MININFRA
EASTERN PROVINCE

REPUBLIC OF RWANDA

THE STUDY ON IMPROVEMENT OF RURAL WATER SUPPLY IN THE EASTERN PROVINCE IN THE REPUBLIC OF RWANDA

FINAL REPORT

SUPPORTING REPORT

November 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

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

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S1. ORGANIZATION FOR STUDY EXECUTION AND WORK SCHEDULE

S1.1 Overall Organization

For execution of this study, a steering committee chaired by MININFRA and Eastern Province, with MINIRENA and the target 7 districts was formed. Reports were presented to the steering committee and agreements were received. Also, information was shared with MINALOC, MINISANTE, MINEDUC and donors, but they are not members of the steering committee.

S1.2 Composition of Study Team

(1) Japanese Side Study Team Composition

The study team is composed of the following members.

Table S1-1 Study Team Member List

Function	Name	Affiliation
Team Leader/Water Supply Plan	Shoji FUJII	Japan Techno
Deputy Team Leader/Hydrogeology/ Water Resources Development Plan	Naoki TAIRA	Japan Techno
Geophysical Prospecting (1st Fiscal Year)	Tetsuo TSURUSHIMA	Japan Techno
Hydrology, Meteorological Analysis/ Water Quality (2nd FY: Geophysical Prospecting)	Chifumi YAMASHITA	Japan Techno
Socio-Economic Survey	Yoko KITAUCHI	Nippon Koei
Facilities Design/Cost Estimation	Jun YOSHIKAWA	Japan Techno
Operation and Maintenance Plan	Toshiaki HOSODA	Nippon Koei
Sanitation Promotion	Chieko YOSHIKAWA	Japan Techno
Environmental-Social Consideration	Rika IDEI	Nippon Koei

(2) Rwandan Side Counterpart Composition

From the counterpart organizations and related agencies, the following counterpart personnel were allocated for this study. The allocated counterparts received technology transfer through working together with the study team on such activities as collection/analyses of required information, assisting in site surveys, participating in seminars, and assisting in formulation of plans.

Table S1-2 Study Counterparts

Affiliation	Name of Counterpart	Position
MININFRA	Mr. NYIRIGIRA Benoit	Water and Sanitation Engineer (PNEAR)
MINIRENA	Mr. MUKIZA Odillo	Water and Sanitation Engineer
Eastern Province	Mr. MAKOMBE Jean-Marie Vianney	Coordinator of District Development Programmes
Nyagatare District	Mr. MUTARAMBIRWA Philip	Coordinator of Economic Development (Former Director of Infrastructure, Urban Planning and Environment Unit)
	Mr. RUTAGWENDA Sam	In Charge of Infrastructure
	Ms. NSHIMUABAREZI Alice	In Charge of Environment
Gatsibo District	Mr. MWISENEZA Jonas	In Charge of Infrastructure (Former Acting Director of Infrastructure and Environmental Technology Unit)
	Mr. KIMENYI Dickson	(Former Director of Infrastructure and Environmental Technology Unit)
	Mr. KINYANA Herbert	(Former In Charge of Infrastructure)
Kayonza District	Mr. NDAYISHIMIYE Nicoles	(Former Acting Director of Infrastructure Unit)
	Mr. RUTAREMARA Claude	In Charge of Environment
Rwamagana District	Mr. NGABONEZA Deodatus	In Charge of Infrastructure
	Mr. KIMPAYE Innocent	(Former Director of Infrastructure Unit)
	Mr. RWAKAYIGAMBA Emmanuel	In Charge of Environment
Ngoma District	Mr. NTIRENGANYA Boniface	Coordinator of Economic Development (Former Director of Planning, Economic Development, Promotion of Employment, Infrastructures, Protection of Environment and Forestry Unit)
	Ir. TUYISABE Augustin	In Charge of Infrastructure
	Mr. NTABANA Narcisse	In Charge of Environment
Kirehe District	Mr. SEBUNDANDI Alphonse	(Former Director of Land, Urbanization, Habitat and Infrastructure Unit)
	Mr. GAKUNZI Emmanuel	In Charge of Infrastructure
	Mr. NSENGIYUMVA Pacifique	In Charge of Environment
Bugesera District	Mr. GASASIRA J. Claude	Coordinator of Economic Development
	Mr. NZEYIMANA Phocus	In Charge of Infrastructure
	Mr. KASIRE Cassien	(Former Director of Land, Urbanization, Habitat and Infrastructure Unit)
	Mr. NSENGIMANA Theophile	(Former In Charge of Infrastructure)
	Ms. UWACU Sylvie	In Charge of Environment

S1.3 Work Schedule

The work schedule for the study is as follows.

Table S1-3 Work Schedule

Year	2008			2009												2010										
Phase	Phase 1						Phase 2																			
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
【Phase I: Formulation of Water Supply Plan】																										
A. Analysis of existing information and preparation of questionnaire	□																									
B. Preparation of Inception Report (IC/R)	□																									
C. Explanation of and discussions on IC/R		■																								
D. Collection and analysis of existing information																										
(1) Socio-economic conditions		■	■																							
(2) Natural conditions		■																								
(3) Development plan, other related plans, plans of other donors		■																								
(4) Legal aspects of water resources development, water supply and sanitation			■																							
(5) Organizational and institutional aspects of rural water supply		■	■																							
(6) Existing database related to water supply		■	■																							
(7) Availability of latest aerial/satellite photos of former MINITERE		■	■																							
E. Survey on present water supply conditions																										
(1) Existing water supply systems (conditions of facilities, water quality, state of operation and maintenance, water fees)		■	■	■																						
(2) Survey on situtation of residents (water use, present state of imidugudu)		■	■	■	■																					
(3) Present state and promotion strategy of rural electrification		■	■																							
(4) Environmental-social consideration		■	■																							
F. Water demand projection			■																							
G. Water resources survey																										
(1) Collection, compilation and analysis of hydrogeological/ meteorological/hydrological information			■	■	■	■																				
(2) Groundwater survey (analysis of aerial photos/satellite images, ground reconnaisance, geoelectrical prospecting)			■	■	■	■																				
(3) Surface water survey (spring flow measurements, river flow data analysis, analysis of lake water level statistics, irrigation survey)			■	■	■	■																				
(4) Water Quality Survey			■	■	■	■																				
(5) Preparation of aerial/satellite photo interpretation map			■		■	■																				
(6) Preparation of simplified hydrogeological map					■	■																				
(7) Water balance analysis					■	■																				
(8) Water potential evaluation						■																				
H. Preparation and submission of Progress Report (P/R)						■																				
I. Formulation of water supply plan																										
(1) Water resources development plan								■	■	■																
(2) Plan for water supply facilities improvement and rehabilitation									■	■																
(3) Recommendation on operation and maintenance plan									■	■																
(4) Recommendation on organizational and institutational plan								■	■	■																
(5) Cost Estimation									■	■																
(6) Support to initial environmental examination (IEE)								■	■																	
(7) Project evaluation (economical, financial, organizational/ institutional, technical, social, environmental)									■	■																
(8) Recommendation on sanitation promotion activities plan									■	■																
(9) Selection of priority project									■	■																
J. Preparation of Interim Report (IT/R)									■	■																
【Phase II: Initial Design for Priority Project】																										
K. Preliminary design for priority projects																										
(1) Collection of supplementary information										■	■	■														
(2) Second geological prospecting										■	■	■														
(3) Preliminary design of facilities												■	■													
(4) Formulation of construction plan												■	■													
(5) Formulation of operation, maintenance and management plan												■	■													
(6) Preliminary cost estimation												■	■													
(7) Formulation of sanitation promotion activities plan											■	■														
(8) Execution of environmental-social consideration (IEE level or EIA level)												■														
(9) Project evaluation (economical, financial, organizational/ institutional, technical, social, environmental)												■	■													
(10) Formulation of project implementation plan (target year: 2015)												■	■													
L. Preparation and submission of Draft Final Report (DF/R)													□	□	□	□	□	□	□	□	□	□	□	□		
M. Explanation of DF/R and holding seminar														■										■		
N. Preparation and sending Final Report (F/R)																								□	□	□
Submission of Reports		▲ IC/R				▲ P/R				▲ IT/R				▲ DF/R1										▲ DF/R2		△ F/R
Seminar and Steering Committee Meeting		●				●				●				●												

IC/R: Inception Report, P/R: Progress Report, IT/R: Interim Report, DF/R: Draft Final Report, F/R: Final Report

□ Work in Japan

■ Work in Rwanda

S2. Rwanda's Policy and Strategy for Water and Sanitation Sector

S2.1 National Development Plans

National development plans for Rwanda include Vision 2020 and MDG (Millennium Development Goals), as well as EDPRS (Economic Development and Poverty Reduction Strategy) as a continuation to PRSP (Poverty Reduction Strategy Papers). Also, the Water and Sanitation Sector Policy is the national development plan for the water and sanitation sector. These development plans are explained below.

Table S2-1 Rwanda's National Development Plans related to Water and Sanitation

Development Plan	Objectives for Water and Sanitation Sector	Commitment to Achieve Objective
Vision 2020	By the year 2020, Rwanda should be a country in which : 1) the entire population will have access to potable water; 2) rainwater harvesting and retention methods will be mastered for both domestic and farm uses; 3) natural water reservoirs, notably high forests, will be reconstituted and managed with caution; 4) water resources will be managed in a rational and integrated manner, and in harmony with the national land use master plans; 5) the population will be able to manage water in an equitable and sustainable manner; 6) infrastructure for water production, protection, distribution and sanitation will be protected and maintained by all.	Rate of access to safe water needs to increase by 2.5% per year
Millennium Development Goals (MDG)	The objectives for the water and sanitation sector are : 1) reduce the population margin that has no sustainable access to drinking water by 2015; 2) develop water resources management frameworks; 3) increase the production benefits by water in irrigation systems for food security, suppression of the pressure on environment, promotion of the possibility to use water in other productive sectors; 4) safeguard human lives by ensuring acceptable drinking water quality; 5) mobilize the financing of national resources investment needs in the water sector; 6) reinforce the institutions and techniques of the country in order to implement integrated water resources management policies; 7) protect the surface water quality and groundwater as well as the aquatic ecosystems and coastal regions.	Rwanda committed itself to reduce by half the percentage of the population without sustainable access to drinking water supply and sanitation by 2015
Economic Development and Poverty Reduction Strategy (EDPRS) 2008 ～2012	During the EDPRS period, the water and sanitation sector aims to : 1) increase the proportion of the population accessing safe water from 64% to 86%, and the proportion with sanitation services from 38% to 65%; 2) increase the proportion of the rural population living within 500m of an improved water source from 64% to 85%, and to raise the proportion of the urban population residing within 200m of an improved water source from 69% to 100%; 3) the number of boreholes with handpumps which will be constructed or rehabilitated will rise from 120 to 350; 4) the proportion of schools with latrines complying with health norms will rise from 10% to 80%, and that the corresponding proportion for rural households will increase from 38% to 65%.	The sector share of public spending must rise from 5.4% to 7%
National Policy and Strategy for Water Supply and Sanitation Services, February 2010	The general objective is to ensure sustainable and affordable access to safe water supply, sanitation and waste management services for all Rwandans, as a contribution to poverty reduction, public health, economic development and environmental protection.. Specific objectives are: 1) to raise rural water supply coverage; 2) to ensure sustainable management structures for rural water schemes; 3) to ensure sound urban water supply services; 4) to raise sanitation coverage; 5) to promote improved public sanitation; 6) to develop appropriate sewerage in urban areas; 7) to enhance storm water management; 8) to implement integrated solid waste management; 9) to develop sector's institutional and capacity strengthening framework.	A harmonized approach to implementation of rural water and sanitation projects; emphasis on sanitation and health; promotion of grouped settlement in rural area; strengthening of monitoring and evaluation system; and a systematic capacity development are needed.

Source : Rwanda Water and Sanitation Expenditure Review Report 2007 (May 2008)
National Policy and Strategy for Water and Sanitation Services, (February 2010)

S2.2 Decentralization

(1) Decentralization Policy

In Rwanda, the cause for occurrence of the genocide from 1991 to 1994 can be blamed on such attributions as excessive centralization, extreme top-down policy, government indifferent to voters, weak grassroots level governance and unequal allocation of wealth between nationals. Therefore, strong promotion of decentralization and democracy are important for Rwanda's reconstruction, and aiming for good governance lead by MINALOC, decentralization activities are being executed through community-driven development with support from internal and external sources as the national strategy to cope with these issues. The issues and objectives of decentralization are conceived to be as follows.

- Unification and reconstruction of the nation, and assurance of peace and security
- Restoration of the rural population by active decision making of issues related to rural residents, early implementation of rural area plans and appropriate supervision of rural issues
- Strengthening of responsibilities for explanations and ensuring transparency
- Clarification of roles and responsibilities upon strengthening the activities of the 3 regional parties, which are public administration, civil society and private sector, for regional development and capacity building of civil society through social security and encouragement of citizens
- Strengthening of capacities for financial support at the rural level, economic/financial planning and management
- Improvement of validity and effectiveness of planning, implementation, monitoring as well as public service provisions

Especially in the 4 sectors of water/sanitation, education, medical care/health and agriculture, the decentralization policy of Rwanda is aiming for clarification of roles and responsibilities of citizens/administrative decision-makers/service providers (centered on use of private sector), under the principle of responsibility for explanation. Also, based on this clarification, the policy is striving to improve the quality of public service providers.

The relationship between promotion of decentralization from a cross-cutting viewpoint and each development issue becomes the basis for national development plans such as Vision 2020 and EDPRS. According to the decentralization policy, ownership of water supply facilities is to be given to the districts.

(2) Community Development Fund (CDF)

The Community Development Fund (CDF) is the driving force for financial activities of decentralization and the source of the district budget which is allocated according to the District Development Plan (DDP) formulated by the districts which are the nucleus of the local administration. The present DDPs were prepared in 2007 and budget applications for use of the CDF are being made.

(3) Progress of Decentralization

Presently, decentralization related to the water and sanitation sector is being promoted through district level participation, community-based concept and program approach investments. About 39% of central government projects for 2007 were implemented by the districts. All large scale projects are now decentralized, but bilateral projects are still being handled by the central government.

By 2010, the main role of decentralization is scheduled to be transferred to the secteurs, and districts staffs are planned to be transferred to secteurs. As a test case for this transfer, some secteurs were selected and they are receiving budgets to carry out their responsibilities.

S2.3 Use of Private Operators for Water Supply Scheme Management

(1) Background of PPP Introduction

(Based on Promotion et la Mise en Place de Partenariats Publics Privés (PPP) pour La Gestion des Systèmes AEP Ruraux : *Mission d'Evaluation et de Programmation*, World Bank/WSP, August 2007.)

In Rwanda, reflecting on the failure of community-based management of rural water supply schemes (unclear roles and responsibilities for management of water supply facilities, degradation of water supply services, neglecting of broken facilities and other failures resulting from over-reliance on Régies), an improvement in water supply services according the actual conditions was needed. Therefore, the Government of Rwanda decided to promote participation of the private sector through the establishment of public-private partnerships (PPP) for management of rural water schemes as a sector policy for 2004-2007. Until now, under the community-based management system using Régies, income from water sales was transferred to the districts. However, since budget allocations to districts are limited, the income from water sales was mostly used for purposed other than water supply services. Therefore, when money was needed for repairs of the water scheme, both the Régies and districts often do not have the budget. Consequently, since repairs are not made, sufficient quantity of water cannot be assured and problems with water quality will become apparent to deteriorate the water supply service quality. In consideration of this fact, if management is entrusted to a private operator, the operator is free to manage the collected water fees (payment for service) for allocation to not only operation and maintenance of the scheme, but also to residents' awareness and other service improvement activities. Also, needed repairs are made and guaranteed to assure the reliability of water supply services.

(2) Important Preconditions for Adopting PPP (Based on above-mentioned PPP Evaluation Report)

- The water scheme must be in good condition and functioning properly, and if not, the necessary repairs must be carried out before transferring to a private operator.
- Under a PPP scheme, water sale must be based on the metered (measured) fee collection method, and therefore, all water points must be equipped with water meters.
- The water scheme owner (district) must have sufficient understanding of the operating and maintenance cost and of the resulting water tariff, in order to be able to assess the financial viability of adopting PPP.
- Selection of private operators is basically through a tendering process.

(3) Responsibilities of Entrusted Operators (Scope of Contract) (Based on above-mentioned PPP Evaluation Report)

- Supply safe water (quality management of water source: periodic inspections and submission of inspection results to district)
- Supply stable amount of water (continuous water supply service through proper operation and maintenance)
- Sensibilization to users (promotion to increase use of safe water, proper use of water facilities, sanitation promotion, etc.)

(4) Setting Tariff for Privatized Management

Since old facilities are difficult for proper operation and maintenance as compared to newly constructed facilities, the following methods are considered for entrusting.

- Continue to use the facilities in the existing condition without raising the tariff
- The contracted operator rehabilitates the facilities, but the cost is not reflected in the tariff
- Rehabilitation through district budget, but the cost is not reflected in the tariff

On the other hand, for newly constructed facilities, the tariff is decided upon discussions between the district and the contracted operator. For rehabilitated facilities, the former tariff is continued. For facilities which were previously supplied free of charge (whether rehabilitated or not), the district decides on the tariff. However, when the contract is renewed, upon negotiations with the private operator, the tariff will be revised as necessary.

(5) Present State of PPP Introduction in Rwanda

In Rwanda, privatization (management through use of private operators) of water supply facilities started in 2001 for the Nyakabingo water scheme located in the present Gicumbi District of Northern Province. As of the end of May 2008, management of 175 water schemes (see table below). These 175 schemes are being managed by 51 different private operators. The types of private operators are as shown in the table below, but all conclude contracts with the district or district committee and are confirmed as a private sector to be entrusted for management of water schemes.

Table S2-2 Types of Private Operators

Type	Characteristic
Individual	A small-scale individual management body with 2 or 3 employees, and many are not registered.
Association (Régie Associative)	Generally restructured from former Régies (water user associations) and working as a group (association).
Cooperative	A cooperative formed under Rwandan law. Investments must be made to qualify as a member. Cooperatives similar to this organization are also active in various sectors other than the water sector such as public health, agricultural and handicrafts.
Entreprise privé	Registered with corporate status

Management contracts are made mainly through tendering, but if the existing water user association (or Régie) is confirmed to have sufficient management capacities, then it is restructured as a new cooperative and is entrusted through direct negotiations. The present state of PPP introduction as of February 2009 is shown below.

Table S2-3 Present State of PPP Introduction for Water Scheme Management in Rwanda

Province	District	No. of Privatized Water Schemes	No. of Private Operators	Year Contracted
Southern	Ruhango	16	2	2005, 2008
	Huye	5	2	2005, 2008
	Nyanza	3	3	2006, 2007
	Gisagara	4	2	2006, 2007
	Nyamagabe	20	4	2006
	Nyaruguru	1	1	2007
Western	Nyamasheke	18	6	2005, 2007
	Ngororero	34	6	2007
	Rubavu	2	1	2007
Northern	Gicumbi	8	5	2001, 2002, 2004, 2005, 2009
	Burera	37	9	2002, 2006, 2007
	Rulindo	2	2	2008, 2009
Eastern	Bugesera*	1	1	2005
	Gatsibo*	24	7	2005, 2006, 2007, 2008
	Kayonza*	19	6	2007, 2008
	Rwamagana*	4	1	2008
Total	16 Districts	198	58	

* Target districts of this development study

In addition to the above schemes, 64 water supply facilities have been constructed and are being managed by private institutions such as parishes, monasteries, hospitals and NGOs. The total of these water schemes, in comparison to the total 847 water schemes around the country, shows that the rate of PPP introduction was about 30% at the end of 2008 and the coverage goal of 35% could not be achieved. The ideal goal for 2015 is 100%, but practical goal is set at 55%.

Table S2-4 Goals and Achievements for PPP Introduction

		2006	2007	2008	2009	2015
Rate of PPP (%)	Goals			35	45	55 (100)
	Achievements	12	26	30	31*	

*As of February 2009

(6) Present State of PPP Introduction in Target Area

The present situation of entrusting management of water schemes to private operators in the target area is shown below.

Table S2-5 Present State of PPP Introduction in Target Area

District	State of PPP Intervention (As of February 2009)
Nyagatare	Using private operators is being planned, but the intervention period is not yet decided.
Gatsibo	The use of private operators started in 2005 and presently, 24 water schemes are contracted to 7 private operators.
Kayonza	The use of private operators started in November 2007. In April 2008, all 19 water schemes in the districts including 4 constructed by the Japanese grant aide project were contracted to 6 private operators.
Rwamagana	In the beginning of 2008, 4 water schemes were contracted to one private operator. The other schemes are under consideration.
Ngoma	At the present stage, using private operators are not in the planning.
Kirehe	The water schemes are now being managed by a District Water Users' Association (DWUA), but plans are being promoted to transform this DWUA into a cooperative.
Bugesera	The one water supply scheme covering almost all of the district was contract to a private operator in 2005. However, when the contract period was completed, the contract was not renewed and thereafter, MINITERE at that time, took the responsibility for management through direct budgeting and is now being continued through the budget of MININFRA.

(Source: WB-WSP, PPP Promotion Consultant)

(7) Issues for PPP

Due to the use of private operators for management of water supply schemes, the increase in reliability of water supply services is anticipated. However, in the present contract, articles on renewal, rehabilitation and extension of facilities (i.e., clear regulations on the scope of services) are not mentioned to give doubts to sustainability of schemes (excluding some cases, for example, that for Nyamasheke District in Western Province). Also, since the contract period is comparatively short from 1 to 5 years, the conditions are especially unfavorable for private operators entrusted for one year, and this does not become an incentive to develop better management and effectiveness may not be expected.

(8) A Measure for Resolving Problems

Most of the private operators of water supply schemes in Rwanda have few experiences, and due to deterioration of contracted water supply facilities, rehabilitation is necessary, but they are not able to plan for proper rehabilitation. To remedy this predicament, a technical training of private operators was held for 6 days from 14 to 19 April 2008 through an 8 million Frw support from World Bank. The training was entrusted to COFORWA, a local consultant/NGO. A total of 7 facilitators composed of COFORWA and PEAMR carried out the training to representatives from 31 private operators. The objectives of the training are as follows.

- Train private operators on proper maintenance of water supply facilities
- Train private operators on proper administrative and financial management
- Improve the activities of private operators for monitoring and evaluation, and marketing

Moreover, the training was conducted for the following topics.

- Policy on management of water supply facilities through PPP
- Functioning of water supply facilities
- Diagnosing of breakdowns, repairing techniques, maintenance of facilities
- Work planning
- Financial management and accounting
- Financial reporting
- Activities for monitoring and evaluation
- Recommendations for effective marketing

Through results from the above training, to exchange experiences and information between private operators to solve problems encountered in management of water supply facilities, the FEPEAR (Forum des exploitants privés des systèmes d'alimentation en eau et d'assainissement au Rwanda) was formed in July 2008 (not yet officially authorized) by private operators. The principal objectives of the forum are as follows.

- Play the role of lobbyist to government and other public-private partners
- Support forum members to improve management of water supply schemes in technical and financial aspects through training
- Create an information exchange network between forum members as well as partners (through newspaper, hand-outs, mass media, etc.)
- Establish a system for easy access to basic tools and spare parts for proper management of water and sanitation facilities

All private operators are obliged to join this forum. At the first meeting, each member contributed 10,000Frw to cover costs such as communications and transportation of the organization. At the next meeting, the forum is planning to decide on annual contributions. Also, the members are working to search for support funds from donors and organizations to maintain forum activities.

S3. NATURAL CONDITIONS

S3.1 Topography

Rwanda is a country landlocked in the central part of Africa between about 1° and 3°'north latitude and about 29° and 31° east longitude, and is bordered by the Democratic Republic of Congo to the West, Uganda to the North, Tanzania to the East and Burundi to the South. Along the western border with Congo lies the Western rift valley which forms part of the African Great Rift Valley. Also in this area, Kivu Lake (elevation 1,460 m) formed by the volcanic activities of the rift valley and the Virunga volcanic mountain ranges where the country's highest peak Karisimbi (altitude 4,507 m) can be found. Starting from these volcanic mountain ranges, the Congo-Nile water divide range stretches to the south, with the Kivu Lake water basin to the west and the Akagera river basin to the east, which covers over 80% of the national land. The Akagera river basin spans from the central plateau to the Eastern plains gradually decreasing altitude and the flow of the Akagera river and its tributaries creates a topography of the "land of thousand hills" with an average altitude of 1,600 m.

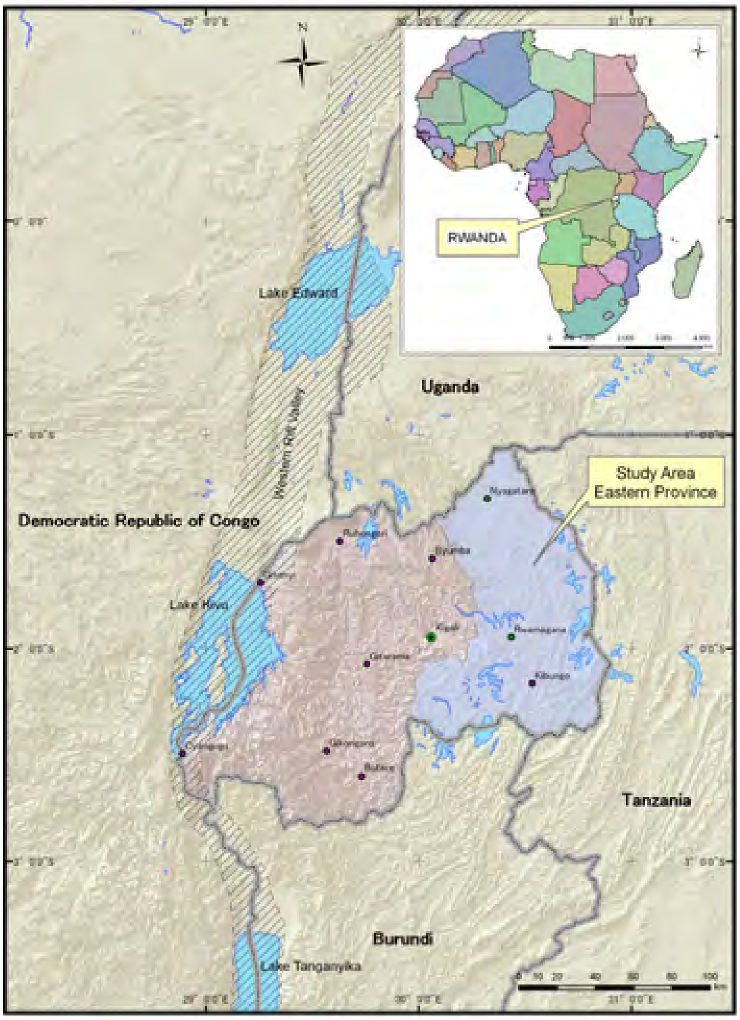


Figure S3-1 Study Target Area

The study area of Eastern Province is located in the Eastern plains region having altitudes from about 1,000 m to 1,500 m with many undulations in the southern part but becoming semi-plains going north. Lowlands and lakes of the Akagera river basin form the southeastern border area and the Akagera national park can be found along the eastern border. Compared to other areas, development of the Eastern Province is said to be delayed, but areas where humans and livestock can enter are already developed as cultivated lands and pastures. Even along the slopes in the southern area where undulations are plentiful, land is used for cultivation and various crops are being planted.

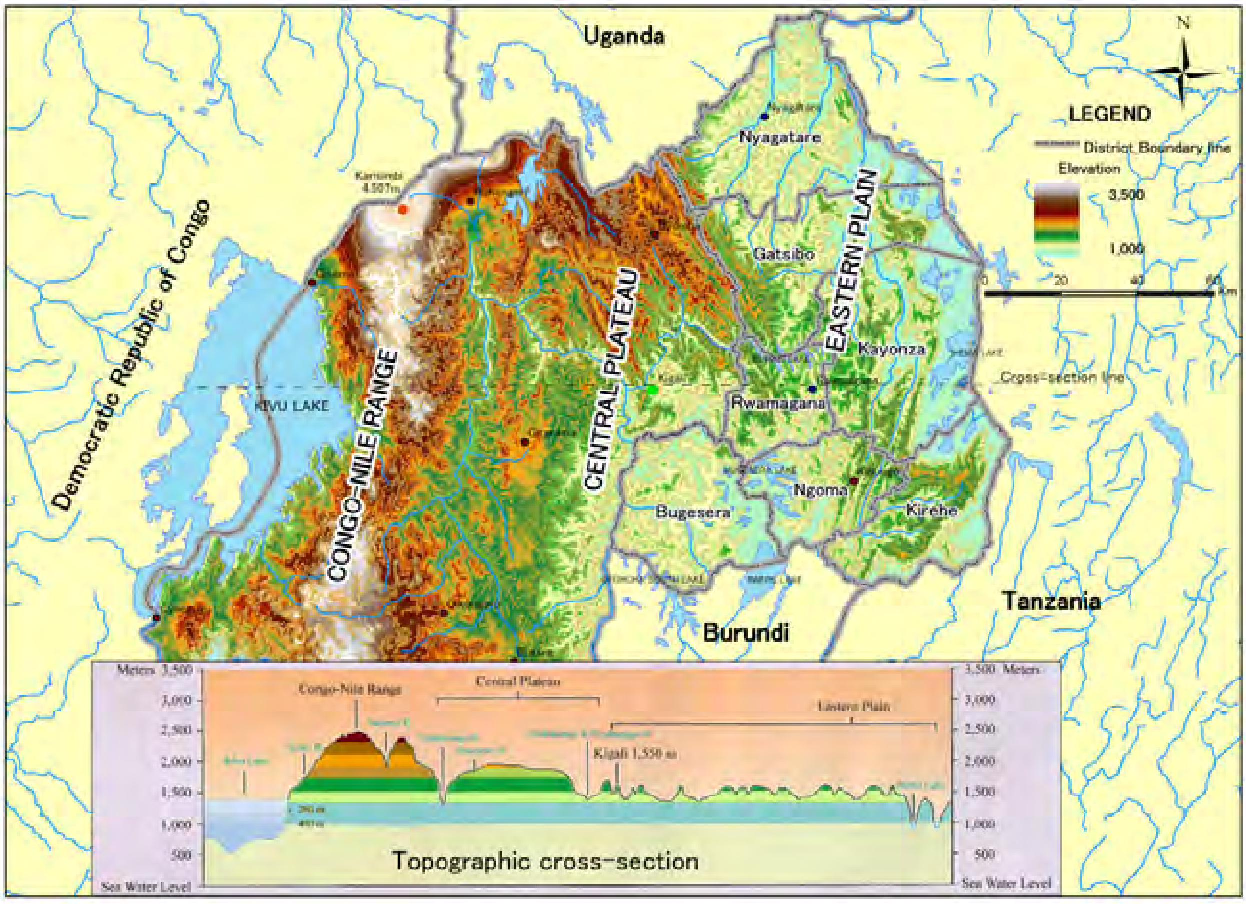


Figure S3-2 Topographical Map of Rwanda

S3.2 Geology

In Rwanda, bedrocks are generally composed of metamorphic rocks and granitic rocks of the Precambrian Period and they are distributed all over the country. Metamorphic rocks are mostly schists produced by low to medium pressure metamorphic actions of sandy to muddy sediments. Also, granitic rocks are intrusive rocks originating from metamorphic actions. After the Cenozoic era, activities of the African Great Rift Valley became active and due to the volcanic activities of the Virunga volcanic mountain range including the Karisimbi Mountains, the whole country became thickly covered with volcanic ashes. Eventually, when the volcanic activities came to an end, the thickly covered volcanic sediments gradually cracked and then talus cone layers from collapsing of mountains sides and sedimentations of gravel carried from the river upstream were distributed as alluvium lowlands and wetlands along rivers and valley floors. A characteristic of the geological formation is the metamorphic rocks of the Precambrian Period stretching in a belt shape from north to south with many faults running in similar directions due to narrowing of the country in the east-west direction by rift valley activities.

Intrusive type granitic rocks are widely distributed in the western part of the province from Nyagatare District through Rwamagana District to Bugesera District. Along the border with the Western Province, metamorphic rocks are distributed in a narrow belt shape. In the central and southeastern parts of the province, metamorphic rocks of quartzite and schist and sedimentary rocks of mudstone and sandstone are distributed in the north-south direction. Along the eastern border with Tanzania is an area of lakes and marshes, and the surrounding area is filled with distributions of sedimented alluviums of few km widths. Also, alluvial layers composed of clay, sand and gravel layers are distributed along rivers and valley floors all over the province.

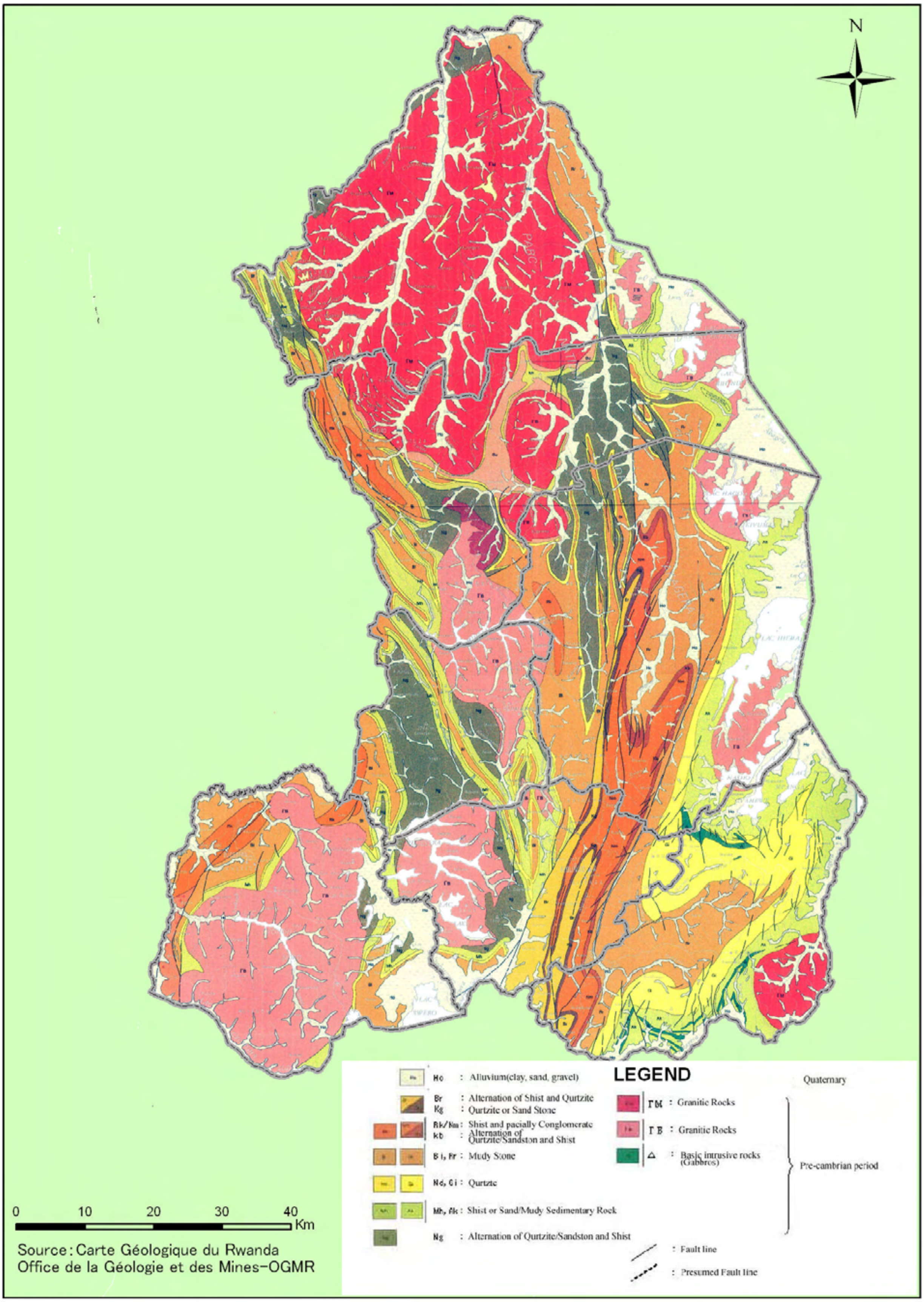


Figure S3-3 Geological Map of Eastern Province

S3.3 Meteorology

(1) Observatories and Meteorological Data

The only functioning meteorological observatories are those at Kigali and in Eastern Province, Kibungo. At the Kigali observatory, temperature, rainfall, evaporation and relative humidity are being measured daily and at Kibungo, temperature and rainfall are measured daily, but some data are missing. Other than these, rainfall only is measured at 5 other observatories.

Table S3-1 Weather Observatories

Observatory	Latitude	Longitude	Altitude (m)	Measured Items	Remarks
Kigali	S 01°58’	E 30°08’	1,490	Temperature, rainfall, evaporation, humidity	Observation continued
Kibungo (Ngoma District)	02°11’	30°30’	1,645	Temperature, rainfall	Observation continued
Sake (Ngoma District)	02°13’	30°23’	1,407	Rainfall (from 2008)	Observation continued
Gabiro (Gatsibo District)	01°33’	30°24’	1,472	Rainfall (until 1990)	Observation stopped
Kiziguro (Gatsibo District)	01°46’	30°25’	1,550	Rainfall (until 1990)	Observation stopped
Ngarama (Gatsibo District)	01°35’	30°14’	1,500	Rainfall (until 1990)	Observation stopped
Kagitumva (Nyagatare District)	01°03’	30°26’	1,280	Rainfall (until 1990)	Observation stopped

(2) Temperature and Rainfall

The monthly average temperature at Kigali and Kibungo stays between 20 ^{o}C and 22 ^{o}C throughout the year without any large fluctuations. The annual maximum temperature at Kibungo is about 29 ^{o}C from March to April, and the minimum temperature is about 14 ^{o}C from October to November.

The annual rainfall at Kigali is about 943mm (average value from 2001 to 2008) and at Kibungo, between 1,000mm and 1,267mm (average from 2007 to 2009). Seasons are the rainy seasons occurring twice a year, from February to April and again in October and November, and the dry season from June to August with almost no rainfall. This rainfall pattern is the same around the whole province.

Figure S3-4 and Table S3-2 show meteorological conditions at these observatories.

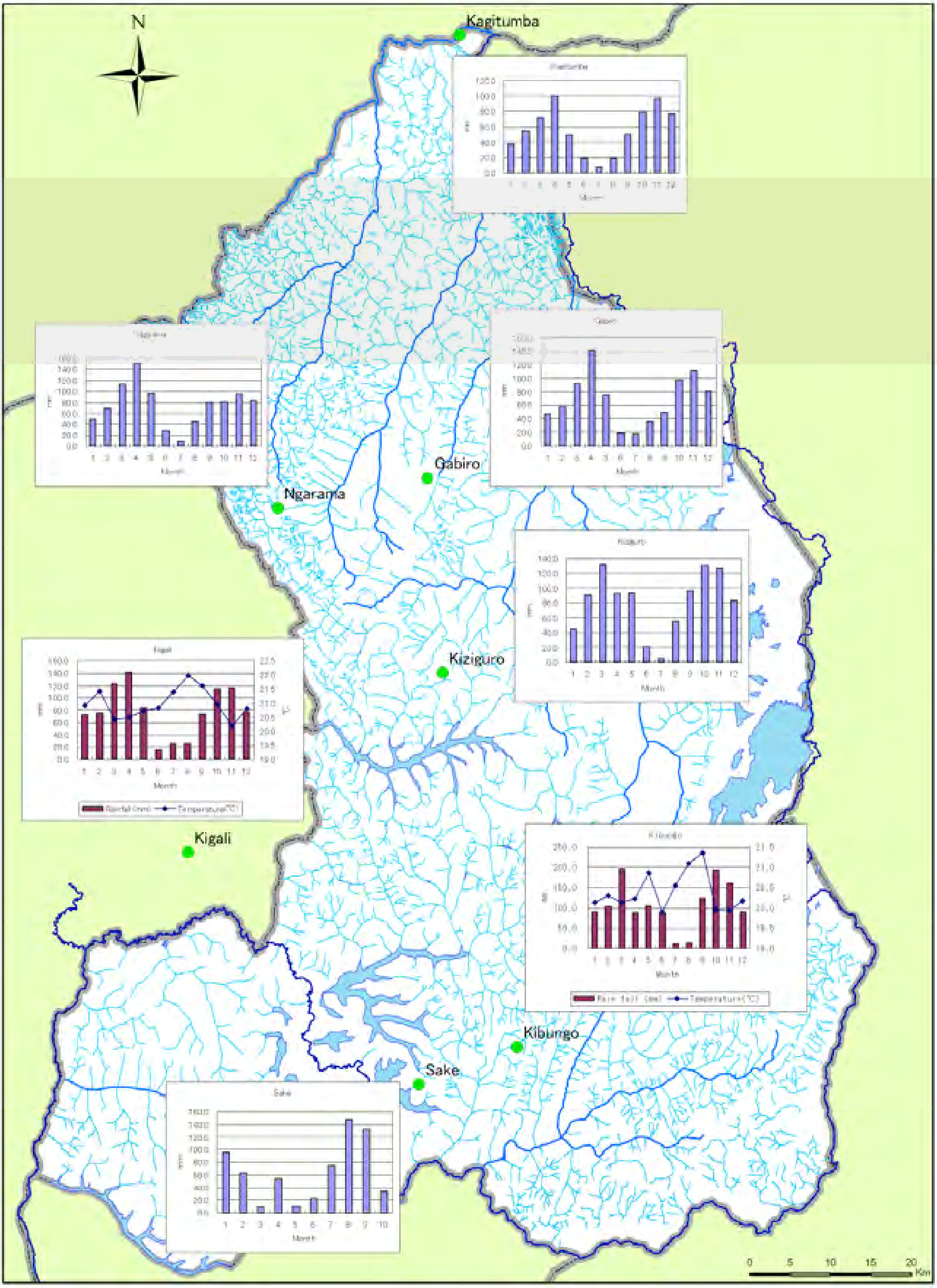


Figure S3-4　Locations of Observatories and Their Temperature and Rainfall

Table S3-2 Monthly Average Temperature (°C) and Rainfall (mm) at Each Observatory

Observatory	Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual
Kigali (2001-2008)	Mean Temp.	20.9	21.4	20.4	20.5	20.7	20.8	21.4	22.0	21.6	20.9	20.2	20.8	-
	Rainfall	72.5	74.4	123.4	140.3	84.2	14.8	26.0	25.4	74.1	114.7	115.6	78.0	943.3
Kibungo (2007-2009)	Mean Temp.	20.1	20.3	20.1	20.2	20.9	19.9	20.6	21.1	21.4	20.0	19.9	20.2	-
	Rainfall	90.2	104.8	195.3	89.2	106.	87.6	11.5	14.1	125.9	191.4	161.7	89.6	1,267.3
Sake (2008-2009)	Rainfall	58.4	-	95.7	63.4	9.4	53.2	10.9	22.1	74.4	146.7	132.5	33.4	700.1
Gabiro (1981-1989)	Rainfall	47.4	57.8	91.8	141.1	74.9	19.2	18.0	35.7	49.8	97.6	110.3	80.6	824.1
Kiziguro (1981-1990)	Rainfall	44.6	90.1	132.3	92.7	93.5	21.0	5.1	55.4	96.5	130.7	126.7	83.9	972.4
Ngarama (1986-1992)	Rainfall	48.6	68.2	113.4	152.1	96.6	27.3	8.4	44.3	79.0	80.4	94.8	82.9	896.0
Kagitumba (1981-1990)	Rainfall	38.1	54.2	72.2	100.4	49.4	18.8	6.6	19.3	50.8	79.6	97.2	77.0	663.6

(3) Relative Humidity

Although data on humidity from the Kigali observatory are available from 2001 to 2008, for Kibungo observatory, data only between January and June 2008 are available. In Kigali, relative humidity during the rainy season is about 80% and 60% in the dry season.

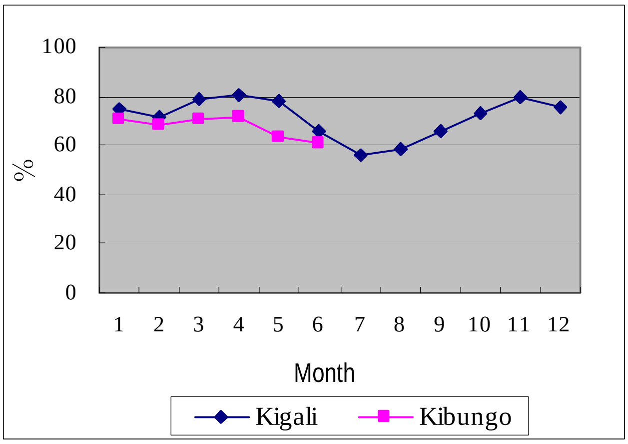


Figure S3-5 Relative Humidity Fluctuation (Kigali and Kibungo)

Table S3-3 Relative Humidity (%) at Kigali (2001-2008) and Kibungo (2008)

Month	1	2	3	4	5	6	7	8	9	10	11	12
Kigali	75.2	71.4	79.1	80.7	77.8	65.6	56.5	58.7	66.0	73.4	80.0	75.5
Kibungo	70.5	68.1	71.0	71.3	63.0	60.7	-	-	-	-	-	-

S3.4 Water Resource of Eastern Province

(1) Types of Water Sources

Water sources exploited in Eastern Province are groundwater and surface waters, complemented by rainwater. Groundwater is used through boreholes in some alluvium areas at foot of hills and valley floors, or is fetched as springs in other areas. Springs flow out from slopes of hills bordering the valley floor (alluvium) or from talus cones accumulated along valley edges. The flow rate of the latter type is generally higher than the former type, and when they appear on the surface either naturally or mechanically, they become surface water. On the other hand, surface waters include river water and lake water, but turbidity of river water increases flowing from upstream to downstream, and at Akagera River which is the lowest stream, the water is brownish. Large and small lakes are found in all districts of the Eastern Province and residents living around lake areas are using these lake waters, but domestic wastewater flows into the lakes and livestock are using these as watering places which contribute to their contamination. Rainwater is collected through rain gutters and stored in plastic tanks of 1 to 5 m^3 capacity at schools and imidugudu to be used for non-drinking purposes.

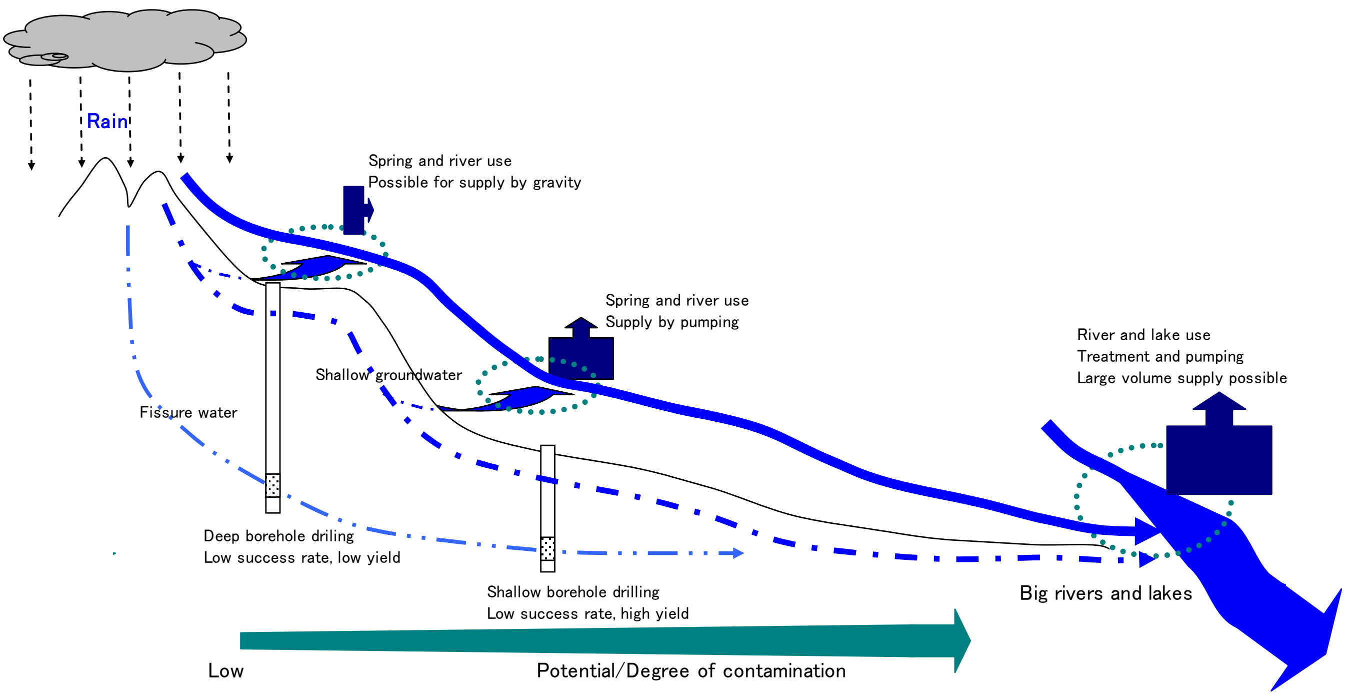


Figure S3-6 Cross Section of Water Use Model

1) Groundwater and Springs

The geological distribution of the Eastern Province, which has a large influence on groundwater existence of this area, can be divided into the following 3 main areas. (Refer to Figure S3-7.)

① Valley area where talus cone layers and alluviums are sedimented

② