JAPAN INTERNATIONAL
COOPERATION AGENCY (JICA)

THE REPUBLIC OF MADAGASCAR

THE MINISTRY OF ENERGY
AND MINING (MEM)

No.

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

FINAL REPORT

MAIN 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.

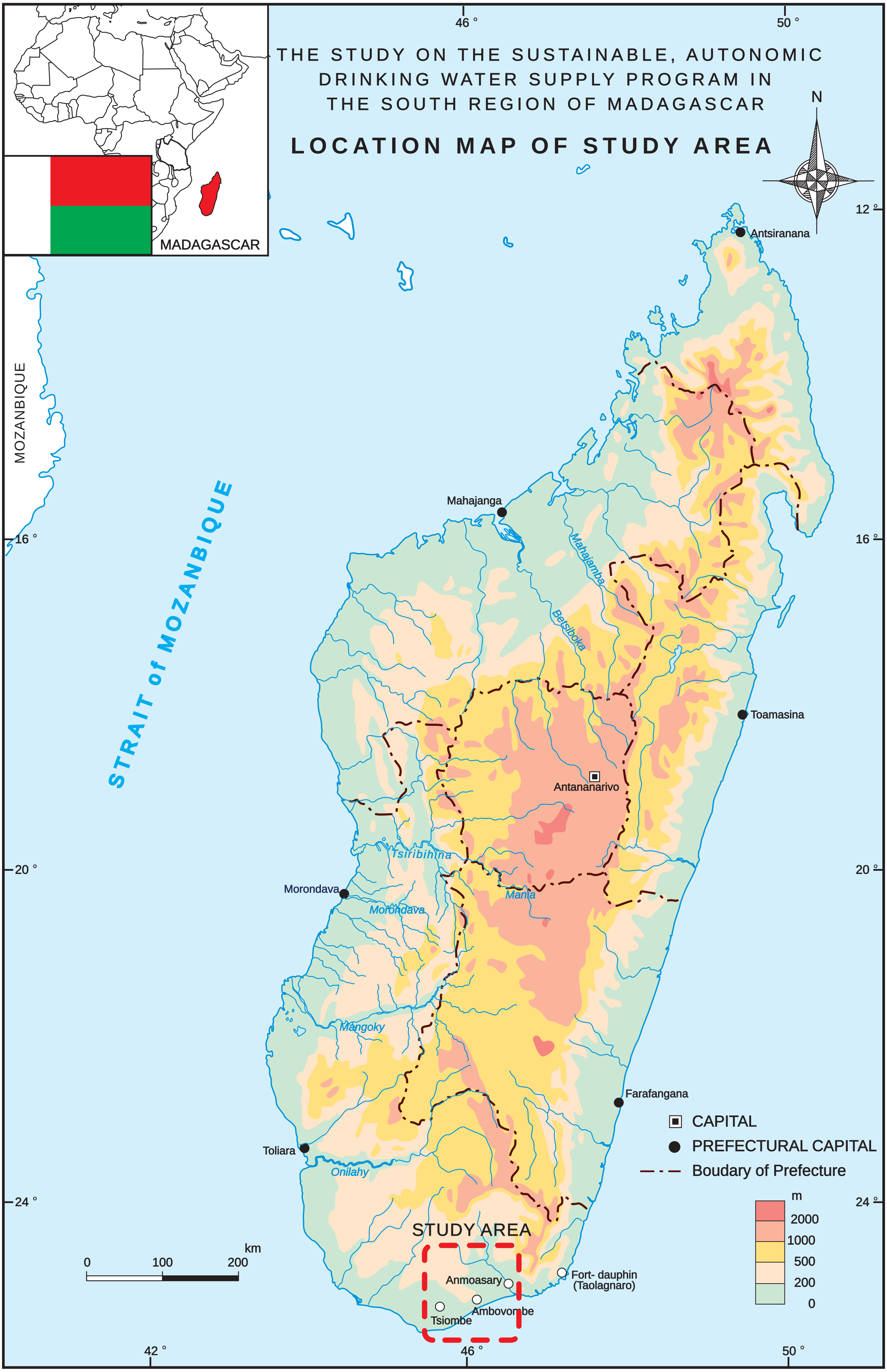
This report consists of the following volumes:

- 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
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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.

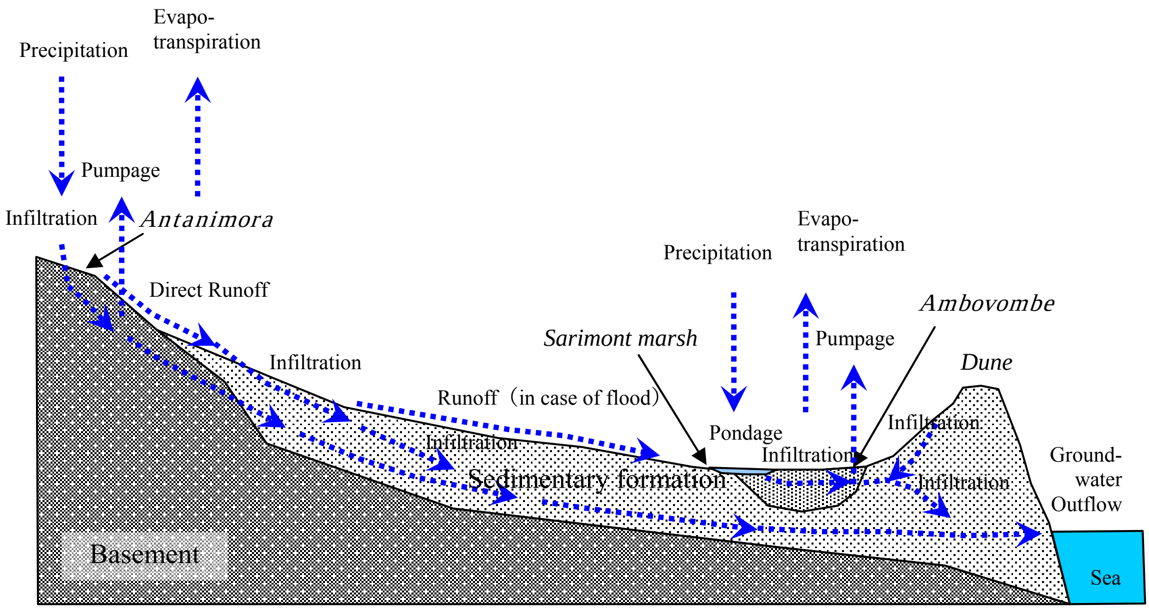
On the other hand, groundwater outflow (Q) is estimated using Darcy's equation for groundwater flow at the edge of the Basin. **Q = T x i x L x h** = 1.512 (m^3/s) = 47,682,432 (m^3/year), where

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.

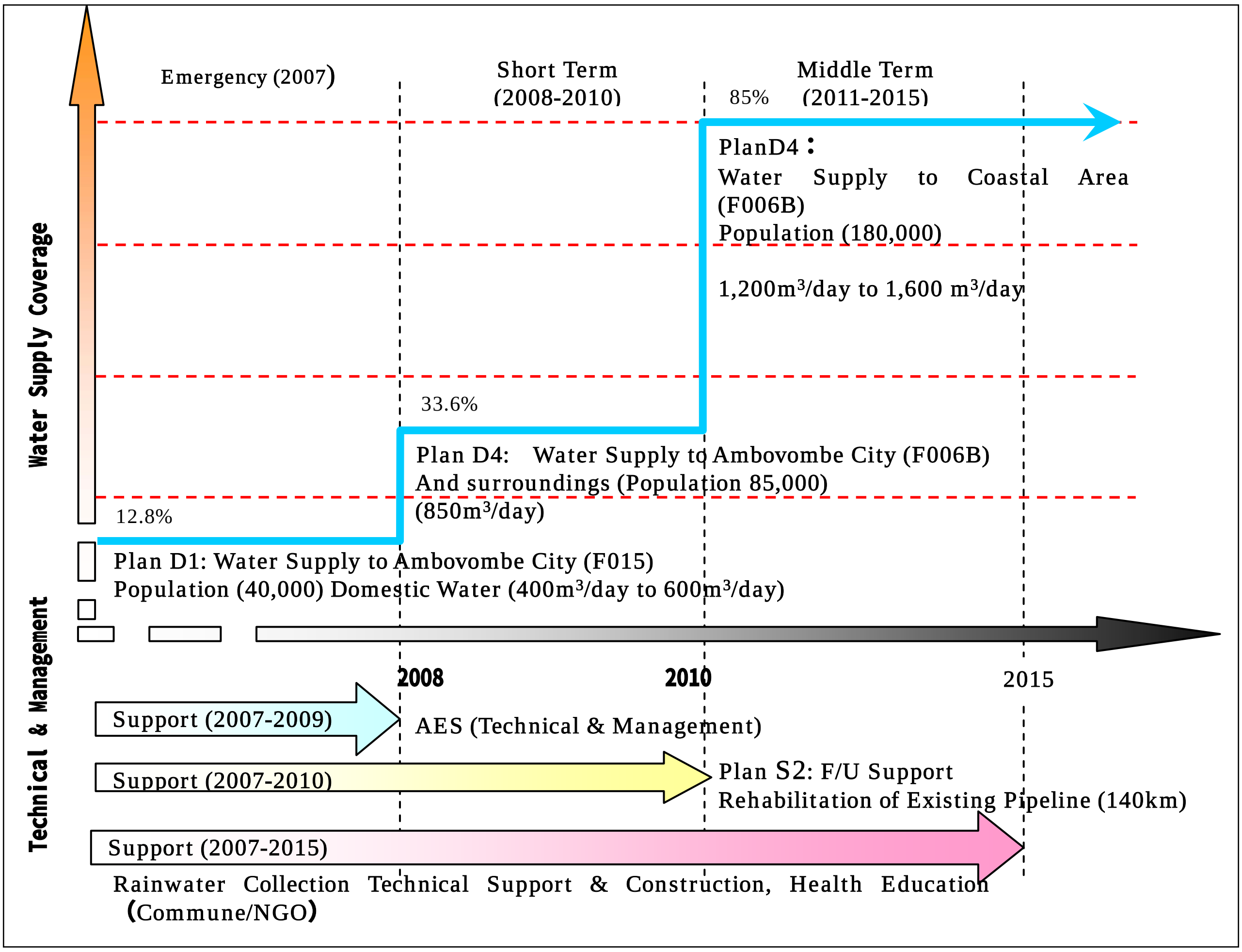
2) It is recommended urgently to develop the successful groundwater source in the suburb of Ambovombe city, that is the test borehole of F015, and to supply water for the city of Ambovombe with population of about 40,000 **(**Plan **D1)**. There is serious shortage of water. Therefore, this can be the 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.

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

FINAL REPORT
MAIN REPORT

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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	Frence	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 was 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

1) Preparation in Japan	Preparation of Inception Report (IC/R)
	Interpretation of Satellite Image
2) Work in Madagascar 1	Explanation and discussion of the IC/R
	Baseline and water resources survey
	Preparation of Progress Report P/R-1
	Explanation and discussion of the P/R-1
3) Work in Madagascar 2-1	Implementation of Test Drilling
	Design of Pilot Project
	Preparation and Discussion of Progress Report (P/R-2)

Phase II: Analysis and Evaluation of Alternatives of Water Supply Facilities and Formulation of Water Use Plan

4) Work in Madagascar 2-2	Implementation of Pilot Project
	Preparation of Interim Report IT/R
5) Work in Madagascar 3	Explanation and Discussion of the IT/R
	Monitoring of Pilot Project
6) Work in Japan 1	Preparation of Draft Final Report DF/R
7) Work in Madagascar 4	Explanation and Discussion on the DR/R
	Implementation of the Seminar for the Technology Transfer
8) Work in Japan 2	Preparation and Completion of Final Report F/R

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.

- The Study Area is limited in the area accessible by vehicle within the above area.
- The Study Area is shown in the map of this Report and the list of Study areas are presented hereafter.

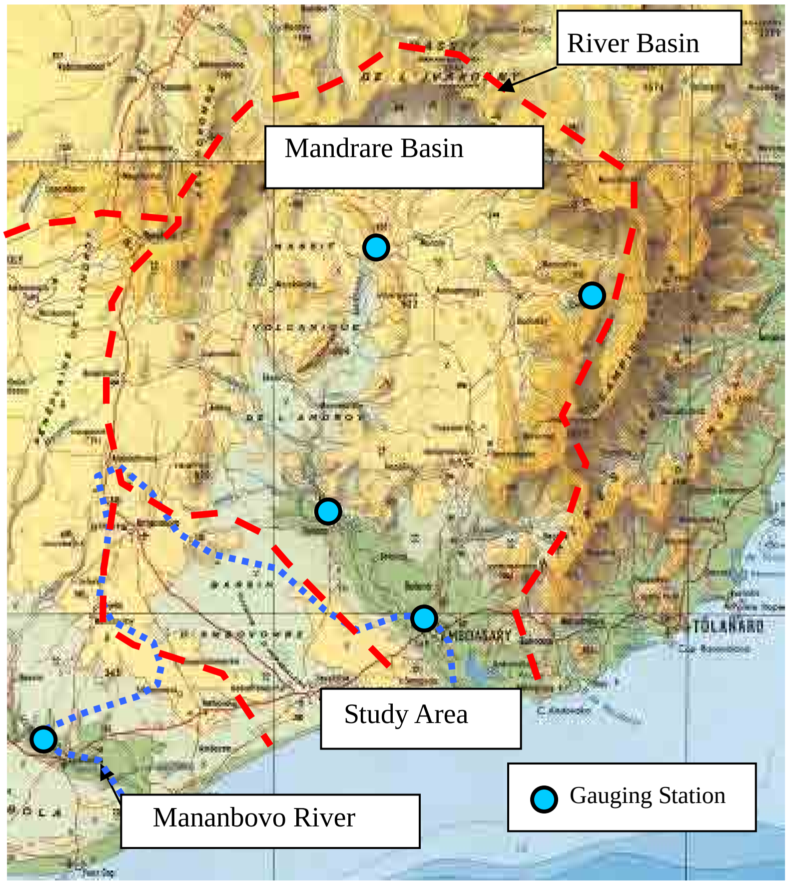


Figure 1.1.4-1 The Study Area

1.1.5 Scope of the Study

This Study was 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) 4) 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.	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

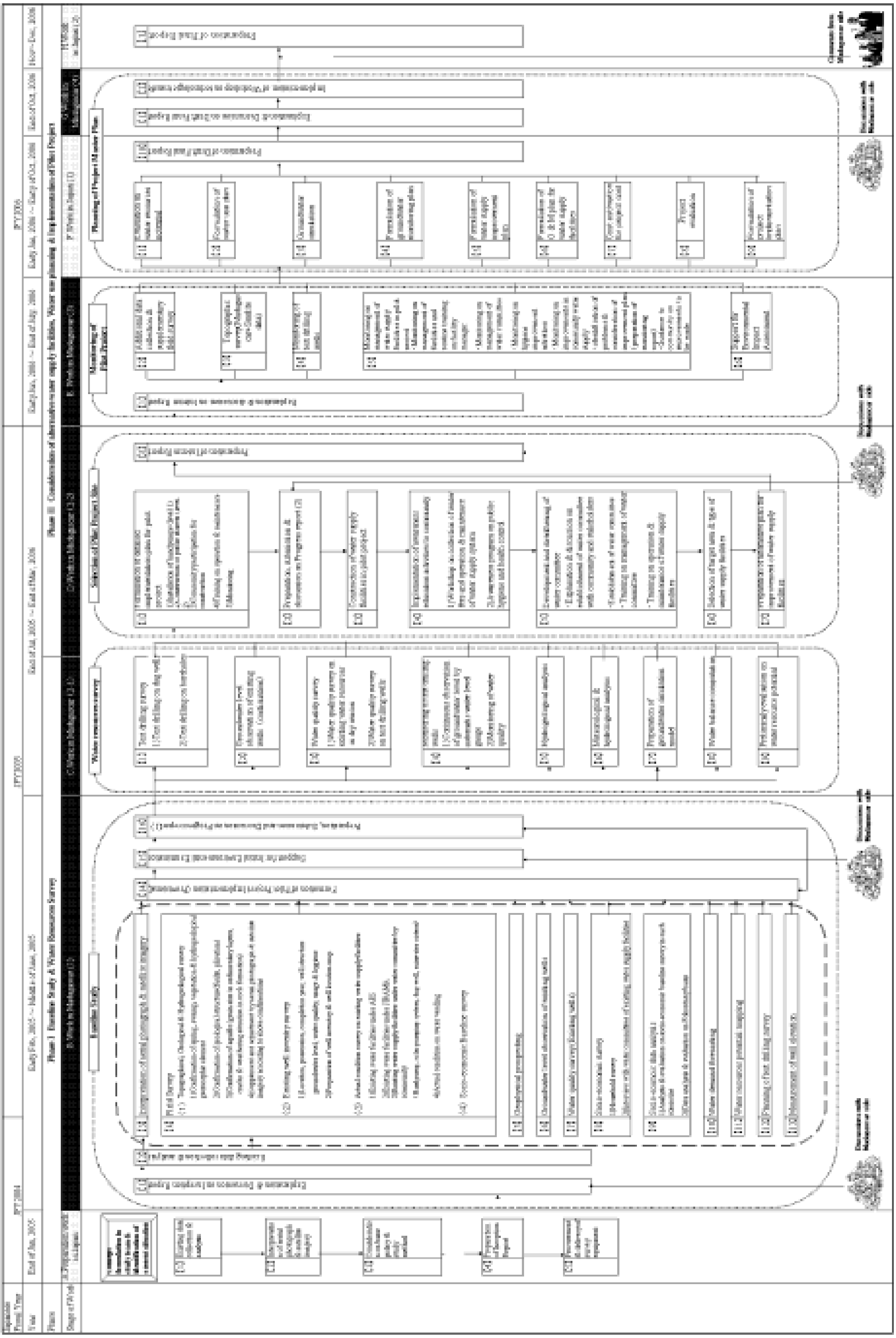


Table 1.2.1-4 The Study Schedule

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
		7)	Preparation of Groundwater Simulation Model
Phase II CONSIDERATION OF ALTERNATIVE WATER SUPPLY FACILITIES, WATER USE PLANNING &		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)**

Submission of Reports	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
		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 1.2.2-2.

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-SOANARIVO 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

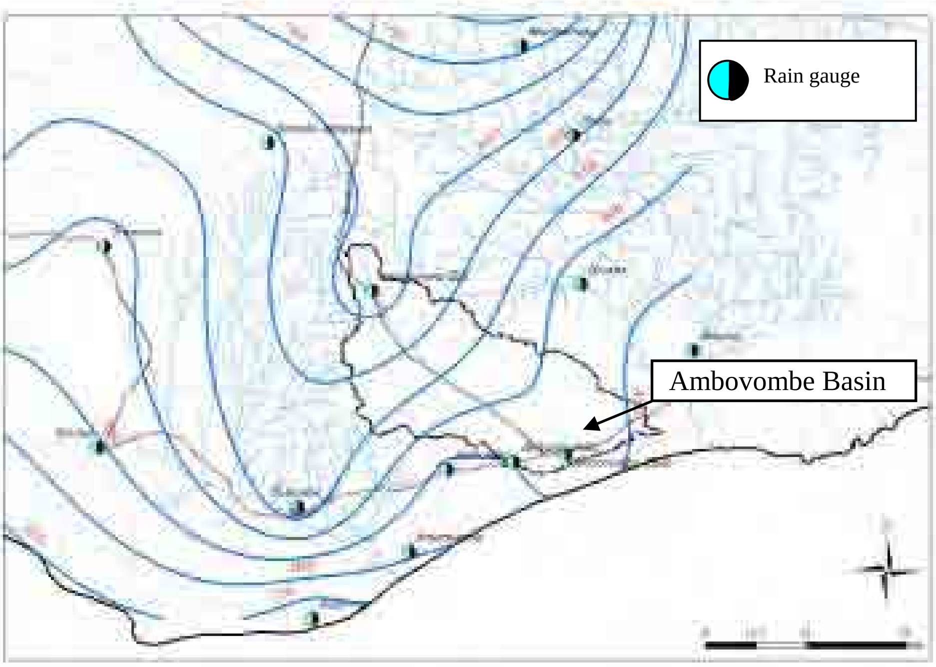
****

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. The area is out of the range from having influence of the tropical low-pressure system, and also, topographically, the mountains of the Fort Dauphine region block the wet trade winds. This unique location makes up the area to have the least amount of precipitation in the country. 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 2.1.2-1 shows the river system around the Study Area.

(1) Mandrare River

The Mandrare River is 270 km in length and has around 13,000km^2 of contributory area. The average altitude of the river basin is around 400m above sea level. The river flow can be observed throughout the year due to much amount of precipitation.

Figure 2.1.2-1 River Systems around the Study Area

(2) Mananbovo River

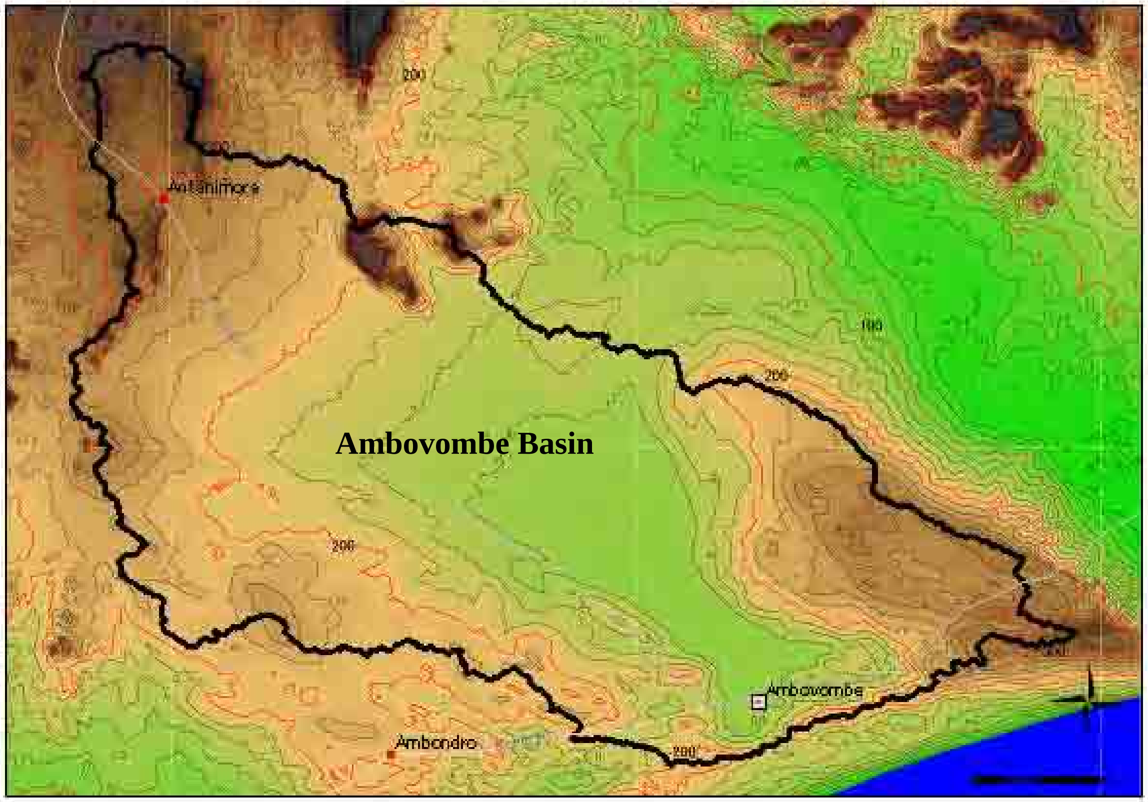
The Mananbovo River has around 4,450km^2 of contributory area and its length is 165km long. In the dry season there is no discharge observed in this river due to insufficient amount of precipitation.

(3) Ambovombe Basin

Within the Ambovombe Basin, there are several streams that occur only during the rainy season. However there are no observed data of such streams. Bemamba River flows from northwestern part of Ambovombe Basin to the center of the basin. Through the site reconnaissance, which was undertaken in the middle of May 2005, no apparent discharge was confirmed within the Basin.

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.



Source: DEM data (SRTM)

Figure 2.1.3-1 Topographic Map of the Ambovombe Basin

Within the basin, thick sediment covers widely and topography is gently undulating. Elevation changes from 120 to 250m height.
Near the seashore, dunes are widely distributed along the coastal line. The elevations of these are from 150 to 300m above sea level. The basin is considered to be a closed basin and there are no signs of streams running off to the sea. Urban area of Ambovombe commune is the lowest part in the basin. The elevation is from 130 to 136m above mean sea level.

2.1.4 Geology and Hydrogeology

(1) Outline of the Study Area

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.

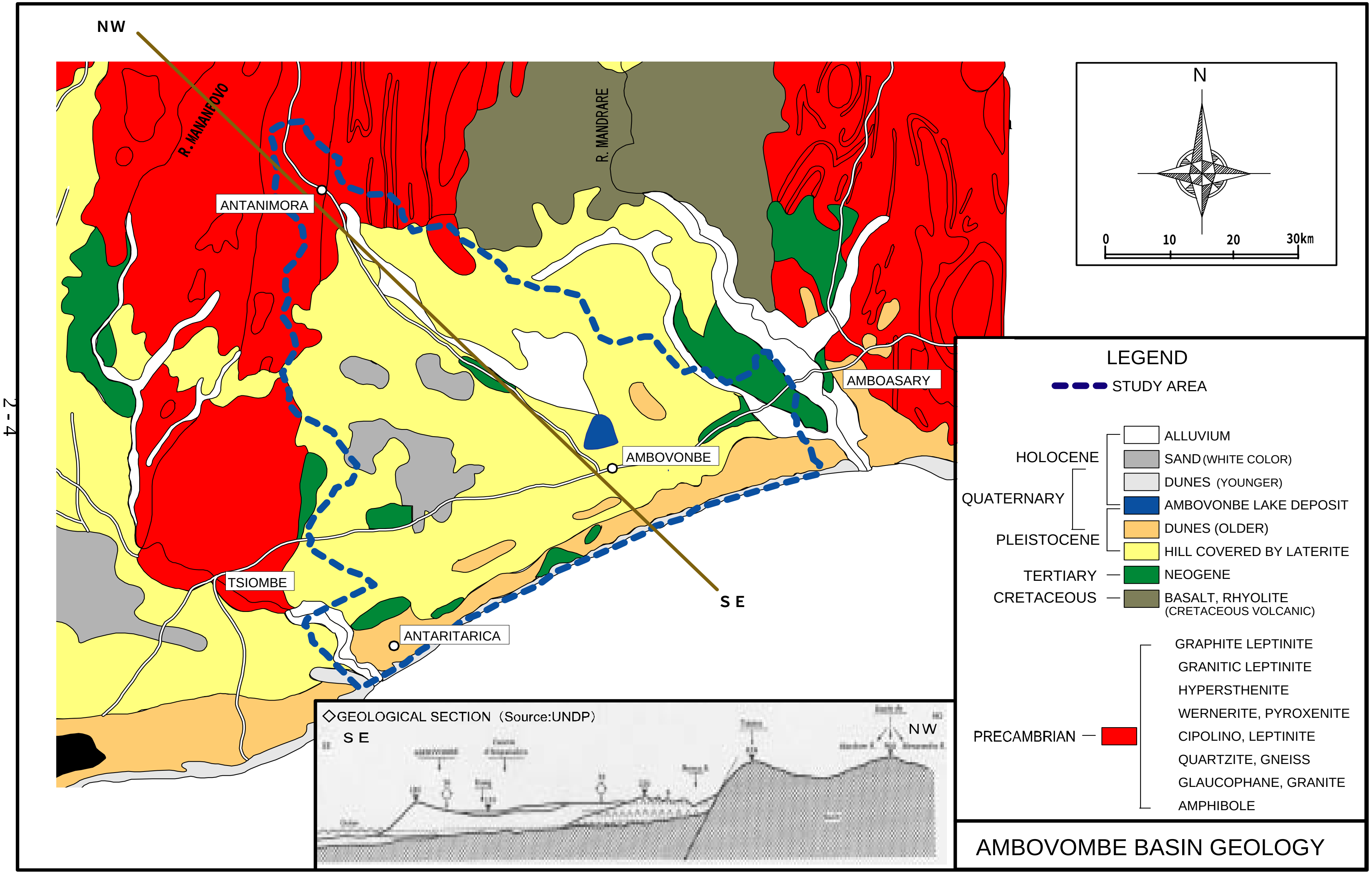


Figure 2.1.4-1 Geological Map of the Ambovombe Basin

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) Pre-Cambrian Basement Zone in the North

In the northern part of Ambovombe Basin, the Pre-Cambrian basement rocks outcrop. It is consisted of well-weathered Leptynites, quartzites, granite, granitic gneiss forming good confined aquifers with good quality, although occasionally high saline water exists. The eastern part of these Pre-Cambrian rocks the Cretaceous volcanic rocks outcrop consisting of basaltic intrusive and rhyolites forming mountains in the area. Confined aquifers are found in the crack of Cretaceous volcanics but it was a moderate potential.

(3) The Center of Ambovombe Basin

Ambovombe Basin was formed by faults in NW-SE direction and graben structures where thick young sediments are deposited. The basement rock is Pre-Cambrian granites, and Tertiary, Neogene continental sediments consisting of calcareous sandstone, siltstone and limestone overlay the young sediments with unconformity. Pleistocene sediments of brown sandy laterites are overlapped by Quaternary deposits consisting of sands dunes deposits, the white sands and Alluvium sediments.

In the area of Erada and Sihanamaro, the Quaternary white sands overlap Pleistocene brown sandy laterites. Village people dug Vovo at a depth of about 10 m to obtain drinking water in the rainy season.

The rim of the Ambovombe Basin is forming a hill where Neogine continental calcareous rocks outcrop. Aquifer is fair there. Therefore, village people depend on the rainwater only for drinking.
In the center of Ambovombe Basin, a large swamp is formed during the rainy season with very shallow depth. It is expected thick Alluvium of lake deposits consisting of mainly clay and silt. According to the village people who lived near the lake, serious floods occurred sometime before 1951 when the National Route 10 was constructed.

The Ambovombe commune is located at the southern rim of Ambovombe Basin. There are many Vovos dug by the village people to obtain drinking water. The depth of Vovo is ranging from 10 m to 30 m, and the static water level is ranging from 5 m to 25 m, mainly 15 m to 20 m. The groundwater in Ambovombe urban is found as an unconfined aquifer of Quaternary sediments, occasionally water quality is saline and biologically contaminated.

(4) Coastal Sands Dune Zone in the South

The coastal zone to the south of National Route 10 forms the small individual basins towards the Indian Ocean. Along the coast, young recent calcareous brown sands is forming new land at sea level. Beyond the narrow beach, cliff of Quaternary calcareous sandstone spreads at about 100 m to 200m height as shown in Figure 2.1.4 -2.

Figure 2.1.4-2 Coastal Cliff of Quaternary Calcareous Sands at 100 m to 200m height

At the foot of the coastal cliff, there are many dug wells of depth about 10 m which has strongly salinized water due to the sea water encroachment. The EC value indicates more than 500 mS/m to 2,000 mS/m. However, the cattle from villages come to drink the saline water. The most of dug wells along the coast are shallow depth at about less than 20 m, the EC is more than 300 mS/m with NO_3 detected more than 45 mg/l, which is not good for drinking to the people. The pure sea water was analyzed at the beach with EC of 5,270 mS/m and 3.33% of NaCl included at 28 ℃ of sea water temperature.

2.2 Social and Economic Conditions in the Study Area

2.2.1 Administrative Organization

This study covers the area of 15 communes of Ambovombé-Androy and Tsihombé districts of Androy Region in southern part of Tuléar province.
Ambovombé-Androy commune and ten surrounding communes lie between National Routes 10 and 13 and the coast, while inland communes of Antanimora, Sihanamaro and Ambohimalaza lie along the National Route 13 northward to the urban of Antanimora. Beanantara commune is situated at boundary between Ambovombé basin and Mandrare river basin.

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 and their location is shown in Figure 2.2.1- 1.

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

Figure 2.2.1- 1 Study area

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.
Income of commune consists of her proper funds coming mainly from taxes and subsidies from the government. Almost all of proper funds and subsidies spent for ordinary expenditure necessary to commune administration.
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: fokontany chiefs and elders of 90 surveyed fokontanys regard impluvium as their property to maintain and manage in terms of collecting water charge or

rehabilitation. Educational facilities and land are also regarded as important properties in 44 and 43 fokontanys respectively.

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 during February to April 2005 by the Region (source: Region of Androy, refer to Figure 2.2.2- 1). As the map in 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)

In 2003, two communes of Analamary and Tsimananada became independent, and, in some communes, borderline was modified. Therefore, the population in precedent population surveys and censuses do not exactly show the population that present communes have. It is possible to compare population between years at the district level: between 2002 and 2005, 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%.

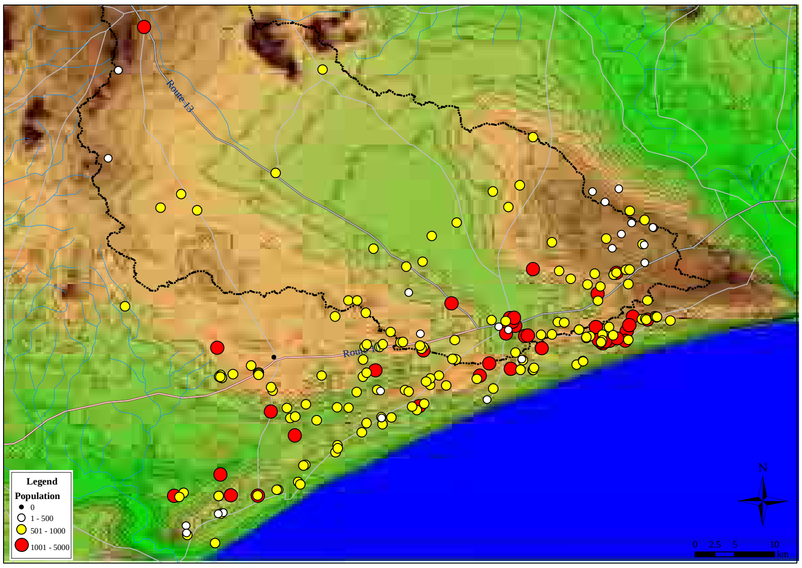


Figure 2.2.2- 1 Distribution of fokontanys and population size

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 of Maloaropoty, Maloaromainty, Erada, Ambazoa and Antaritarika. Crops popularly cultivated here are maize, cassava, and sweet potato as staple food and niebe (a kind of beans). Many people choose crop of a year depending on the precipitation. The first income source is manioc and the second is sweet potatoes for the surveyed households.
Livestock (zebu, goat, and sheep) is raised very commonly in the study area. 59,179 heads of bovines, 12,676 heads of ovins and 28,648 heads of goat are registered in 2004 at the commune offices of 14 studied communes except Antaritarika (Source: Poste d'Elevage, Ambovombé- Androy). Average number of zebu raised by a household in the study area is 6.7 (source: Household survey); that is, one zebu for one persons if considering the household size. 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. Two National Routes and two regional routes which cross there are principal axis for transportation of the study area: 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, the Capital City of Madagascar; port city of Fort Dauphin; Tulear, the capital of the Province; Tsihombé or Antanimora, important inland urbans; and Ambondro, a rural centre within the district. Also, Ambovombé is connected with Ilakaka, a sapphire mine which attracts local people.

(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 takes place from commune to commune on the different days of the week. In weekly markets, people sell local products and buy the goods coming from other commune and other region.
Generally weekly market positions at the center of a commune (*chef lieu de commune*, see the photo of a weekly market in Figure 2.2.4- 1). However, the market of Ambovombé urban is frequented not only by its inhabitants but also by those of Ambanisarika, Analamary, Erada, Maroalomainty, and Tsimananada. They prefer to sell their products and buy goods at the market of Ambovombé. These communes are rather adjacent to Ambovombé comparing to other communes, although even though so, it takes several hours to go there on cart. People living in communes far away from Ambovombé urban go to other commercial centers such as Antanimora, Tsihombé and Ambondro. As for Ambanisarika, its market house is under construction at the time of the

Figure 2.2.4- 1 Weekly market at Antaritarika urban

survey at the time of social survey in 2005, so the inhabitants have to go out of the commune.

(3) Education Institutions and State of School Enrollment

The age of entering primary school in Madagascar is six years old and the duration of primary and junior high school (CEG) education is five years and four years respectively.

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; so, 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) also varies by commune: from 33% in Ambazoa to 97% in Ambovombé-Androy (Source: District pedagogic service). Average rate is around 62.9%. On the other hand, this figure was 72% for the entire Madagascar in 1998 – 1999 (source: INSTAT/DSN cited in PRSP Madagascar); only the figure of five communes, that is Ambanisarika, Anbohimalaza, Ambovombe-Androy, Ambondro and Ambonaivo is over 72%. Therefore, the level of fundamental education in the Study Area is lower than national average of 6-7 years ago.

(4) Health Condition

The basis of rural medical system of Madagascar is CSB (Centre de santé de base = basic health centre) set up generally in commune centres, who meets basic medical needs of local people. In the study area, every commune except two new communes of Analamary and Tsimananada has CSB 1 or CSB 2; CSB 1 is equipped by medical materials and medical staff at higher level than that of CSB2.

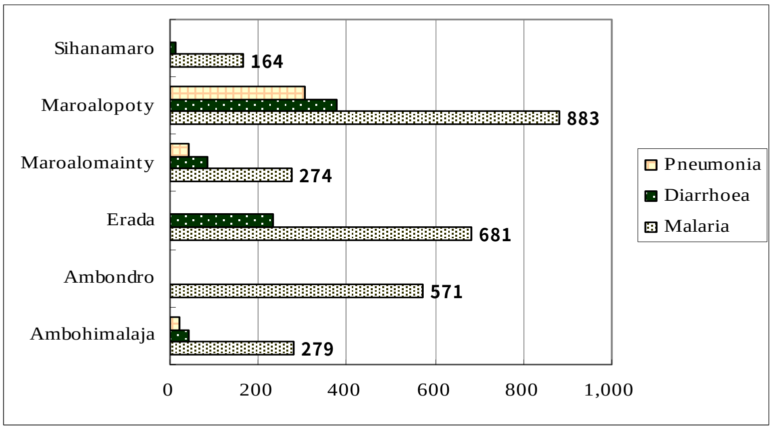


Figure 2.2.4- 2 Diseases frequently catching people (2004) unit: number of patients

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

The out-patient data of CSBs as well as that of district hospital and other higher level medical institutions is the basic data for understanding the health condition of the study area. Based on the interview to CSBs, malaria is found the disease 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). As CSB is not equipped by the laboratory of blood examination, it is sometimes said that doctors tend to diagnose disease accompanied with high fever as 'malaria'. Figure 2.2.4- 2 shows the diseases frequently catching people in eight communes where the records of treatment were available

According to the staff of SSE, it is said that 370 children out of every 1,000 living birth die before reaching age of six in 2002. This figure is more than double of that of entire Madagascar which figure is 162. As same as the primary education level, health condition, especially that of children, is much lower than that of the national standard level. As for statistical data such as number of death at any age, it is not taken at commune or CSB level. It indicates that correct number of disease or death is not available as the statistical form even it is reported by medical staff at the CSB.

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 such as customary individual ownership, customary collective ownership, illegal individual land ownership and community ownership. 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 even though the land is owned by the state. Illegal individual use is that an individual use land without registration. Community ownership means the land is owned by fokontany (administrative organism). 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.

As mentioned above, the village elder decides not only land use, but also almost all village and fokontany matters including the land exploitation or well installation. Without his decision and approval, it seems difficult to get villager's collaboration.

(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). Catholic comes at the fourth place. It is said that traditional belief remains even in the Christian villages. However, tradition of taboo strongly influence on resident's daily life.

There is a vast area recognized as taboo. At a place recognized as a taboo area, it is forbidden to do some human activities. There is no taboo area in cultivated land, but it is forbidden to do one's business near to the cattle park. In the cemetery area, it is forbidden not only to do one's business but also to cut trees near to the tombs or to sow seeds of plants. Even in the place out of the taboo zone, it is also forbidden to take photo of tombs. If a person violates the taboo, he/she has to kill an ox or oxen on the spot that the taboo was violated for purifying the place. The number of ox is said to depend on the strength of sin. It must be noted that establishing boreholes or wells near to cemeteries is included in forbidden affaires.

From viewpoint of Antandroy's taboo, pedal pumps may seem to have a difficulty to be spread. It is said that the Antandroy people do not use the water drawn from the well equipped with a pedal pump because they feel not only the foot but also the water coming from pedal pump is unclean.

Figure 2.2.5- 1 A pedal pump installed by PAEPAR in Antanimora Commune

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. Young generation, especially children, felt no taboo to draw and drank water from the pedal pump. Pedal pumps that have been installed in two pilot project sites of this study are gratefully welcomed by residents of the sites.

(3) Gender Issues in rural communities

According to the Civil Law of Madagascar, men and women have the same right and duty. However, as same as the land ownership, people continue to follow the traditional customs at some degree in which women's right is somehow weaker that that of men in all over Madagascar, and this tendency is rather strong for Antandroy people. At the inheritance, the primary successor is son and wife and daughters (especially married daughters) have less possibility. 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, 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)
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 AEP (Drinking water supply system) 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 tanker network is established in the zones of Ambovombe and its surroundings, and part of the areas of Beloha and Tsihombe.
4) 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 pertnersihp 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 Town

* 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 m^3/day.

Table 2.3.1-1 AES Boreholes by AEP in Antanimora

<table>
<tr><th>Item</th><th>General</th><th>T. D.
(m)</th><th>S.W.L.
(m)</th><th>Q
(m^3/hr)</th><th>Pump depth</th><th>Potential
(m^3/day/well)</th></tr>
<tr><td>Antanimora-1</td><td>Solar pump, Dec. 2003</td><td>77.0 m</td><td>4.6 m</td><td>30 m^3/hr</td><td>30 m</td><td>180 m^3/day/well</td></tr>
<tr><td>Antanimora-2</td><td>Diesel pump, Dec. 2003</td><td>78.0 m</td><td colspan="4">Diesel: @1,900Ar/litter,Antanimora, May 2005</td></tr>
<tr><td rowspan="2">AEP system</td><td>Public Taps: 15 (9 active)</td><td>40Ar/15little</td><td>Population served: 7,500 (4,500)</td><td colspan="2">Feb. 2005
978m^3 by solar</td><td>May 2005
2,149 m^3 by solar</td></tr>
<tr><td>Private Connection: 10 (Families)</td><td>2,070Ar/m^3</td><td>Population: 200</td><td colspan="2">48,015 m^3 by diesel</td><td>49,839 m^3 by diesel</td></tr>
<tr><td>March 2005</td><td>Sold water: 309 m^3/month</td><td>Income: 695,450Ar
Expend.: 705,476Ar</td><td>Balance:
-10,026Ar</td><td colspan="3" rowspan="2">Diesel operation 2 hr/day consumed diesel 3 l/day in good sunshine, and less sunshine 6 l/day</td></tr>
<tr><td>April 2005</td><td>Sold water: 406 m^3/month</td><td>Income: 840,280Ar
Expenditure (-)</td><td>Balance:
-</td></tr>
</table>

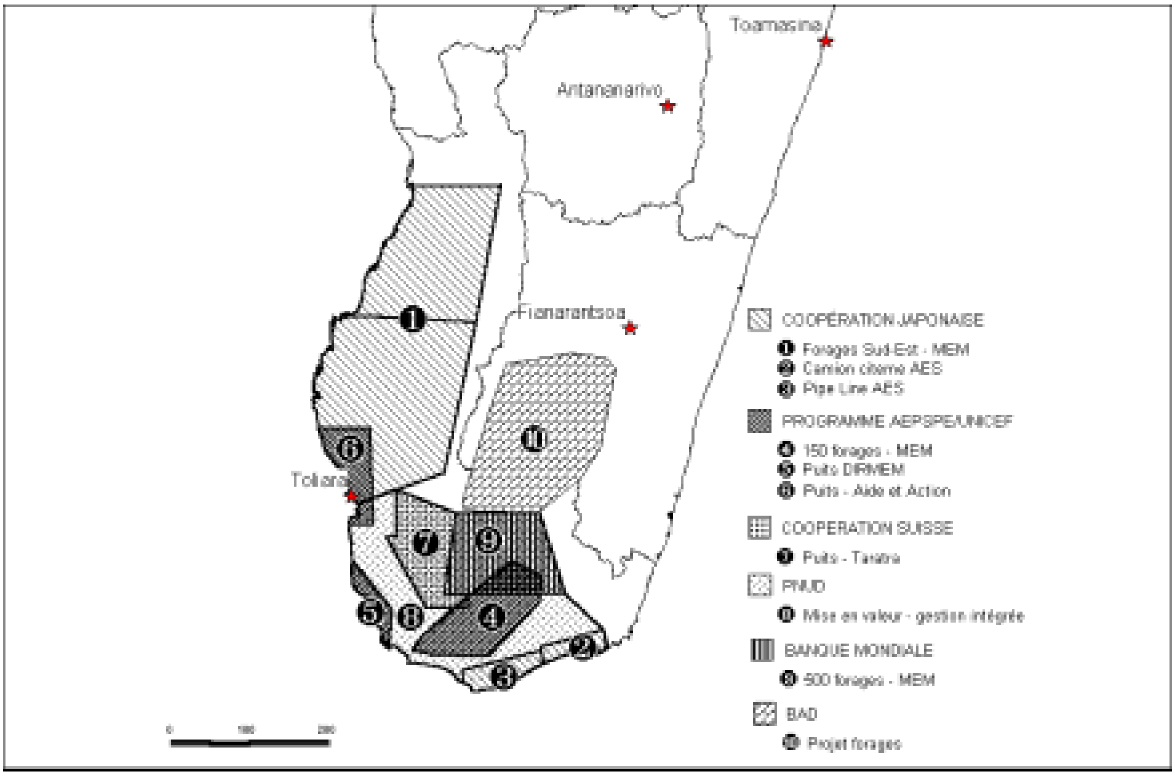
(3) JIRAMA

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 was privatized in a joint venture with foreign capitals of 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 Vergent in April 2005. The African Development Bank (BAD) started the project for 700 boreholes construction in 2005 under the supervision of MEM. 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 Amboasary 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.

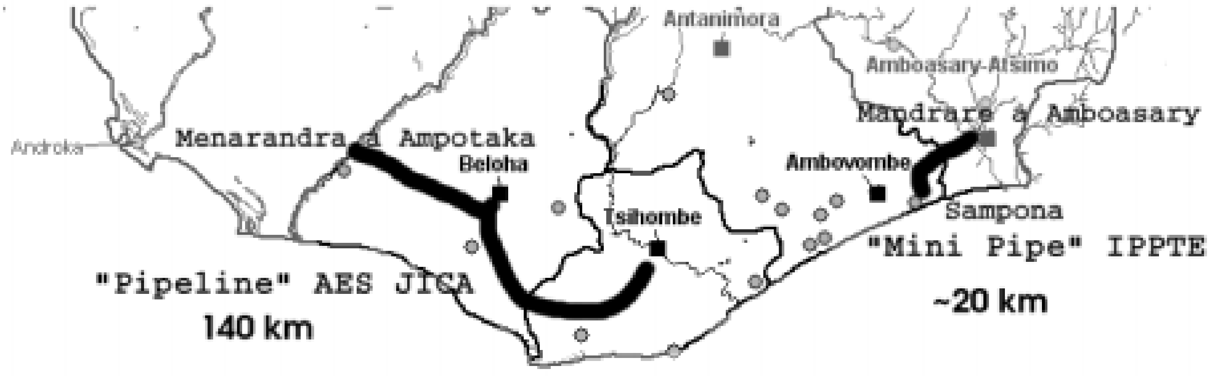


Figure 2.5 -1 The pipeline of AES constructed by JICA , 1995-1999 and the Sampona Project in progress (the IPPTE, 2004-2006) base map prepared by EU, 2005

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 7,266m^3/year of water in 2005 due to decrease of the water tankers 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.

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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

3.1.1 Information on the Hard Rock Area

Table 3.1.1-1 shows groundwater potential of the Pre-Cambrian rock area. These are analyzed from the borehole data of PAEPAR, 2005 a hand-pump project with diameter of 125 mm (ϕ5’). In the main target area of Antanimora, 15 boreholes have been drilled in 2005. Out of them 10 boreholes were successfully drilled and it has good quality with 70 mS/m to 160 mS/m of electric conductivity (EC). Therefore the success rate was 67%. The borehole total depth (TD) was ranging from 14 m to 26 m and static water level (SWL) was 5 m to 17 m. The discharge (Q) was 0.8 m^3/hr/well to 10 m^3/hr/well. Therefore potential discharge of 80m^3/day/well could be expected with the assumption of installation of motorized pumping. The depth of dry hole was 60 m to the fresh basements, and ration of dried well was only 20%, but out of remaining wells, 13 % of them indicated high saline groundwater (EC is ranging from 340 to 520 mS/m).

Table 3.1.1- 1 Groundwater Potential of Pre-Cambrian Rocks

Area Name	Drilling Results			T. D. (m)	S.W.L. (m)	Q (m^3/hr)	E.C. (mS/m)	Potential (m^3/day/well)
1. Ampamata	19	Success	15 (78%)	16 – 49 m	2 – 15 m	0.5 – 10	60 – 240	80
		Dry	2 (11%)	61 m	-	0.1	600	-
		Saline	2 (11%)	11 -32 m	-	0.2 - 0.4	840-850	-
2. Andalatanosy	63	Success	41 (65%)	14 – 54 m	2 – 17 m	0.5 – 10	50 - 195	80
		Dry	13 (21%)	60 – 63 m	-	-	-	-
		Saline	9 (14%)	14 – 49 m	-	0.2- 4.8	300-900	-
3.Antanimora Atsimo	**15**	**Success**	**10 (67%)**	**14 – 26 m**	**5 – 17 m**	**0.8 – 10**	**70-160**	**80**
		Dry	3 (20%)	60 m	-	0.1	110	-
		Saline	2 (13%)	20 – 38 m	-	0.3– 0.9	340-520	-
4. Jafaro	10	Success	3 (30%)	15 – 32 m	7 – 10 m	0.8 – 1.5	140-200	12
		Dry	2 (20%)	60 m	-	-	-	-
		Saline	5 (50%)	13 – 42 m	-	0.2 – 1.4	300-500	-
Average of the Pre-Cambrian Rock	**107**	**Success**	**69 (64%)**	**14 – 54 m**	**2 – 17 m**	**0.5 – 10**	**50 – 240**	**80**
		Dry	20 (19%)	60 – 63 m	-	0.1	311-600	-
		Saline	18 (17%)	11 – 49 m	-	0.2- 4.8	300-900	-

Source: World Bank/BURGEAP/MEM, 2005 analyzed by JICA 2005

The total 106 boreholes in the Pre Cambrian rocks area were summarized as shown in Table 3.1.1-1. The total success rate was 64%, the TD was ranging from 14 m to 54 m and the SWL ranging from 2 m to 17 m. The Q was 0.5 m^3/hr/well to 10 m^3/hr/well, therefore potential discharge of 80m^3/day/well could be expected assuming the motorized pumping. The TD of dry hole was 60 m to 63 m at the basements. Dry hole ratio was only 19%. The rest of 17 % was high saline groundwater, which was the EC of 300 mS/m to 900 mS/m. These hydrogeological results indicate the same trend as Antanimora.

3.1.2 The Information of the Center of Ambovombe Basin

The Ambovombe commune is located at the southern edge of Ambovombe Basin. There are many Vovos dug by the village people to obtain drinking water. The depth of Vovo is ranging from 10 m to 30 m, and the static water level is ranging from 5 m to 25 m, mainly 15 m to 20 m. The groundwater in Ambovombe urban is found as an unconfined aquifer of Quaternary sediments, occasionally water quality is saline and biologically contaminated. Groundwater pumping test for the unconfined aquifer of Quaternary sediments at a level of 20 m to 30 m was carried out by AES/MEM/JICA in 1982-1993 in the southern part of Ambovombe commune as shown in Table 3.1.2-1. Groundwater potential of unconfined aquifer is not bad in the view of the Specific Capacity (SC) and Transmissibility. The SC is ranging from 225 to 356 m^3/day/m, therefore assuming drawdown 1.0 m, potential would be about 225 to 356 m^3/day. It is also reported that the thickness of aquifer is only several meters and the annual fluctuation is about 1.5 m.

Table 3.1.2- 1 Groundwater Potential (Quaternary Unconfined Aquifer)

Geological Age	Area Name	T. D. (m)	S.W.L. (m)	Q (m3/hr)	Δs (m)	S.C. (m^3/day/m)	T (estimate) (m^2/sec)
Quaternary (pumping test: JICA, 1982-1983)	Ambovombe	-	-	-	-	-	-
	1)Androy	21.4m	20.0m	9.8	0.66m	356	5.8×10^{-3}
	2)Dugwell A1	27.6m	26.0m	3.0	0.32m	225	3.4×10^{-3}
	3)Dugwell A2	25.3m	24.2m	3.0	0.29m	248	3.7×10^{-3}

Note: AES/MEM/JICA, 1990

3.1.3 Information on the Coastal Sands Dune Zone in the South

Antaritarika, Tsihombe region is one of the Study sites near the seacoast where borehole was drilled in 1971 reaching the depth of 104 m. The elevation of the site was 115 m above the mean sea level. Hydrogeological evaluation is not completed due to the missing information. The coastal thick sediments consisting of Quaternary to Pleistocene calcareous sandstone, limestone and siltstone are not well identified geologically and hydrgeologically.

3.1.4 Hydrogeological Evaluation

The groundwater of the Study area can generally be summarized based on the previous JICA study and other recent information as shown in Table 3.1.4-1 also shows the geological age, types of aquifers and groundwater potential in the Study area.

Table 3.1.4-1 Hydrogeological Potential Evaluation

Geological Age		Total No.	Success (%)	Dry	Fail	Saline	T.D. (m)	Q (m^3/hr)	Potential (m^3/day)
Alluvium	Dug well	18	11 (61.1%)	0	0	7	11.1m	2.9	29.0
	Borehole	10	9 (90.0%)	0	0	1	22.6m	33.9	339.0
Quaternary	Dug well	11	3 (27.3%)	0	2	6	8.8m	0.04	0.4
	Borehole	11	2 (18.2%)	5	0	4	20.7m	0.2	2.0
Dunes (Young &Old)	Dug well	4	2 (50.0%)	0	1	1	6.9m	0.4	4.0
	Borehole	4	2 (50.0%)	1	1	0	18.3m	0.4	4.0
Sands (White color)	Dug well	50	24 (48.0%)	10	8	8	6.2m	0.07	0.7
	Borehole	10	2 (20.0%)	4	1	3	9.7m	0.04	0.4
Tertiary (Neogene)	Dug well	4	2 (50.0%)	0	0	2	33.3m	1.0	10.0
	Borehole	66	19 (28.8%)	13	0	34	84.6m	1.3	13.0
Pre-Cambrian Rocks	Dug well	0	0 (0.0%)	0	0	0	0	0	0
	Borehole	12	6 (50.0%)	0	0	6	26.3m	7.8	78.0
Total	Dug well	87	42 (48.3%)	10	11	24	6.2m-33.3m	0.04 - 2.9	0.4-29.0
	Borehole	114	40 (35.1%)	23	2	47	9.7m-84.6m	0.04 -33.9	0.4-339.0

Note: AES/MEM/JICA, 1996

The good water source is the confined groundwater due to the less contamination from the surface. The confined groundwater is safe and stable and it hardly dries up even in dry seasons. The Study area is situated in a flat area of Ambovombe Basin which is covered with thick sediments to the basement rocks. Clay, sand, gravel, sandstone and conglomerate layers form the most common unconfined aquifers. On the other hand, Pre-Cambrian weathered granites and gneiss build up the hill where good confined aquifer is found in the northern part of the Basin namely Antanimora Atsimo to Manave. Unconfined and confined groundwater is expected in Quaternary sands, Tertiary and Pre-Cambrian rocks have potential with good quality of water.

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

(1) Groundwater

1) Vovo

a) General
Vovos are the most popular water sources in the study area since the construction cost is small: needs only the labor costs for construction workers with simple equipments. The target aquifer is from few meters to 25m deep in general. Therefore, several vovos form a group and concentrates in small areas where the existence of ground water had been already confirmed. Most of the water sellers own some vovos for their own business. Many vovos exist in Ambovombe and Ambondro, and areas where they are densely developed are listed below. Among the areas, the southeastern Ambovombe is heavily exploited.

Table 3.2.1-1 Area where vovos densely exist

Position in Ambovombe	Area
SW	Ambaro,Mitsangana
NW	Andaboly I
E	Tanambao
SE	Andranokoake, Bevory, Anjatoka III

b) Life Span
Life span of one vovo differs greatly depending on the geology of the area. The vovos in areas where silt or clay exist, walls of the vovos are quite stable, so they exist for a long time. The life span of these vovos are the same as an usual dug well. For vovos where the well walls are not stable, they frequently collapse and the villagers need rehabilitation of the vovos time to time, eventually enlarging the diameter of the well head. Areas where the well head is sand, the shoulder of the well head frequently collapses and forms a sloped entrance to access water. Vovos at Ambondro are of this type.

c) Exploitation

Privately owned vovos are maintained in good condition. They are equipped with hanging ropes to fetch water, and are sometimes covered. However, once the shoulder of well head collapses, then the hygiene condition will no longer be preferable.
In general, vovo is the most exploited water source by private water sellers and play a significant roll.

2) Dug Well

a) General
Most of the dug wells are constructed by the government or the NGOs because the construction cost is high. MEM, the Relance de SUD, the SYNODE FLM are the major donors. Although the target aquifer is the same as vovos, dug wells are much proper facility than vovos in that they are free from collapsing. The size of a liner diameter vary from 800mm to 1600mm, and the mold of the concrete ring is locally available. Areas where the dug wells are encountered are the same as the vovos because the same aquifer is targeted

b) Exploitation
Submersible pump is installed at Ambondro, Ambovombe, Ifotaka, and Tsiombe (JIRAMA). Others are exploited like vovo.

3) Borehole

Many boreholes were constructed in the areas where basement rocks outcrop, for example, Antanimora and Jafaro by projects of the UNICEF, AES and the World Bank (PAEPAR). Since their purpose is to supply water for the village people, boreholes are equipped with manual pumps, such as India MKII or Vergnet pump.
In general, the depth of boreholes are not so deep, mostly 10-30 m. Probably the confined aquifer is targeted to the bottom of the weathered zone. At present, the borehole employed for piped water supply in the study area is only in Antanimora.

In the past, numbers of boreholes were drilled in sedimentary areas of the southern part of Ambovombe basin and coastal dune. Only one borehole is functioning at present and it is difficult to identify the drilled points. The reason of abandonment is said to be the very little yield and high salinity, but more data and logical explanation are needed to prove it. For example, there is no information of how the position of the screen were decided, nor the information of the pumping test done, nor the isolation between different aquifers, etc. The only functioning borehole is located at Andaboly in Ambovombe urban. The data say that the depth is 60.68m, and the SWL is 31m. However, when those were actually measured in this study, the depth was 22.6 m and the SWL was 17.46 – 0.55 =16.96m.

4) Spring

This type of water source does not exist in the Ambovombe basin.

(2) Surface Water

1) Damp (Marsh)

Plenty of damp appears during rain season at depressions and pits where silt and clay settles at the bottom, and form a impermeable layer. Small scale damps, with several meters in diameter, appear all over the

Ambovombe basin, while large scale damps with more than 50m diameter appear around Ambovombe, around Sarimonto, Sihanamaro, around near Ambaliandro, where river flow fade out. Along the Bemamba river at the east side of the RN13, muddy plane appears and prevent access this area. During the rainy season, the water of the damps does not have salinity and the chemical composition is close to the rainwater. It is a convenient water source for the village people but water is contaminated with human and animal waste.

2) River water

The study area does not have river flowing, so this can't be a candidate of water source. However, in some places the riverbed water is exploited.

- Pit dug at the bottom of river, for example Bemamba River, Antanimora
- Dug well near to the dried river, for example Bemamba River, Antanimora
- Dug well near to the river flowing, for example Mandrare River, Ifotaka or Berenty
- With treatment plant, Mandrare River, AES Amboasary

If pipeline construction is feasible, stream in the mountain area becomes one of the candidates. Currently, EU has proposed a plan to utilize Tarantsy river water at the mountain between Amboasary and Fort Dauphine (studied by SOGREAH in 2004). Advantages of this plan are explained as a) No running cost because water will be delivered by gravity b) The targeted area covers all the coastal dune area to Antaritarika. However, this plan contains some technical challenges such like a) Maintenance system for high pressure pipeline. b) Protection from erosion in the mountainous area c) Pressure control in the pipe d) Construction of bridge traversing Mandrare river and so on.

(3) Rainwater

Rain is the most important water source in this area during rainy season. Rain is collected at individual or public reservoir during rain season. From its appearance, it can be classified to the "Impluviums" and the "water tank equipped with trough". Sanitary condition is not proper because water stays for some period and their cover is not well closed. Animals access to collecting surface and leave their feces.
Sometimes the reservoir has cracks and water can't stay, then they are abandoned. Also, it has chance to be contaminated through cracks. Although it sounds improper water supply system in the view of sanitation, the rain collecting system is the most convenient water source for residents during rain season. And water quality regarding salinity and nitrate is better than groundwater. Therefore, a lot of villages put priority in use.

In general, once it rains the water last few days for private use. During the rainy season, it is convenient because it is not necessary to transport water from other places.

3.2.2 Water Source Inventory

(1) General

Since the 1940s, several important studies were carried out in the study area to evaluate water resources potential, but these studies did not leave enough information to justify potential of the quantity and quality as drinking water. Therefore, an inventory survey was conducted to examine the condition and well properties as a water source.

From March to mid April 2005, the inventory survey regarding groundwater source were conducted. As a result, 231 water source points were surveyed. In places where the wells formed a group within small area, a few wells were picked as representative of the group. The survey sheet format is shown in Figure 3.2.2.1-1, a summary table of the results are shown in Table3.2.2.1-2 (Full data is attached at the databook) and a map showing the positions of the water points are shown in Figure 3.2.2-2. In the attached summary table, only major items are picked up from the survey sheet.

Major objectives of this inventory survey are as follows

- To determine the distribution of water source points in the view of type of well.
- To find out the distribution of water quality problems such as salinity
- To find out the human contamination
- To find out the variation of static water level (SWL)
- To find out the variation of well depth

(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.

L'étude d'inventaire de ressource en eau Version 1.0 10March2005

	Nom de surveiller			Date	
1	Position information de site		2	GPS	
1-1	Num de ID de point d'eau		2-1	GPS_ID num	
1-2	Nom de point d'eau		2-2	Latitude	S d m s
1-3	Hamaeux /Cartier		2-3	Longitude	E d m s
1-4	Village		2-4	GPS Altitude	m
1-5	Fukotani		2-5	Elevation (MAP)	m
1-6	Commune		2-6	Baromètre Alti.	mb
	Datum	WGS84	2-7	Pression ambient	mb
4	Propriétaire de point d'eau	1. Forage 2. Puits 3. Bobo protégé 4. Bobo sans protégé			
5-1	Anne établi				
5-2	Nom de Projet				
6	Structure de points d'eau				
6-1	Diamètre Int	1. mesure 2. estime		mm	
6-2	Profondeur	1. mesure 2. estime		m/Rep	Rep=
6-3	N.S.	1. mesure 2. estime		m/Rep	Rep=
6-4	Débit	1. mesure 2. estime		L/min	interview
6-5	Evol. Niv. Saisonel	1. mesure 2. estime		m	interview
6-6	D.N.	1. mesure 2. estime		m/Rep	Rep=
7	Qualité d'eau				
7-1	Température	°C		toute de suit a prendre échantillon	
7-2	pH				
7-3	EC	mS/m		ATC	
7-4	NO3	mg/L			
8	Exploitation				
8-1	Volume exploitation	m3/j		interview/estime	
8-2	Nmbre. vendeur qui exploiter	**person**		interview	
8-3	Conssom. par toute habitantes	L/j		interview	
8-4	Conssom par tout betails	L/j		interview	
8-5	Frquence explote	1.untermittent 2..tourjour 3.autre ( )			
8-6	Total nmbr bénéficie	person/j		interview, total person qui puiser d'eau	
9	Sanitation environ forage/puits				
9-1	Betail	1.Qui 2.Non		fece polluer a le point d'eau	
9-2	Toilete	1.Qui 2.Non		fece polluer a le point d'eau	
9-3	Drainage	1.Qui 2.Non		Drainage retour a point d'eau	
10	Prix d'eau				
10-1	Prix de un seaux d'eau (13L)				Fmg
10-2	Prix l'autre				
11	Entretien				
11-1	Pompe	1.Qui 2.Non			
11-2	type de pompe	1. Vergnet Ancien 2. Vergnet HPV60, 3. autour ( )			
11-3	Couverture	1.Qui 2.Non			
11-4	type de couverture	1.souder 2.vis 3. plat			
12	Evaluation				
12-1	Exploitation	1.Possible 2.Impossible 3.necessaire de améliorer			
12-2	Raison abandonne	1. sanitaire 2. goût 3.quantite 4.etc.			

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Figure 3.2.2-1 Inventory Survey Sheet

Table3.2.2-1 Summary table

	2-1	1-1		1-2	1-6	4	5-1	5-2		6-2		6-3	7-2	7-3	7-4	12-1
Count Num	GPS_ID	Water point ID Num by MEM	Project ID	Water point name	Commune	Type	Year construction	Project name	Method	Depth	Rep=	SWL	pH	EC(ATC)	NO3	Exploitation
										m/Rep		m/Rep		mS/m	mg/L	
1	001	U040082		bureau commune	Ambovombe	2	1960	MEM	1	20.4	1.05	18.44	6.93	596	>45	1
2	002	U040079		Mahavelo A3	Ambovombe	2	1994	JICA	1	22	1.1	20.32	8.08	262	20	1
3	003	U040060	F18	Andaboly F18	Ambovombe	1	1984	AES	1	22.6	0.55	17.46	7	850	>45	1
4	004	Non		Tanambao	Ambovombe	4	Imp	prive	1	10.7	0	10.5	7.35	965	>45	1
5	005	Non		Andaboly I	Ambovombe	4	ancien	prive	1	13.1	0	13.15	7.47	393	>45	1
6	006	Non		Bevoly	Ambovombe	4	?	prive	1	12.8	0	12.9	7.47	170	20	1
7	007	U040070		Puits Ambaro II	Ambovombe	2	2004	ptive	1	13.51	1	13.36	7.48	270	45	1
8	008	Non		Ambaro II Esingo	Ambovombe	4	1991	prive	1	11.80	0	11.6	7.65	170	5	1
9	009	U040086		Anjatoka II	Ambovombe	2	?	?	1	18.9	0.52	18.3	7.2	440	>45	1
10	010	-		AnjatokaIII	Ambovombe	4	1999	prive	1	14.15	0	14.5	7.6	170	45	1
11	011	U040107		Ambatoraty	Jafaro	1	1994	unicef	1	14.94	0.53	5.45	8.19	210	20	1
12	012	Non	F159	Betsumeda F159	Maroalosinty	1	1985	AES	2	56	imp	imp	-	-	-	2
13	013	Non	F166	Soafiry F166	Ambanisarika	1	1992	AES	2	imp	imp	imp	-	-	-	2
14	014	Non	F165	Ankaramena F165	Ambovombe	1	1992	AES	2	imp	imp	imp	imp	imp	imp	2
15	015	U040193		Amboliandro	Antanimora	1	1985	AES	1	20	0.45	14.73	7.85	394	<1	1
16	016	U1331	F21	Manave F21	Antanimora	1	1983	AES	1	68.4	0.54	22.73	7.23	170	1	1
17	017	?	F20	ANTSIRA F20	Antanimora	1	1983	AES	1	37.5	0.8	3.5	7.74	180	5	1
18	018	?	F127	AEP Antanimora F127	Antanimora	1	1990	AES	1	11.45	0.2	4.09	-	-	-	1
19	020	?	FB2	AEP Antanimora FB2	Antanimora	1	1990	AES	1	78	0.87	5.63	7.68	140	2	1
20	021	U040141		Ankifaly	Antanimora	1	1990	AES	1	19.75	0.83	10.95	7.43	170	>45	1
21	022	U040142	F133	AnkilyfdlyIII F133	Antanimora	1	1990	AES	1	13.5	0.5	7.1	7.14	340	>45	1
22	023	?	F134	AnkilifalyIV F134	Antanimora	1	1990	AES	2	-	-	-	-	-	-	2
23	024	U040138	F18	Antanimore CEG F18	Antanimora	1	1985	AES	2	-	-	-	-	-	-	2
24	024	?	F61	Ambatobe F61	Antanimora	1	1985	AES	2	20	?	9	-	-	-	?
25	025	?	F136	Ihorify F136	Antanimora	1	1990	AES	2	26	?	2.5	-	-	-	2
26	026	U040143 U1763	F62	Analamaiky F62	Antanimora	1	1994	AES	1	42.39	0.53	9.16	7.05	60	1	1
27	027	U040144	F62	Analamaiky II F62	Antanimora	1	1985	AES	1	18	0.26	8.42	7.11	40	1	1
28	028	-		Kamisy Antsakoamaro	Jafaro	1	1990	AES	2	32	0.2	4.9	imp	imp	imp	2
29	029	U040108	U1747	Kamisy Antsakoamaro	Jafaro	1	1994	unicef	1	25.3	0.51	2.8	7.56	333	>45	1
30	030	U3166		Kamisy Tanambao	Jafaro	1	2005	PAEPAR	1	19.3	0.1	4.5	7.43	73	<1	1
31	031	U040120	U1754	Andemby	Jafaro	1	1994	unicef	1	16	0.52	1.79	7.62	319	45	1
32	032	U040119		Jafaro	Jafaro	2	?	prive	1	10.7	0.65	10.7	-	-	-	2
33	033	U040118		Jafaro	Jafaro	1	1994	unicef	1	19.8	0.56	10.92	7.37	159	20	1
34	034	U3372		Jafaro SADROI	Jafaro	1	2005	PAEPAR	1	14.55	0.2	2.95	7.42	49	<1	1
35	035	U040116	U1761	Jafaro besakoa	Jafaro	1	1994	unicef	2	18.80	0.52	6.27	7.3	46	2	1
36	038	U040109	U1749	Anjeba I	Jafaro	1	1994	unicef	2	23.41	0.53	3.6	-	-	-	1
37	039	Non	F114	Anjeba II	Jafaro	1	1989	AES	2	18	0.2	17.79	-	-	-	2
38	040	Non	F51	Bongolava	Jafaro	1	1985	AES	2	20.6	0.4	14	-	-	-	2
39	041	Non	F52	Bevotry	Antanimora	1	1984	AES	-	-	-	-	-	-	-	2
40	042	Non	F53	Bevotry	Antanimora	1	1985	AES	2	30	0.25	17.62	7.48	102	20	1
41	043	Non	F67	Andcananivosoa	Jafaro	1	1985	AES	2	38	0.2	22.7	-	-	-	2
42	044		F66	Androvamary	Jafaro	1	1985	AES	-	-	-	-	-	-	-	1
43	082	U040110	U1762	Mandily I	Jafaro	1	1994	unicef	1	20.6	0.53	15.51	-	-	-	1
44	083	U040112	F163	Mandily II	Jafaro	1	1991	AES	2	56	0.2	17.15	-	-	-	1
45	084	Non	F75	Ankotsobe Haut	Jafaro	1	1988	AES	2	12.05	0.2	6	-	-	-	2
46	085	Non	-	Ankotsobe Beraketa	Jafaro	2	1975	prive	?	imp	imp	imp	-	-	-	1
47	086	Non	F161	Ankotsobe Bas Soavozo	Jafaro	1	1991	AES	2	17.2	0.2	4.83	7	678	45	1
48	087	U040113	U1665	Ankorokoroka	Jafaro	1	1994	unicef	2	40.78	0.53	13.1	7.15	610	20	1
49	088	U040133		Ankilimiary	Jafaro	1	1994	unicef	2	12.68	0.52	5.6	8.01	262	1	1
50	089	U040124		Lanany	Jafaro	1	1994	unicef	2	25.64	?	4.7	-	-	-	1
51	090	U3169		Andranohere	Jafaro	1	2004	PAEPAR	1	31.75	0.15	9.95	7.78	85	1	1
52	091	U040125		Ankaranarivo	Jafaro	1	1994	unicef	1	17.54	0.52	1.99	7.75	108	5	1
53	092	Non		Anakaranandindo	Jafaro	1	2004	PAEPAR	1	21.7	0.12	4.85	7.35	135	20	1
54	093	U040126	U1734	Antsakoaniary	Jafaro	1	1994	unicef	1	14.54	0.53	7.18	7.54	156	5	1
55	094	U040127	U1735	Anakaranandindo I	Jafaro	1	1994	unicef	1	14.6	0.52	4.17	7.38	236	20	1
56	095	U040122	U1739	Anjakambana haut	Jafaro	1	1994	unicef	1	18.6	0.53	3.85	7.8	162	45	1
57	096	U040121	U1740	Anjakamba bas	Jafaro	1	1994	unicef	1	23.4	0.53	10.43	7.71	224	20	1
58	097	U3146		befeno Anivorano	Antnimora	1	2004	PAEPAR	1	14.33	0.21	3.66	7.49	306	5	1
59	098	U3147		Ambaliandro Antsakabe	Antnimora	1	2004	PAEPAR	1	17.51	0.21	5.52	9.38	58	1	1
60	099	U040189		Ambaliandro Ankitibe	Antnimora	1	1994	unicef	1	22.92	0.6	10.11	7.58	551	>45	1
61	100	U040170		Bemamba Ampozy	Antnimora	1	1994	unicef	1	28.92	0.6	5.74	7.65	76	2	1
62	101	U040171	F143	Bemamba Ampozy	Antnimora	1	1990	AES	2	20	0.24	7.12	imp	imp	imp	2
63	102	U040172		Bemanga-Marolava	Antnimora	1	1994	unicef	1	36.4	0.53	13.53	8.1	15	1	1
64	103	U040169, U1333		Androtsy-Bezira	Antnimora	1	1994	unicef	2	34.64	0.52	10.26	7.89	114	10	1
65	104	U040168, U1409		Androtsy II	Antnimora	1	1994	unicef	2	34.5	0.5	16.42	7.19	359	20	1
66	105	U3154		Antsira Andido	Antnimora	1	2004	PAEPAR	1	20.32	0.2	6.95	7.84	86	2	1
67	119	U3102		Namolora	Antanimora	1	2005	PAEPAR	1	17	0.15	10.94	-	-	-	1
68	120	U040162		Namolora I	Antanimora	1	1994	unicef	1	25.41	0.58	11.79	770	150	5	3
69	121	U040163		Namolora II	Antanimora	1	1985	AES	2	imp	0.3	imp	-	-	-	2
70	122	U040068		Esingo	Ambovome	2	1950	prive	1	2.4	0.9	18.43	7.03	711	1	1
71	123	Non		Mitsangana	Ambovome	4	?	prive	1	12.8	0	13.15	8.12	200	45	1
72	124	Non		Mitsanoana-Marobe	Ambovome	4	2005	prive	1	13.35	0	13.35	7.7	189	10	1
73	125	U040164		Tanantsoa	Antanimora	1	1994	unicef	1	53.7	0.52	16.75	7.25	200	5	1

	2-1	1-1		1-2	1-6	4	5-1	5-2		6-2		6-3	7-2	7-3	7-4	12-1
Count Num	GPS_ID	Water point ID Num by MEM	Project ID	Water point name	Commune	Type	Year construction	Project name	Method	Depth	Rep=	SWL	pH	EC(ATC)	NO3	Exploitation
										m/Rep		m/Rep		mS/m	mg/L	
74	126	U040165		Imangory	Antanimora	1	1994	unicef	1	30.3	0.55	18.12	7.54	190	10	1
75	127	U040166		Imangory II	Antanimora	2	?	?	1	imp	0.7	14.3	-	-	-	1
76	128	Non		Soalapamiary	Antanimora	1	2004	PAEPAR	1	48	0.19	23.55	7.3	556	2	1
77	129	?	F53	Soalapamiary II	Antanimora	1	1985	AES	2	?	imp	imp	-	-		2
78	130	Laparoy		Laparoy	Antanimora	1	1985	AES	-	-	-	-	-	-	-	-
79	131	Bemanba		Tsarapioky	Antanimora	1	1985	AES	1	44.8	0.18	28.43	709	97	2	2
80	132	U040066		Mahavelo	Ambovome	2	1983	JICA	1	27.17	0.95	24.52	7.41	405	>45	1
81	133	Non	F17	AEP Antanimora F17	Antanimora	1	1985	AES	-	-	-	-	-	-	-	2
82	134	U040064		Mahavelo Toby	Ambovome	2	1990	AES	1	26.93	0.9	23.5	7.13	211	1	1
83	135	Non		AnjatokaIII	Ambovome	4	2000	prive	1	14.35	0	14	7.96	63.7	10	3
84	136	Non	F143	Ampozy F143	Antanimora	1	1985	AES	-	-	-	-	-	-	-	2
85	137	U040134		Analalava	Antanimora	1	1994	unicef	1	17.7	0.51	6.12	7.48	120	20	1
86	138	U040136		Andaboly I	Antanimora	2	colon	prive	1	5.2	0.6	4.9	8.16	68	5	1
87	139	U3144		Andaboly II	Antanimora	1	2005	PAEPAR	1	16.6	0.2	1.63	7.9	47	5	1
88	140	U3145		Andaboly III	Antanimora	1	2005	PAEPAR	1	15.65	0	4.33	7.9	64	2	1
89	141	U040104		Beteny	Antanimora	1	1994	unicef	1	38.75	0.47	4.07	8	233	45	1
90	142	U040105		Betegne	Antanimora	1	1988	AES	2	44	0.15	4	-	-	-	3
91	143	U040106		Beteny II	Antanimora	1	1988	AES	1	24.3	0.1	8.16	8	164	5	1
92	144	U040140		Anikilifaly Soajaro	Antnimora	1	1994	unicef	?	?	?	?	7.57	89	2	1
93	145	Non		Antsira Andnido	Antnimora	2	1989	AES	1	11.45	0.85	8.95	7.67	129	>45	3
94	146	?	F58	Bobafane	Antnimora	1	1985	AES	1	31.68	0.15	18.4	7.3	269	1	1
95	147	U040151		Andranomasy	Antnimora	2	1950	prive	1	11.6	0.3	9.8	7.25	317	1	1
96	148	U040149, U1711		Betioky-Andemby	Antnimora	1	1994	unicef	1	20.85	0.52	5.82	7.18	235	20	1
97	149	U040148, U1710		Angogobo I	Antnimora	1	1994	unicef	1	19.8	0.5	14.5	7.17	228	2	1
98	150	U040145		Angogobo II	Antnimora	1	1994	unicef	1	23.4	0.5	12.43	7.15	254	5	1
99	151	U040231		Mitsoraka	Antnimora	1	1985	AES	1	29.8	0.35	4.9	7.13	803	1	1
100	152	-	F159	Sakave	Ambohimalaza	1	1985	AES	1	42.0	0.15	25.35	7.6	487	1	1
101	153	?		Bemamba Antsatra	Antnimora	1	2004	PAEPAR	-	-	-	-	-	-	-	2
102	154	-	-	Bemamba Ampozy	Antnimora	2	1950	MEM	1	13	0.54	6.73	-	-	-	?
103	155	U040157		Ambovomiaramila	Antnimora	2	1945	senegalais	1	7.53	0.64	4.95	7.73	110	1	1
104	156	U040123	U1366	Tsiabetsaka	Jafro	1	1994	unicef	1	?	?	5.63	-	-	-	1
105	157	Non	U3367	Kobaimirafe	Jafro	1	2004	PAEPAR	2	60	-	-	-	-	-	2
106	158	U040115	U1759	Besakoa-bas-Jafaro	Jafaro	1	1994	unicef	1	36.1	0.52	7.99	7.4	144	<1	1
107	159	Non		Namolora	Antnimora	2	1976	MEM	1	14.77	0.8	sec	-	-	-	2
108	160	Non		Soalaro-ahandsofa	Antnimora	1	1985	AES	-	-	-	-	-	-	-	2
109	161	U040167	U1870	Andranogiso	Antnimora	1	1994	unicef	1	39.1	0.5	15.2	7.1	171	1	1
110	162	Non	-	Elevage	Ambovombe	2	1950	colonie fransais	-	-	-	-	-	-	-	2
111	163	Non	-	Elevage	Ambovombe	1	1983	AES	-	-	-	-	-	-	-	2
112	164	Non	-	Esalo	Ambovombe	2	-	-	1	32	0.8	sec	-	-	-	2
113	165	Non	-	Esalo	Ambovombe	4	-	-	-	-	-	-	740	997	20	2
114	166	-	-	Ambaro II Est de rest JO	Ambovombe	4	2004	prive	1	-	0	14.09	8.21	614	-	2
115	167	-	-	Ambaro II pre de HANSANI	Ambovombe	4	2003	prive	1	13.23	0.21	13.05	7.05	1024	>45	1
116	168	-	-	Ambaro I vers Kotoala	Ambovombe	2	1989	prive	1	9.62	0.24	8.75	8.3	214	?	1
117	169	-	-	Beabo elevage	Ambovombe	2	?	?	-	-	-	-	-	-	-	2
118	170	-	-	Beabo elevage	Ambovombe	2	1945	Colon	1	15.54	0	15.47	7.9	293	>45	1
119	171	U040074	-	Lycee Ambaro	Ambovombe	2	1950	colon	1	17.05	0.45	16.65	7.34	823	>45	1
120	201	Non		Ambondro centtre	Ambondro	2	1966	MEM	1	12.25	0	11	7.1	832	>45	2
121	202	U040000		Ambondro Rova	Ambondro	3	1966	MEM	1	11.9	0.8	10.9	7.15	452	>45	1
122	203	U040010		Nagnera I	Ambondro	2	1982	JICA	1	10.21	0.88	5.42	7.6	158	45	1
123	203	U040004 U040005		Ambondro Rova	Ambondro	4	1980	FLM	1	imp	-	imp	-	-	-	2
124	206	U040011		Nagnera II	Ambondro	2	1982	JICA	1	10.1	0.88	4.28	7.43	270	45	1
125	207	U040013		Ambondro	Ambondro	2	1982	JICA	1	12	0.88	-	-	-	-	2
126	208	U040042		Sihanadiva	Ambondro	2	1984	SYNODE FLM	2	8	0.8	5	-	-	-	2
127	209	U040014(41e rreur?)		Sihanadiva	Ambondro	2	1960	MEM	2	8	0.8	5	-	-	-	2
128	210	Non		Amindredahy	Erada	2	1997	RELANCE DE SUD (FED)	1	10.95	0.8	10.65	7.7	1,015	30	1
129	211	Non		Berehake	Ambazoa	1	1983	AES	1	-	-	-	-	-	-	2
130	213	Non		Kotoala	Ambazoa	2	1990	FLM SYNODE	1	imp	-	-	-	-	-	3
131	215	Non		Kotoala Ambony	Ambazoa	1	1960	Service des mines	1	imp	imp	imp	-	-	-	2
132	216	U024077		Ambohitsy	Antaritarika	2	1995	AES/Fondem	1	8.18	0.8	5.34	7.57	87.9	<1	1
133	221	U240049		Andranomitsinae	Antaritarika	2	1976	Prive et Communautaire(fokoutane)	1	7.8	0.015	8.5	8.06	505	45	1
134	222	U040006		Ambondro Rova	Ambondro	2	1960	MEM	1	?	0.5	4.55	7.85	259	>45	2
135	223	Non		Ankobabe	Ambazoa	2	1995	RELAN	1	3.5	0.85	3.5	7.79	684	45	1
136	224	U040031		Malaindoza	Ambazoa	2	1997	RELAN	1	4.94	0.55	4.77	8.05	477	>10	1
137	225	Non		Malaindoza(lrs)	Ambazoa	2	1955	Colon	1	12.95	0.3	sec	-	-	-	3
138	226	U040008		Ambondro	Ambondro	2	1980	FLM	-	-	-	-	-	-	-	2
139	227	U040043		Belemboka	Ambondro	2	1959	MEM	1	18.8	0.55	10.45	7.25	344	>45	3
140	228	U040016		Andasary	Ambondro	2	1969	FLM	1	5.67	0.5	2.41	7.55	164.4	>45	3
141	229	Non		Lamitihy sud	Ambondro	1	1960	?	-	-	-	-	-	-	-	2

	2-1	1-1		1-2	1-6	4	5-1	5-2		6-2		6-3	7-2	7-3	7-4	12-1
Count Num	GPS_ID	Water point ID Num by MEM	Project ID	Water point name	Commune	Type	Year construction	Project name	Method	Depth	Rep=	SWL	pH	EC(ATC)	NO3	Exploitation
										m/Rep		m/Rep		mS/m	mg/L	
142	231	Non		Analatoanano	Maloalomainty	2	1999	RELAN	1	12.3	0.8	11	7.74	270	>45	1
143	232	Non		Analatoanano	Maloalomainty	2	1960	Fokoulona	1	7.8	0.5	7.4	7.74	6.41	15	2
144	233	Non		Beaniky I	Ambovombe	2	1995	Fokoulona	1	5.4	0	5	7.28	1448	30	2
145	234	Non		Ionka	Erada	4	1998	Fokoulona	1	?	0	5.8	7.83	590	>45	3
146	236	Non		Erakoka esr	Maroalomainty	2	1915	Fokoulona	1	6.8	0.3	5.7	7.34	1340	45	2
147	239	U040016		Maugily	Ambondro	2	1960	MEM	1	SEC	0	SEC	-	-	-	2
148	240	U040018		Miandra	Sihanamaro	2	1954	Colon francais	1	6	0	sec	-	-	-	3
149	241	U040017		Miandra	Sihanamaro	2	1982	FLM	1	12	0	SEC	-	-	-	3
150	242	Non		Miandra	Sihanamaro	2	1954	Colon francais	1	12	0	SEC	-	-	-	2
151	243	-		Fekony	Imongy	2	1960	MEM	1	16.8	0	SEC	-	-	-	2
152	244	U2100		Fekony	Imongy	2	1962	MEM	1	7	0.5	SEC				2
153	245	U210073		Fekony	Imongy	2	1962	MEM	1	6	0	SEC	-	-	-	2
154	246	U040024		Aminake	Sihanamaro	2	1969	MEM	1	5.8	0.8	2.1	7.78	130.6	<2	3
155	247	U040021		Aminake pres bureau commune	Sihanamaro	2	1969	MEM	1	7.74	0.7	3.93	7.75	430	>45	3
156	248	U040039		Andramanera	Sihanamaro	2	1982	FLM	1	12	0	SEC	-	-	-	2
157	249	Non		Beakanga	Sihanamaro	2	1968	MEM	1	15	0.8	3.5	7.6	60.8	20	3
158	250	U040020		Ambohitse	Sihanamaro	2	1982	FLM	1	3.91	0.8	2.5	7.55	577	<20	3
159	251	-		Marokobo	Sihanamaro	2	1956	Colon francais	1	3.3	0	2	6.57	76.4	<1	3
160	252	-		Analamanoy	Sihanamaro	2	1974	MEM	1	14.34	0.7	SEC	-	-	-	3
161	253	-		Namalaza II	Marovato-Befeno	2	1985	FLM	1	11.56	1.28	8.75	7.72	107.9	2	3
162	254	-	-	Marovato	Marovato-Befeno	4	1960	Fokotany	2	10	0	9.5	6.3	45.2	<1	1
163	256	U21025		Bezara	Betanty	2	1950	Colon	1	6.6	0.8	6.25	8	330	>45	1
164	257	U21024		Bezara	Betanty	2	1950	Colon	1	7.5	1.7	7	8.11	515	>45	1
165	258	U210067		Benonoka	Betanty	1	-	-	2	170-175	?	-	-	Saline	-	2
166	262	U040058	-	Ampamolora	Ambohimalaza	2	1950	Prive	2	25	0.2	1.7	-	Saline	-	2
167	263	-		Bemamba rivera	Ambohimalaza	r	-	-	-	-	-	-	9.09	23.3	0	-
168	264	-	F43	Rarazy	Ambohimalaza	1	1970	MEM	2	?	?	?	-	-	-	2
169	265	-		Anday	Ambohimalaza	2	1950	France	2	20	0	sec	-	-	-	2
170	266	U03999		Ifotaka	Ifotaka	2	1962	Francais	2	30	0	?	8.07	31.6	0	1
171	267	U03040	F72	Bezara	Ifotaka	1	1987	AES	?	24	0	7.4	8.16	34.9	0	1
172	268	-		Sakave	Ambohimalaza	2	1965	Francais	1	12	0.7	0	-	-	-	2
173	269			Riviera Sakave	Ambohimalaza	r	-	-	-	-	-	-	8.32	26.5	0	-
174	270	-	F150	Sakave	Ambohimalaza	1	1990	AES	1	>50	0.2	25.2	7.4	473	0	3
175	271	Non		Ambaro	Ambovombe	4	2002	prive	1	8.8	0	8.5	7.98	224	10	1
176	272	Non		Ambaro	Ambovombe	4	1975	prive	1	10.8	0	10.45	8.45	88.9	5	1
177	273	Non		Mitsangana	Ambovombe	4	2002	prive	1	12.6	0	12.5	7.54	507	>45	1
178	274	Non		Mitsangana-Marolava	Ambovombe	4	2000	prive	1	10	0	0	-	-	-	2
179	275	Non		Mitsangana	Ambovombe	4	2000	prive	1	14.24	0	14	8.18	194.3	5	1
180	276	U040072		Ambaro I	Ambovombe	2	1968	prive	1	16.4	0.55	16.2	7.62	426	>45	1
181	277	U040081		Anjatoka I	Ambovombe	2	1979	prive	1	25.8	0.6	25.5	7.6	354	>45	1
182	278	Non		Andamboly I	Ambovombe	4	2001	prive	1	11.8	0	11.62	7.7	131	>45	1
183	279	Non		Berary	Ambovombe	4	2001	prive	1	0	7	0	-	-	-	2
184	280	Non		Andaboly I	Ambovombe	4	2000	prive	1	12.95	0	12.68	8.69	57.8	>45	1
185	281	Non		Andaboly I	Ambovombe	4	2002	prive	1	13.47	0	13.1	8.22	108.7	>45	1
186	282	Non		Andaboly centre	Ambovombe	4	1980	Centre pedagogique Ambovombe	2	12	0	0	-	-	-	2
187	283	Non		Ambovontany	Ambovombe	4	2002	prive	1	7.8	0	7.36	7.76	660	10	1
188	284	Non		Beabo-Andindo	Ambovombe	4	2001	prive	1	8.2	0	7.92	8.15	215	>45	1
189	285	Non		Taunaubao	Ambovombe	4	1970	Ancien Ambattoir	1	11.7	0	11.65	7.84	131.7	15	3
190	286	Non		Andaboly	Ambovombe	4	2003	prive	1	4	0	sec	-	-	-	2
191	287	Non		Avaradrova	Ambovombe	2	1954	prive	1	19.96	0.6	18.13	7.7	605	>45	1
192	288	Non		Tanambao III	Ambovombe	4	1962	prive	1	14	0	13.2	7.21	992	>45	2
193	289	Non		AnjatokaIII	Ambovombe	2	1966	prive	1	14.87	0.25	14.18	7.23	716	>45	1
194	290	Non		Tanambao	Ambovombe	4	1975	prive	1	12.7	0	12.25	7.97	1058	>45	2
195	291	Non		Tanambao	Ambovombe	4	1980	prive	1	12.0	0	11.65	7.32	486	>45	1
196	292	Non		AnjatokaIII	Ambovombe	2	1980	prive	1	13.4	0.6	12.84	7.67	378	>45	1
197	293	Non		AnjatokaIII	Ambovombe	4	1990	prive	1	10.3	0	10	7.77	178.8	>45	1
198	294	Non		Ambaro II	Ambovombe	4	2002	prive	1	14.19	0	13.1	7.97	489	>45	2
199	295	Non		AnjatokaIII	Ambovombe	4	2004	prive	1	13.3	0	12.8	7.83	313	>45	1
200	296	Non		AnjatokaIII	Ambovombe	4	2004	prive	1	13.7	0	12.73	7.52	231	>45	1
201	297	Non		AnjatokaIII	Ambovombe	4	2004	prive	1	15.05	0	14.83	7.33	175.6	>45	1
202	298	Non		AnjatokaIII	Ambovombe	4	2005	prive	1	14.2	0	13.87	8.05	92.7	10	1
203	299	Non		AnjatokaIII	Ambovombe	4	1990	prive	1	15.67	0	14.9	8.04	127	15	1
204	301	U040026 U040027 U040028		Tondroke	Sihanamaro	2	1988	FLM SYNODE	1	4.92	0.95	2.4	7.28	287	>45	1
205	302	Non		Nlsoa	Sihanamaro	2	1985	FLM SYNODE	1	11.6	0.93	3.7	7.99	403	2	3
206	303	U040033		Amagne	Sihanamaro	2	1988	FLM SYNODE	1	5.11	0.58	2.88	7.37	885	<1	3
207	304	U040037		Mientse	Marnato Befeno	2	1988	FLM SYNODE	1	3.0	0.78	2.8	8.58	5760	5	1

	2-1	1-1		1-2	1-6	4	5-1	5-2		6-2		6-3	7-2	7-3	7-4	12-1
Count Num	GPS_ID	Water point ID Num by MEM	Project ID	Water point name	Commune	Type	Year construction	Project name	Method	Depth	Rep=	SWL	pH	EC(ATC)	NO3	Exploitation
										m/Rep		m/Rep		mS/m	mg/L	
208	305	non		Namosirana	Marnato Befeno	2	1958	MEM(Eolienne)	1	-	-	-	-	-	-	1
209	500	Non		Andranokoake	Ambovombe	4	2005	prive	1	18.6	0	18.25	8.3	103.4	10	1
210	501	Non		Andranokoake	Ambovombe	4	2005	prive	1	14.17	0	14.05	7.92	86.7	20	1
211	502	U040077 U040078		Andranokoake	Ambovombe	2	1955	?	1	8.94	0.5	sec	-	-	-	2
212	503	U040095U04 0096U040093		Bevoly	Ambovombe	2	1954	?	1	7	0.8	sec	-	-	-	2
213	504	U040402		Bevoly	Ambovombe	2	1954	?	1	14	0.8	sec	-	-	-	2
214	505	U040075		Tanambao II	Ambovombe	2	1960	prive	1	14.35	0.75	13.56	7.35	668	>45	1
215	506	Non		Andranokoake	Ambovombe	4	1985	prive	1	14.5	0	14.2	8.19	153.6	45	1
216	508	Non		Andranokoake	Ambovombe	4	2004	prive	1	15.5	0	15.35	7.73	84.4	10	1
217	509	Non		Bevoly	Ambovombe	4	2001	prive	1	12.2	0	12.15	7.47	153.5	>45	1
218	510	Non		Bevoly	Ambovombe	4	2002	prive	1	14.7	0	14	8.02	113.2	10	1
219	511	U040100		Bevoly	Ambovombe	2	?	?	1	5	0.4	sec	-	-	-	2
220	512	Non		Bevoly	Ambovombe	4	2004	prive	1	11	0	10.6	7.75	95.1	45	1
221	513	Non		Bevoly	Ambovombe	4	2004	prive	1	11.7	0	11.62	7.89	82.3	10	1
222	514	Non		Bevoly	Ambovombe	4	2000	prive	1	12.9	0	12.8	7.6	65.2	10	1
223	515	Non		Bevoly	Ambovombe	4	2004	prive	1	11.62	0	11.45	7.67	72.1	10	1
224	516	Non		Bevoly	Ambovombe	4	2002	prive	1	13.8	0	13	8.14	80.8	10	1
225	517	Non		Bevoly	Ambovombe	4	2004	prive	1	11.65	0	11.53	8.17	75.1	45	1
226	518	Non		Andranokoake	Ambovombe	2	1985	prive	1	11.03	0.25	10.5	7.47	331	10	3
227	519	Non		Andranokoake	Ambovombe	4	1984	prive	1	9.67	0	9.56	7.4	109.8	>45	1
228	520	U03032	-	Belela	Sampona	2	2001	Fokonolona	1	9.22	0.3	9.02	7.15	681	45	1
229	521	U03034		Elanja	Sampona	2	1997	relance du sud(FED)	1	6.92	0.8	6.8	7.66	371	>45	1
230	522	U03033		Elanja	Sampona	2	1996	relance du sud(FED)	1	7.96	0.8	7.84	7.81	202	>45	1
231	601	Non	F11	CAPJ F11	Ambovombe	1	1982	AES	2	35	-	14.3				2

Classification

- *4 Type : 1. Bore 2. Shallow 3. Vovo prot 4. Vovo sans prot*
- *12-1 Exploitation: 1.Possible 2.Impossible 3.It needs to repair*
- *Measurement method 1. Measure actual 2. Estimation*

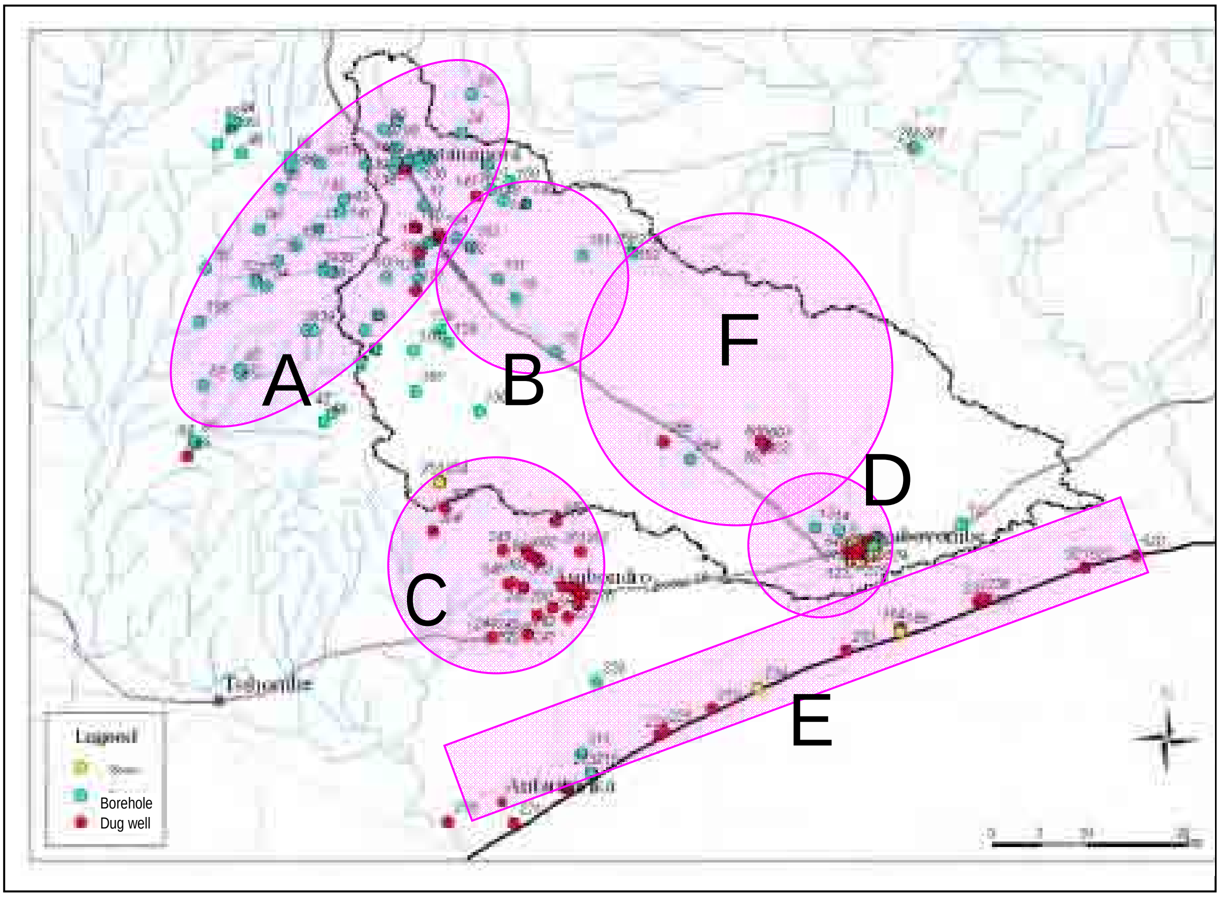
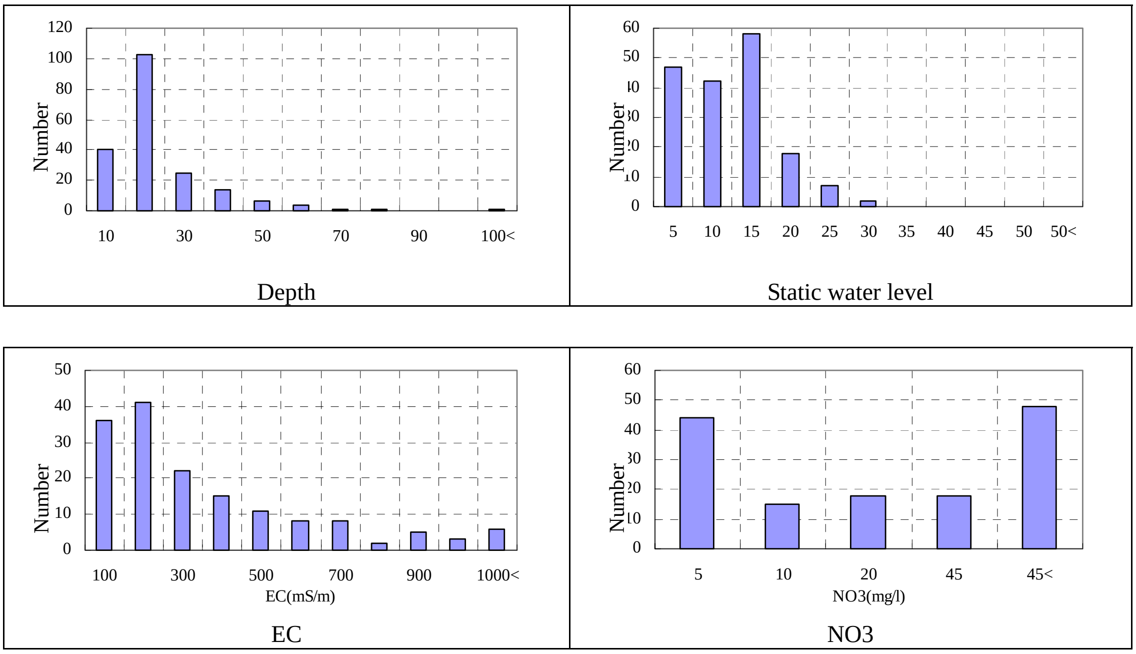


Figure 3.2.2-2 Water Point Plot

(3) Frequency Distribution

1) All of the study area

Frequency distribution is shown below regarding well depth, static water level, electric conductivity and NO3



Note: Surveyed data

Figure 3.2.2-3 Distribution of Numbers for all data

The distribution graphs indicate following characteristics.

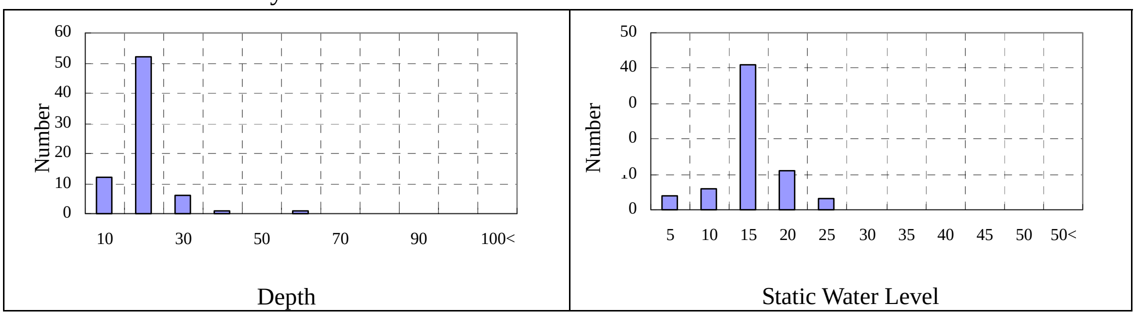
- ➢ Most of well depth are shallower than 30m
- ➢ Several sites have well depth of more than 50m.
- ➢ Static water level is shallower than 30m in general.
- ➢ Some wells showed electric conductivity of even more than 1000 μ S/cm.
- ➢ The most numbered NO3 content is more than 45mg/L

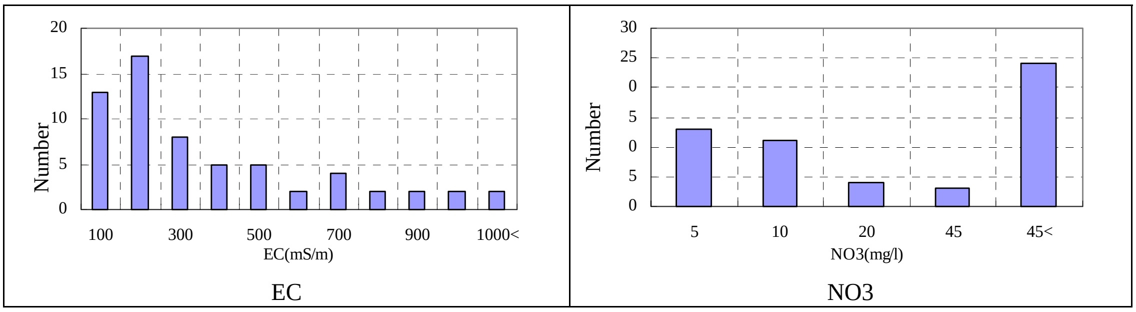
Those support following phenomena

- ➢ Salinity in the ground water spread out at many of places
- ➢ High content of NO3 indicate progress of influence by human activity.

2) Area D and area F

Especially, there are a lot of shallow well at the center of the Basin including Ambovombe urban. Distribution of inventory is shown below.





Note: Surveyed data

Figure 3.2.2-4 Distribution of Numbers for Area D and Area F

The distribution graphs indicate following characteristic.

- Most of well depth are shallower than 30m
- All of static water level is shallower than 30m.
- Electric conductivity is more than 1000 µ S/cm at the most.
- The most numbered NO3 content is more than 45mg/L

(4) Interpretation

1) Local characteristics

a) Water source at the border of coastline (Area E)

Some reports say that there are wells which have artesian, good quality water and have enough amount of yield. However, these revealed to be not true. The target aquifer of the wells are on very thin layer having low salinity above the highly contaminated one from seawater. Water quality is accepted as use for livestock or emergence by habitants, but still conductivity, which is ranging from 300 mS/m – 600 mS/m is too high for drinking and washing clothes.

In case of developing water points, preferable well location is setting them away from the coastline to avoid influence of seawater. However, altitude varies from 40m to 60m with steep slope from coastline, no longer proper location doesn't exist to construct hand-dug wells.
If the groundwater flow from the land exists, and the static water level might be higher than the seawater level, then the thicker layer of fresh water might exist away from the coastline, or, the direction of groundwater migration might be vertical rather than horizontal at the coastal dune.

In case that an aquifer laying above the saline water is targeted, conditions to take into account are:

- Location away from the sea coast to reduce influence of the see water.
- Absolute static water level might be the same as sea water level. So, it needs to evaluate existence of aquifer around 0m carefully or to set a screen for test pumping.

b) Ambovombe (Area D)

Water quality in the southern part is obviously better than the center and the northern part. From that reason, many water points are developed and most of water sellers exploit wells in the southern area of urban Amvobombe. In the past reports, it was interpreted that the origin of pollution, which were presented by the electric conductivity, nitrate or total dissolved sediments, is human activity. This might prove to be right, according to the results of the inventory survey. The major reason is that the depth of aquifer, which overlay impermeable clay formation is, 10-25m while the density of pit latrine exist a lot in the view of population. However, some phenomena suggest existence of several other conditions. For example,

- Location of high nitrate and high conductivity don’t always coincide.
- During rain season, there is a lot of rainfall. All of them, except evaporation, infiltrate to the ground because there is no river in the area. The rain might dilute mineral concentration of the ground water, especially, at the unconfined aquifer.
- If the polluted water migrates from center of city to the surrounding Ambovombe, concentration of salinity might not be extremely high at the area away from habitants.

From those points, the expected characteristics of aquifer at Ambovombe might be as follows

- Impermeable formations exist below aquifer at the center of the town blocking the polluted water to percolate underneath. This impermeable formation forms small-scale local basin.
- This impermeable formation has limited extension. The exceeded amount of water at the local basin migrate to the surroundings of Ambovombe or percolate to underneath.
- Higher permeable formation exist locally above the aquifer exploited and then might be form drainages of rainwater, or high permeable layer continues to the deep locally, which penetrate impermeable formations, then, rainwater percolates underneath through them.

If the static water level in the water saturated formation will be clarified by test drilling, it helps very much to establish better aquifer model.

c) Coastal dune area (Area E)

No water points exist, but in the colonial regime, several boreholes were drilled and were exploited and equipped with windmills. However, salinity was too high to utilize for drinking water. Although sandy limestone and consolidates calcium with sand is outcropped at the dune, it is hard to think that impermeable formation, which hold groundwater, exist in the dune because there isn’t any damps at depression which have altitude only 120m-160m among dunes. Therefore, potential of ground water for dug well might be less at the ridge and the slope of dune.

d) Ambondro area (Area C)

The map kept at the AES indicates an extension of “Sable blanc (White sand)” as high potential area of groundwater. It lays to the northern part of Ambondro. Therefore, a lot of dug wells and vovos were constructed. However, many of them dried up. The difference between the dried wells and productive wells is the depth of well. Most of the dried wells have just a few meters in depth.

e) Basement rock area

Depth of aquifer is targeted to shallower depth and SWL also generally not so deep. Frequently, conductivity and nitrate are highly contained. Taking into account the size of villages, the cause of high conductivity and nitrate might be the geological origin. Therefore, water quality at greater depth is suspicious. And since the Ambovombe basin is located downstream of basement rock area, groundwater from basement rock area also may contribute to degrade water quality.

(5) Synthesis

1) Summary

Characteristics of the water source points shall be summarized below

Table 3.2.2-2 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

2) Required data hereafter

Result of inventory revealed that water source points are distributed unevenly. In some areas well doesn't exist at all. For evaluation of groundwater flow, the location for test drilling is proposed as below from the result of inventory survey

a) Borehole
- Center of basin (West, Center, East)
- Coastal dune (Sampona, SE of Ambovombe, SW Ambovombe, North of Antaritarika)
- South of Sakave, Boundary of water system near Ifotaka

b) Dug well
- Between Manave and Ambovombe to cover area evenly spread.

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.

In general, Impluvium doesn't exist where groundwater is available. The required number of Impluvium in one Commune is calculated by subtracting number of Fokontany, where there groundwater source, from the number of Fokontany.

The number of Fokontany varies depending on the commune. Ratio of functioning and existence are calculated on the number of Fokontany. Existence is 36%, while functioning is 12%. This indicates poor maintenance on the Impluvium. Recently, the OS conducted rehabilitation and new construction project. The number of new construction is 6 and the number of rehabilitation is 15 within the study area. That number is 21 of 43 "Good" Impluvia. The ratio of functioning versus Fokontany is nearly 6% before. Ratio of functioning versus total number is 17%. Those indicate difficulty of maintaining Impluvium.

At Ambanisarika commune, the existence is nearly 100%, while functioning is less than 10%. At Ambovombe there is not much difference between existence ratio and functioning ratio. This indicates that commune rehabilitate many of them by their own. The economic capacity of commune affects ability of maintenance.

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
1	Ambazoa	20	12	5	2	5	0	15	25%	60%
2	Ambovombe	61	17	13	3	1	10	38	21%	28%
3	Ambonaivo	15	16	3	11	2	0	12	20%	107%
4	Tsimananada	10	3	2	1	0	0	8	20%	30%
5	Erada	17	9	3	0	6	0	14	18%	53%
6	Analamary	15	4	2	0	2	1	12	13%	27%
7	Maroalomainty	33	12	4	0	8	0	29	12%	36%
8	Maroalopoty	47	9	4	1	4	0	43	9%	19%
9	Ambanisarika	12	11	1	5	5	0	11	8%	92%
10	Beanantara	27	5	2	2	1	0	25	7%	19%
11	Ambohimalaza	15	9	1	3	4	2	12	7%	60%
12	Amobondro	23	7	1	6	0	4	18	4%	30%
13	Sihanamaro	28	8	1	2	5	10	17	4%	29%
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 Methodology

(1) Satellite Image Data

The Landsat-7 ETM+ data was employed as satellite image interpretation. Of the scenes employed, those without cloud coverage were selected.

(2) DEM Data

The SRTM (Shuttle Radar Topography Mission) data was employed as DEM data. The data were acquired from the mission of the SPACE SHUTTLE ENDEAVOUR, in February 2000.

3.3.2 Data Processing of Satellite image

Data processing of the satellite image was performed with the software Micro Image TNT Maps under the subcontract in Japan in January to March 2005. Some themes were analyzed automatically through the routine installed in the software. Themes analyzed are listed below:

1) Lineaments detection manually with visual judgments, scale 1/250,000
2) Lineaments detection automatically (by the algorithm prepared by software provider), scale 1/250,000
3) Superimposed image with 1/100,000 topographic map, scale 1/125,000.
4) Superimposed image with 1/500,000 geology map, scale 1/500,000
5) River system and boundary detection by automatic, scale 1/400,000
6) Depression detection, scale 1/400,000
7) Surface openings and underground openings, scale 1/400,000
8) Bird's eye view, 1/400,000, scale 1/400,000
9) Shades interpreted with DEM data, 1/400,000, scale 1/400,000
10) Altitude contour and colored, scale 1/400,000
11) Slope interpretation, scale 1/400,000
12) Cross section, scale 1/500,000
13) Vegetation, scale 1/400,000

3.3.3 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 Sakave 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 Manave and Ambaliandro, groundwater might flow out toward east and be drained to the Mandrare River.

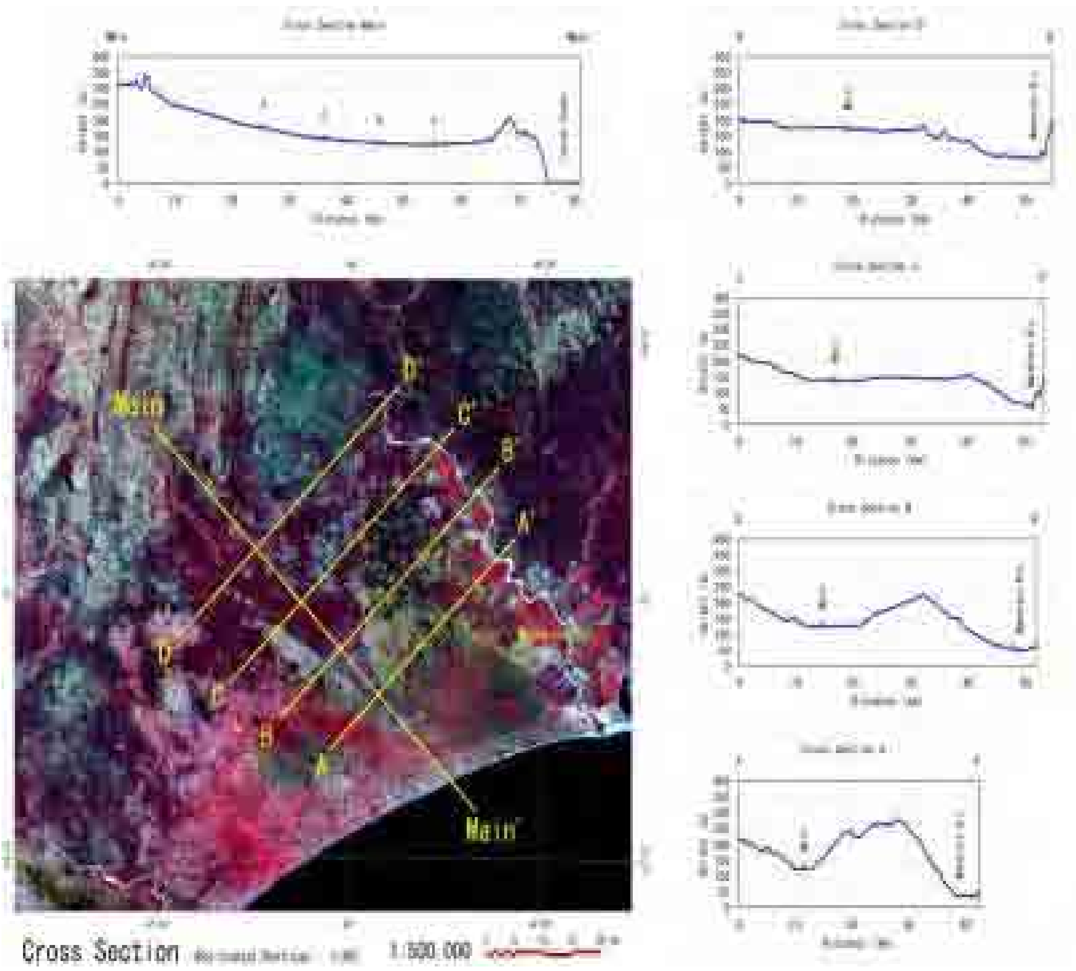


Figure 3.3.3-1 Topographic Analysis

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.

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.

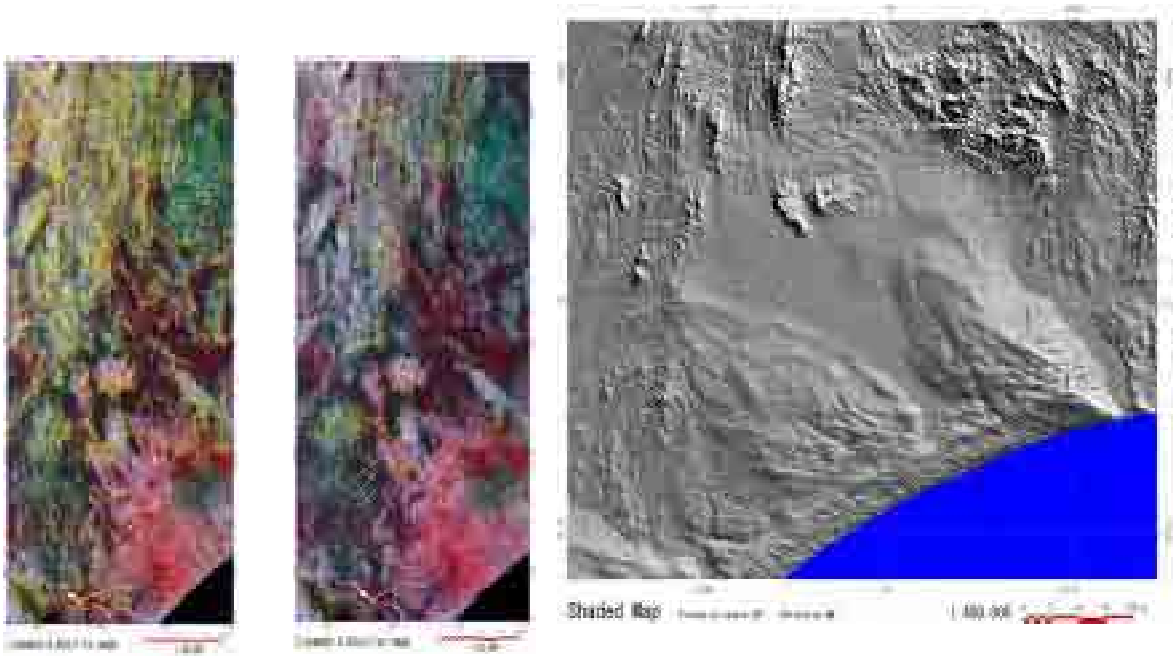


Figure 3.3.3-2 Lineament Analysis and DEM Data interpretation

(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 Beanantara – Sakave - around Antanimora - west of Namorola – Bevoty - Analamalaza - west of Ambanisarika-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.

Figure 3.3.3-3　River System of the Ambovombe Basin

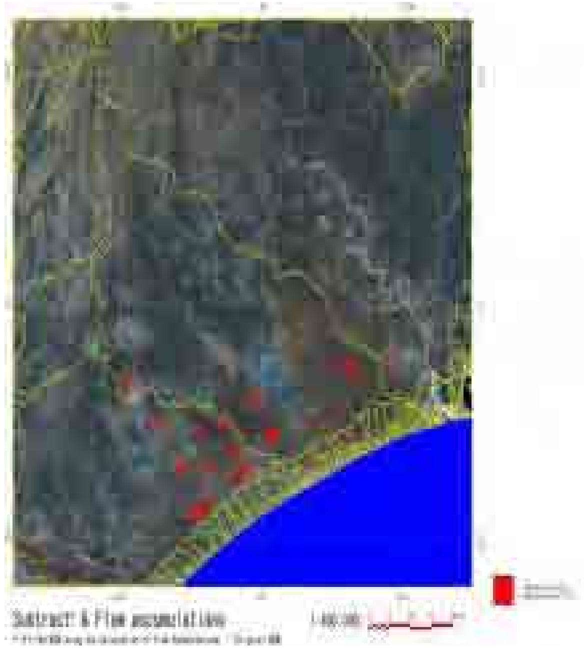


Figure 3.3.3-4 The Damp and Depression in Ambovombe Basin

(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 Benantara.

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, is that silt and clay deposits in the depression and forms impermeable layer. Further analysis can be conducted by superimposing the location of depression with the location of wells.

2)　Between Ambovombe and Benantara

The inclination of slope between Ambovombe and the boundary of Amboasary 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 3.3.3-5 Bird's-Eye View

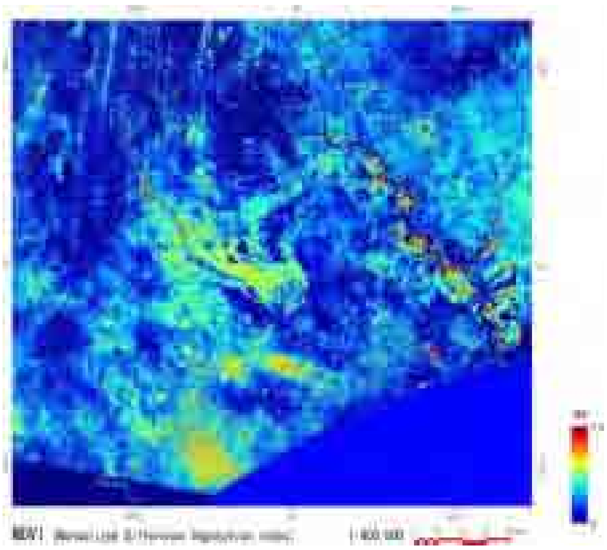


Figure 3.3.3-6 Vegetation and Land Use Map

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 Ampamolora 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

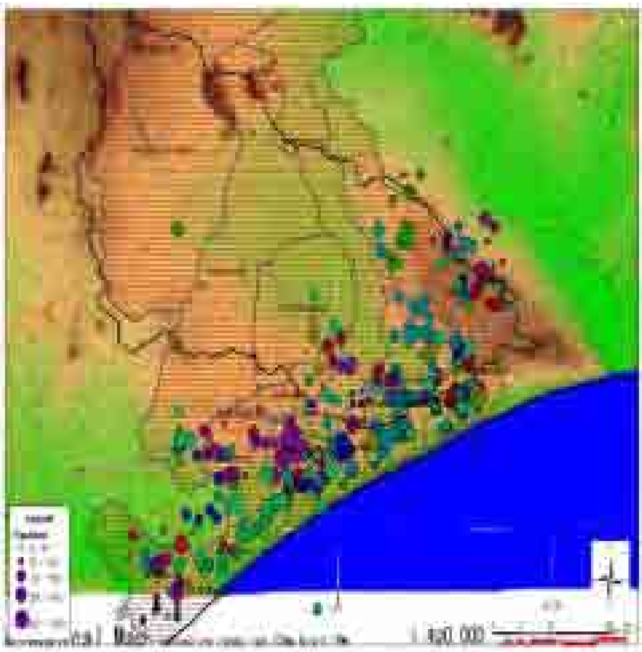


Figure 3.3.3-7 Village Distribution in the Study Area

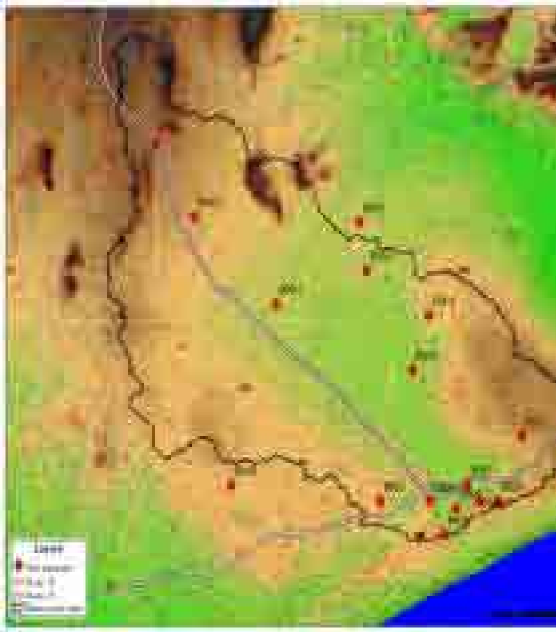


Figure 3.3.3-8 Test Drilling Location

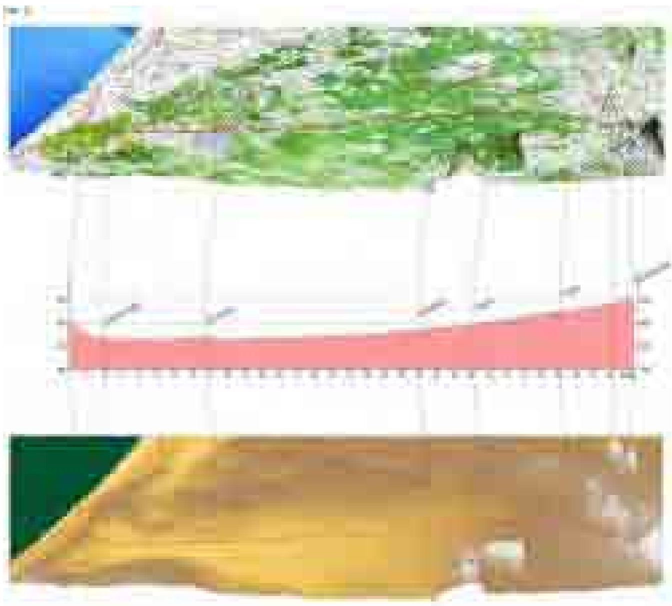


Figure 3.3.3-9 Topographic Measurement Survey by Satellite Image

Figure 3.3.3-10 Topographic Map Overlapped by Satellite Image for Field Reconnaissance

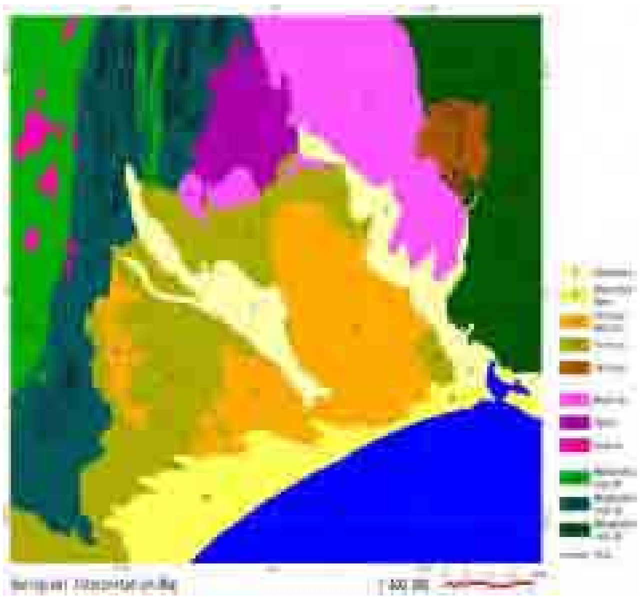


Figure 3.3.3-11 Geological Map from Satellite Image

Figure 3.3.3-12 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.
The names of the missions and the number of sheets purchased from each mission are given below.
Also, the list of aerial photographs purchased is listed on table 3.4.1-1

- Mission – 037 – 1950 – 1/50,000 J63 AMBONDRO 35sheets
- Mission – 038 – 1950 – 1/50,000 L61 TRANOMARO 11sheets
- Mission – 038 – 1950 – 1/50,000 K61 EBELO 20sheets
- Mission – 038 – 1950 – 1/50,000 K62 AMBOVOMBE 57sheets
- Mission – 038 – 1950 – 1/50,000 K63 ERADA 11sheets
- Mission – 038 – 1950 – 1/50,000 J61 IMANOMBO 20sheets
- Mission – 038 – 1950 – 1/50,000 J62 ANTANIMORA 64sheets
- Mission – 038 – 1950 – 1/50,000 L62 AMBOSASARY-SUD 34sheets

* The scale of photographs is about 1/50,000.

Table 3.4.1-1 List of Aerial Photographs

Name of map and photo number Mission – 038/037 – 1950 – 1/50.000							
J63	L61	K61	K62	K63	J61	J62	L62
AMBONDRO	TRANOMARO	EBELO	AMBOVOMBE	ERADA	IMANOMBO	ANTANIMORA	AMBOSASARY-SUD
037	405	230	235	249	024	056	410
038	406	231	236	250	025	057	411
039	407	232	237	251	****	058	412
040	408	233	238	252	074	059	413
041	409	234	239	****	075	060	414
042	****	****	240	254	076	061	415
043	438	273	241	255	077	062	416
044	439	274	242	256	****	063	417
****	440	275	243	****	114	064	418
047	441	276	244	339	115	065	419
048	442	277	245	340	116	066	420
049	443	****	246	****	117	****	421
050	****	321	247	343	****	026	422
051		322	248	344	161	027	****
052		323	****	****	162	028	425
053		324	257		163	029	426
054		325	258		164	030	427
055		****	259		165	031	428
****		358	260		****	032	429
132		359	261		195	033	430
133		360	262		196	034	431
134		361	263		****	035	432
135		362	264		975	036	433
136		****	265		976	****	434
137			266		977	118	435
138			267		****	119	436
****			268			120	437
142			269			121	****
143			270			122	493
144			271			123	494
145			272			124	495
146			****			125	496
147			326			126	497
****			327			127	498
214			328			128	****
215			329			129	
216			330			130	
217			331			131	
218			332			****	
****			333			148	
			334			149	
			335			150	
			336			151	
			337			152	
			338			153	
			****			154	
			344			155	
			345			156	
			346			157	
			347			158	
			348			159	
			349			160	
			350				
			351			978	
			352			979	
			353			980	
			354			981	
			355			982	
			356			983	
			357			984	
			****			985	
						986	
						987	
						****	
						211	
						212	
						213	
						073	
						074	

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 at 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

1) Ambovombe Area

The boundary to the sand dune zone is observed in the southern part of Ambovombe. The dune is presented in a stripped texture. The boundary matches with the areas where the water source points were found. On the other hand, the northern part of Ambovombe is surrounded by dark monotone filed. This can be interpreted as flood plane area. Its boundary is also clearly presented. The remarkable feature is extension of flood plane from north west. It almost reaches to the center of the town. From this detailed topographic features, there may be some possibility to develop groundwater at the edge of dunes.

Ambovombe	
K62	
259	337
258	338

2) Ambanisarika

At the southern part of this area, boundary of dunes can also be observed. On the photographs, the dunes are presented as laminar rather than stripped texture. At the western part, few kilometers from Ambanisarika, monotone plane is observed, which has a linear structure. The same theory with the Ambovombe area can be stated that there may be some possibility to develop groundwater at the edge of dune area.

Ambovombe	
K62	
247	258
248	257

3) Ampamolora and Lake Sarimonto

Lake Sarimonto is not one big water body, but actually is a group of many ponds. These ponds are formed to resemble a tree, spreading out branches. However, there isn't strong orientation of water flow. Even in the upstream area, streams don't seem to exist in the surrounding area. In the north-eastern area of Lake Sarimonto, several green lines, which represent flows, are observed.

Ambovombe	
K62	
244	263
245	262

4) Ananatsakoa (15km to north east north from Ambovombe)

As far as topographical features are concerned, this area can be thought to be suitable area for groundwater development since the altitude is higher than the Ambovombe commune thus the water can be transmitted easily by gravity.

From the observations of the aerial photographs, no apparent feature is observed, but, a stream-like feature can be observed in the center-west on photograph 334, though this is expected to be covered with permeable formation.

Ambovombe
K62
332
333
334

5) Anjira (5km to north from Antaritarika)

The direction of the striped texture changes its direction from EES-NNW to SE-NW, and return to the same direction. Also, since this area has the lowest altitude, some anomaly structure may exist.

Ambondro	
J63	
134	145
135	144

6) Ambondro

Ambondro	
J63	
148(NA)	213(NA)
147	214

This town appears as a well cultivated land in the monotone plane. No apparent feature is observed although many wells are developed.

7) Manave

Antanimora	
J62	
122	157
123	156

The Bemamba River fades out at the point 2km south from the Manave village. The area is presented as light colored. Slight branch of river flow out from there, but fade out again.

8) Bemamba

Antanimora		
J62		
121	157	981

The Bemamba River changes its width at Bemamba village. The main course changes direction about 50degrees to the south while the trace of the river, which is presented in dark color line keep direction. This area is in the transition zone from hard rock to sediments. From this observation, the groundwater flow may disperse in this area. The water recharge to the ground may vary at the location although the Ambovombe basin looks forming even plane. And flow direction change with steep angle at west of the Bemamba. That might be a confluence point of lineament.

9) Antanimora

Antanimora
J62
Imanombo
J61
074

Base texture direction is N-S, lineament represented as a stream erode with direction of SE-NW and SW-NE. Direction of SE-NW is rather clear. According to the well-inventory survey, areas which had lower electric conductivity are spread from the town to the west while the water flowing in the Bemamba river, near the AES base, have high electric conductivity. The observed difference can be an existence of another stream which flow from west to the northern part of Antanimora. The better quality water may be recharged from this stream rather than the Bemamba River. The results of the well inventory survey shows that the borehole at the village Andaboly has the lower conductivity and target aquifer. This seemed to be a high potential area concerning water quality, but maybe, yield is not enough because fresh rock starts shallower depth. If drilling point move to north or west to the lineament, chance to have yield might increase.

10) Bevory

Antanimora
J62
062
061

From the well inventory survey, electric conductivity of ground water is rather lower around this area. The aerial photograph shows that base texture direction is N-S, the lineaments represented as stream erode with direction of SE-NW and SW-NE. Direction of SE-NW is rather clear. Areas of lower electric conductivity are spread from the BEVORY Mountain, but, there is no clear indication which distinguishes with other areas. From this mountain, the north-western part and the south-eastern part show very different texture. At the north-western part, basement rock is outcropped while the south-eastern part covered with sediments. The fracture is well developed at the basement rock area, and then the fractured rocks may continue to the sediments area.

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 technique were applied for the study. Table 3.5.1-1 shows the general information of the applied technique of the geophysical survey.

Table 3.5.1-1 Applied Techniques for the Geophysical Survey

Name of Technique	Objectives and principles	Surveyed Area
VES Survey (Vertical Electric Sounding)	➢ To understand basic geological structure within the study area. ➢ Resistivity of subsurface layer is measured by this survey.	Surveyed points are located to cover the whole study area
IP Survey (Induced Polarization Method)	➢ To understand distribution of weathered or fractured zone within the study area. ➢ Induced polarization value of subsurface layer is measured by this survey. ➢ Resistivity of subsurface layer is also measured by this survey.	Surveyed lines are mainly located in northern part of the study area (Basement Rock Area)
TEM Survey (Time-Domain Electromagnetic Method)	➢ To understand distribution of weathered or fractured zone within the study area. ➢ Resistivity of subsurface layer is measured by this survey.	Surveyed points are mainly located in northern part of the study area and southern coastal area

Figure 3.5.1-1 shows the locations of all surveyed points for applied three type of geophysical survey.

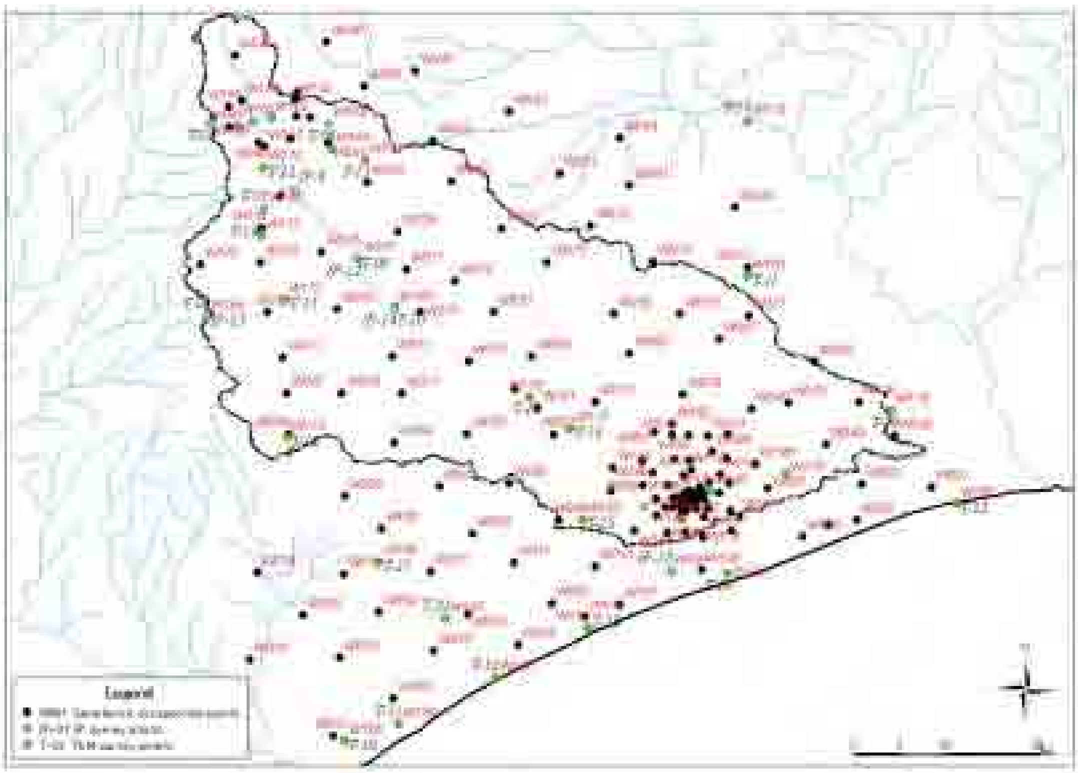


Figure 3.5.1-1 Location map of geophysical survey points

Table 3.5.1-2 summarizes the results of interpretation which are obtained from the three types of geophysical survey.

Table 3.5.1-2 Integrated interpretation of geophysical survey

Area	Integrated interpretation
Central part of the Ambovombe Commune	The distribution of basement rock, aquifer layer and impermeable layer is interpreted by the results of VES survey. Distribution of aquifer layer is also interpreted by the result of IP survey and TEM survey.
Western part of the Ambovombe Commune	The distribution of basement rock and aquifer layer is interpreted by the results of VES survey. Distribution of aquifer layer is also interpreted by the results of TEM survey.
Eastern part of the Ambovombe Commune	The distribution of basement rock and aquifer layer is interpreted by the results of VES survey. Distribution of aquifer layer is also interpreted by the result of TEM survey.
Coastal area	The distribution of basement rock, aquifer layer and impermeable layer is not interpreted by the results of VES survey and TEM survey. Very low resistivity layer is interpreted by VES survey and TEM survey results. This layer thought to be influenced by saline water (sea water). From IP survey result, sand stone layer is interpreted at the deep part.
Central part of the Ambovombe Basin	The distribution of basement rock is interpreted by the results of VES survey. Thickened muddy sediments layer is interpreted by the results of VES survey and TEM survey.
Northern part of the Ambovombe Basin	The distribution of basement rock and aquifer layer is interpreted by the results of VES survey. The distribution of fault zone and weathered zone is interpreted by the results of IP survey and TEM survey.
North end of the Ambovombe Basin	The distribution of basement rock is interpreted by the results of VES survey. The distribution of fault zone and weathered zone is interpreted by the results of IP survey and TEM survey.

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.

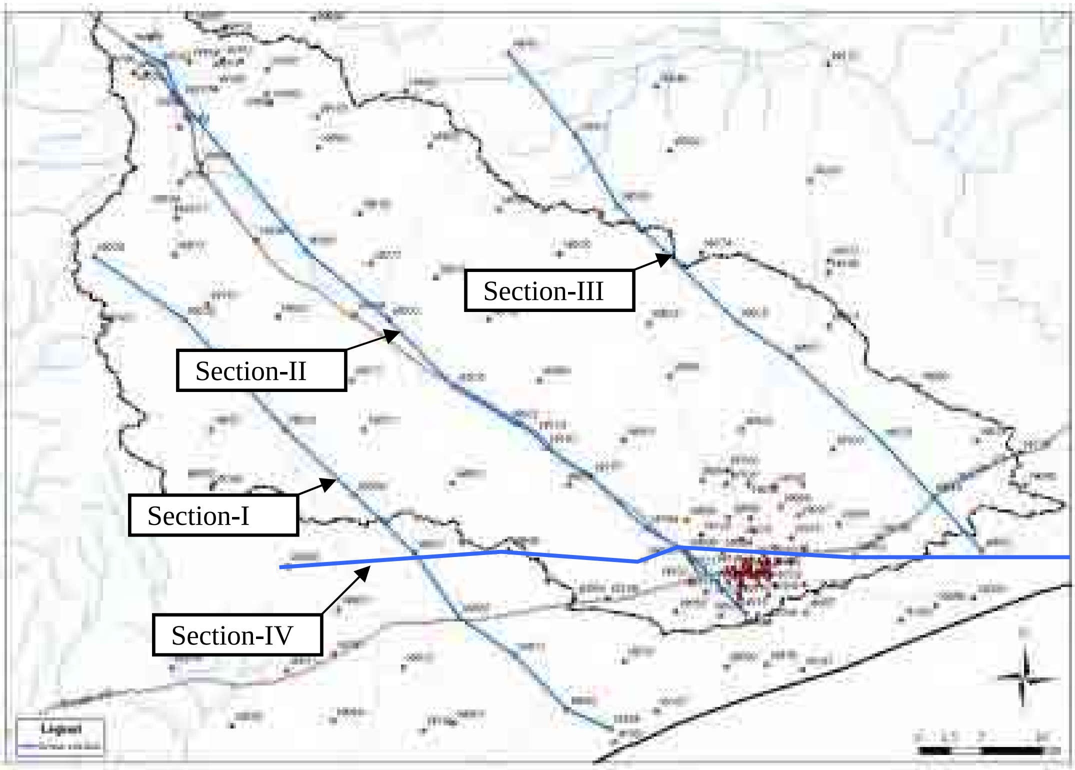


Figure 3.5.2-1 Location Map of Cross Section

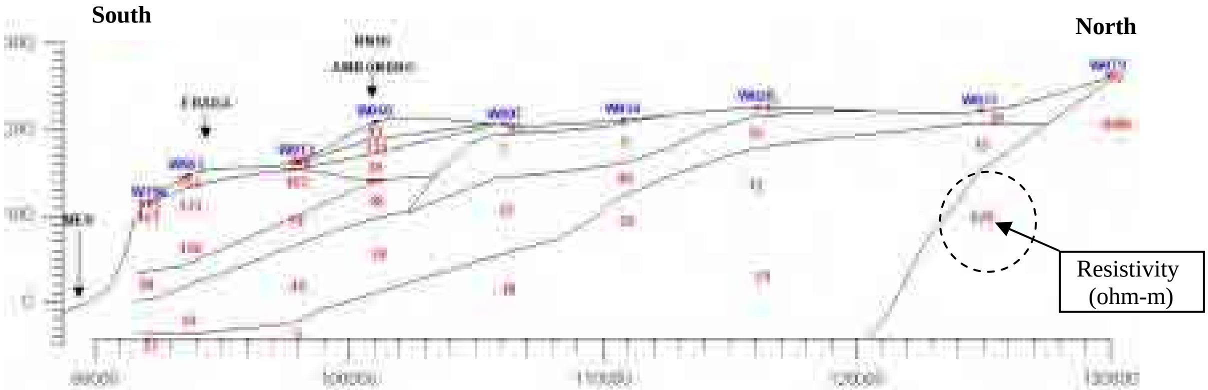


Figure 3.5.2-2 (a) Cross Section I

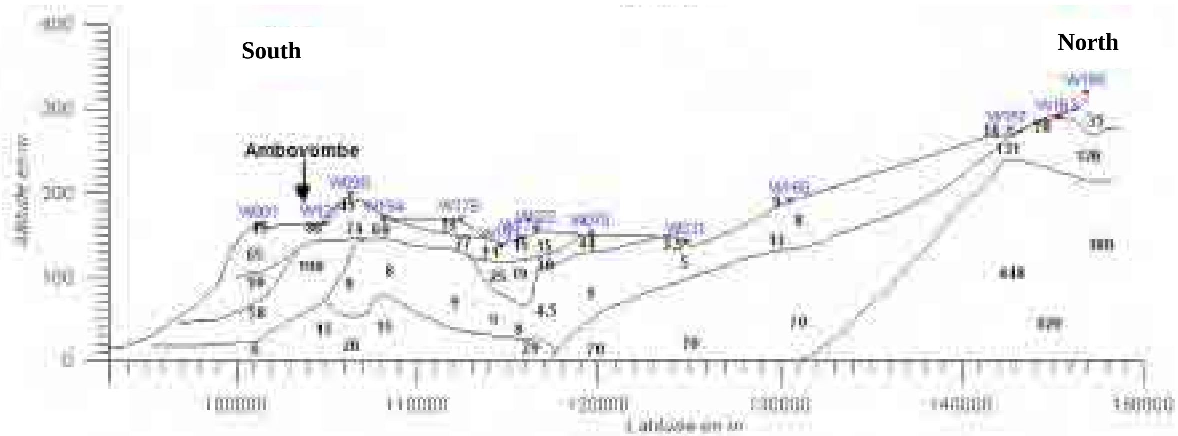


Figure 3.5.2-2 (b) Cross Section II

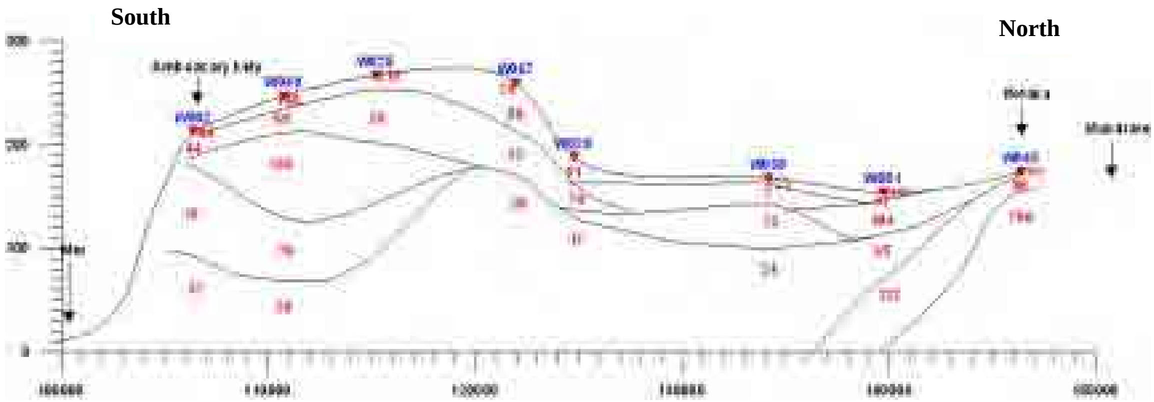


Figure 3.5.2-2 (c) Cross Section III

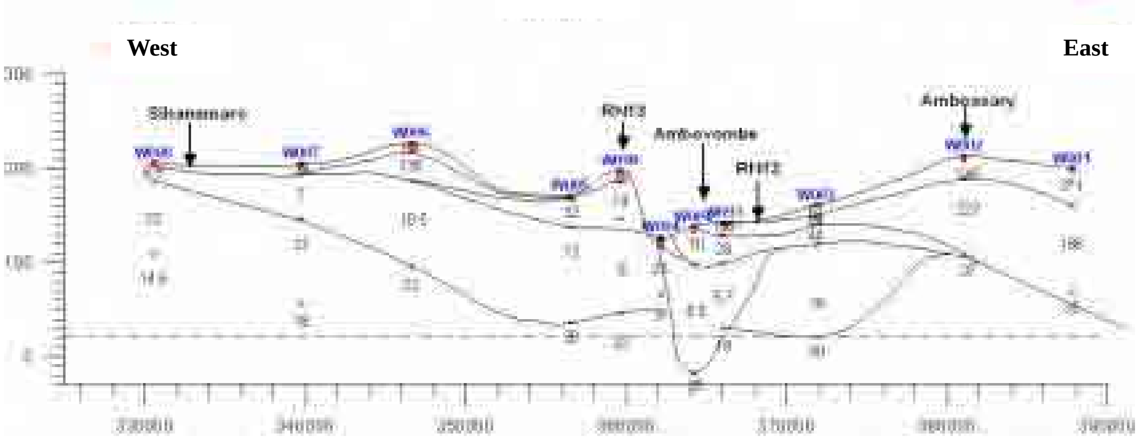


Figure 3.5.2-2 (d) Cross Section IV

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 gauge is 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. Table 3.6.2-1 shows the list of seasonal monitoring wells. 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. Table 3.6.2-1 also shows the list of monthly monitoring wells. 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. Table 3.6.2-2 shows the list of monitoring 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.

Table 3.6.2-1 List of Monitoring Wells

Well No.	Elevation (m)	Depth (GL-m)	GWL (GL-m)	EC (mS/m)	Water Use (Lit/day)	Well No.	Elevation (m)	Depth (GL-m)	GWL (GL-m)	EC (mS/m)	Water Use (Lit/day)
Ambovombe area (29 wells)						Antanimora area (25 wells)					
1	143.7	19.4	17.9	580	no data	15	174.4	20.5	14.3	394	200
2	136.1	21.0	19.2	172	24,000	16	198.6	67.9	22.4	170	1,000
3	135.9	28.2	16.9	1,010	no data	17	267.1	36.7	2.7	180	1,000
7	130.1	13.5	12.6	255	900	20	286.5	77.1	4.8	140	13,000
8	134.1	12.8	11.1	199	2,000	22	296.8	23.3	6.6	340	300
10	140.8	14.2	13.8	137	800	26	250.4	41.9	8.6	60	1,300
122	132.5	23.1	17.6	1,420	800	29	262.9	24.8	2.3	333	2,000
123	133.8	14.7	13.2	159	2,000	34	227.7	15.8	2.8	49	800
124	134.5	14.4	13.4	189	2,000	42	285.3	29.8	17.4	102	2,300
134	136.2	26.0	22.3	197	not used	86	158.5	17.0	4.6	678	no data
168	135.8	10.9	10.5	161	1,200	88	293.5	12.2	1.0	262	300
272	140.0	11.1	10.5	142	1,600	97	297	14.1	3.5	306	300
273	137.9	12.6	12.4	563	no data	98	325	17.6	5.3	58	1,300
275	136.7	14.4	14.2	229	800	102	235.3	35.9	13.0	15	no data
276	139.8	16.9	15.7	440	800	103	255.4	34.6	9.7	114	400
277	154.9	25.2	24.8	362	1,000	125	248.4	53.2	15.8	200	1,000
278	138.6	12.8	11.8	183	400	128	208.5	47.8	23.4	556	2,000
283	132.9	7.8	7.4	641	1,000	131	212.3	45.4	28.3	697	800
284	129.8	8.3	7.9	219	600	140	305	15.7	4.3	64	800
285	133.0	11.7	11.7	152	2,000	143	297.5	24.2	8.1	164	2,000
292	137.9	13.0	12.3	394	1,000	148	242	20.3	5.3	235	600
500	135.1	18.6	18.5	107	800	151	195.5	29.5	4.6	803	1,300
505	137.5	13.7	12.8	669	600	152	173	41.9	25.2	487	not used
510	135.8	14.7	14.4	61	300	161	216.3	38.6	14.7	171	2,000
514	130.8	13.9	12.9	66	500	606	141.2	14.3		394	no data
518	132.9	10.8	10.1	318	2,000	Coastal area (3 wells)					
547	142.3	13.0	12.9	1,019	800	165	12.7	-	6.0	997	
604	150.5	129.8	76.2	730	not used	231	52.6	13.0		-	200
605	150.5	18.4	17.6	171	not used	237	52.6	7.3	5.8	1,340	1,000
Ambondro area (13 wells)											
202	221.0	12.1	10.1	439	150						
203	215.2	9.3	3.1	161	4,000						
206	218.0	9.2	2.2	207	no data						
222	210.3	5.6	3.5	312	very small						
227	201.2	8.3	1.6	173	2,000						
228	205.8	5.2	1.5	146	400						
246	217.5	5.0	1.3	131	100						
249	222.1	4.2	2.7	61	100						
253	206.7	11.0	7.5	108	not used						
301	218.9	4.3	1.1	2,020	50						
302	220.8	10.7	2.5	326	150						
600	222.7	4.4	1.1	238	not used						
602	210.8	5.1	3.1	71	100						

*Monthly monitoring wells

*Data in this table is measured in April-05 except water use (measured in October)

Table 3.6.2-2 List of Monitoring Test Wells

No	Well No.	Commune	Depth (m)	Automatic GWL gauge	No	Well No.	Commune	Depth (m)	Automatic GWL gauge
1	FM001	Maroafo	100	-	9	F 022	Anjira	126	-
2	F 001	Fianrenantsoa-Amposy	80	installed	10	F 030	Ekonka	205	installed
3	F 006	Bemamba-Antsatra	78	-	11	P003	Sihannmaro	20	-
4	F 006B	Bemamba-Antsatra	63	installed	12	P009	Ambovome	19	-
5	F 009	Lefonjavy	82	-	13	NW-1	Sihannmaro	31	-
6	F 014	Ankoba-Mikazy	124	-	14	NE-1	Beabo	19	-
7	F 015	Mangarivitra Tananbao	153	installed	15	SW-1	Mitsangana	33	-
8	F 018	Ambanisalika	202	installed	16	SW-2	Ambaro	24	-

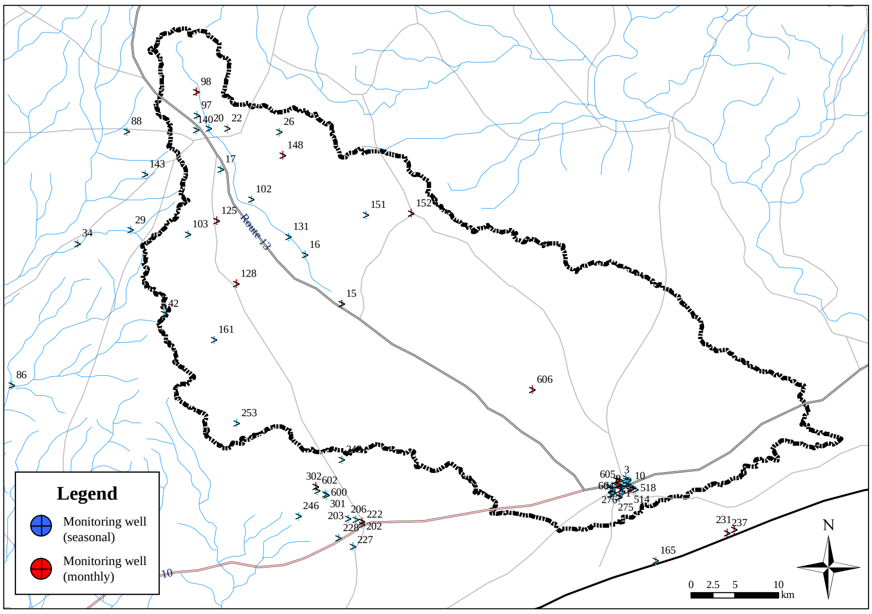


Figure 3.6.2-1 Location map of monitoring wells

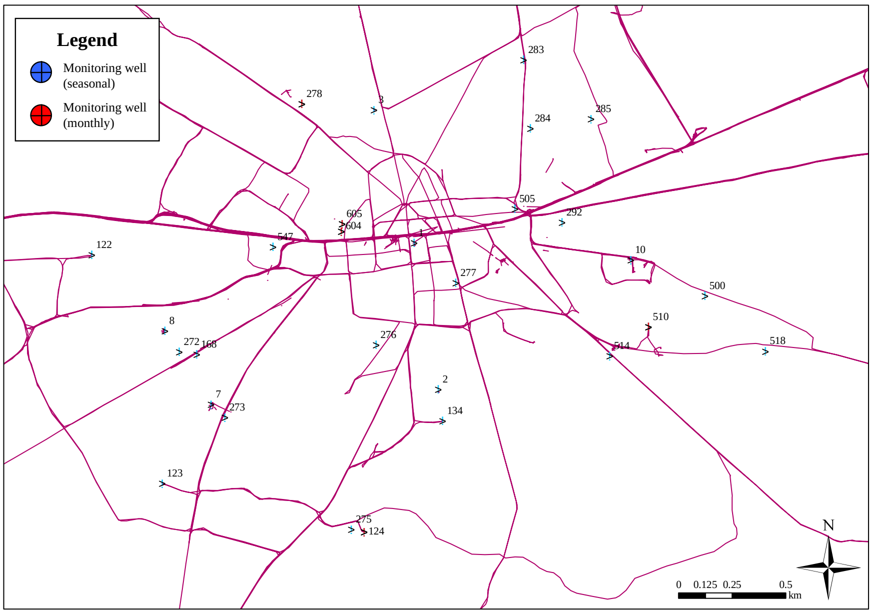


Figure 3.6.2-2 Location map of monitoring wells (Ambovombe)

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.

