JAPAN INTERNATIONAL
COOPERATION AGENCY (JICA)

No.

THE REPUBLIC OF MADAGASCAR

THE MINISTRY OF ENERGY
AND MINING (MEM)

THE STUDY
ON
THE SUSTAINABLE, AUTONOMIC DRINKING WATER SUPPLY PROGRAM
IN
THE SOUTH REGION OF MADAGASCAR

FINAL REPORT

SUMMARY REPORT

DECEMBER 2006

JAPAN TECHNO CO., LTD.
NIPPON KOEI CO., LTD.

GE
JR
06-074

In this report water charges and project cost are estimated based on prices as of October 2006 with the last 6 months average exchange rate of US$1.00 = Japanese Yen ¥ 120.0 = Madagascar Ariary 2,160 = Euro 0.8.

PREFACE

In response to a request from the Government of Madagascar, the Government of Japan decided to conduct the Development Study on The Sustainable, Autonomic Drinking Water Supply Program in the South Region of Madagascar and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a Study Team composed of Japan Techno Co., Ltd. and Nippon Koei Co., Ltd., headed by Mr. Shigeyoshi KAGAWA of Japan Techno Co., Ltd. to Madagascar, four times between January 2005 and December 2006.

The Team held discussions with the officials concerned of the Government of Madagascar, and conducted field surveys at the study area. Upon returning to Japan, the Team conducted further studies and prepared this Final Report.

I hope that this Report will contribute to the promotion of the project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Governemnt of Madagascar for their close cooperation extended to the Team.

December 2006

Matsumoto Ariyuki
Vice-President
Japan International Cooperation Agency
（JICA）

December 2006

Mr. Matsumoto Ariyuki
Vice-President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleasured to submit you the Final Rreport entitled **The Study on the Sustainable, Autonomic Drinking Water Supply Program in the South Region of Madagascar**. This report has been prepared by the Study Team consisting of Japan Techno Co., Ltd. and Nippon Koei Co., Ltd., in accordance with the Scope of Work (S/W) for the Study agreed upon the Ministry of Energy and Mining (MEM), the Government of Madagascar and the Japan International Cooperation Agency (JICA) in Antananarivo on 18th August, 2004.

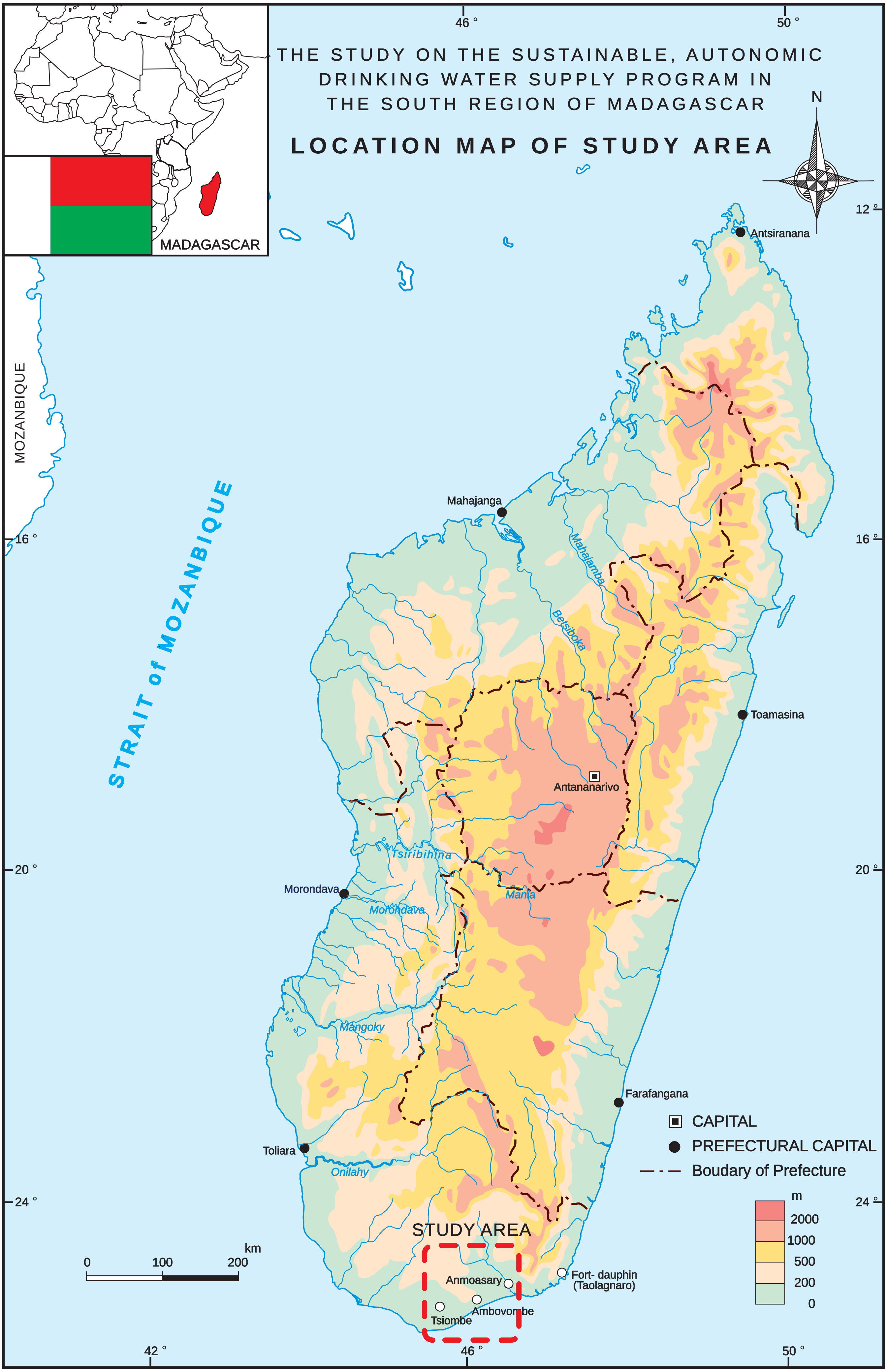
This report consists of the following volumes:

- Summary Report: A concise report on the whole Study results
- Main Report: Description of the Study results including the water resources potential, groundwater development, water supply master plan, pilot project, operation, maintenance and monitoring of pilot project
- Data Book: Survey data of water sources, satellite image, socio-economy, test drilling, water quality, geophysical survey, monitoring of groundwater, seminar, minites of discussions, and list of concerned persons
- Supporting Report: Results of socio-econmic and household survey, geophysical interpretation, test drilling, pilot project, topographic measurements, and operation, maintenance, monitoring and evaluation of pilot project

We wish to take this opportunity to express our sincere gratitude to your agency and the Embassy of Japan in Madagascar. We also wish to express our deep appreciation to the Ministry of Energy and Mining as well as other authorities concerned of the Government of Madagascar for their close cooperation and assistance extended to us during our Study activities in your country.

Very truly yours

Kagawa Shigeyoshi
Team Leader


THE STUDY ON THE SUSTAINABLE, AUTONOMIC
DRINKING WATER SUPPLY PROGRAM IN
THE SOUTH REGION OF MADAGASCAR
LOCATION MAP OF STUDY AREA
MADAGASCAR
MOZANBIQUE
STRAIT of MOZANBIQUE
N
46 °
50 °
12 °
16 °
20 °
24 °
42 °
Antsiranana
Mahajanga
Mahajamba
Betsiboka
Toamasina
Antananarivo
Tsiribihina
Morondava
Mania
Mangoky
Farafangana
Toliara
Onilahy
STUDY AREA
Anmoasary
Fort- dauphin
(Taolagnaro)
Tsiombe
Ambovombe
CAPITAL
PREFECTURAL CAPITAL
Boudary of Prefecture
m
2000
1000
500
200
0
km
0
100
200

Natural and Social Condition of the Study Area **Photo 1**


Main Street at Ambovombe City


Commune Center on Weekly Market


Rural Village


Inland area of Ambovombe Basin (Seasonal Pond)


Coastal Area


Seaside


Forest (Ambovombe Basin)


Arable Land of the Coastal Area

Water Environment of the Study Area **Photo 2**

Local Water Source: Vovo (Traditional Dug Well)

Current Water Source: Marsh (Seasonal Water)

Current Water Source: Seaside Hand Dug Well

Local Water Supply: Water Vender by Zebu Cart

Solar Pumping System in Ambovombe Commune

Impluvium (Rainwater Collection)

Water Supply by Water Service Truck, AES

Rainwater Reservoir at Rural Village

Survey, Test Drilling and Pilot Project **Photo 3**


Inventory Survey and Monitoring of Existing Well


Geophysical Survey (Geoelectric VWS)


Test Drilling, Borehole Construction


Workshop at Pilot Project Site


Pilot Project, Pump Rope at Marobe P009


Pilot Project, Solar Pumping System at Bemamba F006


Pilot Project, Pump Vergnet at Anjira F022


Topographic Measurement Survey for Pipeline Route

EXECUTIVE SUMMARY

Study Period: January 2005 ～ December 2006
Executive Agency: Ministry of Energy and Mining

1. Study Background

The Study area in South of Madagascar is characterized by its dryness and the problem of the lack of drinking water for the people due to the very arid climate and the non-existence situation of water resources such as rivers and wells. In particular, the southern coastal zone of the Ambovombe, people are forced to buy high-priced drinking water from local water venders due to no source of water in the villages, affected by a little annual average precipitation of 543mm observed mainly in the rainy season and also by the malfunction of public water supply through water tank truck. According to the annual report of AES in 2006, public supply water was only 0.4 lit/cap/day for the target population of 278,000 in the area due to lack of water tank trucks and increased fuel and operation costs. Moreover, available water by any means is of low quality and does not satisfy hygiene standard. Therefore, the government of Madagascar puts the highest priority to secure safe water for the Study area.

JICA organized a Study Team in 2005 to conduct the sustainable, autonomic drinking water supply program in the south region. The Study confirms the groundwater potential in the target villages and suitable water supply facilities namely hand pumps and solar pumping system together with operation and maintenance system involving the villagers is recommended through the technical assistance of Test Drilling and Pilot Project together with community participation and monitoring of the Pilot Project. Based on the survey results the following water resources potential and optimum drinking water supply plans including operation, management and maintenance were established.

2. Water Resources Study

The Study Area, situated in the southern region of the Madagascar Island, is within the Arid to Semi-arid Climate. There is no continuous river flowing throughout the year within the Ambovombe basin, and river flows can only be observed during the wet season. The area of Ambovombe basin is 1,923 km^2 and the amount of water resources is calculated to about 1,044 million m^3/year with an average annual precipitation of 543 mm/year as follows.

1) Precipitation (Water Resources)

Thiessen polygon is generated for 6 precipitation gauge stations within the Study area to obtain the amount of precipitation and/or water resources.

Station	(A); Thiessen Polygon area	(B); (A)/Total Area(%)	(Pa);Average Precipitation (mm/year)	(C); (B)×(Pa) (mm/year)	(D); Calculated Precipitation (mm/year)
Antanimora	604.0	31.4%	720.3	226.2	(C)=Σ(B)×(Pa) = 543 (mm/year) (D)=(C)×1,923km^2= 1,044,189,000 m^3/year
Ambondro	317.0	16.5%	399.0	65.8	
Ifotaka	90.5	4.7%	506.6	23.8	
Ambanisarika	314.0	16.3%	480.9	78.4	
Ambovombe	496.0	25.8%	492.5	127.0	
Amboasary	101.5	5.3%	414.1	21.9	
Total	1,923 km^2	100.0%	-	543	

2) Groundwater Recharge

Groundwater recharge (**R**) in the basin is calculated with Groundwater outflow **(Q)** and Groundwater pumping (**GWout**). Based on the inventory survey, the groundwater pumping (**GWout**) was estimated 80,265 m^3/year consisting of 51,977 m^3/year from 68 wells/boreholes in Antanimora and 28,288 m^3/year from 78 wells/boreholes in Ambovombe.

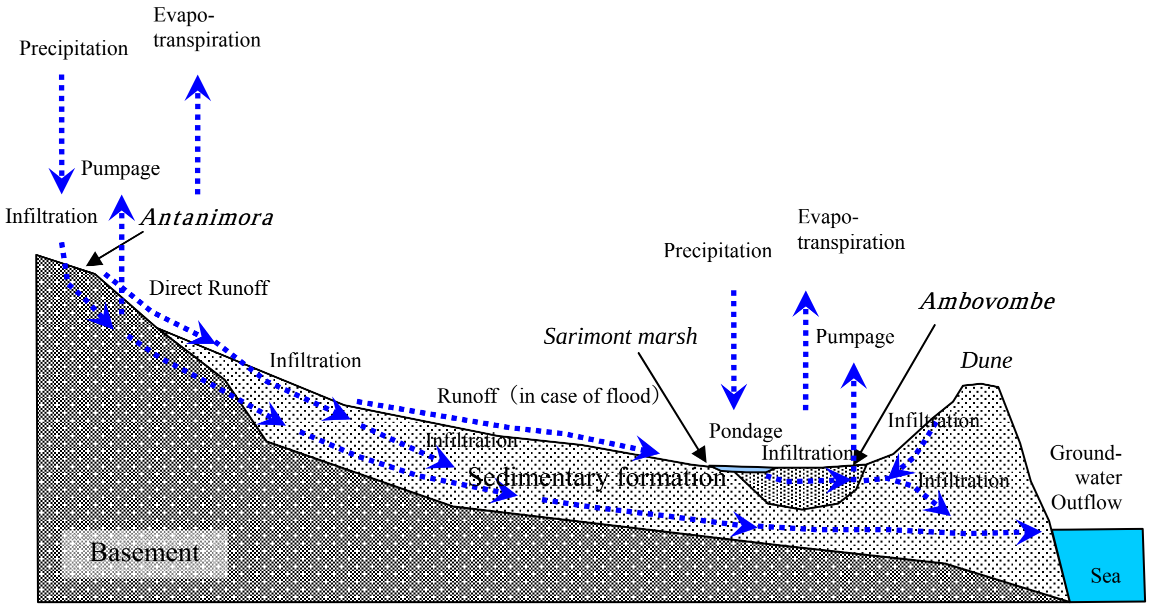
On the other hand, groundwater outflow (Q) is estimated using Darcy's equation for groundwater flow at the edge of the Basin. **Q = T x i x L x h** = 1.512 (m^3/s) = 47,682,432 (m^3/year), where

T: Permeability coefficient = 8.0 x 10^{-2} (cm/s), i: Hydraulic gradient=0.0007, L: Width of aquifer =30(km), h: Thickness of aquifer = 90(m)

Therefore, Groundwater recharge (**R**) in the Basin is 47,762,697 m^3/year which is the sustainable groundwater amount of the Ambovombe Basin.

R = Q + GWout = 80,265 + 47,682,432 = 47,762,697 m^3/year

Obtained **R** is divided by the area of the Basin (1,923km^2), then depth of groundwater recharge is calculated as 24.8mm/year. This is 4.6% of annual average precipitation of 543mm/year in the Basin.



Hydrologic Cycle of Ambovombe Basin

3) Evapotranspiration

Water balance of the Basin can be expressed as P = R + E, because Ambovombe Basin is a closed river basin and there is no continuous river flowing and surface water such as ponds and lakes filled throughout the year. Therefore, Evapotranspiration (E) is calculated as followings;

E = P – R = 1,044,189,000 – 47,682,432 = 996,506,568 m^3/year

Obtained **E** is then divided by the area of the Basin (1,923 km^2), so the depth of evapotranspiration is calculated as 518.2mm/year. This is 95.4% of annual average precipitation of 543mm/year in the Basin. The most of water resources in the Ambovombe Basin is lost by evapotranspiration due to the very arid climate.

4) Water Balance and Water Resource Evaluation

Water balance of the Basin is shown as P = R + E. Therefore, the only stable water resource in the Basin is the groundwater. The groundwater recharge is calculated 47,762,697 m^3/year (130,856 m^3/day), which can be conversed into the annual precipitation as 24.8mm/year in the Basin or 4.6% of annual average precipitation of 543mm/year, so this is the sustainable yield of this groundwater basin.

3. Groundwater Potential Study

As a result of the hydrogeological survey, geophysical survey and test drilling, 20 boreholes and 5 hand dug wells were completed successfully. However, the groundwater suitable for drinking with WHO standard, was found only in Antanimora (F006 and F006B) 60km northwest of Ambovombe city, and water suitable only for domestic use with the limit of water quality standard of Madagascar was found in the suburb of Ambovombe city (F015).

The groundwater potential in Antanimora is as high as 478 to 612 m^3/day with 10m drawdown, and, groundwater pumping level is at about 18.7m to 21.2m., which is suitable for solar pumping system The groundwater potential in Ambovombe city is high as 4,320 m^3/day with 10m drawdown, but the water quality is 306mS/m which is at the limit of Madagascar standard. The water quality of this site is not suitable for drinking water supply but for domestic water use, such as cooking, washing and other purposes. Therefore, sustainable yield is revised as 300 to 400 m^3/day/well within 1m drawdown due to saline water coming from the bottom.

ID	Commune	Total Depth	Discharge	Electric Conductivity	SWL	PWL	Specific Capacity	Groundwater Potential
Test Borehole		m	m^3/h	mS/m	m	m	m^3/hr /m	m^3/day
F006	Antanimora	75.76	10.4	68	15.99	21.22	1.99	478
F006B	Antanimora	61.82	10.8	125	14.41	18.65	2.55	612
F015	Ambovombe	150.00	7.2	306	134.00	134.40	18.00	4,320

Concerning the sustainable yield of Antanimora area, in the upper stream of Ambovombe Basin, there is 350km^2 of river basin(**A**) with 720mm/year of annual average precipitation(**Pa**). Assuming the groundwater recharge(**R**) of 4.6%, the amount of sustainable yield in Antanimora(**Ra**) is calculated as follows.

$$\mathbf{Ra} = \mathbf{Pa} \times \mathbf{R} \times \mathbf{A} = \mathbf{11{,}592{,}000\ m^3/\ year}$$

On the other hand, the groundwater development in Antanimora is estimated to be 636,000 m^3/year consisting of the present groundwater pumping of 52,000 m^3/year in Antanimora and the maximum groundwater development 1,600 m^3/day (584,000 m^3/year) for this Project. The expecting groundwater development is about 5.5 % of the amount of groundwater sustainable yield(**Ra**). Therefore, this groundwater development plan in Antanimora is suitable from the groundwater potential.

Groundwater development in Ambovombe is estimated to be 247,288 m^3/year consisting of the present groundwater pumping of 28,288 m^3/year in Ambovombe and the maximum groundwater development 600 m^3/day (219,000 m^3/year) for this Project. The expecting groundwater development is about 0.5 % of the amount of groundwater sustainable yield(**Ra**) of Ambovombe Basin. This groundwater development plan in Ambovombe is suitable from the groundwater potential, and the most economic and efficient development because the water source is in the main supply area of Ambovombe city. Therefore, the groundwater development is recommended at first in Ambovombe and after this in Antanimora due to the urgency and long range groundwater supply with quantity.

4. Water Supply Plan

4.1 Water Supply Area and Supply Population

The water supply area in this Study is divided into two categories namely the city of Ambovombe Commune and other Communes of rural villages as follows:

1) The city of Ambovombe Commune(58 fokontanys)
   Population in 2005: 38,213, in 2015: 42,000
2) Other Communes of rural villages excluding Ambovombe Commune (332 fokontanys)
   Population in 2005: 239,767, in 2015: 358,000
3) Number of Villages and Population surveyed by JICA Study Team in 2005
   Ideal water supply facility

- Population less than 300: 1,183 villages: Hand Pump Facility
- 300 to less than 1,000: 164 villages: Hand Pump Facility/Solar Pumping System
- More than 1,000: 3 villages: Solar Pumping System

4) Water price (affordable): 30-50Ar/bucket (1.7-2.8Yen/bucket)

4.2 Water Demand and Water Consumption

The target year for water supply facilities is set at the year 2015 to conform to the target year of Millennium Development Goals (MDG). The population in the Study area is estimated using Logistic Curve forecasting calculation in the Study area is estimated to be about 400,000. The population growth is about 3.7% per year. The population in Ambovombe Commune in 2015 shall be 42,000 from the result of this Study, and other Communes of rural villages are estimated as 358,000 in 2015. The Study was planed to supply clean water by 10 litters/capita/day. Therefore, the water demand in Ambovombe Commune is expected as 420m^3/day and 3,580m^3/day for other Communes of rural villages in 2015, respectively.

4.3 Consideration of Water Supply Plan

1) As the results of the full-dress study on groundwater development in Ambovombe basin and surroundings, the drinking groundwater was found only in Antanimora, 60km northwest of Ambovombe city, and the domestic water with the limit of water quality standard of Madagascar was found in the suburb of Ambovombe city. Therefore, we have recommended the water supply facility with 120km pipeline from Antanimora to Antaritarika via Ambovombe city for about population of 400,000 including the city of Ambovombe and coastal area. There are many advantages for the long pipeline for drinking water supply because it is possible to take advantage of the gravity flow from the start at Antanimora to the end at Antaritarika. The groundwater potential of test drilling borehole of F006B is as high as 600m^3/day/well with 10m drawdown and shallow static water level at about 14.4m with 62m depth of borehole. The water quality is 125mS/m with WHO standard. Groundwater level is suitable for solar pumping system at about 100 m^3/day with 6 hours operation.

   The profitable water charge is calculated 15 to 23 Ar/bucket of 13 litters (0.83 to 1.3¥/bucket) assuming the maximum amount of 1,600 m^3/day and the minimum profitable supply amount of 700 m^3/day using combination power sources of solar pumping system and diesel generator due to minimize initial water facility cost.

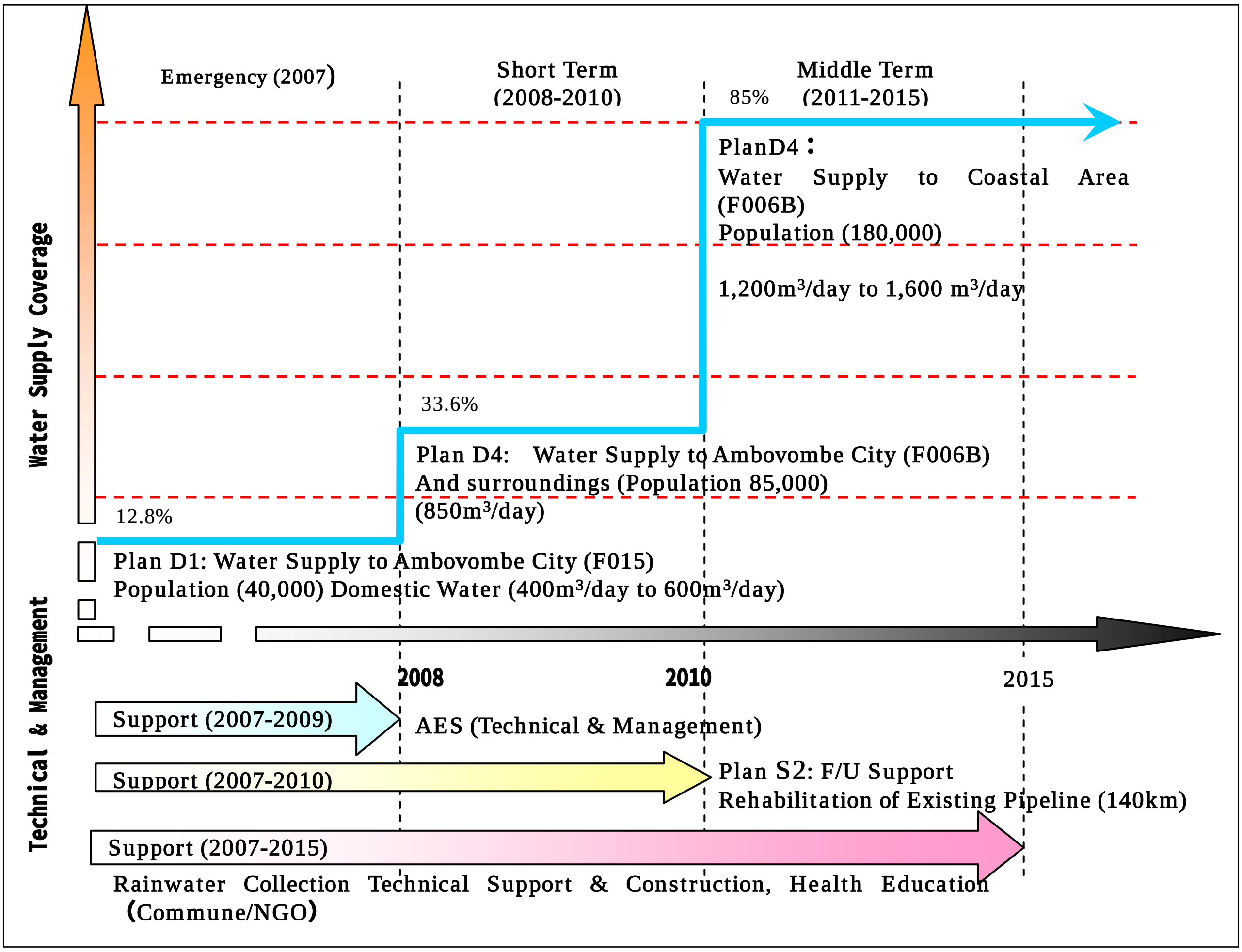
2) It is recommended urgently to develop the successful groundwater source in the suburb of Ambovombe city, that is the test borehole of F015, and to supply water for the city of Ambovombe with population of about 40,000 **(**Plan **D1)**. There is serious shortage of water. Therefore, this can be the most economical and effective water supply facility as it is the nearest water source to the main water supply area. The groundwater sustainable yield is high as 300 to 400m^3/day/well with 1m drawdown, but static water level is deep at about 134m with 150m depth of borehole. The water quality is 302mS/m which is just above the limit of Madagascar water quality standard. Therefore, groundwater is not suitable for drinking supply but only for domestic water such as cooking, washing and other purposes. Also, the groundwater level is not suitable for solar pumping system due to very deep static water level, but for diesel generator pumping system. The profitable water charge is calculated to be 20Ar/bucket of 13 litters (or 1.1 ¥/ bucket) assuming minimum profitable supply amount of 400m^3/day, and using diesel generator as a power source.

   JIRAMA electricity cannot be used for the time being because of lack of capacity, however, this should be strongly considered in the future because of low operational costs. The AES has technical office in Ambovombe city and is currently selling water at 100Ar/bucket in 2006. The present supply capacity is only 20 m^3/day in Ambovombe area and 100 m^3/day in whole AES operational area, serviced by water tank trucks, existing pipeline of 140km, and 5 AEP/AES water service centers. Therefore, the steady water supplies of 400 m^3/day in Ambovombe city should make great improvement to the shortage of water in the area and to the financial management status of AES.

3) There is an urgent need for repair and protection measures for the existing treatment plant in Ampotaka constructed by the Japanese Assistance from 1995 to 1999, which was seriously damaged by the cyclone in March 2005. Under the alternative plan **S2** the rehabilitation of the existing pipeline system including the reinforcement of AES management system are also recommended to improve the water supply facilities especially for generation system, to cope with the increase of the fuel cost and the decrease of the water tank trucks. In 2005 only 2,465 m^3/year (7 m^3/day) of water was sold by this system. This is not at an operational profitable level because the production water cost is estimated to be 392Ar/bucket (22¥/bucket), 4 times of official water rate in 2005. Therefore, the rehabilitation of the system should be included in the solar pumping system project and the 50 m^3/day is the minimum profitable level assuming water charge of 80Ar/bucket (4.4¥/ bucket).

5. Water Supply Master Plan

The water supply master plan is divided into three (3) stages: namely, Emergency water supply (2007) stage, Short term water supply stage (2008-2010) and Middle term water supply stage (2011-2015). The project implementation program is recommended as follows.



Water Supply Master Plan (2007—2015)

Water Supply Master Plan (2007－2015)

	Stage	Year	Water Source	Water Supply Plan	Soft Program
1	Emergency	2007	Ambovombe （F015）**(D1)**	･Domestic water supply to Ambovombe city for 40,000 population	･Technical assistance for AES management, operation and maintenance **(S1)** ･Management support for water charge and operation cost**(S1/S2)**
			Ampotaka Existing (Drinking water） **(S2)**	･Existing drinking water supply system for 80,000 population ･Improvement of present operation facilities using solar pumping system and repair of existing generators	
2	Short Term	2008-2010	Antanimora (F006B) (Drinking water-1) (D4, Phase1)	･Drinking water supply to Ambovombe city and the surroundings for 85,000 at about 63km gravity flow pipeline system ･Phase-1 of Drinking water supply to Antaritarika, coastal sand dune area by gravity flow pipeline system	･Hygiene education and capacity building for local government and water committees **(S3)** ･Rainwater collection technical support for construction and repairing works together with local NGO **(S3)**
3	Middle Term	2011-2015	Antanimora (F006B) (Drinking water) (D4, Phase2)	･Drinking water supply from Ambovombe city to Antaritarika for 180,000 population ･Plan D4, Phase-2 of Drinking water supply to Antaritarika, coastal sand dune area by gravity flow pipeline system	･Technical assistance for extension of existing pipeline from Sampona, Mini-Pipeline to Ambovombe city and Antaritarika, coastal sand dune area ･Project coordination for water supply project between MEM, ADB and Japan ･Monitoring of management, O/M for Mini-Pipe and technical assistance for AES

6. Project Conclusion and Recommendation

1) Upon consideration and attention to the poverty deduction in the Study area, water and community participation are important keywords. The viewpoint of sociology was focused throughout the Study. The rural population, who used to be passive as recipients of the donor-funded projects, is now active actors in the development with participatory approaches. Especially water supply service in the District, commune and/or Fokontany level in South Region of Madagascar has been provided at free as one of the public services by the government. However, due to financial constraints of the government the water supply service in even in rural area has been discontinued. Restoring the water supply service and re-establishing the operation, management and maintenance of water supply service based on the “User-Pay-Policy” are necessary to secure the sustainable and autonomic management. For this purpose understanding of the concept among the local stakeholders like District local-level governments, communes, Fokontany and villagers are essential. Several workshops to encourage their participation were held during the Pilot Project through the sub-contracted local NGO together with Study team and the above-mentioned keywords were focused accordingly. Organization of community, villagers’ willingness to pay for water, set-up of capable management of water supply facility and support from local government and AES/MEM were the issues in the existing management system.

2) Utilization of the procedures used and lessons learned in this Study for groundwater development and water supply planning by the counterpart agency is recommended to expect for improvement of poor water supply coverage (around 3%) through upgrading of water supply in the district city of Ambovombe at first and rural villages based on the proposed plans. At the same time, the rainwater collection facilities are urgently requested to repair and new construction by local district and commune level. The villagers are recommended to involve in the works including hygiene education together with Study team and local NGOs due to available water limited in rainy season in the Study

area.

3) Concerning rural water supply in South Region of Madagascar the AES is expected to take leadership toward improvement of water supply services in the Study area. In the Pilot Project technical, social (community participation and sensitization), financial, economic (provision of subsidy) and legal measures were introduced as a model of this kind of activity. Further extension of this kind of activities for actual implementation of national-wide water supply improvement program is expected.

4) An additional technical assistance **(S4)** is required urgently because the Mini-Pipe constructed by MEM from Amboasary to Sampona started water supply in November 2006. The proposed extension of the Mini-Pipe shall supply drinking water by gravity flow to the coastal area of Antaritarika via Ambovombe city.

5) For the sustainable operation, management and maintenance of the water facilities constructed in the Pilot Project more guidance and support are required and therefore dispatch of short-term experts for this purpose is suggested. As the community-based activity through the NGOs is also necessary to promote operation, management and maintenance of solar pumping system and hand pump, education on health and sanitation and capacity building of villagers, introducing the "Community Empowerment Program" (supported by short term experts and/or technical team) effectively is a possibility. This program is expected to integrate manners to improve the poverty reduction to pay attention for villagers' cash income together with safe water.

6) The water supply Plan D1 is targeted at the highest priority area of Ambovombe city and the beneficiaries are about 40,000 population. The water source (F015) is located in the suburb of supply area of Ambovombe city. Therefore, it is expected to be the most effective and economical water supply system in the Study area. On the other hand, the water supply Plan D4 is also targeted at the highest priority area of Ambovombe city as well as the coastal areas of Antaritarika, and the beneficiaries are about 265,000 population. The water source is located in Antanimora (F006B), 60km northwest of Ambovombe city. It is possible to supply water by gravity flow pipeline in the area and the water source is in good quality of drinking water with WHO water quality standard.

   Without any action, there would be serious shortage of drinking water. Plan D1 and D4 is one of the solution for sustainable and autonomic water supply plan due to the water charge including the cost of operation and maintenance within the beneficiaries' willingness to pay of 50Ar/bucket (2.8¥/bucket) compared with the present cost of 100 Ar/ bucket (5.6¥/ bucket).

7) Drinking water is an essential for the human life. The shortage of water and lack of water in the whole world is caused by the poverty, arid and semi-arid climates, drought, and global climate change. Water supply is the most effective approach and is the gate for the poverty reduction program because it has the essential factors of poverty reduction such as people awareness, participation, ownership, education, capacity building and establishment of close cooperation, operation, management and maintenance included. The largest beneficiaries are women and children as it is their duty to fetch the drinking water for their family everyday from morning to the night. The key to a successful water program is securing a sustainable, autonomic drinking water supply, and the water charge shall be paid by the people on their own will.

8) It is recommended on the point of view of poverty reduction that the water supply project should include a supplementary soft component program aimed at the residents of the rural villages to obtain cash income, enabling the residents to pay for the water. Moreover, the Study team

recommend for the Steering Committee and the concerned agencies to assist the local residents of the rural villages to get more cash income. Consideration in projects (both technical assistance and facility construction) to the cash income of the local people is an important factor for sustainable and autonomic drinking water supply system, including the self support works as specified at sites.

