	Imooni	Mwewe	66	213	392	66	671	221	6	6	2	100	1
20	20A	Kwa Kilango	Mwewe	82	413	544	78	1035	162	6	6	2	100	1
21	21A	Mitauni	Mwewe	55	398	199	68	665	142	5	5	2	70	1
22	22A	Musalani	Mwewe	23	175	172	20	367	95	4	4	2	70	1
23	23A	Miuni	Mwewe	58	188	87	56	331	150	2,5	3	1,5	70	1
24	24A	Kithumulani	Kiliva	52	303	320	29	652	126	5	6	3	5	1
25	25A	Kamukui	Kiliva	42	287	238	42	567	125	6	6	2	50	1
26	26A	Kakunike A	Kakunike	48	218	498	50	766	130	4	4	2	50	1
27	1B	Munyuni A	Kyamukaa	18	188	163	18	369	107	6	6	2	50	1
28	2B	Munyuni B	Kyamukaa	12	145	210	12	367	78	5	4	1,5	50	1
29	3B	Kianguni	Kyamukaa	19	234	303	19	556	89	6	6	2	50	1
30	4B	Kavithe B	Kyamukaa	85	299	196	70	565	157	6	5	3	50	1
31	5B	Kyangala B	Kyamukaa	53	196	0	34	230	100	4	4	2	N/A	N/A
32	6B	Kwa Ngungu A	Kyamukaa	8	108	124	8	240	25	1	1	1	N/A	N/A
33	7B	Nguni	Kyamukaa	26	192	195	15	402	90	4	4	1,5	20	1
34	8B	Kyangombe	Kyamukaa	52	274	349	26	649	89	5	5	1,5	N/A	N/A
35	9B	Musaala	Kiliku	19	263	259	19	541	106	6	6	2	5	1
36	10B	Metika Mbuu A	Kiliku	36	250	218	36	504	126	5	5,5	2	50	1
37	11B	Metika Mbuu B	Kiliku	31	192	311	24	527	107	6	6	2	50	1
38	12B	Nganzani	Nganzani	33	159	238	13	410	95	4	5	2	50	1
39	13B	Kwa Kavula	Nganzani	27	211	143	54	408	115	5	4	2	50	1
40	1C	Kwa Ndifu	Vili	55	255	494	57	806	178	8	8	2	50	1
41	2C	Kwa Masila	Vili	44	284	140	46	470	133	8	8	3	50	1
42	3C	Kwa Nziani	Kilamba	62	362	427	60	849	195	8	8	3	5	1
43	4C	Kwa David 1	Kilamba	36	265	355	36	656	138	4	6	2	5	1
44	5C	Kwa David 2	Kilamba	33	193	192	33	418	108	4	5	2,5	50	1
45	6C	Kwa Robert	Kilamba	25	150	206	25	381	81	4	4	1,5	50	1
46	7C	Kwa Katiwa	Maungu	49	145	164	49	358	159	3	9	9	50	1
47	8C	Kwa Mukola	Mutungini	36	248	182	36	466	111	5	4	2,5	50	1
48	9C	Kwa Nguthu	Mutungini	27	48	102	27	177	121	5	4	1,75	50	1
49	10C	Mutungini	Mutungini	25	185	175	25	385	124	4	5	2,25	50	1
50	11C	Munandani	Mutungini	49	125	292	46	463	149	8	8	3	50	1

Statistics

	duration	men	women	artisans	total	cement	1/4 inch/40 ft	1/2 inch/40 ft	barbed wire	timber	nails
Average	46	252	346	50	634	134,8	4,4	4,8	2,2	52,4	1,0
Median	36	209	259	36	503	121	5	5	2	50	1
Minimum value	8	21	0	8	0	25	0	0	1	0	0
Maximum value	162	1074	1123	192	2014	374	8	9	9	200	3
Variance	1128	36242	68203	1310	190079	4743	4,9	4,2	2,1	1402	0,21
Standard Deviation	34	190	261	36	436	69	2,2	2,0	1,5	37	0,46
Standard Deviation/Average	73%	76%	75%	73%	69%	51%	50%	42%	65%	71%	48%