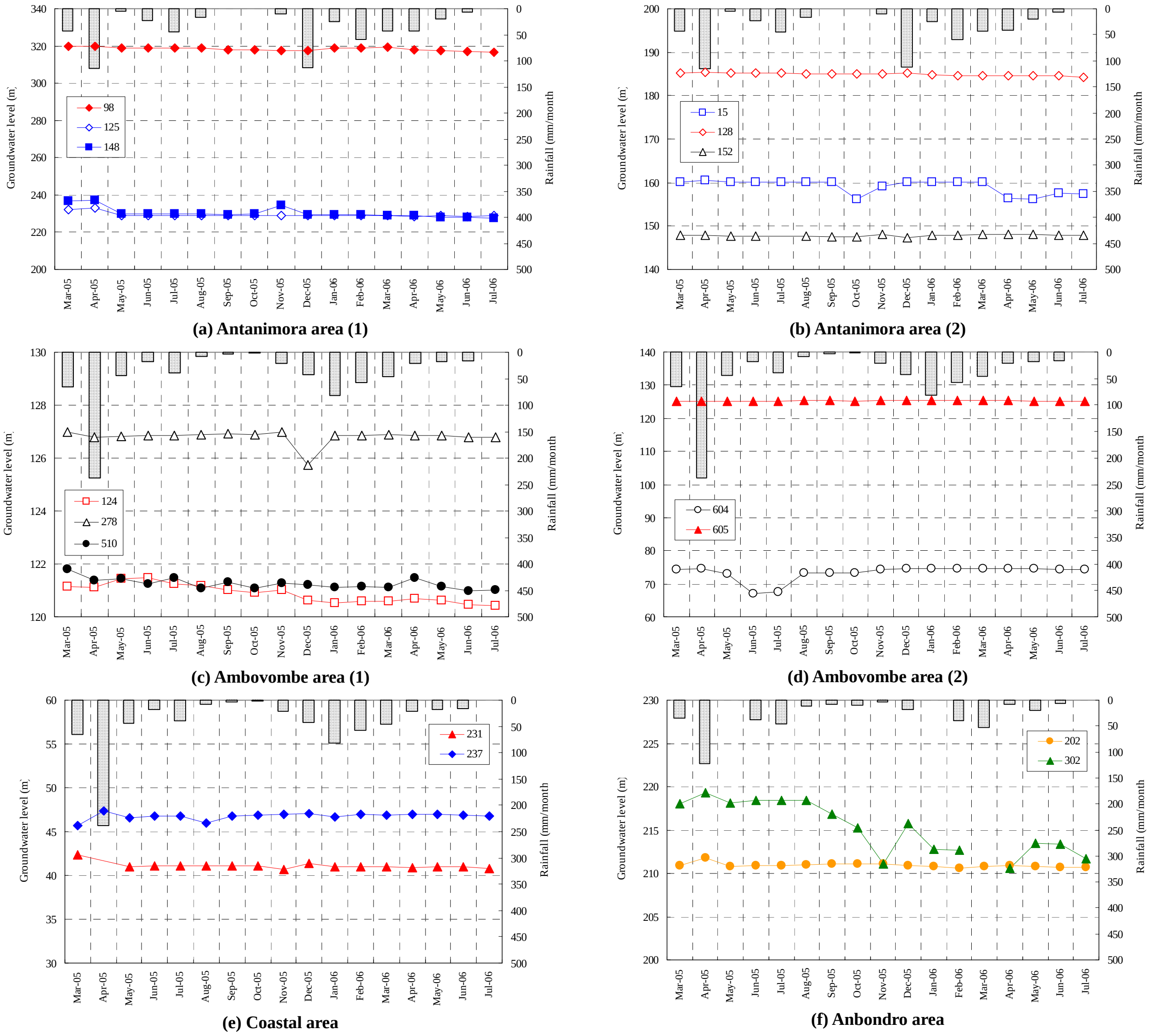


Figure3.6.3-1 Groundwater level fluctuation

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) Detailed Discussion

a) Antanimora Area

Figure 3.6.3-2 shows detailed location map of monitoring wells in Antanimora Area with geological classification. Figure 3.6.3-3 shows fluctuation of groundwater level for each monitoring wells.

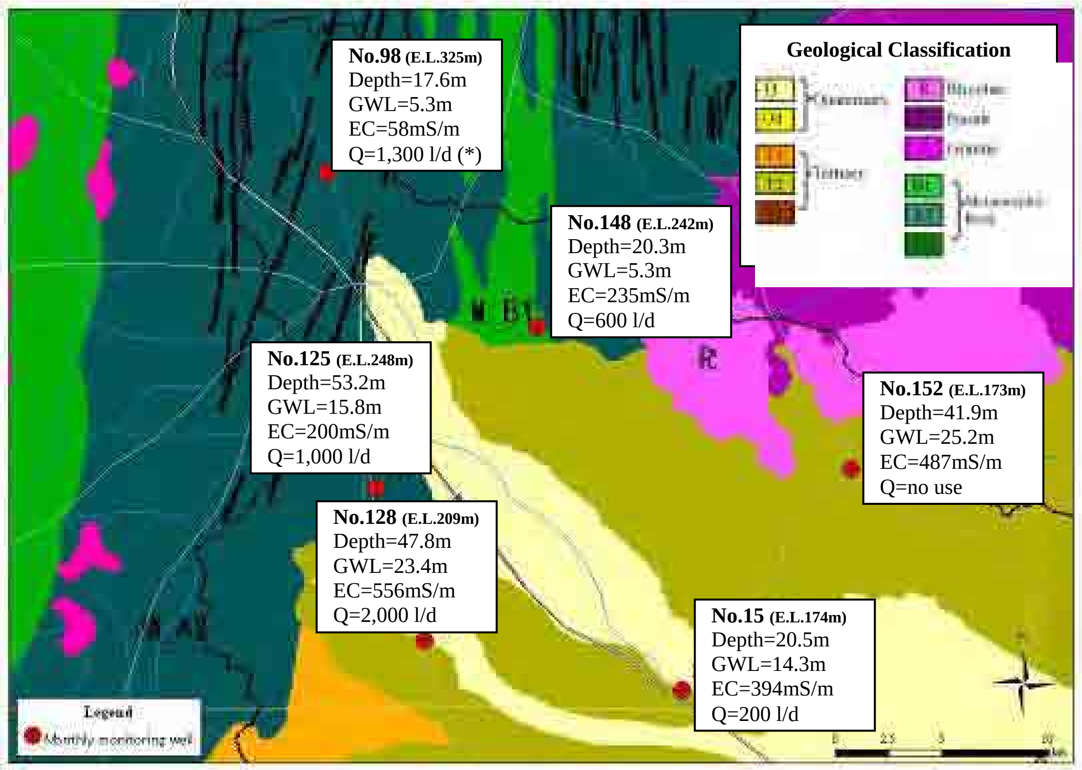


Figure 3.6.3-2 Detailed location map of monitoring wells in Antanimora Area
(*) Q: Quantity of water use from the well

In this area, three wells, No.98, 125 and 148, are located in the metamorphic rock distributed area. Remaining three wells, No.15, 128 and 152, are located in the sedimentary formation area.

For the rock distributed area, according to the Figure 3.6.3-3, from April to May, 2005, there is significant lowering of groundwater level for the well No.125 and 148. This lowering is though to be caused by some kind of external factor (increment of water use, etc.). If this lowering is caused by less amount of rainfall, there shall be similar direct response in accordance with amount of rainfall for continuous period.

Accordingly through a process of exclusion of such an external factor, groundwater level fluctuation of monitoring well has almost similar characteristics.

Especially groundwater level fluctuation of the well No.98 has most drastic fluctuation. And it is supposed that this trend is caused by amount of precipitation.

Due to shallow depth of groundwater level and direct response by amount of precipitation, the well No.98 is thought to be located in unconfined aquifer. And remaining two wells in rock area is thought to be located in the similar aquifer because of similar trend of groundwater level fluctuation. However some of the well is thought to be located in semi-confined aquifer because of small magnitude of fluctuation.

For sedimentary formation distributed area, trend of groundwater fluctuation is almost same. There are similar trend of groundwater level fluctuation of the well No.15, 128, and 152. Accordingly hydrigeological conditions of these wells are thought to be similar one.

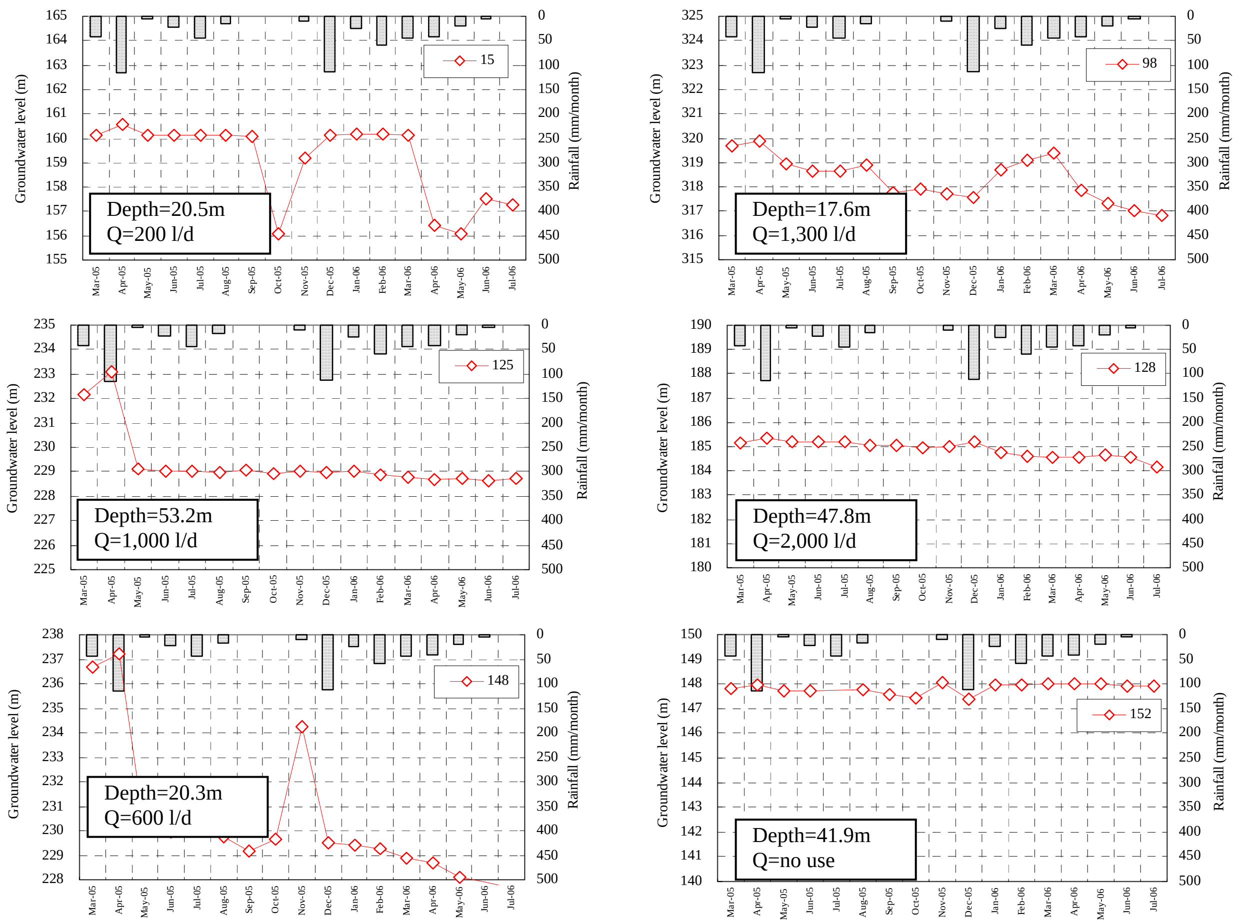


Figure 3.6.3-3 GWL of each monitoring wells in Antanimora Area

b) Ambovombe Area

Figure 3.6.3-4 shows detailed location map of monitoring wells in Ambovombe Area with geological classification. Figure 3.6.3-5 shows fluctuation of groundwater level for each monitoring wells.

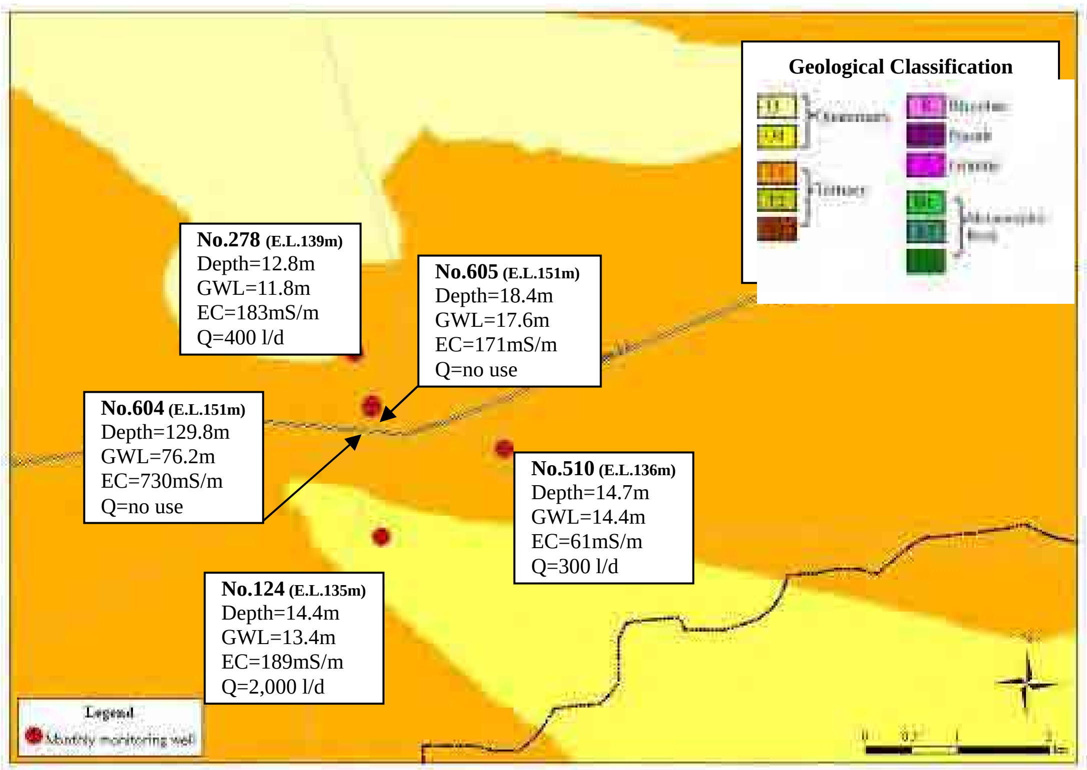


Figure 3.6.3-4 Detailed location map of monitoring wells in Ambovombe Area

All the monitoring wells are located in center or surrounding of Ambovombe urban. Except the well No.604, all the wells are shallow well. These shallow wells are located in unconfined aquifer and the deep well is located in confined aquifer.

From Figure 3.6.3-5, trend of groundwater fluctuation indicates different characteristics.
Groundwater level fluctuation of the well No.278 and 510 indicates uprising from August to October even in the dry season.

There is no apparent relationship between groundwater level fluctuations for the well No.604 (deep well) and 605 (shallow well).
The reason of lowering of groundwater level for the well No.604 is not clear.

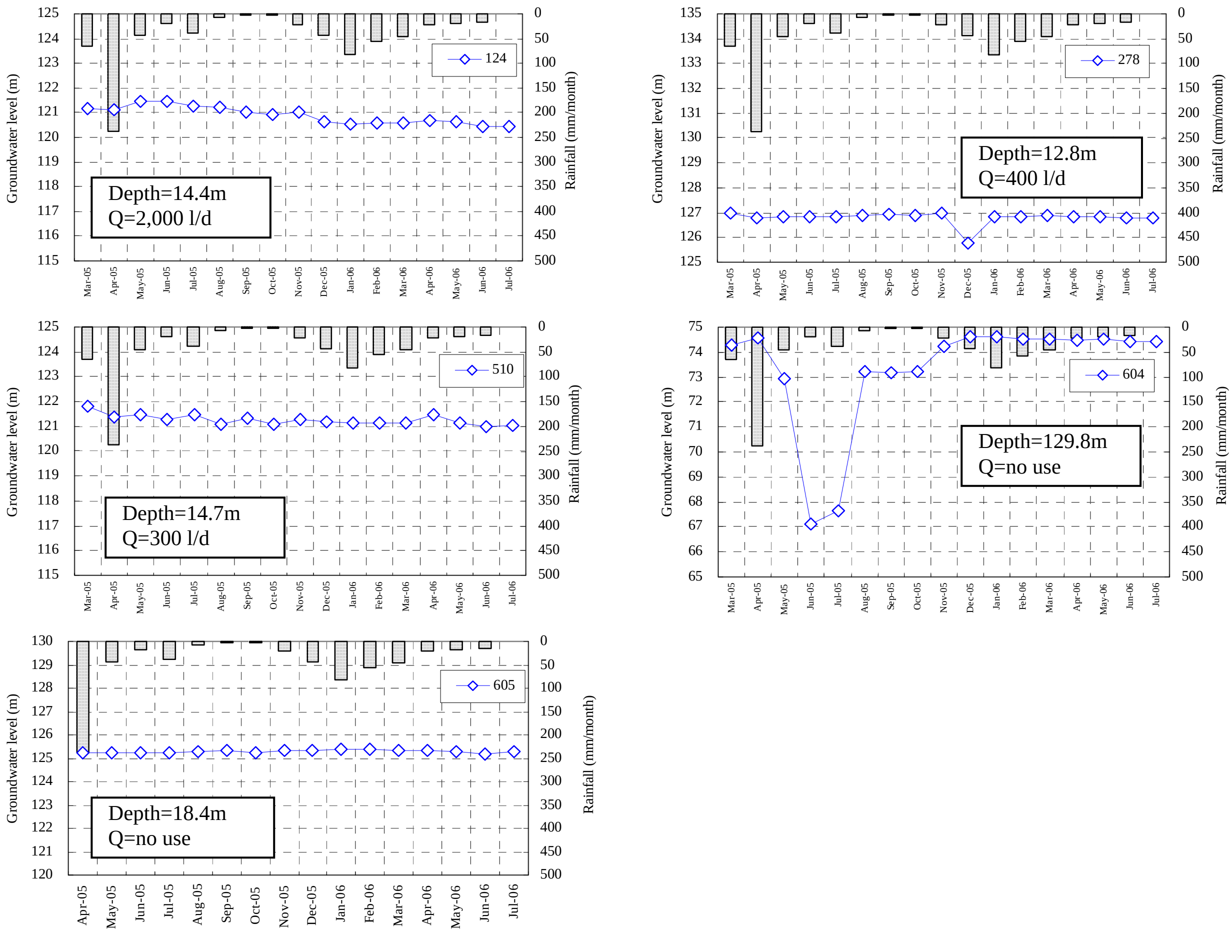


Figure 3.6.3-5 GWL of each monitoring wells in Ambovombe Area

c) Coastal Area

Figure 3.6.3-6 shows detailed location map of monitoring wells in Coastal Area with geological classification. Figure 3.6.3-7 shows fluctuation of groundwater level for each monitoring wells.

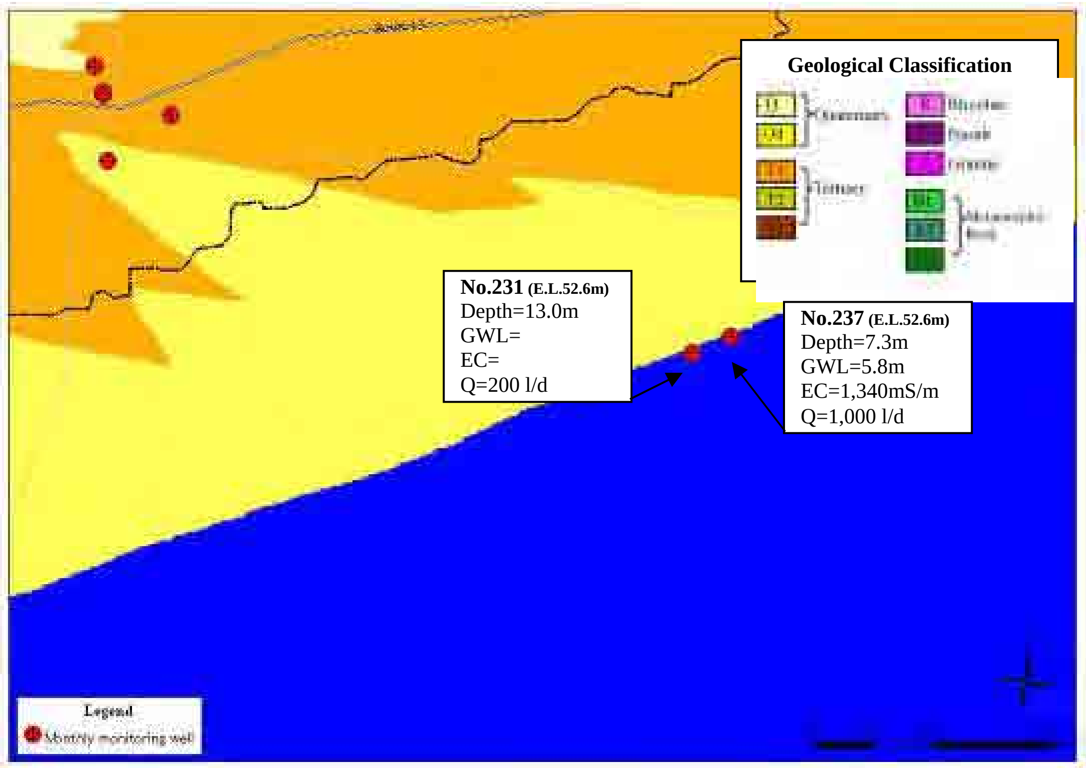


Figure 3.6.3-6 Detailed location map of monitoring wells in Coastal Area

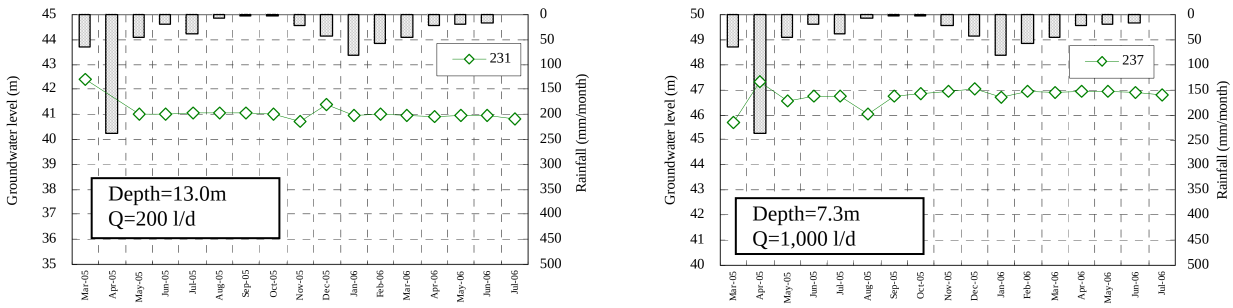


Figure 3.6.3-7 GWL of each monitoring wells in Coastal Area

Two monitoring wells are located beside seashore. These wells are located in unconfined aquifer. Groundwater level fluctuation of the well No.231 indicates flat. On the other hands, groundwater level fluctuation of the well No.237 indicates more drastic change.

d) Ambondro Area

Figure 3.6.3-8 shows detailed location map of monitoring wells in Ambondro Area with geological classification. Figure 3.6.3-9 shows fluctuation of groundwater level for each monitoring wells.

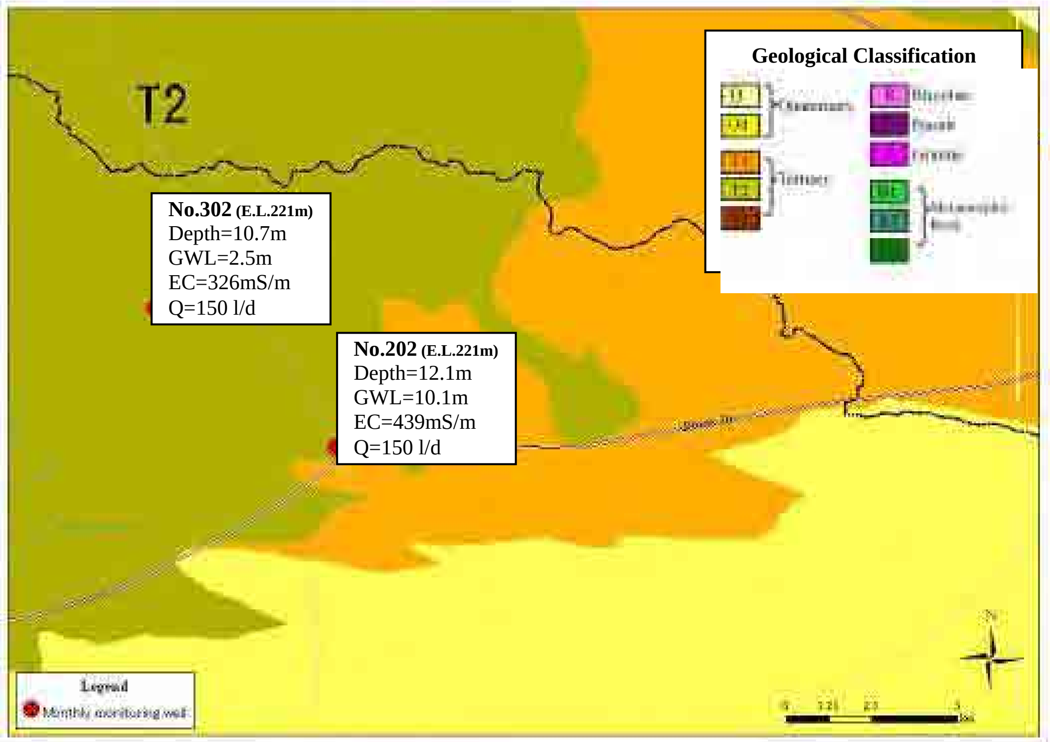


Figure 3.6.3-8 Detailed location map of monitoring wells in Ambondro Area

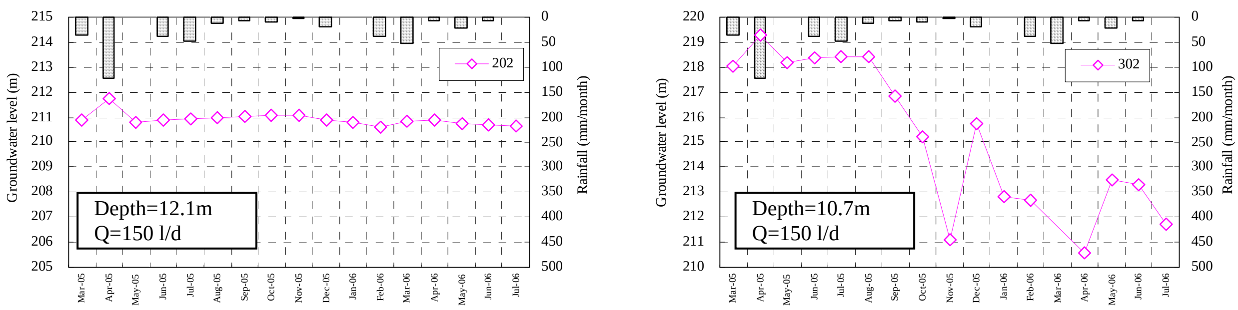


Figure 3.6.3-9 GWL of each monitoring wells in Ambondro Area

Two monitoring wells are located in Ambondro area. These wells are located in sedimentary formation distributed area. The aquifer of these wells is classified into unconfined aquifer.

3.6.4 Results of Seasonal Monitoring

(1) General

Seasonal monitoring was 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 urban between April and October, 2005.

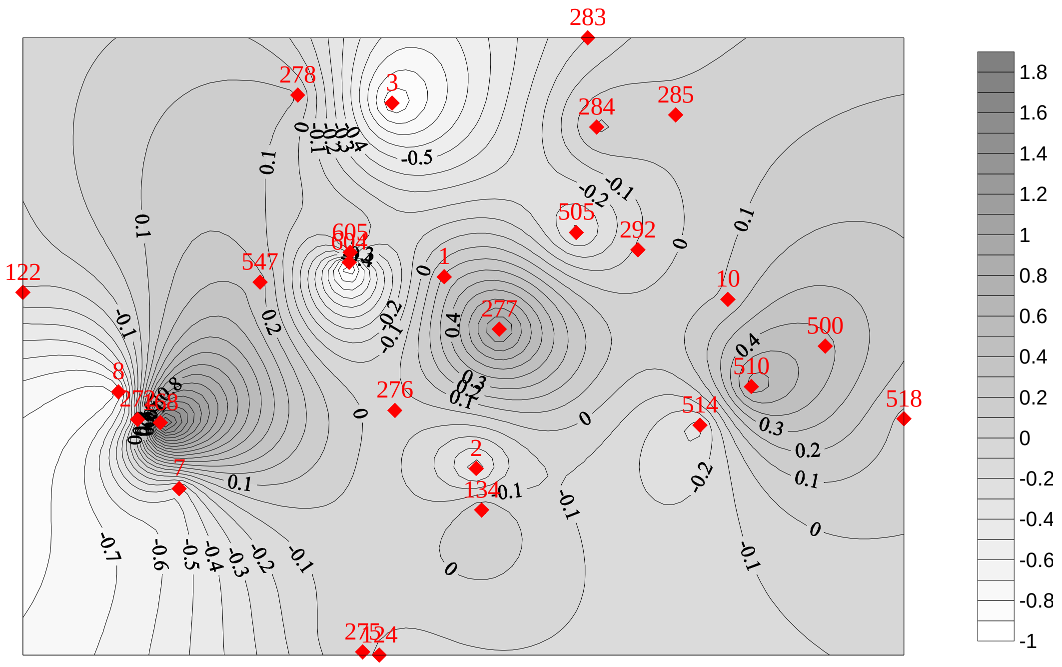


Figure 3.6.4-1 Contour map of difference of groundwater level between April and October

From the Figure 3.6.4-1, there is groundwater level uprising area at the western and eastern part of Ambovombe urban. 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.

a) 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.

b) Middle of Ambovombe Basin

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.

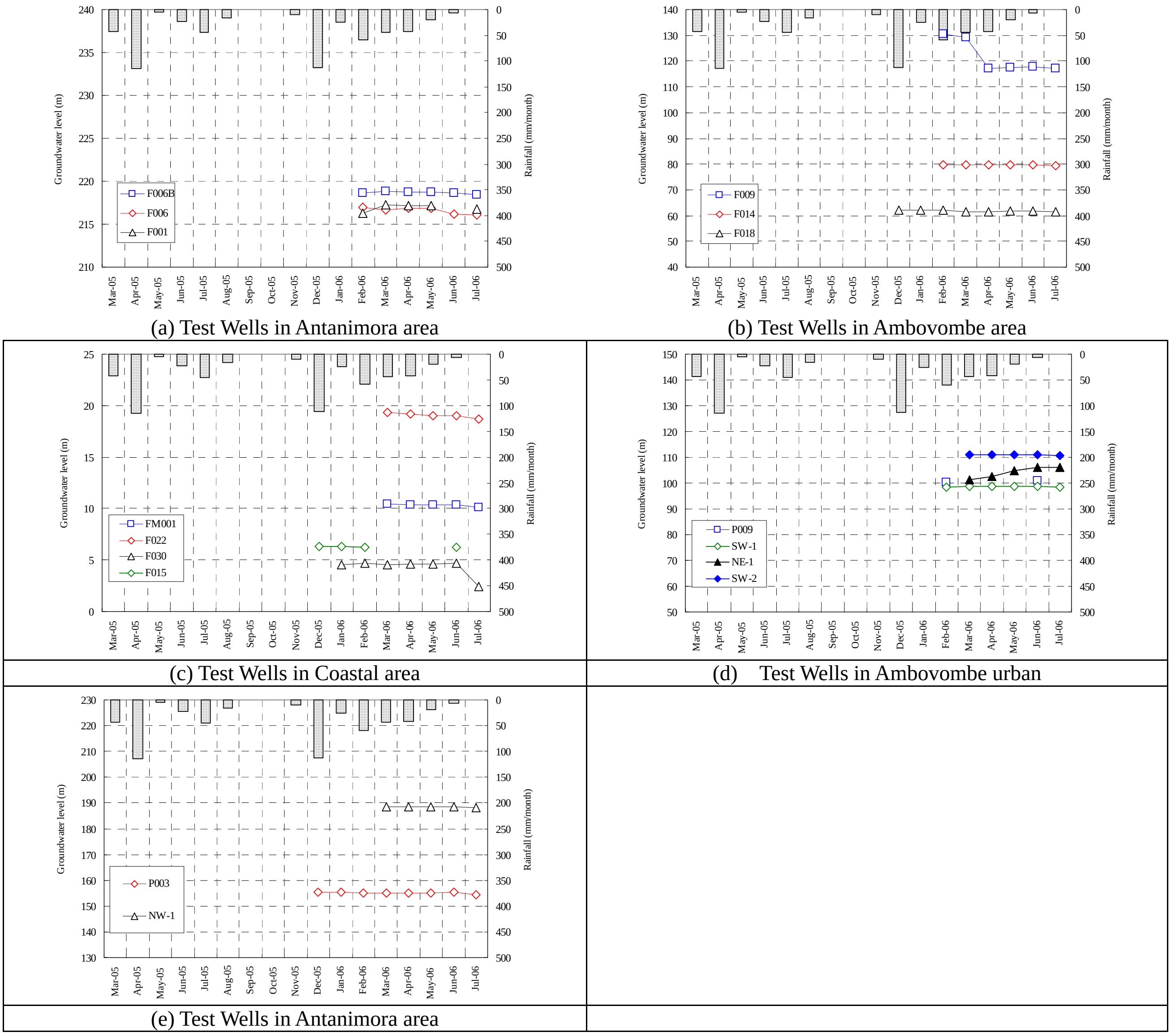
c) Coastal area

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).

d) Shallow wells around Ambovombe urban

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 Ambovombe area

(c) Test Wells in Coastal area

(d) Test Wells in Ambovombe urban

(e) Test Wells in Antanimora area

Figure 3.6.5-1 Groundwater level fluctuation

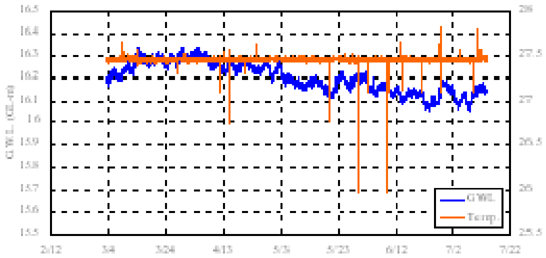
(2) Results of Automatic Groundwater Level Gauge

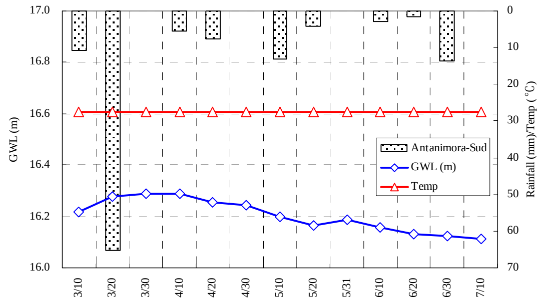
Figure 3.6.5-2 shows results of groundwater level monitoring with automatic gauge. Due to inappropriate installation, sufficient data could not be obtained from the well No.F018.

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.

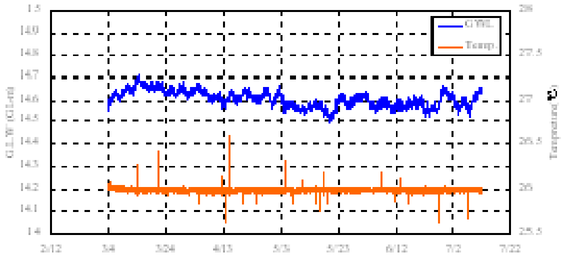
Groundwater level fluctuation of the well No.F015 seems rather stable compare with the other wells.

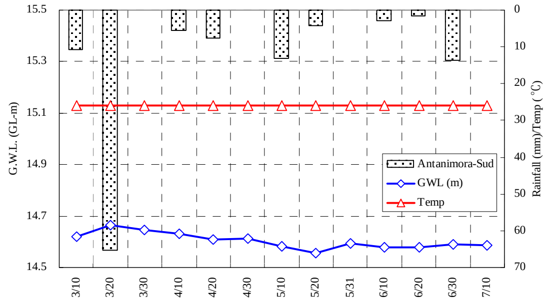




a) Original data b) 10 days average data

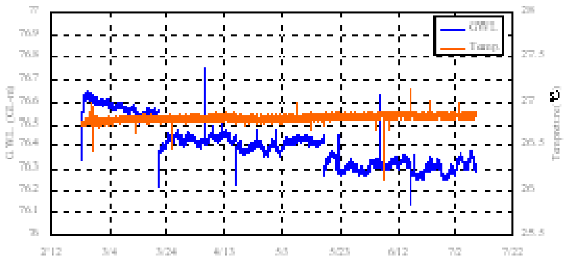
(a) Result of groundwater level monitoring (test well No.F001)

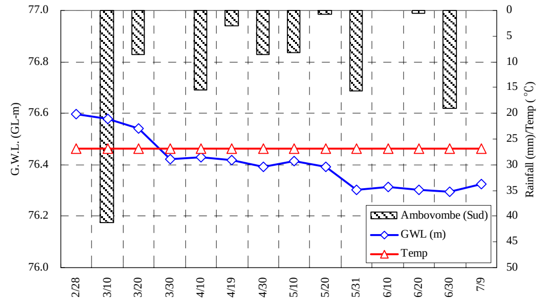




a) Original data b) 10 days average data

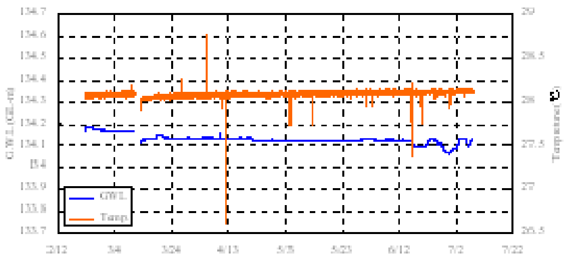
(b) Result of groundwater level monitoring (test well No.F006b)

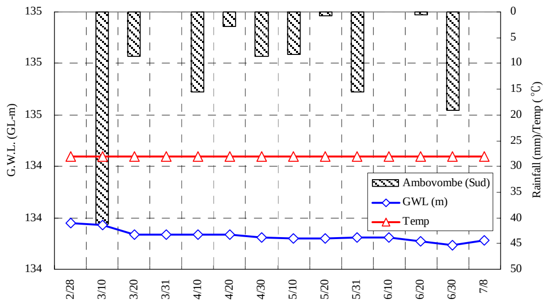




a) Original data b) 10 days average data

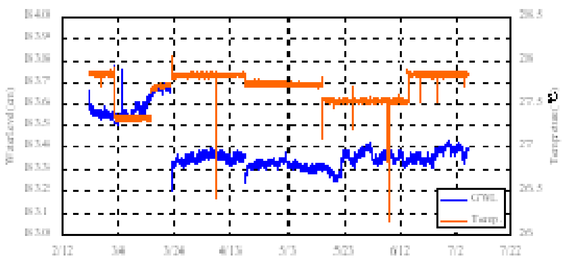
(c) Result of groundwater level monitoring (existing well No.604)

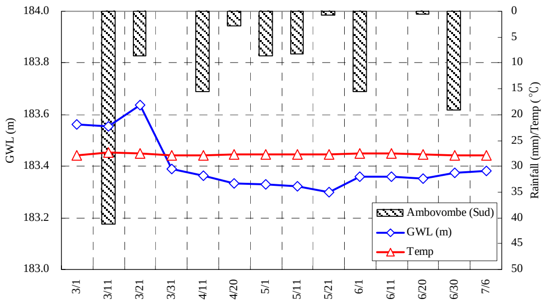




a) Original data b) 10 days average data

(d) Result of groundwater level monitoring (test well No.F015)





a) Original data b) 10 days average data

(e) Result of groundwater level monitoring (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.

In this section, the water quality type and the trends of the chemical components are analyzed as a base data to find the origins of high salinity of the groundwater as well as comparison between the average concentrations of the samples and the national and WHO standards, as a basis of the determination of the quality level of the drinkable water in the area. The discussion shall be basically based on the water quality sampling conducted in May (Wet season) and September (Dry season), combined with the EC measurement results conducted through the inventory survey and seasonal and monthly monitoring.

Also, water quality (EC) depth profiling was conducted on 10 deep wells of test drilling, and water quality monitoring probe was set at 1 deep well (F015) and 2 shallow wells of test drilling.

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, and Fig.3.7.2-1 shows the positions of the sampling points.

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
	Rivers	0	0
Antanimora area	Wells (shallow)	13	13
	Impluvia	0	0
	Ponds	1	1
	Rivers	2	2
Other areas	Wells (shallow)	9	11
	Impluvia	2	0
	Ponds	0	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^-)

(2) Measurement of EC of Other Wells.

EC was measured as part of inventory survey, monthly monitoring and seasonal monitoring. The number of points surveyed is shown in table 3.7.2-3. The locations of sampling points for monthly and seasonal monitoring wells are shown in section 3.6.

Table 3.7.2-3 Number of sampling points of the inventory, monthly monitoring and seasonal monitoring

Survey name	Number	Survey period
Inventory survey	242	Once in the beginning of the Study
Monthly monitoring	16	Every month
Seasonal monitoring	70	Every 6 month

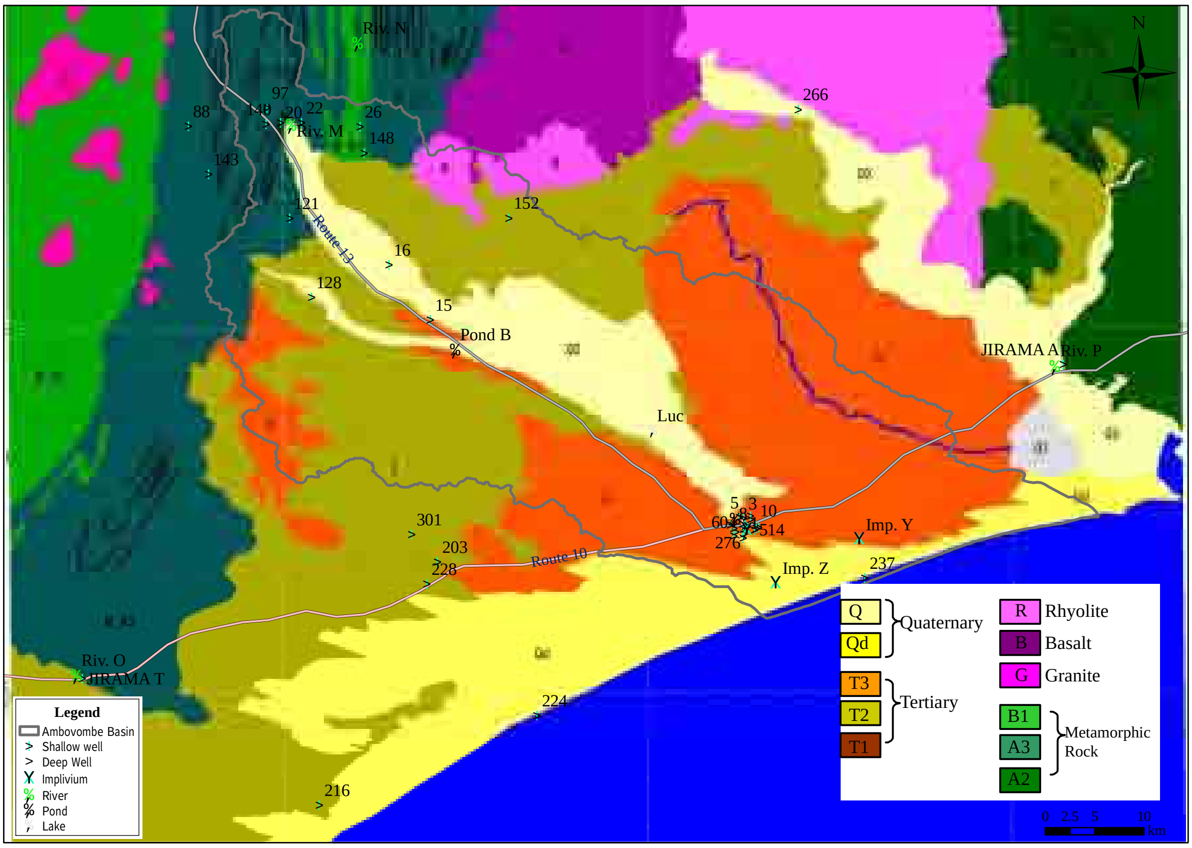


Fig. 3.7.2-1 (1) Sampling points for Water Quality Survey

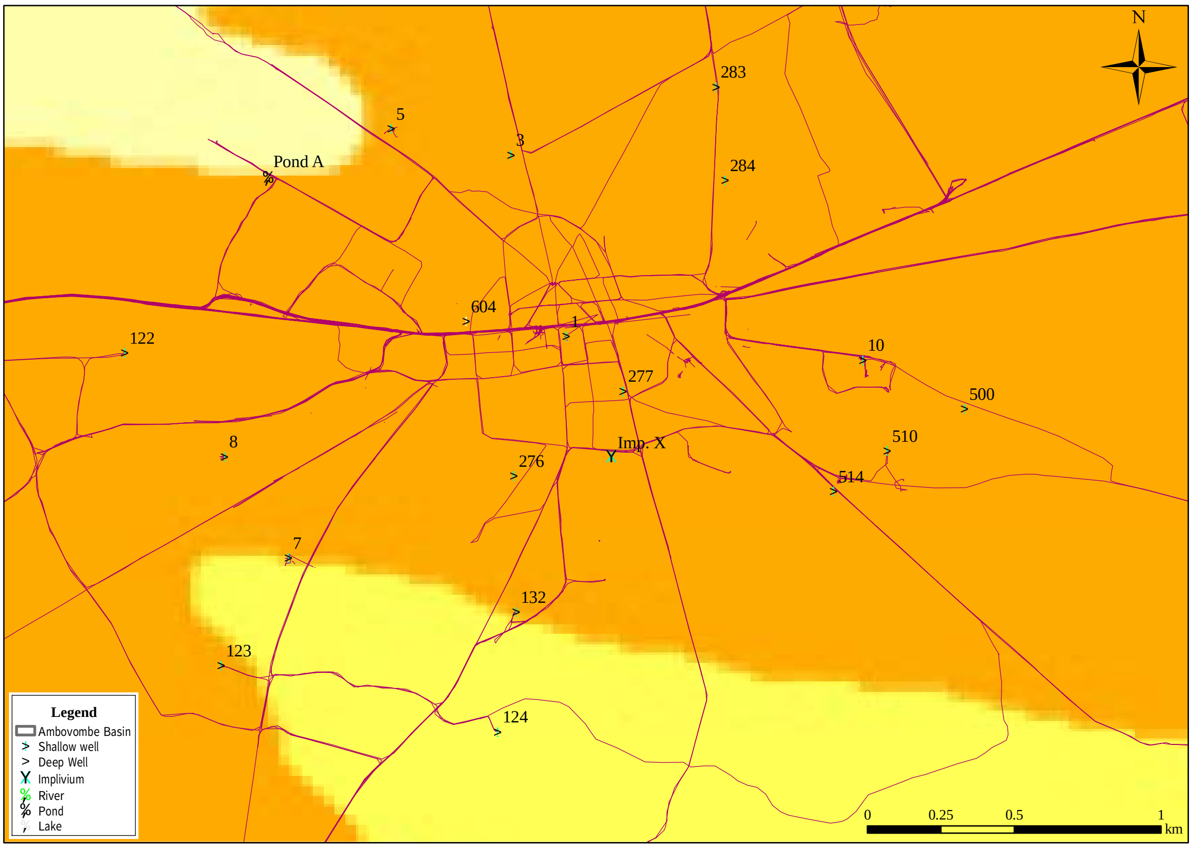


Fig. 3.7.2-1 (2) Sampling points in Ambovombe Area

3.7.3 Chemical Composition Analysis

The results of the water quality analysis are shown in tables in the databook. 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)

There have been many groundwater surveys conducted within the area including Basic Design Survey of JICA, and most of them have been reporting of the high salinity content of the waters in the area. Some of the results of EC measurements from the previous studies area are shown in table 3.7.3-1. The high salinity is especially reported in the vicinities of the Ambovombe area and the south, whereas the groundwater of the Northern part of the target area (namely the Antanimora area) has relatively low salinity.

The EC measurement results from the inventory survey is summarized in table 3.7.3-2. The salinity trend of the target area, in particular the Ambovombe and Ambondro district is also seen, and it may be said that the salinity trend (=EC value) is becoming to be higher than the previous reports, which suggests that the salinity is gradually worsening as time goes on.

Table 3.7.3-1 Results of EC measurements of the groundwater in the previous studies in the Area

Name of Study	Study Area	EC measurement results
JICA Basic Design Study (1981)	Ambovombe (n=3)	147 – 479 mS/m
	Ambondro (n=4)	104 - 958 mS/m
	Antanimora (n=8)	26 – 150 mS/m
JICA Basic Design Study (1990)	Ambovombe (n=4)	115 – 288 mS/m
	Ambondro (n=3)	98 – 135 mS/m
JICA Preliminary Study (2004)	Ambovombe (n=8)	158 – 520mS/m
	Ambondro (n=3)	97 – 240mS/m
USGS (2004)	Antanimora and North (n=127)	25% are above 300mS/m

Table 3.7.3-2 Summary of results of the EC measurements of well inventory study in this study

(mS/m)

Area	Number	Average	Minimum	Maximum
Ambovombe	68	337.9	57.8	1,058
Ambondro	17	341.4	45.2	885
Antanimora	47	193.5	40	678
All areas (incl. other than above)	163	320.0	6.4	1,378

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 exiting 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.

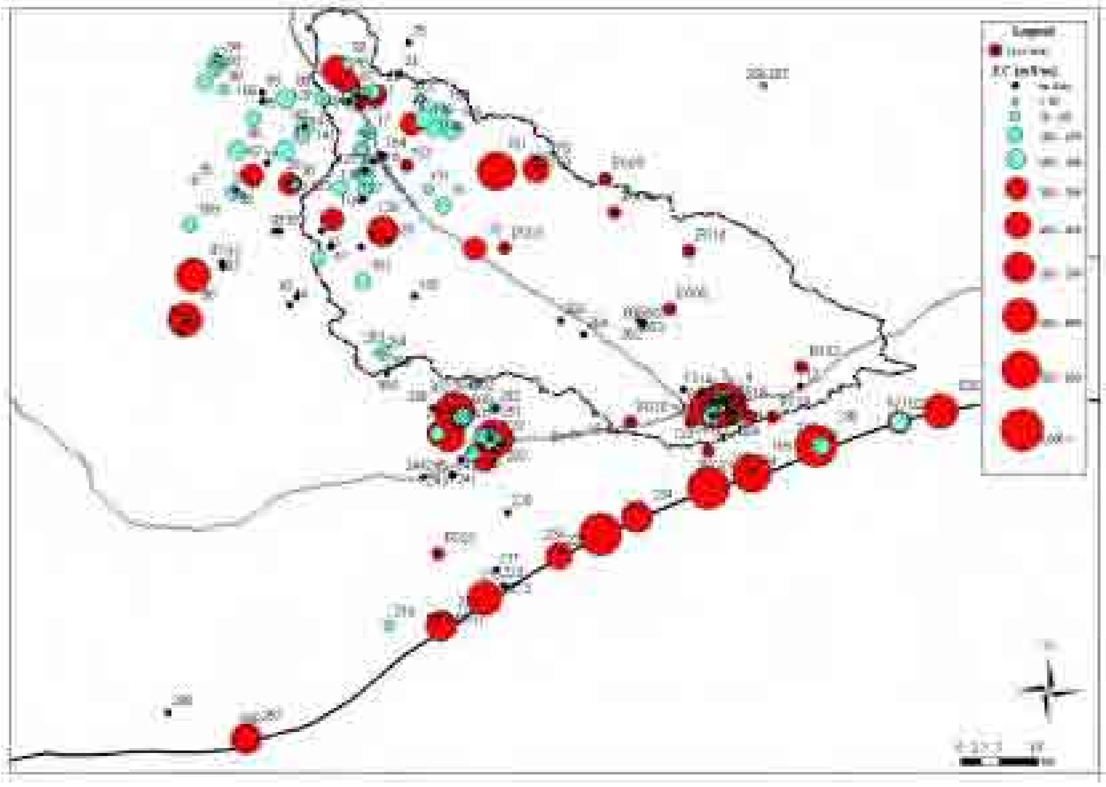


Fig. 3.7.3-1 Spatial Distribution of EC in the area (Inventory survey)

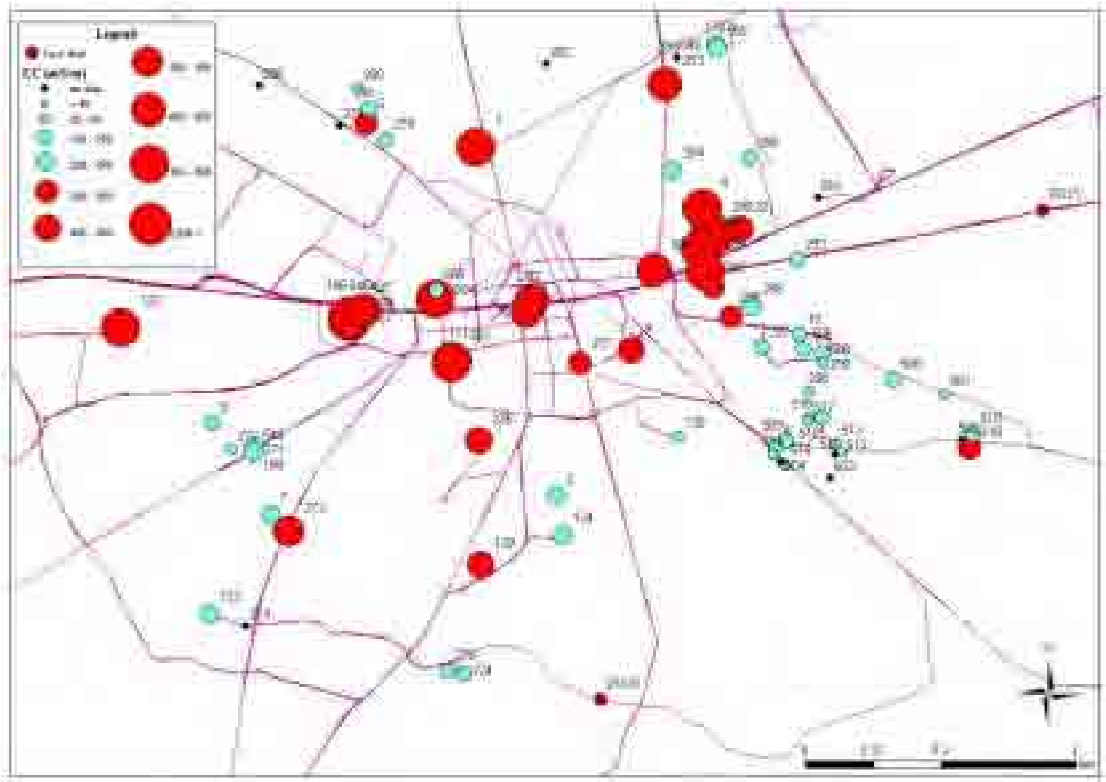


Fig. 3.7.3-2 Spatial Distribution of EC in the Ambovombe area (Inventory survey)

(b) Spatial distribution of major ions in the area (results from the Water Quality Survey)

Spatial distribution of the major ions (Na^+. Cl^-, Ca^+ ,HCO_3^- and NO_3^-) of the target area in the dry season (September 2005) is shown in fig. 3.7.3-3, and the detailed spatial distribution in urban area of Ambovombe in the same period is shown in fig. 3.7.3-4. The markers in red show that the concentration of the concerned ions is above the Madagascar or the WHO standards. The data of the dry season is shown because the data of the wet season (May 2005) showed the same trend as the dry season.

Chloride (Cl) has the same trend as with the EC, in that the concentration of Chloride is low in the north (Antanimora – Ifotoka), and it becomes higher to the south, and around the line connected between Manavy and Sakavy, the concentration becomes suddenly high, which is the same trend as EC. Sodium (Na) and Calcium (Ca) shows almost the same trend. However, Bicarbonate (HCO_3) behaves on the contrary, and the concentration becomes high to the North.

Detailed distribution in the urban area of the Ambovombe (fig. 3.7.3-4) shows that although the concentration of the chemical components area relatively high, Chloride, Sodium and Calcium seems to be even higher along the line crossing the center from south-south west to north-north east. There are some wells with low chemical concentration on the sand dunes in the south east.

Nitrate (NO_3) having great anthropogenic influences, are in general under the Madagascar (WHO standard), but there are two wells in the Northern part of urban Ambovombe having high concentration.

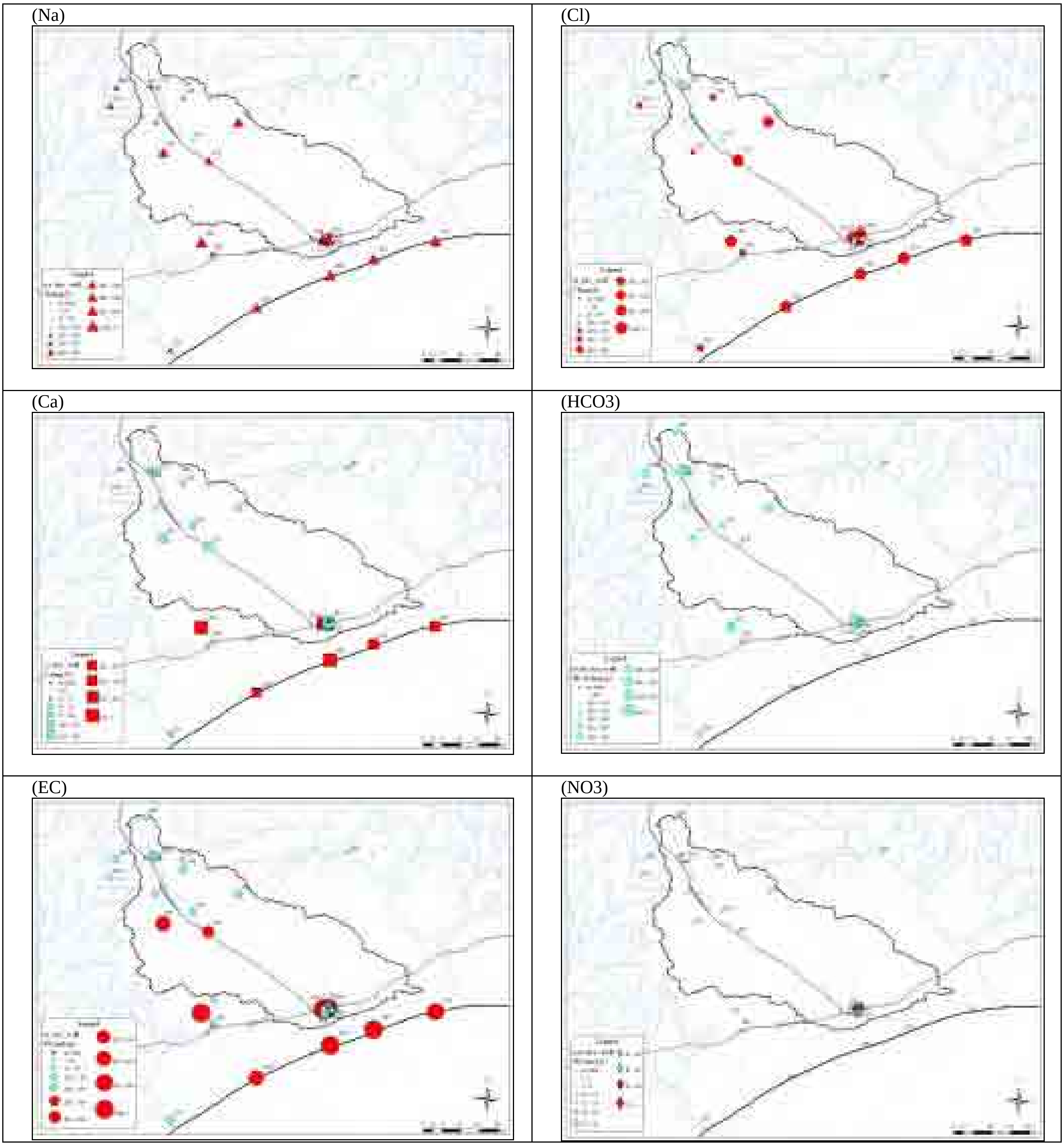


Fig.3.7.3-3 Spatial Distribution of major ions (Wells, Study area, Dry season)

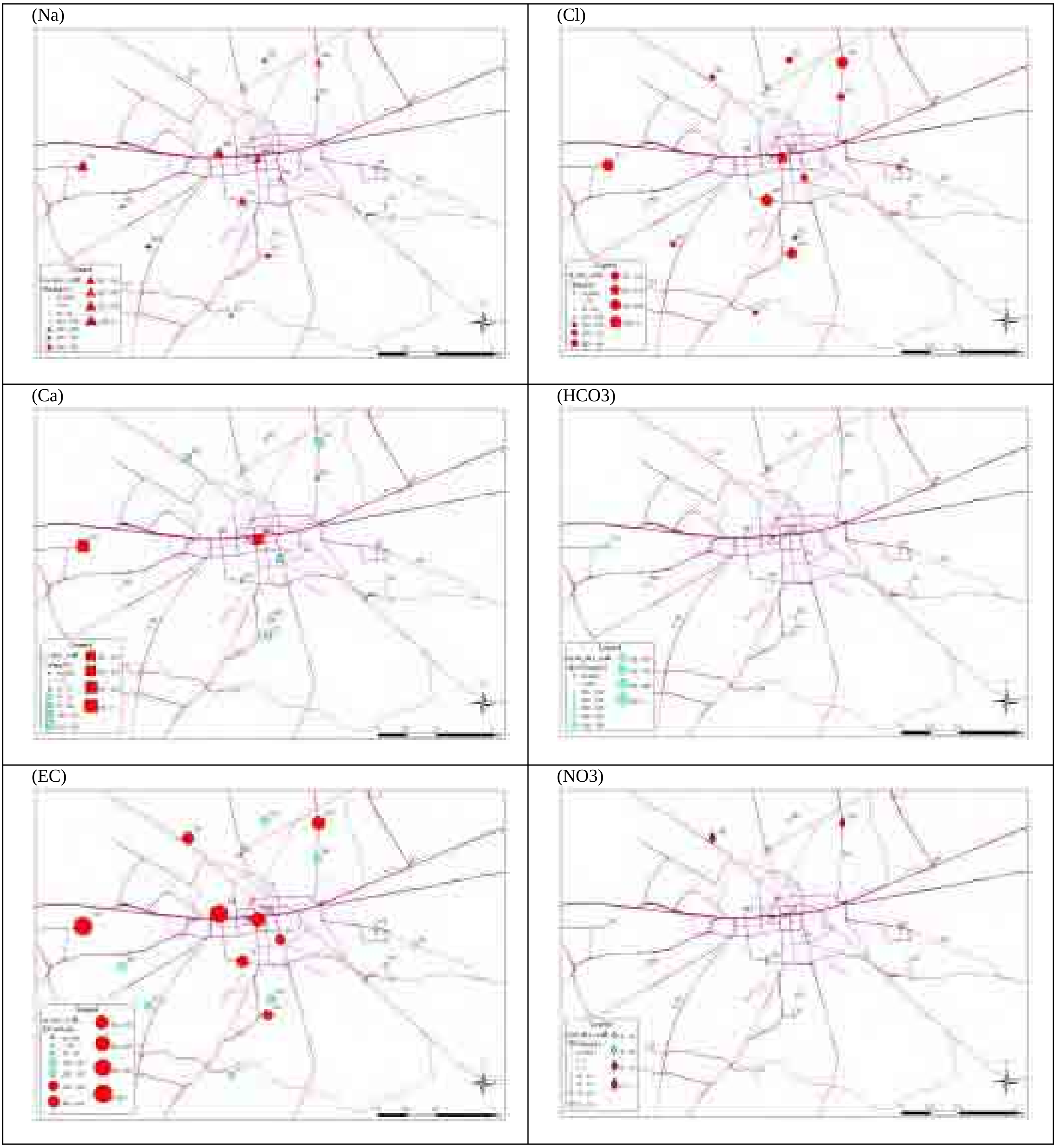


Fig.3.7.3-4 Spatial Distribution of major ions (Wells, Ambovombe area, Dry season)

(2) Depth Distribution of EC

Fig. 3.7.3-5 shows the relationship between depth of the wells and the EC measurements. From the plot it easily can be said that there exists no clear relationship between the depth and the EC. Therefore, within the target area, there is no distinct depth where the EC is high (or low) compared to the surroundings. However, from the below figure, there are two following characteristics. 1) In Ambovombe, Ambondro and Coastal areas, there is a wide range of EC regardless of depth. 2) In Antanimora zone, the EC is observed in certain range regardless of depth.

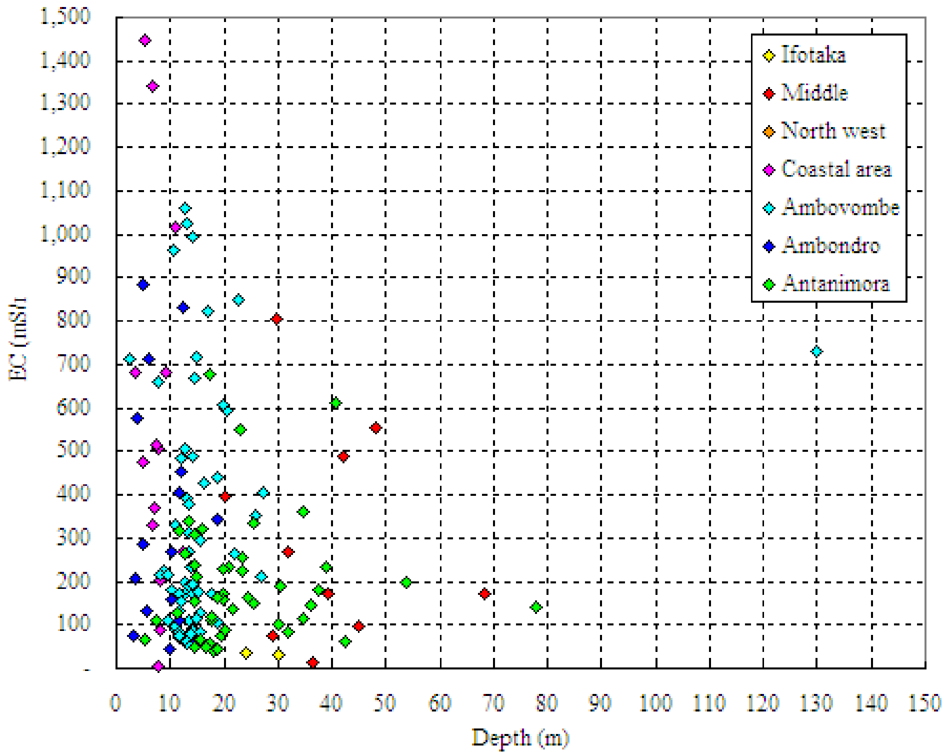


Fig. 3.7.3-5 Relationship between Well depth and EC (Inventory survey)

(3) 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 and Cl are shown in Fig.3.7.3-6 and Fig. 3.7.3-7.

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.

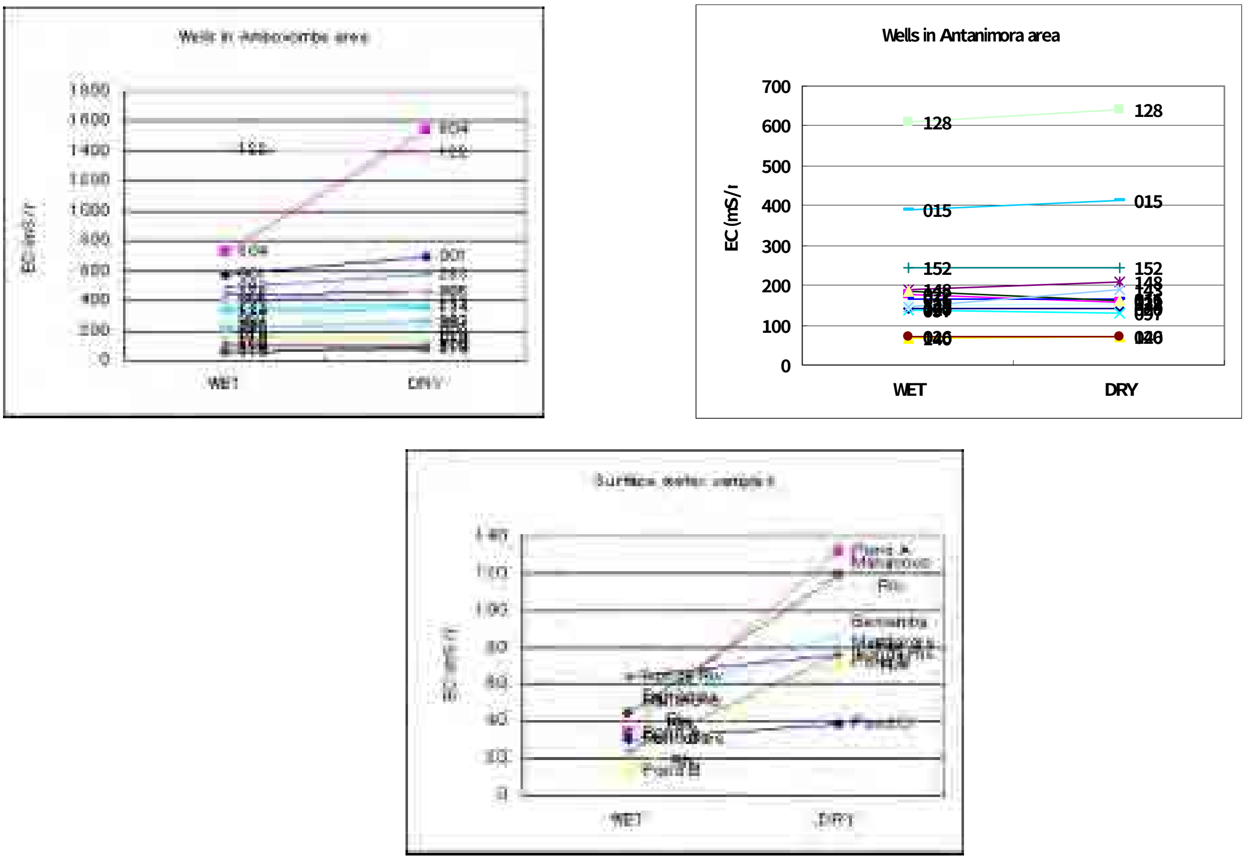


Fig. 3.7.3-6 Seasonal variation of EC of the sampled waters.

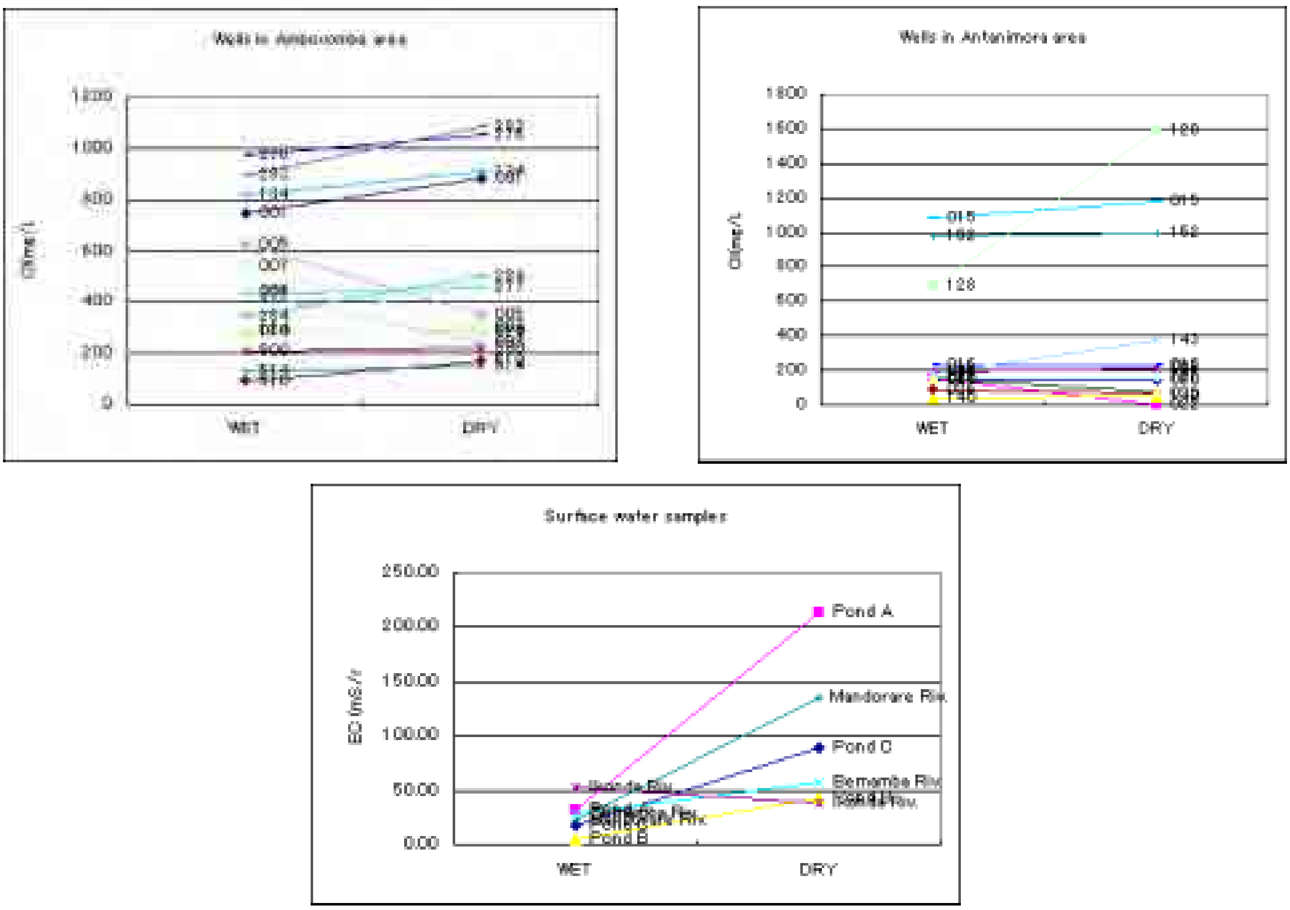


Fig. 3.7.3-7 Seasonal variation of Cl of the sampled waters.

(b) Seasonal variation results from the monthly monitoring results

Figure 3.7.3-8 shows fluctuation of electric conductivity in contrast with monthly precipitation.

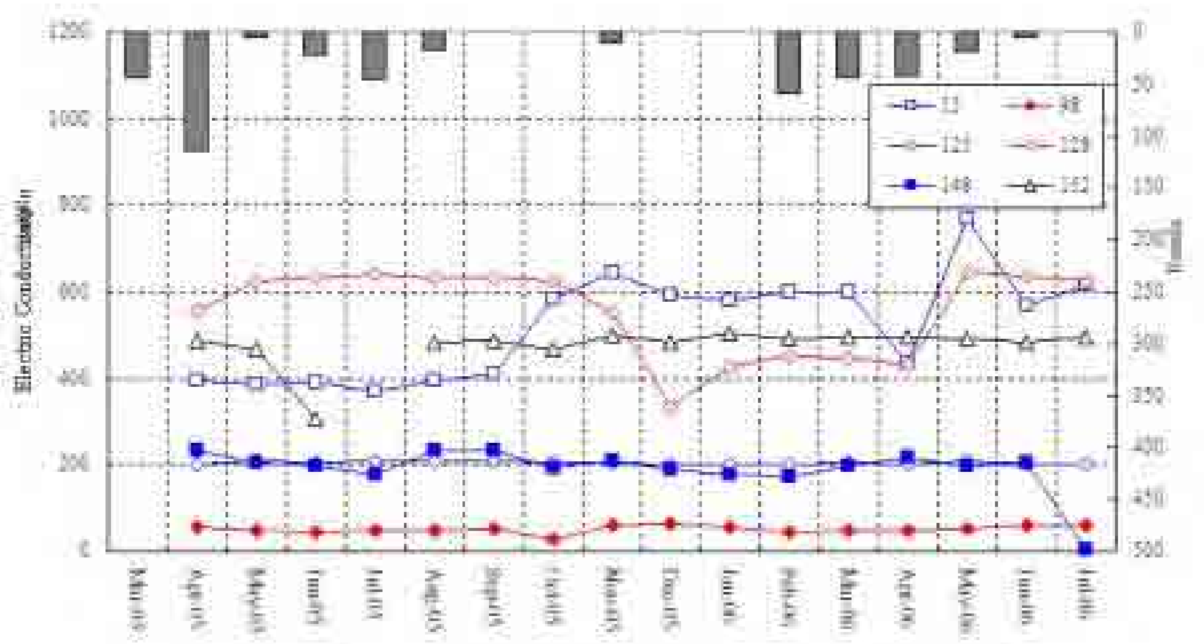


Figure3.7.3-8 (a) Electric conductivity fluctuation (Antanimora area)

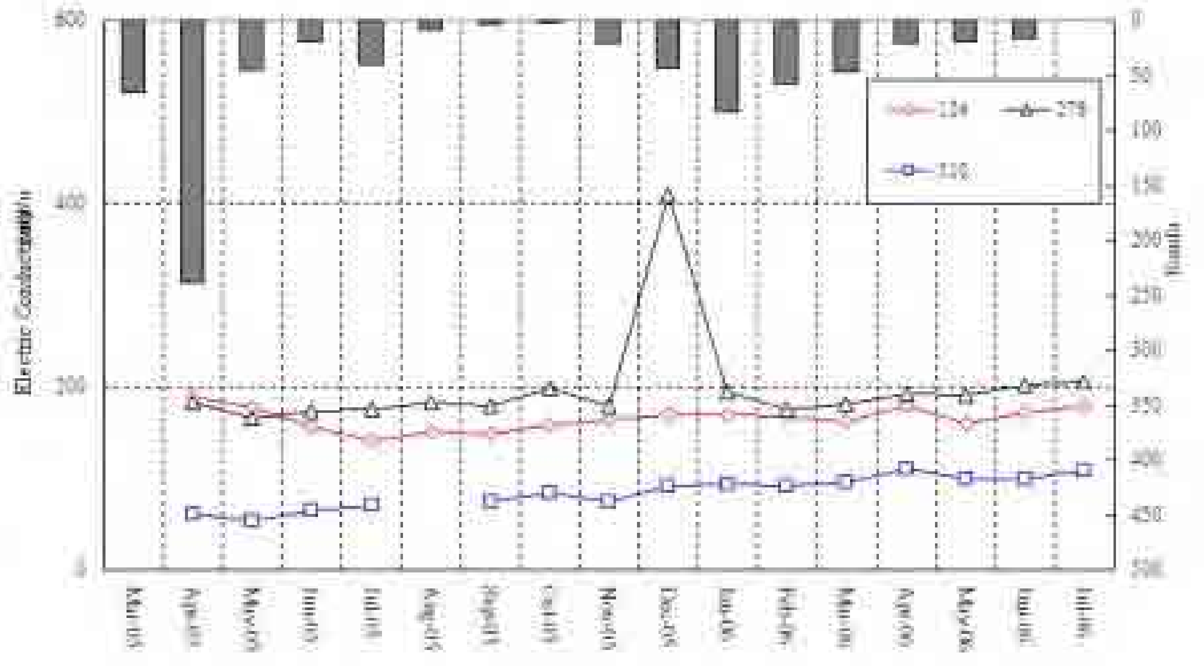


Figure 3.7.3-8 (b) Electric conductivity fluctuation (Ambovombe area)

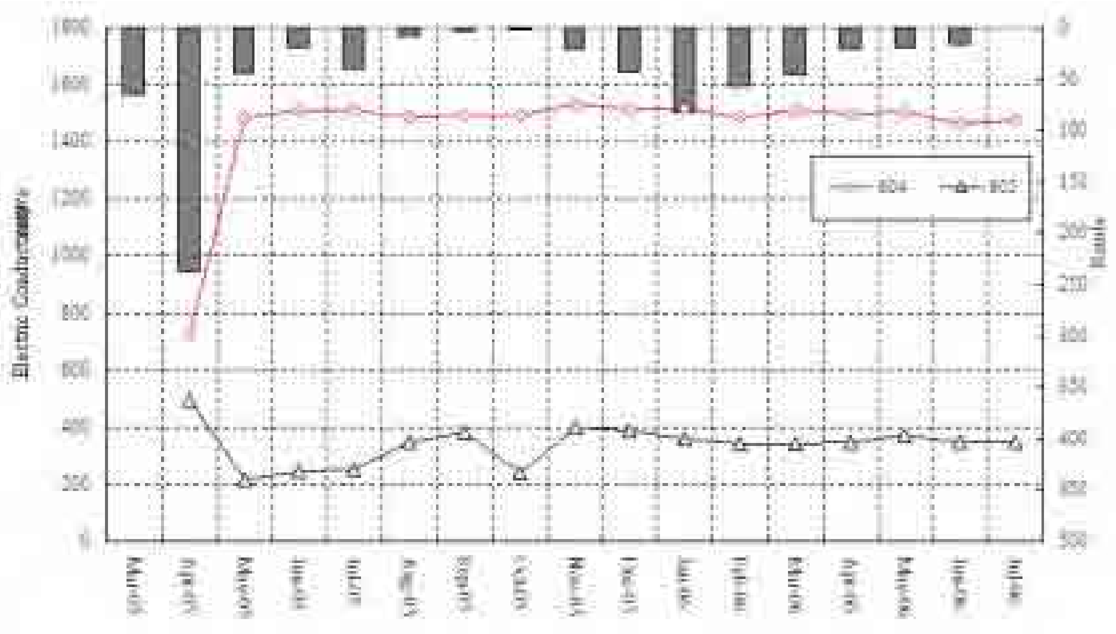


Figure 3.7.3-8 (c) Electric conductivity fluctuation (Ambovombe area)

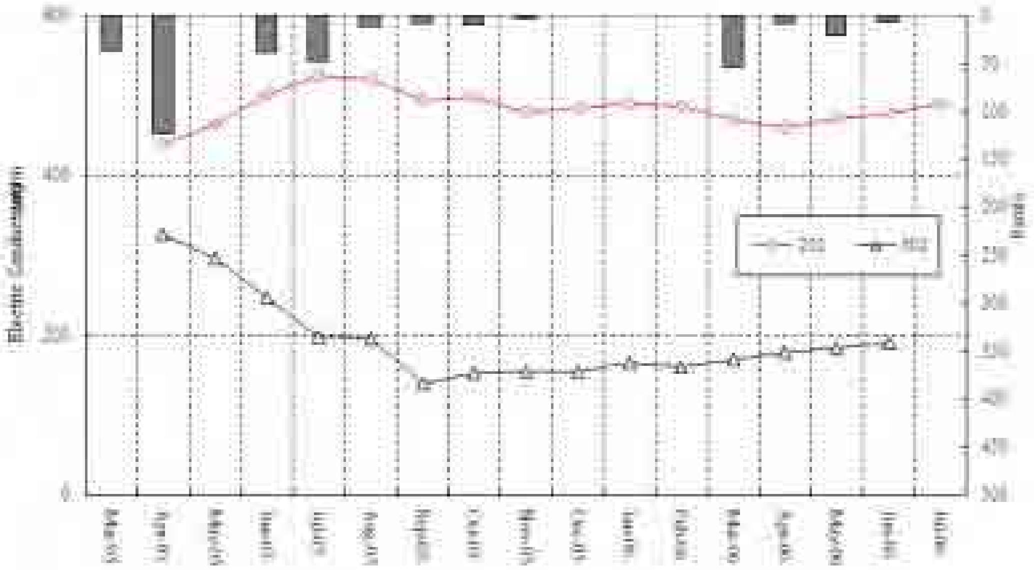


Figure 3.7.3-8 (d) Electric conductivity fluctuation (Ambondro area)

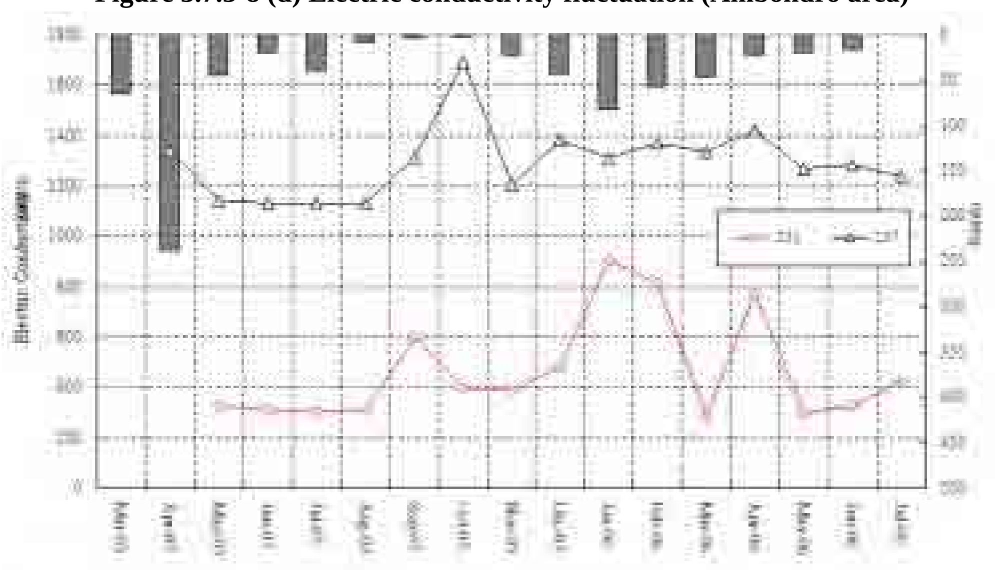


Figure 3.7.3-8 (e) Electric conductivity fluctuation (Coastal area)

The figure 3.7.3-8 (a) (Antanimora Area) shows two types of fluctuation of EC. One is the flat type, as shown by boreholes of 98, 125 and 148. The other shows more fluctuation, typified by boreholes of 15, 128 and 152. The former type have EC of relatively low value (under 200mS/m), and the boreholes are located in the hard rock area in the north of the Ambovombe Basin. The latter have relatively high EC all year round, and the boreholes are located in the sedimentary area.

The fluctuation of three hand-dug wells of Ambovombe seems to have almost the same characteristics (Figure 3.7.3-8(b)). Therefore, it can be assumed that these wells are in the same groundwater movement zone.

Comparison of two wells (hand –dug well and deep borehole) in figure 3.7.3-8(c) shows a contrast in the tendency. The EC of borehole No.604 rose significantly between April and May, then stabilized at this high value. On the contrary, the EC of hand-dug well of No.605 lowered a little during the same period, then stabilized at this value.

In Ambondro, the two wells showed symmetric fluctuation (Figure 3.7.3-8(d)). The EC of 202 gradually rose from April to July, whereas the EC of 302 lowered from April to September. Both stabilized after those periods.

In the coastal area, the EC varied from month to month.

In general, the fluctuation did not synchronize with the rainfall, meaning that dilution from the rain apparently does not occur in the groundwater of this area.

(4) 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 3.7.3-3 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. 3.7.3-9 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 3.7.3-3 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

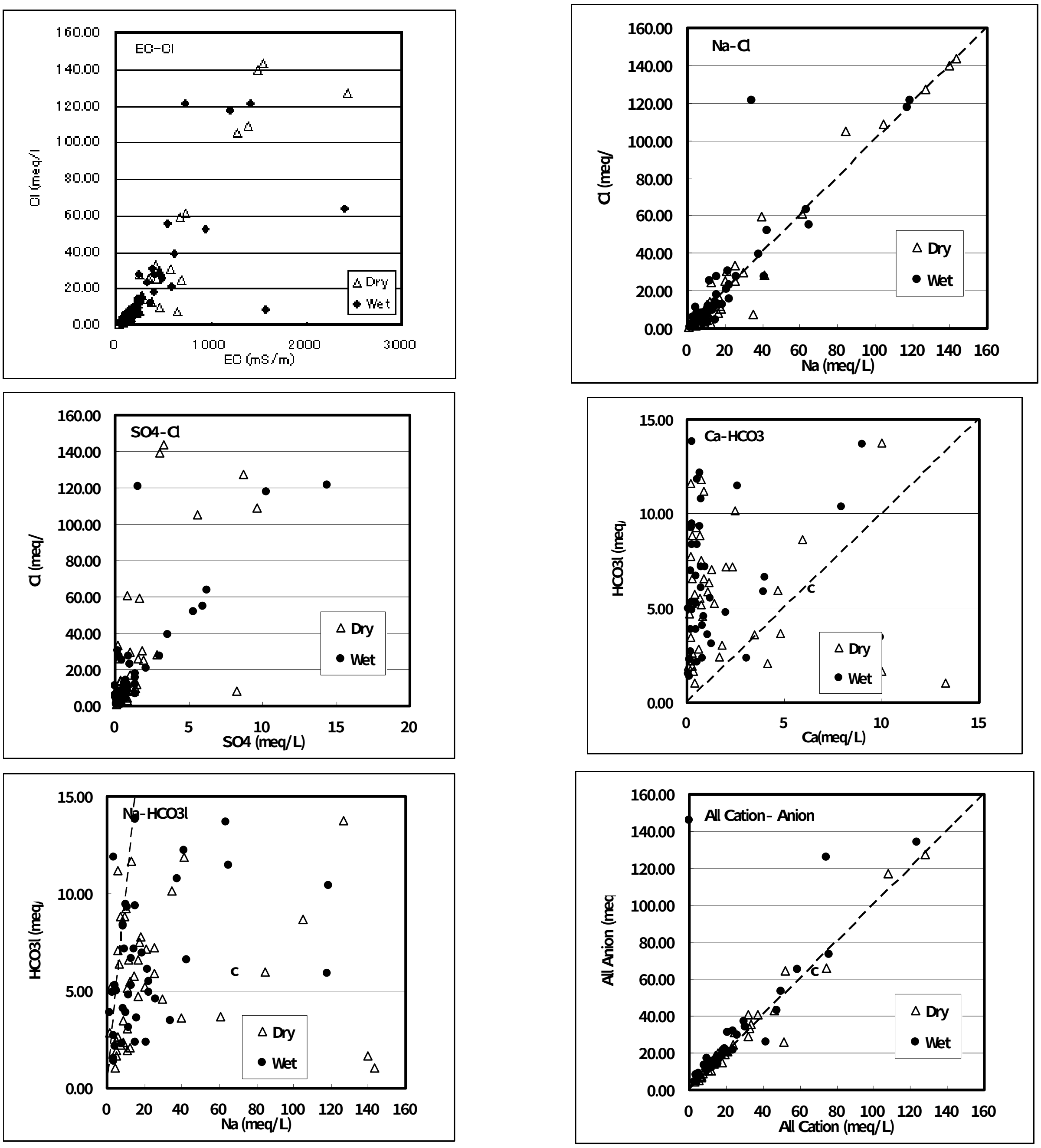


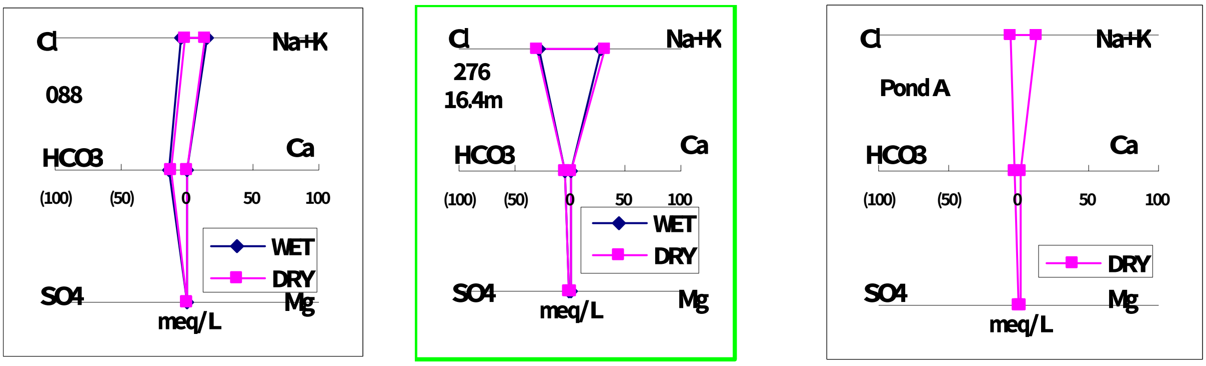
Fig. 3.7.3-9 Correlation between major ions

(5) 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. 3.7.3-10, the hexadiagrams of groundwater samples in the target area in Fig. 3.7.3-12(1), and hexadiagrams in the urban Ambovombe shown in Fig. 3.7.3-12(2)) and also Piperdiagram (Fig. 3.7.3-11) 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 Impluvium, 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 (see Fig. 3.7.1-1(1)and Fig.3.7.1-1(2)), 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. 3.7.3-10 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. Generally speaking, river water, subsoil flow water, and shallow groundwater are plotted in zone I and V, seawater and saline groundwater in zone IV and non-saline deep groundwater is plotted in zone II.

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

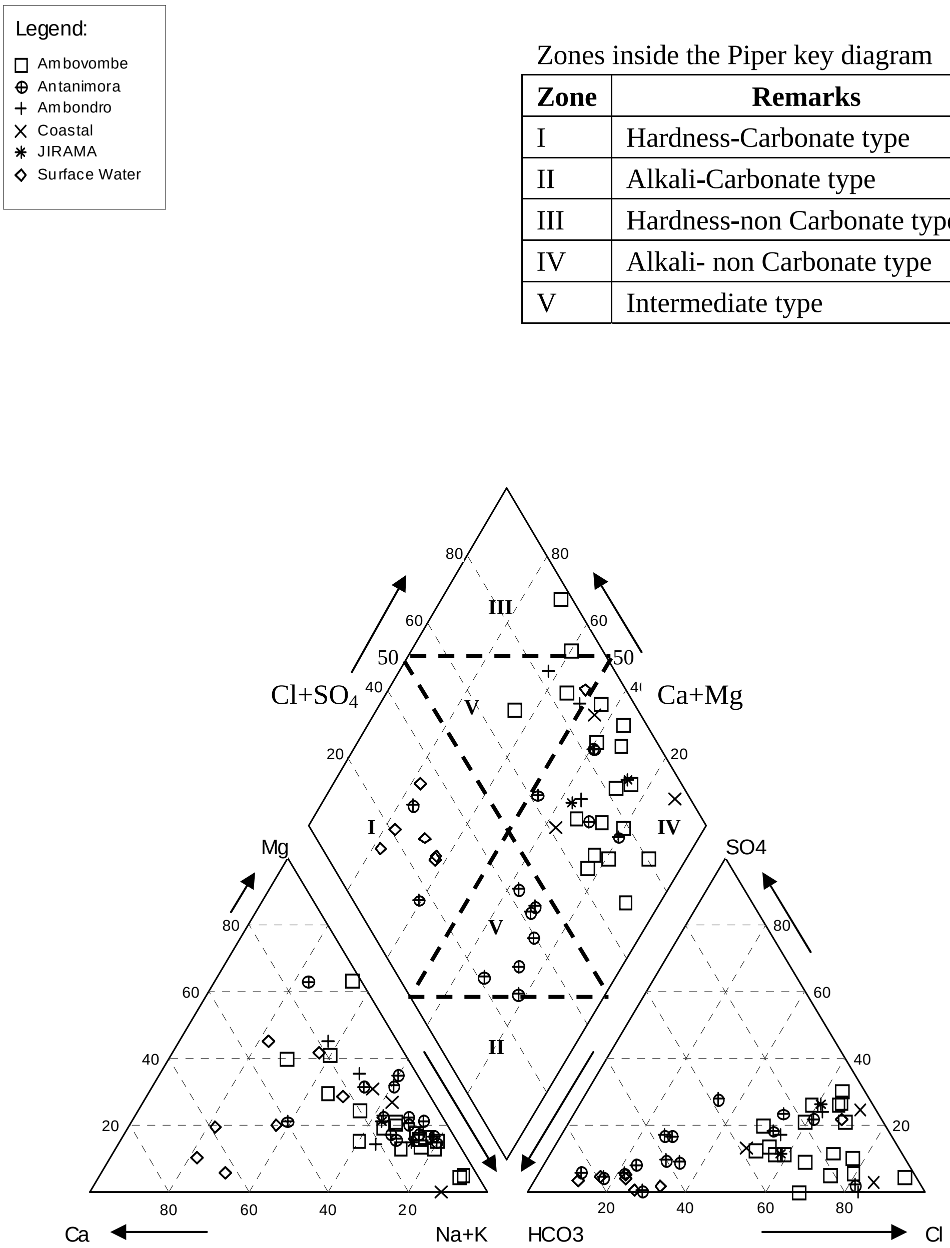


Fig. 3.7.3-11 Piper diagram of the samples analyzed for the dry season

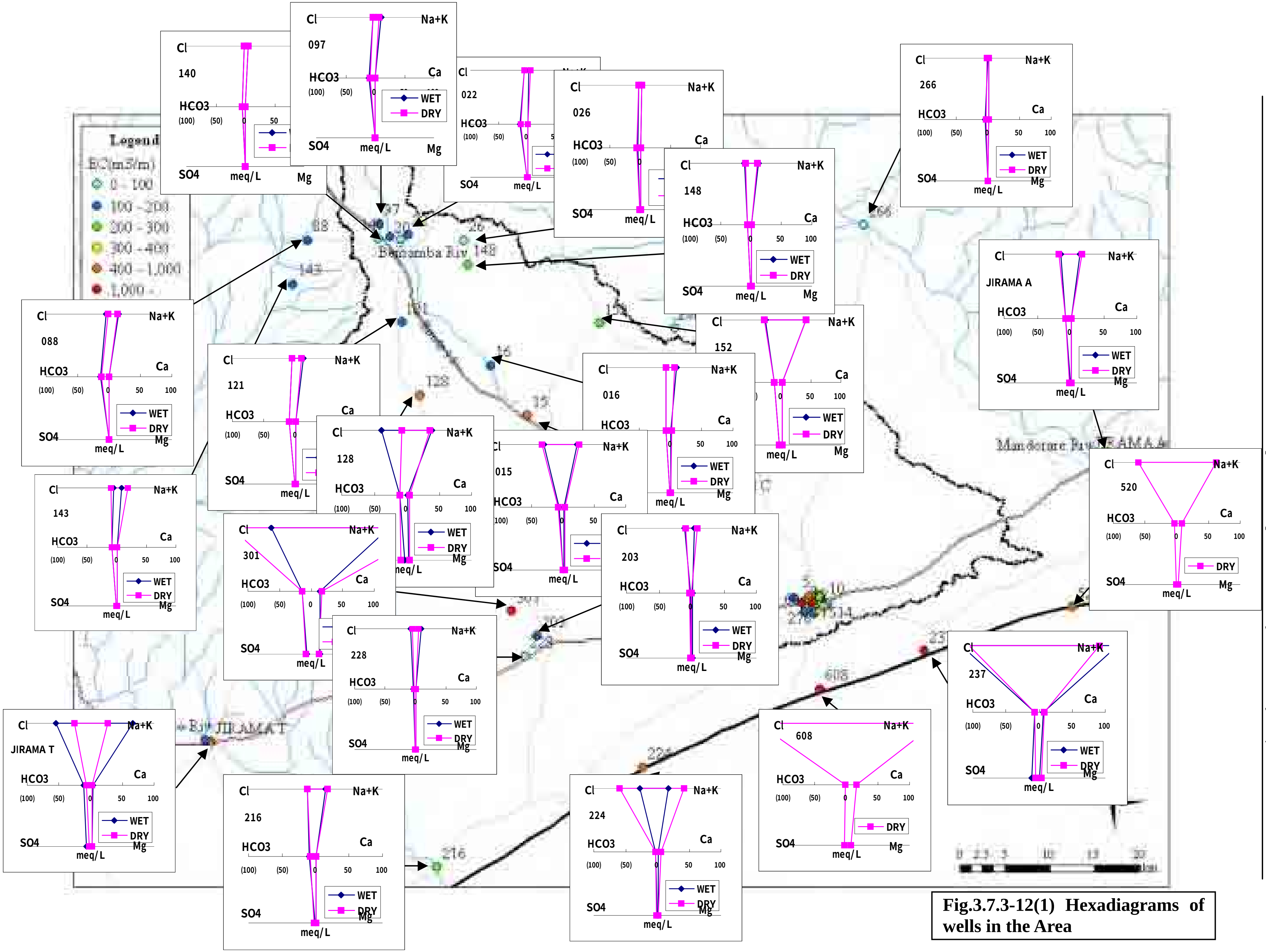


Fig.3.7.3-12(1) Hexadiagrams of wells in the Area

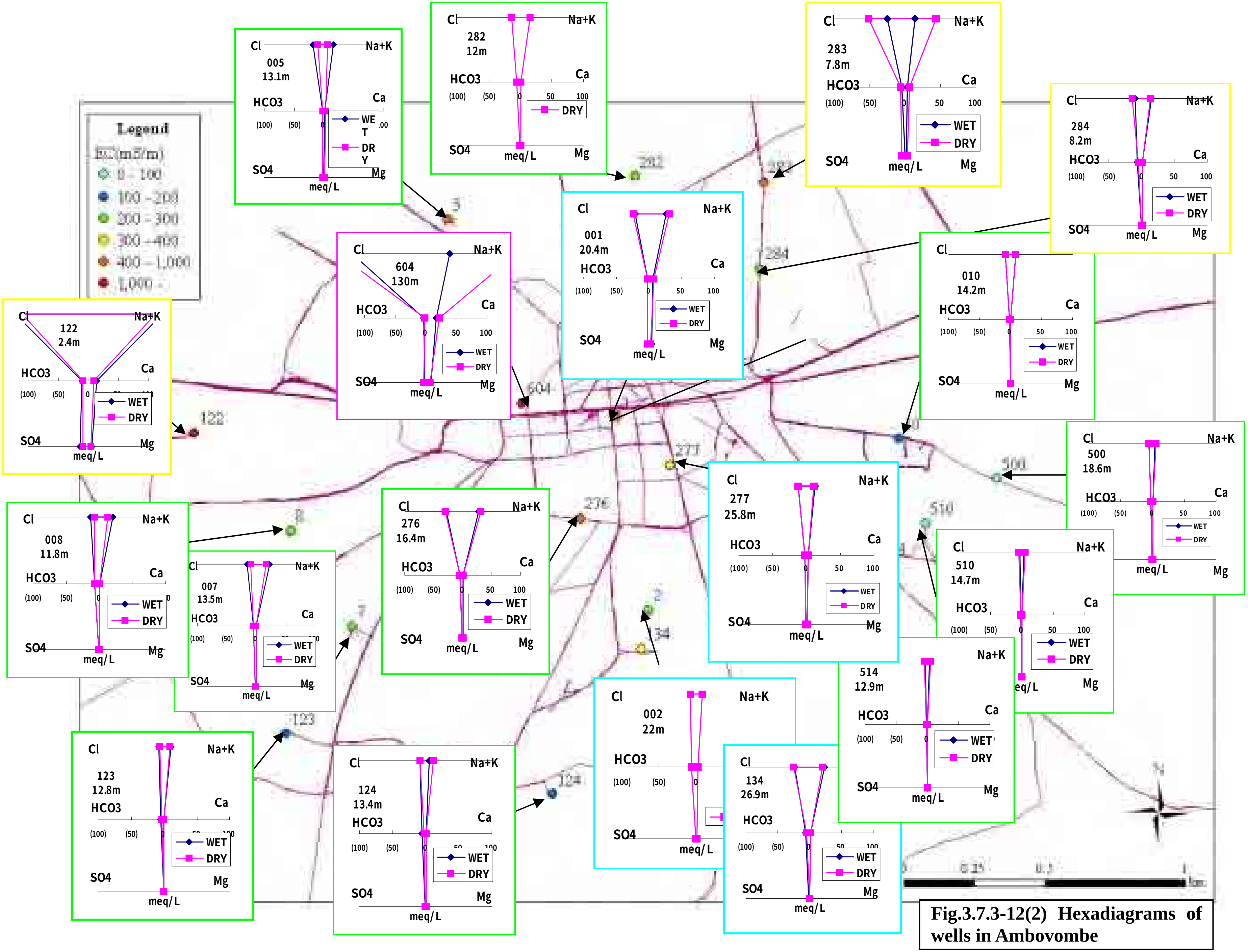


Fig.3.7.3-12(2) Hexadiagrams of wells in Ambovombe

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

First, the location of the points was roughly decided on the map at the end of Phase I, and then, exact points were selected at the Phase II after visiting each site area, taking into account the existence of the nearby village. Actual selection of each site was conducted with the presence of personnel from MEM, AES Ambovombe, District of Ambovombe, Mayor of each concerned communes and chief of the concerned village, to reach a consensus and get an approval of the land owners.

Table 3.8.1.1-1 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.

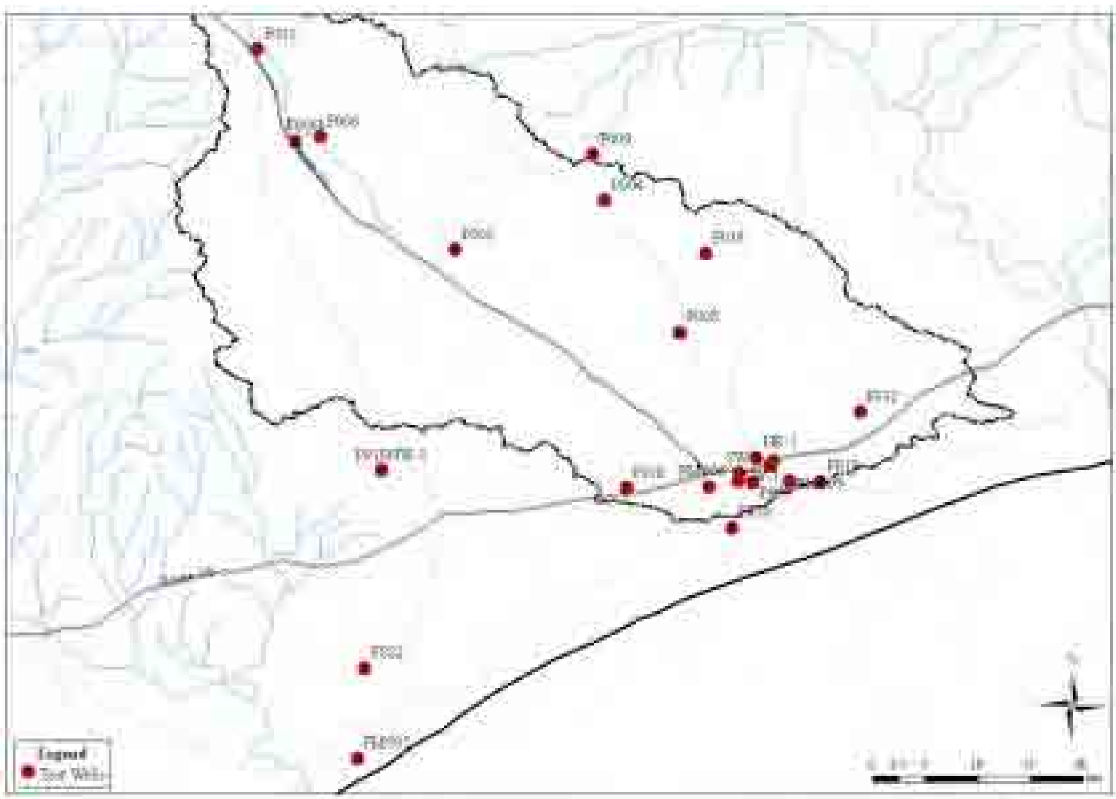
Table 3.8.1-1 Original Program of the Test Drilling

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

The exact position was decided at Phase II. The position of test holes are summarized below:

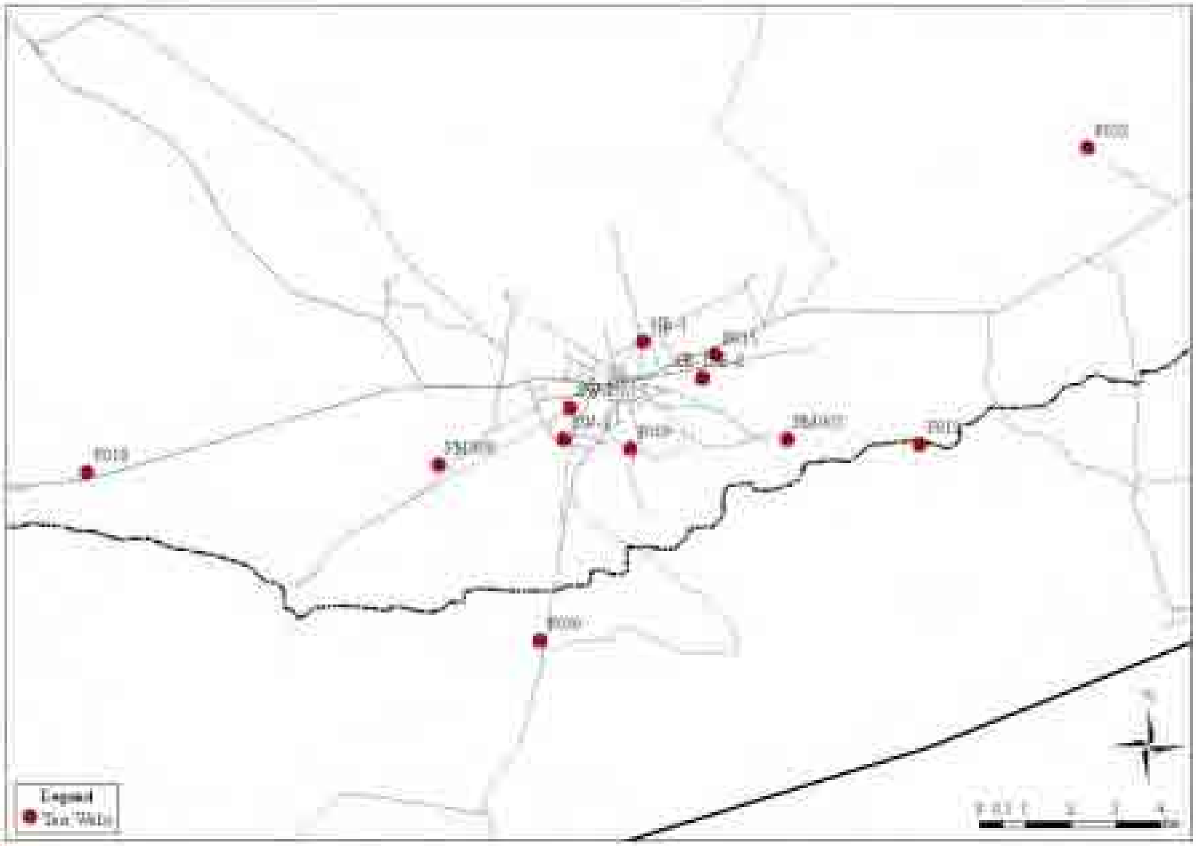
Table 3.8.1-2 Location of the Test holes

C	ID	Village	Longitude(degree)	Latitude(degree)	Altitude(m)
1	P003	Ambalantsaraky	45.8356389	-24.9923333	161
2	P004	Ampanihy	45.9634167	-24.9500833	162
3	P008	Betioky	46.0279167	-25.0630556	138.3
4	P009	Marobe	46.0906500	-25.1917983	130
5	P010	Analaisoka	45.7728056	-25.1811111	130
6	FM001	Maroafo	45.7521417	-25.4277467	82.82
7	PM005	Lavaandrandra	46.1220000	-25.1898889	211
8	PM006	Tsimihevo	46.0525556	-25.1950833	156.1
9	F001	Fianrenantsoa-Amposy	45.6669850	-24.8205567	292.13
10	F006	Bemamba-Antsatra	45.7206733	-24.8953167	228.17
11	F006b	Bemamba-Antsatra	45.6993889	-24.8988333	234.23
12	F009	Lefonjavy	45.9532222	-24.9107778	179
13	F014	Ankoba-Mikazy	46.0505917	-24.9952867	181
14	F015	Mangarivotra Tanambao	46.1077520	-25.1730670	140.12
15	F018	Ambanisarika	45.9821111	-25.1965278	203.4
16	F019	Ambazoamirafy	46.1485556	-25.1909722	220
17	F022	Anjira	45.7582133	-25.3507200	77.8
18	F030	Ekonka	46.0726111	-25.2303611	180
19	F032	Behaboobo	46.1821389	-25.1314167	229
20	SE-1	Anjatoka	46.1051944	-25.1776667	130
21	SE-2	Anjatoka	46.1051944	-25.1776667	130
22	SW-1	Mitsangana	46.0774444	-25.1899722	130
23	SW-2	Ambaro	46.0786111	-25.1836389	130
24	FP010	Analaisoka	45.7728056	-25.1811111	130
25	NW	Beabo	46.0933056	-25.1703056	130



Note: GPS data plot

Figure3.8.1.1-1 Site location map



Note: GPS data plot

Figure 3.8.1-2 Site location map in Ambovombe urbane

(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. The water for mud was drawn from wells of Ambovombe, or from the Mandrare River at Amboasary. The conductivity of the water was about 3,000 μ S/cm for the well water and about 1,000 μ S/cm 25°for the river water. The conductivity of mud was monitored during drilling to identify formation contaminated with salinity. The fish tail bit is employed in general.

Table 3.8.1-3 Equipment and material

Depth	Bit size	Casing		
		Plane	Screen	Gravel pack
6 m	14 -3/4 ‘’	12 ‘’		
50 to 200 m	10 – 5/8 ”	PVC 6 ‘’ Pressure rating >1.2MPA	PVC 6 ‘’	2 - 4 mm Composed of silica Until 5 m above screen

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.

The bottom ring has edge to sink into the formation and one meter of plane body. The next part is the screen which height is 3 m with 280 holes per meter of 8 mm diameter. The hole is perforated with angle of 45° to prevent formation sand dropping into the hole.

At part of the screen, gravel is packed at annular space. Gravel is composed of siliceous with granulometry

10mm - 15mm of local origin (Amboasary, Tranomaro, or Antanimora).

Figure 3.8.1.2-1 shows typical drawing of boreholes and hand dug wells.

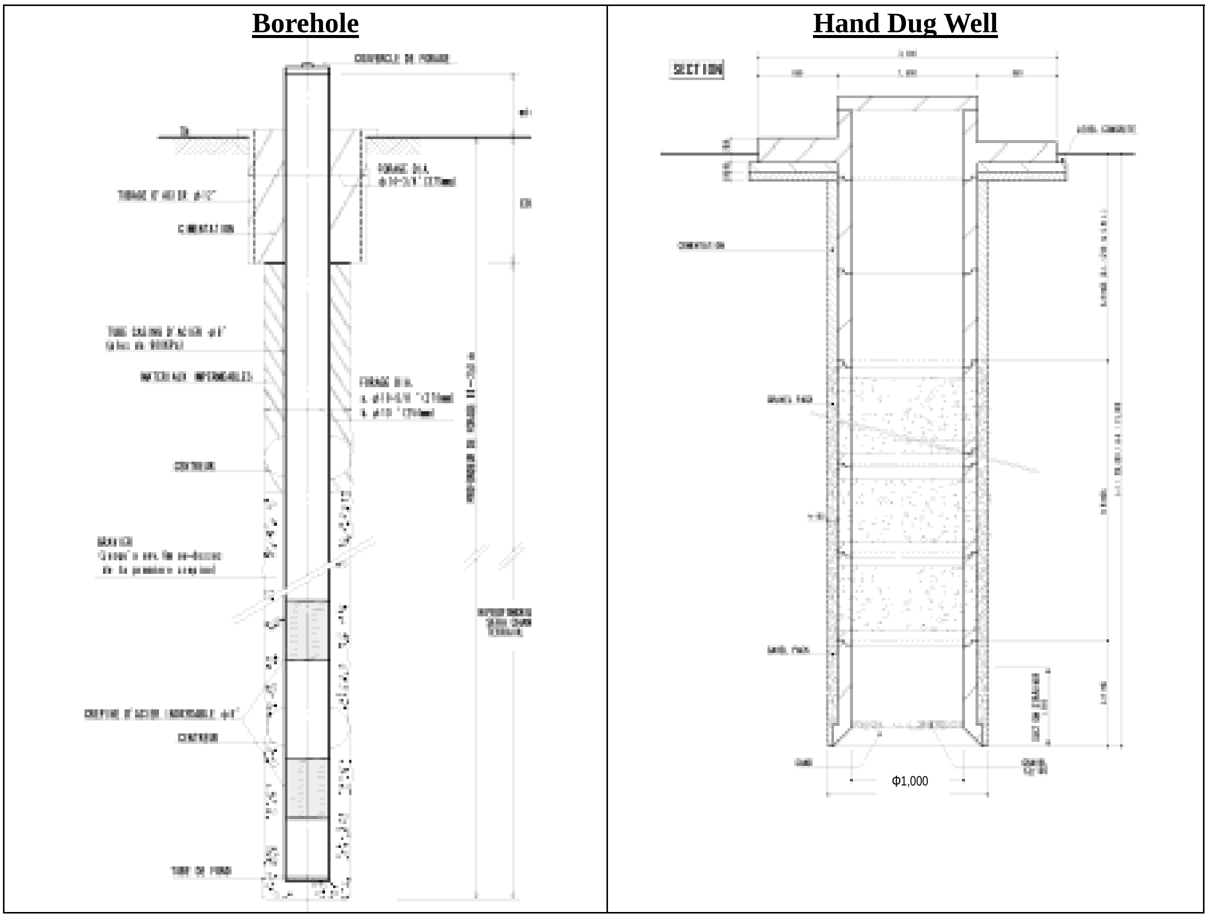


Figure 3.8.1-3 Typical drawings for the Test Well

3) Logging

a) Dugwell logging

At the end of drilling, logging was conducted. Equipment used for logging is the newly purchased equipment from CENTURY, which is an American company. The following parameters were measured:

- Spontaneous polarization,
- Resistivity 16" and 64 "
- Natural Gamma Ray
- Temperature.

The log was referred for justification to confirm correct depth before installing casing. Logging depth is compared with cutting observation and monitoring conductivity, mud loss and inflow.

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:

- Electric conductivity,
- Temperature.

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 characteristics of the aquifer, for example, change of drawdown with function of the yield.
Long duration test follows step drawdown test after recovery of the static water level. The test is conducted for 24 hours continuous pumping constantly to calculate hydraulic coefficient and to verify drawn down and change of mineralization in case of long pumping.

Table 3.8.1-4 Pumping test

Type of test	Duration	Number of step	Yield	Measuring item
Step drawdown test	4-6 hours each step	5 different step	Depending on each well	Water level, yield, conductivity, temperature
constant discharge	24 hours	Constant		

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 listed at table 3.8.1.2-3. Analysis was conducted by the JIRAMA.

Tableau3.8.1-5 Water quality Analysis

Element	Limit for drinking	Element	Limit for drinking
Elément analysé	**Limite de potabilité**	**Elément analysé**	**Limite de potabilité**
In site Conductivity	3 000 µS/cm 20 °C	Calcium	200 mg/l
In site Temperature		Iron	2.0 mg/l
In site pH	6.5 – 9.0	Ammonia	1.5 mg/l
Total hardness	(500 mg/l)	Manganese	0.1 mg/l
Turbidity		Bicarbonate	
Alkalinity		Chloride	250 mg/l
Arsenic	0.05 mg/l	Sulfate	
Sodium		Nitrate	50 mg/l
Potassium		Nitrite	1 mg/l
Magnesium	50 mg/l	Fluoride	1.5 mg/l

3.8.2 Social and Economic State of the Test Drilling Points

The following shows the socio-economic characteristics of each of points.

(1) P003

Commune	Sihanamaro
Fokontany	Ehavo
Village	Ambarantsaraky

This point is situated in a village one hour away by cart from the centre of fokontany of Ehavo (fokontany centre) and 25km away from the commune center of Sihanamaro. No school exists there. The total population of the fokontany is 764.
Inhabitants of the fokontany draw water at the wells at the distance of 3 hours by cart in the dry season and water of marsh 30 minutes away in the rainy season and water is free of charge at both sources. There is no system for water management. It was observed that the inhabitants were accustomed neither to organize an organization nor to pay for water.

(2) P004

Commune	Ambovombe Androy
Fokontany	Esanta Malofoty
Village	Ampanihy

This point is not situated in or near to an agglomeration but situated in the forest being 3km away from the nearest village. This neighbouring village was originated from a camp for transhumance and is also isolated being more than 30 km away from the fokontany centre.
Inhabitants of the village draw water from Mandrare River at a distance of 7 hours by cart in the dry season and from marsh adjacent to the village in the rainy season. Water of both sources is free of charge. There is neither system for water management nor primary school there.

(3) P008

Commune	Ambohimalaza
Fokontany	Betioky
Village	Betioky

This point is situated by the side of a primary school at a village of fokontany center. There exists a primary school and a weekly market in the village.
The fokontany of Betioky with 914 inhabitants has two basins with trough that provide people water in the rainy season. In the dry season they draw water at Bemamba River at the distance of 30 minutes by cart. For managing of the water facilities, there is Water Point Committee (CPE) for each basin, one was established in 2001 and another was established in 2005. The first CPE has experience of water management for 4 years, though it has not collaborated with new CPE on the water management.

(4) P009

Commune	Ambovombe Androy
Fokontany	Marobe Marofoty
Village	Marobe

This point is situated in the suburbs of Ambovombe Urban where the fields and houses are spreading. The population of Marobe Marofoty is 570. Social infrastructures such as school or health facilities are relatively near compared to the sites of rural areas.
There are a number of wells in the same fokontany whose owners gain income by selling water from them. Inhabitants are accustomed to pay for water. Water is sold at the unit price from 50 Ariary to 100 Ariary per bucket of 13 litters or 1,000 Ariary per barrel of 160 litters. But the price often goes up to more than 500 Ariary per bucket in the dry season.
As for people’s cohesiveness, there is no CPE near to the test drilling site and inhabitants are not accustomed to organize themselves. One of the supposed obstacles against to the water management by association is existence of water vendors. So their involvement in the safe water supply system is to be considered.

(5) P010

Commune	Sihanamaro
Fokontany	Analaisoke
Village	Analaisoke

This point is situated at an open place aside of a village of fokontany and it is not far from the commune center, at the distance of about 3 km. The total population of the fokontany is approximately 800. In the village, a primary school exists near to the point, so inhabitants are supposed to have relatively high education level.

As for water source, inhabitants draw water from near marshes all the year round and water of a well in the village in the rainy season. Adding to this, they draw water from another well. Water of all sources is free of charge and there is no organization for water management, so inhabitants may not have the intension to pay for water of new well or borehole. It needs to make people aware of necessity of water management and encourage them on the establishment of an organization.

(6) FM001

Commune	Antaritarika
Fokontany	Maroafo
Village	Maroafo

This point is situated in a village of the fokontany centre, being 3.7km south to the commune center. The total population of the fokontany is 676. In the village there exists a primary school.
Inhabitants of fokontany draw water of a well freely at the seaside that is 30 minutes distant from the village by cart all the year round. The quality is saline.
It is observed that the inhabitants are not accustomed to organize a committee and to pay water rate, though they collaborate for maintenance and repair of the well of the seaside when it is necessary.

(7) PM005

Commune	Ambovombe Androy
Fokontany	Lavaandrandra
Village	Lavaandrandra

This point is situated in open place of the fokontany centre, where a primary school exists. The village is 3 hours away from the Ambovombe Urban by cart. The total population of the fokontany is 933.
Inhabitants of this site are not accustomed to unite for water management, but to pay water charge. They draw water from an impluvium owned by fokontany in the rainy season. Commission members designated by the people do manage it and the fokontany president takes initiative of its management. Water rate is 50 Ariary per bucket of 13 litters. In the dry season, inhabitants go to wells of Ambovombe, where water rate is often more than 50 Ariary per bucket.

(8) PM006

Commune	Tsimananada
Fokontany	Anjeke Miavotse ou Tsimahevo
Village	-

This point is situated along the road to Tsimananada and 5km away from the commune center of Tsimananada and 3km away form the office of AES of Ambovombe. It is within a plantation project site implemented in the scheme of ‘Androy Operation’ in the 1970s. Inhabitants of near villages draw water from impluvia owned by fokontany in the rainy season and buy water of wells in Ambovombe urban.

(9) F001

Commune	Antanimora
Fokontany	Antanimora Centre
Village	Fiarenantsoa Ampozy

This point is situated in a forest and at 100m east from the entrance of the Antanimora urban on the National Route 13.
The nearest village locates at 1km from the site and inhabitants of the village go to the Bemanba River at 30 minutes for finding water all the year round.

(10) F006

Commune	Antanimora
Fokontany	Bemanba Antsatra
Village	Bemanba Antsatra

This point is situated in a forest hundreds meters from agglomerations and 8km north-east of the commune center of Antanimora. The surrounding seven villages with the total population of 400 inhabitants became independent from Manave Fokontany to establish a new fokontany in 2006.
Inhabitants of the fokontany feel the distance from the water point as difficulty in the drinking water supply. They draw water from a borehole constructed by the UNICEF project, whose water rate is, according to the some villagers, 1,000 Ariary per year for a household (it is 1,400 Ariary/year according to the interview to the NGO who support CPE). They also draw water from Bemamba River or water under the river bed,

(11) F009

Commune	Ambohimalaza
Fokontany	Sakave
Village	Lafonjaby

This point is situated in a village with 8km away from the fokontany centre. The population of the fokontany is 630 and there is no primary school in and near the village.
It is observed that the inhabitants are not accustomed to organize a committee or to pay water charge. They draw water of Andrenitoka River of 7 hours from the village by cart in the dry season and water of near marsh in the rainy season. The price of both water sources is free.

(12) F014

Commune	Ambovombe Androy
Fokontany	Ambolabe
Village	Ankoba Mikazy

This point is situated in the village more than 20km away from the fokontany centre, where originally established, like P004, as a camp for transhumance. So, it is supposed to be difficult to receive appropriate assistance from fokontany due to its distance. There is a private primary school (established by church) in the village.
Inhabitants are not accustomed to organize to manage the water sources and to pay for money. In the dry season, inhabitants go to Mandrare River of 6 hours by cart, to draw ‘sweet’ (not briny) water of free of charge or go to Ambovombe, being 4 hours by cart, to buy water of private wells. In the rainy season, they go to Sarimonto Marsh where they draw free water.

(13) F015

Commune	Ambovombe Androy
Fokontany	Tanambao
Village	Mangarivitra

This point is situated on the National Route 13 at the east entrance of Ambovombe Urban and the test drilling was exhibited to all people who pass on the road. The land is actually not used but the flux of agglomeration (urbanisation) comes to the side of the site. Population of the fokontany is approximately 2,400. Inhabitants’ education level is relatively high comparing to people of other drilling points except P009.
Inhabitants are not accustomed to organize for manage water sources but accustomed to pay for water. There is no CPE in the same fokontany but some exist in Ambovombe Urban. Inhabitants of the adjacent area draw water from private wells in the urban whose water rate is 100 Ariary per bucket or more.

(14) F018

Commune	Ambanisarika
Fokontany	Ambanisarika Centre
Village	Ambanisarika Centre

This point is situated 100m to the north from the National Route 10 and near to the commune center of Ambanisarika. Around it, there also exist CSB (Basic Health Centre), market building and primary school. The population of Ambanisarika Centre is 1,646.
Inhabitants buy water from well of Ambovombe Urban or from AES water tanker.

(15) F019

Commune	Ambovombe Androy
Fokontany	Ambazoamirafy
Village	Ambazoamirafy

This point is situated in a village of the fokontany centre, 6km away from Ambovombe Urban. There is a primary school near to the drilling site and inhabitants are supposed to have relatively high education level. The population of Ambazoamirafy Fokontany is 672.
Inhabitants are not accustomed to organize themselves and to manage water facilities. They draw water in rainy season from an impluvium of the fokontany constructed in 1976 and repaired in 2005. Water rate is 100 Ariary per bucket. A CPE started to manage it after the repair finished, so it has no experience of management and maintenance yet.

(16) F022

Commune	Antaritarika
Fokontany	Anjira
Village	Anjira

This point is situated in a village of the fokontany centre 4km north to the commune center, where there is a primary school and a CSB. Inhabitants are supposed to have relatively high education level and assistance from fokontany, commune and CSB can be expected due to the adjacency. The population of Anjira is 1,093.
There had been an impluvium before but it was abandoned because a half of users did not pay for the repair cost when it was required. Actually, inhabitants of the fokontany draw water from Manambovo River at the distance of 2.5km away by cart.

(17) F030

Commune	Ambovombe Androy
Fokontany	Ekonka Malofoty
Village	Ekonka Malofoty

This point is at the side of a village of the fokontany centre of 5km south to Ambovombe. The population of Ekonka Malofoty is 1,193. There is a primary school in the village and inhabitants are supposed to have relatively high education level. Assistance from fokontany and commune can be expected due to the adjacency.
It seems that inhabitants of the fokontany possess the capacity to unite and manage water facilities and are accustomed to pay for water. They have drawn water from an Impluvium of fokontany own in the rainy season since 1976, which has been managed by a CPE since that year. Water rate is decided by the fokontany people at the general assembly but it remains at 20 Ariary per bucket.

(18) F032

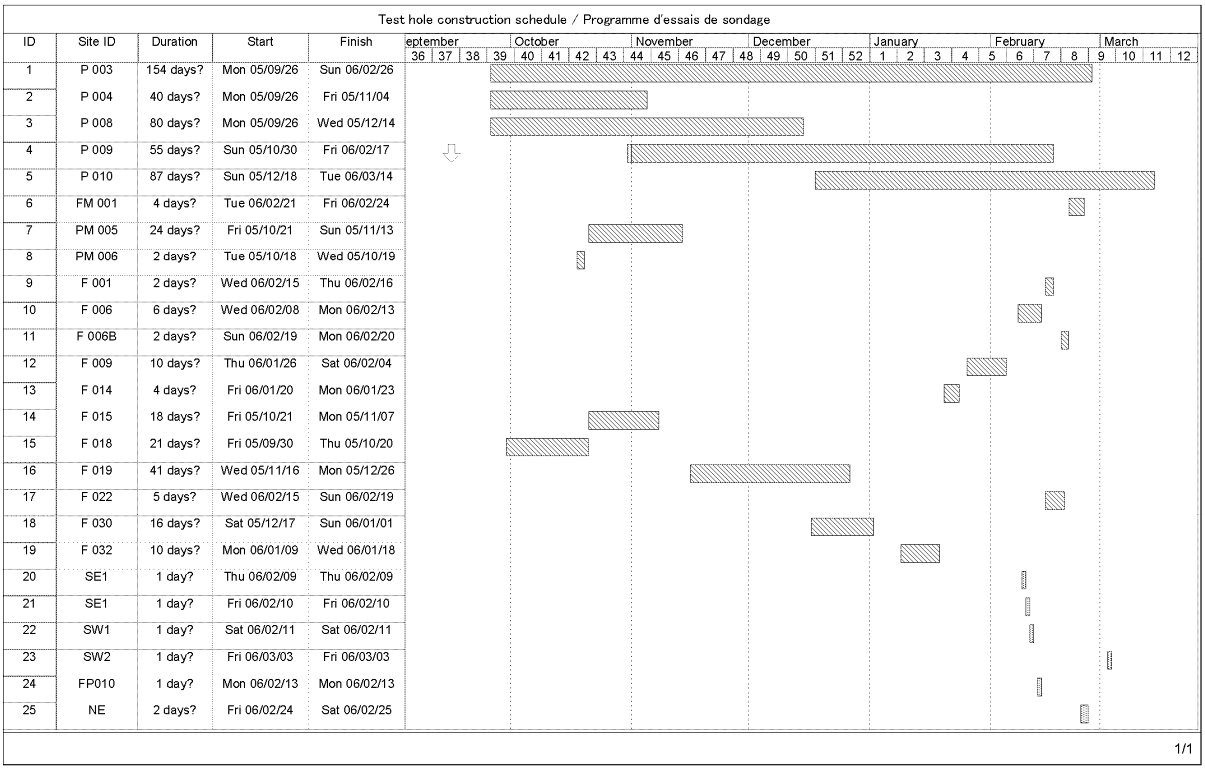
Commune	Ambovombe Androy
Fokontany	Behabobo
Village	Behabobo

This point is situated in a village of the fokontany centre, being 12 km away from Ambovombe. There is no primary school in the fokontany but children go to schools in adjacent fokontanys. Assistance from fokontany can be expected due to the adjacency. The population of Behabobo Fokontany is around 1,021.
Inhabitants draw water from an Impluvium of the fokontany. A commission consisting of 5 members manages it. President of fokontany takes initiative on the Impluvium management, while inhabitants are not accustomed to organize themselves for water management up to present. Being different from other Impluvium of fokontany own, water rate is gratuitous at Behabobo.

3.8.3 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 were PM005, F019 because hole corruption had occurred and was needed to drill another holes.



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

Figure 3.8.3-1 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 3.8.3-1 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	2550	< 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	101.2 3
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	191.7 7
	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

(yellow shading) Estimated

Altitude of SWL is calculated 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 semimetals 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 as 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.

3.9 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.

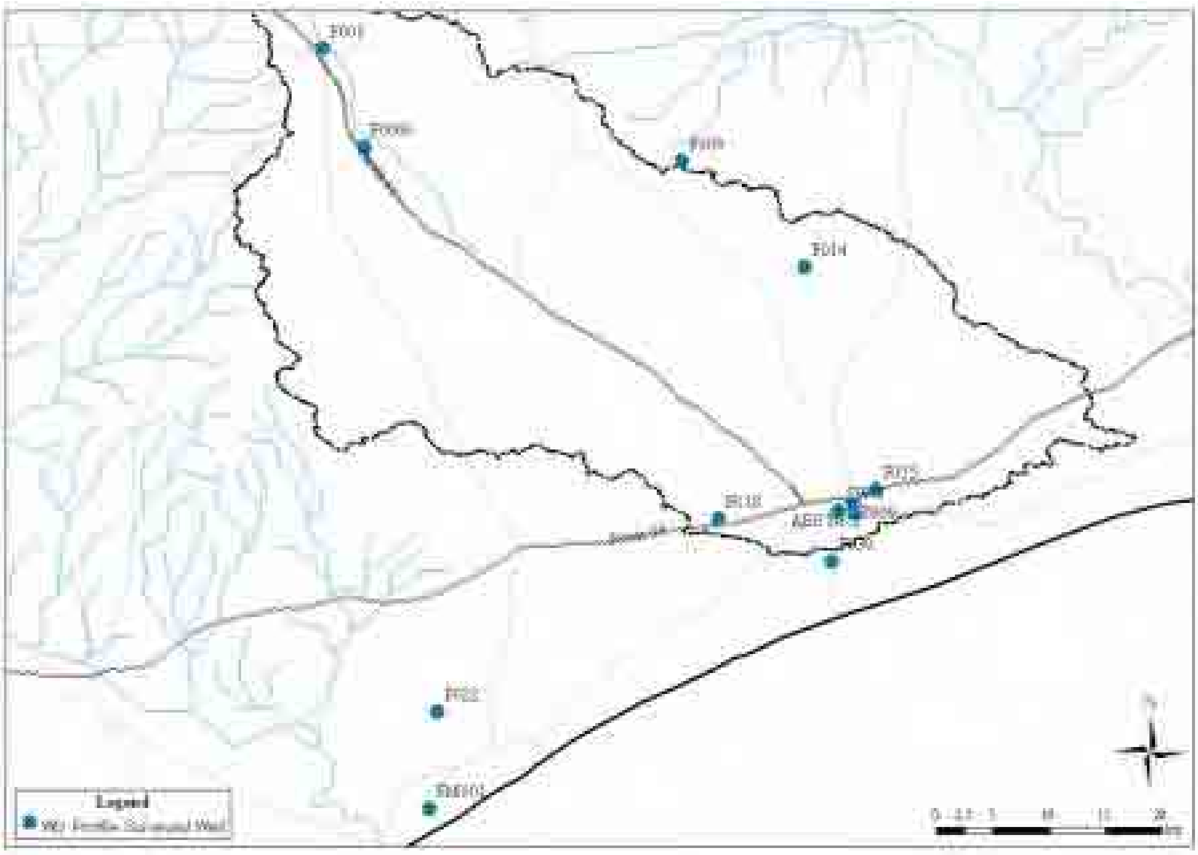


Figure 3.9.1-1(a) Location map of Surveyed Points

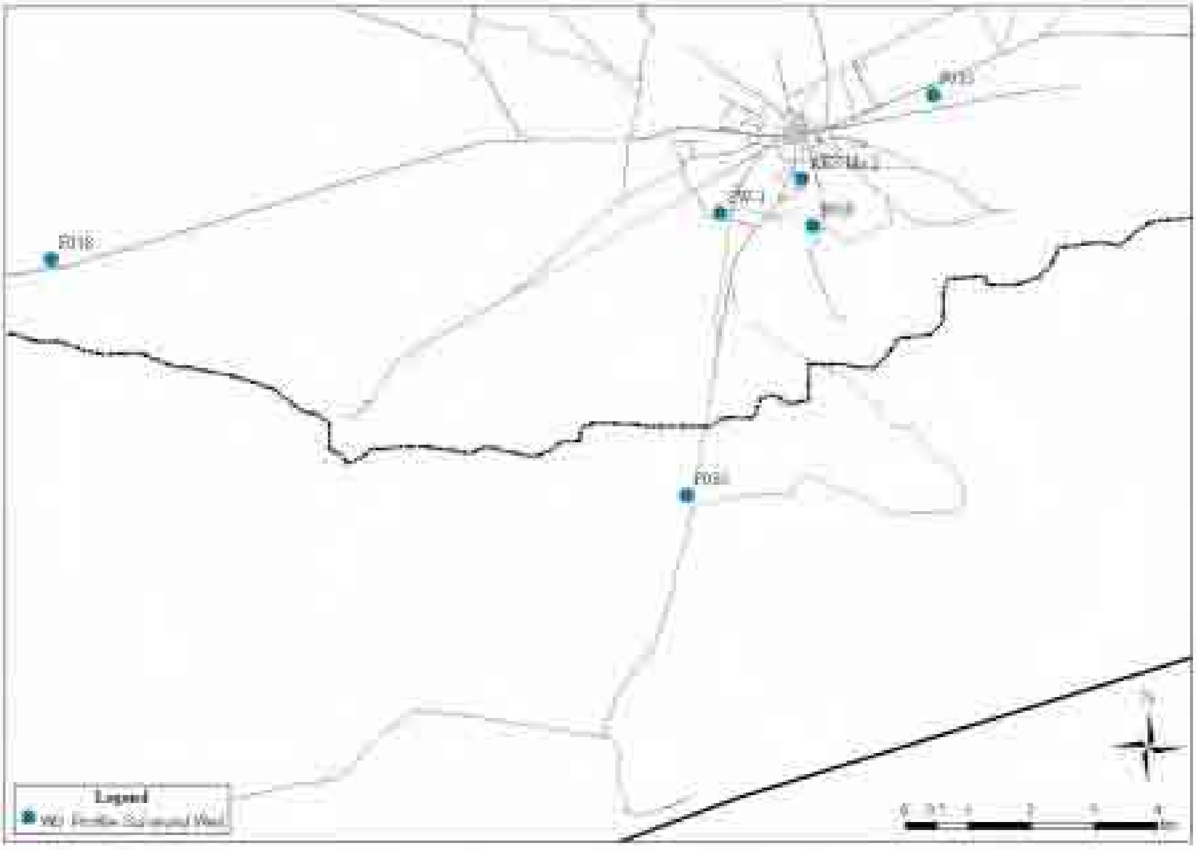


Figure 3.9.1-1(b) Location map of Surveyed Points (Ambovombe city area)

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 (Tube Well)
3	F006b	Antanimora	63	14.4	Test Well (Tube Well)
4	F009	Ambovombe	82	48.3	Test Well (Tube Well)
5	F014	Ambovombe	124	101.2	Test Well (Tube Well)
6	F015	Ambovombe	153	134	Test Well (Tube Well)
7	F018	Ambanisarika	202	152.9	Test Well (Tube Well)
8	F022	Antaritarika	126	58.8	Test Well (Tube Well)
9	F030	Ambovombe	205	181.4	Test Well (Tube Well)
10	FM001	Antaritarika	100	80.7	Test Well (Tube Well)
11	SW-1	Ambovombe	33	23.3	Test Well (Tube Well)
12	AES No.2	Ambovombe	22	20.3	Existing Well

(3) Results of the profiling

Figure 3.9.1-2 shows photograph of vertical profiling survey.

Calibrating the probe

Inserting the probe into test well

State of measurement

Data recording and processing

Figure 3.9.1-2 Photograph of vertical profiling

Figure 3.9.1-3 shows results of measured electric conductivity for the selected 12 points. Detailed data is shown in the Figure 3.9.1-4.

From the Figure 3.9.1-3, 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.

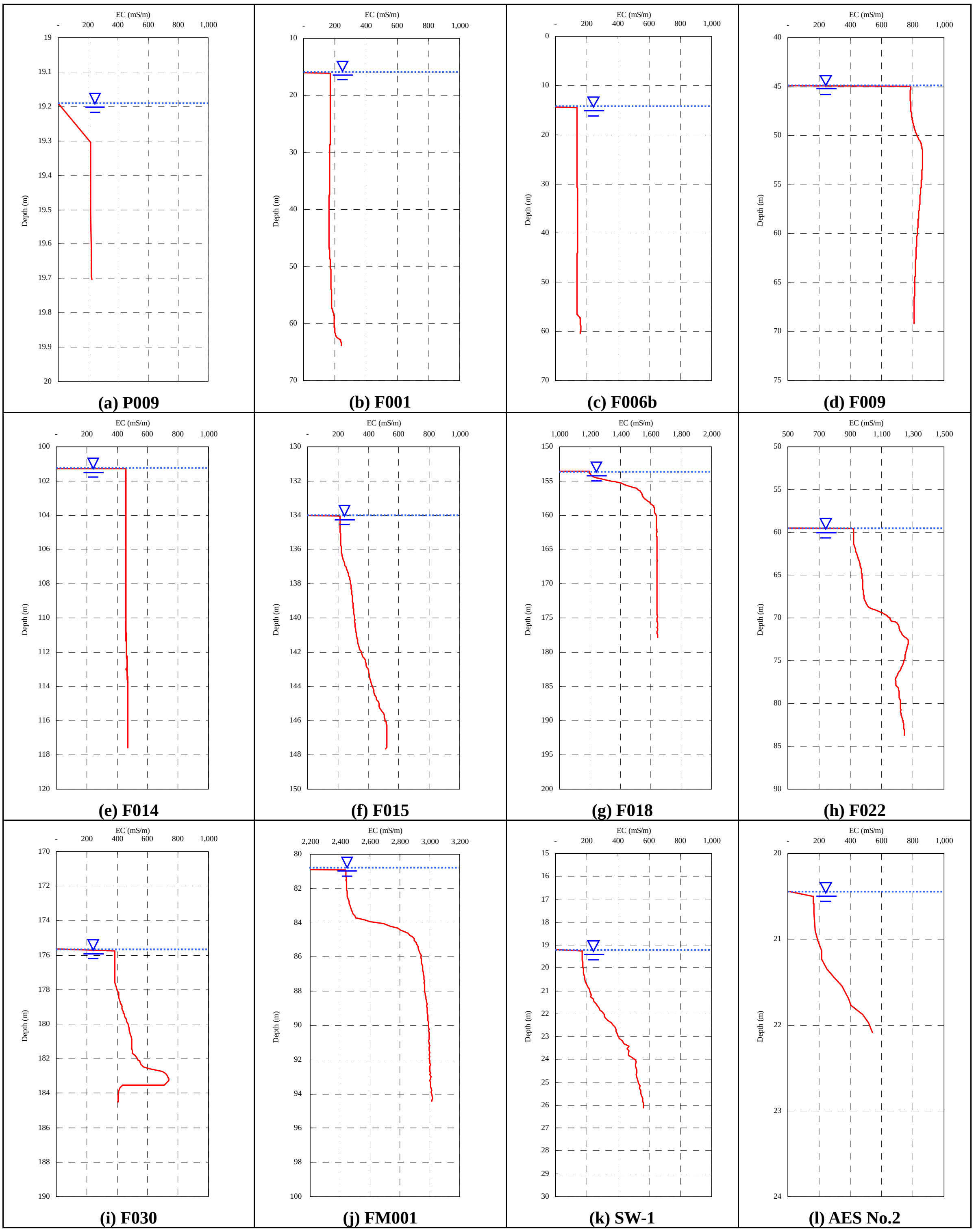


Figure 3.9.1-3 Results of vertical profiling

(4) Discussion

Figure 3.9.1-4 shows location map of surveyed points at coastal area (F015, F030, FM001 and F022). Figure 3.9.1-5 shows comparison of measured electric conductivity data between the well FM001 and F022 and between the well F015 and F030.

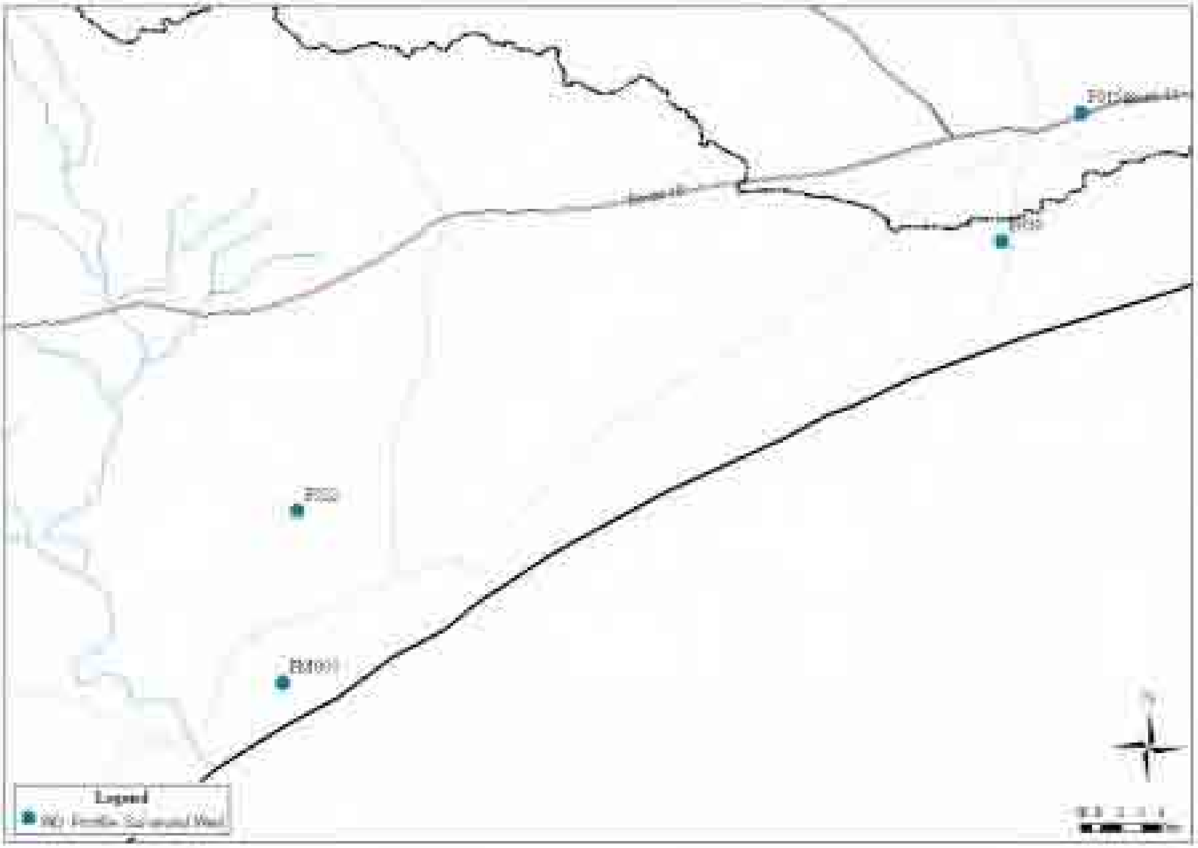
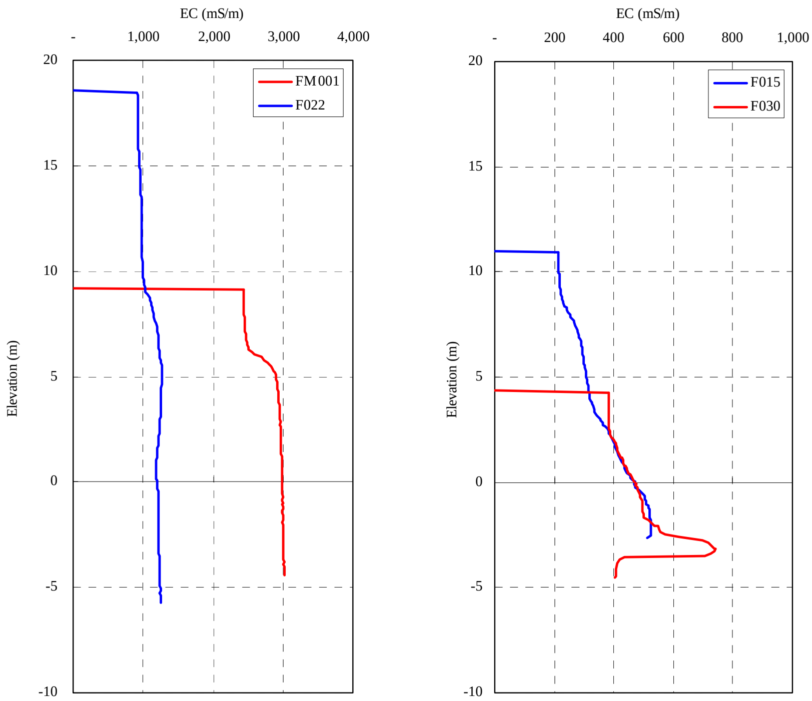


Figure 3.9.1-4 Location map of surveyed wells at coastal area



FM001 and F022 F015 and F030

Figure 3.9.1-5 Comparison of measured electric conductivity data

From the Figure 3.9.1-5, 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 3.9.1-5, 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

Figure 3.9.2-1 shows location map of monitoring points within study area. As shown in the figure, 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 summarizes the list of surveyed points.

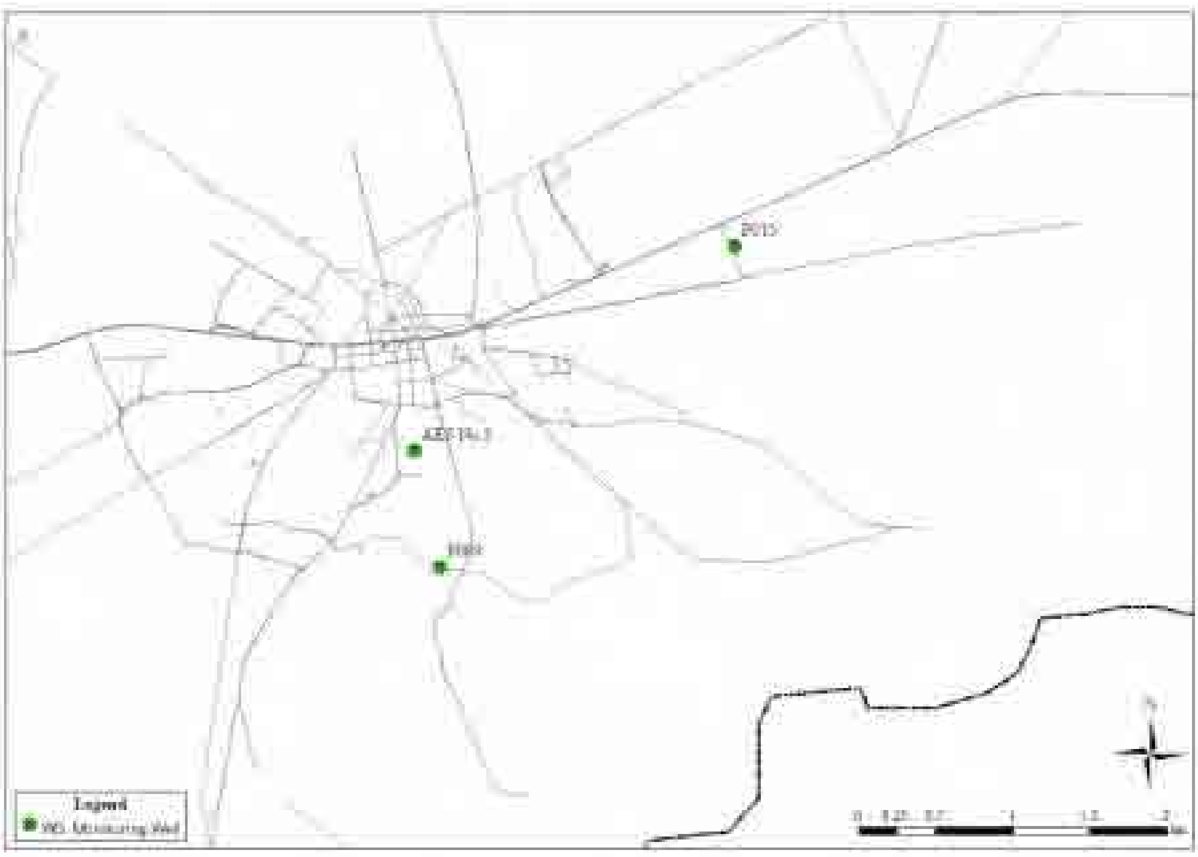


Figure 3.9.2-1 Location map of Monitoring Points

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 (Tube Well)
3	AES No.2	Ambovombe	22	20.3	Existing Well

(3) Results of the profiling

Figure 3.9.2-2 shows photograph of time-series water quality monitoring survey.

Installing monitoring probe at the well P009

Installing monitoring probe at the well F015

Installing monitoring probe at the well AES No.2

Downloading measured data from probe

Figure 3.9.2-2 Photograph of vertical profiling

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

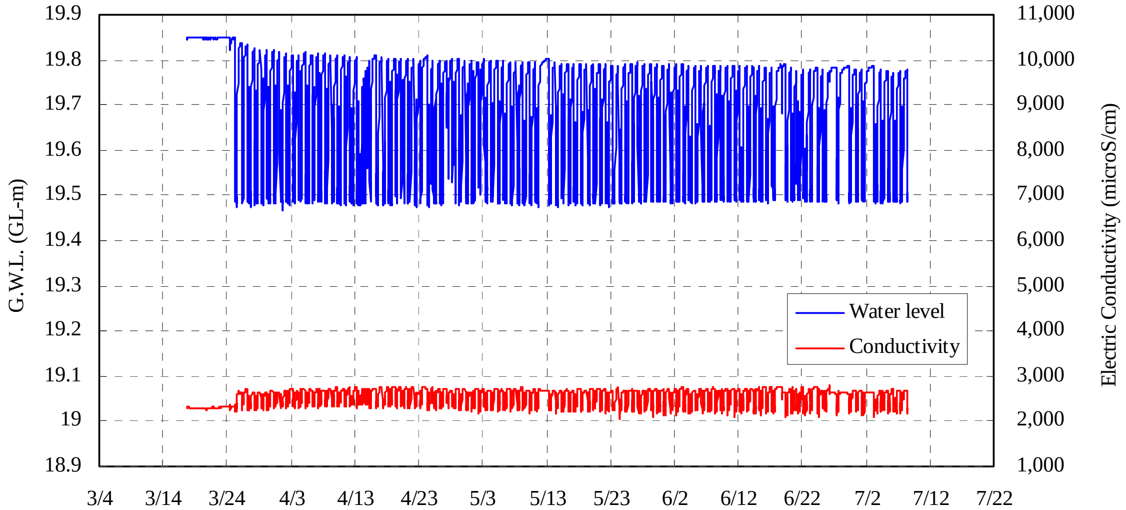


Figure 3.9.2-3 (a) Results of monitoring (P009)

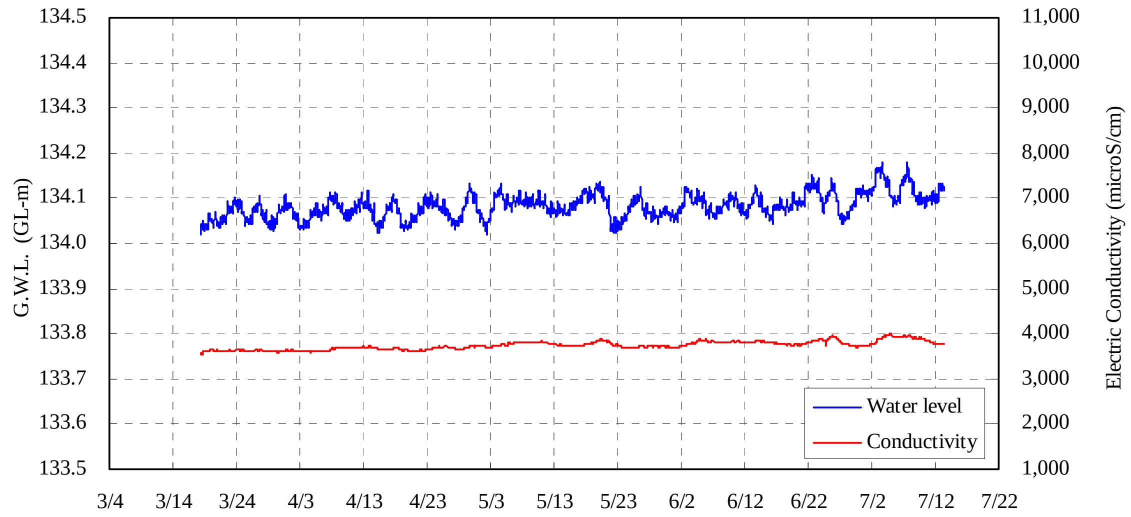


Figure 3.9.2-3 (b) Results of monitoring (F015)

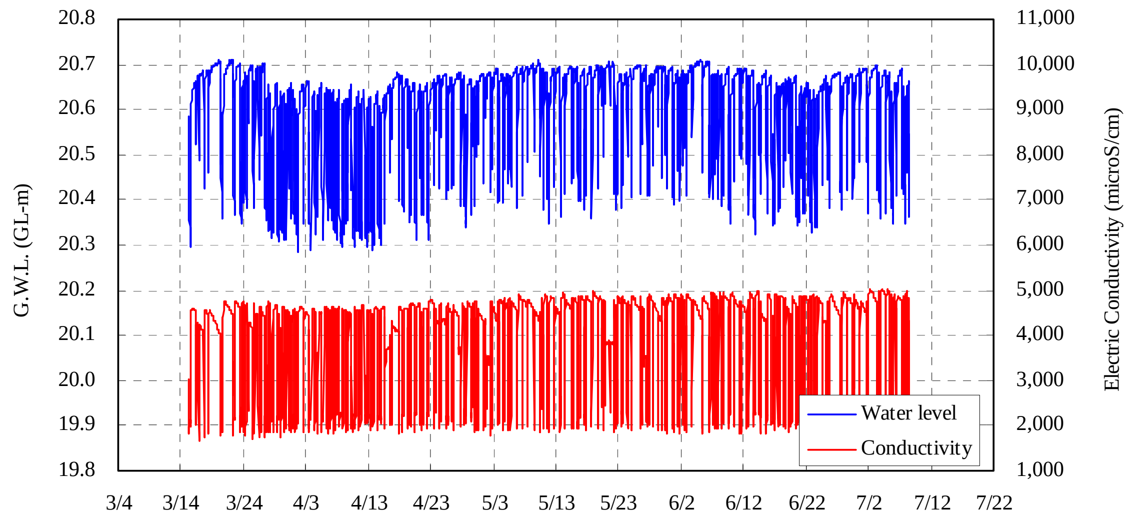


Figure 3.9.2-3 (c) Results of monitoring (AES No.2)

At the well P009 and AES No.2, water pump is installed and there is daily extraction of groundwater from them. Therefore there is drastic change of water level. On the other hand, there is no water extraction 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 3.9.2-4 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.

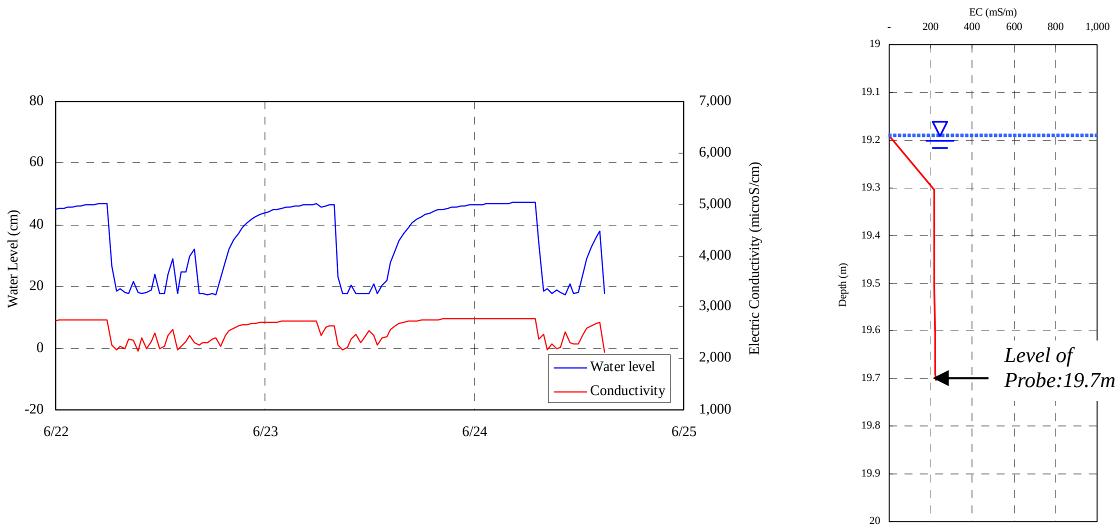


Figure 3.9.2-4 (a) Enlarged monitoring data (P009)

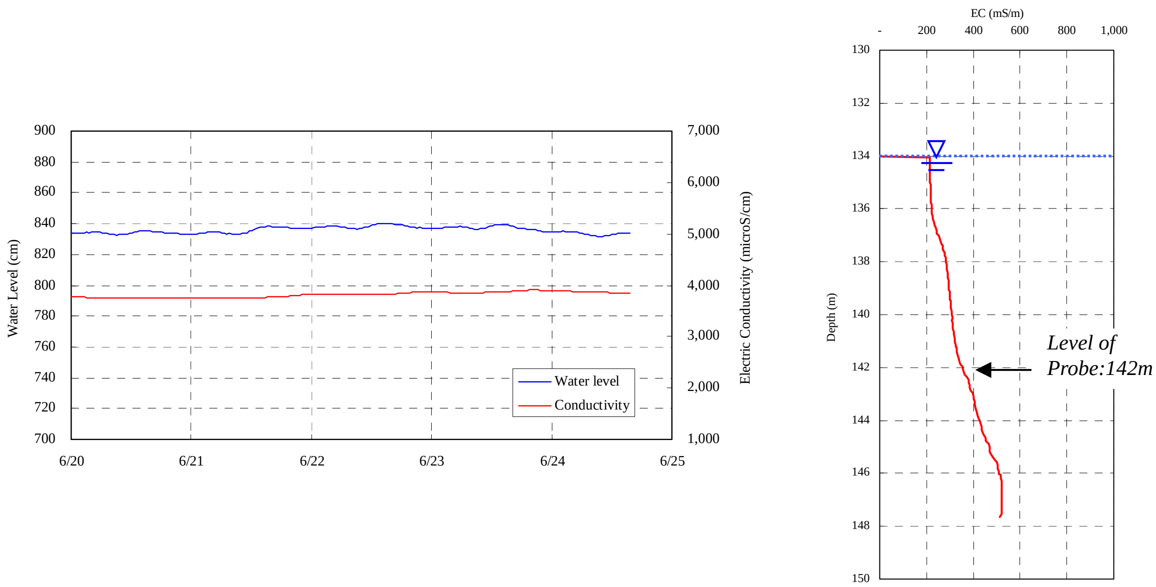


Figure 3.9.2-4 (b) Enlarged monitoring data (F015)

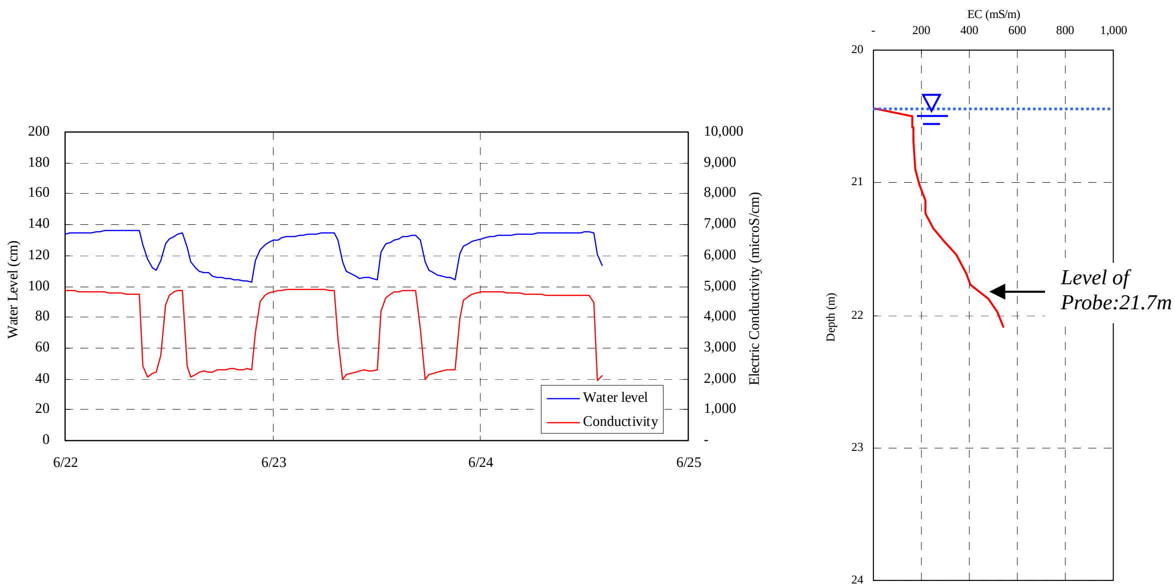


Figure 3.9.2-4 (c) Enlarged monitoring data (AES No.2)

From the Figure 3.9.2-4, 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.

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CHAPTER 4 SURVEYS AND ANALYSIS FOR SOCIO-ECONOMIQUE 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, surveys in the socio-economic field were conducted during mid-April and mid-May 2005 by the JICA study team and a team of sub-contracted local NGO.

The surveys consisted of two parts: one was a baseline survey and the other was a socio-economic condition survey. The baseline survey was targeted on responsible persons of administration organisations 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.

These surveys focused on following fields:
Lists of data obtained from the surveys are attached in the data book.

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. Commune is a governmental body having responsibility for rural development according to the current policy while household is a unit of water consumption having responsibility to pay for water charge.

(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). The number of villages of ten important livelihood sources is shown in Table 4.2.1-1.

Table 4.2.1- 1 Important livelihood sources

No.	Source	Num. villages
1	Manioc/ cassava	1,037
2	Maïs/ maize	992
3	Patate/ sweet potate	991
4	Niébé/ a kind of beans	732
5	Elevage/ livestock raising	476
6	Dolique	437
7	Agriculture	277
8	Volailles/ pourtly	168
9	Lantille/ a kind of beans	96
10	Arachide/ groundnuts	86

Note: Multiple answers. ‘Elevage' includes zébu, caprins and ovins.
Source: Baseline survey (village survey), JICA study team, 2005

Of 1,349 surveyed villages, 1,037 villages (77%) mentioned that cassava is one of the most important livelihood sources for both subsistence and sale. Not only crop cultivation, raising zebus, goats and sheep come the 5th rank of importance. Handicrafts (carpenters, stone masons, etc.) and services (merchants etc.) are not important jobs, which only 37 villages regarded as important.

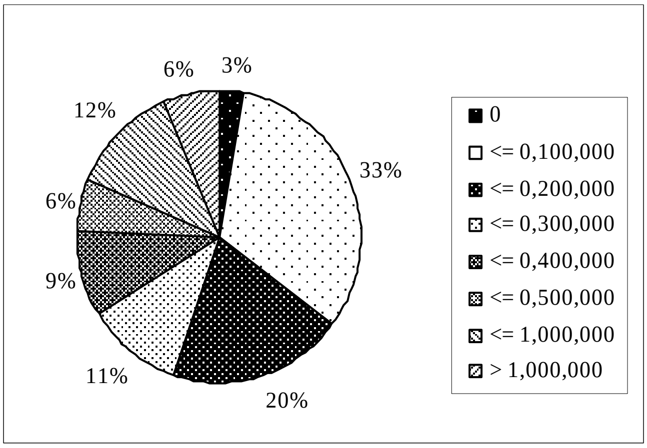


Figure 4.2.1- 1 Annual household income

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. (approximately equivalent to 32,000 Yen). It is only small number of households who gains more than one million Ar a year. To avoid the influence of these rare cases on general tendency, median and mode of the data of household income are applied to obtain more exact data of household economy; as result, median and mode are calculated at 199,440 Ar and 200,000 Ar respectively. This reveals that a household in the study area gains approximately 200,000 Ar 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)" (900 US$ is roughly equivalent to 1,800,000 Ar). Even though households maintain a subsistence economy, the annual income may be greatly insufficient for purchase of the basic needs including water and medicines.

On the other hand, 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%).

Table 4.2.1- 2 Taxes levied by communes in 2004

Levy taxes by commune
1. Taxes
1-1 Direct Taxes: tax on land on the grounds, tax on land on the property built with tax
1-2 Indirect Taxes: taxes on alcohols, levy on casinos, Mining rights and mineral duty; taxes and surtaxes on water and electricity
2. Fee registration of acts
2-1 Civil status: birth, certificates of administrative of life, marriage, recognition, adoption, proof of residence
2-2 Administration: legalization of signature, sale of ground
3. Right and various taxes
3-1 Annual taxes: on motor vehicle, bicycle, cart, television, video apparatuses with lucrative purposes
3-2 Tax on advertisement
3-3 Tax on taking away of sand, stones, ground…
3-4 Tax on slaughtering (of cattle)
3-5 Rebates on local products
3-6 Visitor's tax in the hotel
3-7 Tax on festivals, demonstrations and paying shows
3-8 Tax on traditional ceremonies
3-9 Rights relating to circulation of the Bovidae
4. Right on social events
4-1 Right on conciliation
4-2 Rights on traditional divorce
4-3 Right on traditional rejection
5. Royalties
5-1 Rights on market: stall, sale of Bovidae, caprine, ovine, porcine
5-2 Parking fee: taxi-brousse, taxi.

Source: JICA study team 2005 based on the interview to communes

(2) Economic condition of communes

A commune has her proper budget to function, while fokontany, the lowest administration organ, does not have. Commune's annual revenue consists of her proper funds and subsidies from the government. The proper funds are generally generated by tax. There are a lot of kinds of legal taxes levied by communes as shown in Table 4.2.1- 2, but it depends on the condition of commune whether they adopt each of them or not.

The amount of tax collected by each commune in 2004 varies from 800,000 Ar in Beanantara to 74,679,155 Ar in Ambovombé-Androy. In addition to this, subsidies of the government are important sources of revenue for communes. Generally, 6,000,000 Ar was distributed annually to each commune except Ambovombé-Androy commune. Also, millions of Ar were distributed as supplemental subsidy. Among 11 communes whose data was open, the highest annual revenue in 2004 was 74,679,155 Ar in Ambovombé-Androy (though this commune does not receive the subsidies) and the lowest was 11,756,800 Ar in Beanantara. Table 4.2.1- 3 shows the revenue of each commune in 2004.

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 purposes such as working cost for family register, management of primary schools or basic health centres and reforestation activity. However, it must be noted that no budget was disbursed to manage or develop water supply system for local people in all communes.
No data of expenditure and balance of communes were available at the commune survey, so it is difficult to understand their financial state; however, it can be said that they have little financial capacity to conduct the water supply services under their responsibility.

Table 4.2.1- 3 Revenue of Communes (2004) unit: Ariary

Commune	proper fund	Subsidy	Complementary subsidy	Revenu total 2004
Ambanisarika	N.d.	6 000 000	N.d.	N.d.
Ambazoa	N.d.	6 000 000	Nd	N.d.
Ambohimalaza	8 494 353	6 000 000	1 706 776	16 201 129
Ambonaivo	1 064 000	6 000 000	0	11 958 728
Ambondro	25 972 305	6 000 000	2 680 000	34 652 305
Ambovombé-Androy	74 679 155	0	0	74 679 155
Analamary	N.d.	12 000 000	1 857 800	N.d.
Antanimura	22 651 726	6 000 000	5 788 800	34 440 526
Antaritarika	3 200 280	6 000 000	2 556 600	11 756 800
Beanantara	800 000	6 000 000	3 919 200	10 719 200
Erada	995 000	6 000 000	4 600 000	11 595 000
Maroalomainty	1 600 000	12 000 000	6 926 000	20 526 000
Maroalopoty	17 200 000	6 000 000	4 502 586	27 702 586
Sihanamaro	460 000	6 000 000	N.d.	N.d.
Tsimananada	N.d.	6 000 000	0	N.d.

Source: JICA Study Team 2005 (based on the interview to communes)

4.2.2 Group Activities and Cooperation

Experiences of activities by group and cooperation among residents may be considered as important factors to understand whether they are able to manage the facilities of rural water supply system by their own effort. However, the result of fokontany survey concerning existing groups of residents could not show their positive activity clearly due to the lack of information about concrete results as well as the fact that they started activities recently.

Residents of the study area know the group activities for income generation and improvement of living life, but the diffusion rate is rather low. Residents' groups have been established in about 30% of all 329 surveyed fokontanys; there are 111 groups were identified in 97 fokontanys in the study area. They have not long experience because almost 60 % were established in recent 3 years (2003 to 2005), which indicates that they have only short period of experience.

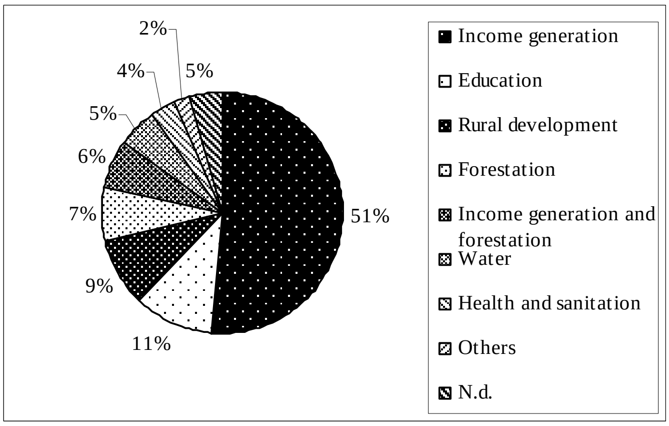


Figure 4.2.2- 1 Residents' groups
N=111
Source: Baseline Survey (village survey), JICA study team

The mission of these groups strongly stressed on income generating activities. More than half of them aimed at income generation through their livelihood activities such as agriculture, fishery or livestock-raising while around 10% of them work for improvement of education condition, especially that of school building. Also, about 5 % of all groups (6 groups) work for improvement of water supply condition: respondents of these groups explained that construction of impluvium was the activity that they had done during a year before the interview. Percentage of missions is shown in Figure 4.2.2- 1.

For achieve 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

The principal water sources used in the study area are: facilities, natural sources and water vendors. Water supply facilities found in the study area are public fountain, borehole, dug well, impluvium, and *bassin.* (water reservoir preserving rain water). They are managed by AES, commune, fokontany, CPE (water point committee) or facility owners. Natural sources mean *vovos* (traditional well, simple hole), rivers, ponds and marshes where no one manages water use from them.

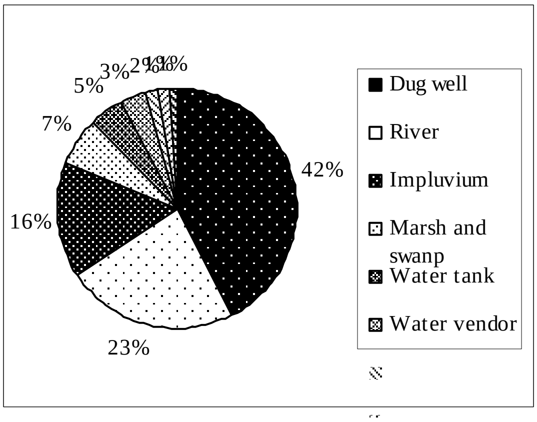
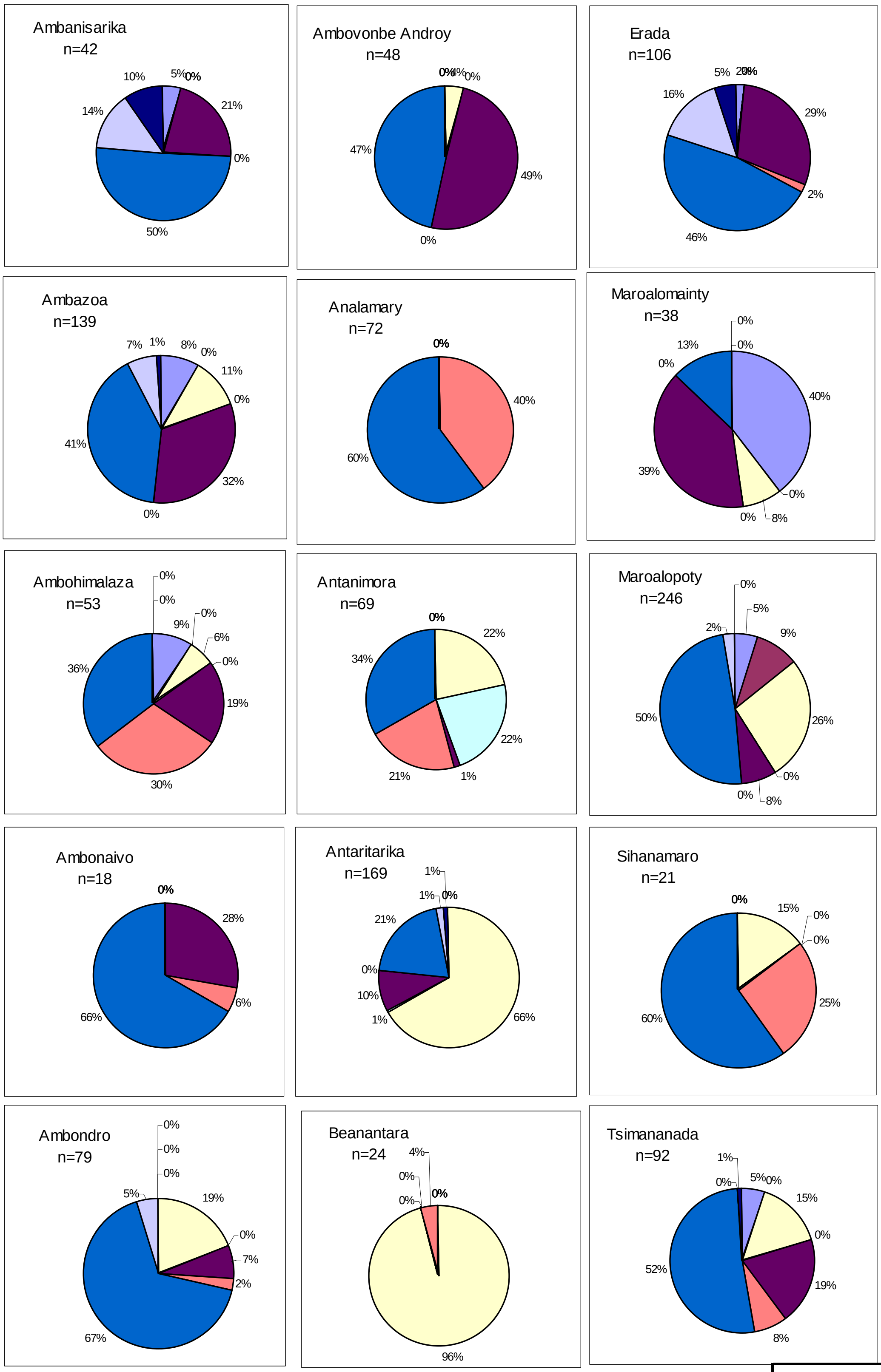


Figure 4.3.1- 1 Source of drinking water
Note: multiple answers *N=1028*
Source: Baseline Survey (village survey), JICA study team 2005

Water provided by water vendors comes from various water sources but vovos and rivers are principal sources that supply water to vendors. Figure 4.3.1- 1 shows the percentage of water sources used in all villages.



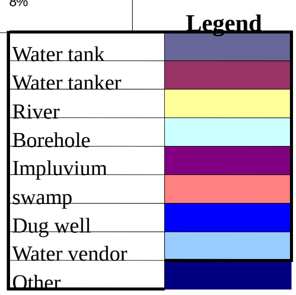


Figure 4.3.1- 2 Distribution of water facilities per commune

Note: multiple answers

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

In about 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.

(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, though well is important in other communes. In villages of the coastal zone (communes of Maroalomainty, Tsimananada, Ambazoa, Erada) and along the Route Nationale 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 4.3.1- 2 shows distribution of principal water sources of the study area based on the interview to villages. 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).

(3) Water Sources for other Purposes

The sources for water for washing are not so different from sources for drinking water, though well water is more utilized: people in more than 48% of all surveyed villages use water of wells. But river water is used for washing as well as for drinking. Water of impluvium is not so much used for washing comparing to drinking.

In more than half of surveyed villages, herd of livestock consisting of cattle, goat and sheep drink water of wells and vovos whose water is sometimes saline. River water comes to the second and water of pond and marsh at the third, while water of impluvium is not used for livestock. In many villages where dug well or impluvium exists, villagers make village rule or *dina* regulating water use, in which livestock is often avoided to use or to approach the water facilities.

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. Number of household classified by daily water consumption volume in both seasons is shown in Figure 4.3.2-1, per capita consumption volume is shown in Figure 4.3.2-2 and related statistical data is shown in Table 4.3.2-1.

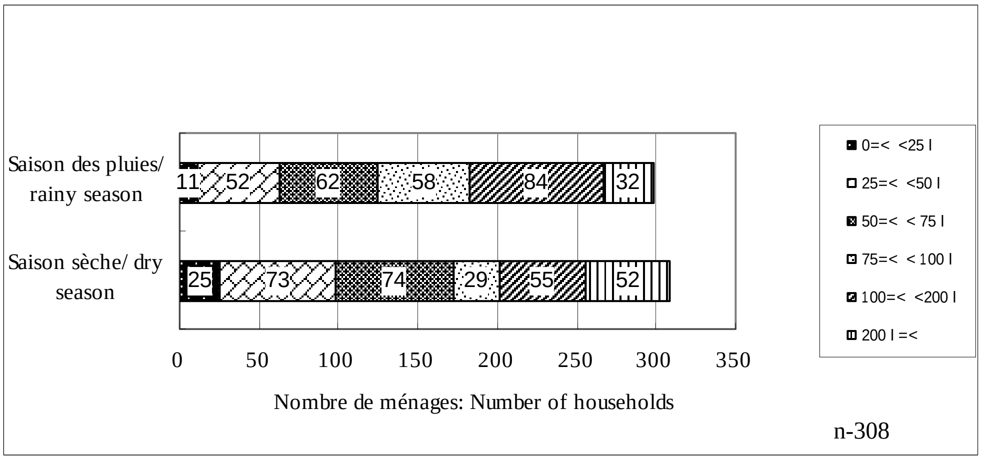


Figure 4.3.2- 1 Daily water consumption volume per household

Note: multiple answers

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

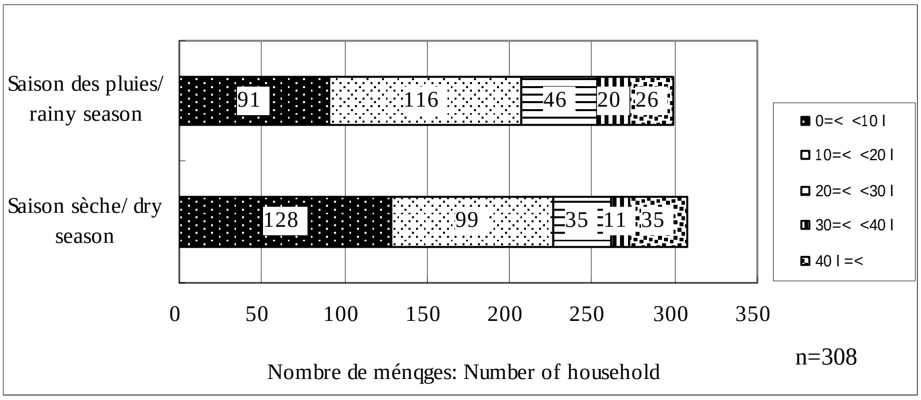


Figure 4.3.2- 2 Per capita daily water consumption volume

Note: multiple answers

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

Table 4.3.2- 1 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

Water charge that a household pays greatly varies according to the principal water sources that the household uses. The result of the household survey indicates that 203 of all 356 interviewed households 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 water charge: median and mode are zero even though average monthly water charge is 7,996 Ar. On the other hand, 26 households pay more than 20,000 Ar every month, but they are extreme cases.

As for the budget for water, extracting from the answer to the question "How much can you afford water at maximum 176 households replied they could not pay any Ar 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, which means some households shift their affordability and/or intention of payment slightly upward. Distribution of water charge paid by interviewed households and budge for water with statistical data are shown Table 4.3.3- 1.

Table 4.3.3- 1 Payment and budget for monthly water charge

Unit: Number of household

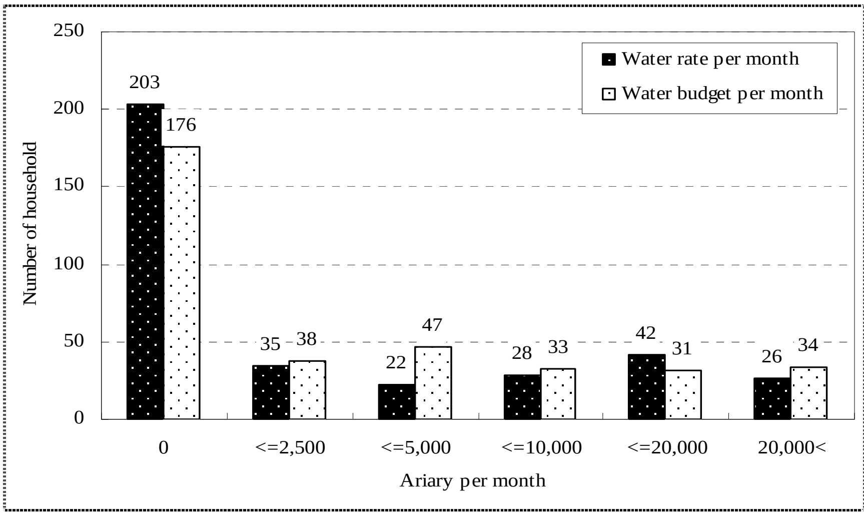
Ariary	Payment		Budget		Statistical data	Payment	Budget
	Number of household	%	Number of household	%			
20,000<	26	7.30%	34	9.50%	Max	180,000 Ar	250,000 Ar
10,000< <=20,000	42	11.80%	31	8.60%	Min	0 Ar	0 Ar
5000< <=10,000	28	7.90%	33	9.20%	Average	7,996 Ar	7,959 Ar
2,500< <=5,000	22	6.20%	47	13.10%	Median	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

Comparison of actual water charge and budget indicate that intention of payment is supposed to strongly depend on the actual water charge. If people draw free water, they must hesitate to pay: and if they are used to pay 100 Ar per bucket, they do not want to pay more but they understand they need to pay for water. 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. It means also that the number of households who mention to pay up to 10,000 Ar per month and more than 20,000 Ar per month is bigger comparing the number of households who actually pay these amounts.

Unit: Number of household



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

Figure 4.3.3- 1 Relation between water charge and budget for water per month

(2) Income and Water Charge

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 (correlation coefficient for the former and -0.027 and -0.030 for the latter). Only between payment and budget, a relatively effective correlation is found: correlation coefficient between them is 0.282. Table 4.3.3- 2, Table 4.3.3- 3 and Table 4.3.3- 4 below indicate these relations by showing the distribution of number of corresponding households.

This result means that income is hardly important factor of payment and budget; but rather, it can be said that budget for water depends on the actual water rate; that is, on the actual water source (facility 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.

Table 4.3.3- 2 Income and monthly water charge

Unit: Number of household

Income (Ar)	Monthly water rate paid (Ar)							Total
	0	0< <=2,500	<=5,000	<=10,000	<=20,000	20,000<	N.d.	
0	5	1	-	3	-	1	-	10
<= 100,000	67	17	10	11	8	3	1	117
<= 150,000	-	-	-	-	-	1	-	1
<= 200,000	29	5	7	9	12	7	1	70
<= 300,000	26	4	1	1	6	1	-	39
<= 400,000	21	1	1	2	6	3	-	34
<= 500,000	14	1	-	-	3	2	1	21
<= 1,000,000	26	2	1	1	6	8	-	44
> 1,000,000	15	4	2	1	1	-	-	23
Total	203	35	22	28	42	26	3	359

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

Table 4.3.3- 3 Income and monthly budget for water

Unit: Number of household

Income (Ar)	Monthly budget for water						Total
	0	<=2,500	<=5,000	<=10,000	<=20,000	20,000<	
0	4	1		4	1		10
<= 100,000	53	16	20	10	5	13	117
<= 150,000	1						1
<= 200,000	27	7	9	9	7	11	70
<= 300,000	25	2	3	1	4	4	39
<= 400,000	18	4	3	4	5		34
<= 500,000	15	1	1	1	2	1	21
<= 1,000,000	19	7	9	4	4	1	44
> 1,000,000	14		2		3	4	23
Total	176	38	47	33	31	34	359

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

Table 4.3.3- 4 Water charge and budget for water

Unit: Number of household

Paid water rate	Monthly budget for water						Total
(Ar)	0	0< <=2,500	<=5,000	<=10,000	<=20,000	20,000<	
0	165	12	15	3	4	4	203
0< <=2,500	5	12	3	2	6	7	35
<=5,000	-	-	10	2	6	4	22
<=10,000	1	3	5	16	2	1	28
<=20,000	-	4	7	8	12	11	42
20,000<	3	6	7	2	1	7	26
N.d.	2	1	-	-	-	-	3
Total	176	38	47	33	31	34	359

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

4.3.4 Classification of Water Sources by Difficulty

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

(1) Unit price

Water charge that a household pay widely varies as mentioned d in 4.3.3 (1), because the unit price also varies greatly. As Figure 4.3.4- 1 shows, out of 1,204 water sources that the residents living in 815 villages use, 37% sources are used free of charge, while the unit price of more than 30% of sources are 100 Ar or over. In the former case, people are supposed to draw water of river and marsh, while in the latter case they buy water from water vendors, water tanker of AES, or from wells.

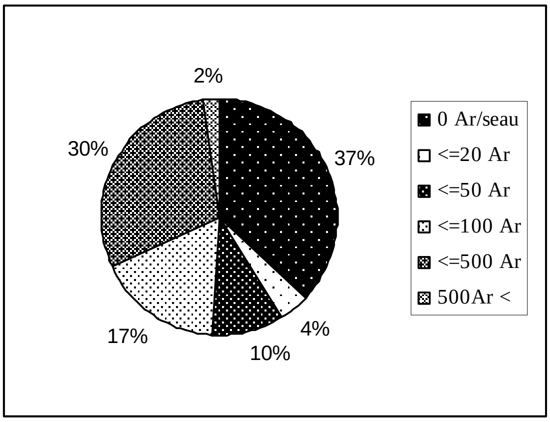


Figure 4.3.4- 1 Unit price of water sources used in the study area ***N=1204***
Source: JICA study team 2006

In terms of unit water price, residents in several communes, especially in the centre of Ambovombé basin, suffer from difficulty in water supply availability. Residents of the communes Ambanisarika, Ambondro, Analamary and Tsimananada, where they live far from rivers and there are scarce marshes, 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 where residents draw water from rivers and mares more than from charged water sources, more than half water sources that they use are free of charge. Figure 4.3.4- 2 shows the distribution of unit

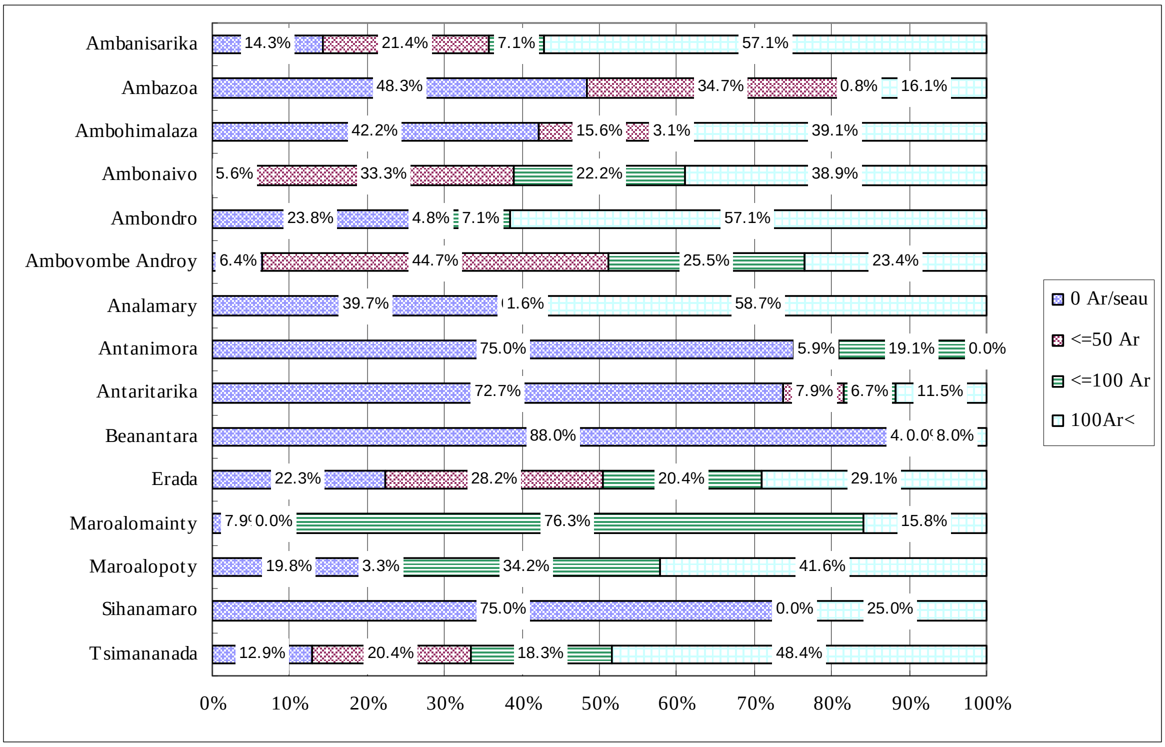


Figure 4.3.4- 2 Unit price of water sources by commune

N=1180 Source: JICA study team 2006

price of water by commune.

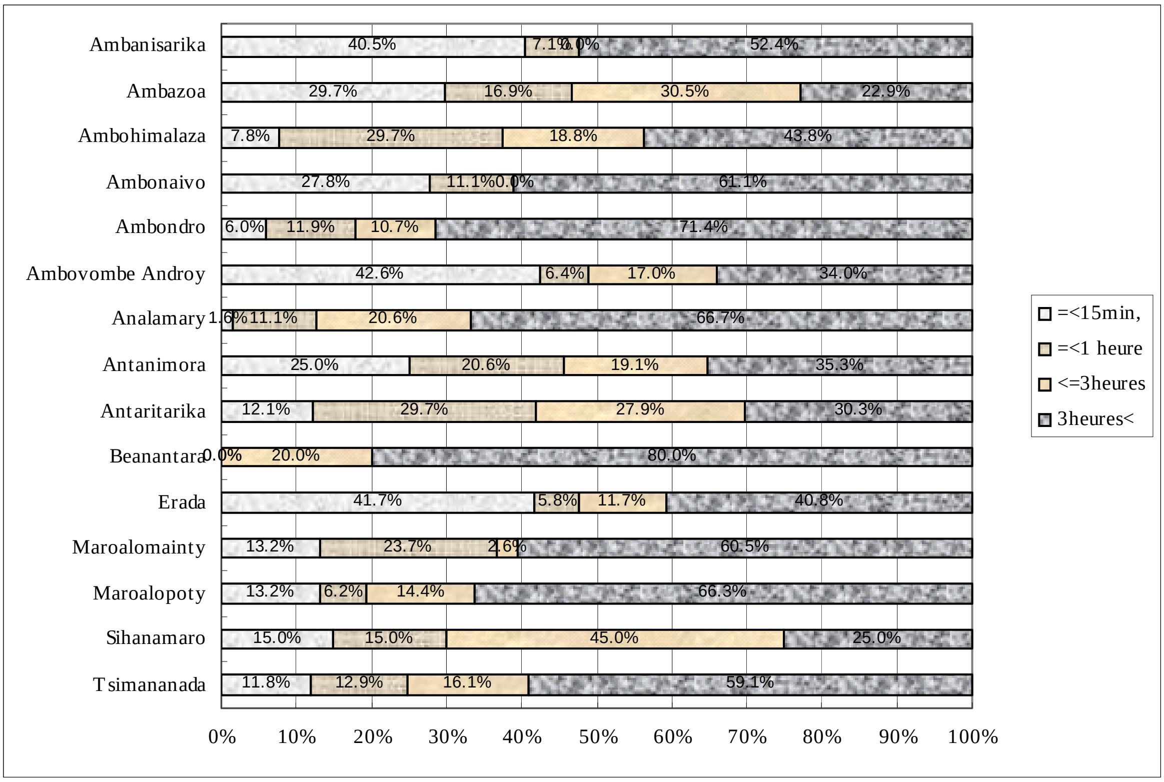


Figure 4.3.4- 3 Distance of water sources by commune

N=1215 Source: JICA study team 2006

(2) Distance

It is not so often that residents can get water in their residential area. Even there exists water sources in the same fokontany, most of them go to the fokontany centre to buy water of impluvium or well. 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- 4 shows, about 29 % of existing water sources, whether they are river or well, locates far from residential area and it is one day work to go there, to draw and go back home, though about 18% of water sources locates within 1km from residential area.

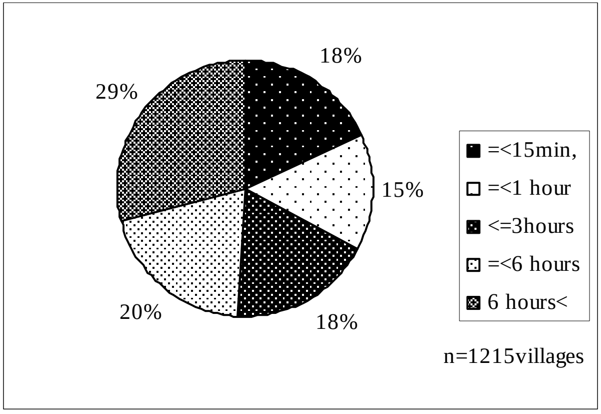


Figure 4.3.4- 4 Distance water sources in the study area ***N=1215***
Source: JICA study team 2006

In terms of distance between residential area and water source, 8 communes of all 15 communes have more difficulty in getting water comparing to other 7 communes. More than half of water sources used in communes Ambanisarika, Ambonaivo, Ambondro, Analamary, Beanantara, Maroalomainty, Maroalopoty and Tsimananada are 3 hours or more from residential areas. Especially Analamary and Beanantara have no water sources that locate within 1 km from residential areas and Ambondro follows them.

People of Ambanisarika utilize different water sources: 40% of water sources used there is at a distance within 1 km from residential area though they also use water source at a distance of more than 3 hours. This condition of distance is as same as in communes Ambovombé Androy and Erada. Figure 4.3.4- 3 shows the distribution of distance of water sources by commune.

(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".

Comparing with other water sources, water of wells is considered as worse than other source including water of marshes. It is supposed this evaluation is based on salinity contained in water of wells rather than contamination. On the contrary, all people who responded to the interview said waters of boreholes and water tanker of AES is good.

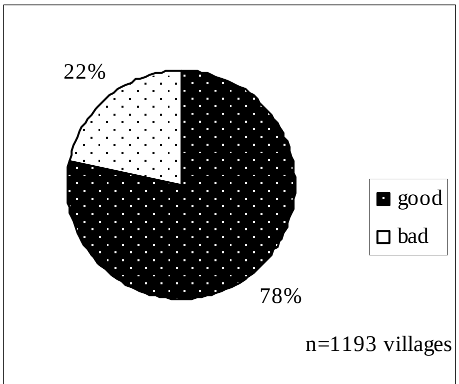


Figure 4.3.4- 5 Water quality in the study area ***N=1193***
Source: JICA study team 2006

If considering the commune that respondent belong to, all communes except Ambazoa and Tsimananada have a good opinion of the water. In these two communes, almost half of water sources are judged "bad", but the reason of their negative opinion has not been revealed. Figure 4.3.4- 6 shows the quality of water sources by types of water source and Figure 4.3.4-7 shows the quality of water sources by commune.

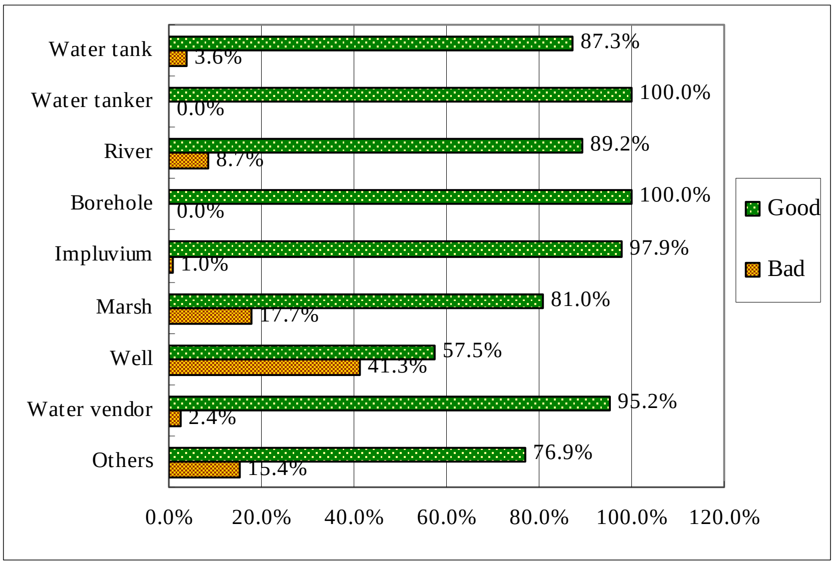


Figure 4.3.4-6 Water quality of each source used in the study area

N=1193

Source: JICA study team 2006

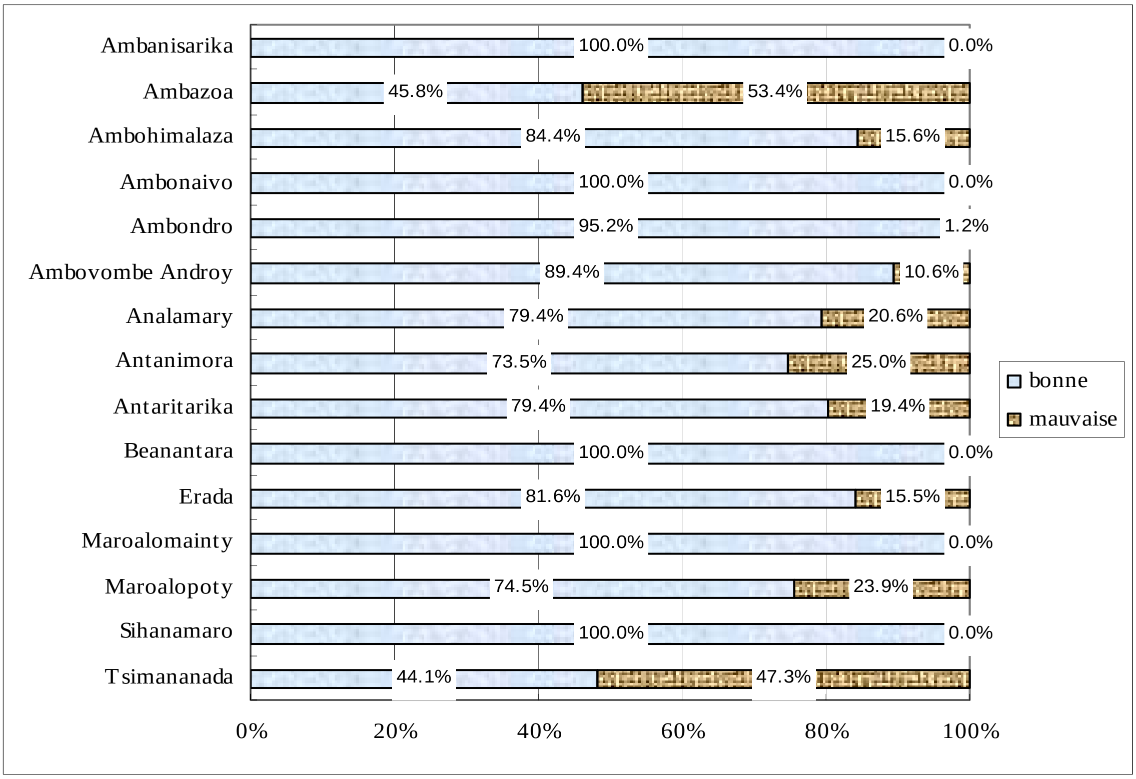


Figure 4.3.4- 7 Water quality by commune

N=1193

Source: JICA study team 2006

(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 applied here because it 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 set 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- 1 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.

Table 4.3.4- 1 Classification of water sources by distance and unit price

Distance	Prix unitaire				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

The percentage of the most difficult water sources is over 50% in the communes on coastal dunes and inland dunes; such as, Ambanisarika, Ambonaivo, Ambondro, Analamary, Maroalomainty, Maroalopoty, and Tsimananada. 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 Figure 4.3.4- on the next page.

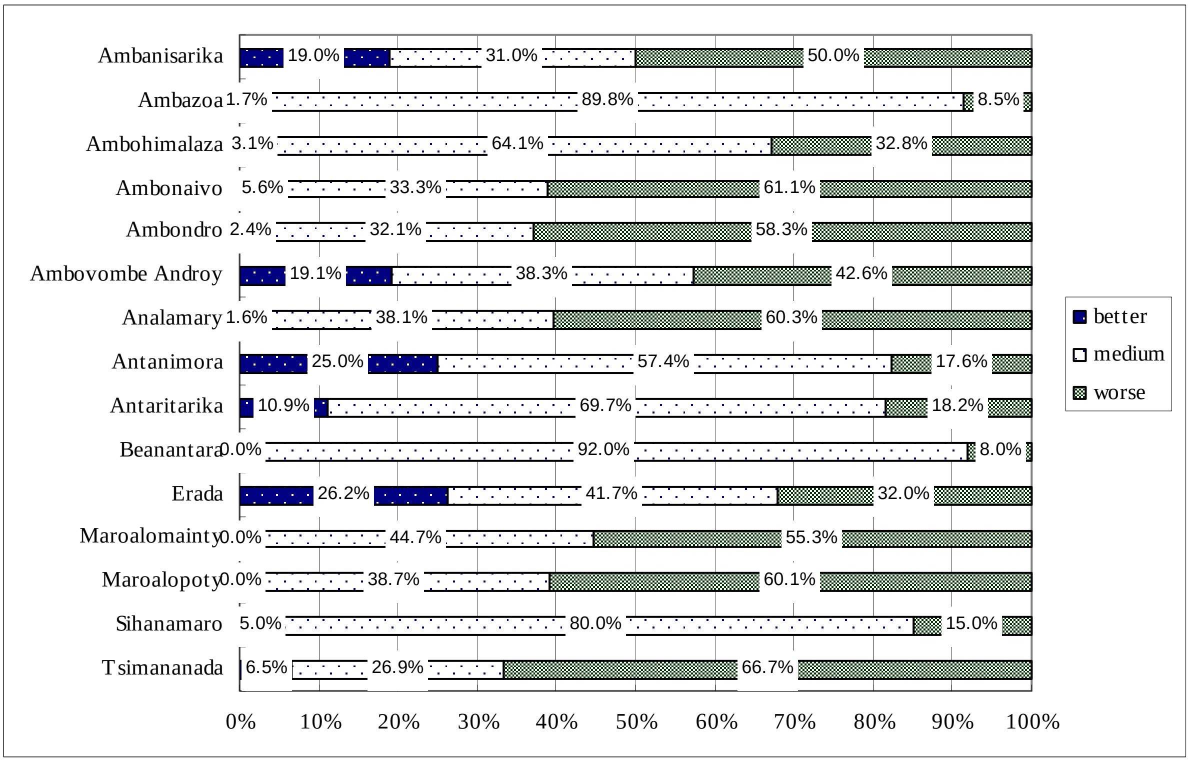


Figure 4.3.4- 8 Classification water sources by commune

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.

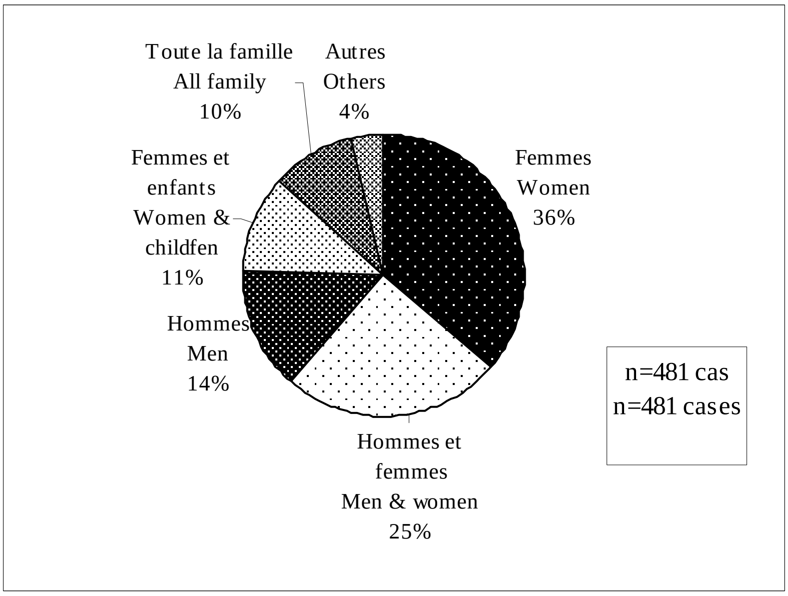


Figure 4.3.5-1 Personne s'occupant de puisage de l'eau
Person in charge of drawing water

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 4.3.5-1).
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 (Refer to Figure 4.3.5-2).

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.

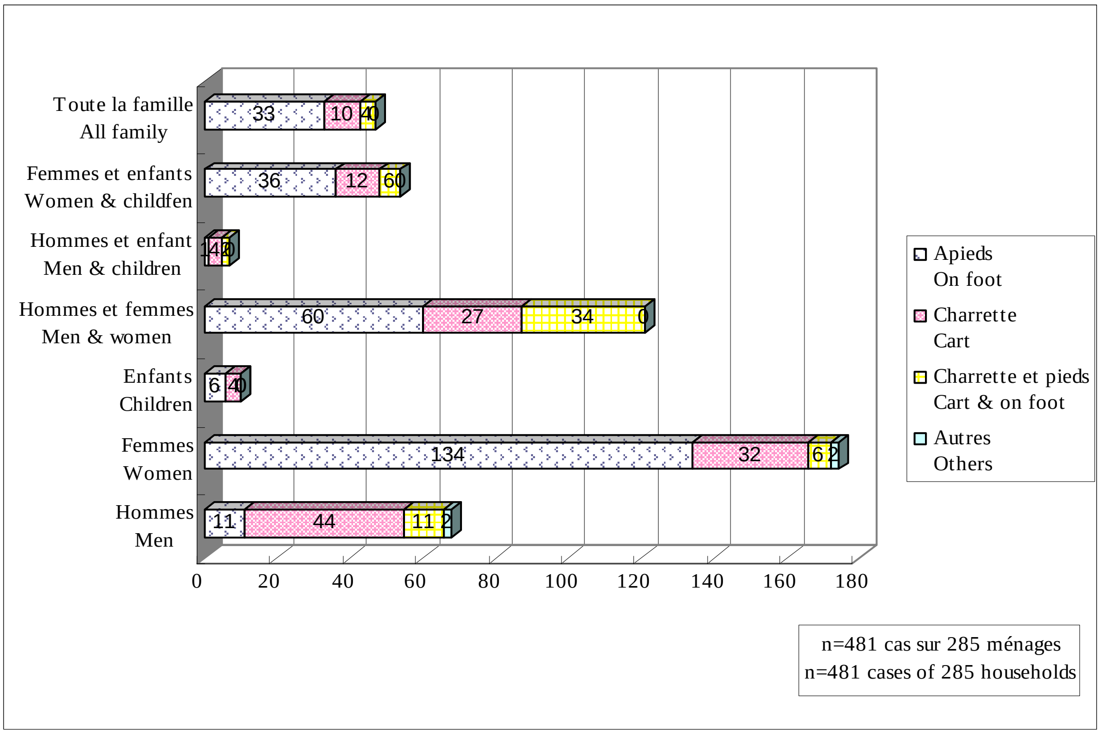


Figure 4.3.5-2 Mode de transport de l’eau / Means of transportation of water

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 Rain

(1) Basic Objective of Survey

- Degree of water quality degradation in the rain rainwater collection 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 rainwater collection system

(2) Result, Observation

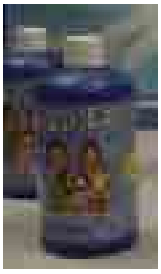
		
Sur Eau refer to 2) in below	Impluvium, refer to 4) in below	Barrel, refer to 5) in below

Figure 4.4.1-1 Photo concerning rain water use

1) water quality degradation

Water in the rainwater collection system is completed to use within 2 month after starting use. Village people think water keeps its quality in the rain water collection system. Team member also used the stored water about 2month, he didn’t notice any odder nor circumstances as degradation.

The users generally clean inside of tank before and after rain season to remove source of pollution.

2) chemical additives

“SurEau” is commonly sold as chemical additives in Madagascar. This exist at pharmacy and even small shop in the Study area. However, users is limited at urban Ambovombe. People in the village doesn’t utilize although they know it. Rural heath center is conducting programs to introduce it to pregnant woman, but, it is not complied with them. Water supply and economic condition is not fit to spread.

3) Utilization of the Proceeds

Water is charged and sales is kept, but village people didn’t respond clearly amount of money with them. They generally expend the proceeds on the payment to school teacher, school construction, and water during drought, but don’t mean for repair.

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. Origin of them is Dubai or South Africa, etc. Second hand is sold at 50,000Ar in the study area.

6) Capacity of repairing tank

Village people had several experiences of repairing tank using resources in the commune. Those method is plastering cement into cracks. But, A lot of tank which once had cracks, had leakage again within a few years, so that, People prefer to construct new one than repair, then the cracked tank is generally abandoned Short span doesn't cause of only quality of work, but also of structure of tank. This is technically difficult.

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 pass by. If tank is filled up, limitation of usage is halt, then water is consumed until water decrease half of tank in general.

		
Refer to 8) Troll roof	Refer to 8) grass roof	Refer to 8) Gutter

Figure 4.4.1-2 Photo concerning rain water use

8) State of private water collection 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 rainwater collection system. People show eagerness to construct it by themselves if they can have water container barrel, but lower ratio of the equipped house indicate difficulty of their own action.

Burglar on barrel sometimes happen even in village, so that, transportable tank is not suitable for a public facility.

(3) Other Matters

		
Crack, refer to 1) in below	Reception, refer to 1) in below	Cylindrical tank, refer to 2) in below

Figure 4.4.1-3 Photo concerning rain water use

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 break through crack of concrete and damage completely.

2) Other design of Impluvium

OS recognized necessity of frequent repaire 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

The result of test well shows absence of utilizable water resources near major consumer area. Water must be transmitted with significant distance to establish water supply system. However, it is not apparently feasible to construct a transmission system at over area. From that reason traditional private water selling system need to be evaluated.

(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

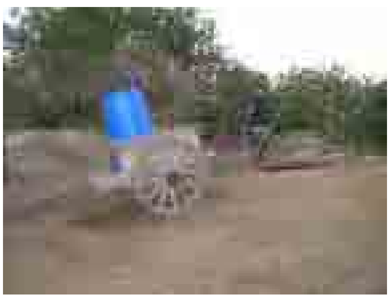
		
Zebu cartt from village, refer to 1)	Owner of vovo refer to 3)	free water source, refer to 3)

Figure 4.4.2-1 Photo concerning water venders

1) Systemization of water venders of zebu cart

It is not easy to systemize zebu carts 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 person, they will have advantage to increase amount of water, stabilization of charge.
- 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 10-20 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 inflate more than 300Ar/bucket. That charge seems to be divergence as business. But, though decrease of water charge is one of the objective, 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 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

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CHAPTER 5 EXISTING INSTITUTION AND ORGANIZATION FOR WATER SUPPLY

5.1 Organization of AES and JIRAMA in the South Region

5.1.1 Organization of AES

The headquarters of AES is in the capital city of Antananarivo, and the General Director and the eighteen (18) staffs are assigned in the office. AES also has a regional office in Ambovombe city serving the South Region with water supply as a center of the service area. To the regional office, a Technical Director and 114 staff in 2006, decreased from 120 in 2005, are assigned for operation and maintenance of the water services.
In the area of Beloha-Tsihombe pipeline water supply system, which was constructed under the water supply project with the official assistance of Japan in 1995 to 1997, there is an area office in Beloha city, and a liaison office in Tsihombe city. In the system, service staffs are arranged at each water supply station to sell the water from the reservoir along the pipeline. Additionally, the water is provided to the remote villages using water tank trucks operated by Beloha office and Tsihombe office. However, the drinking water is not sufficiently provided to the villages due to the shortage of water tank trucks and expensive water charge of AES. One bucket with 13liters of water costs 100Ar, which is equivalent to 6,600Ar/m^3 and 16.5 times of JIRAMA's rate of 400Ar/m^3 in 2005.

Based on the studies of the Consultants of World Bank and the AES himself, the proposal for the improvement of the AES was discussed many times together with the MEM and concerned agencies from September 2005. The important symposium sponsored by MEM for the viability of drinking water supply in the South was held on the 24th and 25th March, 2006 in Ambovombe city to discuss the multiple solutions. It is possible to improve the present situations of AES technically and financially, however, for effective improvement, investment, technical improvement and managerial innovation of the existing system are indispensable. Currently, income of AES mainly from selling water is not sufficient due to technical and managerial difficulty. It is only 36,000 m^3/year (about 100 m^3/day) in 2005.

(1) Situation of AES

The AES has acted as a main agency for the water supply project cooperated with Japan and other donors in the South Region of Madagascar more than 25 years. Main water supply facilities belong to AES as follows:
1) Ambovombe water tank truck system
2) Pipeline system of 140km in Beloha to Tsihombe city
3) Groundwater supply in communes with solar pumping system namely 5 AEP Centers and groundwater development with handpump facilities assisted by World Bank and UNICEF

The main water supply facilities belonging to AES are operated insufficiently due to decrease in number of the water tank trucks and increase of diesel cost for operation. The number of water tank truck is only 2 tankers in Ambovombe office and 1 tanker in Beloha existing pipeline system. The two water tank trucks are run to supply water to the surrounding area of Ambovombe. However, Amboasary water treatment plant which is one of water sources for Ambovombe area has a larger capacity of water treatment than the current operation, and the another water source, groundwater in Ambovombe city, is only 38m^3/day.

Beloha existing pipeline is hardly working from February 2006 due to the high cost of diesel. The most of staffs of AES are in the suspension of the work at this part.

(2) AES Activities in 2005

Activities of Technical Management and Maintenance of AES in 2005 are summarized as follows:
1) Repair of the pumps of AEP center of Amboasary and Antanimora of Isoanala
2) Repair and maintenance of three power generating units namely Sampeza of Manombo, Ambalanosy and Beloha.
3) Repair of electric facilities of AEP Center of Amboasary and pumping station of Mahavelo.
4) Cleansing of the Bases of the AES.
5) Follow-up of the completion of the work of the mini Amboasary-Sampona Pipeline
6) Execution of 350 drillings of wells in Ihosy
7) Detection of all the anomalies on network along the Pipeline Beloha-Tsihombe
8) Other miscellaneous works

Problems involving in the technical matter in AES:
1) Lack of mechanics and electricians
2) Lack of equipment and materials
3) Incompetence of the electric maintenance
4) Breakdown of the treatment plant of Amboasary
5) Lack of the water tank truck system
6) Lack of the vehicles for maintenance work
7) Lack of truck for heavy weight transportation.
8) Engine oil deficit
9) Lack of repair parts for generator

(3) Organization of AES

AES has the Headquarter with sections of finance and audits under the General Director in the capital of Antananarivo, and 18 staffs are assigned in the office in 2005/2006.

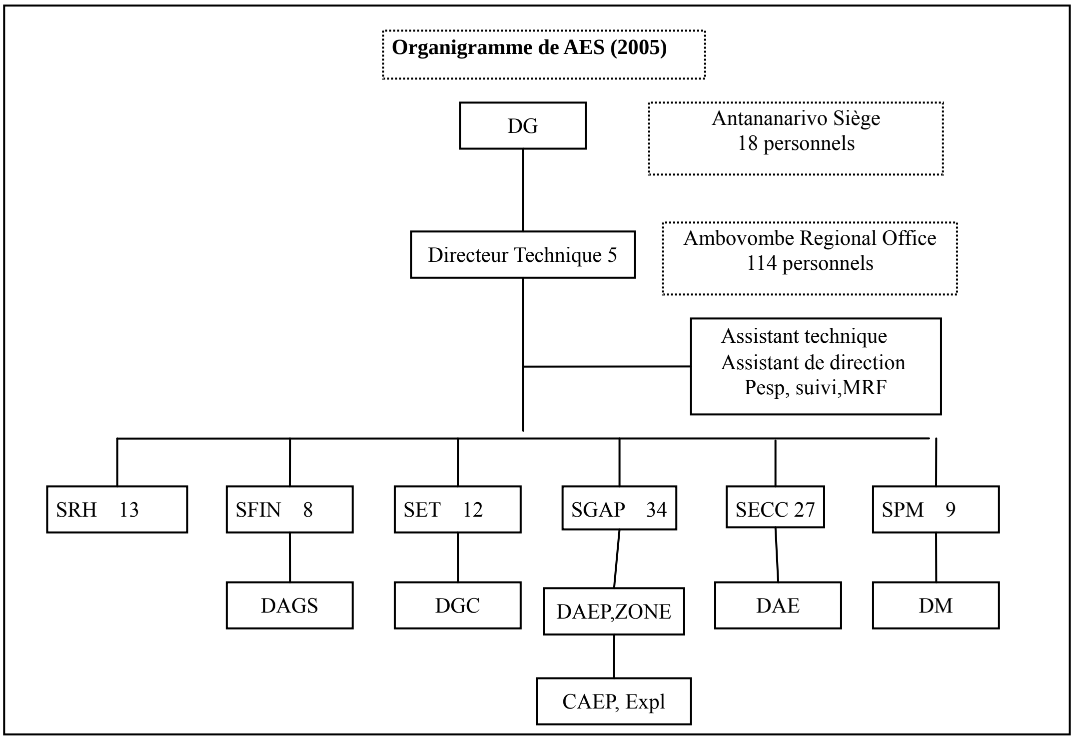
AES has Regional Office in Ambovombe in south region in the water supply area of AES, and a Technical Director manages the office with the operation/maintenance staffs of 114 in 2006 including 12 female staff. (Regional office: 114 staffs)

Under the Regional Office, AES has an area office in Beloha City, and a liaison office in Tsihombe City in the water supply area of the Beloha - Tsihombe Pipeline System that was established by the water supply project completed with Japan in 1999. Additionally, service staffs are arranged at the water supply stations of service water reservoirs along the pipeline system.

(4) Composition of staff in Ambovombe Regional Office

At the end of year 2005, the 114 staffs which are composed of 12 female and 102 male, including 9 senior executive and 105 agents which were left assignment as follows:
- Technical staff:
- Several hydrogeologists,
- 2 mechanics and 2 assistant mechanics

The breakdown of the staff composition of AES is shown as below.



Notes, terminology in the chart

Abbre.	Number	Name of section	Abbre.	Name of division
DT	05	Director Technique Technical director		
SRH	13	Service des ressources humaines Human resource section		
SFIN	8	Service financier Controller	DAGS	Division approvisionnement et gestion des stocks Inventory division
SET	12	Service études et travaux Planning section	DGC	Division génie civil Civil division
SGAP	34	Service gestion des centres AEP et pipe-line Water supply and pipeline section	DAEP CAEP	Division adduction d'eau potable Centre adduction eau potable Pipe water supply division//
SECC	27	Service exploitation des camions citernes Water tank truck section	DAE	Division approvisionnement ea eau Water supply division
SPM	09	Service par cet matériels Purchasing section	DM	Division mécanique Mechnic division
SSE	06			
			Resp,suivi,MRF	Responsable suivi matériels roulants et fixes Store house keeper
TOTAL	114			

Figure 5.1.1 - 1 AES Organization Chart (2005)

(5) Financial Aspect of AES

Most of the current expenditure of AES is composed of operation cost for water tank trucks in the Ambovombe system, and the pipeline operation cost for Tsihombe and Beloha water supply system as shown Table 5.1.1-1 and Table 5.1.1-2. The total expenditure is about 251,329,333 Ar in 2004. On the other hand, water charge income is 106,682,323 Ar in 2004, and the current deficit is 144,647,010 Ar in 2004.

The AES relied on about 320 million Ar of subsidy from national budget which is about 63% of AES yearly current expenditure in 2000 and 2001. Recent total current expenditure of AEA is shown in Table 5.1.1-1. The current deficit in 2005 is still high of 24.1% but has little improved after the subsidy termination. Table 5.1.1-2 indicates that the AEP center type of water supply management makes its balance of operation.

Table 5.1.1 -1 Financial status of AES from 1999-2005 (in Ar)

Year	Water charge	Operation Cost	Balance (1999-2004)	Subsidy from the State
1999	107,601,955	372,327,788	236,535,100	(63.5%)Subsidy
2000	190,421,539	495,501,068	312,719,400	(63.1%)Subsidy
2001	184,558,000	496,677,400	312,119,400	(62.8%)Subsidy
2004	**106,682,323**	**251,329,333**	**-144,647,010**	**- (57.6%)**
2005	**57,212,675**	**58,626,171**	**-1,413,495**	**- (24.1%)**

Data: AES, Annual Activities Report, February 2006

Table 5.1.1 -2 Financial status of AES Year 2004-2005

Supply system	Year	Initial balance	Expenditure	Income	Balance	
Ambovombe System	2004		**122,522,200**	**39,325,070**	**-83,197,130**	**(Ar)**
			48.75%	36.86%	57.52%	
	2005	5,976,128	272,051,595	277,874,582	153,141	(Ar)
5AEP Centres	2004		**39,365,889**	**39,906,952**	**541,064**	**(Ar)**
			15.66%	37.41%	-0.37%	
	2005	445,789	445,789	891,578	1,783,156	(Ar)
Pipeline System	2004		**89,441,244**	**27,450,301**	**-61,990,943**	**(Ar)**
			35.59%	25.73%	42.86%	
	2005	1,194,598	13,565,993	14,364,696	395,895	(Ar)
Total	2004		**251,329,333**	**106,682,323**	**-144,647,010**	**(Ar)**
			100%	100%	100%	
	2005	**7,616,515**	**286,063,377**	**293,130,856**	**2,332,192**	**(Ar)**

Production unit cost of Ambovombe and existing Pipeline System in 2005 is estimated in Table 5.1.1-3 as follows:

Table 5.1.1 -3 Production unit cost of Ambovombe and existing Pipeline System in 2005

Items	Water Supply Amount	Expense (Ar)	Income (Ar)	Supply Unit Cost (Ar/bucket)	Remarks
	A	B	C	B/A	
AES Total	**36,116 (98.9m^3/day)**	**293,130,856**	**286,063,377**	**105**	Including Subsidence (about 1/2 of total expense)
Brake down	Water Supply Amount	Production Expense	Water Charge	Production Unit Cost	Excluding personnel cost
Ambovombe System	7,266 (19.9m^3/day)	34,974,200	-	63	Including 6,612m^3/year : delivered by Water Truck
Tsihombe-Beloha Pipeline System	2,465 (6.8m^3/day)	37,116,021	14,061,738	196	
Sub Total	9,731 (26.7m^3/day)	72,090,221	-	96	
*Above two Systems at supply center				*(100)	
Other 5 AEP/AES	26,385 (72.3m^3/day)	63,300,592	54,489,605	32	

Table 5.1.1-4 Financial status of the water tank truck delivery (2005)

	Total	Break down		
Water production	9,876 m^3 (including water loss)	5,103 m^3 at Amboasary	4,773 m^3 at Mahavelo	
Water sale	7,266 m^3	6,612m^3 by tank truck	606m^3 sale in Mahavelo	48m^3 in Amboasary
Number of trip	1,102 trip	651 v Mandrare	451 trip Mahavelo	
The cost of delivery	34,974,200 Ar		4,406 Ar/ trip	570 Ar AEP Beloha
Total Income	25,459,400 Ar			
Fuel (Diesel) litters	19 084 litters	15,338 litters Expense of the AES	3,746 litters Charge to customers.	
The total cost	26,049,314 Ar	3,747,500 Ar for lubricants		
Acquirement of fifty two (52) new tires, eleven (11) new battery				

Table 5.1.1-5 Financial Aspect of the Pipeline System (2005)

Items	Total	Break down	
Water production	7,053m^3 (Pumped)	5,103 m^3 (Production) Amboasary	4,773 m^3 (Production) Mahavelo
Water sale	A - 2,465.26m^3	681.85m^3 by tuck	547.64m^3 AEP Beloha
Operation Hour	2 126.78h		
Total cost	**B- 14,061.73** Ar	4,406 570Ar by tuck	3,324 186Ar
Gas oil consumption	7 122.82 litters	41.00litres Engine Oil	
*Production unit cost (Estimated)	74Ar/bucket (A/B)	1bucket=10-15litters, in Average 13litters	

Table 5.1.1-6 Composition ratio of water sales at each Supply area, and Delivery unit cost by Water Tank Truck (2005)

Supply place/method	Trucks	AEP Beloha	Service Station	Reservoir	house connection
Water sale (%)	31.34 (%)	23.64 (%)	28.18 (%)	12.54 (%)	4.31 (%)
Tanker delivered					
Volume	A		681.85	m^3	
Trip			113.48	trip	
Distance			4 204	km	
Diesel consummation	B		4 864	Litter (C- 2 130Ar/l)	
*Gas oil unit cost of Tanker for Delivery (Estimated)	(B*C/A)		198Ar/buket	1bucket=10-15litter, in Average :13litter	

Due to the increasing the fuel cost, proper water charge should be the 50 Ar /the bucket of 13 liters and 3,350 Ar / m^3.

5.1.2 Situation of JIRAMA in Amboasary and Ambovombe

JIRAMA provides electricity and water supply services to the regional town of Amboasary and only power supply to Ambovombe, independently. Although electric power supply to Amboasary is currently in deficit due to high fuel costs, the water supply services using groundwater source near the Mandrare River is well managed.

Both tariffs of water and electricity are set by JIRAMA headquarter in Antananarivo, and generally national rates for water and electricity are applied. The water and electricity bill is issued based on the meter reading of the previous month. There is 8 days grace period for non-payment. If the user does not pay within 8 days, the line will be closed within a week.

(1) Situation in Amboasary

Groundwater is the source of water supply. The depth of borehole is 14.5m and water quality is in good condition. The water charge is set simply in two steps as the first 10 m^3/month is 195 Ar and more than 10 m^3/month is 440.6 Ar/month. JIRAMA installed eighteen (18) public faucets but nine (9) faucets were stopped service due to installation of house connections. The remaining nine (9) faucets were contracted operation to the private water venders who sell the water of 10 litters by 20 Ar to make money and public water services in the town.

Table 5.1.2 -1 Financial Condition of JIRAMA in Amboasary (2004) (in Ar)

Year		Revenue	Expense	Balance
2004	Water	16,130,400	1,600,000	130,400
	Electricity	79,075,600	126,897,200	-47,821,600

Table 5.1.2 -2 Outline of JIRAMA in Amboasary in 2005

JIRAMA in Amboassary (Water Supply and Electricity)		
1. Water supply:	Private connection	193
2. Water supply amount:	Production:	83,897 m^3/year (230 m^3/day)
	Accounted for water	57,732 m^3/year (68.8%)
	Water Loss	13%
3.Water quality:	EC: 104 mS/m, pH: 7.99, Turbidity 0.54, Cl: 156 mg/l ,	
4.Water charge (Average : 309.2 Ar/m^3)		
0-10m^3/month	195 Ar (constant)	
10 + m^3/month	440.6 Ar (constant)	
5. Electricity		
0-20 kWh/month	115 Ar (constant)	
20 + kWh/month	395 Ar (constant)	

The number of staff of JIRAMA in Amboasary is only 12. Organization chart of JIRAMA in Amboasary (2005) is shown as follows.

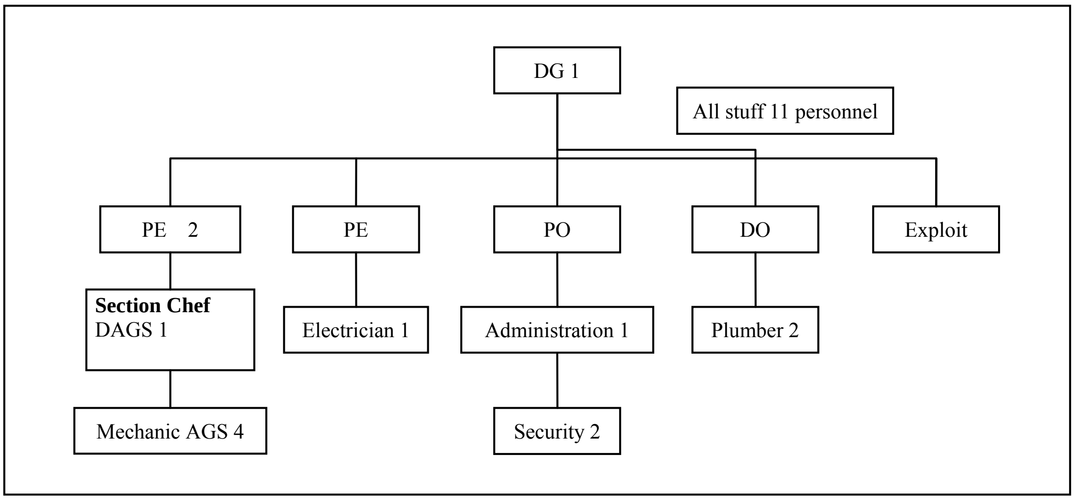


Figure 5.1.2 -1 Organization chart of JIRAMA in Amboasary (2005)

(2) Situation in Ambovombe

The JIRAMA in Ambovombe was established recently in 1999. The duty is only for electric power supply in the urban. However, because of the cost inflation of fuel and purchase of new generator, the financial status is not stable as shown below.

Table 5.1.2-3 Financial Condition of JIRAMA in Ambovombe (in Ar)

Year		Revenue	Expense	Balance	Remarks
2004 (monthly average)	Electricity	6,600,000	10,000,000	-4,000,000	-
2005 (March)	Electricity	7,037,000	16,991,000	-	Purchase: New Generator

Running the electric supply is making heavy loss, but still keeping 24 hours supply. The AES replaced the diesel pumping system to JIRAMA electric base as 38 m^3/day in 2005. This reduced operation cost.

5.2 Commune, Fokontany, and CPE

(1) Actual Water Supply Systems

Table 5.2-1 represents the actual water supply systems by commune in rainy and dry seasons.

Water tanks and shallow wells are also usable on certain conditions. AES water tank trucks distribute water to three communes. There are a lot of people who depend on natural water points such as ponds, ‘rano vato’ (water on rocks), puddles, rivers and so on.

In the dry season, all the 15 communes in the study area depend heavily on the AES water tank truck system. However, local people, especially in remote villages far from Central Ambovombe, are obliged to seek for other means to get enough water, due to the fact that the water quantity distributed by the tank trucks is totally insufficient to meet their demand. They reluctantly buy expensive water carried from far away from their dwellings. Some of them go all the way to rivers or wells for muddy or saline water. Only one commune, Sihanamaro, has a totally different policy for the use of their impluvium: They don’t use the water stocked in the impluvium during the rainy season and save it for the dry season.

Water shortage is an acute problem throughout the whole study area. Especially, people in the suburb hamlets are confronted with more serious situation than in the Ambovombe urban or Ambondro. Particularly, the situation in the dry season is so miserable, indeed: They are forced to take pains to pay no less than 500 to 1,000 Ar for a bucket of water or drag their weary feet toward water points far away from their home.

Table 5.2-1 Actual Water Supply Systems in the Study Area (1/2)

Rainy Season－Saison des pluies

( ) : Rate for a bu

Commune	Water Wagon	Zebu Carriage	Impluvium (Pub.)	Impluvium (Private)	Public Tank	Tank with Gutter (Pub.)	Tank with Gutter (Private)	Deep Well	Shallow Well	Pond	Rano Vato (water on rock dents)	River
Ambanisarika	-	-	10 (100Ar)	-	-	-	(200 - 400Ar)	-	-	○	-	-
Ambazoa	-	-	5 (50Ar)	-	-	-	○	-	-	-	○	-
Ambohimalaza	-	-	8 (50Ar)	○	-	○	○	-	-	○ Artificial Sarimonto*Name of a pond	-	-
Ambonaivo	-	-	15 (50Ar)	-	Under construction	-	(250Ar)	-	-	For animals ○	○	-
Ambondro	-	-	2 out of 7 available (50Ar)	-	Solar (50Ar)	-	○	-	○	○	-	-
Ambovombe	Central town, poured into tanks (100Ar)	from wells nearby (100Ar)	23 out of 28 available, Periphery (50Ar)	-	Wagon (100Ar) Solar (20Ar)	(100Ar)	(100Ar)	○	○	○	○	-
Analamary	-	-	3 (50Ar)	-	-	-	(200 - 300Ar)	-	-	○	-	-
Antanimora	-	-	-	-	-	-	-	○ (AES Public faucet: 40Ar) (UNICEF Pump: 1400Ar/household/year)	-	-	-	-
Antaritarika	(100Ar)	-	9 (300Ar)	-	-	○ (Free)	○	-	-	-	○	-
Beanantara	-	-	2 out of three available (20Ar)	-	-	-	○	-	-	-	○	The Mandrare in case of necessity
Erada	-	-	6 (100Ar)	○	-	-	○	-	-	-	-	-
Maroalomainty	(100Ar)	-	10 (50 - 100Ar)	-	-	-	(200 - 500Ar)	-	-	-	-	-
Maroalopoty	(100Ar)	-	8 (50Ar)	-	-	-	(200Ar)	-	-	Artificial ○	-	-
Sihanamaro	-	-	-	-	-	-	-	-	○	○	○	-
Tsimananada	-	-	3 (50Ar)	-	-	-	(200Ar)	-	-	Natural Aritificial- (50Ar)	-	-

Table 5.2-1 Actual Water Supply Systems in the Study Area (2/2)

Dry Season－Saison sèche

( ) : Rate for a bu

Commune	Water Wagon	Zebu Carriage	Impluvium (Pub.)	Impluvium (Private)	Public Tank	Tank with Gutter (Pub.)	Tank with Gutter (Private)	Deep Well	Shallow Well	Pond	Rano Vato (water on rock dents)	River
Ambanisarika	(100Ar) Insufficient	(From Ambovombe－500Ar) (From Ambondro－500Ar)	-	-	-	-	-	-	-	-	-	-
Ambazoa	(100Ar) Insufficient	-	-	-	-	-	-	-	Saline water near the sea	-	-	The Manambovo (600Ar)
Ambohimalaza	(100Ar) Insufficient	From Ambovomve, Ambondro (600Ar)	1 out of 10 filled by AES (100Ar)	-	-	-	-	-	-	-	-	-
Ambonaivo	(100Ar, when fuel lacks 200 - 500Ar) Insufficient	Some of carriage owners are vendors. (500 - 500Ar)	-	-	-	-	-	-	-	-	-	-
Ambondro	15 Fokontany out of 23	(600 - 800Ar)	-	-	Solar (50Ar) Insufficient	-	(150 -200Ar)	-	600-800Ar (private)	-	-	-
Ambovombe	Central town, poured into tanks (100Ar)	(3000Ar/drum: Central Town) (6000Ar/drum: Periphery)	Rarely buy from AES (100Ar)	-	Wagon (100Ar) Solar (20Ar)	(300Ar)	Central town (150Ar) Periphery (300Ar)	○	○	-	-	-
Analamary	(100Ar) Insufficient	(From Ambovombeから－500Ar)	-	-	-	-	-	-	-	-	-	-
Antanimora	-	-	-	-	-	-	-	○ (AES Public faucet: 40Ar) (UNICEF Pump: 1400Ar/household/year)	-	-	-	-
Antaritarika	(100Ar)	○	-	-	-	-	-	-	-	-	-	The Manambovo (2,500 fmg)
Beanantara	(100Ar) Insufficient	From the Mandrare (600Ar)	-	-	-	-	-	-	-	-	-	The Mandrare
Erada	(100Ar) Insufficient	(300Ar)	-	-	-	-	○	-	-	-	-	-
Maroalomainty	(100Ar) Insufficient	(500Ar)	-	-	-	-	-	-	Saline water near the sea	-	-	-
Maroalopoty	(100Ar) Insufficient	(300Ar)	-	-	-	-	-	-	-	-	-	-
Sihanamaro	In case of insufficiency (50 out of 150Ar saved as communal profit)	From Ambondro (800Ar)	5 (20 - 50Ar, End of dry season, 200Ar)	-	-	-	-	-	○	-	-	The Manambovo (Not for sale)
Tsimananada	(100Ar) Insufficient	From Ambovombe (300Ar)	-	-	-	-	-	-	-	-	-	-

(2) Operation and Management of Water Supply

The actual O/M (Operation and Management) of water supply infrastructures by the authorities of commune or fokontany is described as follows.

(a) Impluvium

14 communes out of 15 have their own impluvia, which are wildly used by the public mainly during the rainy season. Table 5.2-2 shows the three ways of O/M for impluvium (except the Commune of Antanimora). In the rainy season, the most common way of getting water is public “impluvium”, which is widely used by local people in all the communes. Private rainwater collection system.

Table 5.2-2 Different O/M systems for implivium by commune

No.	Commune	Commission (Commune)	Commission (Fokontany)	CPE
1	Ambanisarika	X	-	-
2	Ambazoa	X	-	-
3	Ambohimalaza	-	X	-
4	Ambonaivo	-	-	X
5	Ambondro	-	-	X
6	Ambovombe-Androy	-	X	-
7	Analamary	-	X	-
8	Antanimora *Forage équipé	-	-	X
9	Antaritarika	-	-	-
10	Beanantara	-	X	-
11	Erada	X	-	-
12	Maroalomainty	X	X	X
13	Maroalopoty	-	-	X
14	Sihanamaro	-	X	-
15	Tsimananada	-	X	-
	Total	4	7	5

Generally, public impluvium in a commune are managed by one of the three organizations in the above table. Only in Maroalomainty management system is different from one impluvium to another.

Usually, impluvium water is not free of charge. The rate of a bucket of water (13 liters) is from 50 to 100 Ar in the rainy season, and from 100 to 500 Ar in the dry season. Water rates are different from one commune to another.

The way of using impluvia is not unique. At one in Ambovome, the beneficiaries make it a rule to open the cover of impluvia only four fixed days of the week and limit the maximum quantity per day for one family to 5 bucketfuls.

Long time has passed since the construction of these impluvia. Certain impluvia have quite a few cracks on the concrete, then it can’t store efficiently. From the viewpoint of sanitation, it is a problem that animal excrement is sometimes scattered on the impluvia. In most cases, the local authorities are not competent enough to cope with these problems on their own. Even then one project named “Objectif Sud”, financed by EU (European Union) and French Cooperation is now ongoing in the area. A number of impluvium have been rehabilitated or newly constructed as a component of the project.

Further information about the O/M of each commune is shown in Table 5.2-3 in the next page.

Table 5.2-3 The Status Quo of Operation and Maintenance in the Project Area

* Described mainly on "Impluvium"

Commune	CPU (By beneficiaries)	Commission (By commune)	Commission (By Fokontany)	Operation and Maintenance System	Improvement in beneficiaries' attitude
Ambanisarika	–	○	–	O/M by Commune. Commission consists of a guard and a vendor, paid 10% of proceeds. Communal proceeds from water can be used for other purposes in addition to water supply infrastractures.	**Recently, nothing.**
Ambazoa	–	○	–	O/M by Commune. Proceeds shared between commune and fokontany. Commission consists of a guard and a vendor, now under capacity building. 3% of proceeds paid to them.	Pr/Commune --> Pr/FKT--> Beneficiaries. A session concerning drinkable water was conducted in Nov. 2004 in cooperation with medical experts. Inervention: "Objectif Sud"
Ambohimalaza	–	○	–	O/M by Commune. One member responsible for both of account and sale. Use of communal proceeds from water is limited to water supply infrastractures. One household can use no more than 3 bucketfuls for 2 days.	Pr/Commune visits all the FKT to encourage people to try to collect more water using a tin roof (5 times since 2002). Inervention: "Objectif Sud"
Ambonaivo	○	–	–	Every impluvium has a CPE (proposed by the actual communal president in Nov. 2003). Only vender is paid (10% of proceeds). Proceeds used for rehabilitation, etc. Communal president proposes to deposit CPE procees at post office.	Pr/Commune --> Pr/FKT--> Beneficiaries. Efforts have been made to improve beneficaries' attitude (2 sessions concerning drinlable water, 2005), but not efficient. Intervention: "Objectif Sud"
Ambondro	○	–	–	In central area, solar pump-up system, O/M by CPE. In periphery, impluvia, at 2 of which rehabilitation completed and under establishment of CPE ("Objectif Sud").Proceeds are deposited at post office in Ambovombe.	Pr/Commune --> Pr/FKT--> Beneficiaries. Capacity building of CPE ongoing by intervention of "Objectif Sud".
Ambovombe	–	–	○	O/M by Fokontany (President of FKT, Treasury, Vendor). 10 % of the prpceeds paid to Treasury & Vendor. Commune responsible for monitoring & audit. Communal proceeds from water can be used for other purposes in addition to water supply infrastractures.	Commune does not consider this kind of efforts important. It is not effective, because there is no water. Intervention : "Objectif Sud".
Analamary	–	–	○	O/M by Fokontany. Treasury and vendor designated by beneficiaries are not paid except special occasions (maximum 5% of proceeds). Proceeds used for Fokontany activities.	Pr/Commune called for all the Pr/FKT in 2004 to hold a sesseion concerning sanitation & drinkable water. Intervention: "Objectif Sud"
Antanimora	○	–	–	O/M of each deep well with pump is done by CPE. Beneficiaries rely on 3 technical staffers for daily repairing and financial management. A committee exists as supreme coordination corps.	Beneficiaries have been indulged in too much low annual contribution which is not enough for desirable O/M. But very difficult to change the people's attutude, for the ground water is abundant.
Antaritarika	–	–	–	AES water point in the dommunal center dwelled by a guard's family. Commune has an intention to establish CPE provided that the deep well actually out of use be rehabilitated.	A volunteer group composed of Tsiombe ordinary people has been trying to establish CPE since 1999. This program is financed by EU.
Beanantara	–	○	–	O/M by Commune, through a commission designated for each impluvium. 10 % of the prpceeds paid to Treasury & Vendor. Use of communal proceeds from water is limited to water supply infrastractures.	Communal president called for all the FKT presidents and conducted a traning on water sanitation hand in hand with Service de Santé de District on Jan. 22, 2005. Intervention : "Objectif Sud". Communal president considers afforestation important.
Erada	–	○	–	O/M by Commune. Proceeds are important resourse of income for commune. Commune has no intention to establish CPE.	Commune conducted a session concerning drinkabke water in March 2005. Inervention: "Objectif Sud"
Maroalomainty	○	○	○	O/M by CPE: 3, Fokontany: 6, Commune: 1. As for 3 impluvia with CPE comstructed in 2004, Commune is well informed about O/M. Commission members are not paid. Proceeds are kept in cash.	Commune conducted a session concerning clean water & sustainability for 3 comit és hand in hand with "Objectif Sud" in Nov. - Dec. 2004.
Maroalopoty	○	–	–	O/M by CPE. Members are not paid. Proceeds are kept in cash. CPE proceeds from water can be used for other purposes in addition to water supply infrastractures.	**Nothing special so far. Intervention: "Objectif Sud"**
Sihanamaro	–	–	○	O/M by Fokontany. Commission members selected in Fokonolona meeting (No salary). Proceeds kept in cash by treasury. Communal proceeds from water can be used for other purposes in addition to water supply infrastractures.	Pr/Commune --> Pr/FKT--> Beneficiaries. Pr/Commune calls for Pr/FKT 3 times a month to encourage them to collect more water. 9.800.000 fmg collected from beneficiaries by efforts of Pr/Commune. Highly evaluated by "Objectif Sud".
Tsimananada	–	–	○	O/M by Fokontany. Proceed used for solution of verious problems. Communal president wants to establish CPE.	Pr/Commune conducted 2 sessions (April, 2004) concerning establishment of CPE, making a speech directly to beneficiaries. No reaction so far, though.

(b) Public Water Tank

There is a CPE (Water Point Committee) covering 1,500 household in the center of the commune of Ambondro for distribution of water pumped by solar system. The committee consists of a president, a vice-president, a treasury, a secretary, an auditor, four advisers, two guards, and water vendors. Only guards and water vendors are paid for their daily tasks.

The rate was 10 Ar for a bucketful of water in 2000. Since then it has been going up gradually. The rate is 50 Ar as for April, 2005.

All the facilities including solar panels are in good operation so far. According to the president of the committee, the actual water rate is quite enough for daily O/M, but, not enough to save for repairing or parts exchange.

In the rainy season, there is abundant water in the well. In the dry season, however, it is quite difficult to pump up enough water due to the decrease of water quantity. Therefore, people are compelled to buy water from private shallow wells at ridiculous rate (600 – 800 Ar).

(c) Borehole Equipped with a Hand Pump

It is good to know some information about the O/M system of the boreholes quipped with a hand pump in the commune of Antanimora adjacent to the study area.

In Antanimora, 150 boreholes were drilled and equipped with a hand pump named “India Mark II’, using the funds provided by UNICEF in the middle of 1990s.

At the beginning, a French NGO was responsible for monitoring of the project. Then, in May 2000, the local beneficiaries’ O/M organization, AAEPA (Association d’Alimentation en Eau Potable d’Antandroy) was created to take over the task. The organization chart is shown in Figure 5.2.1.

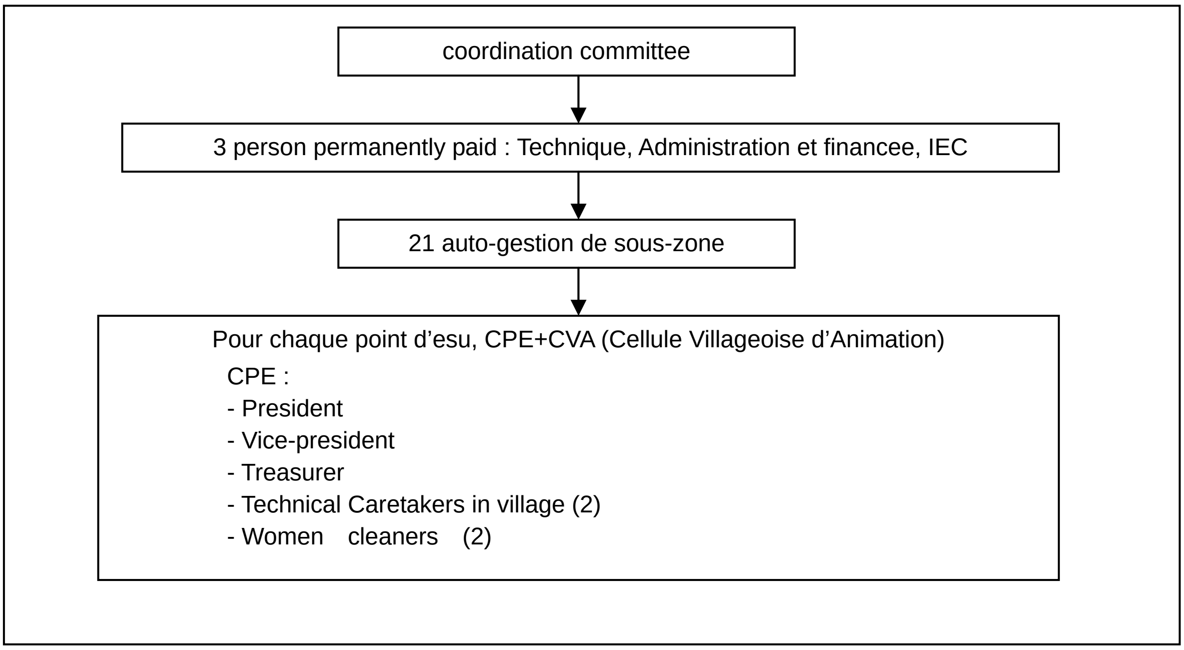


Figure 5.2.1: Organization Chart of the AAEPA

The coordination committee (Comité de coordination) occupies top of organization. This committee consists of a president, a vice-president, a treasury, and an advisor and controls the whole organization. The next lower branch is a three-person-group responsible for technical, administrative, and financial aspects such as well repairing and paper work on daily basis. Then, the O/M committee composed of the representatives from the 21 sub-zones comes. Under a sub-zone, each water point has its own CPE （Comité de Point d ’ Eau）and CVA （Comité Villageoise d ’ Animation） that are in charge of daily

O/M in the covering area. A CPE consists of a president, a vice-president, a treasury, two guard and two sanitation keepers.

According to one of the three staffers for technical, administrative, and financial aspects, the biggest problem which this O/M group is actually confronted with is a shortage of funds. The only income source is the payment from the beneficiaries. As the annual payment born by a household is only 1,400 Ar, the total annual income for the AAEPA is no more than 21 million fmg. For example, the fuel fee of a motorcycle to go to a village located 40 km away from the center of Antanimora is around 15,000 Ar. In the light of the salary for the three staffers depending on the AAEPA's income, it is clear that this financial problem is quite serious.

(3) Improvement in Beneficiaries Attitude

Little effort has been made up to now for the improvement in beneficiaries' attitude concerning the best use of limited drinkable water resource. The biggest reason for this might be absolute insufficiency of water and difficulties to cope with this grave problem. That is, due to a lack of incentives for the beneficiaries, it hasn't been meaningful to try to improve the people's attitude. In spite of that, the situation is getting better as the local people, stipulated by foreign projects like "Objectif Sud", begin to have clear objectives to ameliorate their life conditions. Foreign donors play a significant role in improving the rural people's mentality. Obviously, the leadership and the competence of a communal representative is also very important when it comes to a topic like this.

Though the local authorities have been making some efforts to improve the people's knowledge about drinkable water, collection of rain water, sanitation, establishment of a CPE, and the like, the objective was quite fragmentary or unclear. Recently, however, some foreign cooperative activities have brought mature training programs such as capacity building of local authorities' staff, and improvement in local people's qualification to deal with their own problems.

Recent communal challenges to improve beneficiaries' attitude are summarized in Table 5.2-3. The president of the commune of Sihanamaro succeeded in collecting funds from the beneficiaries that amount to 1.96 million Ar for the construction of a new impluvium. This is a good example: A communal representative gave full play to his ability to find a way out of the difficulties. It might be interesting and useful to keep paying attention to his future performance.

Table 5.2.4 Recent communal challenges to improve beneficiaries' attitude

Method	Details	Nub. of commune
Commune → Fokontany → Beneficiaries (Partially, directly Commune → Beneficiaries) They hold a meeting.	Drinkable water, Collection of rain water, Sanitation, Establishment of a CPE	11
No activities	-	4
Total	-	15

****