* * * * *

THE STUDY ON THE SUSTAINABLE, AUTONOMIC DRINKING WATER SUPPLY PROGRAM IN THE SOUTH REGION OF MADAGASCAR

FINAL REPORT
SUMMARY REPORT
2006

TABLE OF CONTENTS

PREFACE
LETTER OF TRANSMITTAL
LOCATION MAP OF STUDY AREA
Photo Images (3pages)
EXECUTIVE SUMMARY

Table of Contents
List of Tables and Figures

Abbreviation
List of villages encountered in this Study following alphabetical order

CHAPTER 1 INTRODUCTION
1.1 The Outline of the Study 1-1
1.1.1 General 1-1
1.1.2 Background of the Study 1-1
1.1.3 Objectives of the Study 1-1
1.1.4 Target and Study Area 1-2
1.1.5 Scope of the Study 1-2
1.1.6 Basic Study Policy 1-3
1.2 Implementation of the Study 1-3
1.2.1 Study Schedule 1-3
1.2.2 Study Team Member and Counterparts 1-8

CHAPTER 2 GENERAL CONDITION OF THE STUDY AREA
2.1 Natural Environment 2-1
2.1.1 Climate 2-1
2.1.2 Hydrology 2-1
2.1.3 Topography 2-1

2.1.4 Geology and Hydrogeology 2-2
2.2 Social and Economic Conditions in the Study Area 2-2
2.2.1 Administrative Organization 2-2
2.2.2 Population 2-3
2.2.3 Economic Condition 2-4
2.2.4 Social Infrastructure and Related Social Conditions 2-4
2.2.5 Traditions and Customs 2-5
2.3 Water Supply Institution 2-6
2.3.1 Current Situation of Water Supply Sector 2-6
2.4 The Donors Concerned in the South Region of Madagascar 2-7
2.5 Institution and Management of Water Supply in the South Region 2-8

CHAPTER 3 SURVEY AND ANALYSIS FOR WATER RESOURCES
3.1 Existing Data 3-1
3.2 Water Source Inventory of Existing Water Sources in the Study Area 3-1
3.2.1 Classification 3-1
3.2.2 Water Source Inventory 3-1
3.2.3 Impluvium Inventory 3-3
3.3 Satellite Image Interpretation 3-3
3.3.1 Satellite Interpretation 3-3
3.4 Aerophotograph Survey 3-8
3.4.1 Methodology 3-8
3.4.2 Interpretation 3-8
3.5 Geophysical Survey 3-9
3.5.1 General 3-9
3.5.2 Interpreted Hydrogeological Cross Section of Ambovombe Basin 3-9
3.6 Monitoring of Groundwater Level 3-12
3.6.1 Objective 3-12
3.6.2 Monitoring Wells 3-12
3.6.3 Results of Monthly Monitoring 3-12
3.6.4 Results of Seasonal Monitoring 3-15
3.6.5 Results of Monitoring for Test Wells 3-16
3.7 Water Quality Survey of Existing Wells 3-18
3.7.1 General 3-18
3.7.2 Methodology 3-18
3.7.3 Chemical Composition Analysis 3-18
3.7.4 Water Quality of the Drinking Water in the Area 3-26

3.8 Test Well Drilling 3-27

3.8.1 Plan of Test Drilling 3-27
3.8.2 Result of Test Drilling 3-29
3.8.3 Evaluation of Test Wells 3-31
3.9 Water Quality Profiling Survey 3-33
3.9.1 Vertical Profiling of Water Quality 3-33
3.9.2 Time-Series Monitoring of Water Quality 3-36

CHAPTER 4 SURVEYS AND ANALYSIS FOR SOCIO-ECONOMIC CONDITION
4.1 Outline of the Surveys 4-1
4.2 Socio-economic Analysis of the Study Area 4-1
4.2.1 Economic Condition 4-1
4.2.2 Group Activities and Cooperation 4-2
4.3 Present Condition of Water Use in the Study Area 4-3
4.3.1 Current Water Sources 4-3
4.3.2 Volume of Water Consumption 4-3
4.3.3 Water Charge 4-5
4.3.4 Classification of Water Sources by Difficulty 4-6
4.3.5 Gender Issues in the Study Area 4-9
4.4 Current Method Securing Water 4-10
4.4.1 Concerning Utilization of Rain Water 4-10
4.4.2 Water Vendors 4-12

CHAPTER 5 EXSITING INSTITUTION AND ORGANIZATION FOR WATER SUPPLY
5.1 Organization of AES and JIRAMA in the South Region 5-1
5.1.1 Organization of AES 5-1
5.1.2 Situation of JIRAMA in Amboasary and Ambovombe 5-3
5.2 Commune, Fokontany, and CPE 5-5

CHAPTER 6 PILOT PROJECT
6.1 Plans and Objectives 6-1
6.2 Pilot Project Sites and Specification for Water Supply Facility 6-2
6.3 Socio-Economical Conditions of the Target Villages 6-4
6.3.1 Social Conditions of the Pilot Project Sites 6-4
6.3.2 Economic Condition of the Pilot Project Sites 6-5
6.3.3 Current Water Use 6-5
6.4 Participation of the Community Population and Capacity Building of the CPE 6-6
6.5 Creation of CPE and Water Charge 6-7
6.5.1 Creation of CPE 6-7
6.5.2 Water Charge 6-8

6.6 Monitoring of the Pilot Project ······6-12
6.6.1 Essential Plan for the Monitoring of the Pilot Project ······6-12
6.7 Lessons Drawn from the Pilot Project······6-13
6.7.1 Maintenance Based on the Activities of the CPE ······6-13

CHAPTER 7 GROUNDWATER POTENTIAL STUDY
7.1 Hydrogeological Potential Analysis ······7-1
7.1.1 Analysis ······7-1
7.1.2 Classification of Potential ······7-2
7.2 Water Balance and Ground Water Recharge ······7-3
7.3 Groundwater Modeling and Simulation ······7-9
7.3.1 Objective······7-9
7.3.2 Groundwater Modeling ······7-9
7.3.3 Calibration ······7-12
7.3.4 Simulation······7-15
7.3.5 Evaluation of Groundwater Development Potential of the Well F015······7-17
7.4 Groundwater Monitoring Plan ······7-23

CHAPTER 8 WATER SUPPLY PLAN
8.1 Basic Conditions ······8-1
8.1.1 Water Supply Area ······8-1
8.1.2 Water Demand ······8-1
8.1.3 Water Source and Water Supply Zone ······8-3
8.2 Water Supply Alternative Plan ······8-4
8.2.1 The Description of Alternative Plans ······8-4
8.2.2 Methodology of the Selection of Alternative Water Plan······8-40
8.2.3 The Long List ······8-40
8.2.4 The Short List ······8-44
8.2.5 Determination of Order of Priority ······8-45
8.2.6 General Evaluation and Other Considerations ······8-47
8.3 Proposed Water Supply Plan ······8-48
8.3.1 Evaluation of Basic Index for Water Supply Alternative Plans······8-49
8.4 Cost Estimation ······8-57
8.5 Project Implementation Program ······8-57
8.6 Water Charge ······8-59
8.6.1 Evaluation of Water Charge in 2005 ······8-59
8.6.2 Consideration of Water Charge for the Alternative Plans ······8-61

CHAPTER 9 ENVIRONMENTAL AND SOCIAL CONSIDERATION

9.1 Background ···· 9-1
9.1.1 JICA Guidelines for Environmental and Social Consideration ···· 9-1
9.1.2 EIA System in Madagascar ···· 9-1
9.1.3 Results of Consultation with ONE ···· 9-1
9.1.4 Principal on the Environmental and Social Consideration in this Study ···· 9-2
9.2 Summary of the Master Plan ···· 9-2
9.2.1 Background of the Plan ···· 9-2
9.2.2 Objectives of the Plan ···· 9-2
9.2.3 Target Area of the Plan ···· 9-2
9.2.4 Summary of Water Supply Plan ···· 9-2
9.3 Current situation of the Target Area ···· 9-3
9.3.1 Natural Environment ···· 9-3
9.3.2 Social Environment ···· 9-4
9.4 Results of Environmental and Social Consideration ···· 9-5
9.4.1 Regional Economy (including employment and livelihood) ···· 9-5
9.4.2 Social Capital and Local Decision Making Institutions ···· 9-5
9.4.3 The Poor, Indigenous and the Ethnic Minorities ···· 9-5
9.4.4 Inequitable Distribution of Adverse Impacts and Benefits. ···· 9-6
9.4.5 Conflict of Interest Among the Stakeholders ···· 9-6
9.4.6 Gender ···· 9-6
9.4.7 Water Rights ···· 9-6
9.4.8 Groundwater ···· 9-6
9.4.9 Hydrological Regime of Rivers, Lakes and Inland Waters ···· 9-6
9.4.10 Biota/Ecosystems ···· 9-7

CHAPTER 10 INSTITUTION FOR OPERATION AND MAINTENANCE

10.1 Operation and Maintenance of Water Supply Systems ···· 10-1
10.1.1 Establishment of Community-based Organization ···· 10-1
10.1.2 Organization of AES ···· 10-1
10.1.3 Financial Aspect of AES ···· 10-2
10.1.4 Recommendation to AES for Improvement and New Institution in the Area ···· 10-2

CHAPTER 11 PROJECT EVALUATION

11.1 Economic and Financial Evaluation ···· 11-1
11.2 Environmental Evaluation ···· 11-1
11.3 Evaluation on Organization and Institution ···· 11-2
11.4 Technological Evaluation Concerning Water Supply Facility ···· 11-3
11.5 Economic Evaluation ···· 11-3

CHAPTER 12 TECHNOLOGY TRANSFER
12.1 Technology Transfer 12-1
12.2 Implementation of the Seminar for Technology Transfer 12-1
12.3 Instructions for the CPE at Village Level Concerning Pilot Project 12-1

CHAPTER 13 CONCLUSION AND RECOMMENDATION
13.1 Conclusion 13-1
13.2 Recommendation 13-4

REFERENCES

****

List of Tables and Figures

Chapter 1

Table

1.2.1-1	Implementation of the Study	1-4
1.2.1-2	Assignment Schedule	1-5
1.2.1-3	Operational Chart	1-6
1.2.1-4	The Study Schedule	1-7
1.2.2-1	JICA Study Team	1-8
1.2.2-2	Counterpart Team	1-8

Figure

1.1.4-1	The Study Area	1-2

Chapter 2

Table

2.1.4-1	Geological and Hydrogeological Classification in the Study Area	2-2
2.2.1-1	Administration organization of Madagascar	2-2
2.2.1-2	Names of studied communes	2-3
2.2.2-1	Population and number of fokontanys in the study area (2005)	2-3

Figure

2.1.1-1	Isohyet Map around the Study Area (Average of 1999-2004)	2-1
2.1.3-1	Topographic Map of the Ambovombe Basin	2-1
2.1.4-1	The geological conditions of the Study area	2-2
2.2.2- 1	Distribution of fokontanys and population size	2-4
2.2.4-1	Diseases frequently catching people (2004)	2-5
2.3.1-1	Water Service by AES in Ambovombe Urban	2-7
2.4-1	Projects funded by international donors in the South Region	2-8
2.5-1	The pipeline of AES constructed by JICA 1995-1999 and the Sampona Project in progress (the IPPTE, 2004-2006) base map prepared by EU, 2005	2-9

Chapter 3

Table

3.2.2-1	Characteristics of water source points	3-2
3.2.3-1	Inventory of Impluvium	3-3
3.6.4-1	Summary of the comparison between measured data	3-15
3.7.2-1	Sampling points in summary	3-18
3.7.2-2	Items Analyzed	3-18
3.7.3-1	Correlation coefficient between the major components	3-21
3.7.4-1	Comparison of average and maximum sample water quality and the national and WHO standards	3-26
3.8.1-1	Original Program of the Test Drilling	3-27
3.8.2-1	Summary of execution	3-30
3.9.1-1	List of Surveyed Points	3-33
3.9.2-1	List of Monitoring Points	3-36

Figure

3.2.2-1	Water Point Plot	3-2
3.3.1-1	Topographic Analysis	3-4
3.3.1-2	Lineament Analysis and DEM Data interpretation	3-5
3.3.1-3	River System of the Ambovombe Basin	3-6
3.3.1-4	The Damp and Depression in Ambovombe Basin	3-6
3.3.1-5	Bird's-Eye View	3-6
3.3.1-6	Vegetation and Land Use Map	3-6

3.3.1-7	Village Distribution in the Study Area	3-7
3.3.1-8	Test Drilling Location	3-7
3.3.1-9	Topographic Measurement Survey by Satellite Image	3-7
3.3.1-10	Topographic Map Overlapped by Satellite Image for Field Reconnaissance	3-7
3.3.1-11	Geological Map from Satellite Image	3-8
3.3.1-12	Geological Map Overlapped by Satellite Image for Field Reconnaissance	3-8
3.5.1-1	Location map of geophysical survey points	3-9
3.5.2-1	Location map of cross section	3-10
3.5.2-2	Cross Section I (a) – IV (d)	3-10,11
3.6.2-1	Location map of monitoring wells	3-13
3.6.2-2	Location map of monitoring wells (Ambovombe)	3-13
3.6.2-3	Location map of monitoring wells (Test well)	3-13
3.6.3-1	Groundwater level fluctuation (a) – (f)	3-14
3.6.4-1	Counter map of difference of groundwater level between April and October	3-15
3.6.5-1	Groundwater level fluctuation (a) –(e)	3-16
3.6.5-2	Result of groundwater level monitoring (a) –(e)	3-17
3.7.3-1	Spatial Distribution of EC in the area (Inventory survey)	3-19
3.7.3-2	Spatial Distribution of EC in the Ambovombe area (Inventory survey)	3-19
3.7.3-3	Seasonal variation of EC of the sampled waters	3-20
3.7.3-4	Correlation between major ions	3-21
3.7.3-5	Typical Hexadiagrams of the samples in the Target Area	3-22
3.7.3-6	Piper diagram of the samples analyzed for the dry season	3-23
3.7.3-7	(1) Hexadiagrams of wells in the Area	3-24
	(2) Hexaiagrams of wells in Ambovombe	3-25
3.8.1-1	Site location map	3-28
3.8.1-2	Site location map in Ambovombe urban	3-28
3.8.1-3	Typical drawings for the Test Well	3-28
3.8.2-1	Progress of the Test Drilling	3-29
3.8.3-1	Structure of basin and Static water level	3-31
3.8.3-2	Extension of perched aquifer	3-31
3.8.3-3	Location map of the distinguished groundwater	3-32
3.9.1-1	Location map of Surveyed Points	3-33
3.9.1-2	Results of vertical profiling (a) – (l)	3-34
3.9.1-3	Location map of surveyed wells at coastal area	3-35
3.9.1-4	Comparison of measured electric conductivity data	3-35
3.9.2-1	Results of monitoring (a) – (c)	3-36
3.9.2-2	Enlarged monitoring data (a) – (c)	3-37

Chapter 4

Table

4.2.1-1	Important sources for subsistance	4-1
4.3.2-1	Daily water consumption per household	4-5
4.3.3-1	Payment and budget for monthly water charge	4-5
4.3.4-1	Classification of water sources by distance and unit price	4-8

Figure

4.2.1-1	Annual household income	4-1
4.3.1-1	Source of drinking water	4-3
4.3.2-1	Distribution of water facilities per commune	4-4
4.3.3-1	Relation between water charge and budget for water per month	4-6
4.3.4-1	Unit price of water sources used in the study area	4-6
4.3.4-2	Distance water sources in the study area	4-7
4.3.4-3	Water quality in the study area	4-7
4.3.4-4	Classification water sources by commune	4-8
4.3.5-1	Person in charge of drawing water	4-9
4.3.5-2	Means of transportation of water	4-10

Chapter 5

Table

5.1.1-1	Financial Aspect of AES from 1999-2005 (in Ariary)	5-2
5.1.1-2	Financial Status of AES Year 2004-2005	5-3
5.1.1-3	Production unit cost of Ambovombe and existing Pipeline System in 2005	5-3
5.1.2-1	Financial Condition of JIRAMA in Amboasary (2004) (in Ariary)	5-4
5.1.2-2	Outline of JIRAMA in Amboasary in 2005	5-4
5.1.2-3	Financial Condition of JIRAMA in Ambovombe (in Ariary)	5-5
5.2-1	Actual Water Supply Systems in the Study Area	5-6
5.2-2	Different O/M systems for Impluvium by commune	5-7

Figure

5.1.1 -1	AES Organization Chart (2005)	5-2
5.1.2-1	Organization chart of JIRAMA in Amboasary (2005)	5-4
5.2-1	Organization chart of the AAEPA	5-8

Chapter 6

Table

6.1-1	Five sites of the Pilot-Project	6-1
6.1-2	Details of activities and contracts between JICA Study Team and the NGO	6-2
6.3.1-1	Name, location, and commune of the pilot project sites	6-4
6.3.2-1	Main income source of the pilot project sites	6-5
6.3.3-1	Condition of current water use	6-6
6.5.2-1	Charge system of the 5 Pilot-Projects sites	6-9
6.5.2-2	Hypothetical criteria of the contributory charge	6-10
6.5.2-3	Hypothetical criteria of the contributory charge (using rope pump)	6-10
6.5.2-4	Hypothetical criteria of the contributory charge (using Vergnet pump)	6-10
6.5.2-5	Hypothetical criteria of the contributory charge (using solar pumping system)	6-11
6.5.2-6	Hypothetical criteria of the volume charge	6-11
6.5.2-7	Hypothetical criteria of the volume charge (using rope pump)	6-11
6.5.2-8	Hypothetical criteria of the volume charge (using Vergnet pump)	6-12
6.5.2-9	Hypothetical criteria of the volume charge (using solar pumping system)	6-12
6.7.1-1	Water charge hypothetically acceptable for the community population	6-14

Figure

6.1-1	Location of the five sites (5) of the Pilot-Project	6-1
6.2-1	Solar Pumping System facility layout	6-3
6.2-2	Solar Pumping System Flow Diagram	6-3
6.2-3	Rope pump	6-3
6.2-4	Vergnet pump	6-3
6.5.1-1	Typical chart of a CPE, the assistants and its detailed functions	6-7
6.5.1-2	Procedure of creation of the CPE	6-8
6.5.2-1	Concept chart of the basic management	6-9
6.7.1-1	Distribution of the water charge range reasonable by assumption at the level of the beneficiaries	6-13
6.7.1-2	Basic cooperative system between the three major actors	6-14

Chapter 7

Table

7.2-1	Calculated Precipitation	7-5
7.2-2	Calculated Hydraulic Gradient	7-6
7.2-3	Estimation of pumpage in Antanimora area	7-7
7.2-4	Estimation of Pumpage in Ambovombe area	7-7
7.3.3-1	Hydraulic Conductivity Value	7-14
7.3.4-1	Proposed groundwater development plan	7-15

Figure

7.1.2-1	Classified area by groundwater potential	7-3
7.2-1	Hydrologic Cycle of Ambovombe Basin	7-4
7.2-2	Elements for Hydrologic Cycle	7-5
7.2-3	Elements for Groundwater Outflow Calculation (1)	7-6
7.2-4	Elements for Groundwater Outflow Calculation (2)	7-6
7.3.2-1	Area for Groundwater Modeling	7-9
7.3.2-2	Contour map of ground surface elevation	7-10
7.3.2-3	Contour map of basement elevation	7-11
7.3.2-4	Finite different grid used for simulation	7-11
7.3.2-5	Hydrogeological boundaries	7-12
7.3.3-1	Distribution of electric conductivity of existing wells (November, 2005)	7-13
7.3.3-2	Initial concentration boundary	7-13
7.3.3-3	Results of calibration	7-14
7.3.4-1	Location of virtual observation well	7-16
7.3.4-2	Results of simulation	7-17
7.3.5-1	Vertical profile of electric conductivity at the well F015	7-17
7.3.5-2	Initial concentration boundary	7-18
7.3.5-3	Virtual observation points at the observation well	7-19
7.3.5-4	Results of the simulation (a-layer 4) (b-Cross-section)	7-19
7.3.5-5	Time-series change of salt concentration at observation points	7-20
7.3.5-6	Results of observation of salt concentration and electric conductivity at obs. point A	7-21
7.3.5-7	Initial concentration boundary in Case Study I	7-21
7.3.5-8	Results of observation of electric conductivity at point A of observation well	7-21
7.3.5-9	Results of observation of electric conductivity at point A of observation well	7-22
7.4-1	Location map of groundwater level monitoring well	7-23
7.4-2	Location map of groundwater quality monitoring well	7-24
7.4-3	Organization chart for monitoring	7-24

Chapter 8

Table

8.1.2-1	List of Target Communes and Population, Number of Fokontany	8-2
8.1.2-2	Population in the Study Area and the Water Demand	8-3
8.2.1-1	Comparison of Basic Items in Water Supply Alternative Plan (D1 – D6)	8-5
8.2.1-2	List of Water supply systems in the study area(1/3):Facility specification	8-9,10
	List of Water supply systems in the study area(2/3): Cost	8-11,12
	List of Water supply systems in the study area(3/3): Evaluation	8-13,14
8.2.1-3	Water Supply Alternative Plan	8-15 - 8-39
8.2.3-1	Alternative plans of the water supply in the area (Long list)	8-41
8.2.4-1	Alternative plans screened for consideration of priority (Facilities, Short List)	8-45
8.2.4-2	Alternative plans screened for consideration of priority (Soft, Short List)	8-45

	8.2.5-1	Priority order scoring criteria for the facilities	8-45
	8.2.5-2	Priority order scoring criteria for the soft program	8-45
	8.2.5-3	Scoring Results (Facility)	8-46
	8.2.5-4	Scoring Results (Soft Program)	8-47
	8.3.1-1	Reference: outline of waterworks corporate accounting	8-50
	8.3.1-2	Evaluation of Basic Index of Alternative Water Supply Plans (Plan D1 to D6 and Plan S2, S4)	8-51
	8.4 -1	Cost Estimate of Plan D1, Plan D4 and Plan S2	8-57
	8.5-1	The Population Water Served and Water Supply Amount	8-58
	8.6.1-1	Water Production Unit Cost of AES in 2005	8-60
	8.6.2-1	New of Water Charge in by Alternative Supply Plan	8-61
Figure			
	8.1.1-1	Water Supply Area	8-1
	8.1.3-1	Zoning of Water Supply Area	8-3
	8.2.1-1	Water facilities deployment layout in water supply alternative plan (D1 to D6)	8-5
	8.2.2-1	Flow chart of the alternative selection	8-40
	8.2.3-1	Categorization of the alternatives	8-41
	8.2.4-1	Evaluation of the long list (Facility)	8-44
	8.2.4-2	Evaluation of the long list (Soft)	8-44
	8.3.1-1	Hydraulic Chart of Ambvombe District Transmission Pipeline	8-54
	8.3.1-2	Antanimora Suburbs[F006B]/Ambovombe City+Seshore dune Area Water Supply Plan	8-55
	8.3.1-3	Antanimora Suburbs[F006B]/Ambovombe City+Seshore dune Area Water Supply Plan System Flow	8-56
	8.5-1	Water Supply Master Plan (2007－2015)	8-57

Chapter 9

Table			
	9.1.2-1	Types and scales of projects for EIA and EEP concerned with this study	9-1
	9.2.4-1	Summary of water supply plan alternatives	9-2
Figure			
	9.3.1-1	Distribution of dense semi-arid spiny forest in the Target area	9-4

Chapter 10

Table			
	10.1.3-1	Financial Aspect of AES from 1999-2005 (in Ariary)	10-2
	10.1.3-2	AES Water Production and Unit Cost in 2005	10-2
	10.1.4-1	Plan of Staff arrangement and the roles for the new facilities	10-3

Chapter 12

Table			
	12.1-1	Contents of the Technology Transfer	12-1

Chapter 13

Table			
	13.1-1	Existing Solar Pumping System Maintained by AES, Ambovombe	13-4

Abbreviation

（Organization）

Les articles /Items	French	English
AEP	Alimentation en eau potable	Drinking Water Supply
AEPA	Alimentation en eau potable et assainissement	Drinking Water Supply and Sanitation
AEPG	Adduction d'eau potable gravitaire	Drinking Water Supply by gravitation
AES	Alimentation en Eau dans le Sud	Water Supply in the South
AFD	Agence française de développement	French Agency of Development
ANDEA	Autorité nationale de l'eau et l'assainissement	National Authority of Water and Sanitation
Ar	Ariary	Ariary
BAD, ADB BM	Banque africaine de développement Banque mondiale	African Development Bank World Bank
CGDIS :	Commissariat Général au Développement Intégré du Sud	General Committee for the Integrated Development of the south
CNEA	Comité national de l'eau et l'assainissement	National Committee of Water and Sanitation
CREA	Comité régional de l'eau et l'assainissement	Regional Committee of Water and Sanitation
CPE	Comité de point d'eau	Water Point Committee
CSB	Centre de santé de base	Basic Health Centre
DEPA	Direction de l'eau potable et de l'assainissement	Department of drinking water and sanitation
EPIC	Etablissement public industriel et commercial	Industrial and commercial public establishment
FMG	Franc malgache	Malagasy franc
FONDEM	Franc ONG	France NGO
FTM	Foibe Taosaritanin'i Madagasikara (Institut géographique et hydrographique national)	Geographical and hydrographic national institute
IEC	Information – éducation – communication	Information Education Communication
INSTA/DSN	Institut national de la statistique	National institute of the statistics
IPPTE	Initiative pays pauvre très endetté	Initiative of poor and heavily in debt country
JBIC	Banque Japonaise de coopération internationale (Coopération Japonaise - Prêts)	Japan Bank for International Cooperation (Cooperation Japanese - Prêts)
JICA	Agence Japonaise de Coopération Internationale	Japanese International Cooperation Agency
JIRAMA	Jiro sy Rano Malagasy (Société nationale d'eau et d'électricité)	National company of water and electricity
MECIE	Mise en compatibilité des investissements avec l'environnement	Compatibility setting of investments with environment
MEM	Ministère de l'énergie et des mines	Ministry of energy and mines
O/M	Opération et entretien	Operation and Maintenance
OMS, WHO	Organisation Mondiale pour la Santé	World Health Organization
ONG, NGO	Organisation Non Gouvernemental	Non Governmental Organization
ONE	Office National de l'Environnement	National Office of Environment
ORSEA	Organe de régulation de l'eau et assainissement	Body for the regulation of water and sanitation
PAEPAR	Projet pilote d'alimentation en eau potable et assainissement en milieu rural	Pilot Project on drinking water supply and sanitation in rural area
PPTE	Pays Pauvre Très Endettè	Poor and heavily in debt country
DSRP	Documents Stratégique pour la Réduction de la Pauvreté	Strategic Documents for the reduction of poverty
SSE	Secteur du Service de les Eaux et la stratégie	Water supply sector and the strategy
UE, EU	Union Européenne	European Union
WASH	Eau, Assainissement et hygiène	WAter, Sanitation and Hygiene

（Other than organization）

Les articles /Items	France	English
EC	Conductivité Electrique	Electric conductivity
TD	Profondeur Totale	Total depth
NS, SWL	Niveau statique de l'eau	Statique Water level
SC	La capacité spécifique	Specific Capacity
DEM	Le Desital élèvation Modèle	Digital Elevation Model
SEV, VES	Sondage Electrique Verticale	Vertical Electric Sounding
IP	Induced Polarisation	Induced Polarization
TEM	La Méthode Electomagnetic transitoire	Transient Electomagnetic Method
HDPE	Polyéthylène haute densité	High Density Polyethylene
EIA	Évaluation de l'impact Environnemental	Environmental Impact Assesment

List of villages encountered in this Study following alphabetical order

Ambaliandro
Ambanisarika
Ambaro
Ambazoamirafy
Amboasary atsimo
Ambohimalaza
Ambohitsy
Ambolobe
Ambonaivo
Ambondro
Ambonivoha
Amboro
Ambovombe Androy
Ampamahetika
Ampamata
Ampamatabe
Ampamolora
Anafomihala
Anafondrakady
Analahova
Analaisoke
Analamanohy
Andaboly
Andramaray
Anjamaro
Anjatoka
Anjira
Ankaramena
Ankiliabo nord
Ankilifaly
Ankilimafaitry
Ankilimanara
Ankilimiharatse
Ankilirandro
Ankilitelo
Ankoba mikajy
Antanandava
Antanimihere
Antanimora
Antaritarika
Antetibe
Antseky
Avaradrova
Behabobo
Bekokako
Belindo
Bemamba
Bemamba Antsatra
Bemandrabo
Benonoka
Beraketa
Beroroha
Betioky
Bevoly
Ebelo
Ejeda
Ekonka
Erada
Erakoky
Esalo
Esanta
Esanta centre
Esanta Marofoty
Esanta Maromainty
Esingo
Etoly
Fekony
Fierenantsoa Ampozy
Ianakafy
Ifotaka
Imanombo
Kilirandro
Laparoy
Lavaandrandra
Lefonjavy
Mahavelo
Mahavelo Mitsangana
Mananbovo
Manave
Mandrare
Manja (manjasoaloka)
Maroafotse
Maroalimainty
Maroalipoty
Marobe
Maromalay
Mitsangana
Mokofo
Morafeno
Sakave
Sampona
Sarimonto
Sevohipoty
Sihanamaro
Sihanamitohy marolava
Silimosa
Talaky
Talaky marofoty
Tanambao
Tanandava
Taranaka
Tondroke
Tsianoriha
Tsihombe
Tsimananada
Tsimavo
Tsimihevo
Tsingivilahy
Tsirangoty

CHAPTER 1 INTRODUCTION

1.1 The Outline of the Study

1.1.1 General

This Final Report was compiled the results from 2005 to 2006 for the Study on The Sustainable, Autonomic Drinking Water Supply Program in the South Region of Madagascar (hereinafter referred to as "the Study"), in accordance with the Scope of Work agreed upon by the Ministry of Energy and Mining (hereinafter referred to as "the MEM") and the Japan International Cooperation Agency (hereinafter referred to as "JICA") in Antananarivo on 18th August, 2004.

JICA organized a Study Team (hereinafter referred to as "the JICA Study Team") consisting of twelve experts in various fields related to the Study started in the middle of January 2005 in Japan and will be completed in December 2006 with submission of the Final Report. The Study was divided into two Phases as follows.

Phase I: Baseline and Water Resources Study
Phase II: Analysis and Evaluation of Alternatives of Water Supply Facilities and Formulation of Water Use Plan

During the course of the Study, the JICA Study Team carries out the Work in close co-operation with the counterpart personnel from the Ministry of Energy and Mining (MEM) and related the Southern Water Supply Cooperation (AES) and other concerned agencies, with emphasis on technology transfer.

1.1.2 Background of the Study

The Study area in South of Madagascar is characterized by the dryness and the problem of the lack of drinking water for the people due to the very arid climate and the non-existence situation of water resources such as rivers and wells. The share of population in Madagascar accessible for the safe drinking water represents only 11.8% in 2000 and 17% in 2005 in the rural area (PRSP, June 2005 and MEM, July 2006). In particular, the southern coastal zone of the Ambovombe, people are forced to buy high-priced drinking water from local water venders due to no source of water in the villages, affected by a little annual precipitation ranging from 400mm to 500mm especially in rainy season and malfunction of public water supply by water tank trucks. According to the annual report AES in 2006, public supply water was only 0.4 lit/cap/day for the target population of 278,000 in the area due to lack of water tank trucks and increased fuel and operation costs. Moreover, available water by any means is of low quality and does not satisfy hygiene standard. Therefore, the government of Madagascar puts the highest priority to secure safe water for the Study area.

JICA organized a Study Team to conduct the sustainable, autonomic drinking water supply program in the south region. The Study confirms the groundwater potential in the target villages and suitable water supply facilities namely hand pumps and solar pumping system together with operation and maintenance system involving by villagers is recommended through the technical assistance of Test Drilling and Pilot Project together with community participation and monitoring of the Pilot Project.

1.1.3 Objectives of the Study

The objectives of the Study are:

(1) To evaluate the potential of water resources, focusing on groundwater applicable for drinking use in the Study Area.
(2) To formulate groundwater resources development and management program for the Study Area.
(3) To transfer technology to counterpart personnel in the course of the Study.

1.1.4 Target and Study Area

(1) Target Area

The Target Area for water supply will be along National Road No. 10 between Ambovombe and Tsihombe and the coastal zone to the south.

(2) Study Area

The Study Area is in the Tulear Province in the South Region of Madagascar and will cover as follows:
1) Ambovombe Basin
2)The area along National Road No.10 between Ambovombe and Tsihombe and the coastal zone to the south.

Figure 1.1.4-1 The Study Area

1.1.5 Scope of the Study

This Study will be conducted based upon the Scope of Work (S/W) for the Study which was agreed upon between the Ministry of Energy and Mining (MEM) and the JICA Preparatory Team on August 18, 2004. The details of the Study are stated in the following section.

1.1.6 Basic Study Policy

As agreed in the Minutes of Discussion on the Inception Report dated February 3, 2005 in Antananarivo, the JICA Study Team executed the Study, and published the Progress Report 1, June 2005, Progress Report 2, November 2005, Interim Report, June 2006 and Draft Final Report, October 2006 in accordance with the following basic policies:

(1) Existing data and information was organized systematically and used effectively to fully comprehend the local conditions related to the living environment, water supply, sanitation, hydrogeology and other relevant subjects as well as accurate field survey results were acquired for available water resources potentials and to formulate an optimum development plan for groundwater sources for water supply facilities. In addition, similar studies carried out through other donor organizations as well as previous projects implemented through JICA and the government of Japan related to the Study was reviewed and reflected in the present Study.

(2) The Study was effectively carried out for mutual understanding of current water supply conditions, local requirements, and technology transfer in order to:

a) Establish optimum solutions to the prevailing problems for the water resources development program;

b)Formulate a water supply improvement plan which is the most suitable in terms of groundwater resources development and water supply facilities; and

c) Prepare an optimum operation and maintenance plan for water supply facilities considering actual results of Test Drilling and Pilot Project.

(3) The Study was executed in cooperation with the counterpart personnel from the MEM, the AES and relevant agencies in order to complete the Study according to the schedule with emphasis on technology transfer in pursuit of capacity building for water resources survey, design and construction of water supply facilities, and its proper management through the Test Drilling and Pilot Projects.

(4) Through this Study, the pilot projects were implemented at the selected five (5) sites based on the results of test drilling, socio-economic survey, reviews and plans for existing water supply facilities, operation and maintenance, and willingness of people to pay for the water. Through workshop and seminar, the results of the Study were opened and views exchanged with the participants such as government personnel, water supply/sanitation sector related personnel, concerned donor and international agencies representatives, NGO's and other relevant persons.

1.2 Implementation of the Study

1.2.1 Study Schedule

The Study was carried out from January 2005 to December 2006, for a period of twenty two (22) months in Madagascar and Japan. This Study was divided into two (2) phases as described below and shown in the attached operation plan flow chart.

Table 1.2.1-1 Implementation of the Study

Phase I: **(January 2005 to March 2006)** Baseline and Water Resources Study	
1. Preparatory Work in Japan: 1) Preparation of Inception Report (IC/R): 2) Existing data analysis & interpretation of Satellite image	 Late January 2005
2 Work in Madagascar (1): 1) Explanation and discussion of the IC/R 2) Baseline and water resources survey 3) Preparation of Progress Report (1) (P/R-1) 3) Explanation and discussion of the P/R-1	 February 2005 Feb. to June 2005 June 2005 Middle of June 2005
3.Work in Madagascar (2)-1: 1) Implementation of test drilling 2) Design of pilot project 3) Preparation and discussion of Progress Report (2) (P/R-2)	 July 2005 to March2006 Oct. to Nov. 2005 November 2005
Phase II: **(December 2005 to December 2006)** Analysis and Evaluation of Alternatives of Water Supply Facilities and Formulation of Water Use Plan	
4. Work in Madagascar (2)-2: 1) Implementation of pilot project 2) Preparation of Interim Report (IT/R):	 Dec. 2005 to March 2006 March 2006
5. Work in Madagascar (3): 1) Explanation and discussion of the IT/R 2) Monitoring of pilot project	 May 2006 June to September 2006
6.Work in Japan (1): 1) Preparation of Draft Final Report (DF/R)	 July to September 2006
7.Work in Madagascar (4): 1) Explanation and Discussion on the DF/R 2) Implementation of the Seminar for technology transfer:	 October 2006 October 2006
8.Work in Japan (2): 1) Preparation and Completion of Final Report (F/R)	 December 2006

Table 1.2.1-2 Assignment Schedule

	Function	Name	Affiliation	1st Year						2nd Year									3rd Year								
				JFY2004			JFY2005												JFY2006								
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Work in Madagascar	Team Leader/Water Supply Planner	Shigeyoshi KAGAWA	Japan Techno		30 (1.0)		60 (2.0)			30 (1.0)			45 (1.5)				45 (1.5)				45 (1.5)				16 (0.5)		
	Sub Team Leader/Hydrogeology A /Groundwater Development Planner	Toshimichi NAGANUMA	Japan Techno		75 (2.5)							56 (2.8)					36(1.2)				45 (1.5)				16 (0.5)		
	Hydrogeology B /Groundwater Simulation	Takuya YOSHIZAWA	Nippon Koei				60 (2.0)						45 (1.5)				30(1.0)				30 (1.0)						
	Social & Economic Survey	Yoko KITAUCHI	Nippon Koei		30 (1.0)		45 (1.5)										30(1.0)							15 (0.5)			
	Geophysical Prospecting	Toshimasa KOBAYASHI	Nippon Koei			90 (3.0)																					
	Test Drilling Survey	Eric PAULVE	Japan Techno							20 (0.66)			30 (1.0)		70 (2.33)												
	Water Quality Survey ／Environmental Analysis	Keiji NIIJIMA	Japan Techno				60 (2.0)					30 (1.0)		30 (1.0)							15 (0.5)				16 (0.5)		
	Facilities Design/Cost Estimation	Yasuo ONOZUKA	Japan Techno										45(1.5)			45(1.5)											
	Operation and Maintenance (Community Participation)	Koji MORIO	Nippon Koei			45 (1.5)								45 (1.5)				15 (0.5)			30 (1.0)			15 (0.5)	16 (0.5)		
	Operation and Maintenance (Water Works Administration)	Shunichi HATANO	Japan Techno						15 (0.5)												30 (1.0)						
	Coordinator	Coordinator	Japan Techno								15 (0.5)							15 (0.5)							16 (0.5)		
Work in Japan	Team Leader/Water Supply Planner	Shigeyoshi KAGAWA	Japan Techno	10 (0.33)																	10 (0.33)	10 (0.33)	10 (0.33)				15 (0.5)
	Sub Team Leader/Hydrogeology A	Toshimichi NAGANUMA	Japan Techno	10 (0.33)																	10 (0.33)	10 (0.33)	10 (0.33)				15 (0.5)
	Hydrogeology B	Takuya YOSHIZAWA	Nippon Koei																		10 (0.33)	90 (3.0)					15 (0.5)
	Social & Economic Survey	Yoko KITAUCHI	Nippon Koei	10 (0.33)																	10 (0.33)	10 (0.33)	10 (0.33)				15 (0.5)
	Water Quality Survey ／Environmental Analysis	Keiji NIIJIMA	Japan Techno																		10 (0.33)	10 (0.33)	10 (0.33)				
	Facilities Design/Cost Estimation	Yasuo ONOZUKA	Japan Techno																		10 (0.33)	10 (0.33)	10 (0.33)				
	Operation and Maintenance (Community Participation)	Koji MORIO	Nippon Koei																		10 (0.33)	10 (0.33)	10 (0.33)				
				Phase I															Phase II								
Report		Submittal Time			△ Ic/R				△ P/R(1)					△ P/R(2)				△ It/R							▲ DF/R		▲ F/R
Stage of Work				Preparation																	Work in Japan (1)					Work in Japan(2)	
					Work in Madagascar (1)					Work in Madagascar (2)											Work in Madagascar(3)				Work in Madagascar (4)		

Legend： ■ Work in Madagascar □ Work in Japan

Table 1.2.1-3 Operational Chart

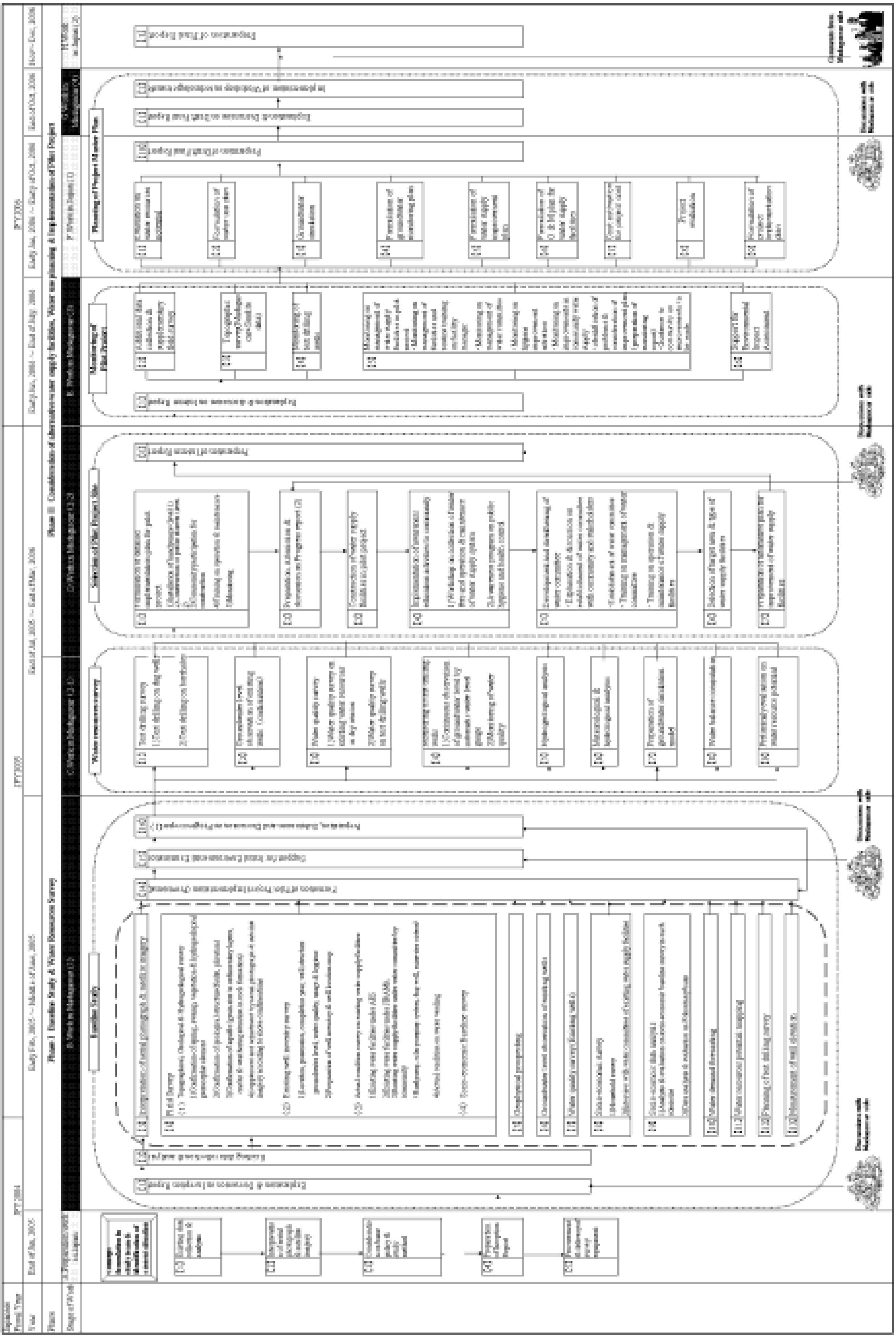


Table 1.2.1-4 The Study Schedule

			Number of Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
			Japanese Fiscal Year	JFY 2004			JFY 2005												JFY 2006								
			Year	2005												2006											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PHASE I BASELINE & WATER RESOURCES SURVEY	(1) Preparation in Japan	1)	Existing Data Analysis	□																							
		2)	Consideration of Basic Policy and Method for the Study	□																							
		3)	**Preparation of Inception Report (IC/R)**	□																							
		4)	Procurement of Survey Equipment & Preparation of Delivery	□																							
	(2) Work in Madagascar(1)	1)	Explanation and Discussion on IC/R		■																						
		2)	Collection & Analysis of Latest Data/Information		■																						
		3)	Interpretation of Aerialphotograph/Satelite Image	□	■																						
		4)	Field Reconnaissance		■	■	■																				
			1)Topography, Geology & Hydrogeology		■	■	■																				
			2)Survey of Well Inventory		■	■	■																				
			3)Survey of Existing Water Supply Facilities		■	■	■																				
			4)Socio-Economic Survey		■	■	■	■																			
		5)	Geophysical Survey			■	■	■																			
			1)Basement Rock Area (IP and TEM Method)			■																					
			2)Sedimentary Area (Geoelectric & TEM Method)				■	■																			
		6)	Water Level Measurements of Existing Wells (1)			■	■																				
			1)Census			■			■			■			■			■									
			2)Seasonal (Rainy, Dry and Between the Seasons)			■	■	■	■	■	■	■	■	■	■	■	■	■	■								
		7)	Water Quality Test (Existing Water Resources)				■						■						■								
		8)	Socio-Economic Survey (Household & Water Committee)		■	■	■																				
		9)	Socio-Economic Data Analysis (Commune & Fokontany)				■	■																			
		10)	Water Demand Forecasting					■	■																		
		11)	Water Resources Potential Mapping					■	■																		
		12)	Planning of Test Drilling						■																		
		13)	Measurements of Altitude for Existing Wells				■	■																			
		14)	Planning of Pilot Project					■	■																		
		15)	Support for Initial Environmental Examination (IEE)				■	■	■																		
		16)	**Preparation & Discussion of Progress Report (1) (P/R-1)**						■																		
	(3) Work in Madagascar(2)	1)	Test Drilling							■	■	■	■	■	■	■	■	■									
			1)Hand Dug Wells（13 wells）								■	■	■	■	■	■	■	■									
			2)Boreholes （15 Boreholes）								■	■	■	■	■	■	■	■									
			3)Water Quality Profiling (15 Boreholes)								■	■	■	■	■	■	■										
		2)	Water Level Measurements of Existing Wells (2)								■	■	■	■	■	■	■	■									
		3)	Water Quality Test (Existing & Test Wells)								■	■	■	■	■	■	■	■									
		4)	Monitoring on Test Boreholes								■	■	■	■	■	■	■										
			1)Installation of Automatic Water Level Gauges at 6 Boreholes								■	■	■	■	■	■	■	■									
			2)Monitoring of Water Quality								■	■	■	■	■	■	■	■									
			A. Installation of Water Quality Monitoring Probe at 1 Borehole								■	■	■	■	■	■	■	■									
			B. Installation of Water Quality Monitoring Probe at 2 Dug Wells								■	■	■	■	■	■	■	■									
		5)	Hydrogeological Interpretation								■	■	■	■	■	■	■	■									
		6)	Meteorological & Hydrological Interpretation								■	■	■														
Phase II CONSIDERATION OF ALTERNATIVE WATER SUPPLY FACILITIES, WATER USE PLANNING &		7)	Preparation of Groundwater Simulation Model																		■	■	■				
		8)	Water Balance Study									■	■														
		9)	Water Resources Preliminary Evaluation									■	■														
		10)	Detail Design of Pilot Project										■	■													
		11)	**Preparation & Discussion of Progress Report (2) (P/R-2)**											■													
		12)	Implementation of Pilot Project												■	■	■	■									
		13)	Community Participation and Capacity Building												■	■	■	■									
		14)	Strengthening of Village Water Committee												■	■	■	■									
		15)	Selection of Target Sites and Type of Water Supply Facilities												■	■	■	■									
		16)	Pllanning of Alternative of Project for Improvement of Water Supply															■									
		17)	**Preparation of Interim Report (I/R)**															■									
	(4) Work in Madagascar(3)	1)	**Explanation & Discussion of Interim Report (I/R)**																		■						
		2)	Additional Data Collection & Supplementary Study																		■	■					
		3)	Topographic Survey and Measurements																		■	■					
		4)	Monitoring of Test Boreholes/wells (2)																		■	■					
		5)	Monitoring of Pilot Project for Operation & Maintenance																			■		■			
		6)	Support for Environmental Impact Assessment （EIA)																		■						
	(5) Work in Japan (1)	1)	Water Resources Potential Evaluation																			■	■	■			
		2)	Water Use Plan																				■	■			
		3)	Groundwater Simulation																			■	■	■			
		4)	Groundwater Monitoring Plan																				■				
		5)	Water Supply Improvement Plan																				■				
		6)	Operation & Maintenance Plan																					■			
		7)	Project Cost Estimation																				■	■			
		8)	Project Evaluation																					■			
		9)	Project Implementation Plan																					■			
		10)	**Preparation of Draft Final Report (DF/R)**																						■		
	(6) Work in Madagascar (4)	1)	**Explanation & Discussion of DF/R**																						■		
		2)	Implementation of Seminar for Technology Transfer																						■		
	(7) Work in Japan (2)	1)	**Completion of Final Report (F/R)**																							■	■
				2005												2006											
Submission of Reports				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
					▲				▲					▲				▲							▲		▲
					IC/R				P/R(1)					P/R(2)				IT/R							DF/R		F/R
JICA Advisory Committee Schedule					■															■						■	

1.2.2 Study Team Member and Counterparts

(1) Study Team

The JICA Study Team is composed of eleven (11) and one (1) coordinator. The work assignment of the Team members is as shown in the assignment schedule, Table 1.2.2-1.

Table 1.2.2-1 JICA Study Team

Name	Function	Affiliation
1. Shigeyoshi KAGAWA	Team Leader/Water Supply Planner	Japan Techno Co., Ltd.
2. Toshimichi NAGANUMA	Deputy Team Leader/ Hydrogeology (A)/ Groundwater Development Planner	Japan Techno Co., Ltd.
3. Takuya YOSHIZAWA	Hydrogeology (B)/ Groundwater Simulation	Nippon Koei Co., Ltd.
4. Youko KITAUCHI	Social & Economic Survey	Nippon Koei Co., Ltd.
5. Toshimasa KOBAYASHI	Geophysical Prospecting	Nippon Koei Co., Ltd.
6. Eric PAULVE	Test Drilling Survey	Japan Techno Co., Ltd.
7. Keiji NIIJIMA	Water Quality Survey/ Environmental Analysis	Japan Techno Co., Ltd.
8. Yasuo ONOZUKA	Facilities Design/ Cost Estimation	Japan Techno Co., Ltd.
9. Yasuji MORIO	Operation and Maintenance (Community Participation)	Nippon Koei Co., Ltd.
10.Shunnichi HATANO	Operation and Maintenance/ Water Works Administration	Japan Techno Co., Ltd.
11.Tadao ARAI	Interpreter (French)	Japan Techno Co., Ltd
12.Naoko SUEHIRO	Coordinator	Japan Techno Co., Ltd.
JICA Advisory Committee		
Dr. Masahiro MURAKAMI	Professor of Kochi University of Technology	

(2) Counterpart Team

The organization of a counterpart MEM/DEA study team represented by the Ministry of Energy and Mining including members from other relevant agencies is required to successfully implement the present Study with mutual cooperation. The Madagascar side was organized the MEM/DEA and AES counterpart team as proposed below in 2005 to participate in the Study and receive technical knowledge as the work progress.

Table 1.2.2-2 Counterpart Team

NAME	QUALIFICATION	DEPARTMENT
1. RANDRIAMANGA William Henri	Team Leader, Water Resources Department Head	DEA
2. MAHASOLO William	Economist	AES Coordinator
3. RAKOTOMAZAVA Hery Tiana	Hydrogeologist/ Responsible for Water Resources	DEA
4. RAKOTONIRINA Jean de Dieu	Geophysicist/Primary Infrastructures Department Head	DEA
5.RANDRIANANTOANDROHARI-SOA NARIVO Désiré	Water Quality Analyst/Responsible for Quality.	DEA
6. RANDRIAMANGA William Henri	Drilling Construction Engineer/ Water Resources Department Head	DEA
7. FAHAMBALA Jérémie	Water Supply Engineer	Technical Director
8. FILAOMENY	Person in charge IEC/Social Study WID/Community participation	AES
9. RAKOTOMAVO Marcel	Sanitation Education/ Public Hygiene / Head of the Department of Data Management and Environment Protection	DEA
10.RAKOTOMAZAVA Hery Tiana	Responsible for Water Resources/Computer Sciences Engineer	DEA
11.RANJASON Hanitrinirina	Assistant	DEA
12.VEROMANITRA Voahangy	Executive secretary	AES
13.RAKOTOMAVO Paul	Office worker	DEA
14.RAKOTOMALALA Edmond	Office worker	DEA
15.DIMBIARISOA Irène	Office worker	DEA

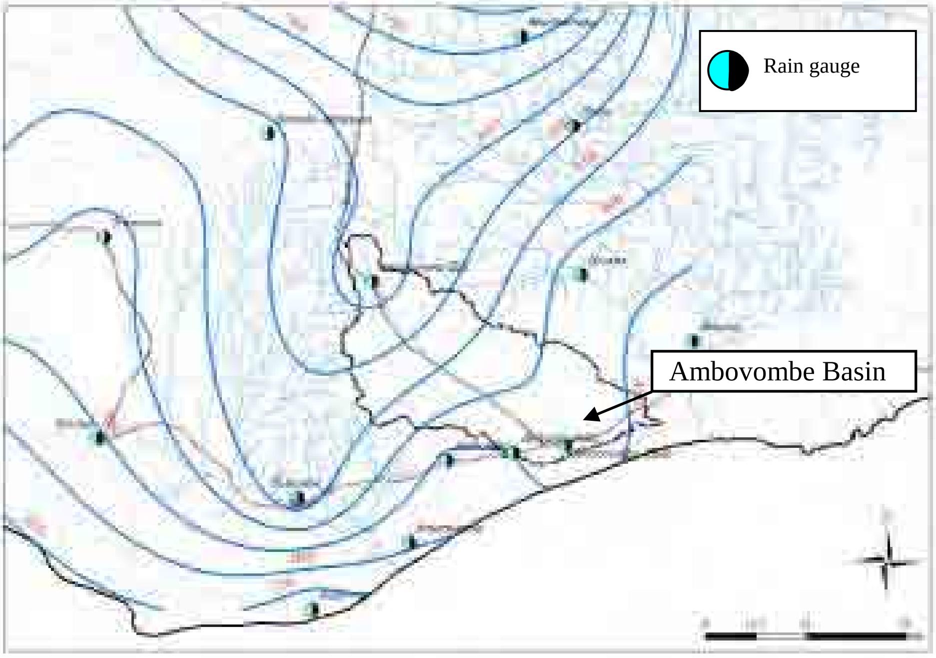
****

CHAPTER 2 GENERAL CONDITION OF THE STUDY AREA

2.1 Natural Environment

2.1.1 Climate

The Study Area, situated in the southern region of the Madagascar Island, is within the Savanna Climatic classification. Figure 2.1.1-1 shows isohyet map around the Study Area



Source : SAP

Figure 2.1.1-1 Isohyet Map around the Study Area (Average of 1999-2004)

2.1.2 Hydrology

Around the Study Area there are two large rivers. One is the Mandrare River flowing in the east, and the other is the Mananbovo River flowing in the west. Ambovombe Basin is located between these two rivers and there is no continuous river flowing throughout the year within the Ambovombe Basin, and river flows can only be observed during the wet season. Figure 2.1.1-1 shows the river system around the Study Area.

2.1.3 Topography

Ambovombe Basin is located between the Mandrare River and Mananbovo River. Figure 2.1.3-1 shows topographic map of the basin. Within the basin, thick sediment covers widely and topography is gently undulating. Elevation changes from 120 to 250m heigt.

Ssource: DEM data (SRTM)

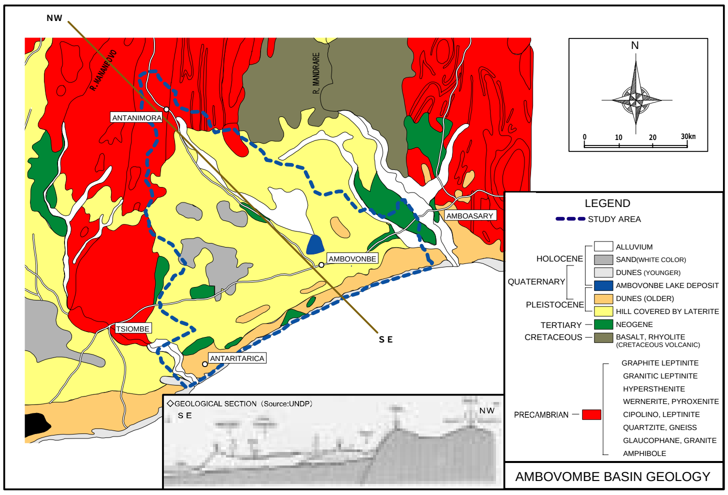
Figure 2.1.3-1 Topographic Map of the Ambovombe Basin

2.1.4 Geology and Hydrogeology

The Study area of Ambovombe Basin and
surrounding area is geologically divided into three (3) zones namely as follows.

1) Pre-Cambrian basement zone in the north
2) The center of Ambovombe basin
3) Coastal sands dune zone in the south

Figure 2.1.4-1 shows the geological conditions of the Study area and Table 2.1.4-1 shows the geological and hydrogeological classification analyzed from the data of 1950s to 2005.



Source: Report A1475 Appendix Minute November 1958, by A. Besairie

Figure 2.1.4-1 The geological conditions of the Study area

Table 2.1.4-1 Geological and Hydrogeological Classification in the Study Area

Geological Age		Lithology		Aquifer	Potential
Quaternary	Holocene	(white)	Alluvium	Unconfined aquifer	△
		(grey)	Sands (white color)	Unconfined aquifer	△
		(light grey)	Dunes (younger)	Unconfined aquifer	×
		(blue)	Ambovombe lake deposits	Unconfined aquifer	×
	Pleistocene	(orange)	Dunes (older)	Semi-confined aquifer	×
		(yellow)	Hill covered by Laterite	Semi-confined aquifer	×
Tertiary	Neogene	(green)	Sedimentary rocks (white grey, continental, calcareous silts and sandstone)	Semi-confined and/or Confined aquifer	△
Mesozoic	Cretaceous	(dark grey)	Volcanic (basalt, rhyolite)	Confined aquifer	△
Pre-Cambrian		(red)	Granites, leptinite (weaseled)	Confined aquifer	○

Note: Symbol of color shows geological classification as shown in Figure 2.1.4-1.
◎: Good potential of aquifer, ○: Moderate potential of aquifer, △: Fair potential of aquifer

2.2 Social and Economic Conditions in the Study Area

2.2.1 Administrative Organisation

This study covers the area of 15 communes of Ambovombé-Androy and Tsihombé districts of Androy Region in southern part of Tuléar province; mainly which lie between National Routes 10 and 13 and the coast, while three communes lie along the National Route 13 northward to the town of Antanimora.

Table 2.2.1- 1 shows the local administrative organisation of Madagascar in English, French and Malagasy languages. Table 2.2.1- 2 shows the studied communes.

Table 2.2.1- 1 Administration organisation of Madagascar

English	Autonomous Province	Region	District	Commune	Fokontany
Français	Province autonome	Région	District	Commune	Fokontany
Malagasy	*Faritany mizaka tena*	*Faritra*	*Fivondronana*	*Firaisana*	*Fokontany*

Source: JICA Study Team, 2005

Table 2.2.1- 2 Names of studied communes

District of Ambovombé-Androy	Ambanisarika, Ambazoa, Ambohimalaza, Ambonaivo, Ambondro, Ambovombé Androy, Analamary, Antanimora, Beanantara, Erada, Maroalomainty, Maloaropoty, Sihanamaro, Tsimananada (in alphabetical order)
District of Tsihombé	Antaritarika

The local administration system in Madagascar consists of commune, fokontany and villages. Commune governed by elected mayor is the centre of local autonomy in such fields as tax collection, family register or social development including water supply. Mayor mediates between fokontanys and district or other administrative organizations.

Fokontany, which does not impose tax to residents, functions as both the lowest administration unit and traditional property management unit. Fokontanys possess their proper properties such as impluvia or schools. Village, or *tanana*, settlement of people or *fokonolona* living in fokontany, is not an administrative unit.

2.2.2 Population

The total population of 15 studied communes is 277,980 according to the latest population survey carried out from February to April 2005 by the Region (source: Region of Androy, refer to Table 2.2.2- 1). As Figure 2.2.2- 1 shows, Fokontanys with high population are located on the dunes along the coastline while inland areas are scarcely populated.

Table 2.2.2- 1 Population and number of fokontanys in the study area (2005)

No.	Commune	Population 2005	Population 2003/2004	Population 2001/2002	Number of fokontany
1	Ambanisarika	11 112	10 079	6 580	12
2	Ambazoa	15 168	13 691	13 410	20
3	Ambohimalaza	13 395	8 615	7 549	15
4	Ambonaivo	9 001	9 863	9 657	15
5	Ambondro	18 556	15 642	14 573	23
6	Ambovombé-Androy	38 213	44 059	45 745	58
7	Analamary*	10 509	4 348	-	15
8	Antanimora	22 725	21 652	14 398	38
9	Antaritarika	14 037	-	10 115	24
10	Beanantra	12 404	9 612	9 525	26
11	Erada	10 799	10 605	9 969	17
12	Maroalomainty	32 645	32 500	32 429	32
13	Maroalopoty	36 394	16 890	18 949	50
14	Sihanamaro	20 120	14 640	12 178	28
15	Tsimananada*	12 902	6 828	-	17
	Total	277 980	-	205 077	390

Note: Analamary and Tsimananada became independent in 2003 from Ambanisarika and Ambohimalaza, and from Ambovombé respectively.
Source: Region of Androy (2003, 2005), SAP (2001-2002)

Though the population in precedent population surveys and censuses do not exactly show the population of present condition due to creation of new communes and change of several boundaries, population at the district level can be compared between 2002 and 2005 as follows; population of district of Ambovombé-Androy has increased by 16,388 persons or 6.1% and that of Tshihombé has increased by 19,568 persons or 27.5%.

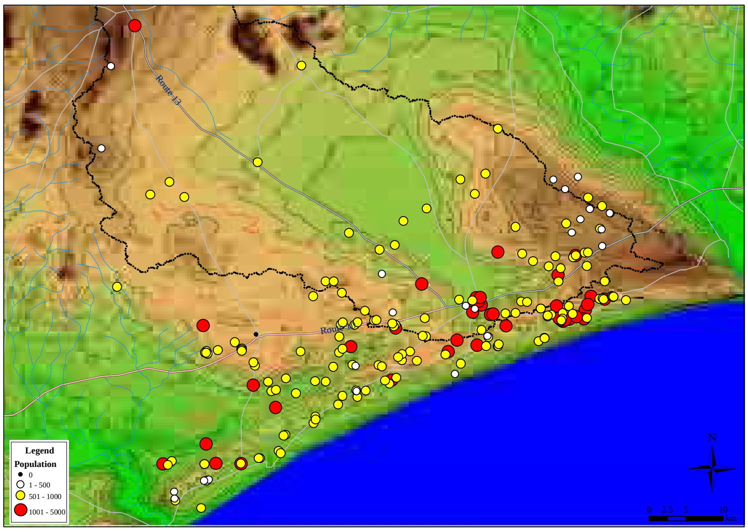


Figure 2.2.2- 1. Distribution of fokontanys and population size

2.2.3 Economic Condition

Except Ambovombé urban, commercial and small manufactures are not developed. Main livelihood source of residents in the study area is agriculture followed by fishing in coastal communes. Crops popularly cultivated here are maize, cassava, and sweet potato as staple food and niebe (a kind of beans). The first income source is manioc and the second is sweet potatoes for the surveyed households but many people choose crop of year's cultivation depending on the precipitation. Adding to them livestock (zebu, goat, and sheep) is raised very commonly in the study area. Average number of zebu raised by a household in the study area is 6.7 (source: Household survey). Livestock are not sold for subsistence but only for the time of emergency or ceremonies.

2.2.4 Social Infrastructure and Related Social Conditions

(1) Road condition and Transportation network

Ambovombé urban is an important transportation point for southern Province. National Route 10 connects Ambovombé and Andranobory and National Route 13 connects Fort Dauphin and Ihosy. Also, local transportation network concentrates in Ambovombé urban through which bush taxis connect it with many national and local centres such as: Antananarivo, Fort Dauphin, Tulear or Antanimora and commune centres of the district.

(2) Market places

Shops are very few even in fokontanys of commune centres if it is located in the remote area. People's economic activities are done in the weekly market which positions at the center of a commune (*chef lieu de commun*) where,people sell local products and buy the goods coming from other commune and other region. Market of Ambovombé urban is much bigger than others.

(3) Education institutions and state of school enrollment

Geographical distribution of primary school does not correspond to the number of children at the school age, though there are 156 primary schools in the study area; thus, the number of pupils in a school varies from 67.5 in Antanimora to 180.8 in Maloaromainty. Net school enrollment rate (the number of pupils actually going to school/ number of people at age of 6 to 10 years old × 100) is 62.9%.on average which also varies by commune: from 33% in Ambazoa to 97% in Ambovombé-Androy (Source: District pedagogic service). Comparing with 72% of the enrollment rate of entire Madagascar in 1998 – 1999 (source: INSTAT/DSN cited in PRSP Madagascar), only five communes of all fifteen is over this figure. Therefore, the level of fundamental education in the study area is lower than national average of 6-7 years ago.

(4) Health condition

CSB (basic health centre),set up generally in commune centres, except two communes, Analamary and Tsimananada, meets basic medical needs of local people.

According to the interview to CSBs, it is malaria that people suffer form most frequently in 2004. Diarrhea and aspiratory affections (general) come to the second and third rank, while the first cause of death at the Hospital of Ambovombé-Androy was 'grave and complicated malaria' (source: District Health Service=SSD). Figure 2.2.4- 1 shows the diseases frequently catching people in six communes where the records of treatment were available

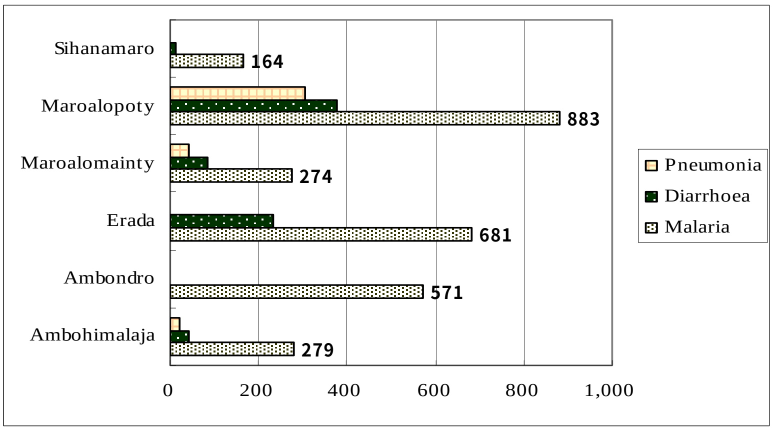


Figure 2.2.4- 1 Diseases frequently catching people (2004)

unit: number of patients

Source: JICA Study Team 2005, based on the records of CSB

According to the data of SSE, the percentage of children who die before reaching age of six is more than double of that of entire Madagascar in 2002. It means, as same as the primary education level, health condition, especially that of children, is much lower than that of the national standard level. Basic statistical data such as number of death at any age are not taken at commune or CSB level.

2.2.5 Traditions and Customs

(1) Land ownership

Generally in Madagascar, land is owned by the state but individual ownership is allowed legally if the land is registered. Even living in the remote rural area, people know this regulation. However, other types of ownership are known to them. Customary individual ownership is a mode that the village elder or clan chief (olom-be) decides land distribution to villagers for cultivation, customary collective ownership means that the village elder decides the usage of non cultivated land based on the tradition. Illegal individual use is that an individual uses land without registration. Community ownership means the land is owned by fokontany. In the study area, cultivated land and homestead in around 80% of surveyed villages are under customary individual ownership; on the other hand, cemetery and sacred forest in three-fourths of the surveyed villages are under customary collective ownership.

(2) Remarkable custom relating to water use and water source development of Antandroy

Antandroy is the dominant ethnic group living in the Region of Androy. Another ethnic group Antanosy lives in some villages surveyed, but this case is rather rare. In more than a quarter of households surveyed, principal religion is traditional belief followed by protestant, FLM (Malagasy Lutheran Church).

In the Antandroy society, village elder has the role and power to decide almost all village and fokontany matters and it seems difficult to get villager's collaboration without his approval.

Tradition of taboo strongly influences on resident's daily life.

There is a vast area recognized as taboo; such as cemeteries or sacred forest. If a person violates the taboo, he/she has to sacrifices an ox or oxen for purifying the place. It must be noted that establishing boreholes or wells near to cemeteries is included in forbidden affaires. From viewpoint of this taboo, pedal pumps may seem to have a difficulty to be spread because Antandroy people regard water coming from under foot unclean. In case of the PAEPAR (drinking water supply project financed by the World Bank), however, people draw and drink water of the borehole adopting pedal pump.

(3) Gender Issues in rural communities

According to the Civil Law of Madagascar, men and women have the same right and duty. However, people continue to follow the traditional customs at some degree in which women's right is weaker than that of men in all over Madagascar, and this tendency is somehow strong for Antandroy people. At the inheritance, the primary successor is son while wife and daughters (especially married daughters) have less possibility to succeed. In village meetings, women are generally seated at the back of the meeting place and have little chance to say their opinions. Women participate in the decision making almost only about domestic matters of household level. Recently, however, women in modern era begin to speak more often and more loudly than before in the villages where women's groups are established and animated by the support of NGOs or donors.

2.3 Water Supply Institution

The following organizations are relevant to the administration of water sector in Madagascar, especially in the Study area of Ambovombe and its surroundings. Department of Water and Sanitation (DEA) in the Ministry of Energy and Mines (MEM), is the counterpart agency of this Study. Among the Study area the actual water supply has been carried out by the Southern Water Supply Cooperation (AES) from 1982 to recent year of 2006. The AES endures the water supply services, management and maintenance of the various small town and rural water supply facilities. On the other hand, the water supply in the provincial towns in the country is undergone by the Jiro Sy Rano Malagasy (JIRAMA) under the supervision of the MEM.

2.3.1 Current Situation of Water Supply Sector

(1) Department of Water and Sanitation (DEA), MEM

DEA is in charge of all the water supply and sanitation services at national level to develop, manage and implement the water policies especially to effectively manage the water resources and safely supply water to the provincial town and rural population.

(2) AES

The AES is a publicly-owned establishment in Industrial and Commercial Matter (EPIC), attached directly to the MEM, is in charge of the water supply in the south part of Madagascar which is characterized by the dryness and the problem of the lack of drinking water because of the very arid climate and its non-existent water resources. The AES manages and maintain four (4) types of water supply services as follows:

1) Water supply services using groundwater called Drinking water supply by pipe distribution (AEP) are established at each supply point in the crystalline zone at 5 centers, namely Antanimora, Andalatanosy, Beraketa, Isoanala and Tsivory.
2) The pipeline water services stretching a total of 142.5 km is established in the areas of Tsihombe and Beloha
3) The water service trucks netwaork is established in the zones of Ambovombe and its surroundings, and part of the areas of Beloha and Tsihombe.

Solar pumping system for water supply services is utilized to reduce the operation cost of diesel is established at the above AEP namely Tsivory, Antanimora and Andalatanosy with the partnership of FONDEM of France and AES from 1999 to 2002. Also, other supporting service to the seven (7) village level CPEs are serviced to Ambondro Nanahera (44 m^3/day by 2 systems), Mahavelo Mitsangana (10 m^3/day in Ambovombe), Toby Mahavelo (8 m^3/day in Ambovombe), Ifotaka (18 m^3/day in Amboasary Sud), Ampomata (in Ambovomve), Lovasoa Ranopiso (12 m^3/day in Fort Dauphin), Andrebasy Ranopiso (12 m^3/day in Fort Dauphin), and Bemavorika Ranopiso (12 m^3/day in Fort Dauphin), and the service population is ranging from 320 to 3,600. These are well managed and maintained for more than 6 years without serious problems.

Figure 2.3.1-1 Water Service by AES in Ambovombe Urban

* Water Charge 100Ar/13 litter/bucket (left), and Solar Pumping System at Ifotoka, Amboasry Sud (right), managed by village level CPEs and maintained by AES, Water Charge 200Ar/month/family, Water Service at Public Taps by Self Services of 18 m3/day.

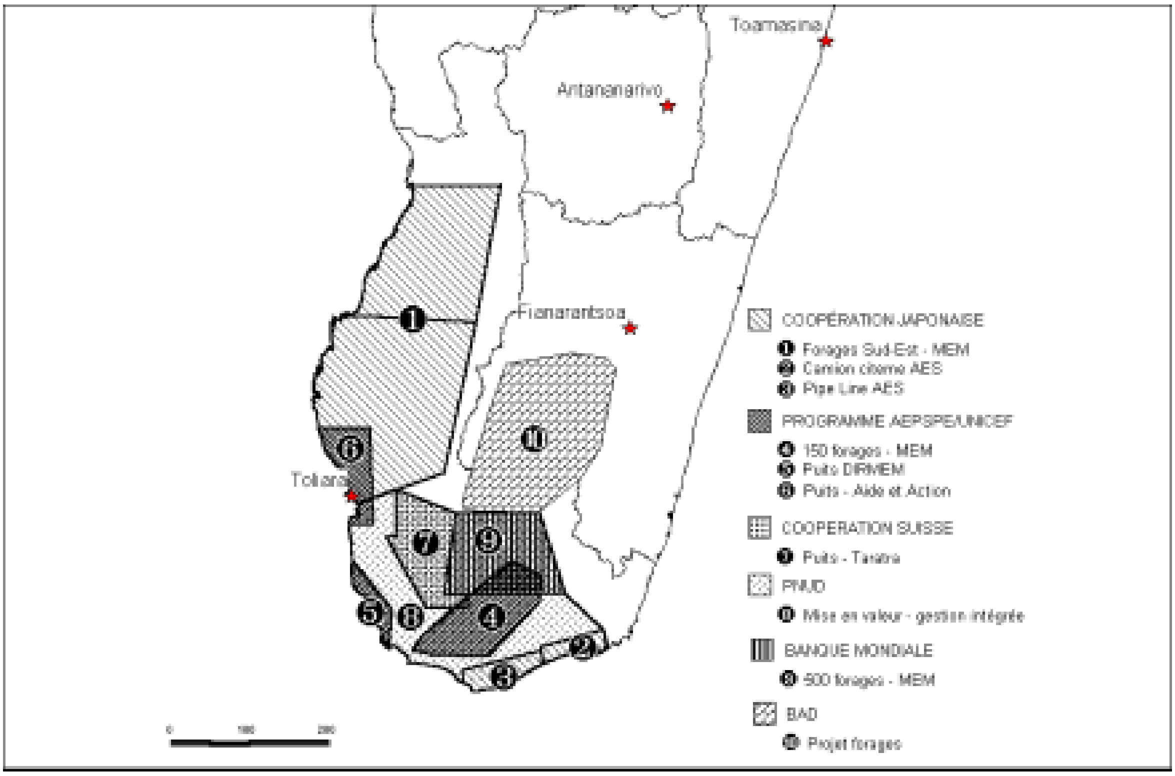
(3) JIRAMA

JIRAMA was a 100% government owned company till 2004 to distribute water and electricity at the national level specializing on provincial towns under the supervision of the MEM, while the management is privatized by JIRAMA in a joint venture with foreign capitals such as Germany in 2005. There are sixty-five (65) provincial town water supply systems managed by JIRAMA in October 2004. The annual water production rate was about 135 million m^3 in 2004. On the other hand, there are eleven (11) provincial town service systems, both water and electricity in the province of Toliara by JIRAMA, but none in the Study area. JIRAMA started only electric power supply in Ambovombe from 1999. Therefore, AES started to pump up groundwater from his own source in Ambovombe which capacity was 38 m^3/day in 2006. The Amboasary Sud and Tsihombe are managed by the JIRAMA's water supply systems situated neighboring to the Study area, and their water supply capacities are as follows:

a) Amboasary Sud: 96 m^3/day (borehole depth: 14.5m, EC: 104 mS/m, pH: 7.99)
b) Tsihombe: 54 m^3/day (borehole depth: 27m, EC: 250 mS/m)
c) Ambovombe: 38 m^3/day (dug well depth: 30m, managed by AES, 2006)

2.4 The Donors Concerned in the South Region of Madagascar

Fig. 2.4-1 shows the donors and international organizations which made activities especially for drinking water supply in the South Region of Madagascar. The PAEPAR project of World Bank working with MEM completed groundwater development and drinking water supply, and installed manual pumps of Vergnet in April 2005. The African Development Bank (BAD) under the supervision of MEM started the project for 700 boreholes construction in 2005. On the other hand, the government of Japan, JICA is the one of the important donors for drinking water supply in the Study area and surroundings in the South Region of Madagascar assisting of MEM and AES from 1980 to 2006.



Note: Data from MEM, 2004

Figure 2.4-1 Projects funded by international donors in the South Region

The UNDP, UNICEF, EDF, FAO, EU and other organizations and NGOs are assisting water supply projects in the South Region of Madagascar to solve the drinking water shortage problems. The UNICEF completed 150 boreholes with hand pumps of India Mark II in the areas of Antanimora, Ambovombe region and Tsihombe region in 1994 to 1995, and the hand pumps maintained by the Local Beneficiaries of O/M organization (AAEPA) in 2006.

2.5 Institution and Management of Water Supply in the South Region

Presently, water tank trucks managed by AES are the only drinking water supply service to the town of Ambovombe and its surrounding villages. EU has a plan of a great pipeline project connecting Amboasary to Antaritarika via Ambovombe city using gravity feed system. Smaller scale pipeline project by the MEM connecting Amobasary to Sampona is undergoing on the installation of pipe and pumping stations, financed through the IPPTE in 2004 to 2006. The actual problems of water supply are the shortage of water sources due to the limited groundwater potential and saline water quality.

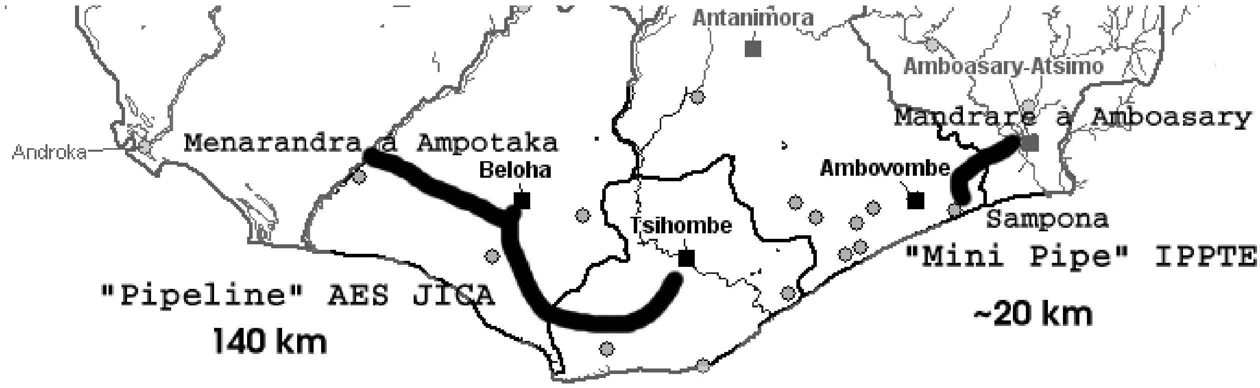


Figure 2.5 -1 The pipeline of AES constructed by JICA , 1995-1999 and the Sampona Project in progress (the IPPTE, 2004-2006) base map prepared by EU, 2005

According to the information from AES, the AES could not supply enough water to the population of about 278,000 in 2005 in the area of Ambovombe and its surroundings. The AES supplied 7,266m3/year of water in 2005 due to decrease of the water tank trucks and increase of the fuel costs from 694 Ar/lit in 2004 to 1,680 Ar/lit in 2005 and 2,130 Ar/lit in July 2006 at Ambovombe. In addition the flood of Mandrare River caused by the cyclone in April 2005 attacked the Amboasary water treatment plant managed by AES, and the situation is very serious and it needs emergency repair and protection of the intake point of the plant, which was constructed through the Japanese economic cooperation in 1990.

****

CHAPTER 3 SURVEY AND ANALYSIS FOR WATER RESOURCES

3.1 Existing Data

Various projects and studies were conducted in this region aiming at development of water resources. These left a lot of useful hydrogeological information. In particular, the following project information is important to understand the basin of Ambovombe.

- Works by Mr. BESAIRIE ‘30s- ‘50s
- Project by FED around ‘80s
- Works by M. RAKOTONDRAINIBE Jean Herivelo at ’70s-‘80s
- Project by UNICEF ‘90s
- PAEPER around ’90s-‘00s

3.2 Water Source Inventory of Existing Water Sources in the Study Area

3.2.1 Classification

Existing water sources in the study area is classified into below types in accordance with the origin of water and the types of facilities.

(1) Groundwater

- Vovo: hand dug well without concrete lining.
- Dug well: hand dug well with concrete lining.
- Borehole: constructed with boring machine. Casing diameter in the study area ranges from 4 to 8 inches.
- Spring: Artesian or water source that flow out naturally.

(2) Surface water

- Damp: It appears during rain season at depression.
- River water: Filtration or directly exploited to supply relatively large amount of water.

(3) Rainwater

- Rainwater: Rain is collected into a tank during rain season

3.2.2 Water Source Inventory

(1) General

From March to mid April 2005, the inventory survey regarding groundwater source were conducted. As a result, 231 water source points were surveyed.

(2) Results and Findings

The following are the summarized results of the inventory survey.

- The proper water source points utilized do not exist between Ambovombe and Manave.
- There are no water source points in the coastal dune area except shorelines.
- There are no water source points on the plateau area between Ambovombe and Amboasary
- Majority of water source points concentrated in Ambovombe at the area of sediments. The water source points are a dug well or a vovo.

- In the Ambondro area, water source points concentrated, but many of them were dried up long time ago or had high salinity.
- At the most of the dried dug wells, depth is less than 10m. On the other hand, the productive wells have 10m-25m depth.
- The significant difference between the JICA dug wells and others is the interval between the static water level and the bottom of the well. To supply stable volume of water, we must have minimum 3-5m interval for installing submersible pump.
- In basement rock areas such as Antanimora area, most of the water source points are boreholes, but not deep
- Salinity and Nitrate sometimes exceeds standard value of the WHO although boreholes are located far from source of pollution in the village.

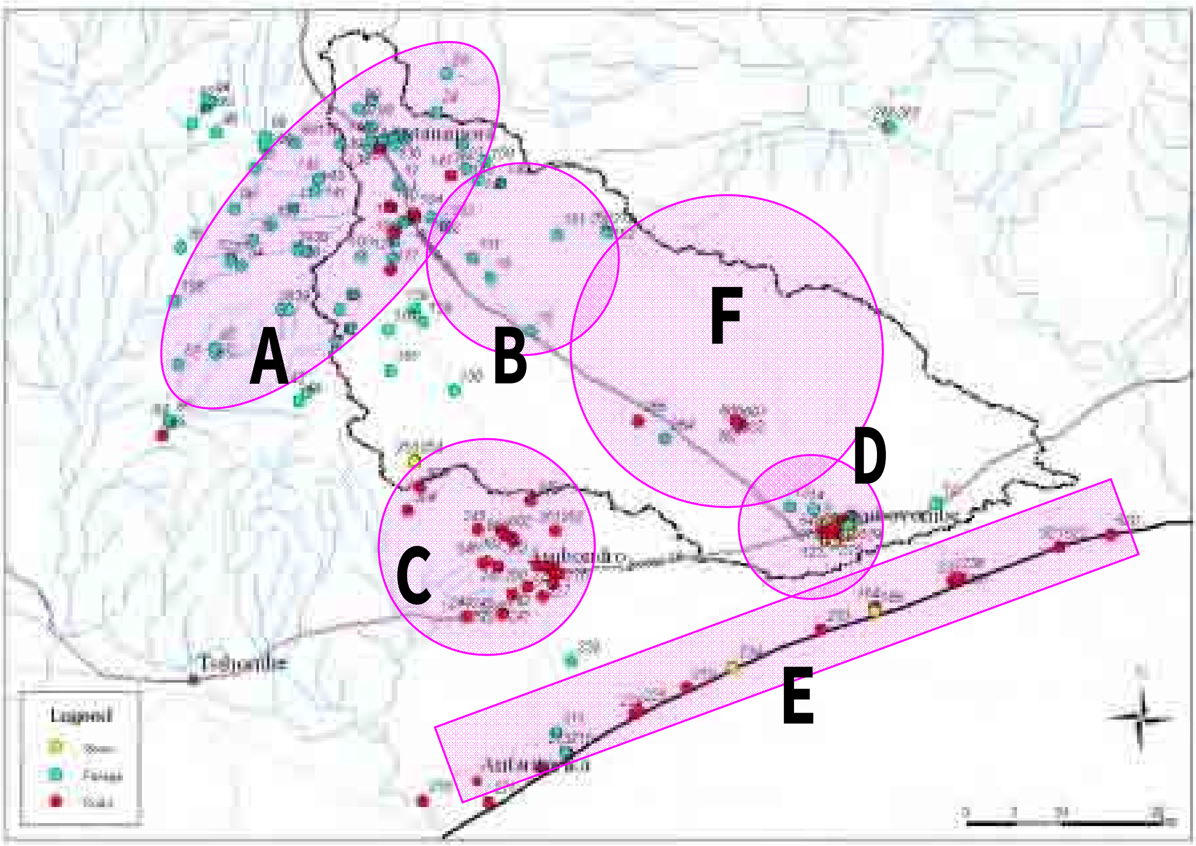


Figure 3.2.2-1 Water Point Plot

(3) Summary

Characteristics of the water source points shall be summarized below

Table 3.2.2-1 Characteristics of water source points

Map	Area	Well depth	Water quality
A	Basement rock area	Aquifer is targeted shallower depth. Aquifer targeted deep does not exist much.	Most of wells have less than 200mS/m of electric conductivity, and low NO3.
B	Northern part of the Ambovombe basin	Aquifer targeted have variation of depth 10-70m	Most of wells have less than 200mS/m of electric conductivity, and low NO3.
C	Ambondro	Only unconfined aquifer	Most of wells have more than 200mS/m of electric conductivity, and high NO3.
D	Urban Ambovombe	Most of well target unconfined aquifer	Most of wells have more than 200mS/m of electric conductivity, and high NO3.
E	Coastal dune	Most of well target unconfined aquifer	Most of wells have more than 200mS/m of electric conductivity, and higher NO3.
F	Central of basin	No data	No data

3.2.3 Impluvium Inventory

Rainwater collecting system varies from private use to public use. Large size of public system which is called as Impluvium, influence to large number of persons. Impluvium was studied in the view of condition. The condition is categorized as either "Good", "Bad" or "Partly". "Good" means no leakage from tank. "Bad" means it can't keep water at all. "Partly" means that one of tanks work or there is leakage but not at the bottom, so that, water can be kept at certain volume.

Table 3.2.3-1 Inventory of Impluvium

			Nbr Fokontany	Nbr Impluvium				GW	Required	Ratio (Nbr)	
				total	good	partly	bad	source	number	function	existence
			①	②	③	-	-	④	⑤=①-③-④	③/①	②/①
5	1	Ambazoa	20	12	5	2	5	0	15	25%	60%
10	2	Ambovombe	61	17	13	3	1	10	38	21%	28%
2	3	Ambonaivo	15	16	3	11	2	0	12	20%	107%
6	4	Tsimananada	10	3	2	1	0	0	8	20%	30%
4	5	Erada	17	9	3	0	6	0	14	18%	53%
14	6	Analamary	15	4	2	0	2	1	12	13%	27%
7	7	Maroalomainty	33	12	4	0	8	0	29	12%	36%
8	8	Maroalopoty	47	9	4	1	4	0	43	9%	19%
3	9	Ambanisarika	12	11	1	5	5	0	11	8%	92%
9	10	Beanantara	27	5	2	2	1	0	25	7%	19%
11	11	Ambohimalaza	15	9	1	3	4	2	12	7%	60%
1	12	Amobondro	23	7	1	6	0	4	18	4%	30%
12	13	Sihanamaro	28	8	1	2	5	10	17	4%	29%
13	14	Antaritarika	29	4	1	0	3	1	27	3%	14%
		Total	352	126	43	36	46	28	281	12%	36%

Inventory list of Fokontany level is attached at Data book DP1.1-2

3.3 Satellite Image Interpretation

3.3.1 Satellite Interpretation

(1) Topography

1) Ambovombe Basin

As it was already identified through the analysis of the topographic map, the Ambovombe basin is a closed basin and there is no water drainage existing nor there is a permanent lake existing throughout the year. The lowest altitude is near Ambovombe, where the difference of altitude with the surrounding area is 50m to 100m. On the other hand, the difference of altitude along the line stretching from Manave to Sakabe then to Ifotaka is less than 50m and the topographic cross section at this line is flat. If impermeable layer blocks the groundwater flow near Manavy and Ambaliandro, groundwater might flow out toward east and be drained to the Mandrare River.

2) Coastal Dune

The coastal dune is known to be consisting of three dune lines. The satellite interpretation proves the same and the lines parallel to the coastline are observed. The river system in the dune area is divided into small river basins.

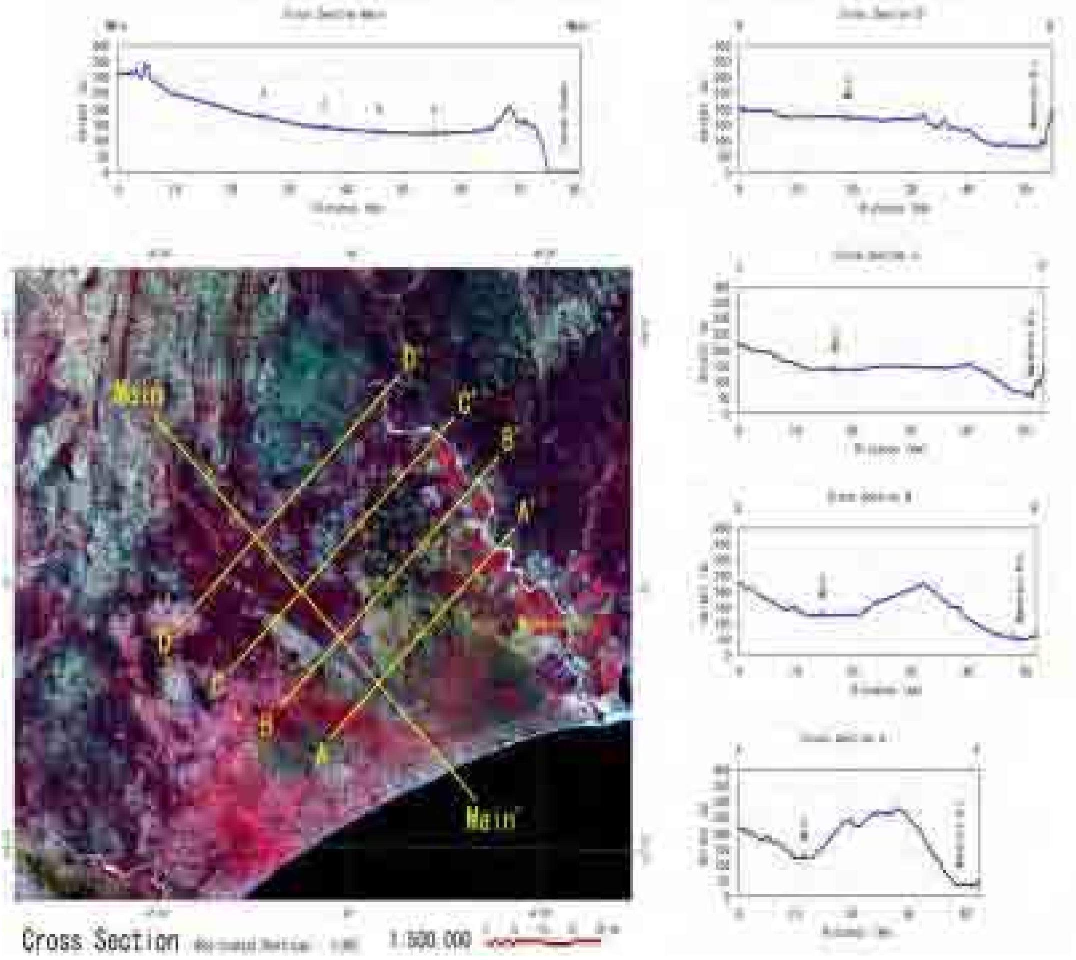


Figure 3.3.1-1 Topographic Analysis

3) Lineament

i) Lineament Antanimora-Ambovombe

Lineament is a geological structural line, which are known to indicate fault zone or crack zones. Thus, these are used to identify the groundwater development areas at the basement rock areas.

The depression line passing Antanimora-Ambovombe coincides with major lineament direction, such as the Mandrare River, which runs from NW to SE. Although this depression is terminated at the coastal dune, groundwater might flow out if the depression was buried with permeable deposits.

ii) Coastal dune

The observed line of dunes has the same direction as the major lineament (stated above), NW-SE. However, the line of dune seems not to reflect the direction of the flow of the water, but created by the movement of sand caused by the strong wind blowing in this area. These sand movement lines are distinguished from the lineaments.

iii) The Western Area of Antanimora

The direction of the lineament in the northern part of Antanimora is in the direction of N-S and E-W. Then, the lineament changes its direction to NW-SE, NE-SW in the southern part of Antanimora. The central Antanimora is located where both directions are observed. Therefore, in general, the rock in this area might be highly fractured and there is a chance to hit larger yield of water in the borehole than other places in the Study area.

iv) The North-Eastern of Ambovombe

Computer analysis of satellite image picked up many lineaments in the N-E and NE-SW direction. However, visually these are hard to recognize. This area has moderate slope and is covered with sand, and the rocks outcrop at the southern part, but lineament isn't observed. The lineament might be buried with unconsolidated formations more than several 10 meters depth.

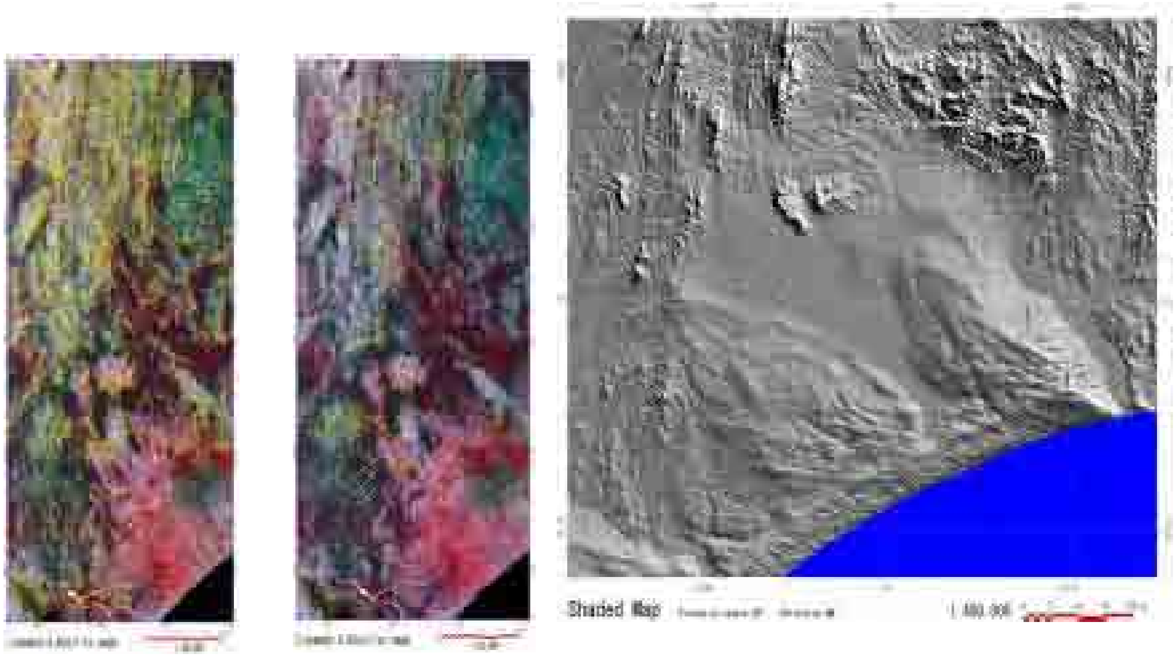


Figure 3.3.1-2 Lineament Analysis and DEM Data interpretation

(2) River System

River system in this satellite image interpretation is defined by tracing the lowest altitude direction. In the topographic map, it is not so clear in the western and eastern part of the basin because the contrast of altitude is not so much, but, through the analysis of the DEM data, it is well interpreted. If water will be conducted to Ambovombe by gravity flow, the water source can be developed within this area to minimize operation cost. The boundary of river system pass thorough Benantara – Sakave - around Antanimora - west of Namorola – Bevoty - Analamalaza - west of Ambanisalika-costal dune. Around Ambondro no longer belong to the Ambovombe basin. This closed river system would be applied to define recharge area by rainwater. Although the Ambovombe basin is the closed basin, water can flow to the eastside and join Mandrare basin if the basin filled with water.

(3) Damp, Depression

The DEM data is used for analysis of damp and depression. Depression is defined if the direction of the lowest altitude can't be followed. Some small-scaled depressions are encountered at Ambondro, the north of Ambanisarika, and between Ambovombe and Beanantara.

1) Ambondro and the North of Ambanisarika

Existence of depression in this area might have linkage with the existence of many dug wells that exists around Ambondro. One of the reasons is for example, that silt and clay deposits at the depression and forms impermeable layer. Further analysis can be conducted by superimposing the location of depression with the location of wells.

Figure 3.3.1-3 River System of the Ambovombe Basin

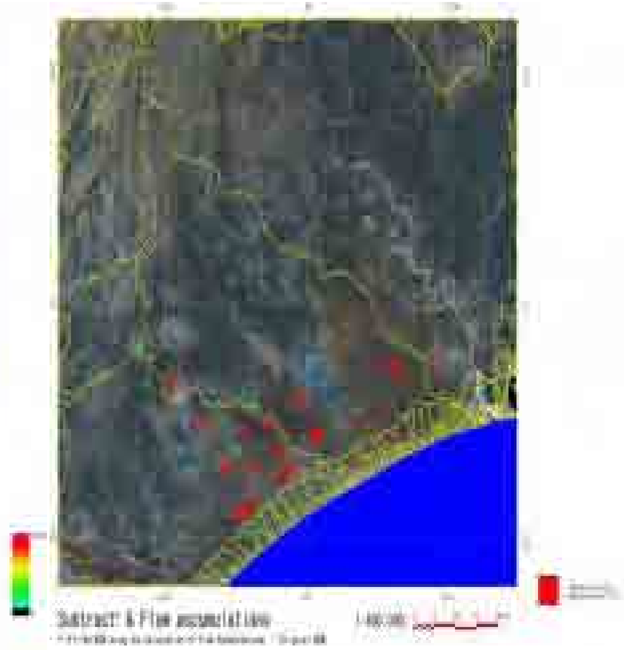


Figure 3.3.1-4 The Damp and Depression in Ambovombe Basin

2) Between Ambovombe and Benantara

The inclination of slope between Ambovombe and the boundary of Amboassary is parallel to the coastline (SW-NE), but the water flow line is formed perpendicular to the coastline. Ups and down is complex, then depressions are formed although there is slope. If depressions exist, water might tend to stay there and form water pond. But, actually, there aren't any water ponds and the trace of erosion by water flow isn't encountered. From this observation, it can be expected that good permeable layer lay from surface to certain depth.

(4) Vegetation

Level of Vegetation is interpreted by false color presentation and NDVI (Normalized Difference Vegetation Index) presentation. In the False color presentation, vegetation is indicated red. The NDVI presents level of activity in the gradation of color. The level reflects activity of chlorophyll in the vegetation.

Figure 3.3.1-5 Bird's-Eye View

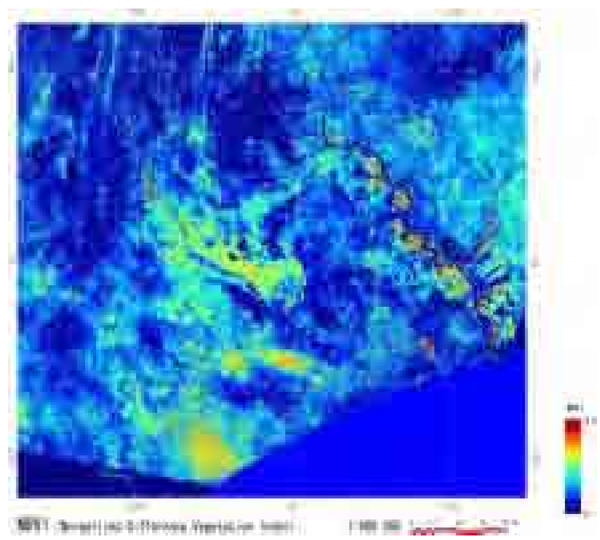


Figure 3.3.1-6 Vegetation and Land Use Map

1) Plantation is indicated in vivid red.
2) Scarce vegetation at the costal dune except around Antaritarika
3) Many 0.5 – 1.0km sized dense vegetation exists along the National Road 10 and in the dune area.
4) Scarce vegetation at East-north side of Ambovombe
5) Scarce vegetation up to Ampamalora from Ambovombe
6) Relatively dense vegetation from Ampamolora to Antanimora
7) Scarce vegetation along the National Road 13th
8) Scarce vegetation from Ambanisarika to Sihanamaro
9) Dense vegetation between Ambanisarika and the National Road 13th
10)Dense vegetation at the north of Antaritarika

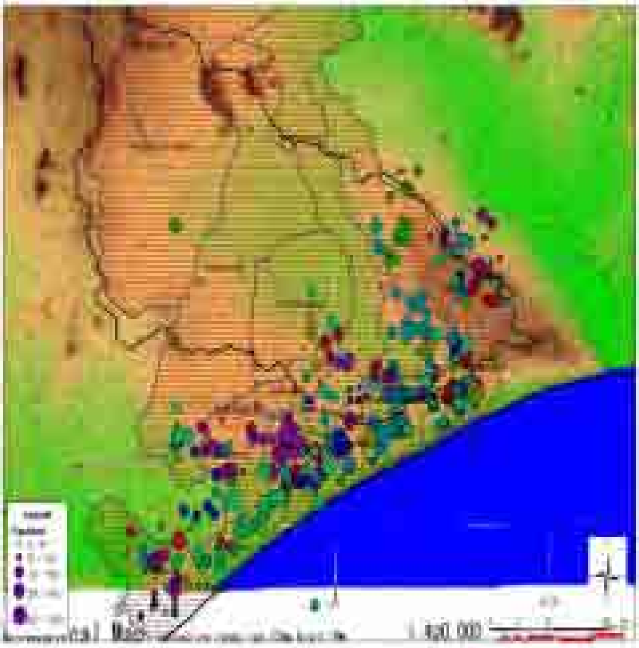


Figure 3.3.1-7 Village Distribution in the Study Area

Figure 3.3.1-8 Test Drilling Location

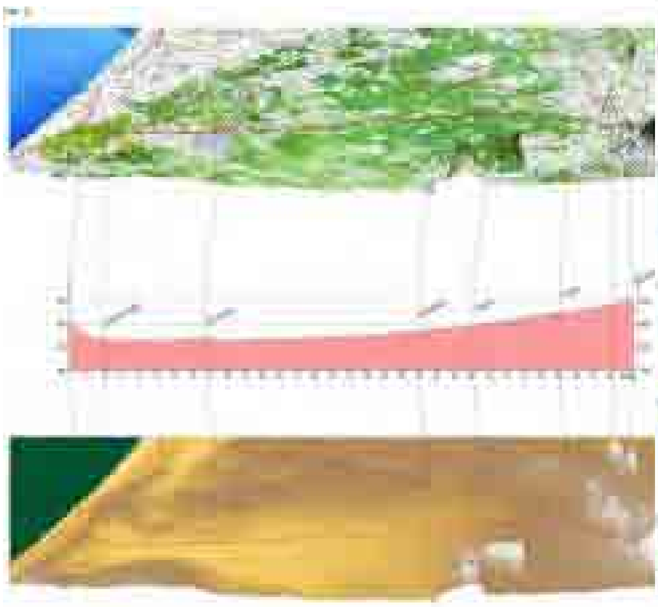


Figure 3.3.1-9 Topographic Measurement Survey by Satellite Image

Figure 3.3.1-10 Topographic Map Overlapped by Satellite Image for Field Reconnaissance

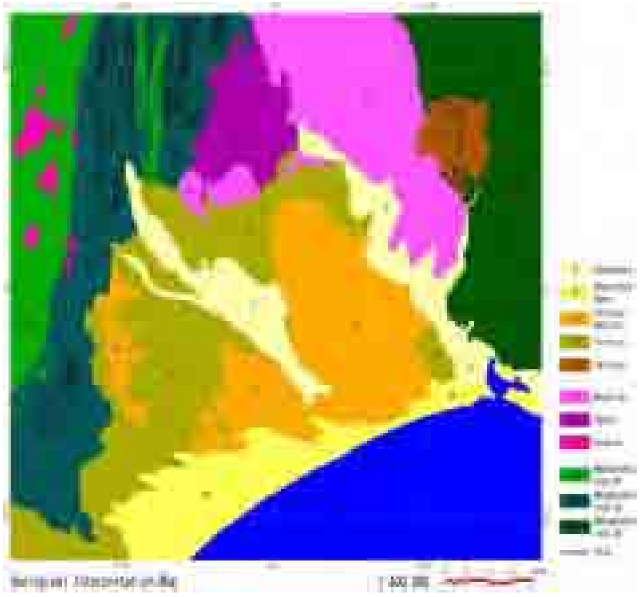


Figure 3.3.1-11 Geological Map from Satellite Image

Figure 3.3.1-12 Geological Map Overlapped by Satellite Image for Field Reconnaissance

The satellite image data is indispensable for the interpretation on the integrated purposes. The applied interpretation is such as groundwater potential and the village distribution within the wide area covering about 100km x 100km. In case of field reconnaissance and analysis of the groundwater potential, the satellite image data is essentially utilized.

3.4 Aerophotograph Survey

3.4.1 Methodology

Aerial photographs were purchased from the National Mapping Institute (FTM), and these covered the whole Study area. The total number of photographs purchased was 272 sheets. The location of the photographs is plotted on the topographic map for the identification of the villages, river system, geological structures and other details as an additional data to the satellite image.

3.4.2 Interpretation

The areas picked up by satellite image interpretation are studied further from aerial photographs through visual interpretation. Also, the location which seemed suitable for groundwater development was also examined. The photographs referred for each area are shown on a table shown on the right table, indicating the number of the photographs together with the map name, and map ID.

Map name	
Map ID	
Photo number	Photo number
Photo number	Photo number

3.5 Geophysical Survey

3.5.1 General

The objective of the Geophysical Survey is to understand the geometry and distribution of geological structure in the study area. Three types of techniques were applied for the study.
Figure 3.5.1-1 shows the locations of all surveyed points for applied three type of geophysical survey.

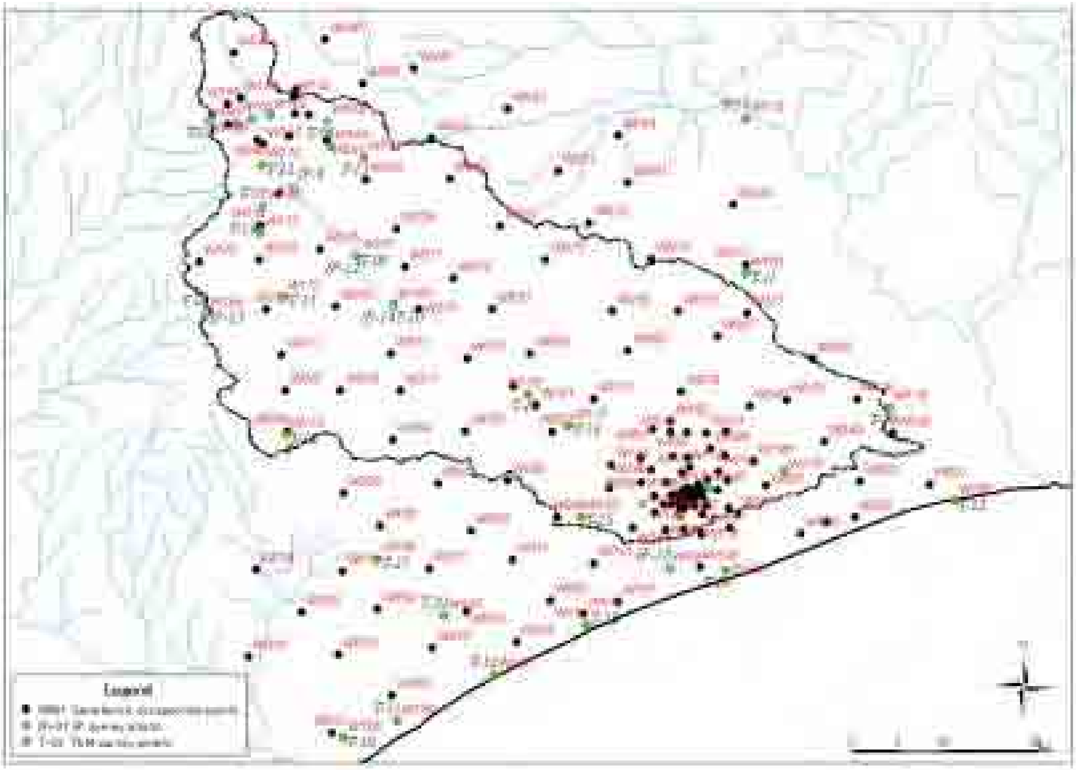


Figure 3.5.1-1 Location map of geophysical survey points

3.5.2 Interpreted Hydrogeological Cross Section of Ambovombe Basin

Figure 3.5.2-1 shows location map of cross section and Figure 3.5.2-2 shows interpreted hydrogeological layer for each cross sections.

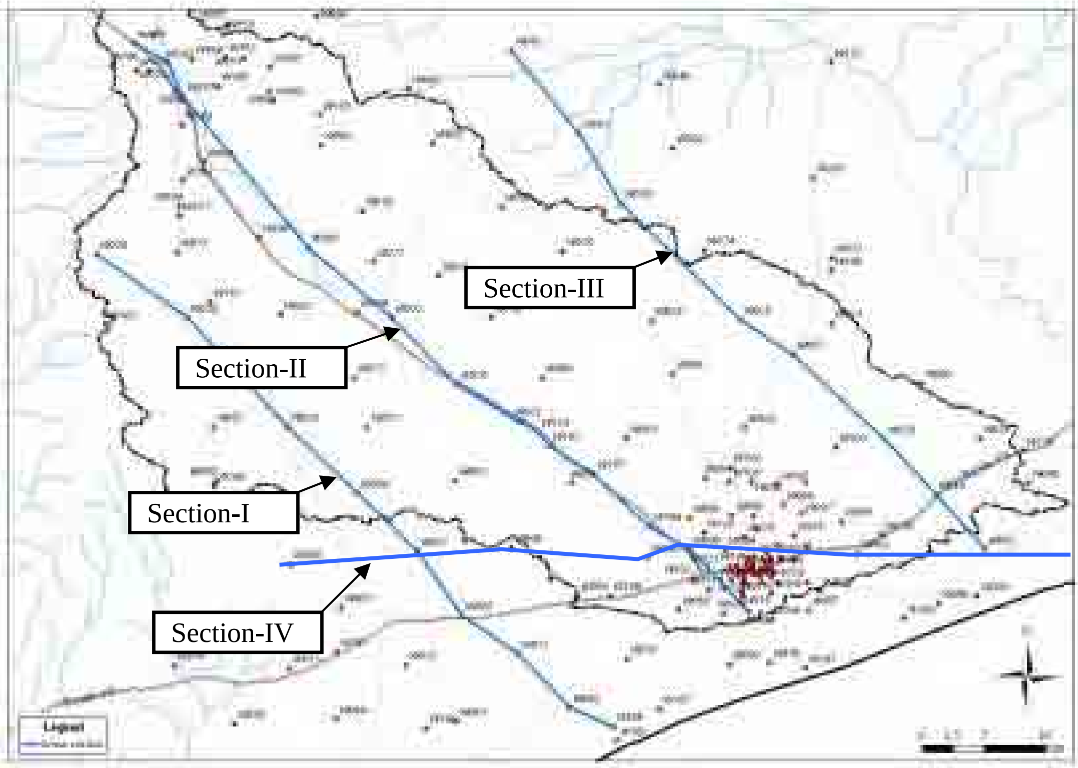


Figure 3.5.2-1 Location map of Cross Section

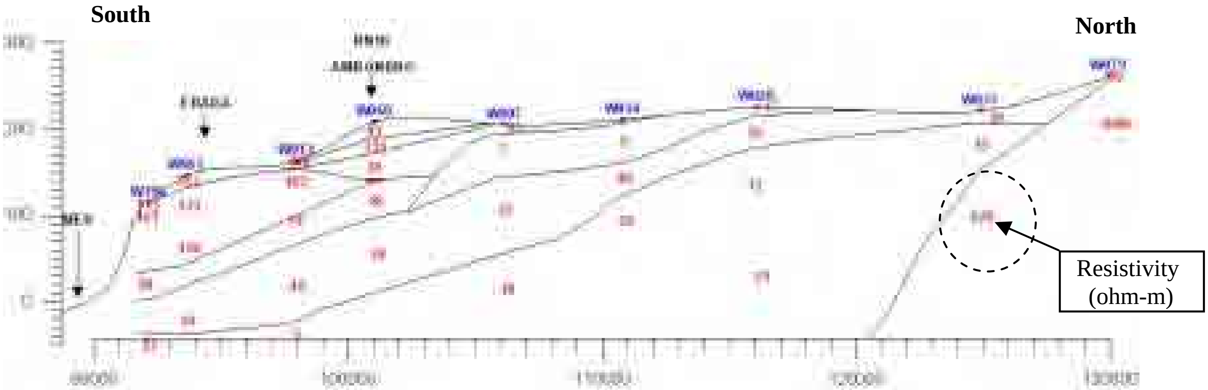


Figure 3.5.2-2 (a) Cross Section I

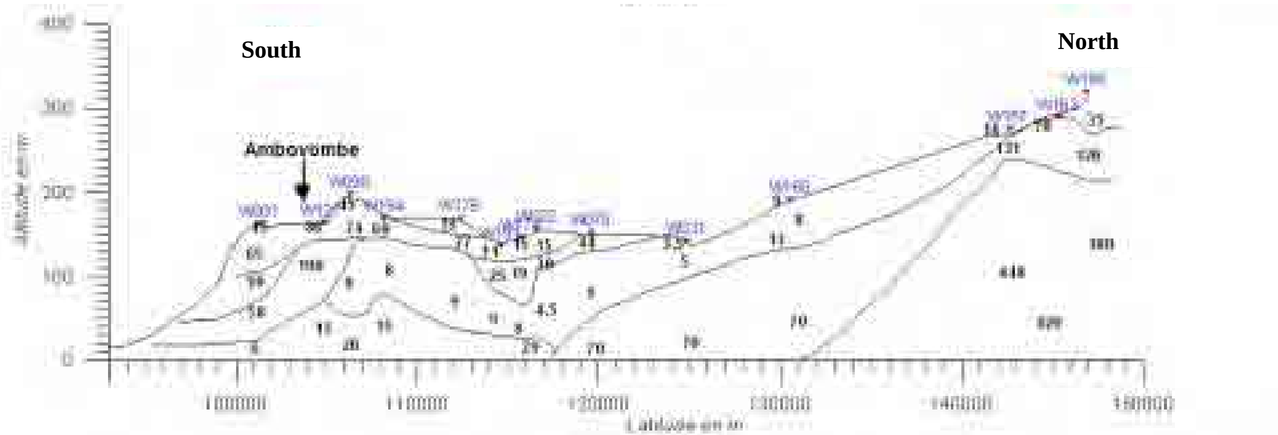


Figure 3.5.2-2 (b) Cross Section II

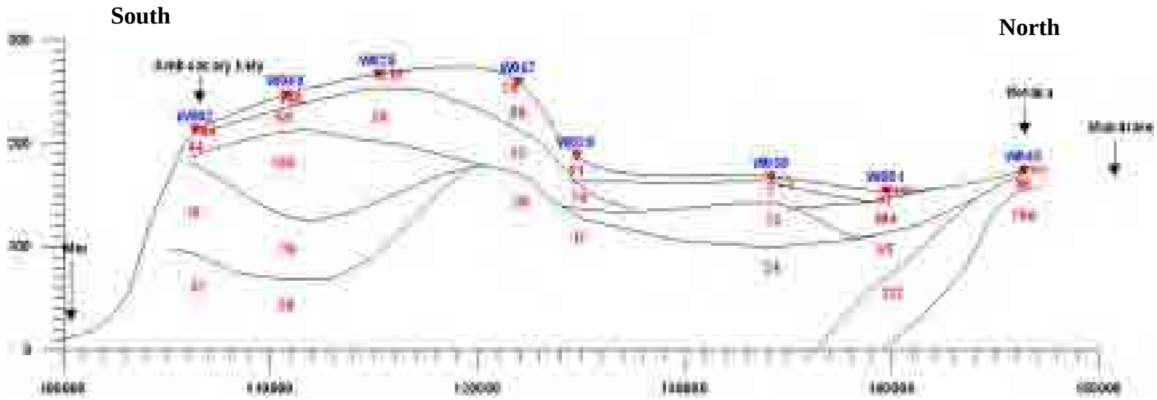


Figure 3.5.2-2 (c) Cross Section III

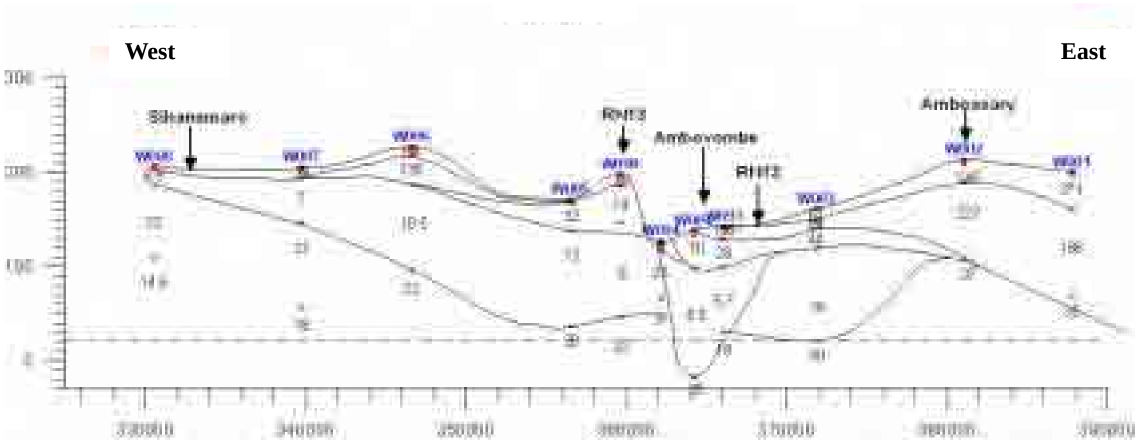


Figure 3.5.2-2 (d) Cross Section IV

Basically layers with high resistivity, ex. higher than 200 (ohm-m), represents hydrogeological basement layer. On the other hand, lower resistivity layer represents sedimentary formation. However it is rather difficult to distinguish exactly between clay layer and sand layer from sedimentary formation because of saline water intrusion.

3.6 Monitoring of Groundwater Level

3.6.1 Objective

Monitoring of groundwater level is essential to characterize distribution and movement of groundwater within the study area. In general monitoring shall be conducted periodically especially to confirm correlation between groundwater movement and amount of precipitation.
In the study, monthly and seasonal monitoring has been introduced for the selected existing wells which were recognized through the well inventory survey. Furthermore the data which have been obtained from the monitoring can be utilized for the evaluation of groundwater recharge.
In addition to above mentioned existing well, test wells are also added to monthly monitoring program. And automatic groundwater level gauges are installed for some of the test wells.

3.6.2 Monitoring Wells

(1) Seasonal monitoring wells
Seasonal monitoring wells are selected from recognized existing wells within the study area. Firstly sixty (60) wells are selected to monitor groundwater movement within Ambovombe Basin broadly. It is also considered that monitoring data can describe three dimensional distribution of groundwater within the basin. In addition to the selection of sixty (60) wells, ten (10) wells are selected as allowance for probable abandonment of the firstly selected wells. Finally seventy (70) wells are selected as seasonal monitoring well. Figure 3.6.2-1 and 3.6.2-2 shows location map of selected monitoring wells.

(2) Monthly monitoring wells
Sixteen (16) monthly monitoring wells are selected from the selected seasonal monitoring wells. Basically wells are selected equally from upstream to downstream of the Ambovombe Basin to trace time series groundwater fluctuation in terms of response to precipitation. The location of these wells are shown in the Figure 3.6.2-1 and 3.6.2-2.

(3) Monitoring for Test wells
In addition to the above mentioned selected existing wells, groundwater level of test wells, except dried wells, has been monitored. Finally 16 wells are selected for monthly monitoring and automatic groundwater level gauge was installed for 5 wells out of these 16 wells. In addition to the selected 5 test wells, existing well No.604 is also selected for monitoring with automatic groundwater level gauge to compare with characteristics of groundwater level fluctuation of test wells. The locations of these wells are shown in the Figure 3.6.2-3.

3.6.3 Results of Monthly Monitoring

(1) General
Monthly monitoring has been conducted every month from May, 2005 to July, 2006. The monitoring is conducted by local expert of AES Ambovombe and this could be considered as a good opportunity for technical transfer from JICA Study Team.

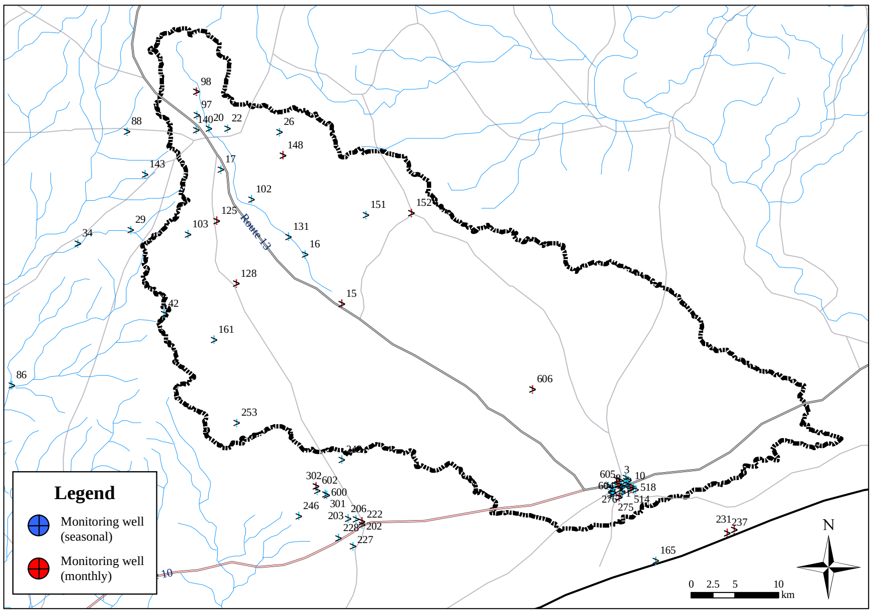


Figure 3.6.2-1 Location map of monitoring wells

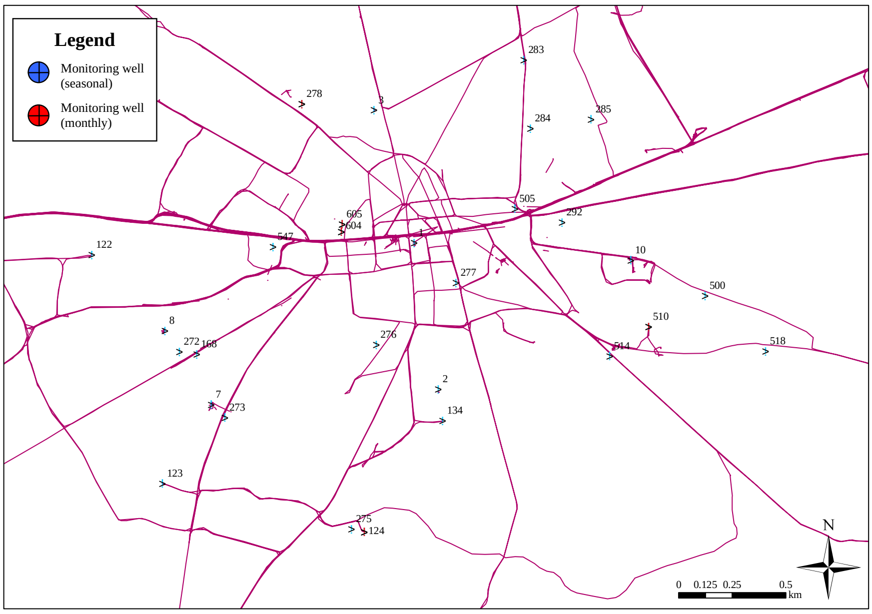


Figure 3.6.2-2 Location map of monitoring wells (Ambovombe)

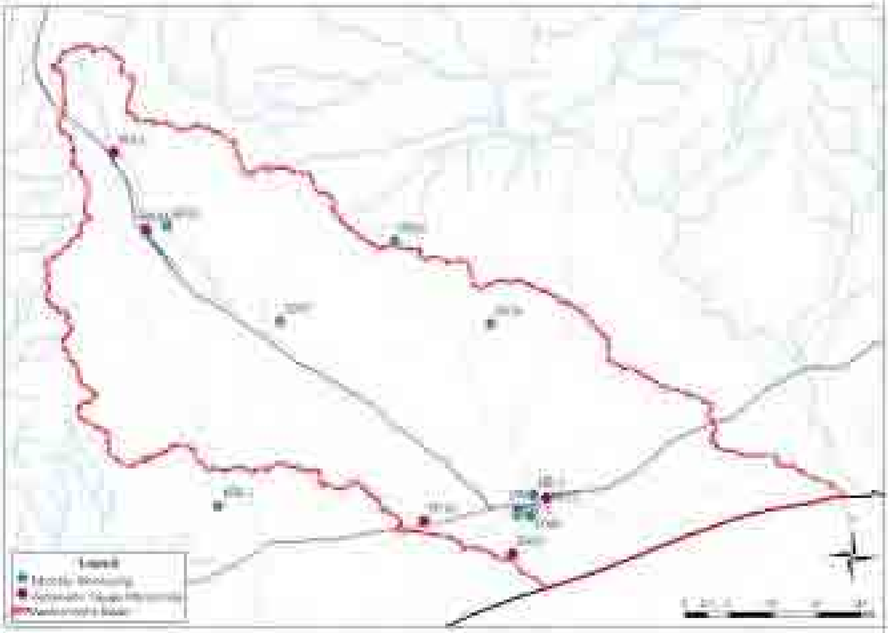


Figure 3.6.2-3 Location map of monitoring wells (Test Well)

(2) Results of Monthly Monitoring

Figure 3.6.3-1 shows fluctuation of groundwater level in contrast with monthly precipitation.

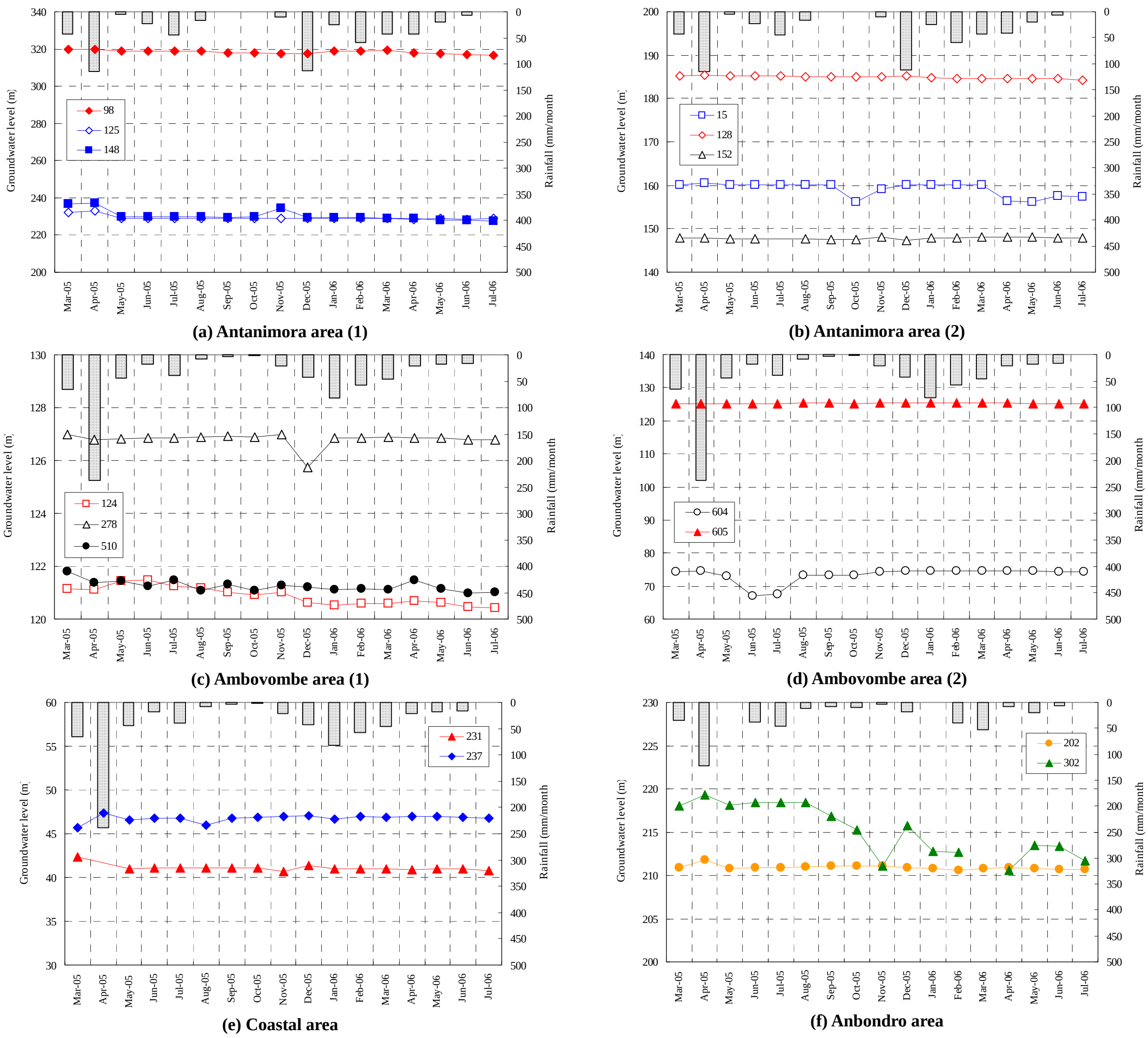


Figure3.6.3-1 Groundwater level fluctuation

Figure 3.6.3-1 (a) shows the trend of groundwater level of the well No.98 indicates gradual lowering from April to October, 2005. However, the groundwater level had been increasing toward the level of April. There are significant decreasing of groundwater level in May, 2005 for the well No.125 and 148. It may caused by a small amount of rainfall. Figure 3.6.3-1 (b) shows the trend of groundwater level is almost stable. However the trend for the well No.15 indicates significant lowering in October, 2005. Figure 3.6.3-1 (c) shows the trend of groundwater level has different characteristic. The trend of the well No.278 indicates gradual uprising from April to November, 2005. The trend of the remaining two wells (No.124 and 510) shows direct response to the amount of rainfall. Figure 3.6.3-1 (d) shows the different trend of groundwater level between well No.604 and No.605. The well No.604 is deep well (130m deep) and the aquifer is considered as confined aquifer. On the other hands, well No.605 is shallow well (17.7m deep), which located beside the well No.604, and the aquifer is considered as unconfined aquifer. The trend of groundwater level of shallow well (No.605) indicates almost flat. On the other hands, deep well (No.604) indicates lowering of groundwater level in June and July, 2005. There is no apparent relationship between groundwater levels and precipitation. Figure 3.6.3-1 (e) shows the trend of groundwater level indicates almost stable for the well No231. There is slight relationship between groundwater levels and precipitation for the well No.237. Figure 3.6.3-1 (f) shows the trend of groundwater level has different characteristic. There is significant lowering of groundwater levels for these two wells in May, 2005. And from May to August, 2005 there are slight uprising of groundwater levels for them. However from August to October, 2005, groundwater level of the well No.202 still keeps on uprising then it is decreasing. On the other hands, groundwater level of the well No.302 suddenly goes down and it is uprising in December, 2005.

3.6.4 Results of Seasonal Monitoring

(1) General

Seasonal monitoring has been conducted totally three times in this study. The first was conducted in April and the second was conducted in July, 2005 and the last was conducted in October, 2005.

(2) Comparison between measured data

Table 3.6.4-1 shows summary of the comparison between measured data in April, July and October, 2005.

Table 3.6.4-1 Summary of the comparison between measured data

Item	Groundwater level (m)		
	Apr.-Jul.	Jul.-Oct.	Apr.-Oct.
Number of samples	56	56	64
Minimum	-12.62	-4.92	-7.59
Maximum	2.19	5.76	1.86
Average	-0.98232	-0.04054	-1.13328

From the Table 3.6.4-1, basically groundwater level of monitored wells goes down from rainy season to dry season. However out of monitored wells, groundwater level of some wells increase even in the dry season. This fact indicates possibility of continuous recharge to the study area.

Figure 3.6.4-1 shows contour map of difference of groundwater level within Ambovombe city between April and October, 2005.

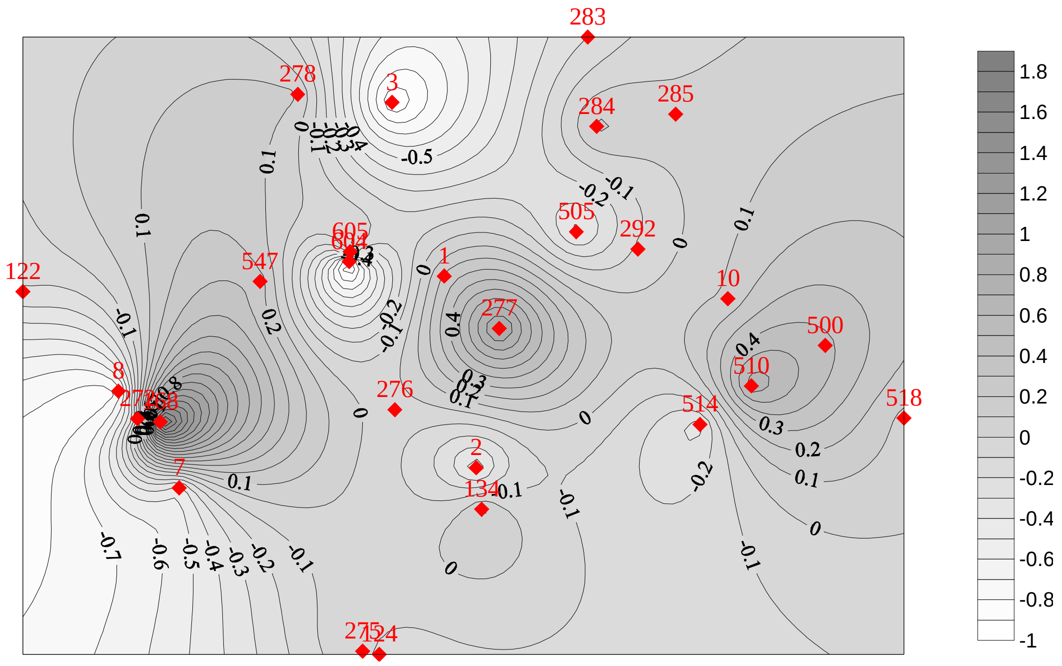


Figure 3.6.4-1 Contour map of difference of groundwater level between April and October

From the Figure 3.6.4-1, there is groundwater level uprising area at the western and eastern part of Ambovombe city. This area is thought to coincide with the area which certain amount of recharge is coming from surrounding area.

3.6.5 Results of Monitoring for Test Wells

(1) Results of Monthly Monitoring

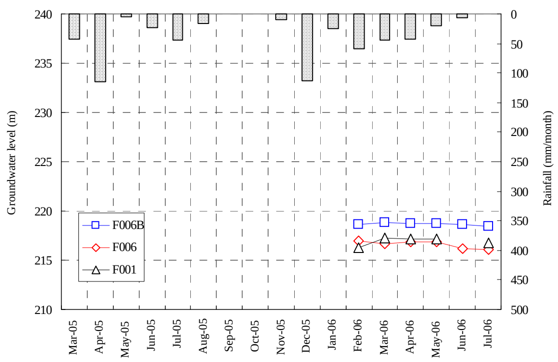
Figure 3.6.5-1 shows fluctuation of groundwater level in contrast with monthly precipitation.

In the Antanimora Area, groundwater levels of three test wells have been monitored. The results show gradual decreasing of groundwater level from April to July, 2006. This may be caused by decrease of precipitation.

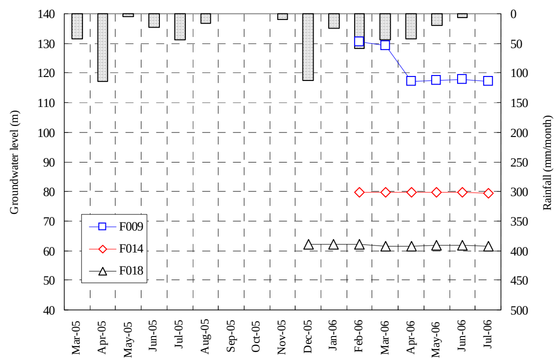
In the Middle of Ambovombe Basin area, groundwater levels of three test wells have been monitored. Except No.F009, the results show stable fluctuation of groundwater level. Sudden decrease of groundwater level on NoF009 may be caused by extraction from the well.

In the Coastal area, groundwater levels of four test wells have been monitored. The results show gradual decreasing of groundwater level from April to July, 2006 for the well FM001 and F022. This may be caused by decrease of precipitation. On the other hands groundwater level of the well F015 and F030 seems stable (except the sudden decreasing in July, 2006 on he well F030).

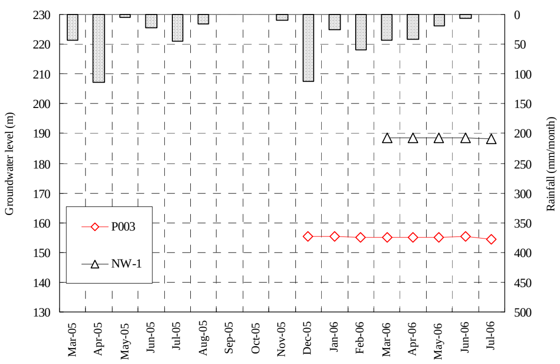
In the Ambovombe city area, groundwater levels of six test wells have been monitored. Except NE-1, the results show stable groundwater level fluctuation. The uprising of groundwater level on NE-1 well may be caused by infiltration to the well.



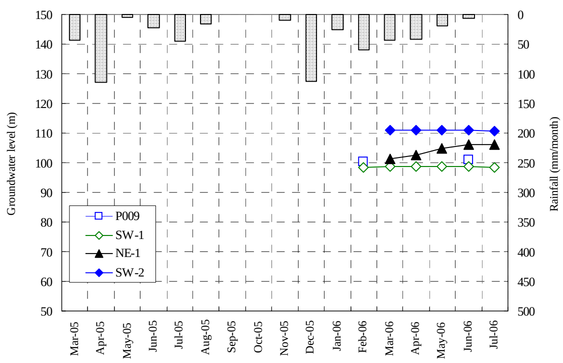
(a)Test Wells in Antanimora area



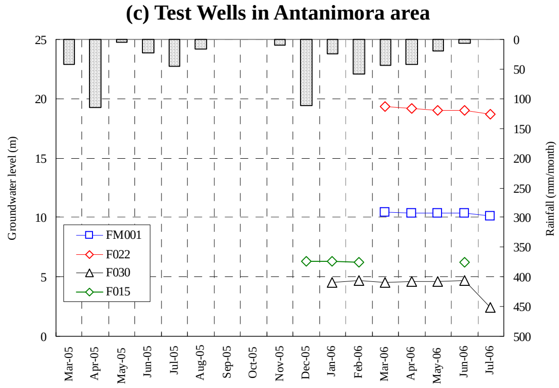
(b) Test Wells in Middle of Ambovombe Basin



(c) Test Wells in Antanimora area



(d) Test Wells in Ambovombe city



(e) Test Wells in Coastal area

Figure 3.6.5-1 Groundwater level fluctuation

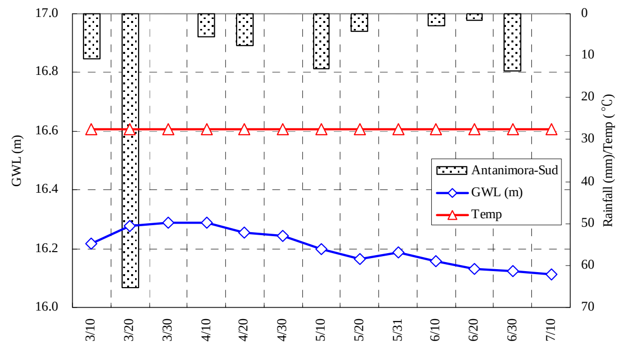
(2) Results of Automatic Groundwater Level Gauge

Figure 3.6.5-2 shows results of groundwater level monitoring with automatic gauge. Due to inappropriate installation, sufficient data could not be obtained from the well No.F018.

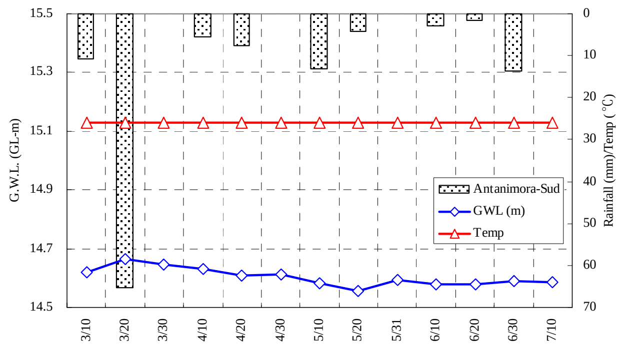
Because the rainfall data is obtained only every 10 days total amount, average of 10 days groundwater level fluctuation data is prepared to compare with fluctuation of rainfall.

According to the Figure 3.6.5-2, basically groundwater level seems gradually decreasing from March to July, 2006 in accordance with the amount of precipitation.

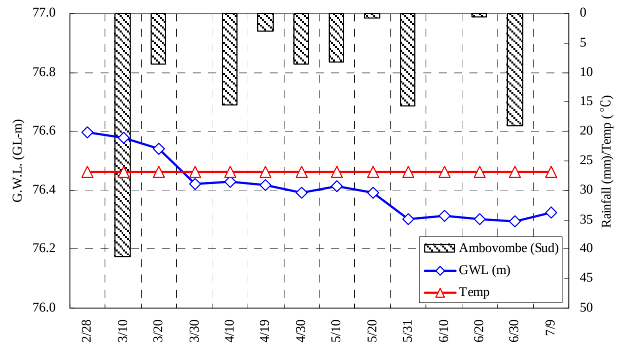
Groundwater level fluctuation of the well No.F015 seems rather stable compare with the other wells.



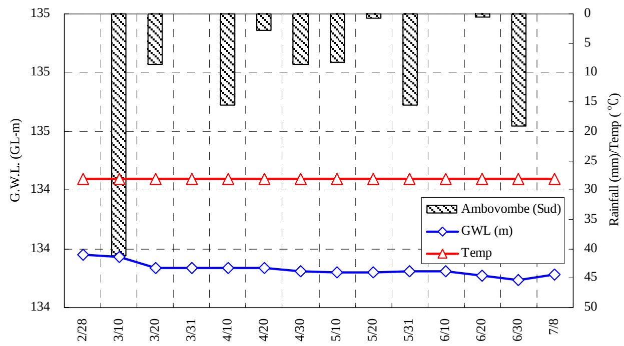
(a)Test well No.F00



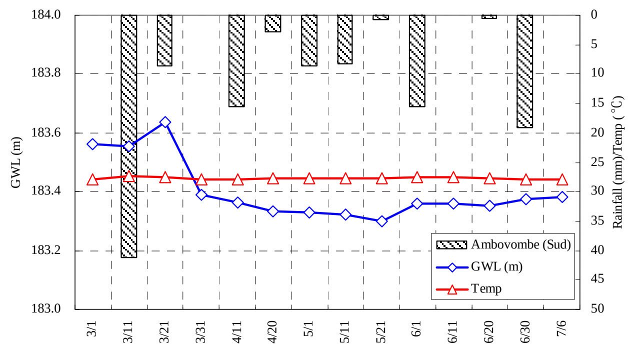
(b) Test well No.F006b



(c) Existing well No.604



(d) Test well No.F015



(e) Test well No.F030

Figure 3.6.5-2 Result of groundwater level monitoring

3.7 Water Quality Survey of existing Wells

3.7.1 General

The objective of the water quality survey can be pointed out into two aspects, namely:

1) To compare the sampled water with the WHO and the Madagascar national standard for drinking water to evaluate whether the water is suitable for drinking;
2) To examine the chemical characteristics of the samples to seek the origin of the chemical components, especially the human effects and the reason why this region has high salinity.

3.7.2 Methodology

(1) Water quality survey

(a) Sampling points

Table 3.7.2-1 shows the summary of the points sampled in the water quality survey.

Table 3.7.2-1 Sampling points in summary

Area	Type of site	Wet season(May, 2005)	Dry season (Sep, 2005)
Ambovombe commune	Wells (shallow and deep)	18	19
	Impluvia	1	0
	Ponds	2	2
Antanimora area	Wells (shallow)	13	13
	Ponds	1	1
	Rivers	2	2
Other areas	Wells (shallow)	9	11
	Impluvia	2	0
	Rivers	2	2

(b) Analyzed items

A total of 29 items were analyzed, and of them 13 were tested on the spot (field test), and 16 were analyzed in the laboratory in Antananarivo. The analyzed items and its purpose are shown in the table below.

Table 3.7.2 -2 Items Analyzed

Basic Purpose	Field Tests	Laboratory Tests
Basic Items	pH, EC, Temperature, Odor, Taste, Color, M-Alkanity, Carbon Dioxide (CO_2), Dissolved Oxygen	Total Hardness, Turbidity
Evaluate whether water is potable	Boron (B), Escheria Coliform Bacteria, Bacteria	Iron (Fe), Manganese (Mn), Arsenic (As), Fluoride (F)
Effects of human activities		Nitrate (NO_3^-), Nitrite (NO_2^-), Ammonia (NH_4^+)
Evaluation of salinity origin		Sodium (Na), Potassium (K). Calcium (Ca), Magnesium (Mg), Chloride (Cl), Sulfate (SO_4^{2-}), Bicarbonate (HCO_3^-)

3.7.3 Chemical Composition Analysis

The results of the water quality analysis are shown in tables in the appendix. Below is the discussion based on the analysis results.

(1) Spatial Distribution of the Major Components

(a) Spatial distribution of EC in the area (results from the Inventory Survey)

Fig. 3.7.3-1 shows the spatial distribution of the EC measurements conducted in the inventory survey. The circles in red shows that the EC values are above the Madagascar National standard for drinking water (300mS/m)

Generally, the EC values in the Antanimora area is low, and wells situate from Ambovombe and the south has low EC values. Because there are not many existing wells in between the Antanimora and

Ambovombe, it is difficult to draw the line where the high salinity starts, but taking into consideration that EC measured in wells on the line connecting No.15 (near Manave) and No.152 (near Sakave) south of Antanimora are over 200mS/m, it might be said that the high salinity content in groundwater begins around this line.

Detailed spatial distribution of EC inside the Ambovombe rural area (Fig. 3.7.3-2) reveals that EC becomes higher in the center. As a whole, there seems to be high salinity area from the north eastern part of the urban area to the south eastern part. In the south, there lies low saline area having EC values under 300mS/m, and in particular there are many wells having EC value lower than 100 in the east-southeastern area of the urban area.

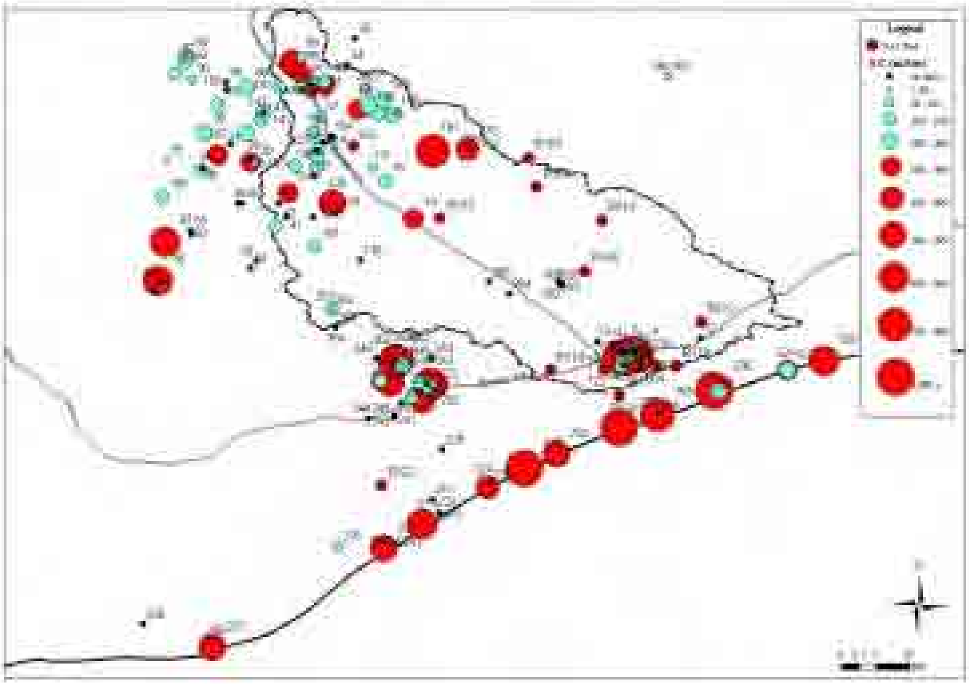


Fig. 3.7.3-1 Spatial Distribution of EC in the area (Inventory survey)

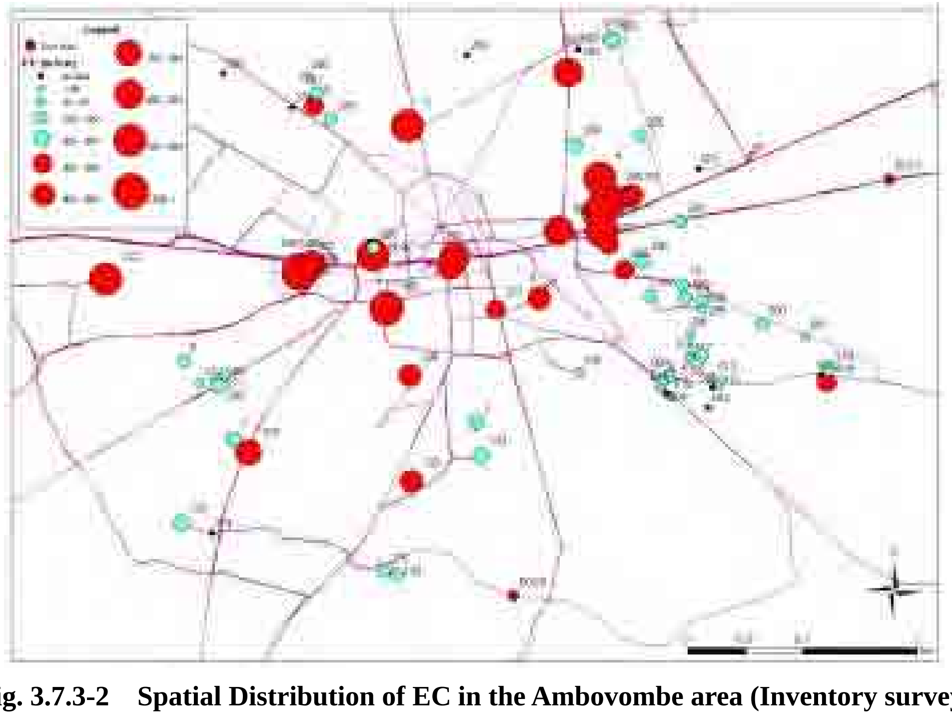


Fig. 3.7.3-2 Spatial Distribution of EC in the Ambovombe area (Inventory survey)

(2) Seasonal Variation

(a) Seasonal variation results from the water quality survey

The seasonal variation (comparison of the results between wet season (May) and dry season (Sep)) for EC is shown in Fig.3.7.3-3.

From these figures, it can be said that the concentration of the chemical components does not change between the seasons, although in some sites dry seasons tend to be more concentrated. This means that the chemical components are in an equilibrium state, having very small reaction with the rainwater. This can be proved also when comparing the surface water samples variation and the well water variation; in that the surface water tend to change drastically and be more concentrated in the dry season having great influence of vaporization.

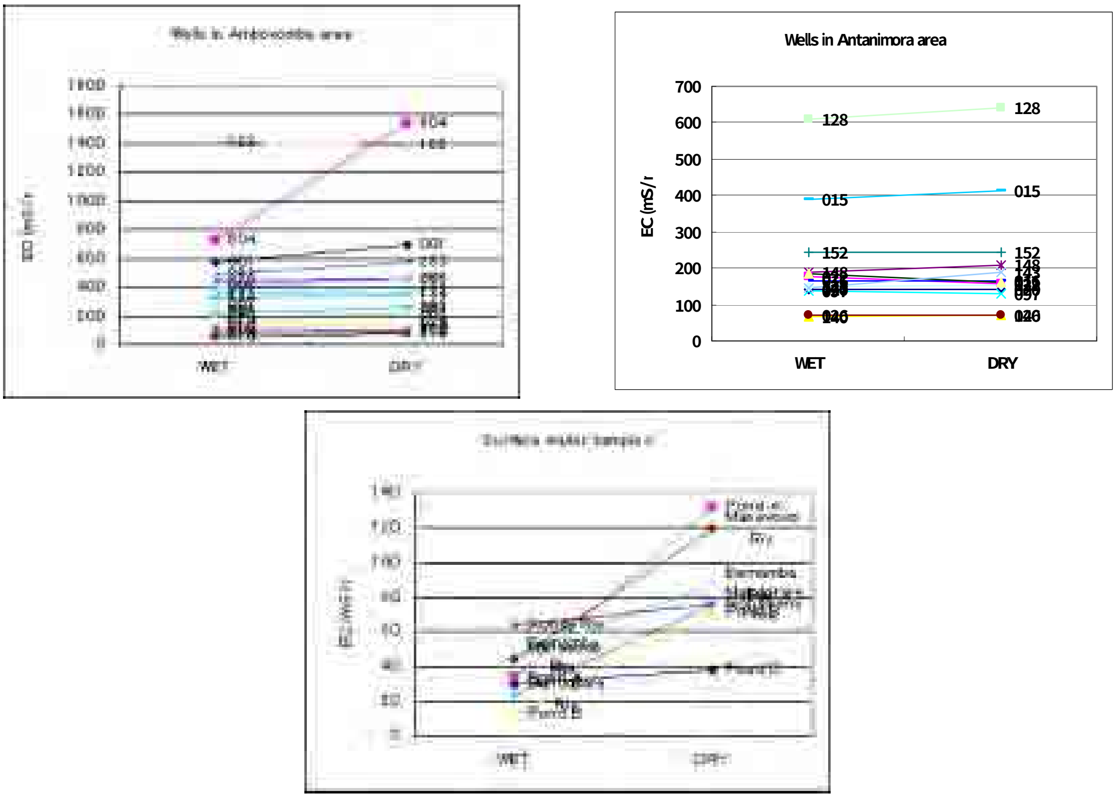


Fig. 3.7.3-3 Seasonal variation of EC of the sampled waters.

(3) The Relationship Between the Analyzed Chemical Components.

Here, the relationship between the major chemical components (EC, Na, Ca, Mg, Cl, SO4, HCO3 and NO3) is studied to grasp the tendency of the behavior of the chemical compositions.

Table 3.7.3-1 shows the correlation coefficient between the major components. The two components have strong relationship if the coefficient is over 0.7 and very strong if they are over 0.8, meaning the behavior of the components should be the same within the groundwater of the target area. Fig. 3.7.3-4 shows some plots showing the correlation between major components.

The chemical components which shows strong relationship with EC are Na, Ca, Mg and Cl. Therefore, these substances determine the EC of the area, which, means that the high salinity is caused by these substances, particularly Na and Cl. Taking note of the plot between EC and Cl, of the two seasons, the dry season has stronger relationship, meaning that in the dry season the mechanism of high salinity is the same as the mechanism of Cl discharge in the groundwater, whereas in the wet season there seems to be another type of mechanism involved for the high salinity, which cannot be found.

Between the chemical substances, Na and Cl has the highest correlation coefficient (r=0.9437). The plotted graph between these substances shows that almost all the samples drop on the y=x line, meaning that these two substances behave as a pair within the groundwater. Other pairs of ions that showed strong correlation (r>0.8) is Ca and Cl. Ca-Mg and Na-Ca. These substances behave together.

On the other hand, HCO3 has low correlation coefficient with all other substances. Within the anions, Cl and SO4 has relatively high relationship.

Table 3.7.3-1 Correlation coefficient between the major components

	EC	M-Alkality	K	Na	Ca	Mg	Cl	SO4	HCO3	NO3
EC	1.0000	0.1992	**0.7158**	**0.8198**	**0.8390**	**0.8483**	**0.8138**	**0.7186**	0.2131	0.4562
M-Alkality		1.0000	0.2793	0.2623	0.1032	0.2499	0.1268	0.3927	**0.9002**	0.1546
K			1.0000	0.4270	0.5430	**0.7996**	0.4105	0.4321	0.3535	**0.7120**
Na				1.0000	**0.8479**	0.6866	**0.9437**	**0.7903**	0.1983	0.2513
Ca					1.0000	**0.8729**	**0.9114**	0.6215	0.0653	0.3285
Mg						1.0000	**0.7350**	0.5836	0.2796	0.4854
Cl							1.0000	**0.7189**	0.0809	0.2929
SO4								1.0000	0.3691	0.2925
HCO3									1.0000	0.1941

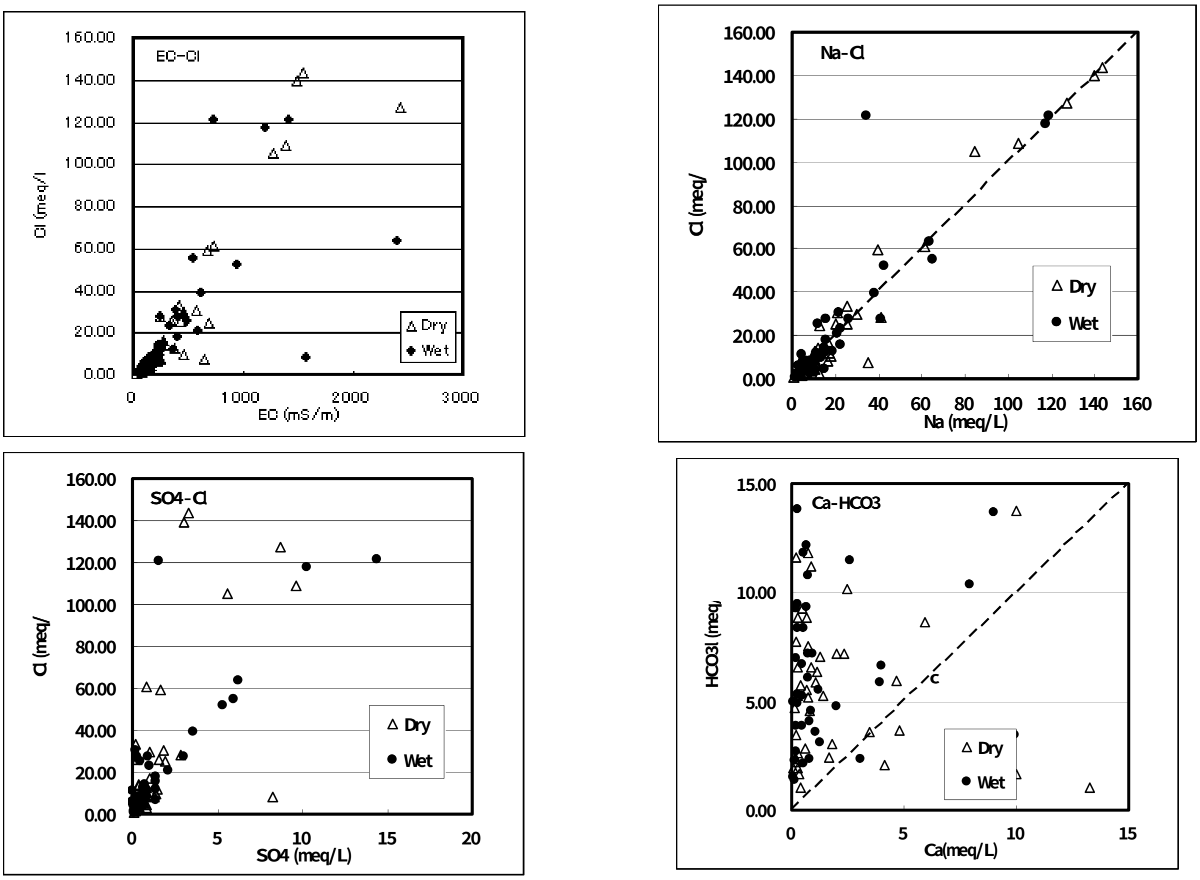


Fig. 3.7.3-4 Correlation between major ions

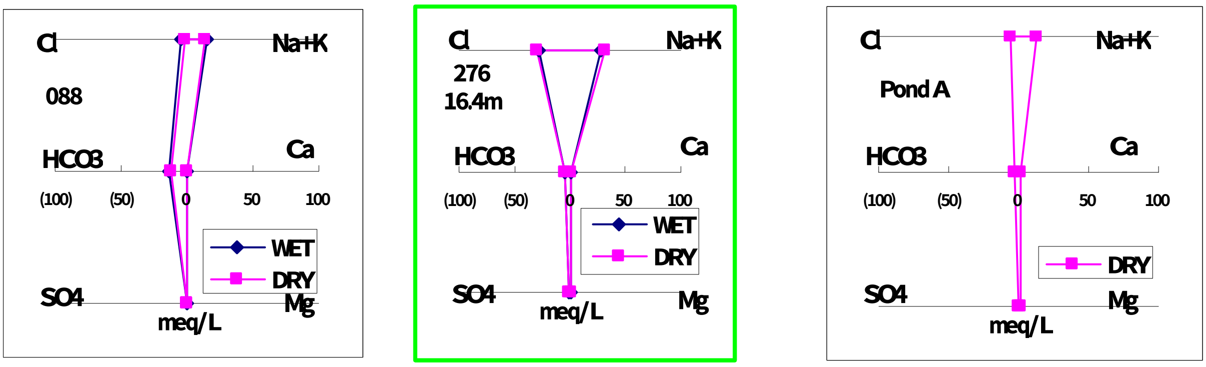
(4) Water Quality type of the Groundwater In the Target Area

To reveal the water quality types of the area, Hexadiagrams of each sample was plotted (typical hexadiagrams shown in Fig. 3.7.3-5, the hexadiagrams of groundwater samples in the target area in Fig. 3.7.3-7(1), and hexadiagrams in the urban Ambovombe shown in Fig. 3.7.3-7(2)) and also Piperdiagram

(Fig. 3.7.3-7) was made.

Firstly, if we take notice of the hexadiagrams, there are two distinctive types of water in the area. The first is the Na-HCO3 type, these can be seen in the hard-rock area of Antanimora and also rainwater in the Implivium, and surface waters of ponds and rivers. Secondly, in the groundwater to the south of southern part of the Antanimora area (including Ambovombe, Ambondro, Coastal dune areas), the water quality type changes to Na-Cl type. The distribution of the Na-Cal type water apparently coincides with the high EC areas, although the type of the hexadiagrams do not change within the area regardless of the value of EC.

If we compare the distribution of the hexadiagrams with the geological map, it is clear that the Na-HCO3 type groundwater (with low EC) is spread in the metamorphic, hard rock area, whereas the Na-Cl type groundwater (with high EC) is spread in the tertiary and quaternary sedimentation formation.



Well 088, Antanimora   Well 276, Ambovombe   Pond A (Surface water)

Fig. 3.7.3-5 Typical Hexadiagrams of the samples in the Target Area

The Piper diagram reveals the type more clearly.

First, on the triangle diagram at the left showing the Cation (Na+K, Ca, Mg) composition, almost all of the samples concentrate on the right side, showing that these sample have high Na+K composition ratio. On the other hand, on the triangle diagram at the right showing the Anion (Cl, HCO3, SO4) composition, the samples can be divided into two groups, namely the samples having high HCO3 content (Antanimora groundwater and the surface water) and the samples having high Cl content (other groundwater samples including Ambovombe area).

Next is the key diagram on the center, showing the composition ratio of all the cations and anions combined. In general, the diagram can be divided into 5 zones as shown on the diagram and they are called: zone I as Hardness – Carbonate type, zone II as Alkali- Carbonate type, zone III as Hardness- non Carbonate type, zone IV as Alkali- non Carbonate type and zone V as intermediate type.

The sampled waters from the Antanimora wells and surface waters are plotted in zone I and V showing typical composition of shallow groundwater or surface waters, but the rest of the groundwater is plotted in zone IV, meaning the groundwater content resembles that of seawater.

Thus, the saline water can be considered to be caused by the below mechanism:

1) Rainwater falls on the ground perching the soil and the superficial geology
2) In the metamorphic rock area, the retention time is short and does not react so much with the basement rock layer, thus low saline.
3) In the tertiary or quaternary sand layer areas, the water reacts with the sand containing salt (mostly halite (NaCl)) and the longer the retention time the higher the saline content, thus high EC.

Zones inside the Piper key diagram

Zone	Remarks
I	Hardness-Carbonate type
II	Alkali-Carbonate type
III	Hardness-non Carbonate type
IV	Alkali- non Carbonate type
V	Intermediate type

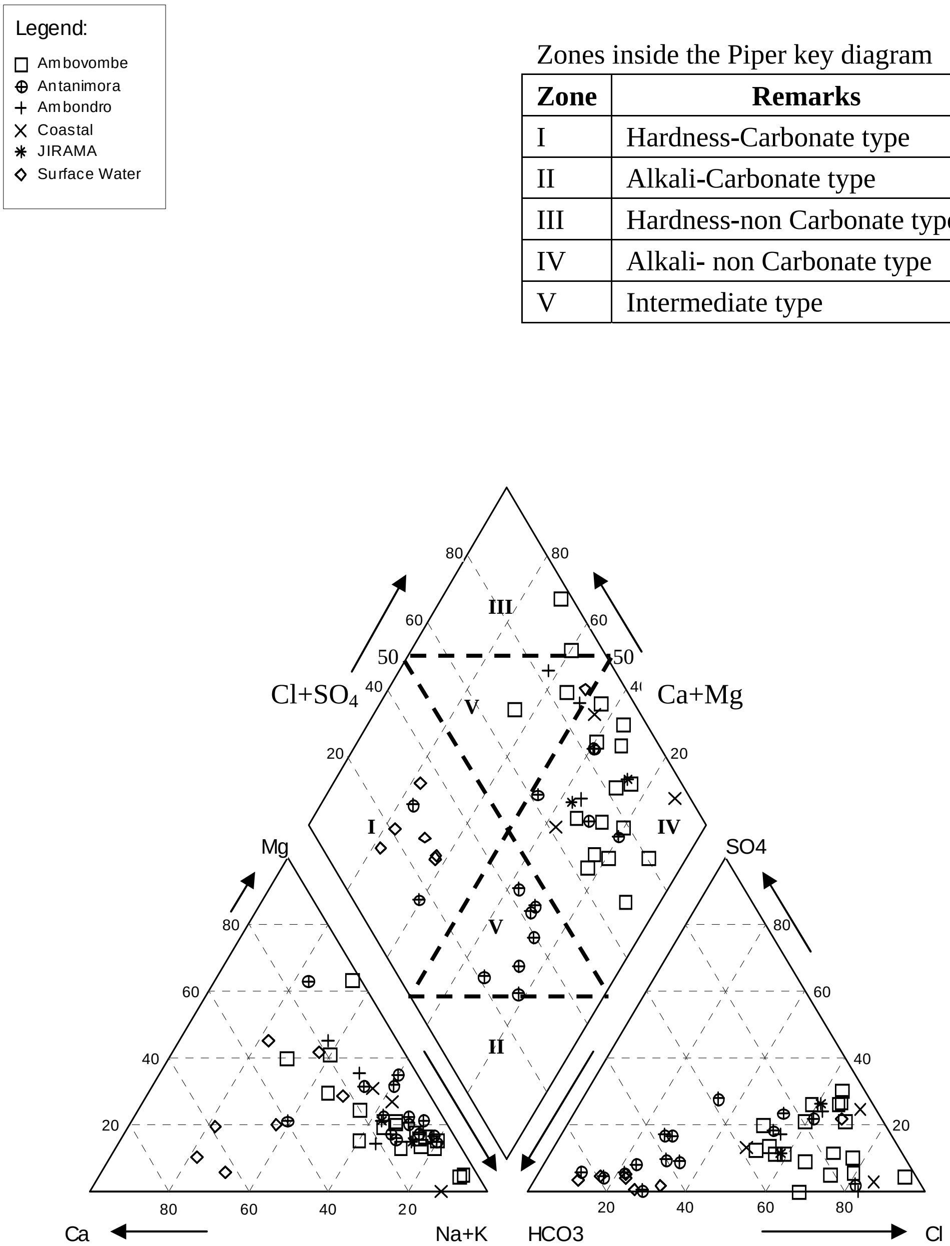


Fig. 3.7.3-6 Piper diagram of the samples analyzed for the dry season

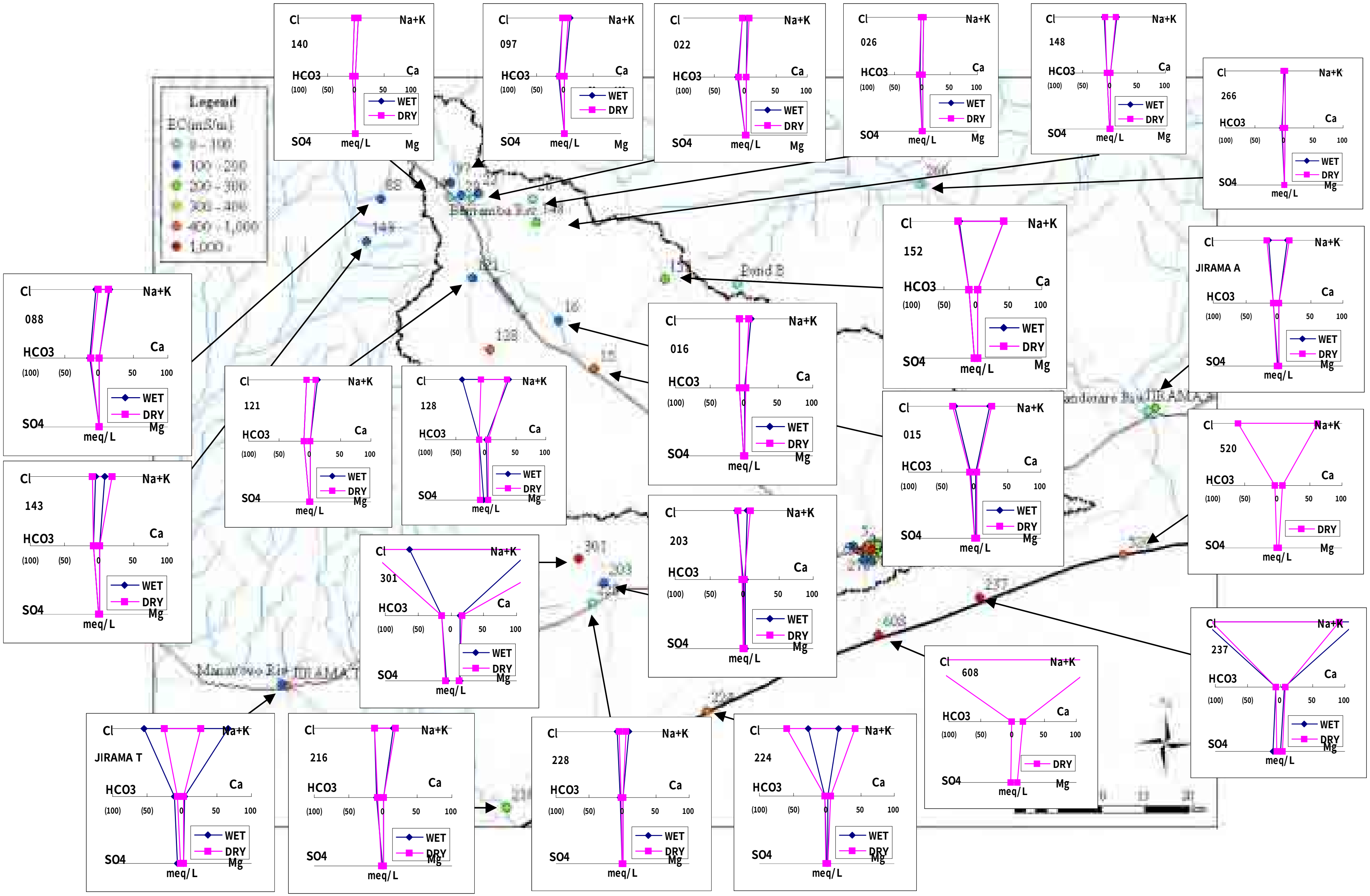


Fig.3.7.3-7(1) Hexadiagrams of wells in the Area

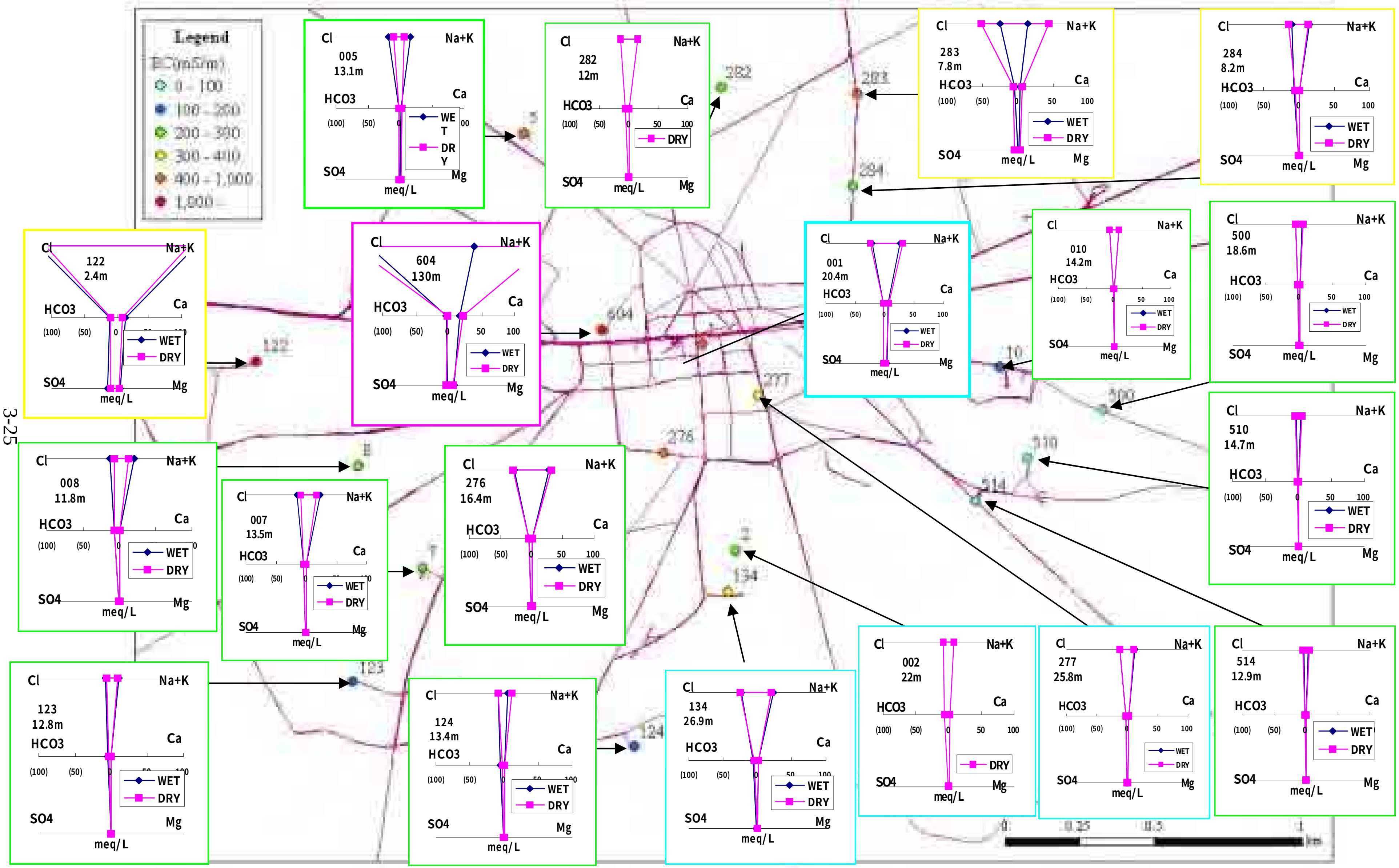


Fig.3.7.3-7(2) Hexadiagrams of wells in Ambovombe

3.7.4 Water Quality of the Drinking Water in the Area

To get an idea of the overall drinking water quality level of the area, average and maximum concentration of the major components of the samples were calculated and compared with the Madagascar and WHO standards. The results are shown in Table 3.7.4-1.

Table 3.7.4-1 Comparison of average and maximum sample water quality and the national and WHO standards (major components, unit: EC:mS/m, others: mg/L)

		EC	Na	Ca	Mg	Cl	SO4	NH4	Mn	Fe	NO2	NO3	As
Madagascar Standard		300.0	-	200.0	50.0	250.0	250.0	0.5	0.05	0.5	0.1	50.0	0.05
WHO Standard		-	*200.0*			*250.0*	*250.0*	*1.5*	*0.10*	*0.3*	3.0	50.0	0.01
Ambovombe	Max.	**1572.0**	2727.6	**636.0**	**459.3**	**4295.5**	**2761.5**	0.2	**0.24**	**44.2**	**9.4**	**100.3**	0.00
	Ave.	**397.4**	444.3	102.7	**79.2**	**712.8**	**289.5**	0.0	0.05	**1.9**	**1.3**	15.7	0.00
Antanimora	Max.	**640.0**	950.8	**196.0**	**318.3**	**1391.6**	**1590.4**	0.2	**0.71**	**28.0**	**6.3**	5.1	0.00
	Ave.	196.0	310.7	49.4	**71.5**	**331.3**	194.4	0.0	**0.08**	**1.1**	**0.5**	1.3	0.00
Ambondro	Max.	211.0	206.5	61.6	**69.0**	**383.4**	145.4	0.1	**0.08**	0.1	**2.4**	**194.0**	0.00
	Ave.	158.3	154.2	36.8	37.5	**295.5**	97.8	0.0	0.02	0.0	**0.6**	**52.1**	0.00
JIRAMA	Max.	**541.0**	1496.9	209.6	**164.0**	**1956.1**	**1146.6**	0.1	**0.46**	0.0	**2.7**	46.1	0.00
	Ave.	**368.0**	702.2	110.8	**120.5**	**988.7**	**442.6**	0.0	**0.14**	0.0	**1.1**	13.5	0.00
Coastal	Max.	**1487.0**	3206.2	**800.0**	**551.6**	**4948.7**	**1972.0**	0.3	**0.11**	0.0	**3.0**	5.3	0.00
	Ave.	**779.9**	1410.0	**293.1**	**183.3**	**2370.1**	**576.1**	0.1	0.04	0.0	**1.1**	2.8	0.00
Surface water	Max.	131.8	441.6	175.2	138.5	**947.9**	**406.4**	0.1	**1.34**	**28.0**	**1.8**	6.2	0.00
	Ave.	53.7	67.5	41.5	33.7	102.0	49.6	0.0	**0.21**	**2.8**	**0.2**	0.6	0.00

note) Madagascar Standard: Law No. 2003-941, modified No. 2004-635
WHO Standard: Guidelines for drinking water quality (The values in *italic* are values for "substances and parameters in drinking-water that may give rise to complaints from consumers)
Bold: data above the Madagascar Standard

The substances and parameters which were over the standard in wells of Ambovombe are EC, Mg, Cl, SO4, Fe and NO2. However, considering that the WHO does not set standard for Ca and Mg, and the WHO standard for NO2 is 30 times of that of Madagascar, and the standard for Cl and SO4 are standard for "complaints from consumers", here we can say that EC and NO3 is the most critical substance to take note of. Taking this into consideration, only substance which to take note of in using the groundwater in this area is EC, which, even the average value in Ambovombe is way over the Madagascar Standard. The water of coastal area is mainly used for cattle and not for drinking because of too high a saline condition.

To be safe, the water in Antanimora area is more suitable for drinking than in any other areas.

3.8 Test Well Drilling

3.8.1 Plan of Test Drilling

(1) Selection of Sites

The location was selected to obtain the following objectives:

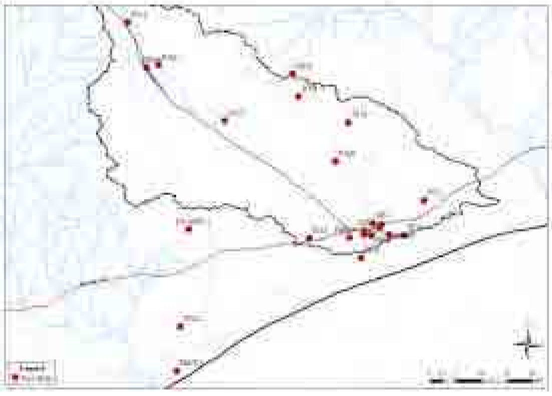
- Confirmation of static water level as well as depth of aquifer
- Distribution and detail characteristic of water quality (in particular salinity) for drinking purpose
- Confirmation of the depth of basement rock associating with the potential aquifers
- Find the location of the possible source well in consideration of the water supply plan

Table 3.8.1-1 shows program of the test drilling of this study. Test well comprises of hand dug well, boreholes (Type-I and Type-II) and additional boreholes.

Table 3.8.1-1 Original Program of the Test Drilling

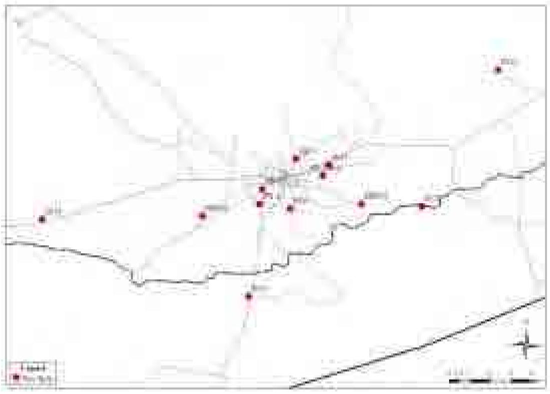
No	Commune	Village	Situation	Target Depth(m)
Hand Dug Wells (25m depth)				
P 003	Sihanamaro	Ambalantsaraky	Upstream center basin	25
P 004	Ampanihy	Ambohimalaza	Upstream center basin	25
P 008	Betioky	Ambohimalaza	Center basin	25
P 009	Ambovombe	Marobey	Ambovombe	25
P 010	Ambondro	Analaisoke	West basin	25
			Sub-Total	**125**
Type-I Boreholes (50-100m depth)				
FM 001	Antaritarika	Maroafo	Coastal sector	100
PM 005	Ambovombe	Lavaadranda	Ambovombe south dune	50
PM 006	Tsimananada	Tsimihevo	Ambovombe south dune	50
			Sub-Total	**200**
Type-II Boreholes (80-200m depth)				
F 001	Antanimora	Fianrenantsoa-Amposy	Upstream sector basin	80
F 006	Antanimora	Bemamba Antsatra	Upstream sector basin	120
F 009	Ambovombe	Lefonjavy	Oriental upstream basin	100
F 014	Ambovombe	Ankoba-Mikazy	Oriental Center of basin	120
F 015	Ambovombe	Mangarivitra Tananbao	East of Ambovombe	150
F 018	Ambanisalika	Ambanisarika	West of Ambovombe	200
F 019	Ambovombe	Ambazozmirafy	Ambovombe southern dune	200
F 022	Antaritarika	Anjira	South west coastal dunes	120
F 030	Ambovombe	Ekonka	South of Ambovombe	200
F 032	Ambovombe	Behaboobo	East of Ambovombe	200
			Sub-Total	**1,490**
Additional Boreholes (30-100m depth)				
F 006B	Antanimora	Bemamba Antsatra	Upstream of basin	Appraisal of F006
FP 010	Ambondro	Analaisoke	Oriental upstream basin	Appraisal of P010
NBASE1	Ambovombe	AnjatakaIII	Vovo in Ambovombe	Shallow aquifer
NBASE2	AnjatakaIII	AnjatakaIII	Vovo in Ambovombe	Shallow aquifer
NBASW1	Mitsangana	Mitsangana	Vovo in Ambovombe	Shallow aquifer
NBASW1	Ambaro	Ambaro	Vovo in Ambovombe	Shallow aquifer
NBANW	Beabo	Beabo	Vovo in Ambovombe	Shallow aquifer

Test points were selected at the end of Phase I to clarify objectives referring result of inventory survey, and old record and study reports. The exact position was decided at Phase II. The position of test holes are summarized below:



Note: GPS data plot

Figure3.8.1-1 Site location map



Note: GPS data plot

Figure 3.8.1-2 Site location map in Ambovombe urban

(2) Methodology

1) Drilling

Drillings were executed by rotary drill with polymer mud where there was sediments formation, and by DTH at hard rock areas.

2) Equipment for dug wells

The 25 m depth wells on average were dug in diameter of 1,500mm and were equipped by a cement lining with diameter 1,200mm X 1,000mm. Figure 3.8.1-3 shows typical drawing of boreholes and hand dug wells.

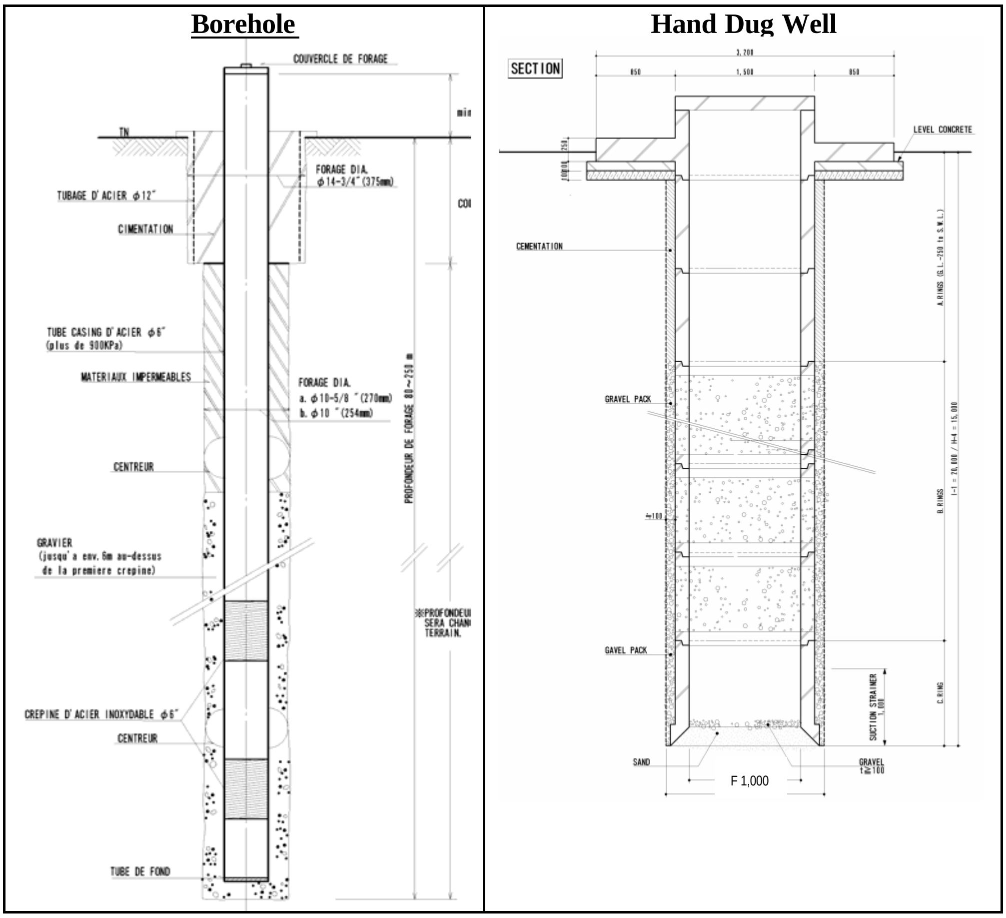


Figure 3.8.1-3 Typical drawings for the Test Well

3) Logging

a) Foramtion evaluation

At the end of drilling, logging was conducted. Equipment used for logging is the newly purchased equipment from CENTURY, which is an American company.

b) Water quality profiling of aquifer

Once the casing installed and mud was cleaned by air-lift, a water quality profiling was conducted to measure the following elements: Manufacturer of this tool is the In-site Company, model is TROLL9000.

4) Pumping Tests

All of the dug wells and boreholes were subjected to pumping test. A step drawdown test allows identifying the characteristic s of the aquifer, for example, change of drawdown with function of the yield.

5) Analysis of the quality of water

During the test, Electric conductivity, temperature, and pH were monitored at the well site.

At the end of the pumping test, water was sampled for analysis of the 17 elements. Analysis was conducted by the JIRAMA.

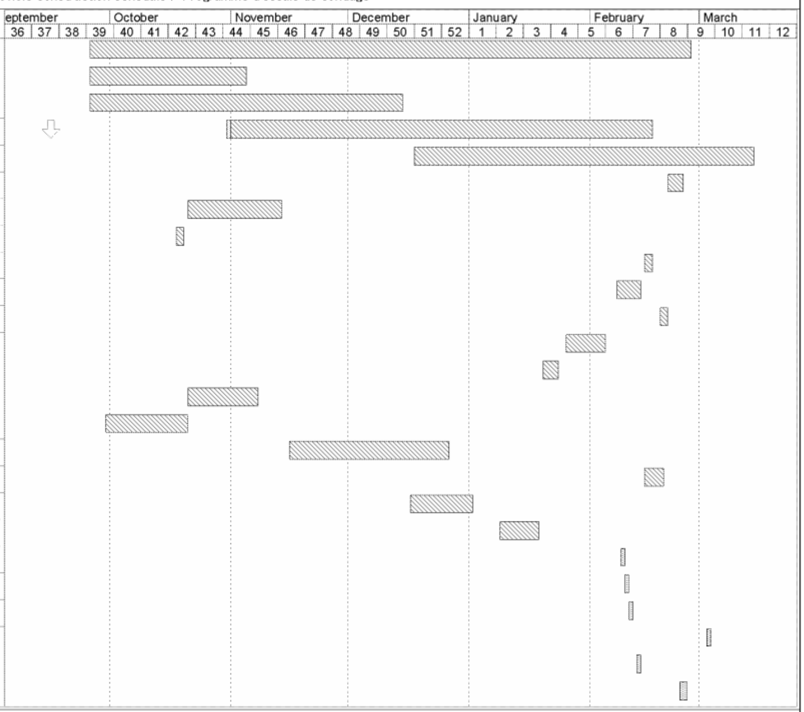
3.8.2 Result of test Drilling

(1) Summary of execution

The execution drilling was as following figure. Period of the work differed among sites because hole stability was depending on he sites. The most difficult sites are PM005, F019 because hole corruption had occurred and needed to drill another holes.

Test hole construction schedule / Programme d'essais de sondage

ID	Site ID	Duration	Start	Finish
1	P 003	154 days?	Mon 05/09/26	Sun 06/02/26
2	P 004	40 days?	Mon 05/09/26	Fri 05/11/04
3	P 008	80 days?	Mon 05/09/26	Wed 05/12/14
4	P 009	55 days?	Sun 05/10/30	Fri 06/02/17
5	P 010	87 days?	Sun 05/12/18	Tue 06/03/14
6	FM 001	4 days?	Tue 06/02/21	Fri 06/02/24
7	PM 005	24 days?	Fri 05/10/21	Sun 05/11/13
8	PM 006	2 days?	Tue 05/10/18	Wed 05/10/19
9	F 001	2 days?	Wed 06/02/15	Thu 06/02/16
10	F 006	6 days?	Wed 06/02/08	Mon 06/02/13
11	F 006B	2 days?	Sun 06/02/19	Mon 06/02/20
12	F 009	10 days?	Thu 06/01/26	Sat 06/02/04
13	F 014	4 days?	Fri 06/01/20	Mon 06/01/23
14	F 015	18 days?	Fri 05/10/21	Mon 05/11/07
15	F 018	21 days?	Fri 05/09/30	Thu 05/10/20
16	F 019	41 days?	Wed 05/11/16	Mon 05/12/26
17	F 022	5 days?	Wed 06/02/15	Sun 06/02/19
18	F 030	16 days?	Sat 05/12/17	Sun 06/01/01
19	F 032	10 days?	Mon 06/01/09	Wed 06/01/18
20	SE1	1 day?	Thu 06/02/09	Thu 06/02/09
21	SE1	1 day?	Fri 06/02/10	Fri 06/02/10
22	SW1	1 day?	Sat 06/02/11	Sat 06/02/11
23	SW2	1 day?	Fri 06/03/03	Fri 06/03/03
24	FP010	1 day?	Mon 06/02/13	Mon 06/02/13
25	NE	2 days?	Fri 06/02/24	Sat 06/02/25



1/1

Figure 3.8.2-1 Progress of the Test Drilling

The principal data are summarized in the table below. The detailed report submitted by the drillers is attached in the databook and supporting report.

Table 3.8.2-1 Summary of execution

ID	Village	Altitude			Drill work		drill depth	casing	Development		
		point	drill	SWL	Start	Comp-let	(m)	(m)	Qf m^3/h	µS/cm	NS m
	Dug wells										
P 003	Ambalantsaraky	161	140.75	141.56	26-Sep-05	27-Feb-06	20.3	20.25	NA	NA	NA
P 004	Ampanihy	162	158.3	NA	26-Sep-05	5-Nov-05	3.7	3.7	NA	NA	NA
P 008	Betioky	138.3	113.3	NA	26-Sep-05	15-Dec-05	25	25	NA	NA	NA
P 009	Marobey	130	109.79	110.69	30-Oct-05	17-Feb-06	20.2	20.21	NA	NA	NA
P 010	Anlaisoka	130	109	<109	18-Dec-05	15-Mar-06	21	15	NA	NA	NA
	Boreholes										
FM 001	Maroafo	82.82	-17.18	2.08	21-Feb-06	25-Feb-06	100	96.84	1.8	10,000	80.8
PM 005	Lavaadranda	211	129	< 129	21-Oct-05	14-Nov-05	82	81.65	<0	2,550	< 80
PM 006	Tsimihevo	156.1	104.96	< 104.96	18-Sep-05	20-Oct-05	51.1	50.69	0	NA	< 51
F 001	Fianrenantsoa-Amposy	292.13	212.13	276.13	15-Feb-06	17-Feb-06	80	67.74	9	1,460	16
F 006	Bemamba-Antsatra	228.17	150.17	212.22	8-Feb-06	14-Feb-06	78	75.76	9	730	15.98
F 006B	Bemamba-Antsatra	234.23	171.08	219.93	19-Feb-06	21-Feb-06	63.2	61.82	9	1,140	-
F 009	Lefonjavy	179	97	130.65	26-Jan-06	5-Feb-06	82	78.48	0.06	2,820	56.73
F 014	Ankoba-Mikazy	181	56.82	79.85	20-Jan-06	24-Jan-06	124.2	120.3	2.18	5,040	101.23
F 015	Mangarivotra Tananbao	140.12	-9.88	6.08	21-Oct-05	8-Nov-05	150	150	1.74	4,620	134.1
F 018	Ambanisarika	203.4	3.4	50.45	30-Sep-06	21-Oct-05	200	199.8	0.08	15,240	164
F 019	Ambazozmirafy	220	17	<17	16-Nov-05	27-Dec-05	203	189.5	< 0,1	2,870	179
F 022	Anjira	77.8	-48.2	19.00	15-Feb-06	20-Feb-06	126	114.5	2.01	3,780	60
F 030	Ekonka	180	-25	4.46	17-Dec-05	2-Jan-06	205	188.1	<0.02	2,760	181.4
F 032	Behabobo	229	24	< 24	9-Jan-06	19-Jan-06	205	193.3	<0.02	3,400	191.77
	Shallow boreholes										
SE1	Anjatoka III	130	86	< 86	9-Feb-06	10-Feb-06	44	NA	NA	NA	NA
SE1	Anjatoka III	130	106	< 86	10-Feb-06	11-Feb-06	24	24	<0.02	3,060	19.98
SW1	Mitsangana	130	97	107.65	11-Feb-06	12-Feb-06	33	30.3	< 0.01	6,650	23.4
SW2	Ambaro	130	106	< 106	3-Mar-06	4-Mar-06	24	20.32	<0.01	2,350	NA
FP010	Analaisoka	130	99	<99	13-Feb-06	14-Feb-06	31	30.16	<0.01	770	NA
NW	Beabo	130	111	<111	24-Feb-06	26-Feb-06	19	15.9	<0.01	1,245	NA

Estimated (shaded cells)
Altitude of SWL is claculated as point - SWL of pumping test

The groundwater potential was found only in Antanimora (F001, F006, F006B) and Ambovombe (F015). In the other area groundwater is low potential due to salinity or dry wells.
Potential in Pre Cambrian area were confirmed as about 500 to 600 m^3/day/well. The elevation of the successful boreholes is about 250m to 300m above mean sea level against the Ambovombe urban of about 150m . It enables to supply water by gravity from Antanimora.

Potential at sedimental area is at the only F015 which has a discharge of 18m^3/hr with EC 320 mS/m, to be possible utilizing as a water source for Ambovombe urban and surroundings, whose population is about 40,000. However, the static water level was 132m of unconfined aquifer, and water quality is a little saline as electric conductivity is 320mS/m which is the limit of Madagascar water quality standard.

Therefore, the water supply plan was needed to be considered based on water source at the two areas, namely Antanimora, and Ambovombe.

3.8.3 Evaluation of Test Wells

(1) Confirmed result

The study provides new information in the view of hydrogeology at the basin of Ambovombe. That information makes enable to revise strategy of groundwater development.

① Confirmation of existence of aquifer. Type of aquifers are (i) an aquifer at near sea level (ii) a perched aquifer at Ambovombe (iii) a perched aquifer at near Ambaliandro (iv) Aquifer in the hard rock

② Confirmation of the strong salinity in the subsoil by checking change of conductivity of drilling mud and experiment of solving cuttings in the water.

③ Decantation of high salinity water at the depth of near sea water level of the downstream of the basin

④ Aquifer near sea level, which is not so saline and permeable, exist at the eastern rim of Ambovombe.

⑤ Permeability of aquifer mostly is not good although formation is consisted with sand deposit.

⑥ Calcareous sand have distribution from surface to near sea level, for example, 200m depth at the downstream of basin and coastal dune.

⑦ Confirmation of very permeable aquifer, that was proposed as a karstic nature of groundwater circulations (assumption was submitted in 1955 by J Archambault of Burgéap Bureau) in the conglomerates and sandstone of Neocene Continental of the central part of the basin and in the marine molasses and quaternary calcareous sandstones of the downstream part. F015 shows that characteristics.

⑧ Confirmation of the structure of "mille feuilles (thin interlayers) " at shallower formation of Ambovombe described by J.H. Rakotondrainibe. That was represents as existence of clay impermeable formation to retain water.

⑨ New information of the limits of the perched aquifers of Ambovombe at the south-east in the south-west of the city by the three test drilling.

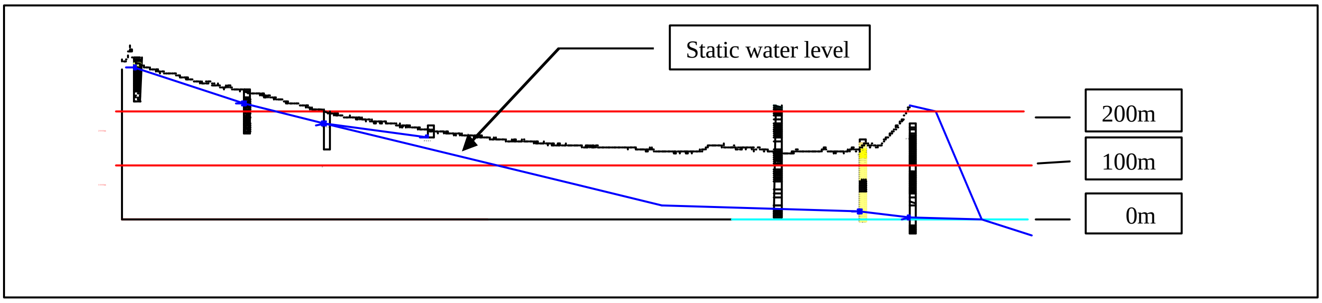


Figure 3.8.3-1 Sturcutre of basin and Static water level (Refer to Fig.3.8.4-3 enlarged drawing)

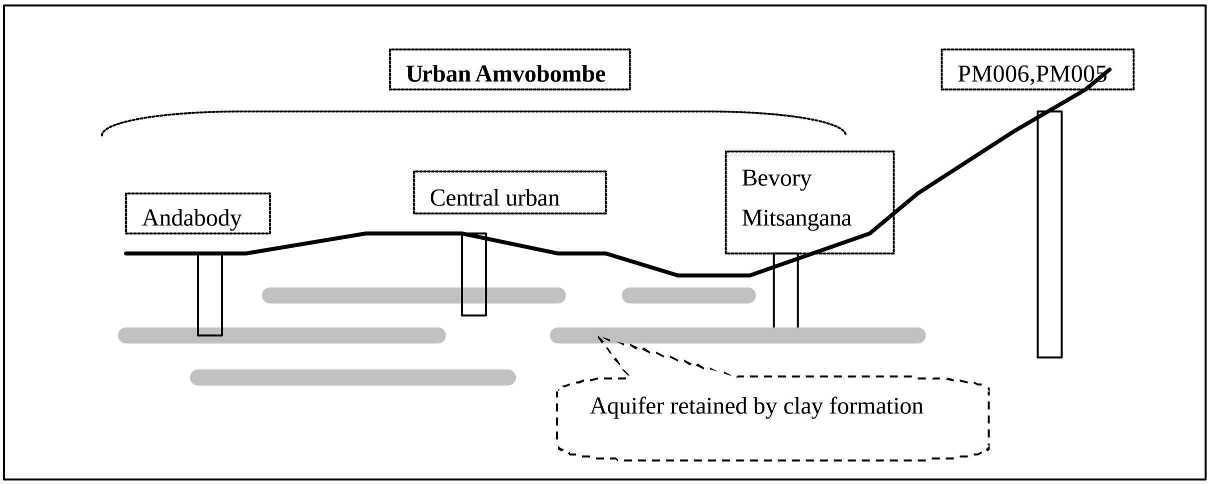


Figure 3.8.3-2 Extension of perched aquifer

(2) Estimated Groundwater Development Area

Location map of the distinguished groundwater

Referring result of test drilling and water source inventory, the groundwater in the study area can be summarized as follows

① Aquifer around Bemamba
② Aquifer around Antanimora
③ Aquifer around Imongy
④ Aquifer in the sediments along Mananbovo river
⑤ Perched aquifer around Ambondro
⑥ Perched aquifer in Ambovombe with high salinity
⑦ Perched aquifer in Ambovombe with low salinity
⑧ Deep aquifer in Ambovombe with lower salinity as 3,000μS/cm
⑨ Perched aquifer around Ambaliandro with high salinity
⑩ Aquifer of which static water level is depending on pressure gradient from the sea. Salinity is high as nearly 10,000μS/cm (Aquifer in the sediments at the most of the part of the basin , not indicated at the map below)

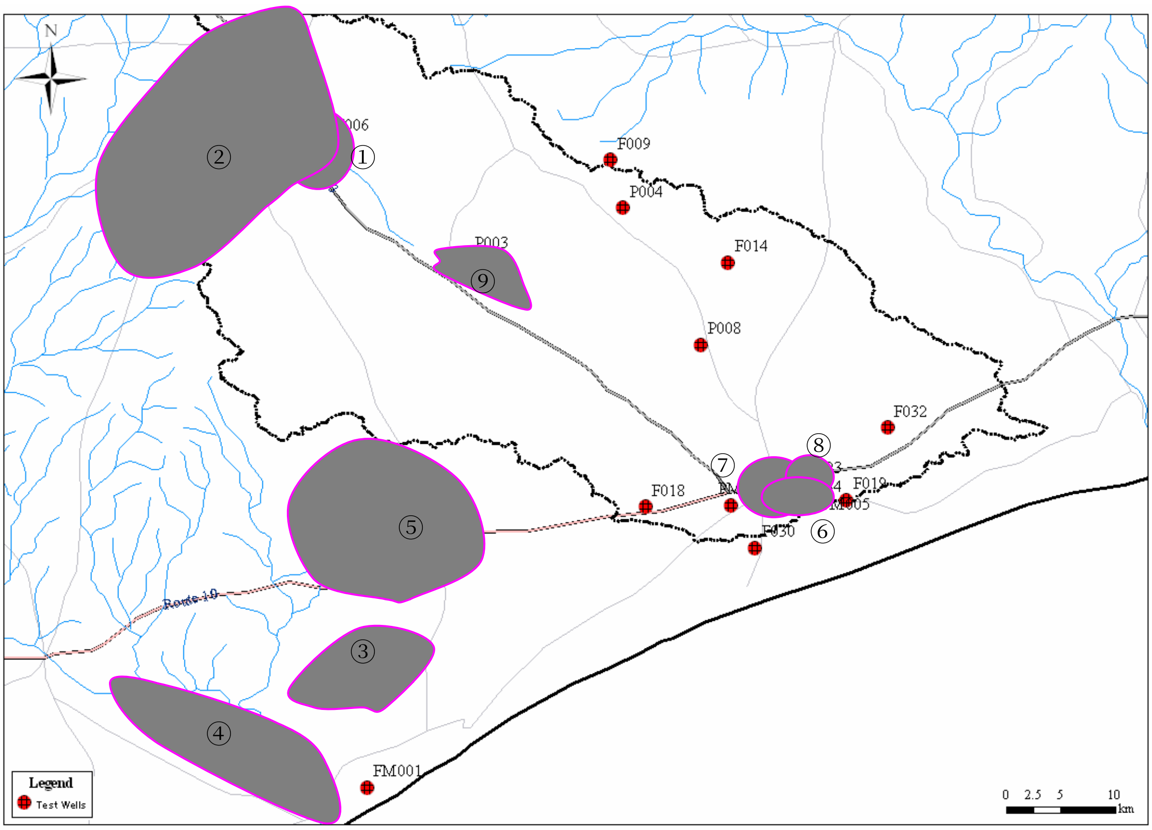


Figure 3.8.3-3 Location map of the distinguished groundwater

3.9 Water Quality Profiling Survey

To understand water quality distribution within the study area is essential to evaluate potential of water resources of the targeted area. In the Study, vertical distribution and time-series fluctuation of water quality of groundwater was observed. This chapter describes the results of these survey.

3.9.1 Vertical Profiling of Water Quality

(1) Objective

Objective of water quality profile survey is to observe vertical distribution of groundwater quality within the study area. The survey was conducted in the middle of March, 2006 using potable water quality profiling probe (MP TROLL 9000).

Through the survey, electric conductivity, temperature was measured at the selected wells together with water pressure which was used to estimate measured depth of the probe.

(2) Surveyed Points

Figure 3.9.1-1 shows location map of surveyed points within study area. As shown in the figure, 12 points are selected for this survey. Out of 12 points, 11 points are selected from test wells which were drilled through this study. And 1 point is selected from existing wells within the study area to get information of the area without any test well. Table 3.9.1-1 summarizes the list of surveyed points.

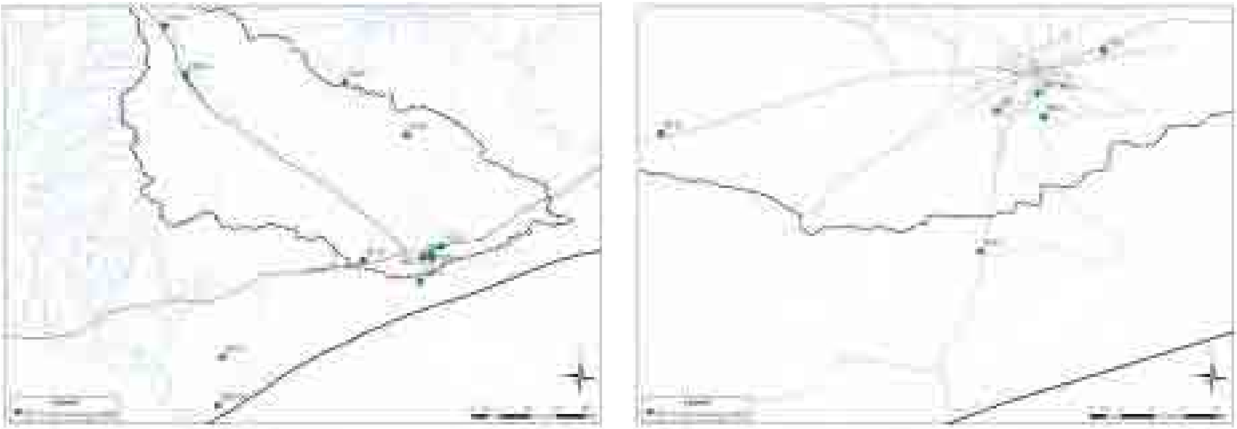


Figure 3.9.1-1 Location map of Surveyed Points

Table 3.9.1-1 List of Surveyed Points

No.	Well No.	Commune	Depth (m)	GWL (m)	Remarks
1	P009	Ambovombe	21	19.5	Test Well (Dug Well)
2	F001	Antanimora	80	16.9	Test Well (Borehole)
3	F006b	Antanimora	63	14.4	Test Well (Borehole)
4	F009	Ambovombe	82	48.3	Test Well (Borehole)
5	F014	Ambovombe	124	101.2	Test Well (Borehole)
6	F015	Ambovombe	153	134	Test Well (Borehole)
7	F018	Ambanisarika	202	152.9	Test Well (Borehole)
8	F022	Antaritarika	126	58.8	Test Well (Borehole)
9	F030	Ambovombe	205	181.4	Test Well (Borehole)
10	FM001	Antaritarika	100	80.7	Test Well (Borehole)
11	SW-1	Ambovombe	33	23.3	Test Well (Borehole)
12	AES No.2	Ambovombe	22	20.3	Existing Well

(3) Results of the Profiling

Figure 3.9.1-2 shows results of measured electric conductivity for the selected 12 points. From the Figure 3.9.1-2, there are two types of the profile of electric conductivity at the measured points. The first type

(P009, F001, F006b, F009 and F014) indicates stable profile of electric conductivity from the top to the bottom of measured level. On the other hands, the second type (F015, F018, F022 F030, FM001, SW-1 and AES No.2) indicates gradual increasing of electric conductivity in accordance with the measured depth. Measured electric conductivity at the points in Antanimora area (F001, F006b) indicates lower value, less than 200 mS/m. And measured electric conductivity at the points in the middle of Ambovombe basin (F009 and F014) indicates higher value, from 500 to 1,000 mS/m. Then measured electric conductivity at the points in coastal area (FM001, F018 and F022) indicates very high value, more than 1,000 mS/m. However measured electric conductivity at the well F015 and F030 indicates rather low value even they are located near coastal area. All the measured electric conductivity at the shallow wells (P009, SW-1 and AES No.2) indicates from lower value, around 200mS/m to rather higher value, around 600 mS/m.

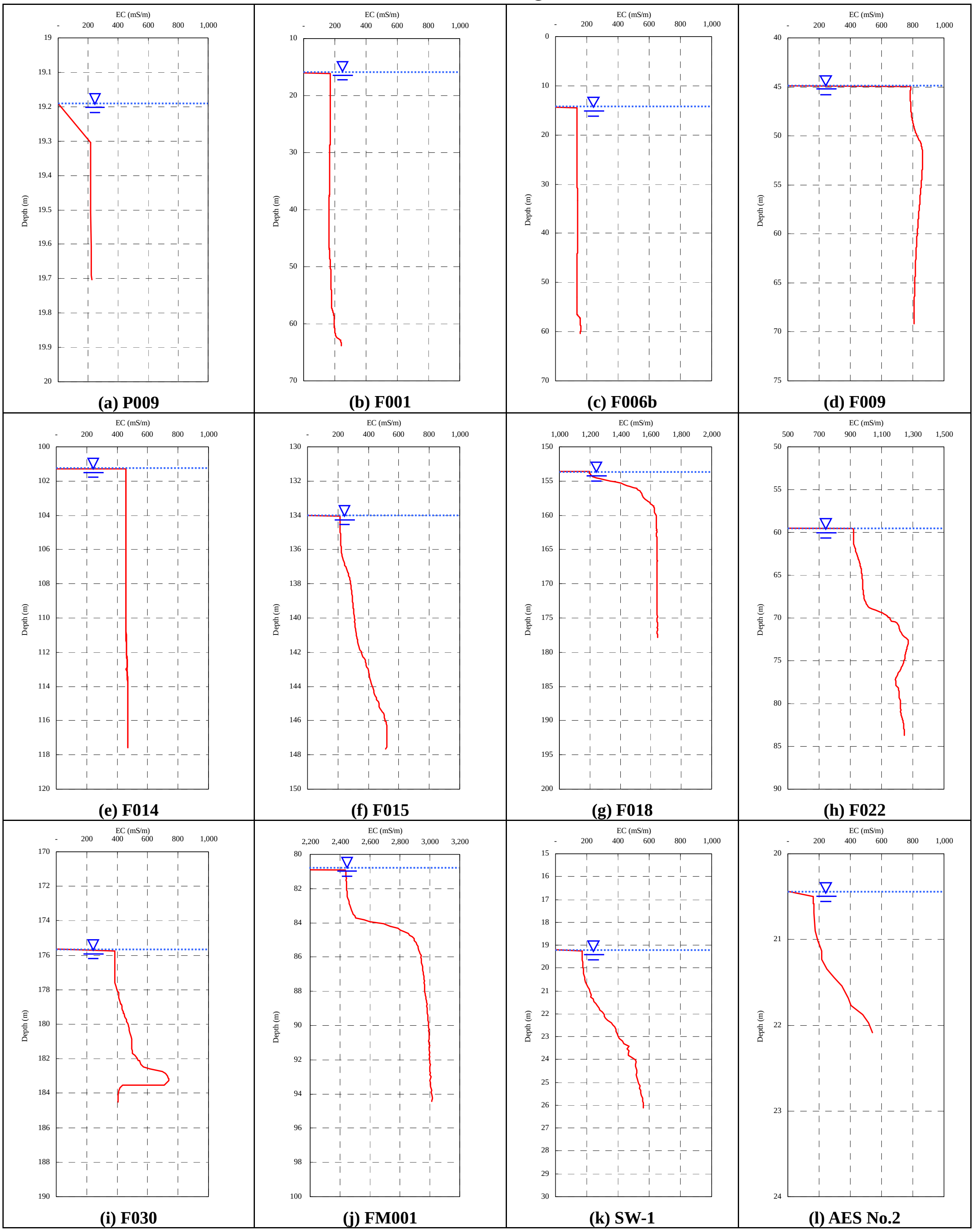


Figure 3.9.1-2 Results of vertical profiling

(4) Discussion

Figure 3.9.1-3 shows location map of surveyed points at coastal area (F015, F030, FM001 and F022).

Figure 3.9.1-4 shows comparison of measured electric conductivity data between the well FM001 and F022 and between the well F015 and F030.

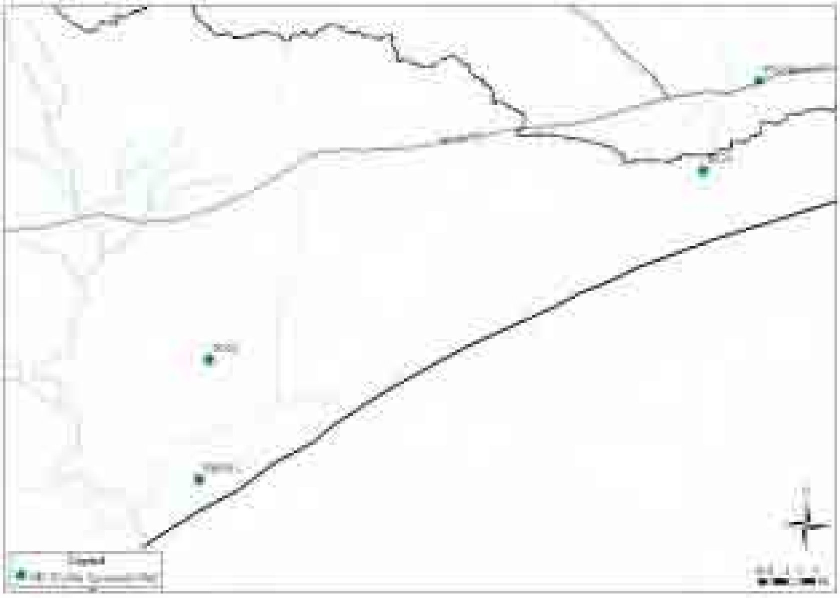
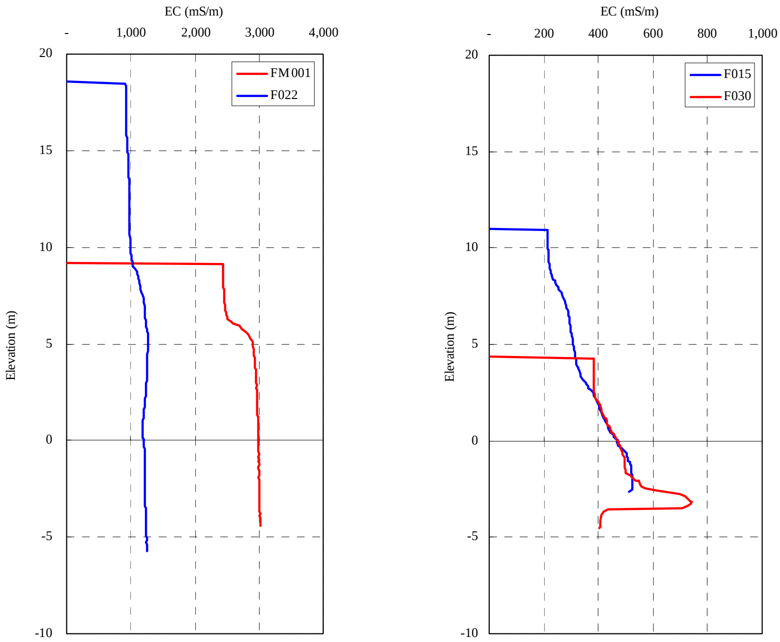


Figure 3.9.1-3 Location map of surveyed wells at coastal area



FM001 and F022 F015 and F030

Figure 3.9.1-4 Comparison of measured electric conductivity data

From the Figure 3.9.1-4, comparison between FM001 and F022, there is no continuity of water quality between these wells and measured electric conductivity of FM001 is three times higher than the data of F022. This result indicates the situation of saline water intrusion at the location of well FM001.

From the Figure 3.9.1-4, comparison between F015 and F030, there is continuity of water quality between these two wells and there are lower electric conductivity layer from the elevation of 5 to 10m at the top of the well F015.

This result indicates that electric conductivity is almost same value from the points of the well F015 to the points of the well F030 at the deeper part. Then lower electric conductivity layer locate above the deeper part around the points of F015. This lower electric conductivity layer may be created by the direct infiltration of fresh water from the ground.

3.9.2 Time-Series Monitoring of Water Quality

(1) Objective

Objective of time-series monitoring of water quality survey is to observe seasonal fluctuation of water quality. The monitoring has been conducted from the middle of March, 2006 using the same equipment as used in the vertical profiling survey (MP TROLL 9000).

Through the survey, electric conductivity, temperature was measured together with water pressure which was used to estimate water level.

(2) Monitoring Points

Table 3.9.2-1 summarizes the list of surveyed points. As shown in the table, 3 points are selected for this survey. Out of 3 points, 2 points are selected from test wells which were drilled through this study. And 1 point is selected from existing wells within the study area to get information of the area without any test well.

Table 3.9.2-1 List of Monitoring Points

No.	Well No.	Commune	Depth (m)	GWL (m)	Remarks
1	P009	Ambovombe	21	19.5	Test Well (Dug Well)
2	F015	Ambovombe	153	134	Test Well (Borehole)
3	AES No.2	Ambovombe	22	20.3	Existing Well

(3) Results of the Profiling

Figure 3.9.2-1 shows results of monitoring of water quality for the selected 3 points.

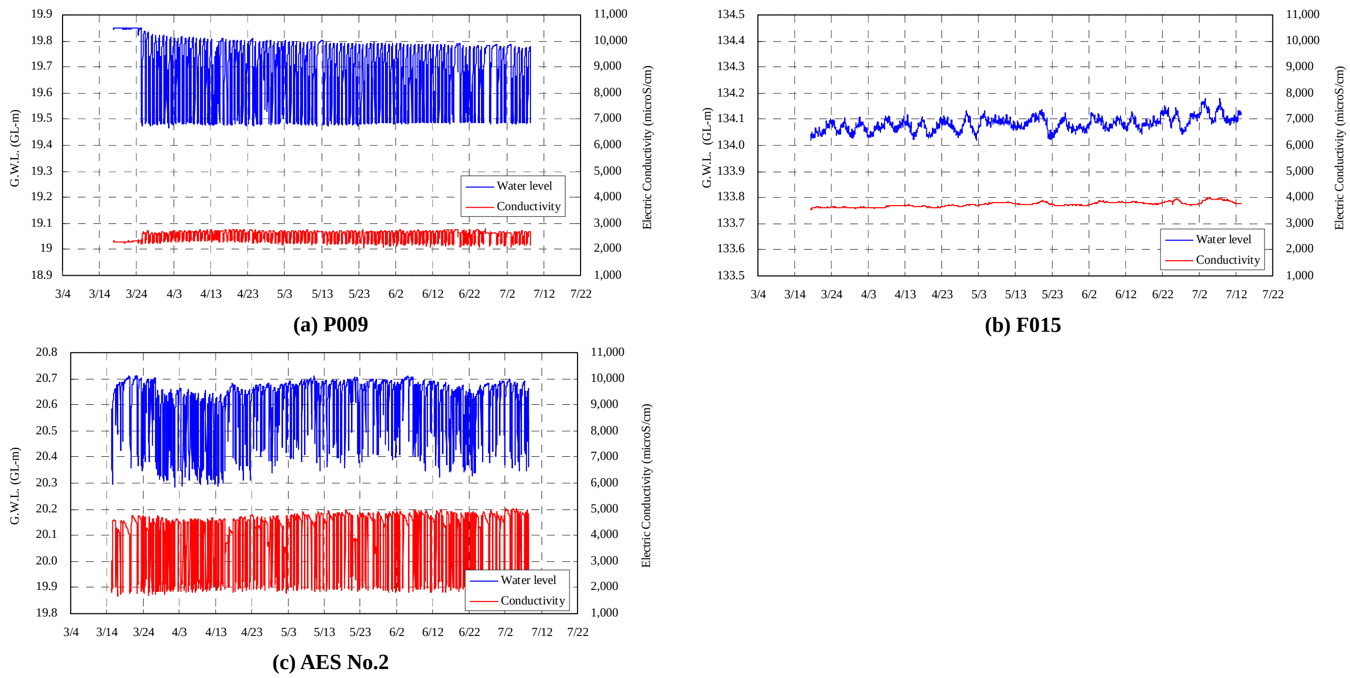
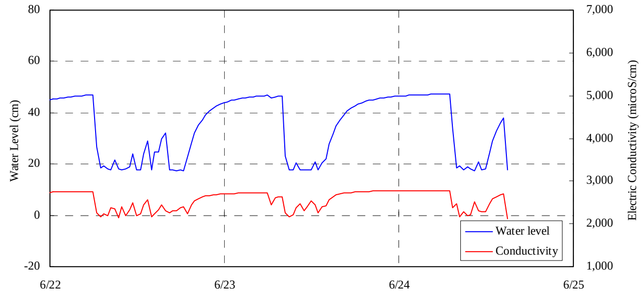


Figure 3.9.2-1 Results of monitoring

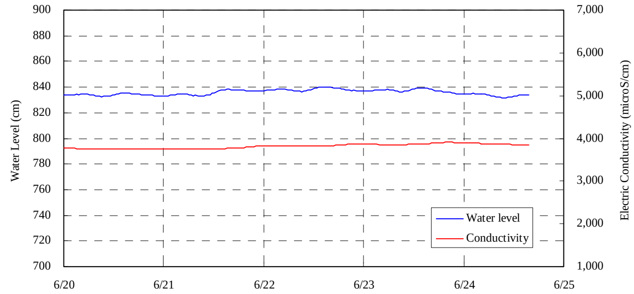
At the well P009 and AES No.2, water pump is installed and there is daily exstraction of groundwater from them. Therefore there is drastic change of water level. On the other hand, there is no water exstraction at the well F015. There are apparent relationships between fluctuation of water level and electric conductivity at the well P009 and AES No.2. However there is no apparent relationship between water level and electric conductivity at the well F015.

(4) Discussion

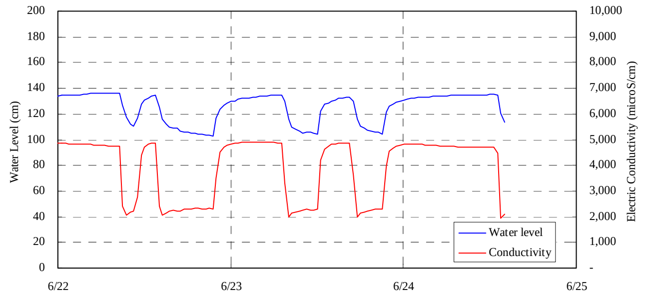
Figure 3.9.2-2 shows enlarged data, from 22 to 25 of June, 2006, of monitoring data for the selected 3 points together with the results of vertical profiling.



(a) P009



(b) F015



(c) AESNo.2

Figure 3.9.2-2 Enlarged monitoring data

From the Figure 3.9.2-2, the relationship between water level and electric conductivity is clear at the well P009 and AES No.2. There is synchronicity of fluctuation between water level and electric conductivity and electric conductivity value goes down while water level goes down.

This data indicates there is inflow from lower electric conductivity layer to the deeper layer while pumping.

****

CHAPTER4 SURVEYS AND ANALYSIS FOR SOCIO-ECONOMIC CONDITION

4.1 Outline of the Surveys

In order to understand the diverse situations of water use in the basin of Ambovombé and its socio-economic background, a baseline survey and a socio-economic condition survey were conducted during mid-April and mid-May 2005 by the JICA study team and a team of sub-contracted local NGO. The baseline survey was targeted on responsible persons of administration organizations such as; 15 communes, 329 fokontanys and 1,349 villages located in the study area. The socio-economic condition survey was targeted on members of 359 households living in 70 villages which were selected by the study team.

4.2 Socio-economic Analysis of the Study Area

4.2.1 Economic Condition

Different two levels such as household economy and commune economy were surveyed and analyzed to understand the actual economic condition of the study area.

(1) Household economy
The principal livelihood sources of the study area are cultivation of cassava, maize and sweet potato and niébé (a kind of beans).

Table 4.2.1- Important sources for subsistance

No.	Source	Num villages
1	Cassava	1,037
2	Maize	992
3	Sweet potato	991
4	Niébé (kind of beans)	732
5	Livestock	476
6	Dolique	437
7	Agriculture	277
8	Poultry	168
9	Lentilles (kind of beans)	96
10	Ground nuts	86

Note: Multiple answers
Source: Baseline survey (village survey), JICA study team, 2005

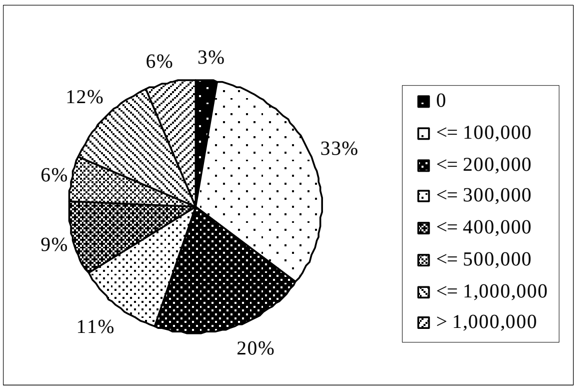


Figure 4.2.1- Annual household income
unit=Ariary, *n=359*

Household income in the study area is at one of the lowest levels in Madagascar. The average annual income of all 359 surveyed households is 549,348 Ar (30,763 Yen), while median and mode are calculated at 199,440 Ar and 200,000 Ar respectively. This means that a household in the study area gains approximately 200,000 Ar (11,200 Yen)as annual income. If simply calculated, this figure is a eighth of 900 US$ which is an estimated PPP of Madagascar at mid-2005 in “The World Fact Book 2006 (CIA)”

As for expenditure for water, a household expenses 17.5% for water form revenue in average. This figure is followed by, food (not available by own production, 12.2%), medical care (8.3%), school fee (5.8%), and transportation fee (4.6%).

(2) Economic Condition of Communes

A commune has her proper budget to function, while fokontany, the lowest administration organ, does not have it. Commune's annual revenue consists of her proper funds which are generally generated by tax and subsidies from the government. Among 11 communes whose data was open, the highest annual revenue in 2004 was 74,679,155 Ar (4,182,023 Yen) in Ambovombé-Androy (though this commune does not receive the subsidies) and the lowest was 11,756,800 Ar (658,381 Yen) in Beanantara.

Almost all amount of the proper funds and subsidy is used for ordinary expenditure. The government subsidy is disbursed to payment of salary for officers and to maintenance cost of communal facilities, while the supplemental subsidy is used for specific purpose. No budget was disbursed to manage or develop water supply system for local people in all communes. Also, it can be said that they have little financial capacity to conduct the water supply services under their responsibility.

4.2.2 Group Activities and Cooperation

Residents of the study area know the group activities for income generation and improvement of living life. Residents' groups have been established in about 30% of all 329 surveyed fokontanys, but almost 60 % were established in recent 3 years (2003 to 2005), which means that they have only short period of experience.

More than half of groups aimed at income generation through their livelihood activities such as agriculture, fishery or livestock-raising. For achieving their missions, more than 40 % of them depend on the *cotisation* (member's contribution) and less than 10% of them depend on the sale of production. Some groups received donation of government or NGO who intervened for local development.

4.3 Present Condition of Water Use in the Study Area

4.3.1 Current Water Sources

(1) Sources for Drinking Water

In 42% surveyed villages people drink water of wells and *vovos* and river water in about 23% surveyed villages. Also, people of about one-sixth surveyed villages drink water of impluvium during the rainy season. Marsh, pond and *bassin* are indispensable water sources especially in the rainy season. Also, in some areas, people buy water from water vendors during dry season. Figure 4.3.1-1 Source of drinking water shows the percentage of water sources used in all villages.

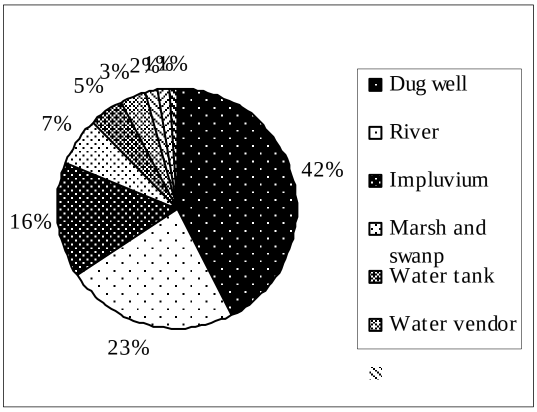


Figure 4.3.1- Source of drinking water

Note: multiple answers *N=1028*

Source: Baseline Survey (village survey), JICA study team 2005

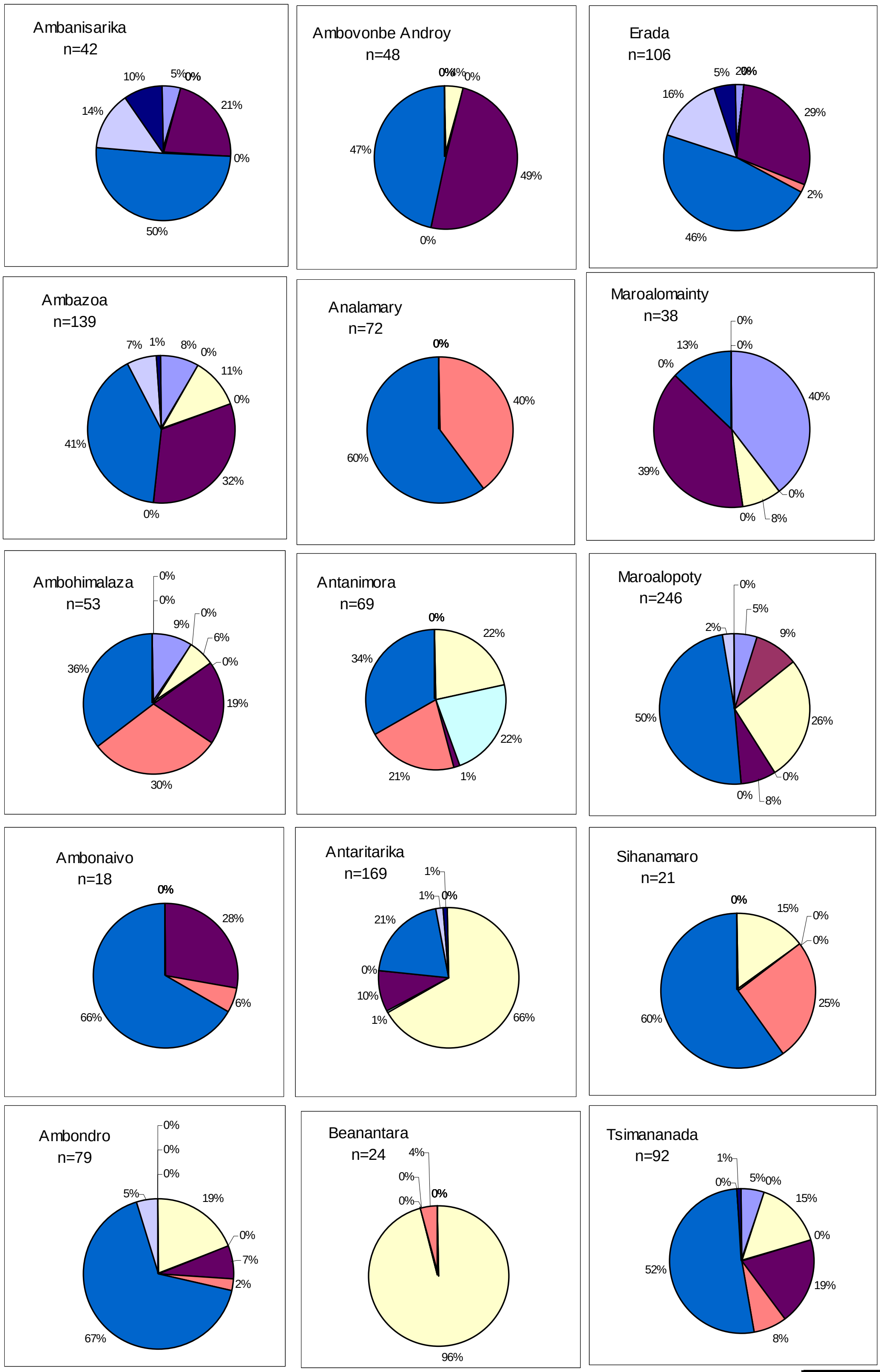
(2) Distribution of Water Facilities

Principal water sources vary from commune to commune. In the communes of the eastern and western boundaries of the study area, Beanantara and Antaritarika, river water is used as a principal water source, on the other hand, well is important in other communes. In villages of the coastal zone (communes of Maroalomainty, Tsimananada, Ambazoa, Erada) and along the Route National 10 (Ambovombé Androy, Ambanisarika, Ambonaivo), impluvium is another important water source. People also purchase water from water vendors in the coastal zone especially in the dry season. For villages of Maroalomainty, it is *bassin* that is the most important before impluvium (though both are used only in the rainy season). In the central and north-western part of the study area (communes of Ambohimalaza, Analamary, Sihanamaro, Antanimora), surface water sources such as pond and marsh are used, some of which are used even in the dry season. Much more people draw water from borehole in Antanimora Commune than in other 14 communes. Figure 4.3.2-1 shows distribution of principal water sources of the study area based on the interview to villages.

4.3.2 Volume of Water Consumption

The result of the household survey indicates that a household draws and consumes 114 litters of water on average every day in the dry season and 108 litters on average in the rainy season. More precisely, median of daily consumption is 60 litters in the dry season and 75 litters in the rainy season, while mode of the all households is 60 litters in both seasons.

When considering of family size, average water consumption per capita is 20 litters in the dry season and 21 litters in the rainy season. If median is applied again, a person consumes 11 litters in the dry season and 14 litters in the rainy season, while mode is 15 litters in both seasons. Even though these figures result from interviews to extracted sample households in 70 villages, it should be considered that actual water consumption unit is to be between 11 and 14 litters per day per capita in the study area. Consumption volume per capita and household is shown in Table 4.3.2.-1.



Légende

Légende	
Water tank	slate blue
Water tanker	dark rose
River	light yellow
Borehole	light cyan
Impluvium	purple
swamp	salmon
Dug well	blue
Water vendor	light blue
Other	navy

Figure 4.3.2-1 Distribution of water facilities per commune

Note: multiple answers

Source: Socio-economic condition survey (village survey), JICA study team, 2005

Note: The number under the graph title indicates that of total surveyed villages and percentage indicates the proportion of each water source used there (multiple answers).

Table 4.3.2- Daily water consumption per household

Unit: liters

Data	Per household		Per capita	
	Dry season	Rainy season	Dry season	Rainy season
Max	3,800	1,350	422	375
Min	0	0	0	0
Average	114	108	20	21
Median	60	75	11	14
Mode	60	60	15	15

Source: Socio-economic condition survey (household survey), JICA study team 2005

4.3.3 Water Charge

(1) Payment and Budget for Water

The result of the household survey indicates that 203 of all 356 interviewed households (57%) do not pay for water. They draw free water from river, pond or marsh even these sources are far from their residences. This fact influences on statistical data of monthly water charge: median and mode are zero Ar even though average monthly water charge is 7,996 Ar.

As for the monthly budget for water, 176 households (49%) replied they could not pay any Ariary for water. The figures of average and mode are almost as same as the actual payment: 7,959 Ar on average and 0 Ar for mode. Only difference is that median is 120 Ar. Distribution of water charge paid by interviewed households and budget for water with statistical data are shown Table 4.3.3- .

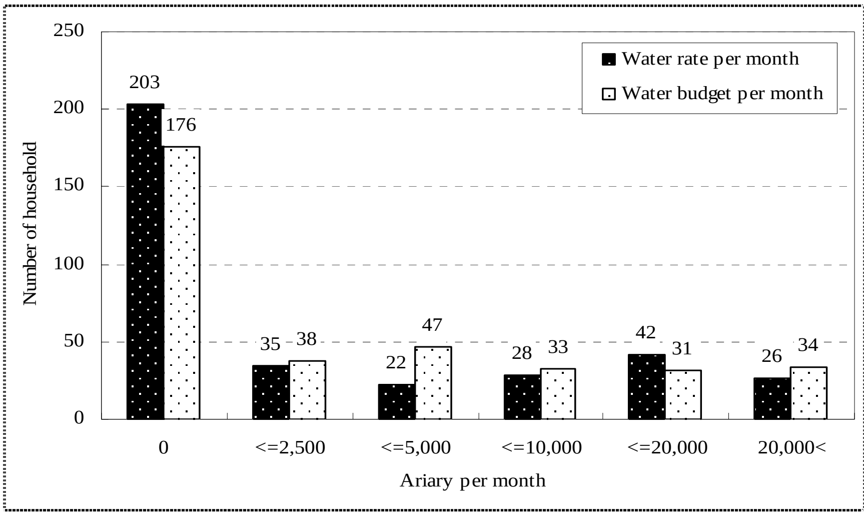
Table 4.3.3- Payment and budget for monthly water charge

Ariary	Payment		Budget		Statistical data	Payment	Budget
	Number of household	%	Number of household	%			
20,000<	26	7.30%	34	9.50%	Max	180,000 Ar	250,000 Ar
10,000< <=20,000	42	11.80%	31	8.60%	Min	0 Ar	0 Ar
5000< <=10,000	28	7.90%	33	9.20%	Average	7,996 Ar	7,959 Ar
2,500< <=5,000	22	6.20%	47	13.10%	Median	0 Ar	120 Ar
0< <=2,500	35	9.80%	38	10.60%	Mode	0 Ar	0 Ar
0	203	57.00%	176	49.00%			
Total	356	100.00%	359	100.00%			

Source: Socio-economic condition survey (household survey), JICA study team 2005

This data indicates that intention of payment is supposed to depend on the actual water charge. And it is a remarkable point for the activity of raising people's awareness about water source management. Figure 4.3.3-1 shows that the number of households who mention not to afford water is smaller comparing to that of households who fetch free water.

Unit: Number of household



Source: Socio-economic condition survey (household survey), JICA study team 2005

Figure 4.3.3- Relation between water charge and budget for water per month

(2) Income and Water Charge

At beginning, it was supposed that there was a strong relationship between income, actual water charge and budget for water at household level. However, meaningful correlation was not found between income and water charge as well as between income and budget. Only between payment and budget, a relatively effective correlation is found: correlation coefficient between them is 0.282. This result means that income is hardly important factor of payment and budget; but rather, budget for water depends on the actual water rate; that is, on the actual water source (structure or natural source). If there is no other option, poor people is forced to purchase expensive water even they reduce expenses for other needs. If there is neither water facilities nor water vendors, people forced to fetch free water to the distant river or marsh even it takes long time.

4.3.4 Classification of Water Sources by Difficulty

Water sources that the residents of the study area use daily were classified by factors of water charge, distance and water quality to understand the difficulty and convenience of the water supply condition.

(1) Unit Price

Water unit price varies greatly. As Figure 4.3.4- 1 shows, out of 1,204 water sources consumed by the residents living in 815 villages, 37% sources are free of charge, while the unit price of more than 30% of sources are 100 Ar or over per bucket of 13 liters.

Residents of the communes Ambanisarika, Ambondro, Analamary and Tsimananada, unit price of more than half of water sources is above 100 Ar per bucket of 13 litters. They have to buy water from water vendors or water truck of AES. On the other hand, in the communes Antanimora, Antaritarika, Beanantara and Sihanamaro, more than half water sources that they use are free of charge. Figure 4.3.4-1 shows the distribution of unit price of water by commune.

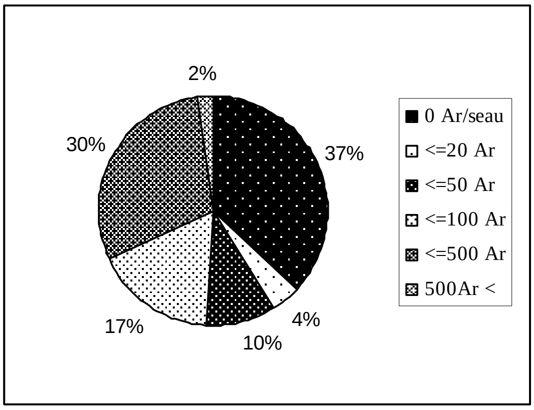


Figure 4.3.4- Unit price of water sources used in the study area ***N=1204***

Source: JICA study team 2006

(2) Distance

It is not so often that residents can get water in their residential area. About half of water sources they use are at the distance of three hours or more on cart or on foot. As Figure 4.3.4-2 shows, about 29 % of existing water sources locate far from residential areas and it is one day work to go there, to draw and go back home, though about 18% of water sources locates within 1 km from residential area.

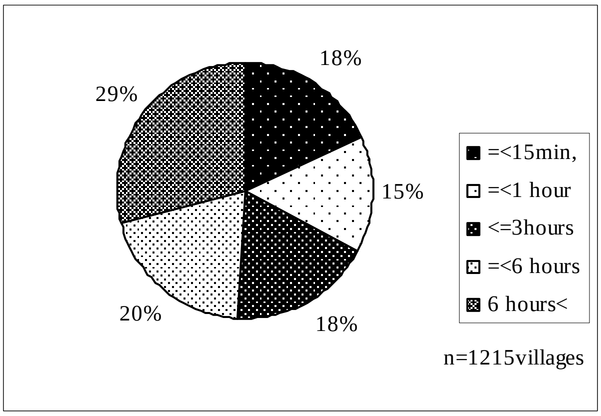


Figure 4.3.4- Distance water sources in the study area ***N=1215***
Source: JICA study team 2006

In terms of distance between residential area and water source, 8 of all 15 communes surveyed have more difficulty in getting water comparing to other 7 communes. Especially Analamary and Beanantara have no water sources that locate within 1 km from residential areas.

(3) Water Quality

The words “water quality” used here does not mean the scientific quality but the sense that the residents feel: it does not mean only muddy water but also means salty water. People regard water of 78% sources where they get water as “good” while the regard water of 22% water sources as “bad” (refer to Figure 4.3.4-3). Comparing with other water sources, water of wells is considered as worse than other source including water of marshes.

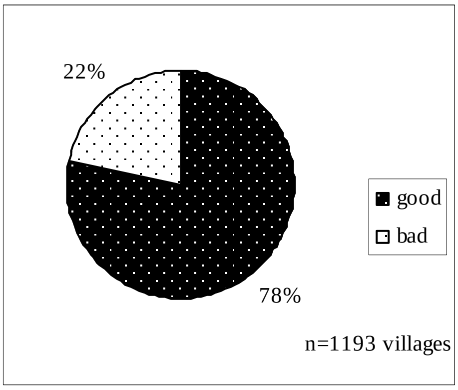


Figure 4.3.4- Water quality in the study area
N=1193 Source: JICA study team 2006

If considering the commune that respondent belong to, all communes except Ambazoa and Tsimananada have a good opinion of the water.

(4) Classification of Communes by Difficulty of Water Use

1,185 water sources used by the residents in the study area that have data were classified by the factors of price and distance to understand geographical distribution of convenience and difficulty of water use. Factor of unit price was divided into four classes: free of charge (0 Ar), 30 Ar or below, 50 Ar or below, and over 50 Ar. 30 Ar per bucket of 13 litters was the average amount that the residents of 14 target villages of the test drilling responded affordable and 50 Ar per bucket was applied here as it was a half of the actual unit price of AES water. Distance factor was divided into three classes: less than 15 minutes, less than 1 hour and over 1 hour. The time of 15 minutes is approximately equivalent to 1 km and implies that the water source locates in the village or in the same fokontany. 1 hour is a time understood a maximum time to fetch water in a day.

Based on this classification, most convenient water sources are supposed at “30 Ar or below and 15 minutes or below”, while more difficult water sources are set at “more than 50 Ar and more than 1 hour”. As Table 4.3.4- shows, there are 89 water sources, or 7.5% of all classified sources, that are classified as the most convenient ones, while 488 water sources, or 41% of all classified sources, are classified as the most difficult ones. If the factor of quality is added to this, the number of the most convenient sources reduces to 80, while that of the most difficult ones reduces to 356.

The percentage of the most difficult water sources is over 50% in the communes on coastal dunes and inland dunes, especially in Maroalomainty and Maroalopoty, no water source is classified as convenient. The percentage of convenient water sources is relatively high in the communes Erada and Ambanisarika: water supply condition of Ambanisarika commune is divided into convenient pole and difficult pole. The percentage of convenient water is also high in Antanimora and Ambovombé Androy.

It needs to mention that residents of a village often draw water from different sources according to the season, financial condition and other reasons. However, it means that they have no stable source of safe water in the study area. The convenience or difficulty of each commune is shown in Figure 4.3.4-4.

Table 4.3.4- Classification of water sources by distance and unit price

Distance	Unit prix				Total
	0 Ar	<=30 Ar	<=50 Ar	50 Ar<	
<=15min (god quality)	*46* *(37)*	*43* *(43)*	52 (51)	67 (65)	208 (198)
<=1heure	*100*	*5*	*33*	35	173
1heure< (good quality)	286 (210)	4 (3)	26 (22)	*488* *(356)*	804 (591)
Total	432	52	111	590	1,185

Source: JICA Study Team 2006

Note: the box at the top-left is the most desirable condition and the box at the bottom-right is the worst condition.

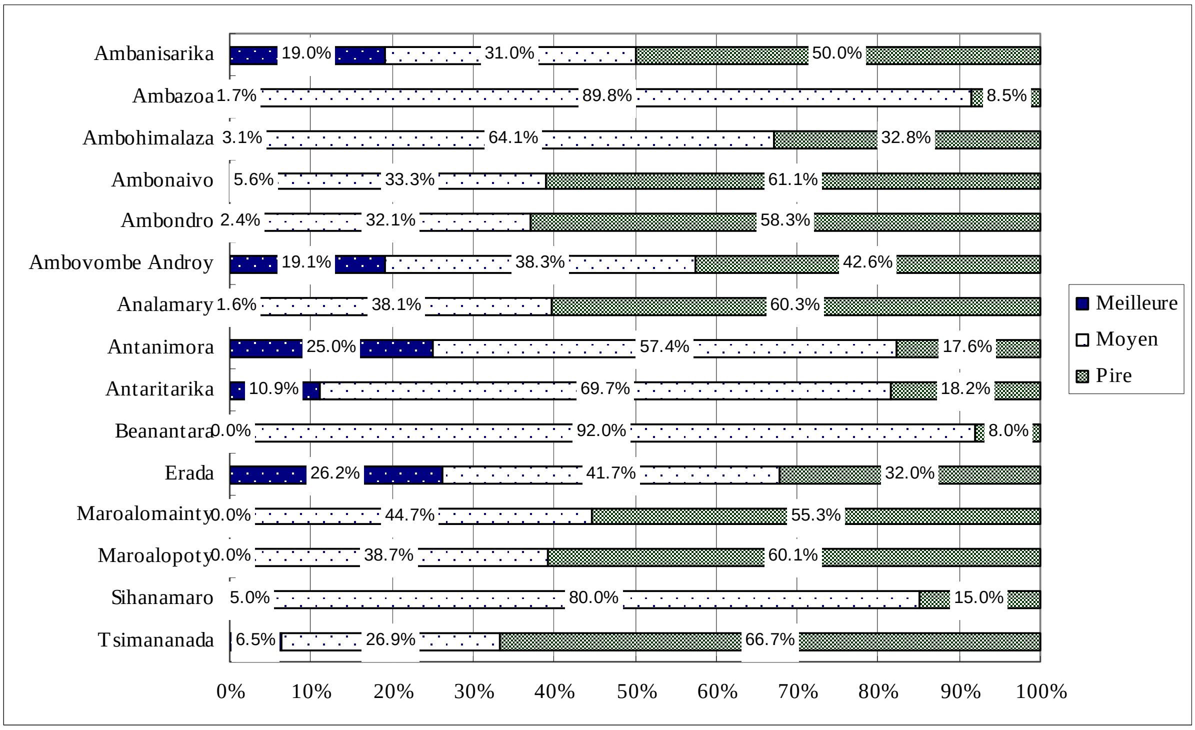


Figure 4.3.4- 4 Classification water sources by commune

N=1185 Source:
JICA study team 2006

4.3.5 Gender Issues in the Study Area

According to the Civil Law of Madagascar, both men and women have the same right and duty. However, people continue to follow the traditional customs which give priority to males at some degree, and this tendency is stronger for Antandroy people than any other place in Madagascar. At inheritance, female's succession is seen in the study area: it is allowed in 1,026 villages of all 1,349 surveyed villages; but primary successors are sons and less possibility are possessed by wife and daughters (especially married daughters). In village meetings, women are generally seated at the back of the meeting place and have little chance to say their opinions, though they participate in the decision making about domestic matters at the household level (refer to Figure 4.3.5-1).

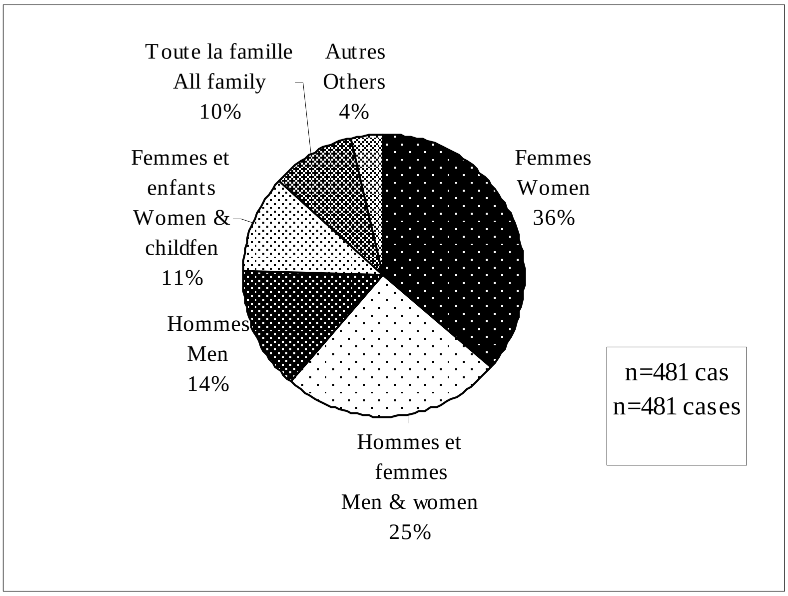


Figure 4.3.5-1 Personne s'occupant de puisage de l'eau
Person in charge of drawing water

Source: Enquête de la condition socio-économique/ Socio-economic condition survey
Equipe de l'étude JICA, 2006

As for the water fetching, women are the first actors of water drawing, but men also work for it. Results of the household survey show that men engage in water fetching in about a half of 481 water fetching cases of 285 households interviewed and 14% of water drawing are done by only men, where as women engage in it in more than 80 %. In about a quarter of cases, children engage in it (Refer to Figure 4.3.5-2).
Means of transportation of water from the water point to houses is different between men and women: men use carts more frequently than women. More than three quarters women of surveyed households go to water points on foot, while almost two-thirds men go there by cart; if men and women go together to draw water, around half of them use cart. This means that men go to further place than women, such as water of rivers or wells of Ambovombe or Ambondro. But it does not mean that women draw water in the water points near by the houses.

Considering these facts, it is supposed that the proposed plans will bring both positive and negative influence on the gender equality.
All proposed plans aim at reducing time used for water drawing. As mentioned above, a lot of men go to distant place to find water by cart. If they find water near to their houses (0.6 to 0.89 km from houses like the case of Bemamba Antsatra=F006), it will women's work to draw and transport water even though it is men's work to go to river or marsh to draw and transport water. In brief, more women may be engaged in water drawing even at nearer water points than actual state.
On the other hand, if women find water nearer than now, it bring an opportunity to women to make groups together to manage water and, if water quantity allows, to start income generation activity using the water. Recently, it is observed that women speak more often and more loudly than before in the villages where women's groups are established and animated by the support of NGOs or donors. Thus, similar effect may

be expected if the new water facilities and water management committees are established as proposed by the plan. At Bemamba Antsatra, just after the new public fountains were constructed as a part of the pilot project of this Study, a woman took initiative to start vegetable cultivation around the facilities and other villages followed her. It may be an example of a good effect of the project.

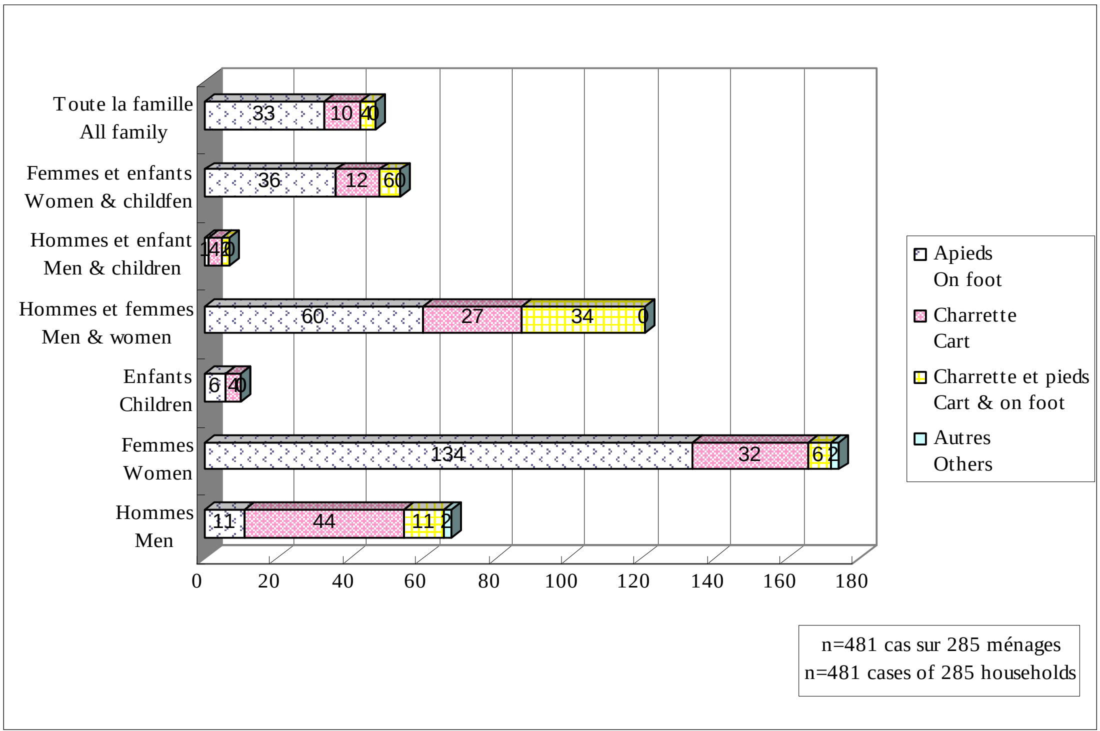


Figure 4.3.5-2 Mode de transport de l'eau / Means of transportation of water

Source: Enquête de la condition socio-économique/ Socio-economic condition survey
Equipe de l'étude JICA, 2006

4.4 Current Method Securing Water

4.4.1 Concerning Utilization of Rainwater

(1) Basic objective of survey

- ➢ Degree of water quality degradation in the rain water collecting system and its effect on the users
- ➢ The state of utilization of chemical additives to sterilize water
- ➢ Utilization of the Proceeds
- ➢ Required number of impluvium at Fokontany
- ➢ Life span of small container for water
- ➢ Repair of concrete tank
- ➢ Duration of utilization
- ➢ State of private water collecting system

(2) Result, observation

1) Water quality degradation

Water in the rainwater collecting system is completed to use within 2 month after starting use. Village people think water keeps its quality in the rain water collecting system.

2) Chemical additives

"SurEau" is commonly sold as chemical additives in Madagascar. This exists at pharmacy and even small shop in the Study area. However, users are limited even at urban Ambovombe. People in the village doesn't utilize although they know it.

3) Utilization of the Proceeds

Water is charged and sales are kept, but village people didn't respond clearly amount of money with them.

4) Required number of impluvium at Fokontany

The existing impluvium are not located at every Fokontany, but at about every 3 Fokontany in average. According to estimation by the Commune, it is estimated two impluvia satisfy consumption.

5) Life span of small 160L-200L container for water

Life time of the barrel type of water container is not short as it can't be identified. That is made of HDPE, originally used as container for engine oil and glycol.

6) Capacity of repairing tank

Village people had several experiences of repairing tank using resources in the commune. That method is plastering cement into cracks.

7) Duration of utilization

Water in the Impluvium is started to use after other water sources dry up, and is consumed within 1 or 2 month. Tank is scarcely completely filled up as long as cyclone passes by. If tank is filled up, limitation of usage is halt, and then water is consumed until water decrease half of tank in general.

8) State of private water collecting system

House equipped with a tin roof, which is suited collecting water, is minor at village level. Even many of those houses aren't equipped with water collecting system.

(3) Other Matters

1) Concrete

Tank gets dry up completely during certain month every year. Those condition easily degrade concrete and make significantly shorten life span of it, even if concrete work is perfect. From that reason, the impluvium constructed by JICA also have leakage at some sites.
Another reason of degradation is germination of grass which breaks through crack of concrete and damage completely.

2) Other design of Impluvium

OS recognized necessity of frequent repair within 5years. So that, they planed to repair by village resources and then trained village people in their program. The proceeds is meant for repair only and forbidden to use other purpose,
The reason of the expected short life is as follows. Iron bar is not set at the side wall of tank, Structure of side wall is constructed with block of calcareous sandstone. Then once tension is loaded and crack opens, cracks easily to be extended. OS tested cylindrical model to improve durability instead of the rectangular model.

4.4.2 Water Vendors

(1) Objective of Survey

- Systemization of water vendors of zebu cart
- Area of coverage by zebu cart
- Water charge stabilization
- System of licence to control regulation

(2) Result, Observation on Theme

1) Systemization of water vendors of zebu cart

It is not easy to systemize zebu cars to supply water efficiently.

- Zebu can't work everyday because water transportation is so hard to take power. It needs to let him rest one or two days. The owner justify her condition
- People don't want use their zebu for work as much as possible because overwork leads to kill their zebu.
- Road condition is also tough to zebu. Sand, steep inclination, a lot of ups and down.

2) Potential of water transportation system establishment without intervention if enough amount of water is supplied at Ambovombe

- Currently, quantity of supply is not enough at Ambovombe. People need to wait for a water recovery and to visit several water sources. For those people, they will have advantage to increase amount of water, stabilization of tariff.
- Distance of transport by Zebu cart is limited due to their capacity. It is rare to go to fetch at more than 20km away. People also want to minimize distance to water sources considering physical condition of zebu. So that, People stay where the area is 10 to 20 km away from Ambovombe, for example, boundary area or place nearer to other water sources will not benefit even if new water source is developed at Ambovombe.
- Activity of water vendors get high when water charge inflates more than 300Ar/bucket. The charge seems to be divergence as business. But, though decrease of water charge is one of the objectives, interest doesn't match between our objective and water vendors.

3) Charge stabilization at low level

- Charge stabilization shall be achieved by supplying enough amount of water. It is advantage for persons who come to Ambovombe to get water by themselves. If the charge at the village is stabilized low, water vendors will not have interests to go to village.

4) Introduction of licensing

- There is licence system at the urban Ambovombe to have income for commune because water selling is active as forming a permanent business. Other commune don't have system of licence because they worry that water vendors just transfer increment to the charge.
- Someone relatively rich in the village go to buy water at like Ambovombe, then they sell the rest of their consumption to the person who doesn't have transportation. Sometimes they take their container to draw water in the free of charge. The current system in the village is not base on business, but on relieve poor people. Then licensing doesn't match to village.
- The commune doesn't have resources for example budget and personnel.

(3) Other Reinforcing Information

1) Water vendors setting up

- Majority of water vendors belong to own village except near water sources. They sell the rest of their consumption to others. For instance they consume half of barrel, and sell the other half of barrel.
- Water vendors from outside of village is active when charge of water rises, especially, 500Ar/bucket after September.
- Distance is the reason of select water sources to go, but traditional relationship in the area also affects their selection. For example, administrative group

2) Water consumption style

- Amount of water is restricted by their targeted expenditure. Village people buy water 2 bucket par household par day in general, but decrease number of bucket to one par day when charge increase.
- Style of consumption differs between Ambovombe urban and village. The end of urban Ambovombe is categorized as area of village style consumption. Even owner of vovo doesn’t take bath and wash clothes like village people.
- The village people don’t consume water for washing clothes, bathing so much. Although the frequency differs between commune and person, for example, they wash clothes once every 3 or 4 month. Water sources along the coast are acceptable for bathing, but not for washing clothes for some people because salty water degrade and damage clothes.
- There is case that water vendors come to sell water at the market day only. They prefer a condition that they can sell efficiently. That indicates lower demand of water in ordinary in the village.
- The people don’t fetch the purchased water to zebu. They fetch cactus or take them to free water source. Requirement for livestock shall be excluded from definition of water consumption amount in the water supply plan

****