General parameters

average porocity 35%

Evaluation Sand-Storage Dams, Kitui District

DATA AND PRIMARY CALCULATIONS
Date: April 2001
by Projectgroup CF599, TU Delft

no.	code	name dam	length	length wing		length spillway			width		heigth	reservoir				volume of dam	average height
			overall	left	right	base	left	right	base	top	spillway	throwback	width	depth	volume		
			m	m	m	m	m	m	m	m	m	m	m	m	m3	m3	m
1	1A	Kamumbuni	28	0	0	28	0	0	1	1	0	2000	35	3,0	12250	26	0,93
2	2A	Kwa Kavoo	30	0	0	30	0	0	1	1	0	2000	40	5,0	23333	57	1,90
3	3A	Kwa Mutinga	26	0	0	26	0	0	1	1	0	400	40	5,0	4667	33	1,29
4	4A	Kwa Mukumbe 1	19	3	0	16	0	0	1	1	0	400	40	2,6	2427	12	0,61
5	5A	Kwa Mukumbe 2	16	0	4	12	0	0	1	1	0	1000	30	2,0	3500	17	1,06
6	6A	Uvalti (colonial dam)	17	0	0	17	0	0	0,9	0,6	0	500	20	2,5	1458	32	2,50
7	7A	Nzemeini	22	0	0	22	0	0	1	1	0	400	20	2,0	933	26	1,16
8	8A	Kwa Langwa	46	0	11	35	0	0	1,2	1	0	500	15	2,0	875	130	2,57
9	9A	Kwa Mangya	16	0	0	16	0	0	1	1	0	1000	10	3,0	1750	23	1,44
10	10A	Kwa Ndunda	23	0	0	23	0	0	1	1	0	1000	40	3,0	7000	30	1,31
11	11A	Kwa Tito	17,5	4	3	1,5	4,5	4,5	1	0,75	0,3	400	10	1,6	373	20	1,28
12	12A	Kwa Mutia	17	3	7	5,5	0,5	1	0,75	0,75	0,3	300	8	3,0	420	29	2,28
13	13A	Kwa Wambua	30	8	8	10	2	2	1	0,75	0,6	500	10	1,0	292	20	0,76
14	14A	Kathini	47	3	2,3	13,6	20	8,1	1	1	1,94	2000	30	7,0	24500	188	4,00
15	15A	Ndia Aimu	43	8,2	12	13,6	4,6	4,6	1,5	0,8	0,8	300	30	3,0	1575	102	2,07
16	16A	Kwa Milu	43	14	12	6	6	5	2	1	0,7	2000	20	3,0	7000	100	1,55
17	17A	Tendelya	31	7	6	10	4	4	0,8	1	0,6	500	15	2,0	875	18	0,66
18	18A	Kyanguni	52	8,3	24,8	10,5	4,2	4,2	1,45	1,15	0,35	2000	17	2,0	3967	129	1,91
19	19A	Imooni	36	8	4,1	16,5	3,7	3,7	1	1,5	0,55	200	20	1,5	350	67	1,48
20	20A	Kwa Kilango	30,6	5,5	6	16,9	1,1	1,1	0,75	0,65	0,25	1500	30	2,0	5250	75	3,50
21	21A	Mitauni	25	6,3	5,1	5,4	5,5	2,7	1	0,75	1,2	200	15	4,0	700	38	1,76
22	22A	Musalani	24	5,6	6,4	5,4	3,3	3,3	1	0,75	0,85	100	15	2,0	175	30	1,41
23	23A	Miuni	37,4	7	12,7	7,2	5,3	5,2	1	0,75	0,57	3000	10	4,0	7000	79	2,40
24	24A	Kithumulani	24,9	12	6,2	3,25	2	1,45	1	0,75	1,3	300	5	2,0	175	39	1,81
25	25A	Kamukui	14	3	2,8	2,6	2,8	2,8	1	0,75	1,5	400	4	2,5	233	49	4,00
26	26A	Kakunike A	41	11	20	6	2	2	1	0,75	0,38	400	10	2,0	467	65	1,82
27	1B	Munyuni A	28	9	9,5	4,7	2,4	2,4	1	0,7	0,5	2000	10	1,0	1167	54	2,27
28	2B	Munyuni B	22,5	6,3	8,8	3,4	2	2	1	0,6	0,55	300	11	1,0	193	31	1,75
29	3B	Kianguni	32	8	10	7	3,5	3,5	1	0,75	0,55	1000	10	1,0	583	32	1,15
30	4B	Kavithe B	27	9	7	9	1	1	1	0,75	1	500	10	4,0	1167	110	4,64
31	5B	Kyangala B	24	4,6	13,2	6,2	0	0	1	0,75	0,68	300	10	3,0	525	36	1,72
32	6B	Kwa Ngungu A	10	0	0	10	0	0	1	1	0	1000	8	1,0	467	5	0,46
33	7B	Nguni	31	5	7	9	6	4	1	0,75	0,78	1000	25	1,5	2188	39	1,43
34	8B	Kyangombe	47	8	4	28	3	4	1	0,75	0,93	1500	60	1,0	5250	28	0,69
35	9B	Musaala	25,9	8	8,1	4,9	2,9	2	1	0,75	0,83	1000	6	1,5	525	48	2,11
36	10B	Metika Mbuu A	26	6	3	7	5	5	1	0,75	1,34	500	10	2,0	583	46	2,02
37	11B	Metika Mbuu B	25	6	3	6	5	5	1	0,7	2,02	500	5	1,0	146	43	2,04
38	12B	Nganzani	29	19	2	6	1	1	1	0,75	0,33	3000	5	1,0	875	32	1,27
39	13B	Kwa Kavula	52	0	0	52	0	0	1	0,7	0	4000	6	2,0	2800	35	0,79
40	1C	Kwa Ndifu	27	9,5	9,5	4	2	2	1	0,75	0,6	200	5	3,3	193	60	2,55
41	2C	Kwa Masila	25,7	13,6	4,2	3,5	2,2	2,2	1	0,75	0,7	400	4	3,0	280	51	2,25
42	3C	Kwa Nziani	39,1	7	21,8	4,3	3,5	2,5	1	0,75	0,7	300	15	2,0	525	73	2,15
43	4C	Kwa David 1	28	7	11	4	3	3	1	0,75	0,95	200	7	4,0	327	47	1,92
44	5C	Kwa David 2	28	10	7,4	4	3,3	3,3	1	0,75	1,1	100	5	4,0	117	54	2,21
45	6C	Kwa Robert	18	4,5	8,5	2	1,5	1,5	1	0,75	0,24	500	6	1,0	175	24	1,55
46	7C	Kwa Katiwa	22,6	3	13	3	1,8	1,8	2	0,8	0,56	1000	5	8,0	2333	144	4,55
47	8C	Kwa Mukola	27	4	14,5	4,1	2,2	2,2	1	0,8	0,45	200	5	4,0	233	68	2,80
48	9C	Kwa Nguthu	16,9	4,3	5,3	4,3	1,5	1,5	1	0,75	0,4	200	5	1,0	58	31	2,13
49	10C	Mutungini	20,9	7	3,4	4,3	3,4	2,8	1	0,75	0,8	400	5	1,0	117	77	4,21
50	11C	Munandani	27	6,9	7,2	5,45	3,15	4,3	1	0,75	0,58	500	6	3,0	525	49	2,06

