FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

URBAN WATER SUPPLY AND SANITATION PROJECT

CONSULTANCY SERVICE FOR MASTER PLAN REVIEW, CATCHMENT REHABILITATION AND AWARENESS CREATION FOR GEFFERSA, LEGEDADI, AND DIRE CATCHMENT AREAS

MASTER PLAN REVIEW

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Acronyms and Abbreviation

IDA	International Development Association
AAWSA	Addis Ababa Water and Sewerage Authority
OSZ	Oromia Special Zone
OWWDSE	Oromia Water Works Design and Supervision Enterprise
OL&EPB	Oromia Land and Environmental Protection
OFWE	Oromia Forest and Wildlife Enterprise
DAs	Development Agents
GTP	Growth and Transformation Plan
EPA	Environmental Protection Agency
TLU	Tropical Livestock Units
MCM	Million Cubic Meter
KM^2	Square Kilo Meter
m.a.s.l	Meter above sea Level
MP	Master Plan
DEM	Digital Elevation Model
SRTM	Shuttle Rader Topography Mission
SCS	Soil Conservation Service
PMF	Probable Maximum Flood
WTP	Water Treatment Plant

PART I. THE EXISTING MASTER PLAN

1. INTRODUCTION

As per the TOR of the "Water Supply Study, design, awareness creation and catchment rehabilitation for Geffersa, Legedadi and Dire catchments areas" project, it is requested to review the Existing Master Plan. This master plan study was prepared by M/S TAHAL Consulting Engineering in association MCE Metaferia Consulting Engineering on February 2000. Contains 14 chapters in the following topics:

Chapter 1: Introduction
Chapter 2: Bathymetric Survey
Chapter 3: The General Context
Chapter 4: Goals and Means
Chapter 5: Land Use and Land Cover
Chapter 6: Evaluation of Raw Water Quality in the Reservoirs
Chapter 7: Existing Treatment Plants and Recommended Upgrading Measures
Chapter 8: Hydrological Evaluation of Water Harvesting:
Chapter 9: Proposed Engineering Works to Reduce Sedimentation and Increase the Water Harvest
Chapter 10: Socio-Economic Surveys
Chapter 11: Physical Planning
Chapter 12: Institutional Aspects
Chapter 13: Land Tenure Aspects
Chapter 14: Economic Evaluation

The following summarizes the content of these chapters

2. THE EXISTING MASTER PLAN (2000) – AN OVERVIEW

2.1 INTRODUCTION

The introduction gives a brief view and information about the study area and the major components that will be studied. Expressing the main objectives of the project which are:

- Minimizing pollution of reservoir water.
- Minimizing silt accumulation on the reservoirs bottoms.
- Increasing their water potential.
- Increasing the efficiency of operation of the treatment plants so as to ensure supply of potable water of the required quality to the metropolitan area.
- Outlining measures designed to improve the regional infrastructure.
- Presentation of an outline plan for upgrading rural community facilities.
- Preparation of a suitable institutional framework for attainment of the above.

2.2 BATHYMETRIC SURVEY

This chapter explains the aim of the survey, how this survey was carried out and the instruments and type of images used. The conclusions out of this survey summarized as follows:
For the Legedadi Reservoir it is found that between 1979 and 1998 the volume of water dropped by 2.1MCM from 45.9 to 43.8. That means rate of soil reaching the reservoir (and deposited at the bottom) in average is 762 ton/km^2/year.
For the Geffersa reservoir the total storage capacity of the reservoir declined from 7.45 MCM after completion of the second stage construction works in 1955 to 6.64 MCM in 1979 and continued to decline to a capacity of 6.23 MCM in 1998.
No records regarding Dire reservoir.

2.3 THE GENERAL CONTEXT

This chapter is explaining the circumstances and events which may have an influence on the project area. The following were taken into consideration:

- **General Area Developments**

  Due to the proximity of the catchment basins to Addis Ababa, both are affected by the developments occurs in each of them. As example the nearby expanding Addis Ababa market will in all probability call for a wider range of vegetables, fruits, pulses, and cereals, requiring introduction of new crops. However, the practices required for production of these crops may not always be favorable from the environmental aspects of water harvesting.
  In short, two separate factors require consideration and will look after parallel processes, namely, the need, on the one hand, to develop new water sources with a higher yield than the existing ones; on the other hand, the danger that the present sources, still vital to the water supply of Addis Ababa, will deteriorate due to various environmental developments.

- **The Contribution of the Legedadi, Dire and Geffersa Basins vs. Stage Ill Water Scheme**

  A proposed principal project is the “Addis Ababa Water Supply Stage III A”. This project is phased-in simultaneously with a gradual reduction of the water supply functions of the Legedadi, Dire and Geffersa catchment basins to a state in which they will serve as only a secondary water supplier. This process will be a long and gradual one. During this period, on-going development and maintenance of regular unimpeded supply of high quality water from the existing facilities is essential and constitutes a beneficial investment calling for allocation of the required capital funds.

- **The Function of the catchment Basins in the National Context**

  The present population density of the catchment areas can be taken as an indication of the intensity of present and possibly - future land use. The present population in the catchment basins forms a negligible part of the Ethiopian population (is only 0.06%).On the other hand, these catchment areas play a unique role at the national level, providing potable water for the federal capital the home of some three million people. Nevertheless, this population cannot be ignored, and suitable solutions must be provided to accommodate it in a manner and at locations that will not interfere with the role of the catchment basins as such.

- **Physical Planning Criteria**

  The planning tasks are summarized in the following.
  - *Reservoir Protection*:
  - *Water Harvesting*:
  - *Community Welfare*
  - *Rural Water Supply and Sanitation*:
  - *Rural Roads*:
  - *Institutional Planning*:
  - *Land Use*:
  - *Catchment Basin Management*:

2.4 GOALS AND MEANS

The purpose of this chapter is to provide an understanding of the concept of the factors which are involved to achieve the purpose of this master plan. The chapter explains how these factors either classified as goals or as means, will be studied and analyzed so as to select the desirable means to achieve the aimed goals. Also explains how this will be done taking in consideration the community issues and the impact of the developments on the catchments areas.

2.5 LAND USE AND LAND COVER

This chapter involves in detail information and classification of land use and land cover of the studied area. The objectives of the study are:

- To produce land use and land cover maps of the Legedadi, Dire and Geffersa catchment areas and to determine their area. The mapping was done at a scale of 1:25,000 and is based on the analysis and interpretation of SPOT satellite images and on a ground survey.
- To describe agricultural land use practices in the catchment areas.
- To estimate the percentage of ground cover by vegetation in each cover unit during the rainy and dry seasons.
- To describe and assess the effects of various land use practices on soil erosion.

The chapter explain in detail the methodology used; which mainly the satellite sensing, topographic maps and GIS software.

Then the chapter explains in detail for each catchment area how is the land covered by the following items.

Built-up Area, Abandoned Village, Trails, Quarry/Darn, All- Weather Road
Intensively Cultivated, Cultivated land, Moderately Cultivated Land, Less Moderately Cultivated, Natural Vegetation, Grassland, Shrub Land, Wooded-Shrub-Grassland, Plantation/Trees, Eucalyptus Wood Land, Cupressus-Pine Wood Land, Eucalyptus Wood, Swamp, Bare Land, Water Body

2.6 EVALUATION OF RAW WATER QUALITY IN THE RESERVOIRS

This chapter deals with water quality stored in the reservoirs. It gives general information about the reservoirs sizes; areas and depths and others. It states types of materials cause pollution, contamination and sedimentation and the sources of these materials. Also it discusses the causes of color and odor pollution. It also states the effect of population practices either in livestock cultivation or agricultural activities. The chapter also explains how this information was collected and obtained.
At the end of the chapter proposed solutions were stated which are: Construction of silt trapping reservoirs, fencing off the reservoirs area and Soil Conservation.

2.7 HYDROLOGICAL EVALUATION OF WATER HARVESTING

This chapter discusses the harvesting of rainfall besides the surface water. It shows that the annual rain fall is high (1000 to 1200mm), but within a relatively short period. As a conclusion additional storage system should be constructed to utilize all the available water to meet the increasing demand for water in the metropolitan area.

2.8 PROPOSED ENGINEERING WORKS TO REDUCE SEDIMENTATION AND INCREASE THE WATER HARVEST

This chapter discusses proposals of engineering works to reduce sedimentation and increase harvested water. It clarify that the minimum expected annual surplus water is about 33 MCM, while the maximum in an abundant rainfall year exceeds 90 MCM. The sedimentation rates are; 0.3%/year in Legedadi reservoir and 0.7%/year in Geffersa reservoir.
Accordingly the proposed works are:

For reducing sedimentation:

- Provision of buffer strips consisting of protection canals, grassed areas and tree plantings around so as to bar access by human beings and cattle to the reservoirs so as to minimize soil erosion and raw contamination.
- Construction of small silt-trap reservoirs (also to increase storage capacity).
- Bypassing extreme muddy floods downstream
- River regulation.

For increasing the amount of water harvested:

- Mechanical removal of sediments.
- Enlarging the existing reservoirs, e.g. by raising the height of the dams and construction of new dams.

- Importing water from other neighboring basins.

Each of the above proposals has been discussed and evaluated in this chapter.

2.9 SOCIO-ECONOMIC SURVEYS

This chapter deals with socio-economic issues. It explains the findings of a survey had been carried by the consultant. The information collected covers population, population distribution, gender issue, education, employment, water supply and sanitation service …etc. Also the survey covers the opinion of the inhabitant regarding to how extend they are affected by the reservoirs and any further works that might be done to in relation with the reservoirs and what their expectations or benefits they might gain. The survey covers the three catchments areas.

2.10 PHYSICAL PLANNING

This chapter explains broad demarcation lines for the following:

- Land use, including delineation of areas whose use, i.e. access to humans for cropping and other purposes and for grazing, should be controlled and/or restricted.
- Locations for rural centers and community facilities.
- A basic infrastructural outline plan.

The chapter states the now situation of settlement pattern, existing main roads, rural roads, water supply and wastewater discharge, and community facilities. Then the chapter describes proposals to improve these services from social point of view and to minimize any negative affect towards the reservoirs.

2.11 INSTITUTIONAL ASPECTS

This chapter presents an outline plan for the institutional framework needed to successfully implement, monitor, supervise and manage the catchment area development plans proposed in this master plan.

The chapter gives general outlook to the present institutions involved in implementation of the master plan proposals and the relationship between then. Then organizational alternatives for project implementation were stated and the most appropriate alternative was outlined stating its building and expected duties and the interrelation with other organizations is involved in the master plan implementation. The organizational set-up proposed in this chapter should assist in attaining project objectives.

2.12 LAND TENURE ASPECTS

This chapter describes land rights dispute. As Addis Ababa is a city where there is an overlapping administrative jurisdiction: by the Federal Government, on the one hand, and the state of Oromia, on the other hand. The chapter gives a general view of the uncertainty of the law arising from frequent government interventions, the absence of law itself, or to lack of a well-defined roles and responsibilities which relevant institutions should fulfill.

Finally it is recommended that the Addis Ababa Administration, particularly AAWSA, should seek the cooperation and agreement of the Oromia Region in jointly defining the responsibilities various players regarding the reservoirs and water supply issues.

2.13 ECONOMIC EVALUATION

This chapter of the plan presents the estimation of the cost and benefit, which enable overall evaluation of the projects recommended in the master plan, including rural water supply and social and community programs and all works related to the construction of the dual-purpose reservoirs and other engineering works, and infrastructural development - rural water supply, roads and community facilities.

3. *GENERAL OBJECTIVES SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS*

The master plan had covered the above 14 aspects in detail and had come with recommendations and proposals where it is necessary to achieve the goals for which the Master Plan Study is requested. These recommendations can be summarized in the following related to the concerned aspect:

- **Raw water quality**
  - Implement measures to reduce sedimentation
  - Set up a monitoring to early warning of potential health effects associated with raw water in the reservoir
  - Foster steps to minimize nutrient through controlled agricultural practice
  - Consider the feasibility of introducing algal biological control by fish so as suppress plankton blooms in the dry season
  - Make efforts to obtain a better understanding of the water quality and of the long-term development trends of the Cyanobacteria since these are toxic to human beings, as well as to livestock and domestic animals.
  - Consider application of algaecides to the reservoirs such as copper sulfate as a curative measure, to be given according to proliferation of the algae blooms.
  - Study the issue of “turbidity versus algae growth” and its impact on the Legedadi reservoir.

- **Reservoir operation**

Implement established routine reservoir operation and management practices as specified in the professional manuals.

- Empty mud through the bottom outlets of the reservoirs at the end of the dry season.
- Program the operation of the small reservoirs to avoid the possibility of bank re-suspension of sediments by applying a discharge regime which would discharge from these reservoirs at a much higher rate than the present 2 to 3 cm/day discharge from the main reservoir.

- **Engineering works**

For reducing sedimentation:

- Provision of buffer strips consisting of protection canals, grassed areas and tree plantings around so as to bar access by human beings and cattle to the reservoirs so as to minimize soil erosion and raw contamination.
- Construction of small silt-trap reservoirs (also to increase storage capacity).
- Bypassing extreme muddy floods downstream
- River regulation.

For increasing the amount of water harvested:

- Mechanical removal of sediments.
- Enlarging the existing reservoirs, e.g. by raising the height of the dams and construction of new dams.
- Importing water from other neighboring basins.

- **Physical Planning**

Settlement pattern

- Maintain the present dispersed settlement pattern and to discourage concentrations of tukuls, except for the proposed rural centers which will consist of community facilities such as schools, clinics, churches, markets, agricultural support services, warehouses, shops, and other low-level threshold businesses.
- Prohibit establishment of industries which may contaminate surface or ground water.

Rural Community Centers and Sanitation

- Foster the development of rural community centers in coordination with State and Local Authorities providing health services, schools, churches, and marketing and production input supply facilities (according to the proposals given in Chapter 12 of the Main Report).
- Foster programs in coordination with State and Local Authorities to promote the use of dry pit latrines

Rural Roads

- Foster the development of rural road networks according to the proposals given in Chapter 12 of the Main Report to serve the community centers and the villages in coordination with State and Local Authorities

Rural Water Supply Systems

- Coordinate implementation of a rural water supply program giving priority to areas in the vicinity of the reservoirs which will no longer be accessible to the human population and livestock after construction of the buffer strips. The following water supply facilities are proposed (detailed costs and the proposed implementation schedule are given in Annex III):
- 24 shallow wells equipped with hand pumps and one deep well (for Sendafa town) in the Legedadi - Dire catchments, with an additional 26 shallow wells and one additional deep well to be constructed by the year 2010.
- 11 shallow wells equipped with hand pumps in the Geffersa catchment, with an additional 6 shallow wells to be constructed by the year 2010.
- To provide cattle troughs in the vicinity of all the wells.
- Promote use of dry pit latrines.
- No proposals are made at present for water-borne sewerage systems in the absence of piped water supply.

Institutional Measures

- Set up an internal AAWSA management unit for the catchment areas (Catchment Area Management Unit - CAMU) to deal with all matters related to the catchments within the framework of a single executive and coordinating body. This integrated management unit would be charged with decision- making, planning, coordinating and dealing with all water-related developments in the three catchment areas, and its control, as well as enforcing measures to protect the reservoirs
- Ensure representation of the Oromia State Government, preferably its Water, Mines and Energy Resources Development Bureau, on AAWSA Board of Directors.
- Foster implementation of non-water related plans by the Regional (Oromian) and Federal Governments, in cooperation with other government agencies, industry, community groups, and land and water managers. AAWSA should serve as the overall authority to assure sustainable regional environmentally- safe development.
- Actively seek and obtain the cooperation of the Regional State Government of Oromia by negotiation.
- Involve the general community in the institutional framework, by means of participation in forums from the beginning of the detailed planning process and throughout implementation of the plans.

- **Land Tenure**

  - The Oromia Region should, promulgate and enforce laws based on the relevant Federal policies and laws which will ensure the farmers uninterrupted and long-term access to the same piece of land and resource.

- **Agricultural Development**

  Although agricultural development is beyond the scope of AAWSA's responsibilities, AAWSA should nevertheless be involved in agricultural development programs so as to fulfill one of its subsidiary goals - improving the well-being of the rural population of the catchment areas, and since the required agricultural development will reduce erosion and reservoir sedimentation. AAWSA should therefore be involved in agricultural development through the following:

  - Encourage the Oromia State and the local authorities in the promotion of agricultural development programs aimed at:
  - Improvement of cultivation practices so as to increase crop yields; improved cultivation practices will also contribute to reducing erosion and reservoir sedimentation;
  - Setting up feed centers, introduction of high yielding fodder crops and of cut-and-carry livestock feed practices to improve livestock nutrition and minimize overgrazing.
  - Introduction of dual-cropping with the aid of irrigation from reservoirs where water storage is adequate without impinging on urban water supply to the metropolitan area, Setting up agricultural support services including extension, research and credit the latter so as to enable farmers to purchase production inputs, especially fertilizers and plant protection materials, while taking steps to ensure controlled application of these materials to prevent pollution of surface and groundwater resources.
  - Promote introduction of soil conservation measures, including afforestation, to minimize erosion of farm lands and rural roads, as well as bare lands.

PART II. MASTER PLAN REVIEW: ENGINEERING & TECHNICAL ASPECTS

1. RESERVOIR BATHYMETRIC SURVEYS

1.1 GENERAL

This chapter presents the results of the bathymetric surveys conducted in 1998 for Legedadi, Geffersa I/II and Geffersa III reservoirs. The surveys were carried out as part of the 2000 Master Plan which is under review and the results are analysed in the plan main report. Both surveys are compared in the master plan with the results of the 1979 survey which also covered both reservoirs.

Since the completion of the Master Plan there has been another bathymetric survey conducted at Legedadi reservoir by Seureca and others (2010). For completeness, in what follows the results of this latter survey are also discussed in the relevant section on Legedadi reservoir.

1.2 GEFFERSA RESERVOIR

The present state of the Geffersa main dam is the result of successive modifications. Originally built in 1943 as a 10 m high masonry dam (Geffersa I), it was first modified in 1955 by raising its height by 6 m (Geffersa II). In 1966 a smaller dam (Geffersa III) was built about 800 m upstream from the main dam to serve as a silt trap and additional water storage. Finally, in 2009, a major rehabilitation project was finished which renovated the dam body and the hydraulic works (spillway, intake). There has been no new bathymetry conducted after the renovation of the dam, however, the design study by Tractebel & others (2002) states that the intended capacity of the reservoir according to the design finally chosen is 7.39 MCM.

The bathymetric survey of 1998 was conducted by a single-beam echo sounder mounted on a boat. The boat covered the reservoir surface in parallel traverse line spaced out approximately 40 m. The coordinates of the soundings were taken by differential GPS with a stated accuracy of 1 m. The X, Y, Z data were transferred to the UTM projection system and contoured. Some manual modifications and corrections to the automatically derived contour lines were performed. The survey was conducted in one day, during which the reservoir was at its maximum water level.

The results of the survey indicated a reservoir volume at FSL of 6.23 MCM. This compares with the result of the 1979 survey which found a total volume of 6.65 MCM at the same elevation. The FSL for Geffersa is 2,585.61m.a.s.l. According to the master plan the topographic map constructed during the raising of the dam in 1955, gave the total reservoir capacity at the time as 7.45 MCM. The master plan back-calculates the reservoir volume in 1966, prior to the construction of Geffersa III to 6.94 MCM assuming the average annual siltation rate between the 1979 and 1998 surveys to hold. The exact same calculation appears also in the Geffersa dam rehabilitation study of Tractebel & others (2002).

According to these figures, the Geffersa reservoir was subject to a siltation rate of 46,400m^3/yr. between 1955 and 1966 (the year Geffersa III was constructed) and the reservoir was exposed to the full sediment load of the catchment. Between 1979 and 1998, the average annual siltation rate dropped more than 50% to 22,105m^3/yr. as a result of sediment trapping in the upstream Geffersa III reservoir.

These results indicate that by 1966, Geffersa reservoir had lost 0.51 MCM, i.e. about 6.8% of its 1955 capacity. This represents an average annual volume reduction rate of 0.62%/yr. for the period 1955-1966.

Since 1966 and the construction of Geffersa III dam, the Geffersa reservoir in 1998 had lost another 0.71 MCM of its capacity, i.e. about 10.2% of its 1966 capacity, an average annual volume reduction rate of 0.32%/yr.. for the period 1966-1998 (22,188 m^3/yr..). The influence of Geffersa III is clearly seen in the 50% decrease in the annual volume reduction rate since the construction of the dam.

The total volume loss in 1998 compared to 1955 was 1.23 MCM or 16.5% of the 1955 capacity, representing an average annual volume reduction rate of 0.38%/yr. The calculated sediment yield for the period up to 1966 is 1198 t/km^2/yr. and since 1966, 574 t/km^2/yr. The sediment density that was assumed for these figures seems to be 1.45t/m^3.

1.3 LEGEDADI RESERVOIR

The Legedadi dam was constructed in 1967. There is a pre-impoundment map available which is considered inaccurate and of limited usefulness by the master plan since it appears to have a vertical difference of about 13 m from later established benchmarks.

The bathymetric survey of 1998 was conducted using similar methodology and equipment as for Geffersa dam. The soundings were taken over a period of four days, during which the reservoir was at about 0.6 m below FSL. To complement the bathymetric survey, a land survey of several cross-sections was performed at the end of the dry season with the reservoir water level withdrawn by some 14 m below FSL.

The methodology and equipment employed during the 2010 survey is similar to the one followed by the master plan. Again a boat fitted with a single-beam echo sounder and a differential GPS was used to cover the reservoir in parallel traverse lines spaced out about 30 m apart. The major difference between this latest and the previous survey is that it was conducted with the reservoir about 3 m lower than its maximum level. To complement the bathymetric survey a land survey was conducted in this zone.

There is some confusion over the exact value of the Legedadi FSL. According to the master plan the FSL is 2,452.915m.a.s.l. However, the older 1979 survey and the water level gauges at the dam are fixed on a datum of 2,466.0m.a.s.l. The latest Seureca & others (2010) survey uses this FSL value to enable comparison with previous surveys.

The 1998 survey indicated a reservoir volume at FSL of 43.8 MCM. This compares with the result of the 1979 survey which found a total volume at FSL of 45.9 MCM. Therefore, Legedadi reservoir has lost 2.1 MCM of volume between 1979 and 1998, indicating an average annual siltation rate of 110,500m^3/yr.

As already mentioned a more recent bathymetric survey is available conducted by Seureca and others (2010). The 2010 survey showed a total reservoir volume at FSL (2,466 m) of 42.17 MCM. This amounts to a volume reduction of 3.72 MCM since 1979 and 1.62 since 1998, or an average annual siltation rate of 120,000m^3/yr. between 1979 -2010, and 135,000m^3/yr. between1998-2010. These figures translate to an average annual volume reduction rate of 0.26%/yr. for the period 1979-2010 and 0.31%/yr. for the period 1998-2010. Between the years 1979 and 1998 this figure was 0.24%/yr. It appears therefore that in later years the rate of siltation of the Legedadi reservoir has increased, something which is consistent with the general context of developments in the catchment to what concerns factors affecting soil erosion and sedimentation.

The resulting sediment yield of the catchment according to the results of the 1998 survey is 762 $t/km^2/yr$.. The 2010 survey report (Seureca & others, 2010) did not include calculations of the sediment yield, but from the results reported a value of 845$t/km^2/yr$. is readily obtained (assuming a sediment mix density of1.3 t/m^3).

1.4 GEFFERSA III RESERVOIR

The master plan includes a bathymetric survey (in actuality, a topographical survey since it was conducted on dry land) of the small Geffersa III reservoir. The survey was conducted in 1999 at a time when the reservoir was dry and therefore accessible by conventional topographic equipment. The total volume at FSL found was 1.17 MCM. This survey was intended to serve as a baseline for future surveys in order to estimate the amount of silt captured by the dam and plan removal operations accordingly. It is suggested to conduct all future surveys of this reservoir on dry land since total emptying of the Geffersa III reservoir to Geffersa I/II is easily accomplished without loss of water stored.

1.5 SYNTHESIS AND COMMENTS

The results of the bathymetric survey conducted at Legedadi reservoir in 2010 calculated the remaining volume capacity to be approximately 42.18 MCM, 1.62 MCM less than the volume estimated by the 1998 survey and 3.72 MCM less than the 1979 survey. Based on the results of the three bathymetric surveys the average annual siltation rates are:

- 1979 to 1998: 110,000m^3/year
- 1979 to 2010: 120,000m^3/year
- 1998 to 2010: 135,000m^3/year

Although the figure for the last 12 years indicates that siltation is increasing, the results of the three bathymetric surveys conducted the last 30 years are of the same order of magnitude and thus we can say that the basic assumption of the 2000 MP that siltation process is not a major problem for the catchments - provided that rates remain under control - is accurate.

The level of accuracy of the three bathymetric surveys cannot be the same, especially of those that the reservoir was not at FSL when the survey was conducted, but the fact that there are strong indications that sedimentation is increasing, taking catchment measures to control soil erosion and capture sediment load before entering the reservoirs should be considered.

It is evident that siltation is occurring at Legedadi reservoir as can be seen from the picture below; in any case if we were facing high soil erosion from the catchment we would expect a much worse situation than the one we met during our field visit in Legedadi in July 2011.

Siltation in the Legedadi Reservoir

For the Geffersa reservoir the average annual siltation rate is estimated to be approximately 46,430 m^3 per year comparing the topographic map of 1955 (volume 7.45 MCM) with the one of 1979 (volume 6.65 MCM). This annual rate has declined by about half after 1966 due to the commissioning of the Geffersa III silt trap reservoir, as indicated by the findings of the 1998 bathymetric survey which showed a reservoir volume of approximately 6.23 MCM (average annual siltation rate 22,105 m3 per year instead of 46,430 before commissioning Geffersa III). The conclusion also for Geffersa is almost the same as for the Legedadi considering that siltation process does not constitute a major constrain for future water storage capacity and that this process can be controlled by silt traps upstream the reservoirs like the Geffersa III.

Nevertheless, the Master Plan proposes that for both catchments measures should be taken to reduce sedimentation in order to improve the quality of the raw water in the reservoirs and alleviate water treatment problems.

The possible means for reducing reservoir siltation rate according to the 2000MP are:

- Developing buffer strips around the reservoirs including protection canals.
- Construct small silt traps.
- Bypass extreme muddy floods downstream.
- Regulate rivers.

The following comments can be made with regard to the reservoir bathymetric surveys conducted so far in the three study reservoirs:

- The methods employed for the 1998 and 2010 surveys at Geffersa and Legedadi are standard and the equipment used was of current technology for such studies (differential GPS and single-beam echo sounder).

- There is some confusion over the exact FSL of Legedadi reservoir. The 2000 MP disagrees with previous and later surveys. The FSL will be assumed 2,466 m for consistency with the latest bathymetry (2010) and the datum of the water level gauges at the dam. The above level is also accepted by the dam operators.
- The master plan continuously refers to the calculated sediment yield values as “catchment soil loss rate”. This is an error, since the actual soil loss from the catchment will be much greater than what reaches the reservoirs because of intermediate deposition of the eroded material throughout the catchment and along the river courses prior to reaching the reservoirs. The figures calculated represent what actually enters the reservoirs and should be referred to as sediment yield, i.e. the sediment load that passes a specific point in the catchment over a specific period of time.
- The siltation rates and sediment yields calculated are not compared by the 2000 MP with other local, regional or global values to get a comparative insight on their magnitude. The values for sediment yield obtained are for example entirely reasonable compared to recent values found by this Consultant (Z&A) after executing bathymetric surveys in Kenyan reservoirs (Upper Tana catchment). The sediment yield calculated was 1,100t/km^2/yr. for the main Tana and Thika river sub-catchments and about 600t/km^2/yr. for the Thiba sub-catchment. These values indicate that the Legedadi and Geffersa sediment yield values are within the range found in the broader East African region.
- The average annual siltation rates found from the difference in volumes calculated by successive surveys are converted into sediment yield without giving any indication of the assumed sediment mix density (t/m^3). The value of 1.45 t/m^3 mentioned in a footnote of Table 9.3 is presumably used. This value relates well to the 762 t/km^2/yr. sediment yield value given for Legedadi but not to the values reported in the above Table. Finally there is no mention in the text of the assumed sediment mix composition (clay/silt/sand) on which this density value is based.
- A good opportunity for AAWSA to collect information on the sediment mix composition is to take advantage of the low water level in the reservoirs at the end of the dry season. Samples could be collected at that time at various locations around the reservoir bottom and analysed to determine the composition of the deposited sediment. It is estimated that about 10 samples weighing 2-3 kg each, evenly distributed around the exposed areas of each reservoir, should be sufficient to determine a median sediment composition and enhance the sediment yield calculations. GPS readings should be taken in all the sampling locations and presented on the reservoir map.

The overall assessment of the previously conducted bathymetric surveys in the reservoirs of the project area is that they provide an accurate assessment of the remaining volume in the reservoirs and of the average annual siltation rates. There is some uncertainty regarding the conversion of this information to estimated sediment yields of the catchments above the reservoirs since there are no data available on the sediment mix composition and hence the related average sediment density cannot be directly calculated (including the compression effects under the weight of the water in the reservoirs). However, sediment yield values estimated according to assumed sediment densities reasonable for the problem in question are well within the range of values encountered in other similar studies in the broader region with similar soils and catchment land uses. Therefore they can serve as a basis to estimate sediment yields in other points within the catchments for planning purposes.

For the Geffersa I-II and Legedadi reservoirs the annual reduction rates presented above are:

Geffersa I-II 0.32%/yr. 22,105 m^3/yr.

Legedadi 0.31 %/yr. 135,000 m^3/yr.

With the above rates and the calculated remaining volume capacity of the two reservoirs the years until total siltation are given in the following table.

Table 1: Reservoir sedimentation data in the study catchments

Reservoir	Reduction Rate (%/yr..)	Remaining Volume (MCM)	Year of last survey	Years to total siltation	Date of total siltation
Geffersa I-II	0.32	7,4	2002	310	2312
Legedadi	0.31	42,2	2010	320	2330

From the figures of the above table it is considered that both reservoirs have a long remaining life expectancy, and in all cases, even if the soil erosion conditions in the catchments change dramatically, we can expect that for at least the next fifty years they will continue to operate and supply the Addis Ababa water distribution network.

We can assume from this analysis that although catchment rehabilitation measures should be taken in the two catchments in order to control and maintain on acceptable levels the soil erosion, the necessity to propose and construct expensive infrastructures like dams only as silt traps, should be carefully examined.

For the Dire catchment and reservoir since it was commissioned in 1999 no conclusions regarding sedimentation are given in the 2000 Master Plan so no comments can be made.

The procedure to be followed in this contract in order to estimate the level of soil erosion in the Dire catchment will be the same with the one for the dual purpose dams proposed by the Inception Report of this Contract. More specifically, GIS-based methods (RUSLE) will be used to produce a soil erosion potential map of the catchment in order to estimate the soil erosion potential of the area draining into the Dire reservoir. This effort is subject to data availability. In particular, it requires the availability of spatial data in digital form on terrain elevation, soil textures, land cover and some information on farming practices. It also requires at least some storm precipitation data (time scales < day). With the data collected until now we consider the use of the RUSLE method possible and suitable for the soil erosion calculations.

2. HYDROLOGICAL & HYDROGEOLOGICAL EVALUATIONS

2.1 HYDROLOGY

2.1.1 Description of the study catchments

The Addis Ababa city is at present supplied with water from three surface water resources, the Legedadi, Dire and Geffersa reservoirs, and ground water sources (boreholes and springs). The Legedadi dam (constructed in 1967) and the dire dam (commissioned in 1999), both situated about 30 km east of Addis Ababa, have a capacity of 42.17 MCM and 19 MCM respectively. The main Geffersa dam (Geffersa I/II) located 18 km to west of the city, was constructed in 1943 and raised in 1955 and has a capacity of 7.39 MCM (all capacities refer to the most recent available data for each reservoir). Recently (2009) the Geffersa Dam was fully renovated and the height was increased by about 1.4 meters. A small dam and reservoir, Geffersa III, is located about 800 m upstream to the north of Geffersa I/II. The capacity of the dam is 1.17 MCM and it was constructed in 1966 as a dual purpose dam, storage and silt trap. All surface water reservoirs and catchments lie within the boundary of the Oromia Region.

Legedadi and Dire catchments

The Legedadi (207.3 km^2) and Dire (77.5 km^2) catchments, defined above the respective dam locations, are located to the east of Addis Ababa. They are both sub-catchments of the Akaki river basin which flows in a northeast-southwest direction and is part of the drainage system that forms the northwest corner of the Awash river basin. The Legedadi catchment area is the largest of the three main water supply sources of Addis Ababa city. The two areas are located 30 km to the east of the city. The average annual surface water potential of the two catchments is estimated by the Master Plan study to be 86 MCM for the Legedadi catchment and 50 MCM for the Dire catchment.

Siltation is occurring in the reservoirs, especially in Legedadi. However, the findings of the bathymetric survey carried out in 1998 indicated that the sediment volume of the Legedadi reservoir increased in the 19 years passed since the previous bathymetric study of 1979, by only 2.1 MCM. The live storage capacity was reduced from 45.9 MCM in 1979 to 43.8 MCM in 1998, representing an annual sediment load of 110,000 m^3 (a 0.3%/year increase in the volume of sediments in the reservoir). The annual siltation load in this reservoir was thus concluded at the time to be rather moderate and hence this reservoir was expected to continue operating for many years to come, provided siltation rates are kept under control.

The region is characterized by a range of volcanic mountains rising to elevations from 2,460 to 3,200m.a.s.l. The major physiographic units found in the catchment area are: mountains, dissected side slopes of mountains, hills, steep to undulating foot-slopes, gullies, valleys, and undulating plains and flat to almost flat plains. The main land uses in the catchments are: small villages surrounded by Eucalyptus wood, intensively and moderately cultivated land, Eucalyptus woodland (young and matured), shrub-land, Eucalyptus grass and natural vegetation, Grassland, bare soil and built-up areas (paved road, dam, concrete buildings in Sendafa town, and water bodies).

The population of the catchments earn its living from rain fed crops and livestock, which may be categorized as subsistence agriculture. High population growth and environmental degradation, limited resources and inadequate land use and water policies have increased raw water degradation in the area.

Geffersa catchment

The catchment upstream of Geffersa reservoir covers an area of about 56 km^2 and has an average altitude of 2,600 meters. The dam is located 18 km west of Addis Ababa. The reservoir is in a shallow basin about 10 km wide, stretching between the Wechacha and Entoto mountains. The Geffersa River and its tributaries are also part of the Akaki river basin. The main dam was built in 1943 (and modified in 1955) and the second smaller dam (Geffersa III) was built in 1966 upstream from the main dam. The present-day water storage capacities are about 7.39 MCM and 1.17 MCM respectively. The average annual surface water potential of the catchment area is estimated in the Master Plan study as 25 MCM. The Geffersa I/II main dam was renovated and commissioned again in 2009. The dam height was increased by 1.4 m. The live storage volume of Geffersa I/II reservoir declined from 7.45 MCM in 1955 to 6.55 MCM in 1979, which reflects an average annual siltation rate of 46,430 m^3 (0.7%/year). The annual siltation rate was reduced to about half after 1966 due to the commissioning of the Geffersa III silt trap reservoir as indicated by the findings of the 1998 bathymetric survey which showed a reservoir volume in that year of 6.23 MCM, constituting a roughly 0.4%/year increase in the volume of sediments in the reservoir.

Catchment boundary delineation

Among the objectives of this review – as stated in the ToR – is the delineation of the boundaries of the study catchments. This was accomplished in two separate ways: (a) using a digital elevation dataset and (b) directly from the 1:50,000 scale maps of the area.

To obtain a reliable and objective delineation of the catchments it was decided to use a publicly available high-resolution digital elevation dataset. The recent Digital Elevation Model (DEM) from the 2000 NASA Shuttle Radar Topography Mission (SRTM) was employed. This DEM is available for the majority of the earth surface at a 90 m resolution which is more than adequate for the purpose of surface catchment delineation and mean catchment elevation computation. Recently, USGS published a processed version of this dataset specifically for hydrological purposes. The relevant files were downloaded from the USGS EROS Data Centre website and merged to a single ESRI type grid file. The dataset is natively available in the Geographic System WGS 84 (Lat-Long, decimal degrees). Study maps are prepared using a UTM (Zone 37N) projection. Catchment delineation proceeded by standard terrain analysis of the DEM. The basic steps include (a) filling sinks (depressions), (b) deriving flow direction, (c) deriving flow accumulation, (d) derivation of stream segments and (e) catchment delineation.

The catchments delineated were the three study catchments above the Legedadi, Dire and Geffersa dams and the catchment areas upstream of the five (5) flow gauging stations available in and around the study area which were identified during a visit to the Ministry of Water Resources. The catchment boundaries above proposed dam locations in the 2000 MP were also delineated and are presented in Chapter 3 further below. Once the catchment boundary was defined, area, relief slope and elevation information was readily extracted from the DEM.

Table 2 lists the major catchment morphological characteristics derived from DEM analysis. The catchments in Table 2 are also shown on the map presented as Fig. 1. The map includes the locations of the rainfall/climate and flow gauging stations obtained for the purposes of this study. These are discussed in detail in later sections.

Table 2: Catchment morphological characteristics

Catchment	Area (km^2)	Min Elevation (m)	Max Elevation (m)	Mean Elevation (m)	Mean Relief Slope (%)
Study catchments					
Legedadi	207.3	2402	3226	2575	5.84
Dire	77.5	2502	3240	2818	19.3
Geffersa	55.8	2559	2976	2677	5.61
Gauged catchments					
Akaki	884.4	2057	3197	2412	8.12
Mutinicha	372.5	2344	3251	2628	9.84
Little Akaki	131.0	2375	3367	2668	9.51
Holeta	119.0	2386	3306	2660	13.4
Kessem at Beke	50.0	2549	3225	2880	14.3

The three study catchments were also drawn by hand on the 1:50,000 scale maps of the region obtained from the Client. The three map sheets covering the study area in its entirety were scanned and geo-referenced following the UTM (Zone 37N) coordinate system and seamlessly mosaicked using AutoCAD. The catchments were then manually delineated on the maps. The results were practically the same as with the DEM delineation. For mapping purposes in smaller scales, the boundary derived manually is preferable because of its smoother appearance.

2.1.2 Relevant hydrological studies

There are three previous studies with important hydrological information and estimations on the project areas. These studies contain useful data and information that will be taken into account in the hydrological investigations of the present project. A brief description of the hydrological content of each study is given below and the results useful for the present project are outlined.

i. *Geffersa and Keranyo Water Supply. Rehabilitation of Dams and WTP (Tractebel-AuE-Coyne & Bellier, 2002)*

This report is concerned with the rehabilitation works of Geffersa I/II and III dams. In terms of hydrology investigations, the study contains a water balance calculation of the Geffersa reservoir to estimate annual inflows.

The results based on 36 years of data (17 of which from the reservoir water balance and 19 through correlation with the Muger flow station in the Gerbi dam catchment) amounts to a mean annual inflow of 28.5 MCM/yr. for Geffersa I/II. Only the mean annual monthly pattern and two characteristic high- and low-flow years are given in the summary. The complete monthly in-flow series is presumably contained in the detailed report in Annex 3 which has been requested as a reference.

The report contains estimates of flood peak rates for various return periods ranging from the 10-yr. flood to the PMF. Design storm data were obtained from AA Obs station with two different storm distribution profiles (details of these are not given in the summary). Losses were computed by the SCS method and regional information from Gerbi dam study was also used. The resulting flood peak rates range from 181 m^3/s (10-yr. flood) through 389m^3/s (1000-yr.. flood) to 1289 m^3/s (PMF) for the most severe storm distribution.

Useful results from this study include the water balance approach employed and the estimation of annual inflows to Geffersa reservoir. The flood hydrology results are also useful as comparison figures.

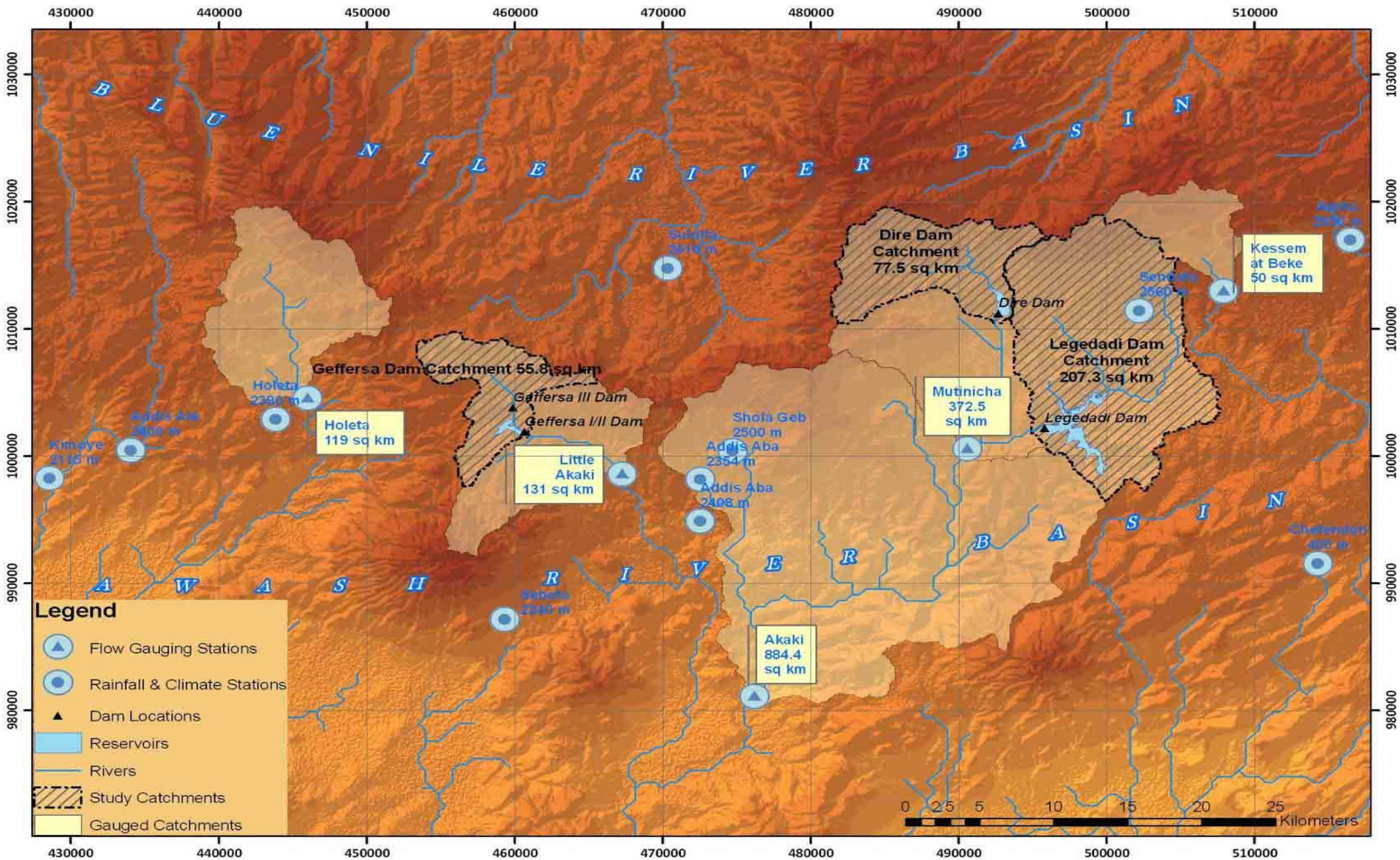


Figure 1: Hydrological map of the broader study area

ii. Consultancy Services for the Increase of Short-Term Availability of Drinking Water for the City of Addis Ababa (Seureca-BRL-TCE, 2010)

This report is concerned with the investigation of options to increase the water harvesting from Dire and Legedadi reservoirs. It contains a very thorough approach of the water balance of both reservoirs, using all available information on spills and bottom outlet operations. There is extensive discussion of the shortcomings of the available data which do not allow the calculation of a reliable water balance at the dams in order to estimate annual inflows. This is mainly due to the lack of adequate information on spill volumes and bottom outlet operations as well as due to the fact that the abstracted volumes are not monitored directly. The WTP production data are also difficult to interpret as the abstractions of both dams are combined in the input.

Despite these shortcomings, the study arrives to an estimate of the annual inflows through assumptions in the water balance components. It also complements the analysis with correlation studies using the Kesem Beke flow station for both dams. The results of the inflow estimation through correlation with Beke amount to a mean annual inflow of 47.7 MCM/yr. for Dire dam (42 MCM/yr. from the water balance) and 94.8 MCM/yr. for Legedadi (83.3 MCM/yr.. from the water balance, using only 4 years of data).

In terms of flood hydrology, the report contains a verification of the flood peak flow rate used for the design of Dire dam (1995). The design flood peak (inflow) was estimated at 570m^3/s for a 10000-yr. return period (the spillway design value is 500 m^3/s after routing the design flood through the reservoir). The report re-estimates the design storm rainfall depth using newer data from AA Obs station and concludes that the statistical estimate is not affected by the inclusion of more recent data. The report then re-estimates the design flood peak of 10000-yr. return period and finds that its value did not change with respect to the dam design report. The final recommendation is to retain the existing design value.

Useful results from this study from the hydrological point of view are the extensive discussion of water balance estimation problems in Dire and Legedadi reservoirs and the provided monthly and annual inflow estimates to the reservoirs. The small amount of data available concerning dam operations in both reservoirs are contained and explained in the report. There is also a very useful discussion of the way the WTP inflows are related to the abstractions of both dams and an approach to estimate total abstractions through the variation of the water level in the dams during the dry period.

The re-evaluation of the design storm rainfall depth and the resulting flood peak flow rate at Dire dam is also useful because it extends the available statistical analysis of AA Obs station annual maximum hourly and 24-hr data to 2009.

iii. Addis Ababa Water Supply Project Stage IIIA. Completion of Detailed Design and Preparation of Tender Documents. Hydrology Report (TAHAL-SMEC-WWDSE-HYWAS, 2004)

This report is not concerned with the three project areas but with revising the hydrologic design parameters for the Sibilu and Gerbi dams in the Blue Nile basin. It is however of interest because it provides an overview of design criteria and accepted methodologies concerning the estimation of hydrologic design values for dam projects in the broader study area. It is also useful with respect to the hydrological data provided, some of which may prove relevant for the purposes of the present project as well.

2.1.3 Master Plan water resources investigations

Summary of Master Plan hydrological investigations

The master plan presents an assessment of potential water resources and of the peak discharges in the three catchment areas in order to introduce quantitative evaluation for purposes of the decision-making process for future planning.

It provides an overview of the available rainfall and flow stations in proximity to the three catchment areas. Flow stations from the Blue Nile basin to the north are also considered. IDF curves for the Addis Ababa Observatory Station are calculated. Statistical analysis of the annual peak daily flows in several flow stations is also provided.

Inflows to the three reservoirs are calculated on the basis of a simple drainage area-annual precipitation-catchment mean elevation ratio method between the dam sites and relevant flow station locations. It is reported that an attempt to use a runoff model did not produce good results because of poor correlation between rainfall records at different stations. The resulting estimate of mean annual inflow for the three reservoirs are as follows: Geffersa 25 MCM/yr. (based on 25 years of data and correlation with Muger flow station), Legedadi 87 MCM/yr. (based on 12yeas of data and correlation with Sibulu basin) and Dire 50 MCM (based on 12 years of data and correlation with Kesem Beke flow station).

Flood hydrology investigations are made to estimate peak flows for different sub-catchments of the three reservoir catchments for return periods between 2 and 100 years. Design storm rainfall data is provided by statistical analysis of the AA Obs station, distributed via the alternating block storm distribution. The SCS method is used to calculate losses and runoff transformation is provided by Clarke's UH method. The resulting sub-catchment flood peaks range from 16 to 124m^3/s for the 10-yr. return period and from 39 to 263 m^3/s for the 100-yr. return period. No attempt was made to route and add the sub-catchment peak flows at the reservoir end of the catchments.

The following sections examine in more detail the hydrological investigations carried out in the Master Plan and provide commentary and directions for further enhancement of the relevant analyses in the context of the present project.

Rainfall & climate

The master plan evaluates the rainfall regime using data from seven (7) rainfall stations in and around the study catchments. The characteristics of the rainfall and climate regime are presented on a monthly basis using data from these stations. The investigations carried out are summarized as follows:

- Presentation of the rainfall and climate regime on a monthly basis, using charts and graphs of the main variables (rainfall, temperature, evaporation).
- An investigation of possible trends in the rainfall regime is carried out through differential mass curves of the annual rainfall data for several stations.
- Evapotranspiration is calculated for the AA Bole Airport climate station by the Penman method.

- A mean annual rainfall isohyetal map is provided on the basis of mean annual rainfall values in all the stations after scaling the mean estimates by correlation of concurrent values with the long record AA Observatory station.
- Mean annual rainfall estimate ranges for the study catchments are provided on the basis of this map.

The results of the above investigations are summarized as follows:

- An overview of the seasonal tropical rainfall regime and its driving factors is derived and presented on the basis of the available data.
- Climate variation in terms of seasonal extremes and range of variation of temperatures, humidity and evaporation is also discussed.
- It is concluded from the trend analysis with differential curves that the rainfall regime shows no signs of significant change over the period covered by the available data.
- The mean annual rainfall range calculated for the three study catchments, estimated on the basis of the isohyetal map provided, is given as:
    - Geffersa catchment: 1,200 – 1,300 mm/yr.
    - Legedadi catchment: 1,000 – 1,250 mm/yr.
    - Dire catchment: 1,230 – 1,300 mm/yr.

On the above investigations and results the following comments can be made:

- It is noted that no attempt is made to assess the quality of the rainfall and climate records. Although a discussion on possible data shortcomings is given (referring to stations located at the existing dams) there is no investigation of possible in homogeneities between stations (e.g. by the double-mass curve technique) nor there is a cross-correlation investigation between stations.
- Missing records and gaps are in filled using the mean monthly value of the respective month. There is a mention of taking into account correlation with neighbouring stations but it appears this is done on the basis of magnitude comparison only. A formal correlation analysis is lacking and would have been useful in this context even if unsatisfactory.
- The scaling of the mean annual rainfall values at the stations using the much longer records of AA Observatory station is a correct procedure. Essentially this is a simple form of record augmentation. There are more advanced record augmentation techniques (e.g. Vogel & Stedinger, 1985; Vogel & Kroll, 1991, improving on the classic procedure by Matalas & Jacobs, 1964) which can also be tried in view of the small number of stations available and in order to obtain long-term estimates of the mean annual rainfall at the stations. They depend however on the correlation between stations in order to substantially improve on the estimated values.
- There is no attempt to establish a relationship between rainfall and elevation over the broader study area; such a relationship is implied in the provided isohyetal map since it depicts a rainfall variation of 400-500 mm over a range of about 800 m in elevation difference.

- The mean annual rainfall estimate over the broader study area (including the three study catchments) can be improved by use of the hypsometric method and using the available digital elevation dataset. The standard hypsometric method consists in dividing the area into elevation zones (say per 100 m) and estimating the average rainfall in each zone by means of the rainfall – elevation relationship derived from the records of the area. Then the average rainfall in each elevation zone is weighted using the ratios of the areal extent of each zone to the total area considered. The sum of the weighted values gives the mean rainfall over the area. The availability of a high-resolution DEM, such as the SRTM DEM available in this case, greatly facilitates these procedures.

  If a meaningful relationship of rainfall with elevation can be obtained from the available data, it can be used to translate the elevation dataset into a mean annual rainfall dataset with the same resolution. Averaging of this derived dataset (to smooth out unrealistic peaks) and then integrating over any closed boundary within the domain (such as the three study catchments and any sub-catchments) would produce mean annual rainfall estimates for all locations of interest. The same analysis can be performed for sub-periods, e.g. the wet period of the year between June and September. Isohyets for the area can also be derived from the rainfall grid by means of spatial interpolation techniques.

The consultant has requested and is in the process of obtaining the data from the Meteorological Service for the rainfall and climate stations listed in Table 3:

These stations are also shown in Fig. 1. They include most of the stations in the master plan and are complemented with other stations that will be used to investigate the hydrology of the study area along the lines proposed in detail above.

Table 3: Rainfall and Climate Stations List.

No	NAME	LAT	LON	ELEV
1	Addis Ababa Obs	9.00	38.75	2408
2	Addis Ababa Bole	9.03	38.75	2354
3	Sebeta	8.93	38.63	2240
4	Sululta	9.18	38.73	2610
5	Kimoye	9.03	38.35	2115
6	Addis Alem	9.05	38.40	2400

7	Sendafa	9.15	39.02	2560
8	Aleltu	9.20	39.15	2550
9	Koremash	9.15	39.25	2660
10	Holeta	9.07	38.48	2390
11	Shola Gebeya	9.05	38.77	2500
12	Chefendonsa	8.97	39.13	2400

The above comments and directions for extending and improving upon the rainfall and climate assessment results and estimations of the master plan will be implemented to the extent possible by the available data in the hydrological investigations of the present project.

Stream flow and inflows to reservoirs

The master plan evaluates the stream flow regime using data from five (5) flow stations in the vicinity of the study catchments. The characteristics of the stream flow regime are presented on a monthly basis using data from these stations.

The investigations carried out are summarized as follows:

- Initially, nine (9) stations are considered for the evaluation of the stream flow regime. Six (6) of these stations belong to the Awash river basin while three (3) belong to the Blue Nile river basin to the north of the project area. After considering the availability of data and other factors – without giving details – the master plan retains for further use only two (2) stations in the Awash river basin (Holeta river and Kessem at Beke stations) and the three (3) stations from the Blue Nile basin (Sibilu, Muger and Deneba stations)
- Presentation of the stream flow regime takes place on a monthly basis, using mean monthly hydrograph charts and monthly time series graphs of stream flow and flow duration curves.
- A statistical analysis of daily peak flow rates is carried out and peak flow rates for return periods from 2 to 100 yr. are estimated.
- Inflows to Legedadi, Dire and Geffersa reservoirs are estimated via a drainage area/mean annual rainfall/mean catchment elevation ratio formula, in other words, through hydrological analogy. The reference sites are the Muger river flow station for Geffersa, the Sibilu river station for Legedadi and the Kessem at Beke station for Dire. These reference sites are selected in each case by a comparison of the geology and soils between catchments, their mean annual rainfall and mean elevations, the dry and wet period monthly flow distribution and the peak daily flow rates estimated previously.

The results of the above investigations are summarized as follows:

- From assessing the availability of flow stations and data it is concluded that stations located outside the Awash river basin in the Blue Nile basin must be used to estimate inflows to Geffersa, Legedadi and Dire dams. In this respect data from stations located downstream of the dams (affected by regulation and diversion of flows) such as Mutinicha and Akaki stations (d/s of Legedadi) and Little Akaki (d/s of Geffersa) are not considered. In particular Little Akaki is not mentioned among the nine (9) stations initially considered.
- The peak daily flow rates for various return periods estimated by statistical analysis range between 17.6 (2-yr.) and 51.2 m^3/s (100-yr.) for the Danebe flow station which has the lowest peak flows and between 92.5 (2-yr.) and 288.0 m^3/s (100-yr.) for the Muger flow station which shows the highest peak flows.
- The assessment of inflows to Legedadi, Dire and Geffersa reservoirs by the hydrological analogy method results in the following inflow estimates: Geffersa 25 MCM/yr. (based on 25 years of data and correlation with Muger flow station), Legedadi 87 MCM/yr. (based on 12 years of data and correlation with Sibulu basin) and Dire 50 MCM (based on 12 years of data and correlation with Kesem Beke flow station).

On the above investigations and results the following comments can be made:

- Regarding the consideration for further use of the available flow stations it is noted that flow stations closely associated with the study catchments (Mutinicha and Akaki flow stations for Legedadi and Dire) are not used in the final evaluations (Little Akaki which is relevant to Geffersa in a similar manner is not mentioned at all). These stations are located d/s of the dams and hence are influenced by their operation. Therefore, in order to use their records, a process of flow naturalisation of the station records could be attempted in each case to produce an independent flow record within the same catchment as the reservoir locations. Available data for Mutinicha and Little Akaki stations range from 1989-2004 and for Akaki station from 1981-2008.

- The master plan makes no attempt to calculate the water balance of the reservoirs at Legedadi and Geffersa. This has been attempted in subsequent studies (see section 2.1.2) and proven difficult because of lack of data on dam operations and spills. However, resolving the water balance for some period of time proved useful if only to verify the order of magnitude of the inflows estimated by other means.

- The hydrological analogy method employed to estimate inflows to the three reservoirs uses the drainage area ratio, the mean catchment rainfall ratio and the mean catchment elevation ratio between the reference sites and the estimation sites. It is curious that the mean elevation ratio is used alongside the mean rainfall ratio since it is usually employed as a surrogate for the mean rainfall ratio (whenever rainfall data are lacking). Perhaps it is intended here as a replacement of the rainfall-elevation relationship which was not specifically investigated as previously mentioned. However, both ratios are largely ineffective in the case of Dire and Geffersa reservoir inflow estimation as can be evidenced by their values given in Table 8.11 of the Master Plan main report: the mean rainfall ratio has a value of 1.0 in both cases and the mean elevation ratio has values of

0.98 and 0.99 respectively. In practice the estimation of inflows for Geffersa and Dire is simply a drainage area ratio between the reference catchment and the reservoir sites. Only for Legedadi the mean rainfall and mean elevation ratios lend some weight in the final calculation (0.92 and 0.93 respectively)

- The resulting mean annual inflow values are reasonable and are also verified by subsequent studies. It has to be noted however, that subsequent studies used the same reference sites in the case of the Geffersa and Dire reservoirs (Muger River and Kessem at Beke stations). The estimate for Geffersa was partially enhanced by resolving the water balance of the reservoir (Tractebel & others, 2002) while the estimate for Legedadi using the reservoir water balance and correlation with Kessem Beke station resulted in about 10 MCM higher mean annual inflow estimation compared with the master plan (Seureca & others, 2010). These approaches were based on correlation between concurrent flows at the reference and estimation sites. Considering the relative ineffectiveness of the rainfall and elevation ratios in this particular case, the correlation approach is preferable because it allows the appreciation of the uncertainty involved with the final estimate.

The consultant has obtained the data (mean daily flows) from the Ministry of Water Resources for the flow gauging stations listed in Table 4. These stations are also shown in Fig. 1.

Table 4: Flow Gauging Stations List.

Code	Name	Description	Available data
31026	Mutinicha	d/s Legedadi dam	1989-2004
31004	Akaki	d/s Legedadi dam	1981-2008
31019	Kesem near Beke	catchment neighbouring Legedadi to the east	1986-2006
31002	Holeta river	catchment neighbouring Geffersa to the west	1975-2009
31021	Little Akaki	d/s Geffersa	1989-2004

Flood hydrology

The master plan evaluates peak flood flow rates for the major sub-catchments of the three study catchments of Legedadi, Dire and Geffersa. The flood flows are evaluated for a range of return periods between 2 and 100 years. The flood estimates are based on:

- Design storm depths resulting from the IDF curve developed for the AA Observatory station for the period 1986-1997. Annual maximum hourly and 24-hr storm data were analysed and IDF curves developed on the basis of modelling with the Gumbel distribution.

- The average intensity for the 100-yr., 10-min duration storm was estimated as 121.8 mm/hr, while the 100-yr., 24-hr duration storm average intensity was estimated as 5.1 mm/hr. The IDF curve based on the data from the station was updated by Seureca & others (2010) extending the record used to 2009. The 100-yr., 24-hr duration storm intensity was found 4.4 mm/hr.
- Rainfall losses were estimated by use of the SCS method. The design storm depth was distributed in time according to the alternating block method. Design storm durations were taken as 3, 6 and 9 hours according to the size of the sub-catchment being studied. Finally flood flows were derived by routing the effective rainfall using Clarke's unit hydrograph method.
- The resulting sub-catchment flood peaks range from 16 to 124m^3/s for the 10-yr. return period and from 39 to 263 m^3/s for the 100-yr. return period. No attempt was made to route and add the sub-catchment peak flows at the reservoir end of the catchments.

On the above investigations and results the following comments can be made:

- The methodologies and approaches employed are standard and appropriate for this kind of estimation. In particular the assumed critical storm durations and rainfall loss CN coefficients according to the SCS method are entirely reasonable.
- The only room for improvement of the calculated peak discharges would be the re-evaluation of flood flows taking into account revised design storm depths from the updated IDF curve for AA Observatory station. However, the IDF update by Seureca & others (2010) resulted in a lower intensity value for the 100-yr., 24-hr storm compared with the one derived in the master plan. Additionally, the re-evaluation of the Dire spillway design flood in the same study, using the updated IDF curve for design storm depth, resulted in a recommendation to retain the existing design flood value since it did not materially change from the previous estimate. It appears therefore that re-evaluation of the estimated flood peak discharges for the particular sub-catchments included in the master plan evaluations is not needed.

2.1.4 Synthesis & directions for future work

Based on the above detailed review of the hydrological investigations included in the master plan and in the subsequent studies of interest that dealt with the study areas of the present project, the following recommendations can be made regarding the hydrological evaluations necessary for the present project:

Monthly and annual inflow estimation into existing and future reservoir(s)

Existing reservoirs

It is clear from the review of all relevant hydrological studies performed within the last 10 years, that the inflow estimation problem for the existing reservoirs of Legedadi, Dire and Geffersa was universally approached in two ways: (a) attempt to resolve the water balance of the reservoir to back-calculate inflows and (b) correlating the reservoir sites with hydrologically similar gauged catchments in the broader area, either by hydrological analogy (drainage area ratio methods – the master plan's method of choice) or by direct correlation of concurrent runoff values recorded at nearby stations. Both approaches were used for all three reservoirs with varying results. The water balance method finally contributed 17 years of inflows (out of 36) for Geffersa (Tractebel & others, 2002), 8 years (out of 23) for Dire and 4 years (out of 23) for Legedadi (Seureca & others, 2010).

It is also clear from all the reports available that the water balance approach, even if partially successful, is fraught with uncertainties and difficulties which arise out of the lack of essential data on dam operations – most importantly spills. Bottom outlet operations are only partially recorded and then only in terms of approximate duration of gate opening. Abstractions are not measured and the only way to estimate them is through the water production data at Legedadi WTP. These however concern abstractions from both Legedadi and Dire dams after 1999, introducing further uncertainty. No inflow data to the reservoirs are directly kept. Therefore, inflow series indirectly estimated from a reservoir water balance exhibit relatively high uncertainty.

Given the above data shortcomings and the fact that the recent studies utilized all available data to establish the reservoir water balance, it is concluded that it is not useful to expend any further effort towards this end. The available water balance estimates (17 yrs. for Geffersa, 8 yrs. for Dire [1986-2008] and 4 yrs. for Legedadi [1999, 2001, 2006-2007]) will be used.

For Geffersa, only an extension of the water balance calculation to cover the remaining years to 2010 should be attempted based on examination of the methodology by Tractebel & others (2002). Their detailed report (Annex 3 of the Final Report) is unavailable at this moment; if made available; the procedure used will be evaluated and used to extend the calculation. This will result in a 44-yr. long monthly inflow time series to Geffersa reservoir (which can also be checked by correlation with nearby flow stations). For Dire and Legedadi, the most reliable estimates were made recently in the Seureca & others study (2010) for both dams.

To improve upon the estimation of the inflow series at the existing reservoirs there are several options which seem to have not been attempted by previous studies. A naturalisation of the flows registered in the available flow stations downstream of the dams (Mutinicha and Akaki for Dire and Legedadi and Little Akaki for Geffersa) could be attempted. This exercise has not been attempted before for reasons unknown, since all studies do not even mention the downstream stations (the master plan considers Akaki and Mutinicha but ultimately does not rely on them). If successful, a monthly water balance model could be calibrated for these stations (if rainfall and evaporation data allow so) and its results applied to the three dam catchments in order to estimate inflows from a different angle.

Future reservoirs

Simple correlation and analogy methods to estimate inflows at potential sites upstream of the existing three dams would be a reliable choice if an inflow series of sufficient length and quality was available at each of the three existing dam sites. If available, such a series would represent the total outflow at the downstream end of the catchments of interest allowing the use of hydrological transfer methods to other upstream sites. This could be accomplished by means of hydrological analogy using a naturalised flow series at one of the downstream flow stations or by a monthly water balance model calibrated against these flows, if such a model proves feasible. The study of previous hydrological studies conducted in the project areas, reveals that this latter approach was attempted though never followed due to sparse data (on a spatial scale) and data shortcomings and inconsistencies. Instead, all studies so far used simple correlation and analogy methods to estimate inflows at the three reservoir locations of Geffersa, Legedadi and Dire in addition to whatever information could be furnished by a water balance calculation of the reservoirs. The consultant shall however investigate all options of estimating the inflows to potential reservoirs before arriving at a documented approach

For single-purpose potential reservoir sites designed for water storage or dual-purpose dams having a water storage component, monthly and annual inflow patterns have to be established. These inflow series should be of a long duration (preferably 30 years or more) for a reliable calculation of expected annual inflows with specific probabilities. The inflow series will be used to simulate the reservoir operation in order to assess the reliable yield from the reservoir and to identify operational parameters such as spilling frequency and volumes.

Flood hydrology studies to determine design flood peak flow rates for spillway design and diversion works.

Return periods for the design spillway floods will be proposed based on examination of International Standards depending on the proposed dam size and conditions downstream and will be discussed with the Client before arriving at a final decision. International Standards to be consulted will be the Australian (ANCOLD), British (ICE), U.S. (USACE) and French (CEMAGREF) standards. The final spillway design value will be determined after routing the design inflow through the reservoir. It is anticipated that a range of return periods will be calculated between 10 and 10.000 years, as well as the PMF (Probable Maximum Flood) if deemed necessary for certain projects.

The design floods for small return periods (up to 200 - 500 years) may be calculated via statistical analysis of the maximum annual peak record. Since only daily flow data are available, the analysis must be based on maximum daily peaks scaled to represent the instantaneous peak. Design floods for higher recurrence intervals will be calculated with the unit hydrograph method. Synthetic UHs must be formulated in the absence of small time scale flow information. Methods employed in previous studies in the project area proven to be suitable will be given priority. Design storm rainfall depths are already available from statistical analysis of annual maximum rainfall in recent studies (SEURECA & others, 2010)

Reservoir sedimentation

Sediment load carried into the potential reservoirs will be calculated on the basis of information from the bathymetric surveys of Geffersa and Legedadi dams. Rates of sedimentation in these reservoirs will be representative of conditions within the dam catchment. If particular differences in soil texture and composition or land use and farming practices are observed, the estimation will be modified according to the conditions of each potential reservoir location. If AAWSA proceeds in the analysis of the composition of the sediment in the reservoirs as proposed in chapter 1.5 of this report, the reservoir sedimentation estimations could probably become more accurate.

Reservoir operation in cascade

The potential reservoir locations are located upstream of the existing reservoirs of Legedadi, Dire and Geffersa. One potential location is located downstream of Dire dam. In all of these situations, the Client has emphasized the need to examine the joint operation of future and existing reservoirs. In case of new reservoirs developed upstream of the existing ones, care must be taken so that the downstream existing reservoirs are filled by priority during the wet season since it is they that feed the WTPs. In case of new reservoirs downstream of existing dams, the amount of storage and the time to reach FSL given that flows are abstracted upstream should be carefully investigated to optimise storage and minimise spills.

These issues will be investigated after the new reservoir locations have been finalised with the use of a proper mathematical model specifically suited to simulate joint reservoir operations. Such a model would be able to impose restrictions and operational rules to each reservoir while simulating the full water balance. The choice of model will be determined after the reservoir characteristics are finalised. Appropriate models may be HEC-HMS (for simple cases), HEC-ResSim (for complicated cases) and MIKE BASIN (for detailed modelling of reservoir operations).

2.2 HYDROGEOLOGY

2.2.1 General

Large scale groundwater development practices in Ethiopia were not widespread enough until the last three years, when a different approach was endorsed mainly by AAWSA, regarding firstly the examination of groundwater potential in areas near Addis Ababa. This examination procedure was materialized through contracts for regional hydrogeological studies and contracts of consultancy services on groundwater development. Unlike the 2000 Master Plan time period, where groundwater development was unorganized and random, these last years are characterized by a more systematic work in order to integrate groundwater stocks into the daily water consumption.

2.2.2 The 2000 Master Plan Data

Most of the data concerning abstractions of groundwater are included in Annex II of the 2000 Master Plan, in the "Rural Water Supply" chapter.

Existing Water Abstraction

<u>Legedadi and Dire Catchment Areas</u>

In these basins, it is clearly mentioned that population (human and livestock) consumes water from a small number of wells and springs. Two different types of wells have been monitored: shallow wells for the rural areas and deep wells for the urban centres like Sendafa, Legedadi and Dire towns. Technical characteristics of those water abstraction points are the following:

1. Shallow wells (rural areas): Hand pumps, 8 hours per day operation, range from 30 to 50 m depth and 0.8 to 1.2 l/s yield.
2. Deep wells (urban areas): 16 hours per day operation, range from 100 to 200 m depth and 1.5 l/s yield.

The data collected for the needs of the 2000 Master Plan gave the following results regarding groundwater abstraction in these basins:

1. Two (2) springs with 1.0 l/s yield each producing 36m³/d water, based on 10 h/d abstraction.

2. Twelve (12) shallow wells with cumulative yield of 12 l/s producing 345.6m³/d water, based on 8 h/d abstraction.
3. Five (5) deep wells with cumulative yield of 7 l/s producing 403.2m³/d water, based on 16 h/d abstraction.
4. The total abstraction from all sources reached 790 m³/d of water (rounded figures).

Geffersa Catchment Area

According to the Master Plan the population in the catchment (human and livestock) consumed water from a smaller number of wells and springs than the Legedadi-Dire area. The data collected and presented in the Master Plan gave the following results regarding groundwater abstraction in this basin:

1. Five (5) springs/wells with average 1.0 l/s yield producing about 150 m³/d water, based on 8 h/d abstraction.

Existing Water Consumption and Demand Estimates

According to the 2000 Master Plan, domestic demand was estimated at 25 l/c/d and the projected demand for the year 2010 was estimated at 35 l/c/d for potable water. The livestock demand was estimated at 30 l/TLU/d for 1999 and 40 l/TLU/d for the year 2010. In the following phases of this contract it will be defined if these numbers are still valid or if they have to be adjusted accordingly.

Existing Water Demand

Legedadi and Dire Catchment Areas

Estimations presented in the 2000 Master Plan resulted in the following:

a. Potable water demand for 31,000 people was estimated at 780m³/d.

b. Livestock water demand for 21,250 TLU was estimated at 630m³/d.

c. Future potable water demand for 43,000 people was estimated at 1,500m³/d.

d. Future livestock demand for 23,400 TLU was estimated at 920m³/d.

Geffersa Catchment Area

Similar estimations in the 2000 Master Plan resulted in the following:

e. Potable water demand for 7,125 people was estimated at 180m³/d.

f. Livestock water demand for 4,180 TLU was estimated at 180m³/d.

g. Future potable water demand for 9,900 people was estimated at 340m³/d.

h. Future livestock demand for 6,300 TLU was estimated at 250m³/d.

Existing Water Deficit

From the figures given above, it is clear that even at 2000, there was a water deficit between daily demands of the people and their livestock and abstraction capabilities from all kind of water sources. Specifically:

1. The 790 m^3/d of total water abstraction in the Legedadi – Dire area could marginally cover only the human population demand (780 m^3/d), with no water availability for the livestock needs and
2. The 150 m^3/d of total water abstraction in the Geffersa area could not even cover the human population demand of 180m^3/d.

The water deficit is probably the main reason of settler's concentration around the reservoirs and it is within the scope of the present project to define if this deficit exists today in absolute numbers or if it has been decreased and how.

The 2000 Master Plan Proposals

The 2000 Master Plan presented proposals to increase the numbers of wells based mainly on the performance of the existing shallow wells. These new wells appeared to provide an adequate solution for rural water supply. The lack of hydrogeological information has been recognized in the Master Plan. Generally, except for Sendafa and Legedadi towns, shallow wells were recommended to discourage concentration of settlers around the reservoirs. Shallow wells coupled with water troughs were recommended to supply livestock needs. The proposed spatial distribution of water points were designed to ensure a maximum distance of 2 km between them.

More specifically, proposals for increasing the number of shallow wells included:

1. Construction of 26 new shallow wells and 1 new deep well in the Legedadi and Dire catchment areas by the year 2010 and
2. Construction of 6 new shallow wells in the Geffersa catchment area also by the year 2010.

Cost estimates were made for all proposed rural water supplies facilities and the implementation plan was that the first wells should be constructed near the existing reservoirs. This implementation in combination with the "Buffer Zone" fences should mitigate the pollution problem. As per our field visit in all three reservoirs, none of the above measures has been implemented till today.

Conclusions

The review of the 2000 Master Plan overall rural water supply status and proposals supported the assessment that the proposals for the new shallow or deep wells were not the result of a hydrogeological study but were mainly based on land planning criteria.

The minimum distance considered between water points (2 km) is not based on the influence radius of existing shallow wells and it seems to be more of a random spatial criterion without hydrogeological scientific basis.

The distinction between shallow wells for rural and deep wells for urban areas is not thoroughly explained and it is probably proposed following the criterion of population concentration. Also it is not explained why one deep well that can supply several villages is not more preferable from several shallow water points. The productivity of proposed new wells is not supported with hydrological analysis.

This part of the 2000 Master Plan must be revised and new data of existing water points and their type of operation must be collected. The new data with the use of the more recent studies presented in the next chapter should give a more clear picture about the groundwater potential of the catchment areas and how aquifers react to the abstractions.

It is noted here that potential impacts on population density trends arising out of proposed water supply works will be carefully taken into account and the water supply plan will be adjusted in order to be harmonised with the provisions of the Oromia Regional Planning study.

The engineers of the study team of this contract responsible for the water supply task will collaborate very close with the Hydrogeologists in order the water supply requirements as will be estimated from this study will be mainly covered by the ground water potential of the catchments following and the requirements of the Terms of Reference of the Contract.

2.2.3 Recent Hydrogeological Studies

More recent hydrogeological reports were collected from the Consultant. These new data were acquired from the Geological Survey of Ethiopia (department of the Ministry of Mines), the Ministry of Water Resources, the company Water Works Ltd, AAWSA and the Oromia (FinFinne) Study. There are still some data to be collected as soon as the new test wells are completed so the evaluation of the recent studies will be made at the following contract phases.

From the Geological Survey of Ethiopia, the following data were collected:

1. The official Geological Map of Ethiopia in scale 1:2,000,000 and the relevant report.
2. The official Hydrogeological Map of Ethiopia in scale 1:2,000,000 and the relevant report.
3. The official Geological Map of Addis Ababa in scale 1:250,000 and the relevant report.
4. The official Geological Map of Debre Birhane in scale 1:250,000 and the relevant report.
5. The official Hydrogeological Map of Addis Ababa in scale 1:250,000 and the relevant report.

From the Oromia (FinFinne) Study, the geological map of the study area was acquired in scale 1:100,000. It is the most detailed geological map and a very significant tool in order to understand the geology of the three catchment areas of the present study.

Along with the Oromia (FinFinne) Study, a regional Hydrogeological Study was conducted. The title is: «*WWDSE Evaluation of Ada'a and Becho Plains Groundwater Basins for Irrigation Development Project*», M.O.W.R., Addis Ababa, 2008.

Based on the a.m. study, the «Addis Ababa Water Supply and Sanitation Development and Rehabilitation Project Office» had procured the: «Addis Ababa Groundwater Development, Design and Construction Supervision Project» which includes the development of 40 deep wells in five (5) well fields. The Consultant awarded with this contract is Water Works Ltd, a local Ethiopian company. During the visit in the company's offices, we obtained the following studies:

1. The «Final Report - Well Accomplishment Report of Production wells in Ada'a & Becho Plains Drilled 2010-2011»,
2. The «Completion Report of Well LLA-1 at Legedadi-Legetafo Prospective Area» and
3. The «Completion Report of Well LLA-2 at Legedadi-Legetafo Prospective Area».

Also from AAWSA and for the same project, we collected the «Addis Ababa Groundwater Development, Design and Construction Supervision Project (40 Deep Wells) - Inception Report (Final)», submitted on March 2009 and approved by the Service. From Water Works Ltd, we have recently obtained the report for well LLA-3 and we are expecting the report for well LLA-4 in the same Legedadi catchment basin.

Finally from the hydrogeological department of AAWSA, we collected three drilling reports for small wells downstream of the Geffersa reservoir. All the above documents and data are currently under evaluation.

3. ENGINEERING WORKS FOR SEDIMENTATION AND WATER HARVEST

3.1 AN OVERVIEW OF THE FINDINGS OF THE 2000 MASTER PLAN

3.1.1 Soil Erosion and Reservoir siltation

A detailed assessment of the findings of the 2000 MP with regard to soil erosion and reservoir siltation is provided in chapter 1 of Part II. Here we summarize the core findings as follows:

- The average annual siltation rates in the reservoirs from the total catchments area are in the range of 45,000 – 135,000 m^3/year for Geffersa and Legedadi reservoirs respectively.
- These results translate to equivalent sediment yields of 1198 t/km^2/yr. for the Geffersa catchment and 762t/km^2/yr. for the Legedadi catchment.
- There is some uncertainty around the sediment yield figures as the sediment mix composition in the reservoirs is not known and hence the true sediment density cannot be directly calculated. However the sediment yields estimated are well within the range of values encountered in other similar studies of the broader region and can be considered reliable.

The possible means for reducing reservoir siltation rate according to the 2000MP are:

- Developing buffer strips including protection canals.
- Construct small silt traps.
- Bypass extreme muddy floods downstream.
- Regulate rivers.

3.1.2 Increasing the Water Harvest.

The mean annual water inflow to the water supply reservoirs in the three catchments was calculated in the 2000 Master Plan to be approximately 160 MCM with a deviation range of ± 30 MCM in dry and wet years. The detailed review of the Hydrology of the 2000 MP is given in chapter 2 of Part II of the present report. In general we can say that the hydrological results are accurate and possibly a little on the conservative side and in any case they could form the base for the proposals of the 2000 MP to increase the water harvest.

According to the findings of the 2000 Master Plan the average water yield of the three catchments is:

- Legedadi (207.3 km2): 86 MCM
- Dire (77.5 km2): 50 MCM
- Geffersa (55.8 km2): 25 MCM
- Total (340.6 km2): 161 MCM

The expected overflows from the three reservoirs have been estimated as follows (Table 5):

Table 5: Estimated water surplus per catchment by the 2000 MP.

Catchment	Average	Maximum	Minimum
Legedadi	27 MCM	42.4 MCM	10 MCM
Dire	23.5 MCM	32.9 MCM	14.7 MCM
Geffersa	12.5 MCM	17.9 MCM	8.1 MCM
Total	63.0 MCM	93.2 MCM	32.8 MCM

The conclusion of the MP is that although there may be a lack of storage facilities in the catchments, there is no lack of water and on average 63 MCM/year spills from the reservoirs and even in extreme dry years about 33 MCM will overflow from the reservoirs.

Although there is some consideration on how the overflows from the reservoirs have been calculated since the available data do not seem to be sufficient for reservoir simulations at least for the Legedadi dam, we can accept that there is a considerable volume of overflows which support the proposal of investigating the possibility of constructing additional dams to increase water harvest and also help in reducing the sediment load in the three main reservoirs.

3.2 DUAL PURPOSE SEDIMENT TRAPPING RESERVOIRS PROPOSED BY THE 2000 MP

3.2.1 General

The 2000 Master Plan proposed the construction of silt/sediment traps in the form of small and medium size reservoirs at strategic sites to assist in reducing sedimentation, as well as harvesting additional quantities of water. The dams will prevent large part of the sediments from entering the reservoirs, thus lengthening their life span and at the same time increasing water harvesting efficiency.

According to the MP the silt traps should be designed to intercept the first floods which contain the main portion of the suspended soils and should have an adequate bypass canal to enable at the same time bypassing of late flood events. Intercepting the first floods will also delay the build-up of turbidity in the early rainy season and will result in immediate alleviation of the coagulation process in the treatment plants.

In Table 9.3 of the Main Report of the 2000 Master Plan the calculation of the specific sediment yield is presented. This calculation is supposed to be based in sediment density of 1.45t/m^3. But the figures given in the table do not match with the calculation. Some of the specific yields have been calculated with a specific density close to 1.0 and some less than 1.0. It is obvious that a mistake has occurred here so the sediment yields presented in the table are ignored in this report.

We will use for the calculation of the specific sediment yield the figure of 1.24t/m^3 which was the result of an analytical calculation conducted recently by the Consultant (Z&A) in a similar assignment in Kenya, in an area with similar soil types as the ones in the catchments under study. The calculation takes also into account the catchment areas calculated by the updated catchment delineation (see chapter 2).

The specific sediment yields for each catchment are presented below (Table 6):

Table 6: Catchment sediment yields

Catchment	Area (km^2)	Annual sediment accumulation (m^3/year)	Specific sediment yield (t/km^2/year)
Legedadi 1998-2010	207.3	135,000	808
Legedadi 1979-2010	207.3	120,000	717
Geffersa I/II before 1966	55.8	46,000	1022
Geffersa I/II after 1966	21.4	22,000	1275 (*)
Gefersa III	34.4	24,000	865
Dire	77.5	77,000	1232

(*) influenced by Geffersa III; see text.

The above specific sediment yields are within the range estimated by other similar studies within the region (Central and East Africa) E&H 2001, HR Wallingford 1981-1983, Bobotti 1988, Z&A 2010. Prof. Des Walling in the E&H 2001 study for the Upper Tana catchment in Kenya expressed the expert opinion that the specific sediment yields should lie between 1,000 and 1,500 t/km^2/year.

The specific sediment yields presented in the above table indicate that soil erosion in the Legedadi is not that significant as estimated also by the 2000 MP, while it is increased in the Geffersa and Dire catchments.

The high figure for Geffersa I/II after the commissioning of Geffersa III is probably due to the fact that some part of the sediment loads entering Geffersa I/II spill from Geffersa III (probably the finer clay fractions of the sediment mix). So the annual sediment inflow to Geffersa I/II cannot be solely attributed to the remaining catchment area draining directly into the reservoir as is assumed in Table 3.2. This can be resolved only by calculating the sediment budget of the two reservoirs in conjunction which requires data on the volume of water passed from Geffersa III to Geffersa I/II.

We will examine below the dual purpose sediment traps for each catchment.

3.2.2 Geffersa Catchment dual purpose reservoirs.

In 1966 the Geffersa III dual purpose dam was commissioned mainly to act as a silt trap but also to increase the water harvest of the catchment. As already mentioned the new reservoir managed to reduce to about half the sediment load entering the Geffersa I/II main reservoir.

The Geffersa I dam was built in 1943, basically as a 10 m high masonry gravity dam. Most of the dam was a free overflow spillway, the ogee shape of which was suitable for a maximum head of 1.40 m.

In 1955 and 1956 the dam was raised by 6 m. For the overflowing section (total length 148.67 m), the top of the ogee masonry crest was cut back to provide a 2.5 m wide platform on which to build an 8 m high concrete wall. The dam since the raising was renamed to Geffersa I/II.

The Geffersa III commissioned in 1966 is an earth fill structure about 15 m high. There is a bottom outlet of concrete pipes with control gates downstream. Information given in former studies indicates problems in the pipes during internal pressure and adjustments in the construction became necessary after impoundment. The spillway is in the left bank and it is of un-gated surface type.

In 2000 AAWSA awarded the J/V of Tractebel Development Engineering and Coyne et Bellier the contract of Rehabilitation of Geffersa Dams and Water Treatment Plants.

The scope of the Study was:

- To determine the reservoir capacities and the full supply levels for Geffersa dams in order to ensure meeting the water demand for the 2020 horizon;
- To define spillway options for discharging the reviewed floods as part of the hydrological studies;
- To assess the dams stability with the new elements and define options for ensuring the dams safety;
- Evaluate the costs of the alternatives; and
- Select spillway and dam reinforcement options to be tender for construction.

The study has shown that two main groups of rehabilitation alternatives may be envisaged to reliably meet the raw water demand of 30,000m^3/day to the target year of 2020.

- The first group (group A) consists in abandoning Geffersa III dam or by maintaining the state of the dam as it is, with some minimum rehabilitation works taking the risk of a dam break.

- The second group (group B) consists in rehabilitating fully Geffersa III, and increasing the reservoir level at Geffersa I/II to El. 121.50.

Six alternatives of group A were examined. The most favourable which was the proposal of the study included the following:

- The full supply level of Geffersa I/II is equal to the maximum water level;
- New gated spillway for Geffersa I/II with a capacity of 490m^3/s;
- The intake tower of Geffersa I/II is rebuild;
- Concrete dam reinforcement for the Geffersa I/II dam
- Geffersa III capacity is maintained;
- An intake tower for Geffersa III was proposed with axes by a boat.
- Minor rehabilitation for the Geffersa III with the main one to be the placing of a toe shoulder downstream.

The works proposed by the study were tendered and constructed; all the rehabilitation works finished by 2009. The pictures below present the Geffersa I/II and Geffersa III as they operate today.

The Geffersa I/II dam after recent renovation works.

The Geffersa III dam with the new tower intake

The 2000 Master Plan proposed the construction of silt/sediment traps in the form of small and medium size reservoirs at strategic sites to assist in reducing sedimentation, as well as harvesting additional quantities of water. The dams will prevent large part of the sediments from entering the reservoirs, thus lengthening their life span and at the same time increasing water harvesting efficiency.

The Master Plan proposed the construction of three dual purpose reservoirs in the Geffersa catchment: at the Menjaro sub catchment (ID: 12), the Menjaro – Dima sub catchment (ID: 13) and the Guje Kersa sub catchment (ID: 14). The basic characteristics of the three proposed dams according to the Master Plan are given in the following Table 7. The location of the proposed dual purpose dams is presented in the following map of the Geffersa catchment as Fig. 2. Photographs of the proposed dam locations are presented in Appendix I.

Table 7: Proposed dams and silt traps in the Geffersa catchment (2000 MP data)

ID Number	Sub-catchment	Sub-catchment area (km^2)	Reservoir volume (MCM)	Years to total Siltation	Cost (M Birr)
12	Menjaro	22.4	1.7	>40	24.2
13	Manjaro / Dima	-	2.5	>32	35.5
14	Guje kersa	6.5	1.5	>40	21.3
Total		**28.9**	**5.7**		**81**

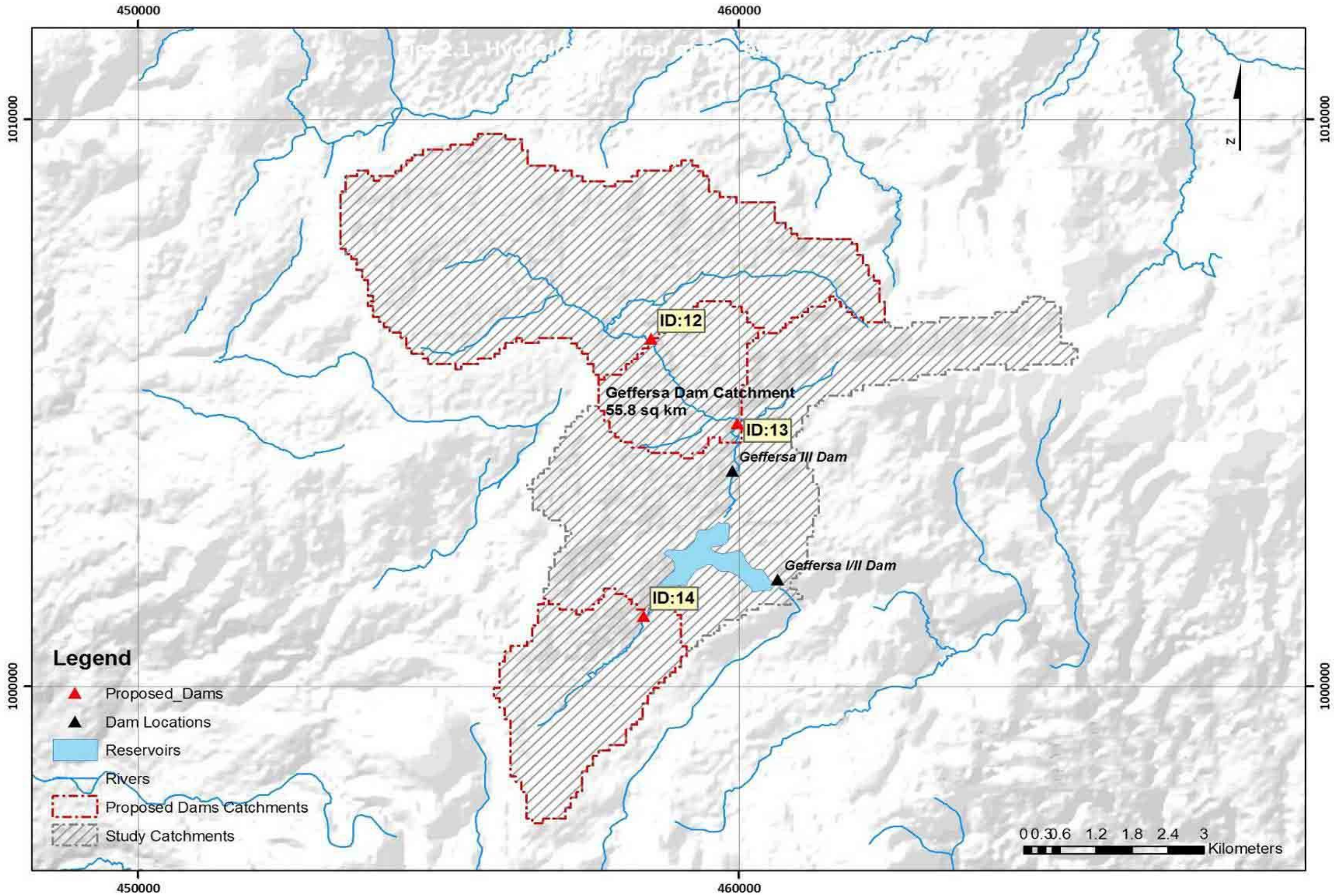


Figure 2: Drainage areas of dams proposed by the 2000 Master Plan Geffersa dam catchment

Table 8: Proposed dams and silt traps in the Geffersa catchment (this study)

ID Number	Sub-catchment	Sub-catchment area (km^2)	Mean Elevation (m)	Max Elevation (m)	Min Elevation (m)	Mean Relief Slope (%)
12	Menjaro	23.4	2704.6	2824.0	2646.0	4.4
13	Manjaro / Dima	4.9 (28.3 total)	2659.5	2716.0	2610.0	5.0
14	Guje kersa	7.6	2616.8	2679.0	2585.0	4.4
Total		**35.9**				

No 12. On the Menjaro Catchment

A very good location for the construction of a storage dam which will also operate as a silt trap, the small width of the gorge offers a good site for the dam axis. Upstream of the gorge the valley opens and a reservoir with significant capacity can be expected. The effect of the reservoir to the surrounding villages has to be checked in order to determine the crest elevation. If allowed, the dam crest can be raised even higher than the top of the gorge. The foundation conditions are very good and the bed rock is visible in both embankments and the river bed. The proposed site is very favourable for the construction of a large dam and should be investigated further.

Initial examination of the site on the available topographical maps indicates the following characteristics of the proposed dam:

Crest elevation: +2660 m

Crest Length: ~ 255 m

Dam height: ~ 25 m

Reservoir volume: ~ 11 MCM

It should be noted that because of the large scale topographical information available at this stage, these figures are only approximate and will be established accurately in the Feasibility Stage.

No 13 On the Menjaro / Dima sub-catchment

The dam is proposed at the tail of the Geffersa III reservoir. The Geffersa III dam constructed as a silt trap for the Geffersa main dam still has a considerable volume capacity. If the proposed new dual purpose dam is to store additional water volume it should be much higher than the existing Geffersa III.

The dam must have a very long crest which will increase the dam volume and the construction cost. Additional to the above the very narrow valley upstream the proposed dam axis is not favourable for creating a significant reservoir.

Probably only a small simple silt trap made of gabions could be considered here if its sediment trapping ability justifies its construction. This has to be investigated during the Feasibility stage.

No 14 On the Guje - Kersa sub catchment.

The proposed location is at the tail of the main Geffersa reservoir. The area is very flat and not suitable for the construction of a dam. Only a very low simple silt trap could be proposed. Even this has to be carefully examined in order not to flood the road to Addis upstream.

3.2.3 Legedadi Catchment dual purpose reservoirs.

The Master Plan proposed for the Legedadi catchment two categories of dams. The first one includes three dams proposed to act as dual purpose silt trap reservoirs. The second one includes eight dams proposed to increase the water storage. The basic characteristics of the proposed dams according to the Master Plan are given in the following Tables 3.5 and 3.6. The Legedadi reservoir and the 11 proposed dam locations in the 2000 Master Plan are presented in the following map in Fig. 3. Photographs of the dam locations taken during the site visits are presented in Appendix I

Table 9: Proposed dual-purpose dams in the Legedadi catchment (2000 MP data)

ID Number	Sub-catchment	Sub-catchment area (km^2)	Reservoir volume (MCM)	Years to total Siltation	Cost (M Birr)
9	Sekoru + Fule	50	1.0	>35	19
11	Sendafa + Bolo	80	2.8	>50	22
16	Lege Beri	22	1.0	>55	18
Total		**152**	**4.8**		**59**

The above estimations for the years to total siltation were based on the bathymetric surveys conducted in 1998 and the assumption that the trap efficiency of the silt traps will be in the 75 – 90% range.

Table 10: Proposed water storage dams in the Legedadi catchment (2000 MP data)

ID Number	Sub-catchment area (km^2)	Reservoir volume (MCM)	Years to total Siltation	Cost (M Birr)
1	10.5	1.7	>30	24
2	15.5	1.2	>30	17
3	21.4	1.3	>30	19
4	22.8	1.7	>30	24
5	9.7	1.2	>30	17
6	33.2	1.7	>30	24
7	23.3	1.6	>30	23
8	18.8	1.5	>30	21
Total	**155.2**	**11.9**		**169**

The above estimations for the years to total siltation were based on the sediment yield figure of $537m^3/km^2/yr$.

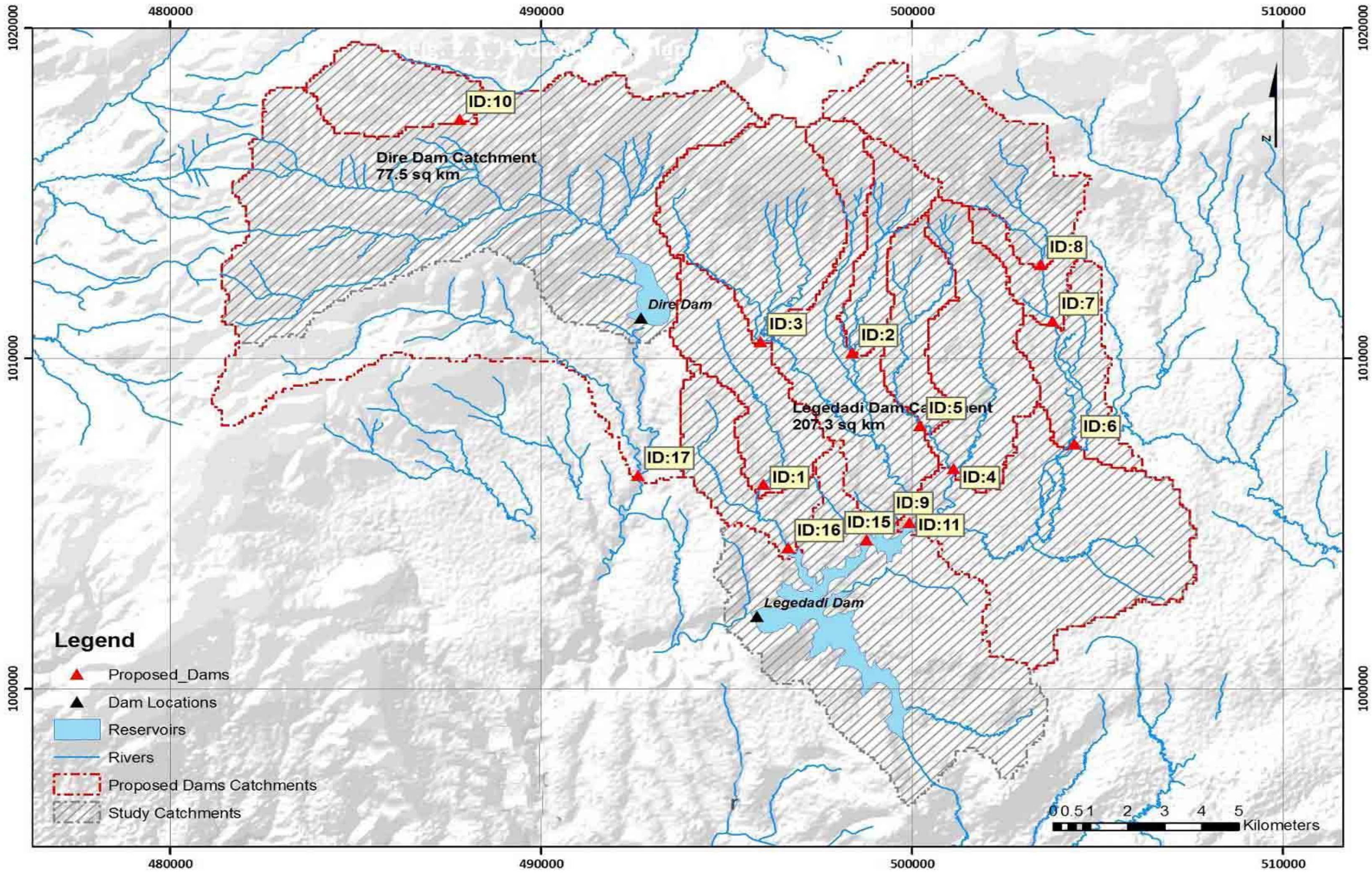


Figure 3: Drainage areas of dams proposed by the 2000 Master Plan Legedadi and Dire dam catchments

Table 11: Proposed dual-purpose dams in the Legedadi catchment (this study)

ID Number	Sub-catchment	Sub-catchment area (km^2)	Mean elevation (m)	Max Elevation (m)	Min Elevation (m)	Mean Relief Slope (%)
9	Sekoru + Fule	19.9 (49.4 total)	2593.1	3211.0	2449.0	6.3
11	Sendafa + Bolo	33.3 (91.2 total)	2509.7	2537.0	2451.0	1.8
16	Lege Beri	9.2 (21.9 total)	2496.0	2542.0	2453.0	2.8
15	Strait dam	140.6	2538.9	3211.0	2449.0	3.4
Total		**162.5**				

Table 12: Proposed water storage dams in the Legedadi catchment (this study)

ID Number	Sub-catchment	Sub-catchment area (km^2)	Mean elevation (m)	Max Elevation (m)	Min Elevation (m)	Mean Relief Slope (%)
1	Lege Beri	12.7	2523.5	2591.0	2471.0	3.1
2	Nya-a	7.2	2662.7	3175.0	2525.0	10.3
3	Doyo	22.3	2692.2	3214.0	2530.0	11.5
4	Kultubi	16.5	2546.8	2786.0	2497.0	3.9
5	Sekara	8.2	2557.2	2724.0	2507.0	4.1
6	Sendafa	9.7 (33.2 total)	2528.2	2591.0	2508.0	2.0
7	Sendafa	4.2 (23.5 total)	2577.3	2729.0	2528.0	4.7
8	Lege Jila	19.3	2849.8	3226.0	2557.0	16.1
Total		**100.1**				

Dual Purpose Silt Trap Reservoirs

No 9. Sekoru and Fule sub catchments.

The silt trap is proposed to be constructed inside the Legedadi reservoir where the Sekoru tributary discharges in the lake. The surrounding area is extremely flat.

The proposed dam height is around 20 m. For that height a dam with a very long crest is required. Due to the large size of the dam structure it is estimated that it will not be possible to be completed within a single dry period. That will result in increased costs because of the required diversion works. The location of this dam requires that the design flow for the spillway should be calculated with a return period close or very similar with the one used for the design of the spillway of Legedadi dam. This will be an additional reason for increased cost of construction. Considering the small storage capacity of the reservoir that will be formed plus the operational implications for the operation of Legedadi this location does not seem very favourable for the purposes of a silt trap since the cost will be high compared with the expected benefits.

No 11. Sendafa and Bolo sub catchments.

This silt trap reservoir is proposed at another edge of the Legedadi reservoir where the Sendafa and Bolo rivers meet. A long crest dam could be proposed here. The two hills on the two embankments could support the construction of a dam. The hill on the left is higher than the one at the right but a 10 to 15 meters dam could be discussed.

Initial examination of the site on the available topographical maps indicates the following characteristics of the proposed dam:

Crest elevation: +2480 m

Crest Length: ~ 480 m

Dam height: ~ 10-15 m

Reservoir volume: ~ 2.7 MCM

The construction of a dam here with a height of about 15 m will create a reservoir with a capacity similar to the one proposed by the Master Plan. There is a possibility, which needs to be carefully examined, that the construction of a dam with a height of about 30 m could result in creating a large reservoir which could increase significantly the volume of the Legedadi reservoir. The effects to the villages and the population living near the reservoir have to be carefully examined.

In this case, as in no. 9 above, the diversion works and the spillway will have to be designed for a significant flood and this will increase the cost of construction. Furthermore the operational implications with Legedadi immediately downstream will need special consideration.

No 16. Lege Beri sub catchment.

The dam axis is proposed inside the reservoir where the Lege Beri River discharges into the lake. The area is very flat especially at the left embankment while on the right there is a very small hill. It is definitely not a favourable location for the construction of a dam. More likely development for this location is a small and simple silt trap constructed with gabions inside the river bed to retain some of the sediment. However, further evaluation must be made in the Feasibility stage considering the amount of sediment trapped and the life expectancy of a structure at this location.

No 15. The Legedadi strait Dam

The Legedadi strait dam has been proposed by the 2000 Master Plan to increase the impounding capacity of the Legedadi reservoir by damming the natural constriction (Legedadi Strait) in the north eastern part of the Legedadi reservoir. It is discussed here with the other proposed dams in the vicinity of the existing reservoir (No 9, 11 and 16) because although it is not a typical dam it nevertheless has the same purpose as the aforementioned, i.e. a large structure immediately upstream of the existing reservoir meant to capture sediment loads before they enter the main reservoir and increase its water storage. Its catchment area is approximately equal to the sum of the catchments above the no. 9 and 11 locations, i.e. 140.6 km^2.

This particular proposal is based on the following: the area of the water surface at normal water level is about 0,5 km^2 according to the 1998 bathymetric survey. Raising the water level to the east of the proposed dam would increase the impounded volume by more than 1 MCM for each 2 m increase. Thus raising the water level by 6-7 m would provide an additional 3,5 – 4,0 MCM for water or sediment trapping. The cost has been estimated to 21 million Birr. The proposed location for the construction of the dam from the morphology point of view is favourable.

It has to be noted that these figures are based on calculations assuming the FSL of Legedadi reservoir to be +2,452.90 m according to the Master Plan; however, both the 1979 and 2010 bathymetric surveys consider an FSL value of 2,466 m. Seureca & others (2010) also reports that this datum is also assumed by the water level gauges installed at the dam. It is not clear why this difference exists but it may influence the validity of the estimations regarding the capacity of the Strait dam.

The opening of the valley is favourable to create a reservoir. But the location of the dam in the middle of the existing reservoir creates great construction difficulties which seem not to have been seriously considered in the Master Plan.

In a similar vein with the other proposed dams in the vicinity of the existing reservoir, the Strait dam will have a long crest and a considerable volume so it will be impossible to construct within a single dry period. Diversion works will need to be constructed along with two cofferdams, upstream and downstream to maintain the construction area dry. The cost of these works will greatly increase the total construction cost.

More important will be the cost for the construction of the spillway. Since the largest part of the Legedadi catchment is upstream of the proposed dam, the required works to protect the dam from floods have to be almost similar to the existing ones in the Legedadi dam. That will increase the construction cost dramatically. Also unpredictable difficulties during the construction phase may be incurred since the dam will be constructed inside an existing reservoir which is filled very fast when the rain season begins.

Water Storage Reservoirs

No 1. On the Lege Beri sub catchment.

It is a very small stream with a maximum depth of around 2.0 m. The surrounding area is very flat. A dam with a long crest could be examined but probably a large cultivated area would be flooded. It appears that a simple silt trap could be the construction of choice here, if justified by its sediment trapping potential. This has to be investigated in the Feasibility stage.

No 2. On the Nya-a sub-catchment

This location is an extremely flat area with a very small stream. It is difficult to see how a dam was envisaged at this location.

No 3. On the Doyo sub-catchment

The proposed location for the dam is flat but two hills exist and could be used as abutments to support the dam construction. The catchment again is very small and the water yield will be very difficult to fill the reservoir created. The dam crest will also be long. The valley upstream is open and a reservoir with a significant size could be created if the water is available. No sign of cultivated land affected could be seen during the site visit. Also the surrounding villages will not be affected from the reservoir. The site should be further examined mainly from the hydrology point of view in the feasibility stage.

No 4. On the Kultubi sub catchment.

The proposed dam is on the same sub catchment with the No 11 proposed dam. The area is very flat and it is considered very difficult to build a dam here. Due to the surrounding villages the dam cannot be high. It appears that at this location to the construction of choice would be a simple silt trap with gabions inside the river bed, if justified by its sediment trapping abilities which is something to be evaluated at the Feasibility stage.

No 5. On the Sekara sub catchment.

This location too seems outlandish for a dam to be built here. The river is very small with a maximum depth of 2.0 m and the surrounding area completely flat. It is difficult to understand how a dam or silt trap can be constructed here.

No 6. On the Sendafa sub catchment.

The river had no flow the day of the visit. Two small hills could be used as abutments to support the construction of a dam, which should be very low in order not to affect the surrounding villages and have a very long crest. The area is very flat and the reservoir will affect a lot of cultivated land. This location is not very favourable considering the above factors at play.

No 7. On the Sendafa sub catchment.

The stream is small and the area outside the river bed is completely flat. Raising a dam outside the river bed will affect the nearby village. The construction of choice here, as in other similar locations, would be a simple silt trap from gabions inside the river bed. The sediment trapping ability of a silt trap at this particular location will have to be examined in the Feasibility stage.

No 8. On the Lege Jila sub catchment.

A very narrow stream which is unlikely to create a reservoir with the volume presented in the Master Plan. Again a simple silt trap made of gabions could also be proposed here. The area outside the river bed is very flat.

3.2.4 Dire Catchment dual purpose reservoirs.

Dire dam was commissioned in 1999. The dam has a very long crest more than 2000 m and a reservoir with a total capacity of 19 MCM. The spillway is un-gated (free over fall). No map of the reservoir area before impoundment is available.

The 2000 Master Plan proposed the construction of only one dual purpose dam to assist in reducing sedimentation, as well as harvesting additional quantities of water. The dam is supposed to prevent large part of the sediments from entering the reservoir, thus lengthening its life span and at the same time increasing water harvesting efficiency. The location of the proposed dam is presented on the map in Fig. 3. Photographs of the dam location are presented in Appendix I. The dam has a catchment area of 9.1 km^2, a reservoir volume of 1.3 MCM and a total construction cost of 18.5 M Birr.

In the same Figure 3 the Lege Hola dam and reservoir proposed by the 2000 MP downstream of Dire dam is also shown. This dam is not inside the Dire catchment and thus is presented separately.

Table 13: Proposed dual-purpose dam in the Dire catchment (this study)

ID Number	Sub-catchment	Sub-catchment area (km^2)	Mean elevation (m)	Max Elevation (m)	Min Elevation (m)	Mean Relief Slope (%)
10	Bura	9.1	3010.7	3240.0	2855.0	19.6
Total		**9.1**				

No 10. Bura dual purpose dam

The dam is located at the northwest part of the catchment with an elevation of about 2900 m. The location is good for the construction of a small dam. The small flow at the day of the visit raises some questions regarding the ability of the catchment to fill the reservoir and so care has to be given in the hydrology study if the design of a dam here is proposed and accepted by the Client. The bed rock is visible both at the river bed and the left embankment. The right embankment needs some excavation for the rock bed to come to the surface.

Initial examination of the site on the available topographical maps indicates the following characteristics of the proposed dam:

Crest elevation: +2900 m

Crest Length: ~ 750 m

Dam height: ~ 10 m

Reservoir volume: ~ 2.3 MCM

The dam is too far away from Dire and will not significantly help in the reduction of the sediment load entering the reservoir. Also sedimentation is not that critical in this part of the catchment. The only reason which could justify the construction of a dam at this location is to supply with water the local communities for irrigation purposes. Even in that case the difference in the elevation of the cultivated land and the reservoir level is an issue that needs to be carefully addressed.

The Feasibility study for this location should clarify the above issues to ascertain whether this dam is of any real value to the purpose of the project or it remains a viable option at the local level, but possibly outside the scope of the Client.

No 17. Lege Hola storage dam

As stated in the 2000 Master Plan the average annual spill from the Dire dam is estimated at 23 MCM. The construction of a dam downstream where Legedadi and Lege Hola rivers meet would bring a dual benefit, namely:

- It will trap the somewhat cleaner surplus Dire water after it has deposited part of its bed load in Dire reservoir.
- It would add the contribution of the Lege Hola catchment in the water supply system of Addis Ababa.

The basic characteristics of the proposed dam according to the MP are a reservoir with a volume of 12.3 MCM and a construction cost of 120.7 M Birr.

Table 14: Proposed Lege Hola water storage dam d/s of Dire dam (this study)

ID Number	Sub-catchment	Sub-catchment area (km^2)	Mean elevation (m)	Max Elevation (m)	Min Elevation (m)	Mean Relief Slope (%)
17	Lege Hola	36.7 (114.3 total)	2760.6	3240.0	2448.0	18.0
Total		**114.3**				

One problem that needs to be addressed according to the Master Plan is the need for the construction of a new Water Treatment Plant downstream the Lege Hola reservoir.

The site is favourable for the construction of a large dam. Foundation conditions are very good and the bed rock is visible in both embankments and the river bed. The dam will create a significant reservoir which is estimated from the available base maps to have a volume of ~ 19 MCM and the dam height will be around 20 to 25 m.

Initial examination of the site on the available topographical maps indicates the following characteristics of the proposed dam:

Crest elevation: +2500 m

Crest Length: ~ 540 m

Dam height: ~ 20-25 m

Reservoir volume: ~ 19 MCM

The reservoir will probably not create any significant problems to the nearby communities and no cultivated land was identified during the site visit. The proposed location for the construction of a large dam seems to be very good and should be further examined. Photographs from the dam location are presented in Appendix I

3.2.5 Synthesis and conclusions.

A number of dual purpose dams were proposed by the 2000 Master Plan in order to reduce siltation in the three study reservoirs and increase water harvesting, targeting also the rehabilitation of the three catchments. In total seventeen (17) locations for the construction of small silt traps or larger dual purpose dams were proposed by the Master Plan for further investigation.

The Consultant was able to visit all the proposed locations to have a first-hand experience of the sites in question. Detailed comments for each site can be found in the preceding sections. Further analyses involving the comparative study of later reports and studies, a desktop study involving GIS tools and the collection of relevant data were made to consolidate the consultant's views on the sites in question.

The 2000 MP addresses, primarily, two main problems – increasing the water harvest and reducing reservoir sedimentation. The overall assessment of the situation in the three study catchments, based on the data collected, the site visit and the analyses performed is that the former is of much greater importance. The bathymetric surveys conducted so far (see section 1.5) indicate that the severity of the sedimentation problem is moderate, even assuming that the present rates of siltation will remain the same or even increased. The problem of increasing the water harvest on the other hand is much more important. Despite the availability of water resources in the study catchments during the wet period, geomorphological reasons hinder possibilities to create extensive surface storage. The overall gentle slope of the majority of the terrain and the significant number of flow pathways which distribute the generated runoff into several smaller streams result in few locations of flow concentration and suitable storage areas. Therefore attention should be given to those sites suitable for providing the largest storages within each study catchment and selecting among them based on a detailed feasibility assessment to maximise the potential of the investments that will be made.

Here we may summarize the findings of this report as follows:

- The best sites for constructing dual-purpose dams in the project area with an eye to increased water storage as well as sediment trapping are the locations with ID nos. 10 (Bura), 11 (Legedadi) 12 (Geffersa) and 17 (Lege Hola). Nos. 10 and 11 are mentioned below in relation with other considerations concerning their construction. For nos. 12 and 17 it appears that they are the most favourable locations within the project area for the purposes of this project. However, final judgement is postponed until the Feasibility stage where all the relevant factors at play will be thoroughly examined.
- The Master Plan proposes a sub-group of dams (nos. 9, 11, 16 and 15, the Strait dam) which are located in the vicinity of the existing reservoir at Legedadi (and in case of the Strait dam, inside it). The closeness of the locations to the existing reservoirs poses significant problems in terms of:
    - increased construction costs because of the need for large diversion works and spillway facilities to match those of the principal Legedadi dam
    - increased construction difficulties because of the location of the worksite and the fact the main dam still has to operate normally during construction
    - relatively large structures required to develop small impoundment volumes
    - operational problems because of the need to operate in conjunction with the existing reservoir from which water abstractions are made
- It is obvious that only one location could be developed among those proposed near the Legedadi reservoir because of all the aforementioned problems. At this time location no. 11 appears the most favourable; however the points raised above will become subject of specific investigations during the feasibility stage for this sub-group of proposed dams.

- There is a number of locations proposed that could support the construction of water storage dams but further analysis needs to be made because of problems foreseen with environmental and human-related impacts. These locations are nos. 3 and 6. The no. 10 Bura dam in the Dire catchment could be placed in this group as well. Although no significant problems are foreseen for this location, its construction could prove viable but beyond the domain of the Client's concerns or scope.
- Many of the proposed locations are obviously more suited to simple silt traps constructed inside the available river beds for the purpose of sediment trapping. These locations are nos. 1, 4, 7, 8, 13 and 14.
    - For the above locations the Feasibility study should verify the possibility of construction, using simple designs and materials which will not increase the cost.
    - More importantly it has to ascertain the sediment trapping ability given the location and the dimensions of the constructions. Options for cleaning up the silt trap should also be comparatively investigated.
- Finally there is a number of locations for which it is considered very difficult to construct either a water storage dam, a silt trap or any kind of such facility whatsoever. These locations are nos. 2 and 5.
- The Consultant, even from the Inception Report phase, started investigating the possibility of locating additional sites for the construction of dams and reservoirs mainly to increase the water storage capacity of the water supply system of Addis Ababa. Some locations have been identified but their ability to supply water to Addis by gravity has to be further studied when more detail topographical data become available. In the feasibility study all these locations will be studied and presented so final decisions can be taken.

3.3 OTHER ENGINEERING WORKS FOR SEDIMENTATION CONTROL AND WATER HARVEST

3.3.1 General

To obtain additional water and to prevent silt to enter the reservoirs, the master plan proposed that one of the following other alternatives (besides dual purpose dams and dams) should be implemented:

- Enlarging the impounding volume of existing reservoirs.
- Mechanical Removal of Sediments from the Reservoirs
- Regulation of Rivers, Streams and Tributaries
- Diversion of Natural Streams
- Buffer Strips

3.3.2 Enlarging the Impounding Volume of Existing Reservoirs

As calculated in the Master Plan the average water surplus for the three catchments is 63.0 MCM with the maximum been approximately 93.0 MCM and the minimum 33.0 MCM. So even during dry years there is a significant inflow from the catchments which cannot be retained by the existing reservoirs and overflows downstream. Specific engineering works have been proposed by the Master Plan in order to enlarge the impounding volume of the existing reservoirs. These works are described and commented below.

Raising the height of Geffersa III Dam

The master plan proposal is that the storage capacity of Geffersa III could be increased by raising the dam by some 2-3 m and this will add a volume of about 0.65-0.8 MCM, thus improving the flood routing effect and add sediment storage volume for at least 20 more years. Additional to that a rehabilitation of the dam structure and the outlet pipe should be carried out concurrently with the raising of the dam.

The cost of raising the dam was calculated $3.70x10^6$ Birr, not including cost of essential repairs and upgrading of the dam and spillway (for safety reasons), which should be done anyway.

The proposal of the Master Plan to raise the Geffersa III Dam was probably the only proposal that was further examined by AAWSA. As described in chapter 3.2.2 of this report the contract awarded to Tractebel and others in 2000 for the rehabilitation of the Geffersa dams and WTP examined also the possibility to raise Geffersa III. Finally the study proposed minimum rehabilitation works for the Geffersa III without increasing the height, while major rehabilitations works were proposed for Geffersa I/II. The works were tender and constructed and the rehabilitated Geffersa dams were commissioned in 2009. (See pictures in chapter 3.2.2)

Diversion from the Lege Beke Catchment

The Lege Beke catchment lies to the east of the Lege Sendafa catchment. The catchment area of Lege Beke is about 62 km^2 and its average annual water yield is approximately 26 MCM

Diversion or partial diversion of Beke flows is feasible as there is a 3 m elevation difference between Lege Beke and Lege Sendafa at the point of minimum distance between them. A topographic survey was conducted and verified that this diversion is possible.

The diversion discharge was estimated approximately to 25-30 m^3/sec and the cost of the works 1.44 million Birr.

The diversion works proposed included the arrangement of Lege Beke river at the diversion point, a weir across Lege Beke, an inlet to the diversion canal, a diversion canal (about 800 m long) with suitable erosion protection, culverts at the road crossings (2x4mx2m) and an outlet structure into Lege Sendafa river or local secondary reservoir.

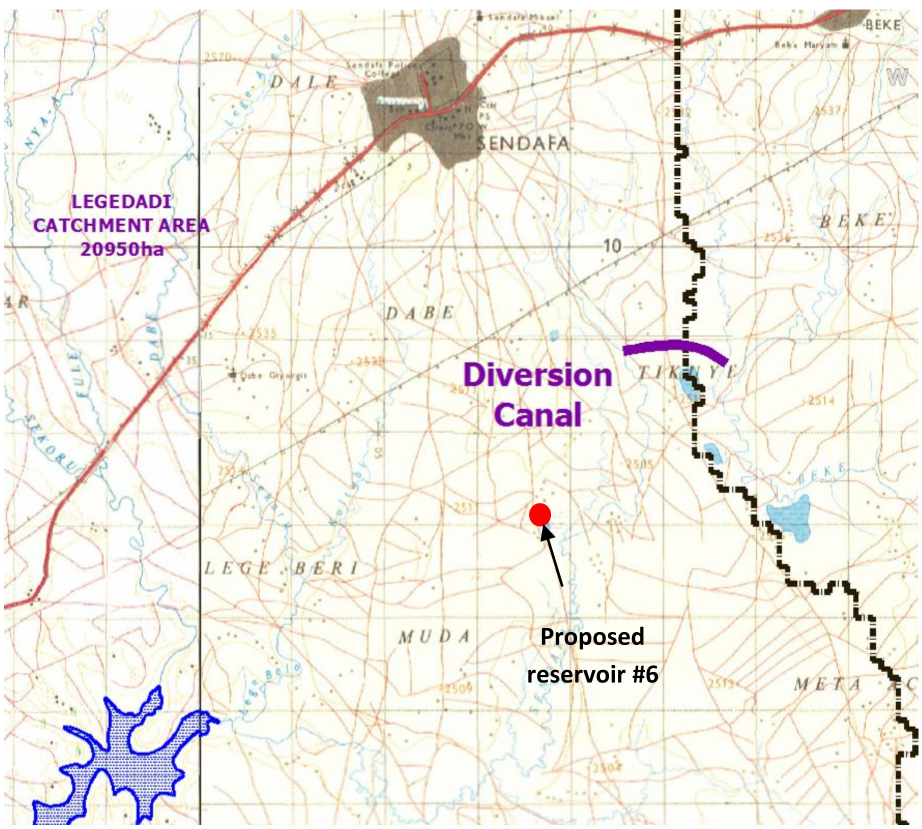
The hydrological conditions in the two catchments are very similar. The Legedadi reservoir has not sufficient volume to retain the inflows from the Legedadi catchment so there is no meaning in increase the inflow from additional catchments when the reservoir volume remains the same.

The only possibility to examine further the abstraction of water from the Beke catchment to the Legedadi reservoir would be if it could be combined with additional storage volume in the Legedadi catchment.

The master plan proposed the construction of the dual purpose dam no. 6 (Tikuye) on the Sendafa river. The possibility of constructing this dam is examined in the preceding sections (chapter 3.2.3). If the construction of dam no.6 will be considered feasible from the feasibility study of this contract and depending on the volume of the reservoir, then it will be possible for AAWSA to examine further the diversion of the Lege Beke catchment and thus add part of the calculated yield of approximately 26 MCM of Beke catchment to the supply system of AAWSA.

The study of this diversion is not in the scope of this contract.

Another possibility which could be examined, if not examined already, since it is not clear from the Master Plan, is to investigate the possibility of constructing a dam and reservoir on the Beke River instead of diverting the water to Legedadi. Again this investigation is out of the scope of this contract which is limited to the three catchments.



Diversion of Surplus Water from Dire Reservoir

As already stated there is an expected average surplus of approximately 23 MCM of water annually from the Dire reservoir.

The following alternatives were examined in the Master Plan regarding the diversion of surplus water from the Dire reservoir:

- Diversion from a point upstream of the reservoir.
- Open earth channel diversion from the Dire reservoir directly to Lege Beri river.
- Direct open earth channel diversion from Dire River downstream of the reservoir spillway outlet.
- Diversion by concrete canal/conduit instead of earth channel according to either of the above alternatives.

In all the examined alternatives the Dire reservoir operates as a silt trap and the diverted water will be relatively clean.

a. Diversion from a Point Upstream of the Reservoir

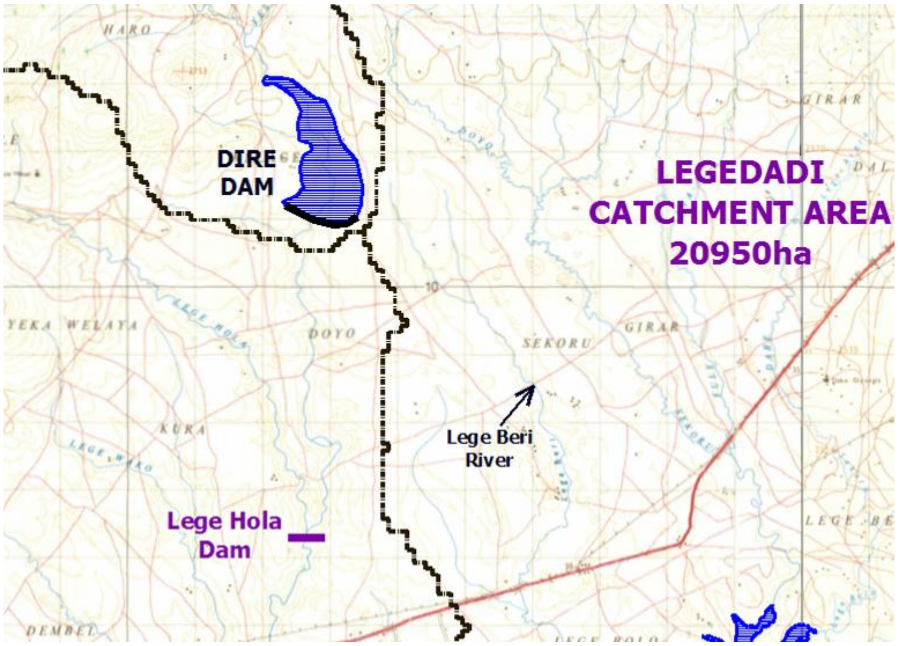
This alternative is not recommended by the master plan because of the high cost to construct a 4 km long canal, the required relocation of villages, land expropriation and siltation problems during flood flows.

b. Diversion from Dire reservoir to Lege Beri River.

Following this alternative the overflow from the dam is diverted to Lege Beri River from an outlet on the eastern side of the reservoir. The period available for diversion will be short, mainly when the reservoir is full, when it will presumably be easier to determine whether diversion to Legedadi Reservoir is necessary and feasible. The diversion is possible from the hydraulic point of view, since there is a difference in elevations between the N.W.L. of Dire and Legedadi reservoirs. The optimal canal alignment would be selected so as to minimize the need for relocation of the local population and for land expropriation. The length of the diversion canal up to the western upper tributary of Lege Beri is about 1.0 km.

The diversion will require the development of a sophisticated operation program taking into consideration the water level in the Dire reservoir, as well as inflow discharges, water supply needs and reservoir losses from evaporation and infiltration.

The discharge was estimated to be 25-30 m^3/sec, the construction cost of the diversion canal 3.6 million Birr and the cost of the river arrangement works as 31.4 million Birr.



c. Direct open earth channel diversion from Dire River downstream of the reservoir spillway outlet.

In this alternative a canal from Dire River downstream the spillway outlet to Legedadi reservoir is proposed, but not recommended, due to the higher cost of the previous direct diversion.

d. Diversion by Concrete Canal/Conduit

In this alternative it is proposed that if any of the above diversions should be examined in a next stage, an alternative of constructing a canal or regulating an existing stream using concrete should be consider, since the dimensions of the concrete canal will be considerably smaller than those of an open earth canal, due to the much lower roughness factor and the possibility of using higher conveyance velocities. A carefully planned concrete canal alignment may prove to be economically feasible despite the higher unit cost of concrete.

Synthesis and conclusions

The main problem of the Legedadi and Dire catchments is the limited storage capacity of the existing reservoirs. Diverting water from one catchment to the other, as explained also above, can give only short term solutions with the better management of the available water resources, but cannot be considered that it is increasing the water harvesting in the catchments and supports significantly the water supply of Addis Ababa.

In chapter 3.2.3 of this report we examined the possibility to construct a large dam on the Lege Hola River downstream of the Dire reservoir. This dam was also proposed by the Master Plan. The proposed location is favourable and although final decisions will be taken after the feasibility study the construction of a 20 to 25m dam is very possible. The volume capacity of the reservoir which will be created after the construction of the dam has been estimated with the available data to be approximately 19MCM.

Since the average annual overflows from the Dire reservoir have been calculated to be 23.5MCM the construction of the Lege Hola Dam could retain most of the average annual surplus without the need of constructing river diversions of questionable efficacy.

3.3.3 Mechanical Removal of Sediments from the Reservoirs

Mechanical removal of silt/sediment from reservoirs is a costly operation. But on the other hand it is a measure to maintain the operational volume of reservoirs free of sediments if no other alternatives exist. Two ways of removal are described in the Master Plan, excavation and dredging.

A large amount of sediments from incoming floods when reservoir water levels are high settle in the flooded area at the upstream end of the reservoir. During the dry season, when water levels drop due to supply and losses, the sediments at the upstream end will dry up and it will be possible to excavate them by heavy earthmoving equipment, working in a downstream direction. The excavated material would be disposed of or spread in areas nearby (in order to lower the cost of disposal).

Dredging of the reservoir bottom can be done throughout the year, although it might be much more expensive during the wet season.

The nature of the dredged material, namely liquid mud, is such that it cannot be spilled freely and should be impounded in settling basins/reservoirs where sediments will settle, while excess water will flow back to the reservoir.

After complete silting-up, the settling basin/reservoir can be used for cultivation or afforestation. Sediments could also be used for other purposes such as raw material for the tile/ceramics/brick industry, improvement of inferior agricultural lands, etc. If such solutions are adopted it is better to determine possible users/uses from the beginning in order AAWSA to share the cost with others.

Because of the high cost of dredging, it is recommended from the Master Plan that sediments/silt settled in the reservoirs be excavated during the dry season, when the water level in the reservoirs is low.

In any case the excavation and certainly much more the dredging are very costly solutions. Since the annual volume reduction of the Geffersa and Dire reservoirs is small, around 0.3% for both reservoirs, as also explained in chapter 1 of this report, the sedimentation is not the major problem off the catchments and all the three reservoirs are expected to continue be operational for a lot of years to come. We consider that implementing very costly methods like the mechanical removal of sediment from the reservoirs in not a necessity for AAWSA at the moment. If the sediment rates be increased in the future, maybe that kind of approach could be reconsidered.

3.3.4 Regulation of Rivers, Streams and Tributaries

Riverbed regulation would assist in reducing that part of sediment migration caused by river bed erosion and would also serve as well to lower flood water levels in the valleys along rivers, streams and tributaries. Regulation will become imperative when the price of the cultivated land and agricultural products are sufficiently high to justify it. At present, regulation is justified only if it is less costly than other means to minimize reservoir sedimentation.

River/stream regulation would consist of excavating the river bed to the design cross-section to enable conveyance of the design flood and protect the riverbed from erosion. The latter would be achieved either by moderating the longitudinal slope (by installing drops) and reducing the flow velocity, or by protecting the cross-section from erosion by vegetation, where the velocity permits, or by riprap or other costly means, where the velocity is too high.

It should be noted that while erosion and sediment load would be reduced following river regulation, sediments that currently settle in the river floodplain would be conveyed downstream in the regulated stretches. Usually grass is used to protect the wetted perimeter up to velocities of 2.2 -2.5 m/sec. The permitted velocity depends on the type of soil and the grass protection.

Since regulation will change the geometry of the river by enlarging the cross-section, it is possible that land requisitioning will be required. The cost estimates given in the following table do not include compensation for land requisitioning (costs of 2000 from the Master Plan).

Table 15: Cost Estimation (million Birr per km) for Riverbed Regulation.

SLOPE [%]	Designed Discharge [m^3/sec]			
	30	**60**	**90**	**120**
30	4.19	5.47	8.61	9.54
15	3.28	5.89	6.77	10.43
10	3.49	5.45	7.2	7.86
5	1.08	5.1	5.83	6.33
3	0.95	1.64	6.43	6.94

River Regulation in the Legedadi Catchment

According to the Master Plan, river regulation in the Legedadi plains will reduce the inundated areas, but will only benefit agriculture crops. From the siltation point of view, it might even prevent some precipitations of silt in the inundated areas by shortening the water courses directly to the reservoir. Since the benefit of this regulation is more agricultural it was proposed that AAWSA will not initiate any such measures unless it wishes to benefit the local population.

Considering the high cost of the river regulation and the small benefits we find the proposal of the Master Plan acceptable and reasonable.

3.3.5 Diversion of Natural Streams

The possibility of diverting natural streams by constructing diversion canals was examined in the Master Plan in order to divert a part of the sediments flowing to the reservoirs during the rainy season. This measure should be commenced after the reservoir is full of water. The following diversions were examined.

Diversion from Geffersa Catchment

Of the annual volume of water harvested in the Geffersa catchment, about 45 present spills over the Geffersa I/II spillway. Diversion of a part of this amount, which transports about 45% of the sediments, will reduce the siltation rate in the Geffersa reservoirs. The possibility was examined by diverting floods in the Lege Menjaro and Lege Dima after filling the Geffersa reservoirs with water, by a 3.5-4.0 km long diversion canal. Several problems were raised within this examination.

- The only possible route for such a diversion canal will be past Geffersa village at an elevation higher than it and this would endanger the inhabitants
- It would also involve land requisitioning and engineering problems since the flood water would have to be conveyed over a distance of some 300 m and an elevation difference of 50-60 m in order to discharge them downstream to the river.
- The above will also raise the need of a bridge under the Addis-Ababa – Geffersa main road.
- The diversion canal will have a moderate longitudinal slope. Therefore it will have to be maintained constantly during the wet season in order to remove sediment so as not to endanger the village, the main road to the west and the reservoirs.

None of the streams in the catchment draining directly to Geffersa I, II reservoir can be diverted along the northern side of the reservoir. The Guje Kersa tributary is the only one whose diversion might be of any consequence but seems to be of little significance because of the little quantity of sediments. The cost of this diversion is estimated at 3.8 million Birr.

Diversions from the Legedadi Catchment

There are seven main rivers and streams in the Legedadi reservoir watershed, whose diversion might assist in reducing siltation of the reservoir. These are the Bori, Sekoru, Fule, Dabe, Kultubi, Sendafa and South-eastern Tributary. Diversion of any given river/stream would have to start at a point that is sufficiently upstream (thus ensuring a downward slope) to reach a given point outside the catchment where the floodwater of the river/stream would be discharged.

Diversions from the Dire Catchment

Siltation in the recently commissioned Dire reservoir should be measured to check the rate of sedimentation and then to take the required decisions. According to the Master Plan and regarding stream diversions only the Hurufa and Bosena rivers could be diverted but the design of such a diversion would has to take into account the nearby relocated villages.

Proposals

None of the described diversions in the above paragraphs considered feasible and none was recommended from the Master Plan taking into account the high cost and other several problems raised from the construction of canals.

Except from the cost and the problems described, this system is based on a limited operational period, only after the reservoirs are full. It also diverts from the reservoirs only a small percentage of silt, floods other areas and is very difficult to manage.

It should not be discussed further.

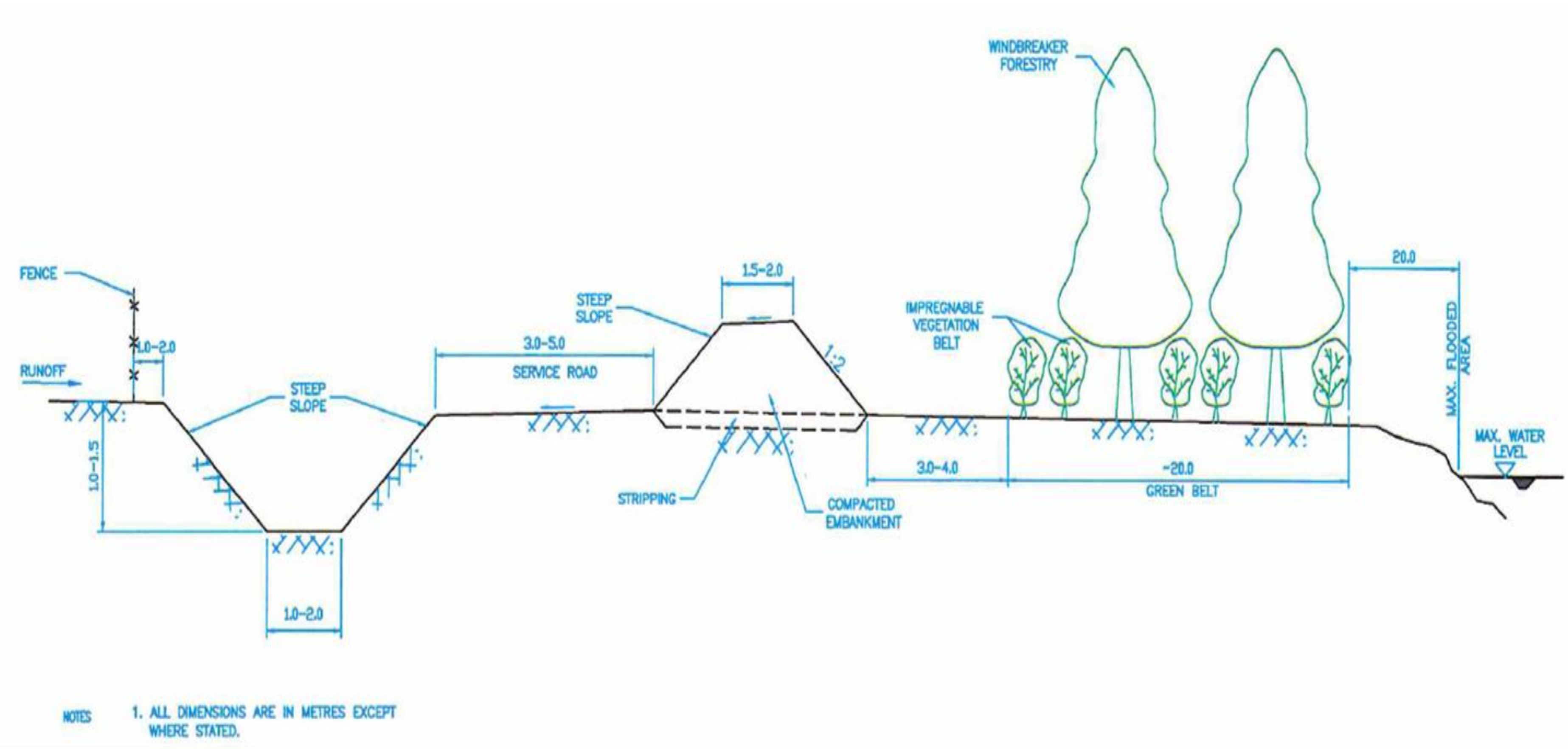
3.3.6 Buffer Strips

Proposals of the Master Plan

The Master Plan proposed three buffer strips. The main one, the exclusion zone, is the one near the reservoir and consists of a fence, a protection canal, a rural road, an embankment, and a green area (grassed areas, dense trees and bush planting). The other two buffer strips are the area of minimum activity and the supervised zone. The strips are running more or less parallel with the shore line of the reservoir, have a total width of 1,750 meters and would serve a dual purpose:

- Preventing sediments generated by catchment erosion and small stream erosion from reaching the reservoir directly
- Preventing the local inhabitants and livestock from reaching the immediate vicinity of the reservoir

A typical cross section of the proposed buffer strips is given below. The three types of the buffer strips are presented in the following paragraphs.


WINDBREAKER FORESTRY
FENCE
1.0-2.0
RUNOFF
STEEP SLOPE
3.0-5.0
SERVICE ROAD
STEEP SLOPE
1.5-2.0
1:2
IMPREGNABLE VEGETATION BELT
20.0
MAX. FLOODED AREA
1.0-1.5
STRIPPING
COMPACTED EMBANKMENT
3.0-4.0
~20.0
GREEN BELT
MAX. WATER LEVEL
1.0-2.0
NOTES
1. ALL DIMENSIONS ARE IN METRES EXCEPT WHERE STATED.

First Buffer Strip: Exclusion zone

The water body of the reservoirs and its nearest shore line will be totally separated from any kind of human/livestock direct contact by buffer strips. The proposed buffer strips surrounding the reservoirs will be fenced by strong barbed wire fence to be set up 2 to 3m above the reservoir maximum level and controlled by AAWSA. This roughly 250m wide buffer strip will consist of: a fence, a protection canal, a rural road, an embankment and a green area (grassed areas, dense tree and bush plantings).

Second buffer strip: Area of Minimum Activity

This second buffer strip in which only minimum activity will be allowed will be about 500m wide beginning from the boundary of the first buffer strip and will consist of hardy grasses such as Cynadon, Digetaris, Bracharia, sedge grasses and others propagated by rhizome and non-seed producing plants. These will serve as fine sediment trappers to obtain clean water. Heavy seeders and highly decomposing types or plants will be avoided to reduce organics.

Third buffer strip: Supervised zone

Trees and small shrubs will be planted in this area with natural vegetation or fodder plant to be harvested by cut and carry methods. Shrubs and grass in staggered pattern are acceptable in this zone. The kinds of shrubs to be used in this zone are Agam, Kai apple (Koshim) Kega, Enjorey and other types of non-seed dispensing bushes. Similar shrubs can be staggered with non-shading trees like Acacia Abyssinica, Gravilea robusts Junperious, Podocarpus, Pine radiate, Shenis molle planted on the periphery. The third buffer strip will be about 1000m wide.

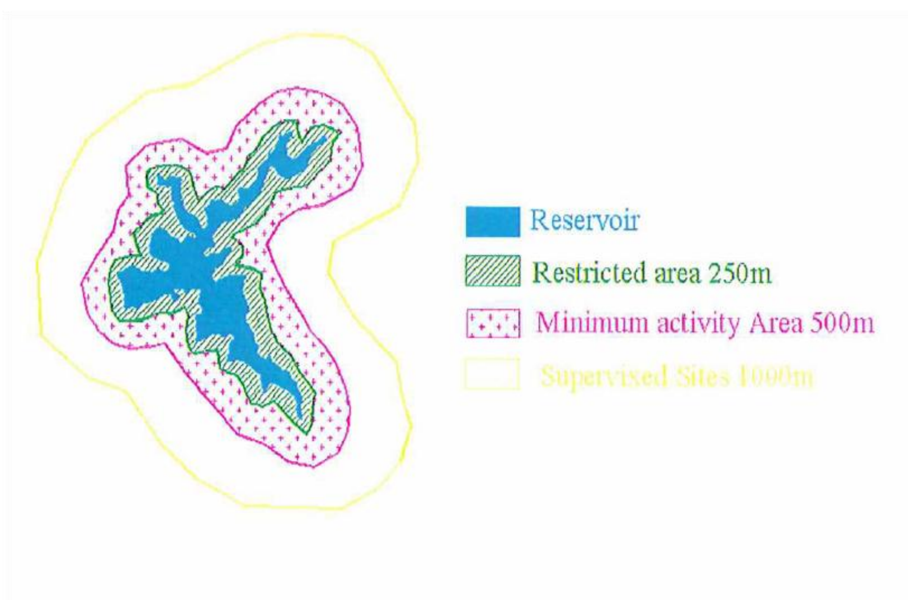


Figure 4: Buffer Strip Layout

Protection canals could be excavated near and outside the green vegetative zone to prevent grazing and access to the reservoir, and acting as a belt of windbreaks. Such a canal would have to be bridged or discontinued where access is needed for inspection, maintenance, control, etc. The canal would also serve for collection of drainage and runoff water. This would be let into the reservoir by inlets (protected from erosion) about every 500 m or less. The steep sides and the sediments settling in the canal will call for regular maintenance, perhaps even during the wet season.

Comments on the Master Plan proposals

The large amount of the sediment load is transferred to the reservoir through the rivers and streams discharging in it. The surface of the areas directly affecting with sediment the reservoirs is rather small and it is presented in the following Table 16 for each reservoir.

Table 16: Areas immediately affecting with sediment the reservoirs

Reservoir	Total Area (Km^2)	Areas affecting the reservoir (Km^2)	Percentage
Legedadi	290.5	41.2 km^2	14%
Geffersa	56.0	6.2 km^2	11%
Dire	81.5	6.1 km^2	8%

To protect the reservoirs from the soil erosion and the sediment load transferred directly to them the Master Plan proposes the construction of a very heavy and costly buffer strip system with a huge width which will affect directly the Kebeles near the reservoirs. A lot of them will need to be relocated and the cultivated land will be reduced since the proposed buffer strip will cover a zone of at least 1.75 km in the perimeter of each reservoir.

The construction cost of this proposal was estimated to be approximately 23.0 million Birr in the year 2000 as it is presented below.

Table 17: Technical details and cost of 2000 MP buffer strip

Reservoir	Length of the protection canal (km)	Inlets (no.)	Culverts (no.)	Green belt (ha)	Cost estimate (million Birr)
Legedadi	30	60	15	60	12.85
Geffersa I-II	7	14	4	14	3.41
Geffersa III	2.2	4	2	4.4	1.14
Dire	7.5	25	6	25	5.54
				Total	**22.94**

The cost of the proposed buffer strip is highly increased due to the proposed canal operating as a silt trap and the required number of inlets and culverts. This cost is not justified since it will protect the reservoirs from only a small part of the catchments, namely 14% for Legedadi, 11% for Geffersa and 8% for Dire.

Proposal for the Silt-trap system

The basic difference of the herein proposed system with the 2000 MP design is that the construction of the costly canal with all the required inlets and culverts is not proposed.

The silt-trap zone is designed to prevent silt transported with water that originates from the catchment close to the reservoir and from the silt-trap-zone itself to enter the reservoirs. It covers the perimeter of the reservoir and it is separated into three sub-zones:

- The tree zone
- The shrub zone
- The grass zone

Between the shrub zone and the tree zone, a fence is proposed to be constructed along the perimeter. This fence will protect the reservoir and the grass zone from any human and livestock interferences. The design components of each zone are presented below.

The tree zone

The tree zone is the outer and upper part of the silt-trap zone. This is the zone which is meant to filter out and contain larger sediments that are mobilised with the runoff during heavy rains. It will also form a barrier discouraging human and cattle movements, if dense enough. The trees will be planted with a spacing of 1.0 or 1.5 meters.

The shrub zone

The shrub zone is the middle part of the silt-trap zone. This is the zone which is to filter out and contain sand and gravel that are rolling to the silt-trap zone from overlaying terrains.

The shrubs will be planted with a spacing of 1.0 meters. The difference between the tree zone and the shrub zone is that the individual shrubs have multiple stems which can densely fill up the line creating a good blockage that serves as a barrier to any gravel escaping the tree zone and passing through to this zone. It will also serve as an impassable barrier to cattle movements.

The grass zone

The grass zone is the inner and lower part of the silt-trap zone. This is the zone which is to filter out and contain the silt that is escaping through the tree and shrub belt of the silt-trapping zones.

This layer needs to be very thick to contain the silt and release only the filtered water downstream to the reservoir. In addition to protecting the reservoir from silt deposition, this zone serves as a buffer zone for protecting the dam.

The total width of the zone as proposed is about 60 to 100 meters instead of the 250m of the Master Plan proposal. A buffer strip with the proposed width is easy to be constructed without creating major problems to the inhabitants near the reservoirs.

The necessity of the two other zones proposed by the Master Plan the minimum activity zone and the supervised zone with a total width of 1,500 meters is not necessary from the technical point of view but it remains to the socioeconomic part of this contract to examine further the need of it.

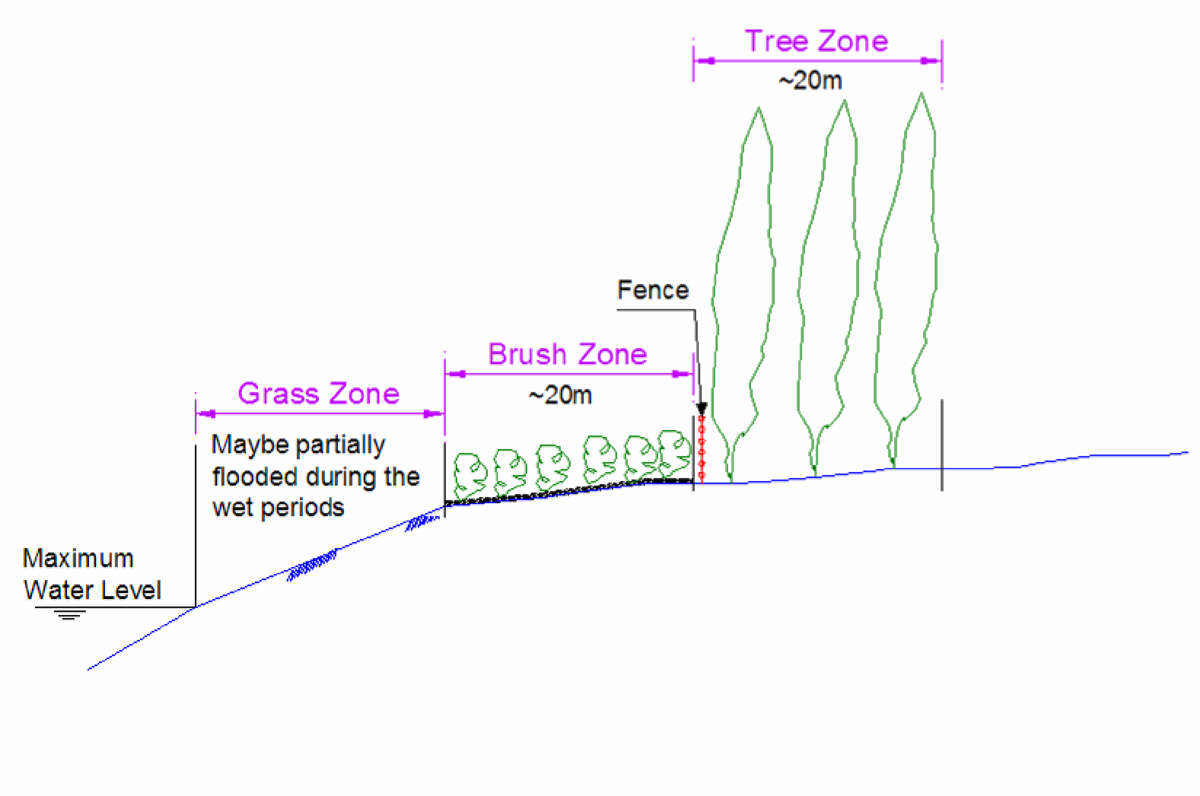


Figure 5: Typical cross section to the proposed Buffer Strip around the reservoir

4. RURAL WATER SUPPLY

4.1 MASTER PLAN 2000 REVIEW

The MP 2000 had discussed this issue by giving a picture of the existing status at that time and gave proposals the following is a summary.

4.1.1 Introduction

The metropolitan area of Addis Ababa is sewed with potable water from Geffersa, Legedadi and Dire reservoirs. Legedadi, Dire and Geffersa reservoirs are situated in areas populated mainly by farm families engaged in rain fed agriculture and in raising livestock.

The 1999 population of the Dire-Legedadi and Geffersa catchment areas is estimated at 31,000 and 7,000 inhabitants, respectively.

The 1999 livestock population in Legedadi-Dire catchments, expressed in terms of Tropical livestock Units (TLU= 250 kg live-weight) is estimated at 21,000 TLU, and at 5,700 TLU in Geffersa catchment area. An alternative water sources have to be provided as the population of the area will not be allowed to reach the reservoir water.

The existing water supply facilities will be assessed. The 1999 and projected year 2010 water demand of the human population and the livestock will be estimated.

4.1.2 Existing Rural Water Supply Facilities

Legedadi and Dire Catchment Areas

The human and livestock population consume water from the three reservoirs, as well as from a small number of shallow wells and springs. The population of the urban centres, such as Sendafa, Legedadi and Dire, obtain water from deep wells. The shallow wells, which are operated by hand pumps 8 hours a day, have depths ranging from 30 to 50 m and yields of 0.8 to 1.2 l/s. The deep wells, which are operated for 16 hours a day and generally have depths ranging from 100-200 m, are reported to have capacities of about 1.5 l/s. The approximate location of the wells and springs in the Legedadi-Dire and Geffersa catchments are shown, respectively, in Figs 6 and 7.

The catchment areas were divided into ten water supply zones, five in Legedadi-Dire catchments and five in Geffersa catchment.

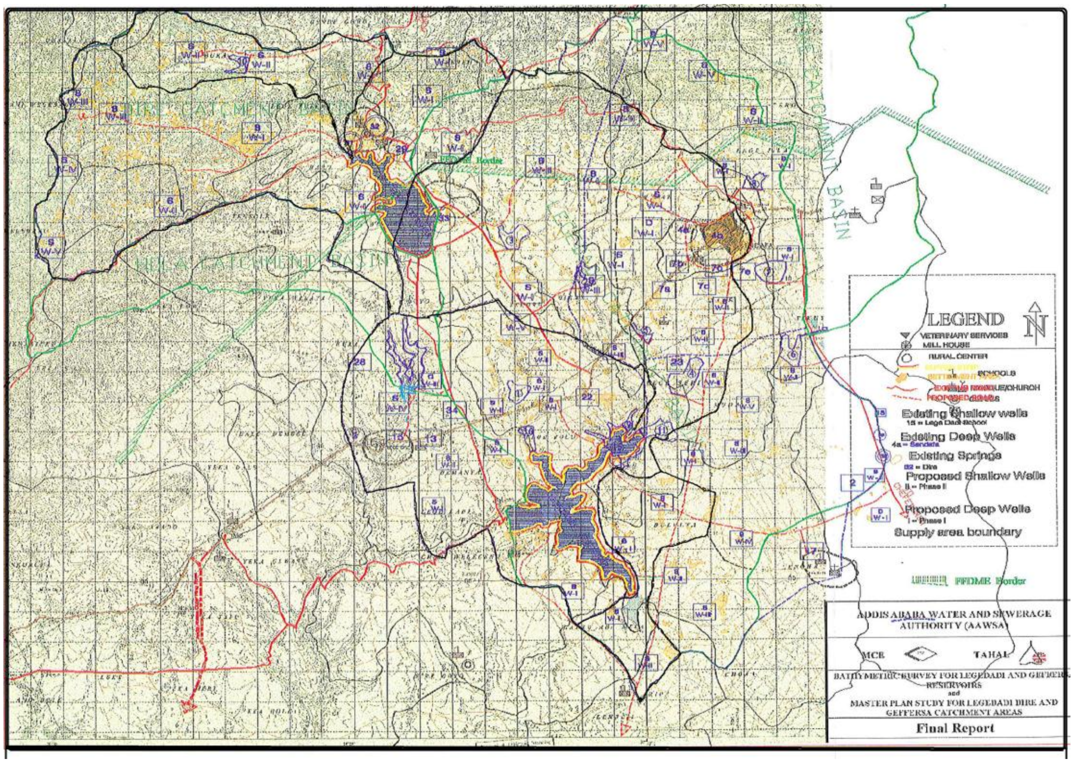


Figure 6: Legedadi and Dire Catchment Area – Location of Existing and Proposed Water Supply Facilities

Table 18: Number and Yield of Wells and Springs in Legedadi and Dire Catchment Areas

No.	Water Supply Zone	Springs			Shallow Wells[1]			Deep Wells[2]			Total Yield[3]
		No	Yield ℓ/s	Yield m^3/d	No	Yield ℓ/s	Yield m^3/d	No	Yield ℓ/s	Yield m^3/d	
1	Legedadi	-	-	-	3	3	86.4	1	1.5	86.4	170
2	Choba Lencha	-	-	-	3	3	86.4	-	-	-	90
3	Sendafa	-	-	-	6	6	172.8	2	3	172.8	350
4	Gerare Bereh	-	-	-	-	-	-	1	1.5	86.4	90
5	Dire	2	1	36	-	-	-	1	1	57.6	90
	Total	2	1	36	12	12	345.6	5	7	403.2	790

(1) Based on an average yield1.0 ℓ/s or 3.6m^3/hr. X 8hours/day

(2) Based on an average yield1.5 ℓ/s or 5.4m^3/hr. X 16hours/day

(3) Rounded figures

Geffersa catchment area

The existing water supply facilities in Geffersa catchment area are very limited. It is reported that there is even a shortage of reservoir water supply for both domestic and livestock uses during the dry period of the year.

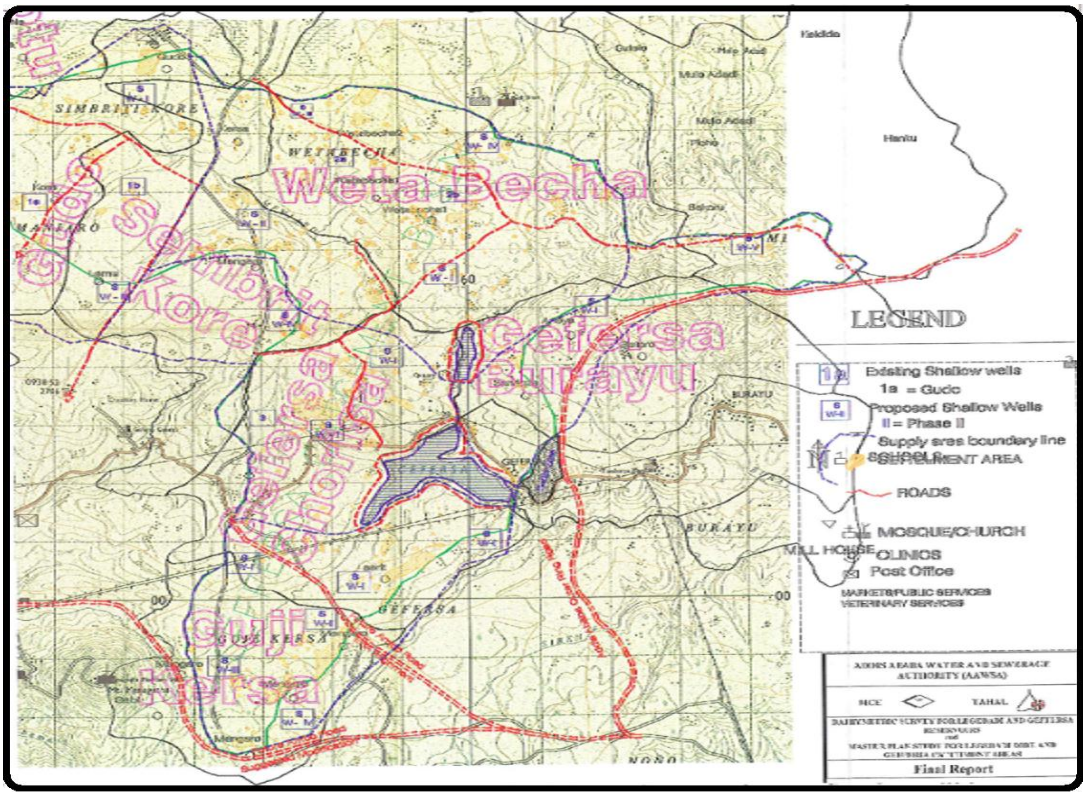


Figure 7: Geffersa Catchment Area – Location of Existing and Proposed Water Supply Facilities

Table 19: Number of Springs/Wells and their Yields in Geffersa catchment Area

No.	Water Supply Zone	No. of (1) Springs/Wells	Yield m^3/d
1	Gudo	2	60
2	Gull Kersa		
3	Geffersa Chorisa	1	30
4	Weta Becha	2	60
5	Geffersa Burayu		
	Total	**5**	**150**

(1) Based on an average yield1.0 ℓ/s or 3.6m³/hr. X 8hours/day

4.1.3 Water Consumption and Demand Estimates

Table 5 Present domestic demand is estimated at 25 *l/c/d* and demand projected for the year 2010 in this master plan at 35*l/c/d,* while livestock consumption rates have been taken at 30 *l*/TLU/d for 1999 and at 40 *l*/TLIJ/d for the year 2010.

Table 20: Consumption Norms Adopted for Rural Communities

No	Use	Norm l/c/d l/TLU/d		Source	Proposed Norm l/c/d l/TLU/d	
		Current	Projected		Current	Projected
1	Domestic	25	30	ESRDE	25	35
		25		WMERDB		
		15	20	WMED(FICHE)		
		20		WMED(AMBO0		
2	Livestock	30	40	WMED(FICHE)	30	40

ESRDE= Ethiopian Social Rehabilitation and development Fund
WMEDDB= Water, Mineral and energy Resources Development Bureau, Oromia Regional State
WMERD= Water, Mineral and energy Resources Department, Zonal office of Oromia Region

The total water supply demand for the three catchment areas is based on the assumption that the population of the catchment areas will increase at annual rate of 3%, whereas the livestock population is expected to grow at a rate of only 1% since the livestock carrying capacity of the area is near its maximum.

The above proposed figures were applied and the results are tabulated in the following tables.

Table 21: Estimated Rural Water Demand in Legedadi and Dire Catchment Areas for 1999 and 2010 Years

Water Supply Zone	1999					2010				
	Population	Human	Livestock		Total	population	Human	Livestock		Total
		m^3/d	TLU	m^3/d	m^3/d		m^3/d	TLU	m^3/d	m^3/d
Legedadi	7006	180	3921	120	300	9695	340	4313	170	510
Lencha	4235	110	5306	160	270	5863	210	5837	230	440
Sendafa	11602	290	7134	210	500	16059	560	7847	310	870
Gerar Bereh	1716	40	1399	40	80	2374	80	1540	60	140
Dire	6337	160	3497	100	260	8779	310	3847	150	460

Total	**30896**	**780**	**21257**	**630**	**1410**	**42770**	**1500**	**23364**	**920**	**2420**

Table 22: Estimated Rural Water Demand in Geffersa Catchment Area for 1999 and 2010 Years

Water Supply Zone	1999					2010				
	Population	Human	Livestock		Total	population	Human	Livestock		Total
		m^3/d	TLU	m^3/d	m^3/d		m^3/d	TLU	m^3/d	m^3/d
Gudo	1113	30	1534	50	80	1542	50	1687	70	120
Guji Kersa	1681	40	2349	70	110	2326	210	2584	100	180
Geff. Chorisa	2102	50			50	2911	80			100
Weta Becha	1816	50	1534	50	100	2528	100	1687	70	160
Gff. Burayu	413	10	299	10	20	571	90	329	10	30
Total	**7125**	**180**	**21257**	**180**	**360**	**9878**	**340**	**6287**	**250**	**590**

4.1.4 Proposed Water Supply Facilities in the Catchment Areas

Depending of several geological and hydrogeological studies and investigations the following Facilities were proposed

Table 23: Proposed Rural Water Supply Facilities in Legedadi and Dire Catchment Areas, Years 1999 and 2010

Water Supply Zone	1999								2010							
	(1)	No. of Wells		(2)	No. of Wells		Total		(1)	No. of Wells		(2)	No. of Wells		Total	
		S	D		S	D	S	D		S	D		S	D	S	D
Legedadi	10	1	-	120	1	1	2	1	170	3	1	170	6	-	9	1
Lencha	20	1	-	160	6	-	7	-	120	4	-	230	8	-	12	-
Sendafa	+60	-	-	210	7	-	7	-	150	3	1	310	11	-	14	1
Gerare Bereh	+50	-	-	40	1	-	1	-	10	-	-	60	2	-	2	-
Dire	70	3	-	100	4	-	7	-	220	8	-	150	5	-	13	-
Total		**5**	**-**		**19**	**1**	**24**	**1**		**18**	**2**		**32**	**-**	**50**	**2**

Table 24: Proposed Rural Water Supply Facilities in Geffersa Catchment Area, Years 1999 and 2010

Water Supply Zone	1999								2010							
	(1)	No. of Wells		(2)	No. of Wells		Total		(1)	No. of Wells		(2)	No. of Wells		Total	
		S	D		S	D	S	D		S	D		S	D	S	D
Gudo	+30	-	-	50	1	-	1	-	10	-	-	70	2	-	2	
Guji Kersa	40	2	-	70	3	-	5	-	80	3	-	100	3	-	6	
Geffersa Chorisa	20	1	-	-	-	-	1	-	70	3	-	-	-	-	3	
Weta Becha	+10	-	-	50	2	-	2	-	30	1	-	70	3	-	4	
Geffersa Burayu	10	1	-	10	1	-	2	-	20	1	-	10	1	-	2	
Total		**4**		**-**	**7**	**-**	**11**	**-**		**8**	**-**		**9**		**17**	

(1) Human water deficit m^3/day
(2) Livestock water deficit m^3/day
(3) D= deep well , S= shallow well

4.2 THIS MASTER PLAN

In the next stage activities of this MP it is essential to investigate the situation of the existing wells. The locations, the operational situation and the productivity of the wells will be investigated. The collected data will be used in the designing stage.

The 2011 population of the Dire-Legedadi and Geffersa catchment areas is estimated at 52000 and 18000 inhabitants, respectively.

The 2011 livestock population in Legedadi-Dire catchments, expressed in terms of Tropical Livestock Units (TLU= 250 kg live-weight) is estimated at 39000 TLU, and at 13000 TLU in Geffersa catchment area.

The 2011 water demand estimates including the human population and the livestock are projected to the year 2035.

4.2.1 Water Consumption and Demand Estimates

General

The domestic water is used for cooking, drinking, washing of utensils and clothes, and for bathing. Tables 25 and 26 Present domestic demand is estimated at 25 l/c/d and demand projected for the year 2035 is estimated by 40 l/c/d

Table 25: Existing Water Demand

	Direct Consumption	Cooking & Washing	Hygiene & Sanitation	Total
Gallon	1.5	2	3	6.5
Liter	5.7	7.6	11.4	24.6

Table 26: Future Water Demand 2035

	Direct Consumption	Cooking & Washing	Hygiene & Sanitation	Total
Gallon	2.5	3.5	4.5	10.5
Liter	9.5	13.2	17.0	39.7

Livestock consumption rates have been taken at30 l/TLU/d for 2011 and at40 l/TLU/d for the year 2035.

It is assumed that the population of the catchment areas will increase at annual rate of 3%, whereas the livestock population is expected to grow at a rate of only 1%.

4.2.2 Water Demand Assessment

Legedadi - Dire Catchment Areas

Table 27: Estimated Rural Water Demand in Legedadi and Dire Catchment Areas, Years 2011 and 2035

Zone	2011					2035				
	Human		Livestock		Total (m^3/d)	Human		Livestock		Total (m^3/d)
	Population	Demand (m^3/d)	TLU	Demand (m^3/d)		Population	Demand (m^3/d)	TLU	Demand (m^3/d)	
Legedadi	15024	376	4810	144	520	30866	1235	6115	245	1479
Lencha	8325	208	6509	195	403	17102	684	8275	331	1015
Sendafa	16084	402	8752	263	665	33042	1322	11126	445	1767
Gerar Bereh	4752	119	1716	51	170	9762	390	2182	87	478
Dire	7808	195	17292	519	714	16041	642	21982	879	1521
Total	**51992**	**1300**	**39079**	**1172**	**2472**	**106814**	**4273**	**49679**	**1987**	**6260**

Table 27 shows that about 1300m^3/day of potable water are required at present to supply the water demand of the human population of about 52000 living in Legedadi-Dire catchments. For 39000TLU livestock 1200m^3/day of water is required. Then the total estimation of existing demand is 2500 m3/day.

The Future 2035 water demand it is expected to reach 6300m^3/d of almost about 4300m^3/d for human demand and of 2000 m^3/d for livestock.

Geffersa Catchment Area

Table 28: Estimated Rural Water Demand in Geffersa Catchment Area, Years 2011 and 2035

Zone	2011					2035				
	Human		Livestock		Total (m3/d)	Human		Livestock		Total (m^3/d)
	Population	Demand (m^3/d)	TLU	Demand (m^3/d)		Population	Demand (m^3/d)	TLU	Demand (m^3/d)	
Gudo	2420	61	3471	104	165	4972	199	4413	177	375
Guji-Kersa	3655	91	5316	159	251	7510	300	6757	270	571
Geff. Chorisa	4572	114	0	0	114	9393	376	0	0	376
Weta Becha	6223	156	3471	104	260	12785	511	4413	177	688
Geff. Burayou	898	22	677	20	43	1846	74	860	34	108
Total	**17769**	**444**	**12935**	**388**	**832**	**36505**	**1460**	**16443**	**658**	**2118**

Table 28 shows that about 450 m^3/day of potable water are required at present to supply the water demand of the human population of about 18000 living in Geffersa catchment. For 13000TLU livestock 400 m^3/day of water is required. Then the total existing demand is estimated by 850m3/day.

The Future 2035 water demand is expected to reach 2100 m^3/d of almost about 1450m^3/d for human demand and of 650 m^3/d for livestock.

Depending on the above calculation of demands, the numbers of facilities that will be required to satisfy the total estimated demand are estimated in tables below.

Table 29: Proposed Rural Water Supply Facilities in Legedadi and Dire Catchment Areas, Years 2011 and 2035

Water Supply Zone	2011								2035							
	Human m^3/d	No. of Wells		Livestock m^3/d	No. of Wells		Total		Human m^3/d	No. of Wells		Livestock m^3/d	No. of Wells		Total	
		S	D		S	D	S	D		S	D		S	D	S	D
Legedadi	376	8	2	144	5	-	13	2	1235	20	3	245	9	-	29	3
Lencha	208	7	-	195	7	-	14	-	684	24	-	331	12	-	36	-
Sendafa	402	5	3	263	9	-	14	3	1322	31	5	445	16	-	47	5
Gerare Bereh	119	1	1	51	2	-	3	1	390	14	-	87	3	-	17	-
Dire	195	5	1	519	18	-	23	1	642	22		879	31	-	53	-
Total	**1300**			**1172**			**67**	**7**	**4273**	**111**	**8**	**1987**	**71**	**-**	**182**	**8**

Table 30: Proposed Rural Water Supply Facilities in Geffersa Catchment Area, Years 2011 and 2035

Water Supply Zone	2011								2035							
	Human m^3/d	No. of Wells		Livestock m^3/d	No. of Wells		Total		Human m^3/d	No. of Wells		Livestock m^3/d	No. of Wells		Total	
		S	D		S	D	S	D		S	D		S	D	S	D
Gudo	61	2	-	104	4	-	6	-	199	7	-	177	6	-	13	-
Guji Kersa	91	3	-	159	6	-	9	--	300	11	-	270	9	--	20	-
Geffersa Chorisa	114	4	-	0	0	-	4	-	376	13	-	0	0	-	13	-
Weta Becha	156	6	-	104	4	-	10	-	511	18	-	177	6	-	24	-
Geffersa Burayu	22	1	-	20	1	-	2	-	74	3	-	34	1	-	4	-
Total	**444**	**16**	**-**	**388**	**15**	**-**	**31**	**-**	**1460**	**52**	**-**	**658**	**22**	**-**	**74**	**-**

The above tables 29 and 30 show the required number of wells, shallow and deep, that cover the demand at 2011 and 2035 years. After field investigation, to verify the situation of existing wells, whether they are in operation or not, then the needed new wells to be drilled will be concluded.

PART III. MASTER PLAN REVIEW: ENVIRONMENTAL & PHYSICAL PLANNING ASPECTS

1. PHYSICAL PLANNING ISSUES

1.1 INTRODUCTION

1.1.1 Characteristics of the Study Areas

The Legedadi, Dire and Geffersa catchment areas characteristics are as follows:

- The catchment areas have a vital role in harvesting of water which is stored in the three reservoirs for supply water to the metropolitan area.
- A good part of the area of the catchment basins is cropped or utilized for grazing of cattle.
- The physical characteristics of parts of the catchment areas are subject to erosion due to their relief and the bare soil cover which results from overgrazing. The existing forest cover is also being denuded due to unregulated felling of trees to provide household fuel amongst other purposes.
- There is a constantly growing pressure on land use due to the steady increase in the population and the need to farm additional areas.

1.1.2 Physical Planning Objectives

The physical plans seek to provide broad demarcation lines for the following:

- Land use, including delineation of areas whose use, i.e. access to humans for cropping and other purposes and for grazing, should be controlled and/or restricted.
- Locations for rural centers and community facilities.
- A basic infrastructural outline plan.

1.1.3 Implementation of the Master Plan Proposals

Implementation of a master plan is a multi-disciplinary and on-going activity and thus involves numerous authorities at the local, regional and metropolitan level.

A first condition for adoption of the master plan therefore requires the consent and cooperation of the related institutions and agencies. AAWSA, as the authority responsible for the project and the principal party to implementation, will have to secure this cooperation at the institutional and administrative, as well as legal levels

1.2 SETTLEMENTS

1.2.1 Existing Settlement Pattern

At the time of the TAHAL Master Plan of the 2000 year the general nature of the settlement pattern is rural and traditional. Clusters or homesteads of tukuls are generally rather sparsely scattered throughout the area with a low tendency towards concentration. This situation is still the same at present.

Sendafa, which is situated in Legedadi catchment area is the only really concentrated settlement in all three catchments, serves as a Woreda town and as a rural center with schools, clinics, shops, government offices, etc.

Dire-Sekoru, another semi-concentrated settlement in Dire basin, is a partly planned village. Nearby, east of Dire reservoir, a new settlement has developed in the past few years around the Salini construction camp which was set up for construction of Dire dam.

A number of small towns/villages located beyond the boundaries of the catchment areas, but near the catchment boundaries, could render services to the catchment area population, so they should therefore be taken in consideration.

These villages are as follows:

- The village of Legedadi, on the Asmara road which has a number of community facilities.
- The village of Sire Goyo, southwest of Legedadi reservoir, which has a school and a clinic.
- The town of Burayu, east of Geffersa, at present intended for development.
- The village of Menagesha, west of Geffersa.
- Two concentrations in the Mangaro area, just outside Geffersa basin.

1.2.2 The Proposed Settlement Patterns

It is a common practice in the world to endeavor to maintain water catchment basins free from human land uses, such as settlements, agriculture, etc. But as it is socially and physically impossible the TAHAL Master Plan had proposed that the type of settlement, which is rural and traditional, to be kept and Encouraged. Scattered settlement pattern is preferable since the pollution caused by scattered tukul clusters has a less adverse effect on reservoir water quality compared with that contributed by concentrated settlement.

As for the services required by the inhabitants of the catchment areas, these should be provided by certain towns and villages which considered as rural centers. The rural centers will accommodate, in addition to the residential buildings, the required community facilities such as schools, clinics, churches, markets, agricultural support services, warehouses, shops, and other low-level threshold businesses.

The above policy proposals will have to be coordinated with the central and local authorities, and measures taken to facilitate their implementation, including their embodiment in legal regulations.

1.2.3 Proposed Location of Rural Centers in Legedadi and Dire Catchments Areas (See Fig. 12)

- Sendafa, the main rural center, already has many facilities and offices. In addition to being a higher level center in the regional hierarchy (a Woreda town), it serves as a low-threshold center for the north-eastern part of the basins.

- Dire-Sekoru, together with the complex which has developed around the Salini camp, will serve as a center for the north-western part of Legedadi-Dire area. Although the service radius to the farthest clusters in Dire catchment area, such as Genda Mola and Degele Bolabata, is around 10 km and involves travel in mountainous terrain, the low population density of these clusters does not justify establishment of another closer rural center.

  As per the Master Plan of the year 2000 Dire Sekoru accommodated an elementary school, church and a market, in addition to that, Dire now accommodates three government Services and an Agricultural support service also. But still there is no hospital, clinic or high school.

- The 2000 M.P. proposed that the buildings of the Salini camp (set up for construction of Dire dam) be transferred - at least partly - to the community for public purposes. This partially happened as this facility now accommodates one agriculture support unit and three government services. As mentioned above still there is no high school or clinic in both location Direr and this one.

- As mentioned above, it is proposed to rely on a number of rural centers located outside the basin boundaries, such as the village of Legedadi to serve the central-western part of Legedadi catchment. As per year 2000 M.P. Legedadi accommodated a church, a secondary school, a market and a clinic. In addition to that now it accommodates three secondary schools, one agriculture support unit and four government services.

- At the year 2000 the south-eastern wing of Legedadi catchment does not have any definite existing nucleus which could develop into a rural center. It is therefore proposed that a rural center be set up east of Legedadi reservoir in the Choba Lencha Kebele. Construction of two roads, will improve the accessibility of this area which is at present difficult to reach.

  Now, this area accommodates an elementary school, an agriculture support services and three government offices. Still there is no clinic, market or high school.

From the above the proposed rural centers in these two catchments areas have been developed since 2000. But some more facilities still needed in Dire, Chobea Lencha, like clinics high schools and market. It is also noticed that no hospital in the whole area.

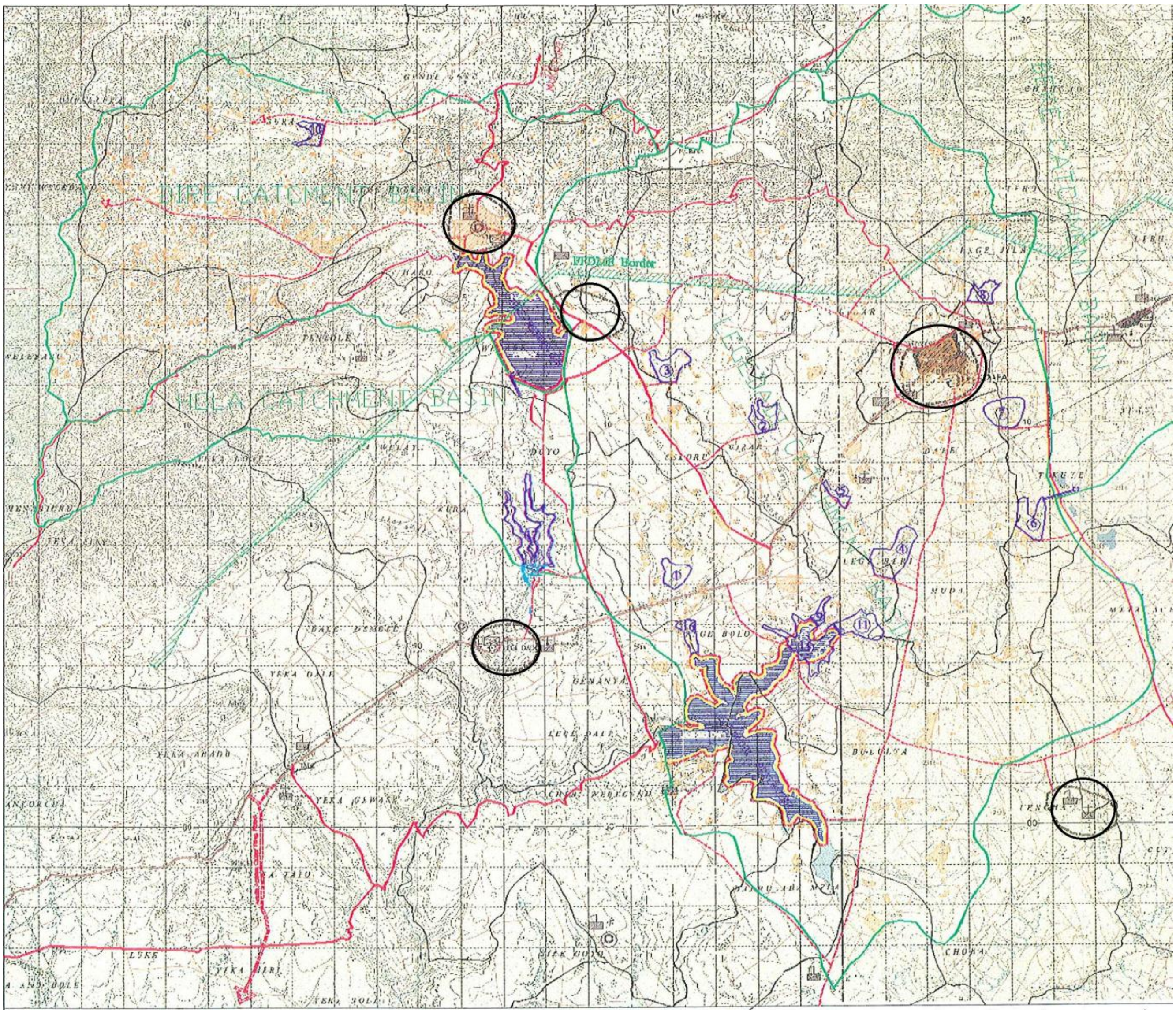


Figure 8: Proposed Location of Rural Centers in Legedadi and Dire Catchment Areas

1.2.4 Proposed Location of the Rural Centres In the Geffersa Area (See Fig. 13)

- The northern part of the basin, including the valley and the sides of the Dima River, can be served by a rural center to be established in Wetabecha. This village accommodates now two Churches, two elementary schools, one agriculture service office and three governmental offices. Still there is no clinic, market and a high school.
- There is a settlement concentration in Geffersa Chorisa Kebele, near the Ambo road, which could provide a nucleus for another center. This village accommodates now elementary school, one agriculture service office and three governmental offices. Still there is no clinic, market and a high school.
- Mangaro in the Guji Kersa Kebele, on the southern boundary of the catchment, could serve as the rural center for this area of the catchment. This village accommodates now elementary school, one agriculture service office and fifteen governmental offices. Still there is no clinic, market and a high school.
- The town of Burayu, situated to the east of the catchment, is near enough to provide services to the central part of the catchment. This town accommodates now a church, secondary school, elementary school, one agriculture service office, three governmental offices, and a clinic, market and a high school.

From the above information regarding the available facilities in these proposed rural center, some developments occurred but still more services still needed like clinics, markets and high school. Also there is no available hospital in area.

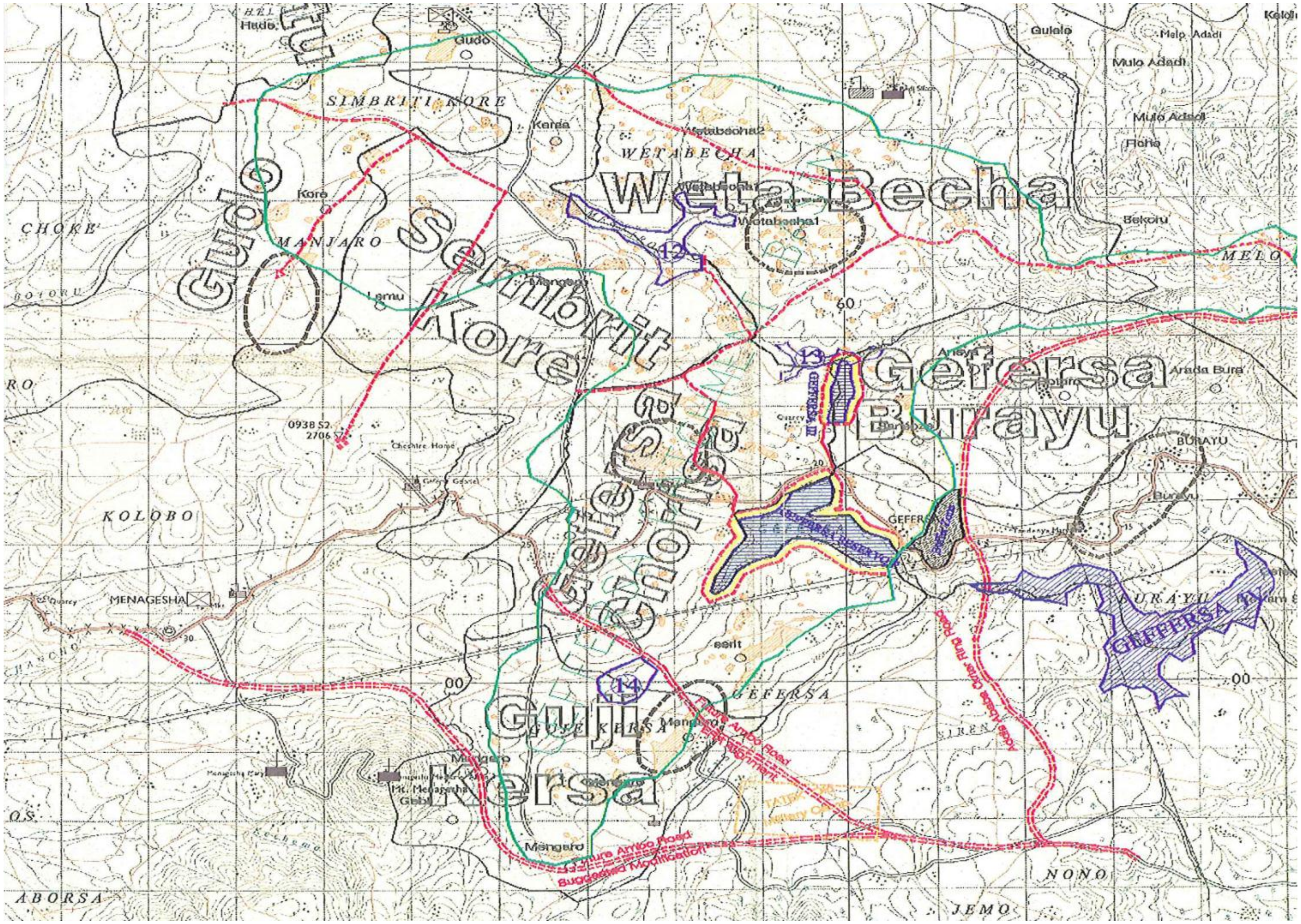


Figure 9: Proposed Location of Rural Centers in Geffersa Catchment Area

1.3 ROADS

1.3.1 Main roads

As per the 2000 M.P. there were only two main roads crossing the catchment areas, but now new road is also passing through this area:

- Geffersa catchment area: The Ambo road traversing the catchment from east to west.
- Geffersa catchment area: New Ambo road is another main road crosses this area at the south side connecting it with Addis Ababa. (new road)
- Legedadi—Dire catchment areas: The Asmara road crossing Legedadi basin from the north-east to the south-west.

Both roads Asmara and Ambo are in a relatively good condition, although the Ambo road in Geffersa area is of a lower geometric standard. In both cases, the vehicle travel time to Addis Ababa is around half an hour, which highlights the dormant potential of the areas due to the proximity of the capital. The planned Addis Ababa outer ring road will join the above-mentioned roads, but the junctions of the ring road with the Ambo and Asmara road will lie beyond the boundaries of the catchment basins.

1.3.2 Rural Roads:

There are several rural roads in the area. Like:

- A road crossing the western part from north to south through the Kebeles of Sembit Kore, Geffersa Chorisa and Guji Kersa in Geffersa catchment.

And the following in Legedadi and Dire catchment areas

- The AAWSA service road from Legedadi dam to Addis Ababa;
- The AWSA service road from Dire dam to the Legedadi treatment plant;
- The road from the Asmara road to Dire-Sekoru settlement and then continuing northwards through the mountain range to Muketuri;
- A forest road from Dire-Sekoru to the south-west on the boundary of Dire basin;
- A forest road from Dire-Sekoru to the south-west on the boundary of Dire basin;
- A road from the Asmara road (2 km east of Sendafa) southwards to Chefe Donsa and Debre Zeyt.

The attached two figures (Fig. 14 and Fig. 15) for Geffersa, Dire and Legedadi catchments show the existing main roads, the existing rural roads and the proposed by 2000 year M.P. and by this study. The intention of the proposed roads is connecting villages together and with existing main road.

1.3.3 Trails

Paths and trails, whether created and used by humans or by cattle, crisscross the countryside in all directions.

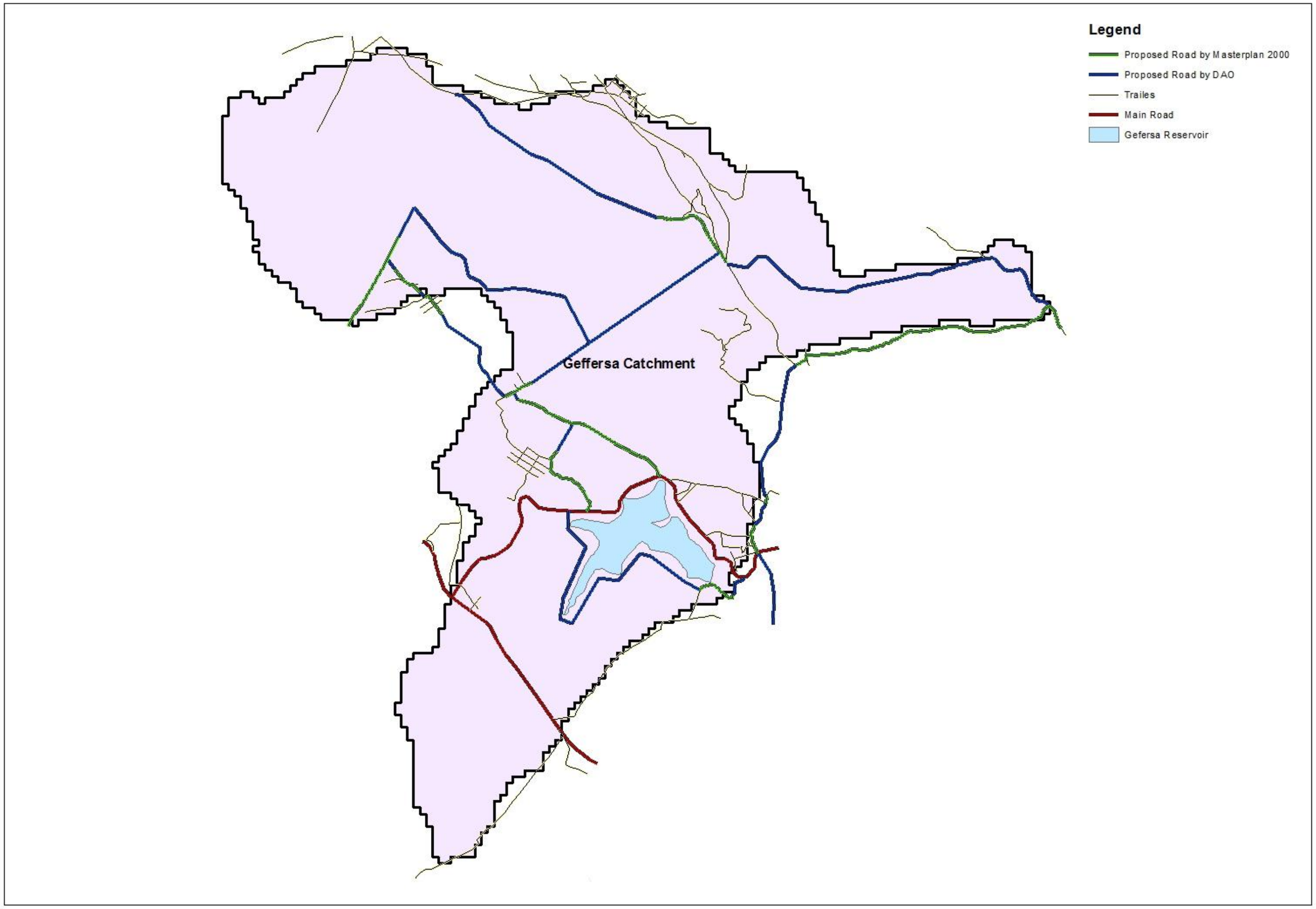


Figure 10: Geffersa Roads

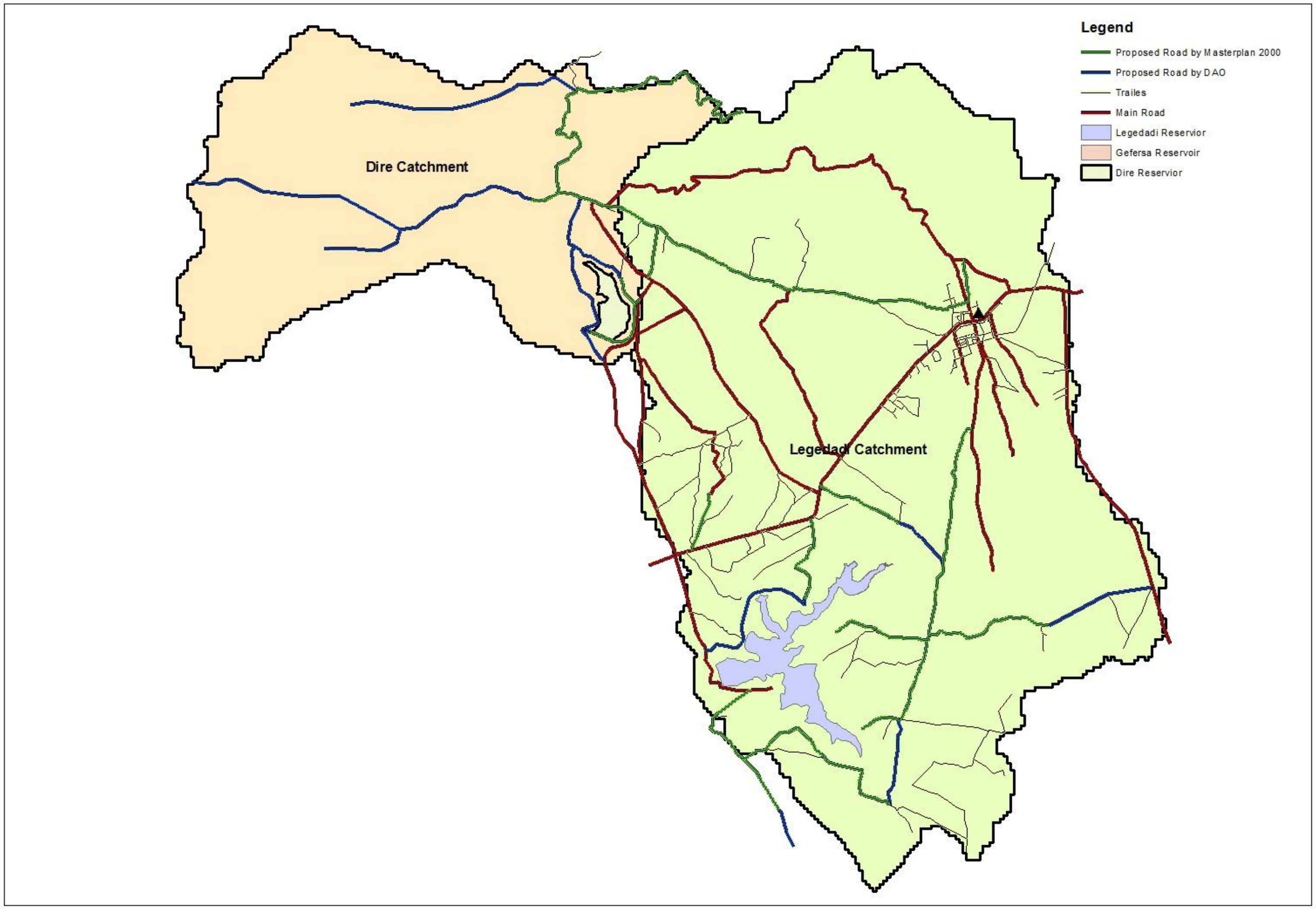


Figure 11: Legedadi & Dire Roads

2. LAND USE AND LAND COVER CHANGES & TRENDS

Introduction: the TOR requesting to identify the difference between the present and the previous Land use and land cover.

The Land Use and Land Cover aspect had been covered by Master Plan Report issued on 2000 year, and FinFinne Surrounding Special Zone of Oromia Report, Volume III which has been submitted on March 2011.

Methodology: the FINFINNE study covers larger area than the three catchments area. So to identify the land use in catchments areas using GIS maps. This was done by adding the shape files of the catchment areas boundaries to the FINFINNE GIS land use maps. This will represent the situation at the time of FINFINNE report was prepared. To identify the changes between FINFINNE report and now situation the GIS maps produced by the previous step were added to Google Earth Images. Out of that the following information can be developed.

1- ***Geffersa Dam Area:*** The Table 22 summarises the findings regarding Geffersa Dam Catchment area. Taking into consideration that there 2000 report and FINFINNE report used mostly the same categories defining the land use and land cover but there is a slight difference.

Table 31: Land use of Geffersa Catchment

Land Use and Land Cover	Area Now	Percentage %	
		Now	Year 2000 report*
Bare land	0	0.00%	2.1
Cultivated land	2968.38	53.5%	22.6
Plantation Forest	375.74	6.8%	26.6
Settlement	546.54	9.8%	0.2
Water body(Dam)	140.09	2.5%	2.4
Open grassland	1306.9	23.5%	29.5
Woodlot	212.34	3.8%	0.2
Bush shrub land	0	0.0%	16.4
Total	5550	100%	100

* note: the listed figures taken from year 2000 table No. 5.2 page 5.11

From the table one can read the following: the bare land and bush shrub land areas disappeared. The open grass and plantation forest areas reduced. While the cultivated area increased to more than 200%. The settlement area increased by a more than fifty times, actually 2000 year report had taken the concrete structures and roads only into consideration as noted in the report in same time it gives separate figures for small villages, while FINFINNE report took all build up areas including small villages.

2. ***Legedadi Dam Area:*** The Table 23 summarises the findings regarding Legedadi Dam Catchment area. Taking into consideration that there 2000 report and FINFINNE report used mostly the same categories defining the land use and land cover but there is a slight difference.

Table 32: Land use of Legedadi Catchment

Land Use and Land Cover	Area Now	Percentage %	
		Now	Year 2000 report*
Bare land	2497.1	12.1%	5.4%
Cultivated land	13582.42	65.9%	54.9%
Plantation Forest	1591.96	7.7%	6.4%
Settlement	1681.9	8.2%	0.4%
Water body(Dam)	374.42	1.8%	2.2%
Open grassland	691.1	3.4%	28.2%
Woodlot	84.73	0.4%	2.9%
Bush shrub land	96.4	0.5%	0.7%
	20600	100%	101%

* note: the listed figures taken from year 2000 table No. 5.5 page 5.24

From the table one can read the following: the bare land, the cultivated land and plantation forest land areas are increased. The bare land nearly doubled. The cultivated land increased by 20%, also the plantation forest increased by the same percentage 20%. While the settlement area increased by about 20 times, the same as mentioned before the year 2000 report did not take the small villages in the above figure while FINFINNE report take it into consideration. The other land cover categories decrease. The open grass areas went down to one eighth of its previous area. The woodlots went down to one seventh of its previous area. While the bush shrub land slightly dropped to 70% of its previous area.

3. Dire Dam Area: The Table 24 summarises the findings regarding Dire Dam Catchment area. Taking into consideration that there 2000 report and FINFINNE report used mostly the same categories defining the land use and land cover but there is a slight difference.

Table 33: Land use of Dire Catchment

Land Use and Land Cover	Area Now	Percentage	
		Now	Year 2000 report*
Bare land	3053.83	39.3%	3.3%
Cultivated land	2697.38	34.7%	44.0%
Plantation Forest	1690.77	21.8%	20.4%
Settlement	193.69	2.5%	0.2%
Water body(Dam)	134.33	1.7%	0.0%
Open grassland	0	0.0%	18.1%
Woodlot	0	0.0%	11.7%
Bush shrub land	0	0.0%	2.3%
Total	7770	100%	100%

* note: the listed figures taken from year 2000 table No. 5.8 page 5.34

The year 2000 report was prepared before the Dire Dam was completely constructed. So, major changes occurred after the Dam was completed. From the table one can read that the bare land increased to ten times. The water body of course was not there and it appears in the now figures. The open grass, the bush shrub and woodlot disappeared. The cultivated area decreased by about 10%. The settlement area increased to twelfth times, taking in consideration the same note that the year 2000 report did not take inconsideration the small village in the above figure while FINFINNE report take it. The plantation forest increased by about 1%.

3. EXISTING FARMING PRACTICES AND LIVESTOCK MANAGEMENT

Farming practices

Agriculture is mainly tuned towards subsistence and the main crops cultivated are cereals (wheat, teff, oats and barley). Pulses are also widely cultivated (lentils, vetch, chickpeas, horse beans). In addition there are small commercial eucalyptus plantations – beside the region owned stands - and vegetable fields (onion, garlic and cabbage). Agriculture is rain-fed in all the catchments. The absence of irrigation and the general poor moisture management techniques explain a large annual fluctuation in yield between years with good rainfall (2002 ET) and relatively modest rainfall (2001 ET – see table 34). The yields are considerably lower than what is possible under research conditions (table 35). The use of agro-chemicals is modest. According to the District Agriculture office an average of 100 kilograms of fertilizer is used (DAP and Urea). Pesticide is typically applied on vegetable fields and amounts to 1 kg/ha. Although pesticide application is relatively low at the moment, from other areas in Ethiopia can be seen that with increased development, there is an increase in unregulated pesticide use, leading to severe pollution of water bodies. This will need to be taken into account when designing development intervention; both through training and awareness creation among farmers, as well as establishing water quality monitoring systems.

Table 34: Cropped area and yields (meher) in Berek and Welmera woredas

	Berek 2001 EC		Berek 2002 EC		Welmera 2002 EC	
	Area	Production	Area	Production	Area	Production
Cereals (Total)	**29439**	**487339**	**27159**	**819650**	**36024**	**1049579**
Teff	9458	118558	8929	220993	11137	210073
Wheat	15076	294112	12999	492257	13829	522168
Barley	4905	74669	5232	106400	11027	316563
Maize					31	775
Pulses (Total)	**10401**	**123695**	**7720**	**193563**	**7461**	**112180**
Lentils	3378	42452	2856	65690	1542	15480
Horse beans	3781	35233	-	-	2283	40240
Chick peas	1637	21530	1322	35689	1512	24270
Field peas	150	1200	1084	23372	627	8238
Vetch	1455	23280	2458	68812		
Grass peas					1497	23952
Oilseeds (Total)	**400**	**1600**	**104**	**1023**	**1041**	**10133**

Linseed	400	1600	104	1023	467	6323
Oth oilseeds					574	3810
Vegetables (Total)	**169**	**8665**	**128**	**8905**		
Onion	41	1210	13	771		
Local cabbage	23	1720	33	2666		
Garlic	46	2710	41	2661		
Other veg	59	3195	41	2807		

Table 35: Crop yield ranges under research station setting and small holder cultivation

Type of crops	Research station Yield Qt/ha	Small holder Yield Qt/ha.
Teff	20-28	10-15
Wheat	53	12-32
Barley	57-60	10-16
Faba bean	15-25	15
Field Pea	12-16	15

Source: OWWDSE (2011)

Livestock production

Livestock is equally important and cattle and sheep are the most common bred animals, followed by equines. Due to land scarcity and demographic pressure, fodder resources are being stressed beyond their capacity. The main sources of livestock feed are natural pasture, hay, crop residues, and weeds. Fallow lands are also used for grazing. Natural pastures are used year-round and they are not rested. As a consequence these areas are often degraded as the most palatable species are consumed and not given sufficient opportunity to regenerate.

Livestock productivity is also affected by the widespread occurrence of common diseases. The major cattle diseases are Contagious Bovine Pleuropneuminia (CBPP), Foot and Mouth Disease (FMD), Anthrax, Blackleg, Pasteurolosis, Brucellosis and other viral diseases, internal parasites /Nematodes, Liver fluke, Fascilosis, Strongloides and Lungworm. External parasites /ticks, Mange Mites are common too. The major diseases of small ruminants are Pesto det Petits/PPR/Contagious Caprine Pleuropneumonia/CCPP/, internal parasites and external parasites. In addition to the above mentioned there are diseases like Epizootic lymphangititis, Ulcerative lymphangities, glandess, cardiac for of African Horse sickness, contagious Ecthyma (Orf), Dermatophylosis.

Availability of animal health infrastructure is very important to improve animal productivity and control animal diseases. During the year 2002 there were for instance in Welmera 5 clinics with 7 animal health personnel – including veterinary doctors. From the woreda office there is also a program to improve cattle stock by cross breeding local and foreign cows. This has had positive results – especially in milk yields and disease resistance.

Table 36: Livestock population in Berek and Welmera District (2002 EC)

Type	Berek	Welmera
Cattle	122589	175846
Sheep	91175	101450
Goats	2213	14339
Horses	13949	7528
Mule	57	215
Donkey	17195	13135
Poultry	84843	182647
Beekeeping	2772	

After investigating land-use change and land-cover the MP2000 goes into a detailed description of what are the main agricultural practices in the study areas. Livestock management and farming are always considered as terms of the same equation and are always practiced together.
The MP2000 discerns and characterizes the main agricultural and pastoral activities according to the three catchments.

Geffersa

Crops are cultivated mainly on the sloping areas in between streams, on the foot-slopes and on the undulated landscape. Barley is the main crop alongside with teff and wheat. Around the household, Kale cabbage and Enset are the most common cultivated plants. The crop fields are ploughed with oxen after the little rainy season (belg) and left bare at the onset of the erosive main rainy season. The total cropping land occupies 22.6% of the land and thus offers a good protection against erosion. Farmers plough along the contour lines, use cutoff drains and draining ditches. Fields are often left to rest for one year (fallow). The boundaries between fields are said to be acting as grass strips.

Land-use change towards cropping land is the main concern regarding erosion and land degradation. The MP2000 suggests agriculture intensification to permit higher yields per hectare and to decrease the expansion of the cropping land towards the grassland and forested areas. It is suggested to apply chemical fertilizers (50 kg DAP and 50 kg Urea) and to introduce improved seeds.

Legedadi

The crop fields are spread extensively on the foothills, flatlands and mid-lower slopes. Black soils, grey soils and light soils are individuated as main soil groups. The most fertile are the black soils (vertisols) that can be found in flat areas and valley bottoms. They require a good preparation, drainage system and they are less prone to erosion. Grey soils are found on undulating landscape and on hill-sides; they are often burnt or fallowed to increase fertility. Light and red soils are shallow and are common in steep areas and are prone to erosion. Most of the fields are left bare from February until August when the sown crops finally provide a good protection against rain impact. Additionally, cultivated fields are expanding and they are encroaching the grassland. In 1994 the grazing land and the farmland occupied 34 % and 45% of land respectively. In 2000 the figures for grazing-land and crops changed to 28% and 55% respectively.

Dire

The area is mountainous and shows an altitude difference of 660 m. The higher part of the catchment is occupied by forest plantation under regional authority. The livestock is allowed to freely graze in between the trees. Crop cultivation occurs in the narrow valley bottoms and on the erosion prone foothills. The most common crops are oats barley and horse bean. The yields are said to be decreasing due to erosion and loss of fertility. Farmers cannot afford fertilizer and do not apply soil conservation measures. The fields are ploughed several times in every direction and draining ditches are dug along the slope to redirect runoff and run-on. The lower part of the catchment has the best potential for agriculture, but there the population pressure is particularly high. This can be partly attributed to the construction of Dire reservoir that caused farming land to shrink in size. Furthermore the relocation caused a higher encroachment on marginal-sloping areas of the upper catchment. Furthermore, there are a high number of landless people. The area is highly affected by soil erosion in form of landslides, gullies, sheet and rill erosion. Bunds, Grass boundaries and vegetation along gullies with a poor design and maintenance were documented in few cases. The eroded soil is deposited into the streams.

Feedback on the master plan

It is particularly relevant the change occurred in Geffersa since the MP was compiled. If back in 2000 only 22.6% of the land was cultivated, nowadays more than 55.3% is under cropping. This change together with backward agricultural practices is endangering the ecosystem and increasing the amount of land degraded and prone to erosion. We observed Gullying features, wounded landscape and poor soil conservation. We agree with the suggestion of intensifying production to decrease crops expansion.

Dire catchment situation did not change dramatically, but shows aggravated signs of soil erosion and poor land and fertility management all over the place and in particular on the foothills. Subsistence farming is still the main way of living. It is clear that a big portion of the community is landless and relies on by-product of the region owned forest and on livestock that graze on the common land and in the forest plantations. The dislocation of people in 1998 for the construction of the dam increased the cultivation on marginal land. It is important to learn from this event. When the farmer is compensated and dislocated it is vital to also give him some alternative other than farming.

Legedadi has good potentials for developing a more sustainable and advanced agriculture-livestock system. The deep and fertile vertisols when provided with proper draining and good fertilization can give high yields. The increasing size of the crop fields is taking away land from the pastures and it is causing degradation of the area. A decrease in number of animals, stall feeding and improved fodder management would decrease the magnitude of the challenge.

Overall, the agricultural development constraints that existed at the time of the 2000 G.C. Master Plan, are similar today.

The main agricultural challenges that need to be stressed are:

- Land-use change
- Soil erosion and loss of fertility
- Nutrient mining
- Low productivity and backward farming practices
- Use of low quality seeds
- Low mechanization and use of agrochemicals
- Proper and controlled use of agro-chemicals
- Scarce awareness
- Lack of soil conservation techniques
- Animal health and fodder sources
- Lack of alternatives

Although pesticides application is relatively low, from other areas in Ethiopia can be seen that with increased development, there is an increase of unregulated pesticide use, leading to severe pollution of water bodies. This will need to be taken into account when designing development interventions; both through training and awareness creation among farmers, as well as establishing water quality monitoring systems. It is clear that soil tillage is the main way of farming and it is practiced repeatedly leaving the soil exposed to erosive rain. By early sowing this side-effect can be undermined because the crops would establish a dense canopy earlier and it will protect the ground from runoff and rain-splash. To achieve early sowing, improved seeds and mechanization might play a key role. Additionally the fields are ploughed in every direction instead of following the contour lines as suggested by the best soil management practices. This practice favours runoff and soil erosion (Fig 6).

The agro-ecological soil nutrient cycle is severely disrupted. The absence of grazing land and fuel for household stoves triggers a vicious cycle in which manure is note returned to the field but burnt or sold (Fig 16). Crop residues are never ploughed into the soil but fed to the livestock. The consequent decrease of organic matter in the soil decreases its stability and makes it more susceptible to soil erosion. Additionally the vegetation cover is often minimal due to excessive over grazing. A decreased agro-pastoral activity together with an improved forest-woodlot management would help in breaking the cycle.

Alternative agricultural developmental paths need to be explored and pursued. The city of Addis Ababa is an enormous and steadily growing market, and the communities in the catchment areas should be enabled to tap into this. Without ignoring the importance of staple crops, value chains of alternative products such as highland fruits, honey, bamboo (indigenous varieties) spices and herbs (higher added value after processing/drying) could and should be developed. The growing hospitality industry in Addis Ababa already forms a major market for such products. The supply of highland fruits such as apples to the capital comes mainly from import and to a limited extent from the Chencha area, in Southern Ethiopia, rendering the price per kilogram very high. Other options that could be explored, amount to farmer outgrowing schemes for fruit or vegetables, whereby an investor buys a guaranteed level of produce from small-holder farmers and markets this in larger quantities to large markets. A more detailed description of alternative income generating activities is given in chapter 4.2.

Furthermore in all catchments is necessary to augment awareness on soil erosion and measures to tackle it. Extension work, trainings and participatory learning mechanisms are suggested tools to reach the community and promote a better land stewardship.

4. SOIL CONSERVATION MEASURES

4.1 THE MASTER PLAN PROPOSALS

The 2000 Master Plan presents in detail the surface water soil erosion phenomenon, the impact of soil erosion on the water reservoirs and the impact on the agriculture and infrastructure of the catchment.

The situation in the catchments is presented analytically starting from the soils type where the soils in the Geffersa catchment (mainly luvisols) are considered to be less prone to soil erosion, whereas soils of Legedadi and Dire are more prone to erosion.

Data regarding land use, morphology and rainfall are given as well as information regarding existing soil conservation practises. The main results are as follows:

- A large part of the soils in Geffersa, Legedadi and Dire catchments are prone to soil erosion.
- The expected siltation rate of the Dire catchment is expected to be higher than that of the Legedadi.
- Rainfall intensities of up to 60 minutes are very high, but are moderate for longer periods.
- The common agricultural practices and the trend of converting grassland and shrub-land into cultivated land is harmful from the aspect of triggers soil erosion.
- Almost no soil conservation measures are rarely is practiced by the farmers.
- Water quality deterioration process in the Legedadi reservoir is severe.
- Overgrazing and cattle trails with subsequent severe erosion are widespread.

Two main measures are proposed by the Master Plan in order to control soil erosion, to rehabilitate already eroded lands and to minimize transportation of eroded soil and pollutants to the reservoirs. These namely are

- Introduction of more advanced cultivation practices and cropping patterns bringing higher farmer incomes.
- Application of soil conservation measures.

The main advanced cultivation practices and alternative activities proposed by the Master Plan in order to bring higher farmer income and replace certain present practices which foster soil erosion are:

- Introduce fruit trees suited to the local climate and soil conditions.
- Expansion of poultry breeding on a family scale.
- Introduction of honey production.
- Introduction of mushroom production.
- Rising of earth worms.
- Introduction of dairy farming.

Regarding the soil conservation methods the Master Plan does a very analytical presentation of the existing practices and finally proposes the following depending on the land slope. Some measures are listed as auxiliary because they are not conservation measures per se but help in protecting the soil:

Table 37: Soil conservation measure for varying slopes

Auxiliary measures	Cut off drains, Protected and improved waterways, check dams, area closure, cut and carry livestock feeding, controlled grazing, continuous grazing rotational grazing, grassland improvement, re-vegetation
Up to 4%	Proper drainage with cut off drains and protected waterways.
Between 4% and 15%	Grass strips, alley cropping
More than 15%	Graded bunds, grassland maintenance, control overgrazing, area enclosure

Finally the Master Plan considers that soil erosion and catchment rehabilitation should combine the following approaches:

- Alternative agricultural practices, crops and sources of income for the farmers.
- Alternative sources of income for the farmers should be examined not bound to land, water and cattle.
- Perennial crops, such as fruit trees, grass land with controlled grazing and Eucalyptus plantations should to some extend replace annual cultivated crops such as teff, wheat and barley.
- Soil conservations measures should be applied according to land use and slopes.
- Silt traps should be constructed in the proximity of the reservoirs to trap eroded particles and to avoid reservoir siltation.

4.2 CURRENT PRACTICE

In contributing to the welfare of the inhabitants of the catchment areas as well as to reducing erosion and consequent siltation, soil conservation measures in the catchment contribute to both primary and secondary goals of AAWSA (as also suggested by the Master plan 2000). Soil conservation as such should then be seen as major development opportunity in the catchment areas. The situation as sketched in the Master plan and supported by ESIAs (Seureca, 2010) is that Geffersa, Legedadi and Dire Catchments areas are typical of peri-urban highland mixed cropping-livestock farming systems with rain fed season crop production and a strong livestock farming component. There is serious shortage of land in the three catchment areas for both farming and grazing. Livestock browse freely in the catchments with consequent overgrazing, a prime cause of erosion, as well as pollution, while the livestock also encroach on the reservoirs to drink water with resultant contamination.

An additional challenge is the expansion of the city of Addis Ababa with the consequent increasing investment in the suburbs, nearing the catchment areas. Particularly in Geffersa uncertainties over their own land, makes farming communities weary to take effective measures for resource conservation. To tackle this uncertainty suggested in the Master Plan is to ensure farmers uninterrupted and long-term access to the same piece of land and resource.

Identified in the Master Plan 2000 as one of the constraints to land conservation, is land tenure. Leasers of any product, be it land or any other commodity are only willing to invest in the product as long as lease contracts are clear, binding and of considerable duration. Since the master plan in 2000 the Government of Ethiopia has gone to considerable efforts to improve the land lease conditions, improving confidence of farmers to investment and adapt agriculture practices for longer term benefits. These improved regulations combined with the willingness of farmers (as identified in the Master plan 2000 field surveys) should allow for improvements, although investments (loans / credits) and cooperation in the farming sector would be required. Although agricultural investment maybe of secondary importance in this project, the fact is that a lot of examples of best practices exist within Ethiopia’s borders of (holistic) sustainable land management (SLM) which improve livelihoods socio- economic conditions and contribute to conservation of landscapes. In implementing physical, biological, soil and water conservation practices it is important to consider the different possibilities, i.e. to allow a basis of packages, that: give a variety of options and make a farmer self-sufficient.

Soil and water conservation practices are not yet near the scale that is required to secure these vital catchments although the local woreda’s have set up training and awareness programs among resident communities to overcome the typical problems. Current thinking in particular is that watershed management has to be done at scale and not piecemeal, so as to trigger a transformation of landscapes, soil and water processes and micro-climates. It also appears that a number of techniques that would be much appropriate in the catchment of Dire and Legedadi are not applied: such a grass strips, controlled intensive grazing, buffer strips along local streams. Neither are the opportunities in integrated crop-livestock systems – from composting to stall feeding fully utilized. Terracing is accelerating but the scale is still small related to the requirement.

A lesson from successful programs in other parts of Ethiopia is the importance of local planning of the interventions and creating the long term ownership for these activities. The proposed activities in the Master Plan have yet to take shape.

Table 38: Soil and water conservation activities in Berek Woreda

Activities	Unit	2001 EC	2002 EC
Seedling production	(Mill Pes)	0.154	20.5
Seedling Plantation	(Mill. Pes)	0.138	15.68
Nursery establish marked	Numbers	2	2
Nursery Operation	Numbers	2	2
Seed story contrition	Number	-	-
Grass seed multiplication	Kg	-	-
River diversion	Numbers	1	3
Terrace construction	Km	127.02	212.7
Terrace maintenance	Km	685.30	1528.8
Check dam construction	Km	-	116
Land rehabilitation	(Ha)	-	-
Surface pond construction	Number	24	-
Spring development	Numbers	-	-
Candle construction	Km	-	-
Feeder rood construction	Km	4	31
Feeder rood maintenance	Km	15	34
Trained farmers	**Num**	**-**	**-**

Source:- District Agricultural office

4.3 CONCLUSIONS AND RECOMMENDATIONS

Geffersa, Legedadi and Dire Catchments areas are typical of pre-urban highland mixed cropping-livestock farming systems with rain-fed season crop production and a strong livestock farming component. There is serious shortage of land for both farming and grazing. Livestock browse freely in the catchments with consequent overgrazing, a prime cause of erosion, as well as pollution, while the livestock also encroach on the reservoirs to drink water with resultant contamination. Soil and water conservation practices are almost non-existent although the local woredas have recently set up training and awareness programs among resident communities to overcome the typical problems.

An additional challenge is the expansion of the city of Addis Ababa with the consequent increasing investment in the suburbs, nearing the catchment areas. Particularly in Geffersa uncertainties over their own land, makes farming communities weary to take effective measures for resource conservation. To tackle this uncertainty suggested in the Master Plan is to ensure farmers uninterrupted and long-term access to the same piece of land and resource. In Oromia land certificates issuing are already at an advanced stage at is a step forward compared to the situation in 2000.

If land tenure is well regulated a lot of examples exist of best practices within Ethiopia's borders of (holistic) sustainable land management (SLM). In implementing physical, biological, soil and water conservation practices it is important to consider the different possibilities, i.e. to allow a basis of packages, that: give a variety of options, make a farmer self-sufficient, major components & effectiveness are the output of the system.

From the proposals of the Master Plan described above and with the exception of the silt traps in the proximity of the reservoirs commented in chapter 3.3.6 of this report, we in general agree with the proposed measures to introduce advance cultivation practices and cropping patterns combined with the proposed above uninterrupted and long term access to the same piece of land and resources for the farmers.

Many studies underlined the physical effectiveness of soil conservation measures. In a recently conducted soil erosion study by the Consultant (Z&A) in Kenya (Upper Tana Catchment) with the development of a SWAT soil erosion model, different scenarios of soil conservation methods were examined. More specifically three different soil conservation methods were examined:

More specifically three different soil conservation methods were examined:

- The use of **vegetative contour strips**, consisting of grass or other perennial plants in a contoured field to help trap sediment and nutrients. Runoff flows slower and evenly across the grass strip, reducing sheet and rill erosion. The simulation indicated that the erosion rate was reduced by 67% in the coffee areas, by 44% in the maize areas and by 57% in the tea areas. The overall simulated reduction of the soil erosion rate by using grass strips was approximately 50%.

Vegetative contour strips

- Applying **mulching**: Crop residues or other organic materials collected elsewhere are spread homogeneously on the soil surface. They protect the soil from erosion and reduce compaction from the impact of heavy rains. Finally, introducing mulching in the same areas gave average results with the overall reduction to be approximately 20%. The model showed that erosion was decreased – on average - by 20%.

Mulching

Another technique which was examined consists of making **soil ridges** of varying width and height, average being 30 cm width and 20 cm height. At regular intervals, cross-ties are built between the ridges. The ties are about two-thirds the height of the ridges, so that if overflowing occurs, it will be along the furrow and not down the slope. This technique is applicable in the areas where subsistence crops are cultivated. The tied ridges gave excellent results in the areas where maize is cultivated with a reduction of soil erosion of approximately 61%.

Tied soil ridges

The basic conclusion from the scenarios run in the Upper Tana study is that for different crops different soil conservation techniques should by applied in order to achieve the best results.

The model showed that when soil conservation is practiced at scale its effectiveness varies according to different crops and conditions. Nevertheless the conditions of Dire, Legedadi and Geffersa are remarkably different from the upper Tana (Kenya). Crops and farming techniques are different and therefore the figures obtained from the model should be considered as an indicative figure of possible change in erosion rate and not as a planning tool to choose among conservation measures. Furthermore, the variation in landscape characteristics requires the use of a mixture of measures according to the landscape section to be treated and not of a homogenous blanket approach with only one or few techniques involved.

The tied ridges gave excellent results in the areas where maize is cultivated with the reduction of the soil erosion to be approximately 61% while the reduction in the coffee and tea areas was practically zero.

Finally, introducing mulching in the same areas gave average results with the overall reduction to be approximately 20%. In addition the effect of the different soil water conservation measures on soil moisture needs to be considered – as this forms the foundations for more rewarding type of land use.

From the review of the Master Plan we propose the following at this stage – to be further fine-tuned during the stakeholder discussions – taking into account on-going programs and farmer (short and long term preferences)

Consequently, we propose to develop a package of Soil and Water conservation techniques. A wide range of typologies ranging from physical to biological erosion control measures can thus adapt to the local needs and agro-climatic conditions. It is furthermore suggested to provide training to local DAs and competent offices in order to enable them to choose consciously among the techniques in the package and adapt them to the different sections of the watersheds. The material has to be developed starting from the needs, requisites of the local communities in order to be accepted. Furthermore techniques and approaches coming from successful projects and farmers can be brought in and adapted

Table 39: Soil and Water conservation techniques

Typology	Methodology	Description
Improved drainage	Cut-off drains	Shallow ditches are dug above the sloping field to protect it from the runoff coming from outer areas. The water is collected and diverted safely to the sides. They need to have a gentle lateral gradient towards the bigger draining waterways along the field side/s.
	Broad bed maker (BBM)	Ethiopian developed technology: it is an adaption of the traditional maresha plough. It can be used to create raised beds along the contour line. It improves drainage on heavy soils and safely disposes excess water.
	Safe drainage through protected, Natural and/or artificial waterways	Cut-off drains and in-field drains must spill water laterally with a low gradient. The discharged water can then flow downstream via lateral waterways.
	Waterways protection	Lateral permanent waterways need to be designed and protected carefully. Reinforced, stepped and vegetated drains are examples of protected waterways that can resist the erosive power of excess, discharged water.
Physical control	Graded bunds	Earthen and stone bunds along the contour lines are an effective way to break the

		slope and the erosive power of runoff. A slight lateral inclination is needed to discharge excess water. Ties are sometimes constructed above each bund in order to decrease the lateral flow speed and favour soil infiltration (Fig 3). Bunds can be reinforced with a permanent vegetation cover. After some years of sediment deposition they can naturally become terraces.
	Terracing	A series of cut shelves can be dug and filled on the foothills (see fig 1). The obtained flat benches trap sediments and moisture. The construction of terraces is labour intensive. Many terraces design are available for different conditions.
	Gully rehabilitation	Gullied land can be healed by enclosing the area and by constructing little barrier within the eroded features. Trash, branches, rocks and gabions can be used to build plugs across the gully. These barriers decrease runoff speed and trap sediments.
	Organic Mulch	By leaving crop residues or other organic material on the ground the soil is sheltered by atmospheric agents, it retains moisture and decrease erosion (Fig 13). At the moment, the catchment areas are lacking any surplus of possible mulching material.
Biological control	Grass strips	Grass strips along the contour create a vegetative barrier that helps in slowing down runoff and retaining eroded soil particles. In the catchments, boundaries between fields are sometimes simple grass strips, but many times are not following the

		contour lines.
	Improved vegetation soil cover	By improving the vegetation ground cover, the soil is less exposed to erosive runoff and drop splash that occur during the rainy season. Early sowing, reforestation, agro-forestry and mixed crops are measures that help towards the objective.
	Riverine protection	Mixed grass, trees and shrubs shelter belts around the streams provide an effective protection against soil erosion. Riverine plants such as Salix can improve the stability of the banks
Farming practices	Alley cropping	Cultivation of annual crops and tree edges in strips along the contours. The trees help protecting the soil from the rain, provide wood and can enrich the soil with nutrients and organic matter.
	Minimum tillage	Without ploughing the field as a whole the farmer can till and sow only were strictly needed. The crop residues in the inter-row space help protecting the soil from erosion. It needs herbicides otherwise it is rarely economically viable.
	Contour Ploughing	By ploughing only along the contour lines the soil is less likely to be pushed downward by the plough. Furthermore the micro-relief created favours lateral drainage.
	Strip cropping	Similar to alley cropping but it entails the use of different annual crops. The different crops with different ploughing and sowing time can guarantee that at least a portion

		of the field is covered by the crop at the onset of the rainy season.
	Composting	Manure can be processed together with organic household waste to produce compost in simple composting pits. The obtained compost enriches the soil of nutrients and improves its structure.
	Agro-forestry	The use of trees as source of food, fodder and fuel alongside with annual crops, helps in retaining and protecting the soil and improve the livelihood of the household.
Water harvesting	Road water harvesting	Roads and paths often produce large quantities of runoff water that cause erosion. Small ditches can divert a little portion of the water towards household vegetable gardens and small family plastic lined ponds.

It is important to have a clear idea on existing initiatives that promote better land management because they can be reinforced and helped in scaling up their practices and commitment. Some tentative to heal gullies have been seen in Dire and Geffersa catchment (Fig 15). Even though poorly performing these initiatives are appreciable because they show an understanding of the problem and the willingness to face it. Furthermore, the Woreda already have a watershed rehabilitation program that is ready to be implemented. Through awareness raising and training, the program aims to reach each community at kebele and sub-kebele level. It is of foremost importance to join and reinforce these initiatives.

The Special zone surrounding FinFinne has elaborated a detailed land-use plan defining future scenarios. The extensive work has considered the agricultural development of the area and defined what the most suitable crops for each area are. The crop suitability was assessed for: Bread wheat, Durum wheat, Barley, malting barley, Highland maize, Lowland maize, highland sorghum, Lowland sorghum, Oats, Teff, Triticale, Niger seed, Linseed, Rapeseed, Chick peas, Faba beans, Fenugreek, Field peas, lentils, cabbage, Carrot garlic onion, potato, tomato, apple, enset, peach, strawberries. By optimizing the agricultural production according to the most suitable crop, the yields are likely to increase and consequently the higher income per hectare can sustain more investments in S/W protection. A more intensive production can also be translated in a lower expansion of cultivation towards marginal lands.

The importance given to participatory watershed management yielded remarkable results when the local community was engaged, empowered and involved in the rehabilitation process. The "Community based Participatory watershed development" guideline was developed by MoARD and underlines these principles:

> *"Watershed development has been problematic when applied in a rigid and conventional manner. This is true when applied without community participation and using only hydrological planning units, where a range of interventions remained limited and post-rehabilitation management aspects were neglected. This resulted in various failures or serious shortcomings difficult to correct. Some examples can be cited in Ethiopia and elsewhere. For instance, the case of the large Borkena dam in South Wello in the 80's where the dam was constructed before sufficient conservation measures were in place. Besides, runoff and sedimentation rates were seriously underestimated. It resulted in the filling with silt and coarse materials of the multi-million Birr dam within one rainy season." (Desta et al, 2007)*

Thus the techniques selected and studied can be technically the most effective, but without a thorough understanding by each component of the community its implementation is likely to be scattered and to require big and continuous investments. Otherwise, if a participatory cycle is started the local community might understand the problem and the risks and be willing to participate voluntarily in rehabilitating their own land.

Alternative activities that can divert pressure on natural resources and thus decrease the rate of erosion must be identified and promoted. Among the opportunities:

Table 40: Community based alternative income generating options

Proposed activity	Features, existing initiatives
Eco-tourism	Bird-watching, Horseback riding, Hiking, Eco-lodges, Athletics.
Agro-forestry	Introduction of fruit trees such as apple trees that yield considerable retail prices on urban markets. Few farmers are already experimenting in Dire catchment. Fruit orchards or agro-forestry (Annual crops and fruit trees) may be the options.
Horticulture	Few small plots are already established by women groups in Bereh woreda. The projects are supported by a local church and by IDE. Vegetables are good cash-crops that can improve the household income.
Plant nurseries	Few plant nurseries can help in producing stocks for afforestation and agro-forestry projects. After training and initial support it is a self-sustaining activity. It needs to be located in proximity of a water source and road.
Participatory forestry management (PFM)	Indigenous or Eucalyptus trees can be planted around households, along the field edges or in defined areas. If managed properly the trees can

	provide fuel and timber for local consumption and/or to be sold on the market. Consequently, cow dung can be used to fertilize the soil and tree litter can be left on the ground to protect it from erosive rain showers. GIZ is running a PFM project on the wechecha mountain, near Geffersa.
Aloe vera	*Aloe vera* cosmetic, pharmaceutical and nutritional products are highly requested on the international market. This plant seems to be the only one striving alongside with eucalyptus on the upper Dire-Legedadi catchment. A form of sustainable agro-forestry (eucalyptus-Aloe) should be investigated. New varieties (non-bitter) might need to be introduced.
Small scale poultry industry	Poultry is easy to keep, does not need much space and has much more efficient feed-to-meet conversion than ruminants. Eggs and chicken meet yield excellent prices on the market. Furthermore the droppings can be used to produce excellent fertilizer. In some cases is conjugated with fish farms. The fish can feed on phytoplankton that is stimulated by poultry droppings.
Beekeeping	Eucalyptus stands offer an excellent source of nectar.
Handicraft production	Weaving, pottery making, Hay baskets etc.
Dairy production	Stall feeding conjugated with improved cut and carry pasture system can bring much more efficiency in local livestock management. A swap towards dairy production is likely to increase the income of the farmers that too often just produce milk and butter for household consumption. Furthermore oxen are too often the focus because of their use for draft power. The introduction of machinery (through farmers associations) may decrease oxen need and help in promoting dairy production.

Figure 12: Terraces with vegetated risers

Figure 13: Organic mulching

Figure 14: Tied graded bunds

Figure 15: Badly positioned gabion gully plug (Dire)

Figure 16: Cow dung cakes ready to be sold

Figure 17: Field worked and tilled along the slope in proximity of Legedadi reservoir

5. ENVIRONMENTAL ASSESSMENT: IMPACTS & BENEFITS

5.1 GENERAL

This chapter presents the analysis and updates of the environmental assessment conducted as part of the 2000 Master Plan which is under review and the results which are presented in Annex III annexed to the plan main report. The environmental analysis conducted comply with the Environmental Protection Guidelines (1996) and the Environmental Protection Proclamation Draft (EPA, 1998) issued by the Environmental Protection Authority (EPA).

5.2 POTENTIAL ENVIRONMENTAL IMPACTS

Assessment of environmental quality starts from identification of human activities those having either positive or negative impact on the environment. Since the year 2000 a lot of changes has been introduced in terms of the land use/cover, and as such the quality of the environment has changed. Several human interventions contributed to the change in land use/cover such as intensive farming, expansion of settlements, flower farming, over grazing, tree cutting, etc. Enhancement of the quality of the environment should focus on the conservation practice of natural features in order to maintain the biodiversity of the surrounding and the minimum human social interaction on natural features.

Environmental quality could be bad or good, good quality environment stands for the area with better vegetation cover and less interference with human activity and the reverse is true for bad environmental quality. According the FinFinne special zone land use study, the current land use/cover condition, quality of the environment categorized into four classes high, medium, poor and deteriorated. Environmental quality assessment indicate that 1.96 % of the zone has high environmental quality, 13.30% medium, 77percent poor and 8.12% is deteriorated environmental quality.

The environmental issues related to the proposed intervention within the Master Plan of the catchment areas pertain to the following issues:

- Soil Conservation and loss of land cover
- Dual purpose Dams
- Reservoir protection and buffer zone management
- Agricultural practices
- Human waste and Solid waste practices within the catchment

Soil Conservation and loss of land cover

The presently poorly managed upper streams and hills aggravate soil erosion and induce deep gullies. These are the source of transported sediments deposited in the reservoirs. The proposed buffer strips will reduce erosion and will encourage indigenous plants will assist in conserving the ecosystem and bio-diversity It will also protect soil particles from detachment and movement, and reduce the resulting erosion effects caused by the heavy seasonal flooding. It is also worth noting that large areas are planted with eucalyptus trees especially in the immediate vicinity of the reservoirs. This fast-growing tree is an intensive user of the soil moisture and also depletes its nutrients.

Dual purpose Dams

Dual purpose dams have both positive and adverse impacts on the environment. On the one hand, reservoirs created behind dams will assist in micro-climatic modification, benefit birds and wildlife, and also contribute to the ground water recharge process. The water collected will also enhance the supply of water. On the other hand, there are changes on land use which are triggered by the increase in Dam height and the introduction of new dams. This should be controlled to minimum extent to reduce the need for compensation to be provided to the community and individuals whose lands are permanently affected.

Reservoir protection and buffer zone management

The proposed buffer strips will act to serve several purposes including: denying entry of livestock to the reservoirs in order to reduce the animal waste deposited in the reservoirs; preventing sediments generated by catchment erosion and small stream erosion from reaching the reservoir directly, Preventing the local inhabitants from reaching the immediate vicinity of the reservoir and reducing farming activities to reduce chemical runoff into the reservoir. Excessive fertilizer use may increase algae blooming induce growth of large amounts of higher order aquatic plants with a resultant increase in the organic matter content of the reservoirs, and generate anaerobic conditions with consequent bad odour and taste of the water.

Human waste and solid waste practices within the catchment

The Master Plan report introduces four methods are usually used to dispose of wastes:

- Collection and burning/ or transporting the wastes to a landfill site on the outskirts and their conversion to useable products.
- Thermal incineration-effective but costly.
- Disposal to semi-solid deep-well ponds outside the catchment area.
- Deep well injection, also outside the catchment area.

The Master Plan report introduces yet another possibility of converting the wastes by the bio-degradable bio-gas process, extraction of ammonia gas, and use of the waste to grow Eucalyptus, Lacunae and other plants for paper pulp and wood chip industries.

Additionally, there are many dispersed dwelling places within the catchment areas and some near the reservoirs. Human waste from these housing clusters may cause pollution of the nearby reservoirs. Small pit dry latrines could be used to minimize this human waste problem. It is proposed to build latrine for the household who do not have any and community latrine should be built. Other type of Collection and dispose human waste is to construct cesspits, which a wet pit that collects all used water in the house, but this will affect ground water due to infiltration. The other alternative is to collect the wastewater by integrated systems, this will be costly, due to dispersed settlement type and at the end a WWTP will be needed. So the dry latrines are the best solution and should be encouraged.

PART IV. MASTER PLAN REVIEW: SOCIO-ECONOMIC & INSTITUTIONAL ASPECTS

1. INSTITUTIONAL ASPECTS: PROBLEMS AND PROGRESS

1.1 INTRODUCTION

The Master Plan document for Legedadi, Dire and Geffersa catchment areas (Tahal, 2000) has broadly addressed institutional development issues for implementation of the Master Plan in Annex I of the report. The plan acknowledges institutional aspects to be main implementation challenge of the Master Plan. The reason for this is that water to be supplied to Addis Ababa Metropolitan Area originates and is collected, stored and treated in the three catchments in Oromia Regional State, beyond the boundaries of the Addis Ababa Municipality. This challenge remains valid today – there has been very little land improvement in the catchment areas and this explains the unabated siltation. This lack of land management in these otherwise very vital catchments is related to the lack of a coordinated effort between the two regional units. This is exacerbated by the fact that the reservoirs bring no benefit to surrounding villages and towns in Oromia and that projects to partially correct this have not been entirely successful. In addition to this, major changes in land use in the areas adjacent to the catchments and partly in it require a rethink of the institutional arrangements for land and water resources management in the three catchment areas.

In the 2000 MP several proposals were made with regard to the structure and functioning of the Catchment Areas Management Unit (CAMU). The purpose of this unit was to design, plan, coordinate and deal with all development in the three catchments, and with its control and enforcement. It was envisaged that the CAMU would collect comprehensive data on catchment issues and circulate the relevant information to all pertinent bodies so that the decisions reached will be based on a common basis and understanding. Since the time of the 2000 MP the situation has somewhat changed. The following tries to sketch the overview of the structure and function of the current unit.

The previous Catchment Areas Management Unit (CAMU) merged with the Water Quality unit in 2008 as part of internal re-engineering process to form the actual Catchment Management and Water Quality unit (CMWQ). In its current form, the CMWQU is a body that consists of a dozen staff personnel units. The personnel is mostly technical with expertise ranging from water quality, environmental sciences, socio-economics etc. The CMWQ works in parallel with the water distribution unit and the water treatment unit, under control of the water deputy manager. When a challenge arises, the unit acts in consultation with water distribution and water treatment units, due to thorough awareness among staff that all actions and duties between these units should be closely connected. For urgent issues the deputy manager is consulted directly.

Every year the CMWQU carries out awareness and training activities aimed at the local communities. The main topics covered are soil conservation, farming and environmental issues in general. The local woredas choose 150 farmers that are then trained by the CMWQ. This initiative is important and shows the existing commitment to work with the local community. It can be considered a positive example to reinforce and build on for future awareness campaigns at community level.

Nevertheless, the impact of this campaign is not having the envisaged impact and is not directly noticeable "on the ground". The scale should be broadened and the teaching material analyzed in order to target specific problems in the catchment areas. We suggest development of teaching material that can help DAs to raise awareness and promote good practices at root level and in context rather than in a classroom format. This approach will be worked out in the stakeholders and awareness raising components.

Approximately a decade has elapsed since the recommendations in the Master Plan – unfortunately with little follow up in practice. During this period a lot of organizational rearrangements, establishment of new institutions that will be potential actors of the implementation of the Master Plan have taken effect, particularly in Oromia Regional State. Parallel with this, there are changes and modifications in laws and regulations and shifts in roles and mandates of various actors.

The Master Plan analyzed a number of actors at Federal and Regional Levels. Thorough assessment of major actors particularly at lower level (and their engagement) is imperative. Although the Master Plan foresaw the need and at the same time challenge of handling multidisciplinary activities by a single entity the actual recommendations in the Master Plan lean towards execution by a single entity. The implementation should not only be multidisciplinary in nature, but also demands multi-sectorial and a participatory integrated approach. The various mandates of different actors demand sound and clear institutional agreements and arrangements

Among the four alternatives, The Master Plan recommended Alternative D that read as:

> *The last considered alternative is to assign the overall responsibility for implementation of the master plan to AAWSA, whose main mission at present (water supply and sewage disposal for the national capital) is considered a National Goal. Under this alternative, AAWSA would actively seek and obtain cooperation with the Regional Government of Oromia by mutual negotiation, culminating in agreements which would provide for suitable compensation. If in the future disputes between AAWSA and the Addis Ababa City, on the one side, and Oromia State, on the other, will arise, these will be resolved by the House of Federation according to Art. 62/6 of the Constitution. In this context it should be noted that AAWSA has considerable managerial capacity….*

Land administration and management issue is a key factor to be addressed in this project. AAWSA is the owner of the project and the project is located in Oromia Regional State. This raises a number of pertinent questions such as: ' Who shall implement the watershed plan and manage the land as per the design?' Who shall own it and get the benefits, if any?', 'What is the compensation mechanism, if required?'. These and related questions need to be answered to implement the designed catchments Master Plan. Land issue is a very delicate that makes the institutional arrangement more complicated. The four most important issues related to the three catchments are:

- The location of the reservoirs that is in a different Administrative state, a federal Sate
- The two regions have different institutional arrangements on land issues

- Land value is very high and is a scarce resource
- There are complex socioeconomic and political conditions

Although there are very comprehensive physical watershed plans, the issues of land tenure and land administration is not well addressed in the Master Plan.
For these reason any proposal on this matter needs to be intensely discussed and debated. Oromia Regional State has recently prepared its own Integrated Land Use Plan that incorporates the three catchments (OWWDSE, 2011). Addis Ababa City Administration may have no intimate knowledge of this plan yet. Oromia Administrative Region has established a Bureau of Land Administration and Environmental Protection to administer land and regulate the implementation of the prepared plan. Except those watershed management plans in the master plan document, Addis Ababa City Administration has done little to introduce integrated land use planning both in the city and its urban periphery agricultural areas.

The primary objective of the institution proposed in the Master Plan is to secure the safety of the reservoirs by benefiting the community within the watershed. Any arrangement that may not bring sustainable support to the community within the watersheds may not be lasting solution. Making the community beneficiary from this arrangement will make both Administrative regions work for the same goal beyond boundaries and enhance their cooperation level.

The next section identifies the agencies responsible for the implementation of the Master Plan at different levels and provides first suggestion for possible institutional arrangements.

1.2 IDENTIFIED AGENCIES RESPONSIBLE FOR IMPLEMENTATION OF THE MASTER PLAN FOR THE CATCHMENT AREAS

1.2.1 Key Actors at Federal Level

Ministry of Water and Energy

At the time of the development of the original Master Plan, there were two distinct ministries, namely the Ministry of Water Resources and the Ministry of Mines and Energy. Recently a new, combined ministry was formed, dealing with country-wide water and energy issues. Besides setting out policies on water resources development and management, the Ministry among many things keeps account of all hydrological data (hydrographic stations) including that from within and outside the project areas. Through its international links the Ministry can assist in fund soliciting and provide technical support when required for the implementation of the Master Plan. The Ministry also has a role in mediating conflicts between the two involved regions.

Federal Environmental Protection Authority

The overall objective of EPA is to formulate policies, strategies, laws and standards including EIA guidelines and procedures which foster social and economic development in a manner that enhances the welfare of communities and the safety of the environment in a sustainable way. These catchments are very much vulnerable to any kind of environmental disturbances. Their protection requires engagement of all potential law enforcing and regulatory organs. In this regard EPA can play both a leading and coordination role to assist the environmental protection institutions of the two states to work together towards same goal.

Ministry of Urban Development and Construction

This Ministry guides and facilitates urban development and standards for housing and construction. It ensures that urban centres develop master plans and it regulates and issues licenses to engineers and architects amongst others.

Ministry of Agriculture and Rural Development

This body is responsible for agricultural and rural development policies and regulation at the national level. It also builds capacity of the regional bureaus of agriculture. It is among the lead agents for several major national programmes, namely: the Productive Safety Net Programme (food insecure woredas), the Sustainable Land Management programme (food secure woredas that are at the risk of becoming food insecure) and the Agricultural Growth Programme (surplus producing woredas).

Ethiopian Institute of Agricultural Research (EIAR)

This government institute aims "to conduct research that will provide market competitive agricultural technologies that will contribute to increased agricultural productivity and nutrition quality, sustainable food security, economic development, and conservation of the integrity of natural resources and the environment". It comprises 55 research centers and sites across various agro-ecological zones in Ethiopia.

1.2.2 Existing key actor institutions in Addis Ababa Administration and their role in the project

A. Regulatory Institutions

Addis Ababa City Administration

Addis Ababa has the status of both a city and a state, with a charter endorsed by the Federal Government. It has a special status, similar to that of other states in the Federation and has accountability to the city council, elected by its residents. Administratively the city administration is also accountable to the Prime Minster Office. The city has Supreme Organs and executive committee which are accountable to the Mayor. Addis Ababa's city council, which is elected directly every five years, provides the Mayor with a cabinet. The cabinet's role is to assist the Mayor in decision-making. Addis Ababa City Administration is responsible to manage and administer the city.

The Administration at present has three ladders of hierarchical administrative structures: City, Sub city and Woreda. Those arrangements which were in existence during the Master Plan preparation time have been changed a lot. The change involves elimination of kebele structures by merging groups of kebeles together and establishing permanent woreda (district) structures with manageable population sizes. Similarly the previous zonal administration system has been changed to a sub-city administration system. This new arrangement allowed a more decentralized system. The city at present comprises 10 municipalities, each representing around 400,000 inhabitants; 90 per cent of services are provided at municipality level or lower. These municipalities have been offered a great deal of freedom: for example, they can set their own budgets.

Governance, however, primarily focuses on the Woreda. As owners of the dams and reservoir area the City administration is expected to play a leading role in implementation of the Master Plan.

Addis Ababa City Environmental Protection Authority

Duties and Responsibilities:

- Drafts environmental policies, regulations, directives and standards in line with the standard adopted by the Federal Environmental Protection Authority;
- Coordinates various environmental protection stakeholders;
- Disseminates ideas for sustainable environmental protection and wise use of natural resources;
- Follows up and controls the disposal of municipal, industrial wastes and by-products;
- Based on the relevant environmental declarations, gives licenses to various manufacturing and service industries and
- Gives licenses and controls sub-surface mineral waste and construction.

Having these mandates the Authority plays a key role in protecting the catchments from any threats coming from the metropolitan Administration boundary and in collaboration with Oromia Land and Environmental Protection Bureau can regulate the environmental safety of the catchments.

B. Implementing Agencies

The Addis Ababa Water and Sewerage Authority (AAWSA)

AAWSA is established with the objectives of supplying safe adequate water and provide waste water and sludge disposal services for Addis Ababa. It is this mandate that made it both owner and main actor to implement the Master Plan. Whatever arrangement comes, AAWSA remains to be the leading actor to implement the Master Plan.

Urban Plan Institute

Urban Plan Institute can play a key role in integrating the current and future development plans of the city with the Master Plan. Any future regional and local development plans are expected to incorporate all areas of high influence/importance to the city. This demands high level cooperation with Oromia Regional State that has its own corresponding institute. In this regard the role of this institution is vital.

Cleaning and Parks Development Agency

This agency which is established with an objective of creating a clean and beautiful city can play active role in implementing the Master Plan. Addis Ababa is lacking large parks and green areas that can serve as touristic and recreation sites. In line with the Master Plan Proposal, this agency can play a role in transforming the catchment areas into such important uses.

1.2.3 Existing Key Actor Institutions in Oromia Regional States

A. Regulatory Institutions

Oromia Regional Government

As stated in the Master Plan document the Oromia Regional Government is the source of water, hence plays vital role in implementation of the plan. The implementation of the plan demands a high level state to state negotiations and collaborations. Bringing implementing actors from both states can be made possible after agreements have been made at states level. There are already established high level cooperation on defining boundaries and selection of waste disposal sites. This cooperation arrangement can be extended to implementation of the Master Plan.

FinFinne Surrounding Oromia Special Zone Administration

The creation of this special zone is a good opportunity for implementation of the Master Plan. During the preparation of the master plan the three catchments were falling in two administrative zones of Oromia. No emphasis was given to these zones in the Master Plan document. But mandates given to these zones could have made them important actors. The FinFinne Surrounding Oromia Special Zone Administration hosts all sector offices and has a responsibility to administer and manage the Special Zone.

It is established with a main objective of managing the hot spot of the region that surrounds Addis Ababa city and to create systematic linkage with the metropolitan for common objectives and goal. For this purpose the special zone has prepared its own integrated land use plan that incorporates urban-rural, urban-urban and rural-rural links with Addis Ababa city Administration and within itself. The three catchments are part of the plan. Delayed implementation of the Master Plan may have forced the special zone to come up with its own development plans. As per its establishment objectives the Special Zone Administration has started to work in collaboration with Addis Ababa City Administration on a common issues, like waste disposal site selection and boundary delineations works. Implementation of the Master Plan highly demands the involvement of this key actor.

Oromia Land and Environmental Protection Bureau

This is a regulatory body responsible for and authority of land use and land allocation, setting priorities based on land use plans; designating protection areas, reviewing and approving EIAs submitted by investors. Their role will be pivotal in creating change in land cover and land use. Its structure extends to zone and woreda levels. Many of the district level offices already run implementation of the studied integrated land use plan and environmental awareness raising programs.

Oromia Investment Commission

Next to Addis Ababa City Administration both local and FDI is attracted to Oromia Regional State, particularly to places within the three catchments. A Turkish industrial park, large real estate developments, various industrial and floriculture investments are flourishing in these areas. These activities and the growing interest in these catchment areas makes the Oromia Investment Commission a key actor that can assist to maintain the safety of the reservoirs. The environmental safety of the reservoirs can be ensured if only there is collaborative work and agreed standard and norm between the licensing body, environmental protection agencies, administrative organs and Master Plan implementing body.

Woreda Administrations

The two Woredas in which the three catchments are located play very decisive role for implementation of the Master Plan. The Ethiopian Federal System has given much autonomy to Woreda Administrations. They have potent political and administrative power. With this autonomy and their closeness to the community their role as a key actor is vital. Woredas are directly accountable to Regional States- the Council. Unlike the zone Administrations they have their own elected council and cabinet to approve development plans and declare budget and give collective decision on every aspects of the woreda. It is clear that any development activity within the woreda cannot be implemented without the knowledge and support of the woreda Administrations and sector offices under them. Community mobilization and consensus building on issues of the Master Plan implementation that involve the community and other stakeholders within respective woredas of the catchments is possible mainly through this actor.

B. Implementing Agencies

Oromia Water, Mines and Energy Resources Bureau

This Bureau has gone into lots of rearrangements since the preparation of the Master Plan. Before taking its current shape, both the Oromia Water Resources Bureau and Mines and Energy Bureau were separate (during the period between the Master Plan and currently). However, recently, in line with the merging of the two federal ministries it was restored to its status and arrangement that it was during the Master Plan preparation. It has maintained the duties and responsibilities mentioned in the Master Plan document. As a key actor for implementation of the Plan, it is expected to involve in all water supply and related aspects of the Master Plan. It also plays a key role in regulating quarry development and mining activities that may affect the catchments and the safety of the reservoirs.

Oromia Forest and Wildlife Enterprise

Oromia Forest and Wildlife Enterprise is a public enterprise established with the objective of managing and make economic and environmental use of the forest and wildlife resources of the region. All government forest concession areas in the region, including FinFinne Forest Enterprise, have been transferred to this Enterprise. It is the main responsible body for development of all identified forest and protected areas in the integrated land use plan of the Oromia Special Zone Surrounding FinFinne.

The experience this enterprise has gained in the past few years in creating sense of ownership among the community within and around the forest and wildlife resources of the region through participatory management approach is a big lesson to be used in implementing the Master Plan.

Oromia Agriculture Bureau

Despite its potentially vast role to play in the implementation of the Master Plan, Oromia Agriculture Bureau is one of the overlooked Bureaus in the Master Plan document. Apart from its main responsibility of enhancing agricultural productivity, it has the responsibility of watershed management. The Bureau act as umbrella organization that contains important institutions like Oromia Agricultural Institute, Oromia Livestock Enterprise, and Oromia Seed Enterprise which are important for the implementation of the Master Plan. The smallest administrative units, the kebeles, are highly linked with this Bureau and its lower level woreda structures. At lower levels of its structures it also acts as delegate of those sectors that don't have structures at grassroots levels. Its Development Agents (DAs) are vital for the implementation of the Master Plan.

Farmers' Institutions and Community Based Organizations (CBOs)

Similar to other institutions these vital organizations, to whom the community and individual farmers are accountable to, are overlooked in the Master Plan documents. The most important among these is the Kebele Administrations/Farmers' Associations (FAs). Kebeles/FAs have the responsibility of:

- As the lowest level in the administration chain, communication between the public and the administration is performed through the kebeles. The Farmers' Associations/Kebeles in Oromia have at least three permanent staffs with different responsibilities that act as development agents.
- The Kebele Administration has the authority and duties to set up a development committee with the participation of the community. Youth and women associations and the development teams (*geres*) that are organized within each kebeles will act as key agents of the implementation of the plan.
- Follow-up unlawful socio-economic activities and monitor anti-disciplinary acts
- Take care of the natural environment
- Collect income based on the government rules
- Administer communal property
- Record statistical data of the Kebele dwellers

Apart from the government sponsored structures local religious institutions (both modern and traditional ones) and community based organizations like *Idirs, Welda, etc* can be tools for successful implementation of the plan. Experiences show that negative responses from such institutions are reasons for implementation failures of many projects.

Non-government Organizations and Donor Agencies

Most of the engagement areas of NGOs and donor agencies in development are the drought prone parts of the country. The little engagement in the project/catchment areas is rarely goes beyond provision of health and gender related activities. For this reason there is no prominent NGO and donor agency that is engaged in catchment management activities. This doesn't mean it remains like this. The proper implementation of the Master Plan may attract NGOs and donor agencies if their role to play is clearly defined. Among many potential collaborators for the implementation of the plan those who are already taking part in the city's development can be put forward. The German and French Agencies that are actively taking part in the city's development at present are potential actors, as are national and international non-governmental organizations involved in natural resources and environmental management. As an African Capital and a seat of the ECA, EU, UN agencies and AU will be kin to take part in development of the catchments for betterment of the city life, if approached with proper plans.

The Institutional Arrangement

The Master Plan has many components of which catchment management and related activities like resettlement and restoration of the environment are the main ones. The size of the catchments is considerably large. Their geographical location that made them very dynamic and the benefit they are giving to the community within them make the implementation of the Master Plan a complex task. Lots of changes have taken place during the past decade that requires the revisit of the recommendations given in the master plan.

The fourth alternative, Alternative D as mentioned above, is chosen for implementation. This alternative gives the overall responsibility for implementation of the master plan to AAWSA. It might be possible to enforce this option through the provided conflict resolving option. The mentioned AAWSA's sound technical implementation capacity is not the only means of implementation.

There are lot of political, economic and social issues to complicate implementation of the Master Plan by a single entity as mentioned earlier. It will be a big burden for AAWSA to handle by its own. For these reasons and the physical, economic and social changes that took place during the past decade it is important to revisit the recommendation and come up with wider options. The options to come shall insure sustainability of the implementation of the Master Plan by answering all sensitive issues facing implementation of the project. As indicated earlier, the FinFinne Surrounding Oromia Special Zone Administration, which hosts permanent representation of both Addis Ababa Municipal government bodies, as well as Oromia Regional government bodies, forms a very suitable entry point for development and cooperation.

Land administration issues

As stated in the Oromia Special Zone Surrounding FinFinne Master Plan report, "the concepts of sustainable development and environmental rights are enshrined in the Constitution of the FDRE. Article 44 of the revised Constitution of the FDRE states that all persons who have been displaced or whose livelihood has been adversely affected because of state programs have the right to commensurate monetary or alternative means of compensation, including relocation with adequate state assistance. However, the compensation does not take into account the value of land." In order to ensure well-being and sustainability of livelihoods of affected households, this value will need to be assessed/taken into account.

As mentioned earlier in the Inception Report, the Oromo Gadaa System, the informal system of societal law, is an important element to take into account when assessing the institutional landscape and implementing mechanisms. Despite their proximity to Addis, parts of the catchment have remained relatively isolated, and this traditional system has survived.

2. SOCIO-ECONOMIC BACKGROUND

2.1 EMPLOYMENT AND INCOME

Almost all of the rural population are employed in agriculture or related activities (Seureca, 2010) differentiating in productive and non-productive activities the shares are 40% and 60% respectively. Although most of the income ought to generated from agriculture the surveys in the Master Plan 2000 already indicated that for Geffersa, Dire and Legedadi respectively only 10% and 25% of the population engaged in agriculture is self-sufficient. With the largest share of the population (90% and more) keeping livestock and planting trees (mainly Eucalyptus) as a contingency in case of food shortage. Loans are also commonly taken to finance agricultural input and overcome periods of stress, with 40% and 80% of the population in Geffersa and Dire Legedadi taking loans. Given the vicinity to a mass urban market, the relatively good (though) recent infrastructure and the land and water resources in the Legedadi and Dire catchment the predominance of low value farming and low intensity livestock farming is surprising. This translates in widespread poverty in the catchment areas – with in Geffersa and Legedadi/ Dire respectively 88% and 68% earning less than ETB 500/ month (see Socio-Economic Appraisal, according to data from Oromia Special Zone surrounding FinFinne Master Plan). This falls within the poorest category (high, medium, poor) and is below the international poverty line which is set at 1.25 USD per day.

2.2 LAND QUALITY

Land degradation is a main concern. It directly translates into the relatively rapid silting up of the reservoirs (see concerned section), but is also a major factor in the relatively low productivity of land in the area and the amplified response to drought – as this immediately translated in moisture stress under current cultivation methods. During field visits (this study) and supported by the observations made in the Master Plan 2000 studies and the ESIAs (Seureca, 2010) it can be said that much cultivation occurs 'on the slope' with furrows running downhill, causing loss of soil cover and lack of water retention – directly affecting crop yields and contributing to sediment transport downhill.

The cumulated results of land degradation – soil erosion and landslides – are seen to contribute more to the decline of effective size of land holdings than the land fragmentation that inevitably comes with inheritance in a rapid growing population, table 27 gives an indication of the main reasons for declining land size. These results support the implementation of land conservation and

Table 41: Reasons for Declining Land Size

Reasons for land size decline	Proportion (in percentage)
Land Degradation	25.98
Land Sliding	16.91
Fragmentation	40.84
Investment Activity	3.95
Other	12.39

Source: OWWDSE 2010

2.3 LAND TENURE SYSTEM

According to the Constitution, land is the property of the people but is administered on their behalf by the state (Article 40, sub article 3, 4, 6 and 7). Citizens have usufruct right on the land they possess and land cannot be sold, exchanged or mortgaged. However, it can be leased or sharecropped for short period of time and can be utilized by hired labour. In addition, the constitution allows transfer of land to one's heirs. Regions reproduce their own rules and regulations basing the constitution. Amendments have been made since 2000 however, wives now have similar rights as their husbands, i.e. are registered as shared leasers on the deeds, as well as that terms and conditions have become more favorable for leaseholders.

Unlike in some areas, particularly pastoral areas, the land tenure in the catchment areas is largely characterized by privately owned land holding. Moreover, there are activities to provide land certificates to farmers. Several of them acquired the certificate, while others are waiting due to some technical problems observed in some areas.

Land holding highly influences the overall productivity of agriculture, though intensification with technology has proved that productivity can be maintained even by smallholding; in the Ethiopian context, it is the major factor for limited productivity. The majority of the farmers possess less than half hectare, 35% of farmers in the Oromia Special Zone that includes Berke and Welmere - have a land size of less than or equal to half hectare. The rest categories of land holding convey similar proportion, with slight difference, whereas 30% of farmers own between 1 and 3 hectares of land. On the other hand, more than 40 percent of farmers own more than two hectares of land. Relating these results to those of the Master Plan 2000 it can be noted that Geffersa was estimated to have an average landholding size of 3.2 ha and in the Dire Legedadi area this was estimated at 4.7. These averages would seem to be well above the current average between 1 – 2 hectares, see table 42.

Table 42: Distribution of rural land holdings per size in Oromia Special Zone

Land size (ha)	< 0.5 ha	0.5-1	1-2	2-3	3-4	4-5	> 5
%	35	9	16	15	11	7	8

Source: OWWDSE 2011

2.4 INVESTMENT DEVELOPMENT

Besides the activities of the local communities, the Regional Government is also stimulating investment by giving out land titles. In Berek 165 ha of land has been given out to 24 investors. This represents a capital investment of ETB 226 M and predicted job creation of 2761. In Berek investment in diary and poultry farming is most prevalent. Two more investment are about to be approved. In Weldera 257 ha has been given out to 22 investors, representing a capital investment of ETB 328 M and anticipated job creation of 3188. Most common are flower and vegetable farms and some industry. In Welmera a botanical garden is planned as well. The appendix gives the overview of the current investments.

In general, there are several issues related to the acquisition of public land and in land administration in general – in both rural and urban areas, related both to the procedures as the general land market (see tables 43 & 44).

Table 43: Major Problems in relation to Land Acquisition – Rural and Urban (Percentage)

Major Problems – Land Acquisition	Rural	Urban
Very Difficult/ Elongated Bureaucracy	38.7	39.4
Corruption	22.1	35.6
High Land Lease Price	20.3	26.1
Easy Availability of Land from Individuals	7.1	18.4
Other	18.1	28.3

Table 44: Major Problems in relation to Land Administration – Rural and Urban (Percentage)

Major problems – Land administration	Rural	Urban
Very Difficult/ Elongated Bureaucracy	38	38.7
Corruption	36.8	40.1
Shortage of Professional Composition	18.4	39.3
Weak Implementation of Rules & Regulations	28.3	35.8
Illegal Land Acquisition	14.1	22.2
Infrastructural Problems	38.3	25.1
Other	5.8	6.5

Source: OWWDSE 2011

Information obtained concerning planned investment in the 2 woredas, it appears that the major types are floriculture and dairy farming development. Both could pose challenges to the protection of the reservoirs as a result of agro-chemicals and contamination, and mitigation measures need to be explored. Useful examples with regard to sustainable floriculture are to be found near lake Ziway in the South, whereby flower farms are implementing water treatment systems coupled with periodic water quality monitoring, undertaken by appropriate government institutions. To ensure protection of the catchment and consequently high water quality standards, future catchment management mechanisms need to consider and attract sustainable investment (as opposed to large scale industrial or agricultural investment such as floriculture). One example could be the development of (eco) lodges, through public private partnerships (f.e. relevant Oromia Government Enterprise in combination with a private investor). Again, the relative proximity of the area to Addis Ababa is emphasised here, making it an ideal area for the establishment of eco-hotels and conference venues, employing local communities and sourcing products locally (both building materials as well as food).

The following Tables show the planned investment in Welmera and Berek Districts

Welmera Investment

Table 45: Welmera Woreda

Number	Investor	Capital (ETB M)	Area (ha)	Type of Investment	Job opportunities
1	Jariko Flower	24.7	25	Flower	350
2	Jardaan River	23.3	15	Herbs	300
3	Deam Flower PLC	25	20.91	Flower	200
4	Alliane Flower PLC	47	20.91	Flower	250
5	Kush Hotel	1.5	1	Hotel	337
6	Mangasha Integrate Farm	0.2	6	Farm	25
7	Flower Ama	12.5	18.5	Flower	50
8	Margin ar PLC	21	30.74	Flower	254
9	United Friend bio farm	3	5	Bio Farm	300
10	Tigst Tamene	1.75	5	Dairy Farm	35
11	Sun bless PLc	13.1	17.5	Vegetable Farming	40
12	Bezale Construction		9.21	Brick factory	140
13	Galica flawer	8.8	32.56	Flower	200
14	Fatuma Nur	2.9	0.2	Wheat Flour	250
15	Eegersaa Guuda (Markos park)	1.75	5	Hotel	15

16	Holataa bisin cement	121.09	15	Cement factory	20
17	Echo Home PLC	4.13	19.5	Fruit vegetable	230
18	Salomon Yimaam	1.5	1	Dairy Farm	25
19	Mnbera	2	0.3		30
20	Amin Nechural Water	4	7.3	Botanic garden	20
21	Sebewangel sedessaa	8	1.3		25
22	Abdul Amid General	1.225	0.3	Metal	92

Source:-Welmera district investment Bureau.

Berek Woreda Investment

Table 46: Investors and Investment Profile in the Woreda up to 2009

No.	Name	Project	Land (ha)	Capital	Job Opportunities	Approved date	Kebele
1	Musama Aman	Mam Trading	20	66,940,000.00	300	5/5/1997	Wolgoo
2	Daniel Ben Tarah	Magikal Farm	20	21,630,000.00	416	3/2/1997	Dire
3	Mr. Bas Vloet	Abisyninia Farm	17.5	15,000,000.00	180	7/2/1996	Dire
4	Twitu Godana	Beren Agro Industry	2.16	2,000,000.00	35	22/5/1999	D/Gadoo
5	Girma Taye		2.5	550,000.00	20	15/2/1997	Giraar
6	Sh/Girma Alemu	Dairy Farm	0.2	500,000.00	10	9/3/1998	Giraar
7	Kidane	Dairy Farm		500,000.00	10		L/Barii
8	Mardiya Umar	Dairy Farming	40	1,000,000.00	25	1/10/1967	Graar
9	Wagaye Gejo	Hotel and Recreation	21.7	1,000,000.00	18	1/7/1911	Giraar
10	H/Mariam Faranda	Boarding School	1.096	3,000,000.00	7	5/7/2000	Wolgoo
11	Frehiwot Birus	Sheep Rearing	9	45,500,000.00	742	24/8/2000	Wolgoo
12	Salabadin Hasen	Milk and Milk Process	2	1,800,000.00	20	12/10/2000	L/Barii
13	Temesgen Wogari	Hormata Luku	2	5,000,000.00	280	22/5/2000	Wolgoo
14	Teklu Kinfe	Food Complex	2	1,000,000.00	50	22/5/2000	Wolgoo
15	Bachinesh Tesfaye	Poultry Processing	1	22,000,000.00	200		L/Barii
16	Mastwawat Zelleke	Poultry Processing	1	1,000,000.00	23		L/Barii
17	Yimer Hamza	Say Plc Diasy Farm	4	6,000,000.00	32	14/9/1999	L/Barii
18	Tsidena Trading Plc.	Coffee Roosting	0.5967	4,200,000.00	40	11/11/2000	L/Barii
19	Negash Yimam	Dary Farm	2	313,868.00	18	1/10/2000	D/Gadoo
20	Asnakech Tomas	Bone Flower	12.74	18,200,000.00	230	15/2/1998	D/Gadoo
21	Eleyas Adamu	Dairy Farm	0.69675	200,000.00	10	28/1/1994	L/Barii
22	Engineer Ejiigu Damisse	Dairy Farm	2	3,210,000.00	55	6/10/1998	L/Barii
23	Solomon Tesfaye	Steel Metal Factory	2	5,000,000.00	30		L/Barii
24	Abbabu Mamo	Dairy Farm	0.5	1,000,000.00	10		L/Barii
Total			166.689	226,543,868.00	2761		

3. SOCIO-ECONOMIC APPRAISAL OF GEFFERSA, LEGEDADI AND DIRE AREAS

This section describes the socio-economic profile respectively for Legedadi and Dire Catchment and for Geffersa Catchment and is an update of the Master Plan studies. It describes subsequently the general population characteristics (3.3.1), economic position (3.3.2) and access to basic amenities – health, education, roads and – of particular interest – water supply (3.3.3).

3.1 GENERAL POPULATION

Legedadi and Dire Catchment

The population figures for Berek Woreda of which includes the two catchments of Legedadi and Dire are given in table 4.1. As Kebele boundaries have changed over the last ten years of the comparison with the Master Plan cannot be made one-to-one, but a comparison with the Master Plan suggests an overall population increase that is in line with national trends – but with variations between different parts of the catchment (150-230% in 17 years). There has however not been a strong inflow into these areas– unlike the situation in Addis Ababa. This may change however with the changed road connections to Legedadi and Dire, as a fast growth of the small settlements (still outside the catchments proper though) can be observed.

The lack of inflow is also apparent from the population composition. The majority of area surrounding Addis – including Legedadi and Dire Catchment and also Geffersa - - is of Oromo ethnicity (97.8%) with the only other group of minor statistical significance being Amhara (1.5%). The main religion is Orthodox Christian (88.9%) – followed by Muslim (9.5%) and Protestant (1.5%). The gender balance in Bereh Woreda is slightly tilted towards men. This suggest that also there is little labour migration out of the area, which is also confirmed by the data on income sources (see section 4.3.2) – where remittance or casual labour does not figure high.

Geffersa Catchment

Table 4.2 is an overview of the population of Welmera Woreda – that includes the Geffersa Catchment. In Welmera urban population has increased but the rural population has followed a similar trend as in Bire. The Oromo population group is by far the largest (93%) but there is large contingent of Amhara origin (6%). The main religion is Orthodox Christian (91%), followed by Muslim. There is also little indication of much in and out migration in the rural kebele’s of Geffersa, despite the widespread poverty and the Addis Ababa labour market. Men are slight overrepresented in the population.

Table 47: Population Bereh Woreda (Legedadi and Dire Catchments)

	Population 2011				
	Both Sexes	Male	Female	Number of Households	Number of housing unit
BEREH-WoREDA	**82909**	**42101**	**40807**	**17284**	**16915**
JOTE MUGNA	2715	1340	1374	587	574
BURA ALELITU	1858	928	930	382	375
ACHENI	2981	1498	1483	611	611
BURA BURAH	2470	1245	1225	493	484
DIBIDIBE KIKI	2240	1135	1105	460	448
CHEFA HULUKO	2528	1290	1238	550	538
BURA MARU TULU KORJICHA	2938	1506	1432	579	572
TENIKOLE WEREBI	2630	1350	1280	506	496
SODRE KORE	4451	2200	2251	948	909
GIRARI REH	3176	1580	1596	632	617
DABE MUDA GUDO	4161	2066	2095	868	852
LEGE BERI LEGE BELO	3599	1845	1754	694	687
WELIGEWO	9271	4603	4669	2051	1999
YEKA SADI	5933	3057	2876	1476	1432
HABRU KENO KURA JIDA	3374	1719	1656	678	656
ABUROGE	3722	1955	1767	711	696
KONITOBA WEDECHA	3357	1690	1667	652	640
REPA DENIBEL	2932	1496	1436	605	601
HEBRU ABA MELA MUGER	2838	1455	1383	593	581
CHEBI SIRE GUYO	4802	2460	2342	931	913
LENICHE CHOBA SULULITA	5564	2855	2708	1139	1123
META GUTA KOMBOLE	5371	2830	2541	1140	1113

Source: 2007 CSA census and projected by the consultant

Table 48: Population Welmera Woreda (Geffersa Catchment)

	Population 2011				
	Both Sexes	Male	Female	Number of Households	Number of housing unit
WELMERA-WOREDA	**88479**	**44650**	**43829**	**18755**	**18234**
DUFA	1910	943	966	393	387
ULAFOYATA	3467	1737	1730	695	683
ULA SELASSE	1886	917	969	378	375
HAROBOKI	4797	2440	2357	987	977
TELECHO GEBRIEL	3314	1681	1633	660	644
BURKUSAME GEBIYA ROBI	3556	1780	1776	699	687
NANO GENENU	6844	3402	3443	1533	1501
ADELEBERITYQORE	5963	3008	2954	1192	1116
SOKOROAWASO	4290	2144	2146	902	851
WETABECHA MINJARO	6858	3438	3419	1533	1482
WECHECHA	1658	817	841	333	331
BERIFETA LEMEFA	6286	3183	3103	1397	1345
BERFETA TEKOFA	6085	3048	3037	1305	1255
WAJETU HARBU	2324	1170	1154	452	435
DAWA FILAFITO	1945	1017	928	395	377
GERSU SEYIDA	2614	1264	1349	539	531
NANU SUBA	4181	2133	2048	921	898
WAJETU WATO DALECHA	3106	1609	1498	664	656
GEBA KEMISA	4470	2242	2228	950	925
FALE TULURADA	2966	1500	1467	632	617
GOLE LIBEN	4568	2386	2183	1037	1017
NANO KERSA	4948	2579	2368	1037	1023
SUBA YEMENIGIST DEN	443	211	232	122	121

Table 49: Age composition per Woreda

DISTRICT NAME	18-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	60+
Berek	3.1	14.2	10.8	15.4	13.1	10.8	6.5	11.9	14.2
Welmera	5.3	10.7	12.0	14.4	11.1	13.9	9.0	12.5	11.1

Source: OWWDSE 2011

3.2 LIVELIHOODS

The livelihood of the rural population in both areas remains firmly agricultural. The majority of households (80%) derive their income from mixed agriculture – crop production and livestock. A smaller proportion depends on crop production only (14.2%) or livestock only (3.1%). Daily labor is a secondary source of income only – for 15.5% of the population. There is a sharp contrast with urban population in the area, which is large employed in either public sector, private sector or in civil society.

Poverty remains widespread – in the entire area around Addis Ababa and the catchments of Geffersa, Legedadi and Dire is no exception. For 68% of the rural population in Bire Woreda monthly income is less than ETB 500 (i.e. below the poverty line), whereas for 20% it is between ETB 500 and 1000. For Welmera the situation is even worse – with 88% resp. 9% of the population in these poverty classes (table 49).

Table 50: Sources of Income – Rural and Urban (Percentage)

(Secondary source of income in brackets)

SOURCES OF INCOME (RURAL)	PROPORTION
Mixed Agriculture	80 (.9)
Crop Production Only	14.2 (6)
Livestock Production Only	3.1
Daily Laborer	0(15.5)
Trade and Related	2.7 (10)
Total	**100 (32.4)**

SOURCES OF INCOME (URBAN)	PROPORTION
Government Organization	24.5
NGO	19.4
Private Organization	22.4
Family Support	1.6 (9)
Own Business	27.6 (6.2)
Remittance	0 (3)
Other	4.5 (8)
Total	**100 (26.2)**

Source_ OWWDSE 2011

Table 51: Monthly Incomes in ETB – Rural (Percentage)

District Name	Below 500	501-1000	1001-1500	1501-2000	2001-2500	Above 2500
Berek	68.5	20.0	5.4	2.7	.4	3.1
Welmera	87.5	9.9	1.2	.2	.5	.7

Source: OWWDSE 2011

As agriculture is the almost sole means of livelihood in the areas, employment follows very much the agricultural calendar. The peak times for employment are May-August (only 7% unemployed) and September to December (11% unemployed). The slack time is January to April when unemployment is at 39%.

3.3 ACCESS TO AMENITIES

Access to water supply

Rather remarkably for areas that serve to source water to the capital, the coverage of water supply services in the catchment areas is poor. A small majority of people in the catchment derives water from protected sources (58%) – though much investment is taking place with coverage increasing with 9% in ETB 2002. This score is still below the official national coverage for rural areas 65% - though other sources come with a lower coverage for the country. The main sources of water in order of importance are dug wells, springs, rivers and improved water points.

In Welmera water supply coverage is higher - 65%. The mains sources of water are also dug wells, shallow wells and springs. The advantage of these systems is that they are relatively robust and do not suffer from non-functionality as other systems. In non-functionality is below 10%.

Table 52: Number of drinking water systems in 2002 EC

	Welmera	Berek
0Deep wells	0	7
Shallow wells	47	17
Hand dug wells	114	82
Spring development	16	15
Total no. of schemes	177	121
Population		

Source: **-** District rural water resource offices

Sanitation coverage is considerably – close to the Ethiopian average of 29%. There are moreover several public health hazards – such as disposal of solid and liquid wastes and cattle grazing close to the banks of the existing reservoirs.

Access to energy

The penetration by modern form of energy has progressed since the Master Plan of 2000 – but coverage is still low. In Welmera for instance all urban settlements (and 25% of houses) have been connected to the electric grid. Coverage in rural areas is very low however (less than 1%).

To date traditional sources of energy are still most important. In urban areas, charcoal is the most important energy source followed by firewood, electricity, crop residues and animal dung's. On the other hand, fire wood is the major energy source in rural area followed by crop residue, animal dung and kerosene. The reliance on biomass – charcoal and firewood – puts on constant pressure on the catchments – particularly as only very limited woodlot plantation is going on.

Table 53: Sources of domestic energy supply (by %) in Welmera

No	Source of Energy Supply	Rank	
		Urban	Rural
1	Charcoal	90%	10%
2	Fire wood	80%	100%
3	Animal Dung	5%	70%
4	Crop Residue	-	10%
5	Kerosene	70%	80%
6	Electricity	100%	-

Source: Welmera district Agricultural and Rural Development Office

Access to education

There are 36 schools offering education in class 1-4 and 16 schools offering education in class 1-8 in Bire Woreda. The total number of teachers is 356 classrooms is 378. This comes down to respectively 48 students per teacher and 45 students per class room. Of these schools four only are provided with water facilities. Net enrollment in the lower grades is 76.6%. There is a mild male gender bias in the children going to school (10%).

Table 54: Enrollment in Berek Woreda

	Net enrollment %	Gross Enrollment %
1st cycle	76.6	156
2nd cycle	34.2	49.7
1-8	63.4	105

Table 55: Number of students in the last five years (2003)

Class	Total	male	female
1-4	13110	7007	6163
5-8	3877	2158	1719

Table 56: Educational status – rural (percentage)

District name	Illiterate	Can read & write	Grade 1-8	Grades 9-12	Certificate	Diploma	Above diploma	Informal education	Other
Berek	53.1	23.5	12.7	2.7	.0	.4	6.5	1.2	53.1
Welmera	56.5	11.3	25.0	4.6	.4	.2	1.2	.9	56.5

Table 57: School Accessibility – Rural (For Grades 1-4) (Percentage)

District Name	Not Accessible	Below 5km	5-10km	11-15km	Above 15km
Berek	.0	91.9	7.3	.4	.4
Welmera	6.0	80.3	12.0	1.8	.0

There is a quality concern with respect to education. In Welmera for instance 50 % only of the primary school teachers at grade 5-8 fulfill the minimum qualification (diploma level) to teach at this level. 182 teachers (out of 348) follow the continuous professional development program

Housing conditions

The following part provides an overview of average types of housing and status for the whole Oromia Special Zone, but has been assessed to be representative for the respective Woredas Berek and Welmera. The data has been taken from the Oromia Special Zone Surrounding FinFinne Land Use Plan.

Table 58: Construction Material of Houses – Rural and Urban (In Percentage)

	Construction Materials					
	Mud & Wood	Bricks	Corrugated Iron	Plastic Tiles	Bamboo	Other
Rural	75.8	1.4	19.3	0.3	0.7	2.5
Urban	76.8	12.3	9	0	0.1	1.7

Table 59: Housing Facilities Accessibility and Ownership – Rural (Percentage)

Facilities	Accessibility	Ownership Type	
		Private	*Shared*
Toilet	38.8	34.2	4.9
Bath	1.3	1	0.5
Electricity	22.4	17.9	4.5
Water	30.4	0.5	31.9
Sewerage	1.4	0.8	1.4
Fixed – Tel.	0.3	0.2	0.2
Mobile – Tel.	18	16.7	1.5

Access to health

The population per health center and health post is 29439 and 4424 in Berek and 44234 per health worker and 3539 per nurse, bringing the health coverage to 83%. In Welmera the situation is slightly worse. Although a substantial improvement in the situation, after the time of the Master Plan, there is still a way to go. In neither district there are no clinics, hospitals or special pharmacies. Most common diseases are environmental and related to inadequate public health: malaria, diarrhea, parasites.

Table 60: Most common diseases

No	Welmera 2002 ET			Berek 2002 ET		
	Type of disease	Number	%	Type of disease	Number	%
1	Malaria	925	21.9	Pneumonia	841	11.2
2	Other Lung diseases	741	17.5	Parasites	595	7.9
3	Parasites	518	12.2	Diarrhea	592	7.8
4	Diarrhea	494	11.7	Gastritis	540	7.1
5	Rheumatia	296	7	Diarrhea	527	7.0
6	Tonsillitis	271	6.4	Tonsillitis	464	6.12%
7	Febril Illness	269	6.4	Rheumatism	290	3.82%
8	All other Skin disease	263	6.2	Dermatitis	278	3.67%
9	Other Abdomen disease	240	5.7	Gengivititis	251	3.31%
10	Gastritis	212	5	Conjunctivitis	204	2.69%

Source:- District health offices

Access to other Infrastructure (credit, roads and communication)

In Berek there is one bank and credit association. Road infrastructure is rapidly improving – with in Berek for instance 40% of all weather roads added between 2001 EC and 2002 EC. In Berek there is now 148 km of gravel route, 38.5 km of soil dry weather road and 30 kilometer of asphalt road. Welmera District has 55 km length of gravel road (all weather), 52 km of dry weather road and 62km of Asphalt road which is under construction.

Communication: - In Berek and Welmera district the most common communication sector are radios, telephone, and press and so on in descending order, whereas TV and postal service are restricted at town level giving service to a small proportion of people. Urban areas of the district has supplied with wave satellite type of telecommunication, whereas most rural areas of the district are supplied with wireless type of telephone services. Since there is total mobile network coverage in all kebeles of Welmera district, most of the peasants are mobile telephone users and wireless telephone users in all kebeles.

Economic aspects

One of the main issues associated with the economic valuation part of the Master Plan, seems to be the fact that the costs for land acquisition as a result of increased land requirement for different project activities and relocation of communities/households, as well as the benefits of proper soil conservation activities have not been taken into account and thus not valued to their potential. Even without these aspects, the net returns of potential interventions were predicted to become positive after an initial period of seven years

PART V. CONCLUSIONS & RECOMMENDATIONS

1. ENGINEERING & TECHNICAL ASPECTS

1.1 RESERVOIR BATHYMETRIC SURVEYS

The overall assessment of the previously conducted bathymetric surveys in the reservoirs of the project area is that they provide an accurate assessment of the remaining volume in the reservoirs and of the average annual siltation rates. There is some uncertainty regarding the conversion of this information to estimated sediment yields of the catchments above the reservoirs since there are no data available on the sediment mix composition and hence the related average sediment density cannot be directly calculated (including the compression effects under the weight of the water in the reservoirs). However, sediment yield values estimated according to assumed sediment densities reasonable for the problem in question are well within the range of values encountered in other similar studies in the broader region with similar soils and catchment land uses. Therefore they can serve as a basis to estimate sediment yields in other points within the catchments for planning purposes.

For the Geffersa I-II and Legedadi reservoirs the annual reduction rates presented above are:

Geffersa I-II	0.32%/yr.	22,105 m^3/yr.
Legedadi	0.31%/yr.	135,000 m^3/yr.

From these figures it is estimated that both reservoirs have a long remaining life expectancy, and in all cases, even if the soil erosion conditions in the catchments change dramatically, we can expect that for at least the next fifty years they will continue to operate and supply the Addis Ababa water distribution network.

We can assume from this analysis that although catchment rehabilitation measures should be taken in the two catchments in order to control and maintain on acceptable levels the soil erosion, the necessity to propose and construct expensive infrastructures like dams only as silt traps, should be carefully examined.

1.2 HYDROLOGICAL & HYDROGEOLOGICAL EVALUATIONS

It is clear from the review of all relevant hydrological studies performed within the last 10 years, that the inflow estimation problem for the existing reservoirs of Legedadi, Dire and Geffersa was universally approached in two ways: (a) attempt to resolve the water balance of the reservoir to back-calculate inflows and (b) correlating the reservoir sites with hydrologically similar gauged catchments in the broader area.

The water balance method finally contributed 17 years of inflows (out of 36) for Geffersa (Tractebel & others, 2002), 8 years (out of 23) for Dire and 4 years (out of 23) for Legedadi (Seureca & others, 2010).

It is also clear from all the reports available that the water balance approach, even if partially successful, is fraught with uncertainties and difficulties which arise out of the lack of essential data on dam operations – most importantly spills. Therefore, inflow series indirectly estimated from a reservoir water balance exhibit relatively high uncertainty.

Given the data shortcomings and the fact that the recent studies utilized all available data to establish the reservoir water balance, it is concluded that it is not useful to expend any further effort towards this end. The available water balance estimates (17 yrs. for Geffersa, 8yrs. for Dire [1986-2008] and 4 yrs. for Legedadi [1999, 2001, 2006-2007]) will be used.

For Geffersa, only an extension of the water balance calculation to cover the remaining years to 2010 should be attempted based on examination of the methodology by Tractebel & others (2002). For Dire and Legedadi, the most reliable estimates were made recently in the Seureca & others study (2010) for both dams.

To improve upon the estimation of the inflow series at the existing reservoirs there are several options which seem to have not been attempted by previous studies. A naturalisation of the flows registered in the available flow stations downstream of the dams (Mutinicha and Akaki for Dire and Legedadi and Little Akaki for Geffersa) could be attempted. This exercise has not been attempted before for reasons unknown, since all studies do not even mention the downstream stations (the master plan considers Akaki and Mutinicha but ultimately does not rely on them). If successful, a monthly water balance model could be calibrated for these stations (if rainfall and evaporation data allow so) and its results applied to the three dam catchments in order to estimate inflows from a different angle.

The examination of the 2000 Master Plan overall rural water supply status and proposals and of especially the relevant Annex II results in the assessment that the proposals for the new shallow or deep wells were not the result of a hydrogeological study and they were based mainly on land planning criteria.

The minimum distance considered between water points (2 km) is not a result of calculations on the influence radius of existing shallow wells and it seems to be more of a random spatial criterion without hydrogeological scientific basis.

The separation between shallow wells for rural and deep wells for urban areas was not explained but seems to have been chosen according to a criterion of people concentration, which cannot explain why one deep well that can supply several villages is not more preferable from several shallow water points. Also, the productivity of these new wells was not ensured.

This part of the 2000 Master Plan must be revised and new data of existing water points and their type of operation must be collected. These new data should give a clearer picture about the groundwater potential of the catchment areas and how aquifers react to continuous abstractions.

It is noted here that potential impacts on population density trends arising out of proposed water supply works will be carefully taken into account and the water supply planning will be adjusted in order to be harmonised with the provisions of the Oromia Regional Planning study.

The engineers of the study team of this contract responsible for the water supply task will collaborate very close with the Hydrogeologists in order the water supply requirements as will be estimated from this study will be mainly covered by the ground water potential of the catchments following the requirements of the Terms of Reference of the Contract.

1.3 ENGINEERING WORKS FOR SEDIMENTATION AND WATER HARVEST

Dual-purpose reservoirs

A number of dual purpose dams were proposed by the 2000 Master Plan in order to reduce siltation in the three study reservoirs and increase water harvesting, targeting also to the rehabilitation of the three catchments. In total seventeen (17) locations for the construction of small silt traps or larger dual purpose dams were proposed by the Master Plan for further investigation.

The 2000 MP addresses, primarily, two main problems – increasing the water harvest and reducing reservoir sedimentation. The overall assessment of the situation in the three study catchments, based on the data collected, the site visit and the analyses performed is that the former is of much greater importance. Therefore attention should be given to those sites suitable for providing the largest storages within each study catchment and the selection among them will be based on a detailed feasibility assessment to maximise the potential of the investments that will be made.

Here we may summarize the findings of this report as follows:

- The best sites for constructing dual-purpose dams in the project area with an eye to increased water storage as well as sediment trapping are the locations with ID nos. 10 (Bura), 11 (Legedadi) 12 (Geffersa) and 17 (Lege Hola). For nos. 12 and 17 it appears that they are the most favourable locations within the project area for the purposes of this project.
- The Master Plan proposes a sub-group of dams (nos. 9, 11, 16 and 15, the Strait dam) which are located in the vicinity of the existing reservoir at Legedadi (and in case of the Strait dam, inside it). At this time location no. 11 appears the most favourable; however the points raised in the report will become subject of specific investigations during the feasibility stage for this sub-group of proposed dams.
- There is a number of locations proposed that could support the construction of water storage dams but further analysis needs to be made because of problems foreseen with environmental and human-related impacts. These locations are nos. 3 and 6. Although no significant problems are foreseen for no. 10 Bura dam in the Dire catchment its construction could prove viable but beyond the domain of the Client's concerns or scope.
- Many of the proposed locations are obviously more suited to simple silt traps constructed inside the available river beds for the purpose of sediment trapping. These locations are nos. 1, 4, 7, 8, 13 and 14.
- Finally there are a number of locations for which it is considered very difficult to construct either a water storage dam, a silt trap or any kind of such facility whatsoever. These locations are nos. 2 and 5.

- The Consultant, even from the Inception Report phase, started investigating the possibility of locating additional sites for the construction of dams and reservoirs mainly to increase the water storage capacity of the water supply system of Addis Ababa. Some locations have been identified but their ability to supply water to Addis by gravity has to be further investigated when more detail topographical data become available. In the feasibility study all these locations will be studied and presented so final decisions can be taken.

Other engineering works

The main problem of the Legedadi and Dire catchments is the limited storage capacity of the existing reservoirs. Diverting water from nearby catchments can give only short term solutions with the better management of the available water resources, but cannot be considered that it is increasing the water harvesting in the catchments and supports significantly the water supply of Addis Ababa.

In chapter 3.2.3 of this report we examined the possibility to construct a large dam on the Lege Hola River downstream of the Dire reservoir. This dam was also proposed by the Master Plan. The proposed location is favourable and although final decisions will be taken after the feasibility study the construction of a 20 to 25 m dam is very possible. The volume capacity of the reservoir which will be created after the construction of the dam has been estimated with the available data to be approximately 19 MCM.

Since the average annual overflows from the Dire reservoir have been calculated to be 23.5 MCM the construction of the Lege Hola Dam could retain most of the average annual surplus without the need of constructing river diversions of questionable efficacy.

Mechanical removal of sediments (dredging)

The excavation and certainly the dredging of sediment from the reservoirs are very costly solutions. Since the annual volume reduction of the Geffersa and Dire reservoirs is small, around 0.3% for both reservoirs, as also explained in chapter 1 of this report, the sedimentation is not the major problem off the catchments and all three reservoirs are expected to continue be operational for many years to come. It is considered from this report that implementing very costly methods like the mechanical removal of sediment from the reservoirs in not a necessity for AAWSA at the moment. If the sediment rates be increased in the future, maybe that approach could be reconsidered.

River regulation

According to the Master Plan, river regulation in the Legedadi plains will reduce the inundated areas, but will only benefit agriculture crops. From the siltation point of view, it might even prevent some precipitations of silt in the inundated areas by shortening the water courses directly to the reservoir. Since the benefit of this regulation is more agricultural it was proposed that AAWSA will not initiate any such measures unless it wishes to benefit the local population. Considering the high cost of the river regulation and the small benefits the proposal of the Master Plan is considered acceptable and reasonable.

Diversions from nearby catchments

None of the described diversions in the 2000 MP are considered feasible and none was recommended from the Master Plan taking into account the high cost and other several problems raised from the construction of canals.

Buffer strip

To protect the reservoirs from the soil erosion and the sediment load transferred directly to them the Master Plan proposes the construction of a very heavy and costly buffer strip system with a large width which will affect directly the Kebeles near the reservoirs. A lot of them will need to be relocated and the cultivated land will be reduced since the proposed buffer strip will cover a zone of at least 1.75 km in the perimeter of each reservoir.

The construction cost of this proposal was estimated to be approximately 23.0 million Birr in the year 2000. The cost of the proposed buffer strip is highly increased due to the proposed canal operating as a silt trap and the required number of inlets and culverts. As demonstrated in the report, this cost is not justified since it will protect the reservoirs from only a small part of the catchments, namely 14% for Legedadi, 11% for Geffersa and 8% for Dire.

A different design for the buffer strip is proposed by this report, the basic difference of which with the 2000 MP design is that the construction of the costly canal with all the required inlets and culverts is not proposed.

The silt-trap zone is designed to prevent silt transported with water that originates from the catchment close to the reservoir and from the silt-trap-zone itself to enter the reservoirs. It covers the perimeter of the reservoir and it is separated into three sub-zones:

- The tree zone
- The shrub zone
- The grass zone

Between the shrub zone and the tree zone, a fence is proposed to be constructed along the perimeter. This fence will protect the reservoir and the grass zone from any human and livestock interferences. The design components of each zone are presented in detail in the report.

2. ENVIRONMENTAL & PHYSICAL PLANNING ASPECTS

2.1 SOIL CONSERVATION MEASURES

We agree in general with the proposed measures of the Master Plan to introduce advanced cultivation practices and cropping patterns.

This has to be combined with uninterrupted and long term access to the same piece of land and resource for the farmers. Such practice will encourage the adoption of long-term conservation practices which otherwise might be difficult to implement given the uncertainty of the farmers over their long-term association with a particular land area.

The proposed silt traps in the proximity of the reservoirs were specifically commented upon in chapter 3.3.6.

Based on experience derived from previous work in the broader East African region (Upper Tana, Kenya) one basic conclusion is that different soil conservation techniques should be applied for different crops in order to achieve the best results.

Regarding the soil conservation methods proposed in the Master Plan or commonly used in the region we consider the grass strips and tied ridges (depending on the kind of plantation) as the most appropriate and easy to implement measures for the region and the specific area.

3. SOCIO-ECONOMIC & INSTITUTIONAL ASPECTS

Socio-Economic

The catchment presents a picture of low value agricultural land use with considerable degradation in areas that location-wise have all the chances to develop into high value farming. To safeguard the vital catchments there needs to be (1) intensive water buffer development and soil water conservation measures (2) development of high value chains. This will ensure both environmental sustainability and economic growth, reversing a situation of dire poverty and low value land use.

In terms of soil water conservation it is important that a process of intensive local planning starts – instead of piecemeal interventions. This requires (1) capacity building of local leaders and land users (2) developing local plans – identifying a wide range of measures (3) bundling efforts to finance these activities and explore self-financing mechanisms.

There is considerable reason to assume that better land management in the area will greatly improve productivity of the existing crops – such is the experience in the region. Table 34 is included based on a literature overview of a number of land management measures.

Apart from introducing better land management there is scope to support the development of higher value land use in the three catchment areas. The following options are need to be explored and work out in operational detail:

(1) Higher value livestock keeping. There are range of measures to be introduced – starting from improved local veterinary care, to supplementary feeding, controlled grazing – and introducing feedlots and dairy farming.
(2) Commercial woodlot forestry with indigenous trees. The development of eucalyptus plantations is taking off in the catchment area, but can be expanded in particular with the introduction of different less water demanding eucalyptus varieties as well as the introduction of other tree species - indigenous
(3) The proximity to urban markets creates a large demand for perishable horticultural crops, and more can be done to introduce and propagate fruit trees and shrubs on small holder farms,
(4) Combine the above activities with value addition – recreational and nature-tourism.

In developing any of these directions care has to be taken that the ultimate aim of protection for undue sedimentation and pollution is safe guarded. This however may well be and best be combined with introducing more productive and sustainable land uses. A wealth of successful examples for value chain development exists in Ethiopia; for example the development of forest based value chains in South Western Ethiopia, increasing household income and contributing to watershed protection at the same time. Similar, innovative approaches could be followed for the catchments. Other income generating mechanisms that can be explored are Payment for Environmental Services (PES), whereby downstream water/land resource users pay upstream stakeholders for protection of resources, and carbon credits (see box below on Participatory Forest Management).

Table 61: Orders of magnitude: investment costs (in labor) and benefits of different 3R buffer management techniques (in USD)

Technique	Cost / Ha	Cost/ m^3 storage	Overall Cost	Prime benefits	Additional benefits
Mulching and land preparation measures				Yield increases of 2-4	
Tree planting	160-2500				Base flows Reduce erosion Micro climate
Contour bunds and planting pits	75-250			Yield increase factor 4-18	
Grass strips and trash lines	30-80				Base flows Reduced erosion
Terracing	120–1800			Yield increase factor 4-18	Base flows Reduced erosion
Intensive grazing	10 -1000			Stocking rate increase 2-8	Better water buffers
Small surface storage					Strategic storage
Subsurface dams	240	0.35-1.4			Storage in riverbed and riverbank
Sand dams					Storage in riverbed and riverbank
Flood water spreading and spate irrigation	250-1800			Yield increases factor 2-5	Stabilizes the landscape
Gully plugging	140-200			400/ha/year	
Leaky dams			1200		
Shallow tube wells			30-150		Secure access groundwater

Box 1: Participatory Forest Management as a tool for watershed protection

In the South Western part of Ethiopia, the Baro-Akobo sub-basin, major headwaters of the Nile, several NGOs together with local and regional government institutions have been working on the implementation of participatory forest mechanisms and related non timber forest products. The programme not only benefits the communities in the target area, but has substantial benefits to communities residing far downstream into Gambella Region. Within the project area, the establishment of community production and marketing groups for honey, coffee, spices and bamboo has been facilitated. Through linkage of improved NTFP production with market opportunities and secured access rights to forest resources through PFM arrangements, improved livelihood conditions and a sound basis for sustainable forest management have been achieved. (Ethio-Wetlands and Natural Resources Association's programme in the South West of Ethiopia "Sustaining Headwater Forest Landscapes in the Baro-Akobo Basin through Participatory Forest / Land Use Management and Environmental Service Payments", currently ongoing)

Box 2: Community conservation and tourism development potential

Preliminary site visits and discussions with various stakeholders have indicated that the three catchment areas harbour a high potential for (eco)-tourism development. Given the proximity to the capital, a market potential exists for a range of tourism related activities. Currently only in the North and South of Ethiopia, community based tourism has been successfully developed. Various community conservation sites have been developed and connected, in which tourists can undertake a range of activities, such as trekking, horse-back riding and watching cultural performances. Because these activities are nature-based, the natural resources are perceived by the communities as an asset, supporting their income generation, and are thus protected. Establishing viable community conservation sites in the catchment will stimulate sustainable management of natural resources.

Box 3: Gender

When designing development interventions in the Ethiopian context, specific attention needs to be paid to the role, potential of women. Although households are dependent on women and women therefore generally form the "back-bone" of society, they are very much disadvantaged in accessing basic services. Therefore, it is vital to take into account specific gender issues in the catchment area. Women can not only be involved, but even be given the responsibility for the development of nature based value chains such as honey, herbs, spices and fruits, increasing their economic dependency and improving overall household livelihood base, because women are known to invest in this much more so than their male counterparts.

Institutional

The current political-administrative set-up remains a challenge to be addressed. However, the so-called Common Development Committee for the Oromia Special Zone Surrounding FinFinne is a suitable entry point for a new or similar institutional arrangement. Both Addis Ababa Municipality as well as Oromia Regional State are represented on this Committee.

4. RURAL WATER SUPPLY

There is a shortage of water supply. Also due to the direct feed from reservoirs the water is contaminated. So to reduce contamination of reservoirs' water and to satisfy the people needs it is essential to provide water to the people use and livestock feed at points near to residence areas.

From the details in chapter 4, MP 2000 had proposed certain number of wells to be dug at certain locations and equipped properly. Also we had calculated the now needs and projection of these to the year 2035 and estimated the number of wells needed. A field investigation supposed to be done next stage of this study to verify the situation of the existing wells, their operation and productivity situation. Depending on that the exact number of new wells will be defined to cover the needs of water. These wells will be located at locations that serve as much communities as it is possible at reasonable distances.

Appendix I:

Photos of the 2000 MP proposed

Dams' locations

APPENDIX I: PHOTOS OF THE 2000 MP PROPOSED DAMS LOCATIONS

The area where the dam axis has been proposed. The very flat area can be easily understood.

The Sekoru river in the area of the proposed dam axis.

No 9. Sekoru and Fule sub catchments.

The left embankment on the proposed dam axis.

The area upstream of the dam axis where the reservoir is proposed.

No 11. Sendafa and Bolo sub catchments.

The right embankment and the upstream area from the proposed axis.

The left embankment. The very flat area can be easily understood from the picture.

No 16. Lege Beri sub catchment.

The left embankment on the proposed axis.

The area upstream the proposed axis. The small depth of the stream can be seen.

The right embankment.

No 1. On the Lege Beri sub catchment.

The small size of the stream is obvious.

The very flat area can be seen in the photo.

No 2. On the Nya-a sub catchment.

The hill on the left embankment and the proposed dam axis.

The area upstream. The open valley can be seen.

No 3. On the Doyo sub catchment.

Both pictures are characteristic of the flat area.

Possible location for the construction of a simple silt trap inside the river bed.

No 4. On the Kultubi sub catchment.

No 5. On the Sekara sub catchment.

The very flat area is obvious.

Very small stream with no water.

No 6. On the Sendafa sub catchment.

Small stream suitable only for a simple silt trap.

Flat area outside the river bed with houses very near.

No 7. On the Sendafa sub catchment.

The very flat surrounding area is obvious from the pictures.

No 8. On the Lege Jila sub catchment.

The area in the axis of the proposed dam. The left embankment can be seen.

No 15. The Legedadi strait Dam

The proposed site for the dam construction.

The good condition of the bed rock can be seen in the picture.

The nearby villages that could be supplied by the reservoir.

No 10. The Bura dual purpose dam

The dam site from above.

The right embankment at the proposed axis. The rock can be seen.

The area where the reservoir will be created.

No 17. Lege Hola storage dam.

The proposed site for the dam axis. The small gorge can be seen.

The open valley behind the dam for the reservoir.

The foundation conditions are very good and the bed rock is visible in both embankments and the river bed.

No 12. On the Mangaro Catchment

The dam is proposed at the tail of the existing Geffersa III reservoir.

The required long crest and big dam in order to store additional water can be understood from the picture above.

No 13. On the Mangaro / Dima sub-catchment

The flat area can be seen in the picture.

The main Geffersa reservoir is fenced all around though the fence needs to be maintained as can be seen from the picture below.

No 14. On the Guje – Kersa sub catchment