Statistics

Average	28,3	5,7	6,7	11,1	2,6	2,3	1,05	0,83	0,58	878	16	2,6	2658	53,1	1,96
Median	27,0	6,0	6,1	6,6	2,1	2,0	1,00	0,75	0,56	500	10	2,0	642	41	1,86
Minimum value	10,0	0,0	0,0	1,5	0,0	0,0	0,75	0,60	0,00	100	4	1,0	58	5	0,46
Maximum value	52,0	19,0	24,8	52,0	20,0	8,1	2,00	1,50	2,02	4000	60	8,0	24500	188	4,64
Variance	99,1	18,1	33,4	102,9	9,7	3,6	0,05	0,03	0,24	740527	161	2,3	25197648	1370	1,00
Standard Deviation	10,0	4,3	5,8	10,1	3,1	1,9	0,23	0,16	0,49	861	13	1,5	5020	37	1,00
Standard Deviation/Average	35%	75%	86%	91%	119%	84%	22%	20%	86%	98%	81%	59%	189%	70%	51%

Evaluation Sand-Storage Dams, Kitui District

DATA AND PRIMARY CALCULATIONS

Date: April 2001

by Projectgroup CF599, TU Delft

no.	code	name dam	average height	average height per m from the left side at X m																																																				
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
			m	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*	*m*
1	1A	Kamumbuni	0,93	0,20	0,25	0,40	0,60	0,55	0,45	0,30	0,35	0,35	0,45	0,55	0,60	1,10	1,10	1,00	0,85	1,10	1,35	1,50	2,05	2,00	1,25	1,75	1,90	1,55	0,90	0,80	0,85	0,85																								
2	2A	Kwa Kavoo	1,90	1,90	N/A																																																			
3	3A	Kwa Mutinga	1,29	1,00	1,00	1,00	1,10	1,20	2,00	2,00	2,00	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,40	1,15	0,85	0,80	0,50	0,50																										
4	4A	Kwa Mukumbe 1	0,61	0,35	0,30	0,30	0,15	0,85	0,80	0,85	0,80	0,80	0,75	0,65	0,75	0,75	0,80	0,80	0,60	0,65	0,55	0,50	0,25																																	
5	5A	Kwa Mukumbe 2	1,06	0,25	0,30	0,45	0,55	0,65	1,05	1,20	1,35	1,50	1,30	1,40	1,20	1,40	2,20	1,10	1,05	1,05																																				
6	6A	Uvalti (colonial dam)	2,50	2,50	N/A																																																			
7	7A	Nzemeini	1,16	2,40	2,40	2,05	2,00	2,05	2,70	2,55	2,15	0,80	0,55	0,60	0,20	0,20	0,25	0,20	0,15	0,10	0,15	0,35	0,85	1,25	1,35	1,40																														
8	8A	Kwa Langwa	2,57	2,00	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,30	2,40	2,40	2,40	2,40	2,40	2,40	2,40	2,40	2,40	2,70	3,00	3,00	3,00	3,00	3,00	3,00	3,00	3,00	3,00	3,00	3,00	3,00	3,00	3,00	3,00	3,00	3,00	2,30	2,30	2,30	2,30	2,30	2,30	2,30						
9	9A	Kwa Mangya	1,44	1,90	1,90	1,90	1,90	1,90	1,90	1,90	1,90	1,90	1,90	0,90	1,20	1,40	1,20	0,50	0,10	0,10																																				
10	10A	Kwa Ndunda	1,31	2,40	2,40	2,40	2,30	2,30	2,25	2,10	2,15	0,85	0,80	0,65	0,80	0,65	1,00	0,95	1,40	1,40	1,25	1,10	1,10	0,90	0,10	0,10	0,10																													
11	11A	Kwa Tito	1,28	1,80	1,90	1,90	0,40	0,85	1,20	1,40	1,75	1,80	1,90	1,90	1,85	1,45	1,25	1,50	0,50	0,30	0,30	0,30																																		
12	12A	Kwa Mutia	2,28	2,00	2,00	2,00	2,00	2,00	3,00	2,50	3,00	3,00	3,00	2,50	2,00	2,00	2,00	2,00	2,00	2,00	2,00																																			
13	13A	Kwa Wambua	0,76	0,55	0,35	0,40	0,45	0,50	0,50	0,55	0,55	0,60	0,60	0,65	0,65	0,70	0,85	1,10	0,95	1,05	1,05	1,05	1,35	1,05	1,80	1,05	1,25	0,80	0,60	0,50	0,35	0,30	0,65	0,65																						
14	14A	Kathini	4,00	4,00	N/A																																																			
15	15A	Ndia Aimu	2,07	0,20	0,20	0,50	0,90	1,00	1,30	3,10	3,20	3,40	3,50	2,80	2,60	2,50	2,30	2,10	2,00	1,80	1,70	1,60	1,40	1,80	1,70	1,50	1,50	1,40	1,60	1,70	2,00	2,20	2,40	2,50	2,60	2,70	2,90	3,10	3,50	3,40	3,10	2,80	2,50	2,30	1,80	1,00	1,00									
16	16A	Kwa Milu	1,55	0,65	0,65	0,75	0,95	1,25	1,60	2,15	2,15	2,15	2,10	2,15	2,05	2,10	2,10	2,10	2,15	2,20	2,15	2,30	2,30	1,95	2,00	2,00	1,90	1,95	2,10	2,15	2,00	1,85	1,70	1,60	1,55	1,40	1,10	1,05	1,10	1,00	0,65	0,55	0,65	0,60	0,50	0,40	0,40									
17	17A	Tendelya	0,66	0,70	0,70	0,13	0,25	0,31	0,31	0,30	0,32	0,31	1,00	1,00	0,38	1,10	1,10	1,12	1,10	1,10	1,10	1,00	1,00	1,00	1,42	1,00	0,32	0,36	0,38	0,38	0,38	0,38	0,39	0,39	0,39																					
18	18A	Kyanguni	1,91	2,80	2,80	2,80	2,80	2,80	2,80	2,80	2,80	2,80	2,80	2,80	2,80	2,80	2,80	2,80	2,80	2,80	2,80	1,50	1,50	1,50	2,00	2,00	2,70	2,70	1,55	1,55	1,55	1,55	1,55	1,55	1,55	1,55	1,55	1,55	1,40	1,40	1,20	1,20	1,40	2,70	2,70	1,50	1,20	1,10	1,00	0,80	0,80	0,70	0,65	0,65	0,40	0,40
19	19A	Imooni	1,48	1,55	1,55	1,50	1,35	1,50	1,45	1,66	1,90	1,85	1,90	1,66	1,45	1,35	1,55	1,45	1,30	1,25	1,20	1,25	1,25	1,40	1,55	1,40	1,00	1,10	1,80	2,20	2,05	2,15	1,55	1,65	1,55	1,40	1,20	1,05	0,95	0,90																
20	20A	Kwa Kilango	3,50	3,50	N/A																																																			
21	21A	Mitauni	1,76	1,00	1,00	1,10	1,65	2,65	3,00	3,00	3,25	3,10	2,95	2,30	2,05	1,70	1,60	1,45	0,85	0,75	0,85	1,20	1,40	2,00	1,85	1,40	1,20	1,05	1,40																											
22	22A	Musalani	1,41	0,70	0,70	0,75	0,75	0,80	0,80	0,95	1,20	1,30	1,30	1,75	1,75	1,75	1,75	1,75	1,75	1,40	1,50	1,60	1,70	1,80	1,90	1,90	1,90	1,85																												
23	23A	Miuni	2,40	2,40	N/A																																																			
24	24A	Kithumulani	1,81	0,65	0,65	1,00	1,20	1,30	1,70	1,40	1,30	1,35	1,40	1,20	1,65	2,10	2,60	3,05	3,45	3,05	3,30	2,70	2,40	2,05	1,85	1,50	1,45	1,40	1,30																											
25	25A	Kamukui	4,00	4,00	N/A																																																			
26	26A	Kakunike A	1,82	1,60	1,60	1,80	1,80	1,80	1,90	1,90	1,90	2,00	2,00	2,00	2,00	1,40	1,40	1,40	1,40	1,40	1,40	1,70	1,70	1,70	1,70	1,60	1,60	1,60	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00	2,00											
27	1B	Munyuni A	2,27	1,50	1,50	1,65	1,70	1,70	1,80	1,95	2,00	2,20	2,55	2,70	2,15	2,00	1,85	1,85	1,85	2,00	2,00	2,55	3,00	2,90	2,90	3,00	2,25	2,35	3,00	3,00	3,00	3,00																								
28	2B	Munyuni B	1,75	1,50	1,70	1,80	1,90	1,90	1,80	1,70	1,60	1,55	1,55	1,55	1,55	1,55	1,65	1,80	1,90	1,90	1,90	1,90	1,90	1,90	1,90	1,80																														
29	3B	Kianguni	1,15	0,80	0,80	0,80	0,90	1,20	1,50	1,50	1,50	1,55	1,60	1,35	1,00	0,90	0,80	0,75	0,75	0,95	1,00	1,25	1,35	1,25	1,10	1,20	1,10	1,20	1,00	1,10	1,20	1,30	1,30	1,30	1,40	1,40																				
30	4B	Kavithe B	4,64	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	4,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00	5,00																									
31	5B	Kyangala B	1,72	0,80	0,80	0,85	0,90	0,95	1,25	0,90	1,10	1,15	0,95	0,95	0,85	0,90	0,95	1,45	2,10	2,30	2,60	2,45	3,25	3,10	3,20	3,00	3,10	3,10																												
32	6B	Kwa Ngungu A	0,46	0,00	0,20	0,35	0,40	0,53	1,08	0,70	0,45	0,55	0,40	0,40																																									
33	7B	Nguni	1,43	1,55	1,50	1,55	1,50	1,45	1,40	1,40	1,55	1,60	1,40	1,45	1,25	1,35	1,20	1,05	1,05	1,05	1,05	1,15	1,75	1,90	1,90	1,85	1,95	2,20	1,60	1,00	1,40	1,30	1,25	1,20	1,00																					
34	8B	Kyangombe	0,69	0,90	0,80	0,65	0,60	0,45	0,50	0,60	0,65	1,15	1,05	1,00	1,00	1,00	1,05	1,00	0,90	0,90	0,90	0,80	0,85	0,80	0,75	0,70	0,65	0,55	0,50	0,50	0,55	0,60	0,80	0,65	0,65	0,65	0,70	0,80	0,80	0,75	0,70	0,65	0,65	0,60	0,45	0,35	0,50	0,40	0,30	0,15	0,10					
35	9B	Musaala	2,11	2,50	2,50	2,50	1,90	1,80	1,40	1,30	1,15	1,80	1,70	1,65	1,60	1,60	1,70	1,56	1,80	2,23	3,10	1,95	1,85	3,27	3,65	2,50	2,50	2,50	2,50	2,50																										
36	10B	Metika Mbuu A	2,02	1,20	1,20	1,10	3,00	3,40	3,50	3,50	3,55	3,50	3,50	3,30	2,60	1,10	1,10	1,50	1,50	1,50	1,50	1,50	2,50	1,50	1,20	1,00	1,10	1,50	1,50	1,20																										
37	11B	Metika Mbuu B	2,04	1,30	1,30	1,50	2,00	2,35	2,30	2,40	2,50	2,65	2,80	2,60	1,00	1,00	1,00	1,00	1,00	1,10	2,00	2,50	2,70	2,80	3,00	3,00	2,50	2,40	2,40																											
38	12B	Nganzani	1,27	3,00	3,00	3,00	2,00	2,00	2,00	1,50	1,50	1,00	1,00	1,50	1,50	1,50	1,25	1,00	1,00	1,00	1,00	1,00	1,50	1,00	1,00	0,50	0,50	1,00	0,70	0,50	0,50	0,25	0,00																						
39	13B	Kwa Kavula	0,79	1,90	1,60	1,40	1,20	1,10	0,90	1,10	0,70	0,70	1,00	1,00	1,10	1,50	1,40	1,50	1,40	1,20	1,20	1,40	1,60	1,40	1,10	1,00	0,90	0,85	0,75	0,70	0,65	0,55	0,45	0,35	0,30	0,15	0,05	0,15	0,25	0,30	0,45	0,50	0,60	0,60	0,75	0,80	0,60	0,50	0,60	0,35	0,40	0,35	0,25	0,20	0,10	0,00
40	1C	Kwa Ndifu	2,55	2,10	2,10	2,40	1,50	2,30	3,20	3,40	2,90	2,40	2,90	2,10	2,00	2,40	3,20	3,10	3,00	3,10	2,50	2,70	2,80	2,90	2,70	2,20	2,10	2,10	3,20	2,10	2,10																									
41	2C	Kwa Masila	2,25	0,60	0,60	0,70	1,10	2,30	2,60	2,30	2,70	2,80	2,90	3,20	3,20	3,10	3,20	3,20	3,20	2,90	2,80	2,80	2,80	2,60	2,20	2,10	1,50	1,40	1,00	1,00																										
42	3C	Kwa Nziani	2,15	1,50	1,50	1,60	1,60	1,80	1,80	1,75	1,85	1,80	1,85	2,00	2,05	2,10	2,15	2,10	2,10	2,75	2,75	3,00	3,15	3,25	3,00	3,00	2,90	2,90	2,70	2,50	2,50	2,50	2,40	2,00	2,00	2,00	2,00	1,90	1,80	1,60	1,50	1,20	1,00													
43	4C	Kwa David 1	1,92	0,00	1,10	1,35	1,40	1,50	1,80	1,90	2,00	2,70	2,60	2,80	3,00	3,20	3,20	3,20	3,00	2,70	2,80	1,00	0,80	2,00	1,90	1,80	1,70	1,60	1,40	1,30	1,00	0,80																								
44	5C	Kwa David 2	2,21	0,00	1,80	2,00	2,30	2,20	2,40	2,50	2,60	2,70	2,90	3,00	2,50	2,40	2,30	2,20	2,15	2,15	2,35	2,55	2,50	2,20	2,15	2,00	2,30	2,30	2,20	2,10	1,80	1,60																								
45	6C	Kwa Robert	1,55	0,00	1,45	1,80	1,90	2,00	2,05	1,10	1,05	1,35	1,50	2,05	2,15	2,00	1,45	1,75	1,65	1,55	1,45	1,25																																		
46	7C	Kwa Katiwa	4,55	0,00	1,10	1,40	1,90	2,00	2,35	3,70	5,10	5,45	5,35	5,05	6,00	6,00	6,00	6,10	6,20	6,30	6,00	5,75	5,65	5,55	5,45	5,40	5,40																													
47	8C	Kwa Mukola	2,80	0,80	0,80	1,00	1,00	1,85	1,85	2,85	2,85	4,90	4,90	4,85	4,85	4,85	4,85	3,55	3,55	2,80	2,80	2,60	2,60	2,70	2,70	2,55	2,55	2,00	2,00	1,95	1,95																									
48	9C	Kwa Nguthu	2,13	0,20	1,00	1,30	1,80	2,10	2,30	2,50	2,40	2,70	2,70	2,60	2,80	3,00	2,80	2,80	2,70	2,60	0,00																																			
49	10C	Mutungini	4,21	5,60	5,60	5,70	5,80	5,90	6,00	6,00	6,00	5,80	5,60	5,50	1,80	1,90	2,00	2,10	2,60	3,00	3,40	3,40	3,00	3,00	3,00																															
50	11C	Munandani	2,06	1,70	1,70	1,80	1,88	1,50	2,40	3,25	2,80	2..65	2,30	2,60	2,60	2,50	2,55	1,80	1,55	2,00	2,00	2,15	2,10	2,20	2,20	1,80	1,65	1,65	1,65	1,75	1,55																									

Statistics

Average	1,96
Median	1,86
Minimum value	0,46
Maximum value	4,64
Variance	1,00
Standard Deviation	1,00
Standard Deviation/Average	51%

APPENDIX 4: CALCULATION FOR EVALUATION DAMS

Dam volume

Since every dam differs from other dams, calculating the exact volume of a dam with a general formula is not possible. Nevertheless, we use a general formula, because of the simplicity and the fact that the data is not reliable enough to do exact calculations.
For the calculation of the volume of the dam, we calculated the average height of the dam first. If the data for the height of the dam was not available in the documentation of SASOL, the height determined at our visit of the dams is used instead of it.
The cross-section of the dam is represented by a trapezoid, with the height equal to the average height of the dam. Multiplying this trapezoid with the length of the dam gives the volume of the dam.
No reductions are made if the dam has a spillway, because the height of the dam is given without the height of the spillway.

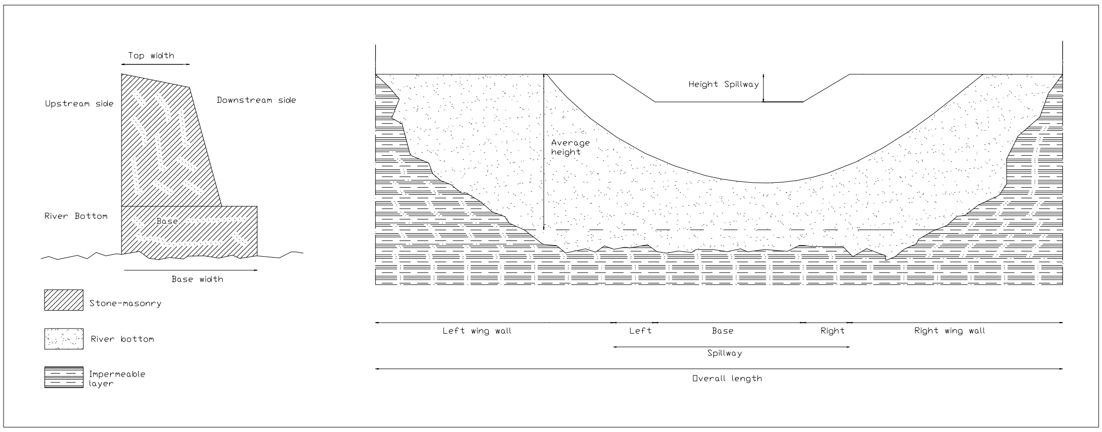


Figure A3.1: Cross-section and front view dam

So the formula for the volume of the dam is (see also figure A3.1):

$$Vd = \frac{1}{2} \cdot (T + B) \cdot h \cdot L$$

in which

Vd = Volume of the dam
T = Width of the top
B = Width of the base
h = Average height
L = Overall length

The shape of the spillway does not only distort the calculated volume of the dam, but also the fact that a local rock foundation can reduce the volume of the concrete dam. So, a good location can reduce the volume of the concrete construction. Less volume means also less costs. Other aspects will also be affected by this phenomenon.
Another disturbance is that the wing walls of the dams can have less width than the crest of the dam. This cause that the calculated volume of the dam will be larger than it actually is.

Reservoir volume behind the dam

The water that can be stored behind a small sand-storage dam is very difficult to determine. It is hard to measure the sizes of the reservoir and determine the porosity of the soil in the reservoir.
In the literature about sand-storage dams, a general formula for the volume of a reservoir can be found. This formula is general accepted, so we use this formula to calculate the volume of the water stored behind a sand-storage dam (see figure A3.2).

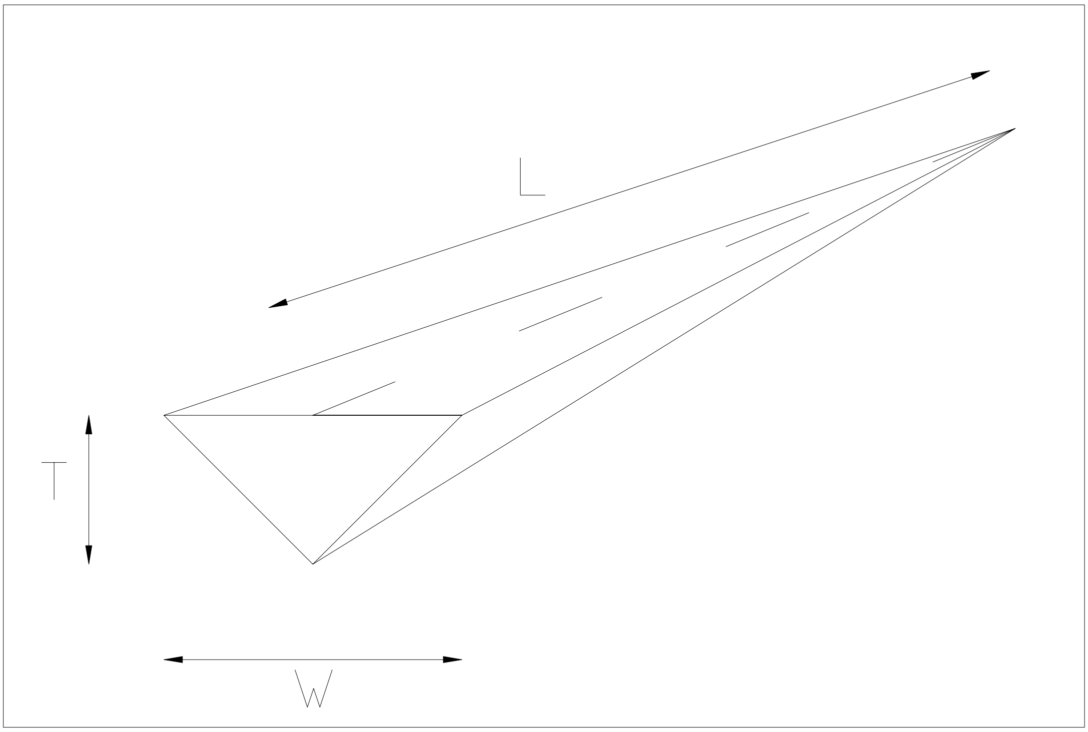


Figure A3.2: Dimensions reservoir behind sand-storage dam

$$Vw = \frac{1}{6} \cdot L \cdot T \cdot W \cdot p$$

Vw = Volume of the water stored behind a small dam
L = Length of the throwback
T = Depth of the reservoir direct behind the dam
W = Width of the reservoir direct behind the dam
P = Porosity of the soil behind the dam

For the porosity of the soil behind the dam, we choose the same porosity as sand. This is because the most dams of SASOL have sand in their reservoirs. The porosity of this sand is set on 35 percent.
The technical manager of SASOL estimates the length, depth and width of the reservoir. Since the big nominal number of the length of the reservoir, made the calculation of the reservoir volume most unreliable. So in the end the calculations of the reservoir volume of the dams have to be seen as a very raft estimate.

APPENDIX 5: RELATIONS, CORRELATION AND COSTS

Evaluation Sand-Storage Dams, Kitui District

COSTS, COMPARISONS AND CORRELATION

Date: May 2001

by Projectgroup CF599, TU Delft

no.	code	name dam	river	volume of dam	workforce					working days	materials	reservoir	cost 2001	cost 1998	cost comparison 2001		cost comparison 1998	
					men/total	women/total	artisan/total	total/days	workforce	execution speed	cement use	efficiency	total	total	cost/volume	cost/res.cap.	cost/volume	cost/res.cap.
				m3	*%*	*%*	*%*	*workmen/day*	*workmen/m3*	*days/m3*	*bags/m3*	*m3/m3*	*Ksh*	*Ksh*	*Ksh/m3*	*Ksh/m3*	*Ksh/m3*	*Ksh/m3*
1	1A	Kamumbuni	Kiindu river	26	19%	70%	12%	30,7	31,9	1,0	4,4	470,8	166.130	158.005	6.385	14	6.072	13
2	2A	Kwa Kavoo	Kiindu river	57	7%	81%	11%	17,9	5,0	0,3	1,2	409,4	75.400	71.915	1.323	3	1.262	3
3	3A	Kwa Mutinga	Kiindu river	33	18%	72%	10%	28,6	25,6	0,9	3,6	139,7	168.560	160.610	5.044	36	4.807	34
4	4A	Kwa Mukumbe 1	Kiindu river	12	20%	54%	26%	13,9	25,0	1,8	5,5	208,5	80.070	74.475	6.880	33	6.400	31
5	5A	Kwa Mukumbe 2	Kiindu river	17	19%	63%	18%	20,9	29,6	1,4	4,9	206,6	113.620	106.755	6.707	32	6.302	31
6	6A	Uvalti (colonial dam	Kiindu river	32	N/A	N/A	N/A	N/A	N/A	N/A	N/A	45,8	N/A	N/A	N/A	N/A	N/A	N/A
7	7A	Nzemeini	Kiindu river	26	12%	78%	11%	14,5	14,8	1,0	3,7	36,5	101.160	96.570	3.961	108	3.781	103
8	8A	Kwa Langwa	Kiindu river	130	23%	75%	2%	32,6	11,2	0,3	1,2	6,7	243.960	239.165	1.873	279	1.836	273
9	9A	Kwa Mangya	Kiindu river	23	18%	79%	3%	53,8	39,8	0,7	3,1	76,2	155.550	153.010	6.773	89	6.663	87
10	10A	Kwa Ndunda	Kiindu river	30	37%	51%	12%	14,6	15,5	1,1	2,7	232,3	106.000	101.850	3.517	15	3.379	15
11	11A	Kwa Tito	Katili	20	89%	2%	9%	6,0	12,8	2,1	8,2	19,1	125.650	121.178	6.429	337	6.200	325
12	12A	Kwa Mutia	Katili	29	26%	71%	3%	32,9	27,2	0,8	3,4	14,5	145.320	142.350	5.004	346	4.902	339
13	13A	Kwa Wambua	Kwa Ngoo	20	26%	67%	7%	16,6	23,4	1,4	7,8	14,7	145.480	140.265	7.326	499	7.064	481
14	14A	Kathini	Mwewe	188	57%	37%	6%	20,7	10,0	0,5	1,1	130,3	334.370	323.988	1.779	14	1.723	13
15	15A	Ndia Aimu	Mwewe	102	36%	52%	12%	10,0	15,8	1,6	3,6	15,4	417.640	399.270	4.079	265	3.900	254
16	16A	Kwa Milu	Mwewe	100	44%	50%	6%	15,9	20,2	1,3	3,3	70,1	416.025	401.775	4.164	59	4.022	57
17	17A	Tendelya	Mwewe	18	48%	45%	8%	7,1	33,3	4,7	6,8	47,5	146.100	141.640	7.934	167	7.692	162
18	18A	Kyanguni	Mwewe	129	31%	61%	8%	11,3	14,3	1,3	2,9	30,8	431.400	414.360	3.349	109	3.217	104
19	19A	Imooni	Mwewe	67	32%	58%	10%	10,2	10,1	1,0	3,3	5,2	210.720	202.510	3.161	602	3.037	579
20	20A	Kwa Kilango	Mwewe	75	40%	53%	8%	12,6	13,8	1,1	2,2	70,0	216.240	209.200	2.884	41	2.790	40
21	21A	Mitauni	Mwewe	38	60%	30%	10%	12,1	17,3	1,4	3,7	18,2	165.560	159.353	4.301	237	4.140	228
22	22A	Musalani	Mwewe	30	48%	47%	5%	16,0	12,4	0,8	3,2	5,9	100.330	97.663	3.384	573	3.294	558
23	23A	Miuni	Mwewe	79	57%	26%	17%	5,7	4,2	0,7	1,9	89,1	132.380	125.883	1.686	19	1.603	18
24	24A	Kithumulani	Kiliva	39	46%	49%	4%	12,5	16,6	1,3	3,2	4,4	150.375	146.755	3.818	859	3.726	839
25	25A	Kamukui	Kiliva	49	51%	42%	7%	13,5	11,6	0,9	2,6	4,8	141.890	137.765	2.896	608	2.812	590
26	26A	Kakunike A	Kakunike	65	28%	65%	7%	16,0	11,8	0,7	2,0	7,2	165.090	159.875	2.533	354	2.453	343
27	1B	Munyuni A	Kyamukaa	54	51%	44%	5%	20,5	6,8	0,3	2,0	21,6	107.690	105.305	1.991	92	1.947	90
28	2B	Munyuni B	Kyamukaa	31	40%	57%	3%	30,6	11,7	0,4	2,5	6,1	88.250	86.640	2.805	458	2.754	450
29	3B	Kianguni	Kyamukaa	32	42%	54%	3%	29,3	17,2	0,6	2,8	18,0	116.490	114.595	3.603	200	3.545	196
30	4B	Kavithe B	Kyamukaa	110	53%	35%	12%	6,6	5,2	0,8	1,4	10,6	166.500	159.965	1.518	143	1.458	137
31	5B	Kyangala B	Kyamukaa	36	85%	0%	15%	4,3	6,4	1,5	2,8	14,6	91.400	87.880	2.533	174	2.436	167
32	6B	Kwa Ngungu A	Kyamukaa	5	45%	52%	3%	30,0	52,2	1,7	5,4	101,4	42.110	41.280	9.154	90	8.974	88
33	7B	Nguni	Kyamukaa	39	48%	49%	4%	15,5	10,4	0,7	2,3	56,3	98.680	96.393	2.542	45	2.483	44
34	8B	Kyangombe	Kyamukaa	28	42%	54%	4%	12,5	23,0	1,8	3,1	185,7	125.070	122.525	4.424	24	4.334	23
35	9B	Musaala	Kiliku	48	49%	48%	4%	28,5	11,3	0,4	2,2	11,0	124.195	121.795	2.595	237	2.545	232
36	10B	Metika Mbuu A	Kiliku	46	50%	43%	7%	14,0	11,0	0,8	2,7	12,7	134.775	130.700	2.932	231	2.844	224
37	11B	Metika Mbuu B	Kiliku	43	36%	59%	5%	17,0	12,1	0,7	2,5	3,4	124.570	121.885	2.870	854	2.808	836
38	12B	Nganzani	Nganzani	32	39%	58%	3%	12,4	12,7	1,0	2,9	27,1	103.580	101.365	3.206	118	3.137	116
39	13B	Kwa Kavula	Nganzani	35	52%	35%	13%	15,1	11,7	0,8	3,3	80,2	121.730	116.935	3.488	43	3.350	42
40	1C	Kwa Ndifu	Vili	60	32%	61%	7%	14,7	13,4	0,9	3,0	3,2	199.110	193.185	3.300	1.034	3.202	1.004
41	2C	Kwa Masila	Vili	51	60%	30%	10%	10,7	9,3	0,9	2,6	5,5	140.530	136.555	2.775	502	2.697	488
42	3C	Kwa Nziani	Kilamba	73	43%	50%	7%	13,7	11,6	0,8	2,7	7,1	215.355	208.825	2.933	410	2.844	398
43	4C	Kwa David 1	Kilamba	47	40%	54%	5%	18,2	14,0	0,8	2,9	7,0	156.435	151.885	3.333	479	3.236	465
44	5C	Kwa David 2	Kilamba	54	46%	46%	8%	12,7	7,7	0,6	2,0	2,2	116.360	112.780	2.147	997	2.081	967
45	6C	Kwa Robert	Kilamba	24	39%	54%	7%	15,2	15,6	1,0	3,3	7,2	93.550	91.030	3.826	535	3.723	520
46	7C	Kwa Katiwa	Maungu	144	41%	46%	14%	7,3	2,5	0,3	1,1	16,2	157.380	152.025	1.093	67	1.056	65
47	8C	Kwa Mukola	Mutungini	68	53%	39%	8%	12,9	6,8	0,5	1,6	3,4	123.150	119.400	1.808	528	1.753	512
48	9C	Kwa Nguthu	Mutungini	31	27%	58%	15%	6,6	5,6	0,9	3,8	1,9	96.580	92.943	3.069	1.656	2.954	1.593
49	10C	Mutungini	Mutungini	77	48%	45%	6%	15,4	5,0	0,3	1,6	1,5	120.030	116.358	1.558	1.029	1.510	997
50	11C	Munandani	Mutungini	49	27%	63%	10%	9,4	9,5	1,0	3,1	10,8	148.790	144.335	3.057	283	2.965	275

Statistics

Average	53	40,4%	51,2%	8,4%	16,7	15,2	1,0	3,1	59,9	156.476	151.281	3.668	325	3.545	315
Median	41	41%	52%	7%	15	12	0,9	2,9	15,8	134.775	130.700	3.206	231	3.137	224
Minimum value	5	7%	0%	2%	4	2	0,3	1,1	1,5	42.110	41.280	1.093	3	1.056	3
Maximum value	188	89%	81%	26%	54	52	4,7	8,2	470,8	431.400	414.360	9.154	1.656	8.974	1.593
Variance	1370	3%	3%	0,2%	86	95	0,5	2,4	9702,1	7.012.783.694	6.487.253.341	3.390.757	121.650	3.140.659	114.059
Standard Deviation	37	16%	17%	5%	9	10	0,7	1,5	98,5	83.742	80.543	1.841	349	1.772	338
Standard Deviation/Average	70%	40%	32%	56%	55%	64%	68%	49%	164%	54%	53%	50%	107%	50%	107%
Correlation		0,60	0,60	0,73	0,76	0,66	0,62	0,65	0,38			0,70	0,24	0,70	0,23
Covariance		29195	5803	11142	10749	10362	766	1636	69537			2140437	97741887	2066546	92761914

General parameters

technical

average porocity	35%	
costs	*2001*	*1998*
cost artisan per day	280	230 Ksh
cost labour per day	100	100 Ksh
cost cement per bag	560	530 Ksh
cost iron bars 1/4 " round per 40	120	290 Ksh
cost iron bars 1/2 " round per 40	350	450 Ksh
cost barbed wire per 25 kg	2200	2250 Ksh
cost timber per ft 2" x 2"	7	6,9 Ksh
cost nails per kg	60	70 Ksh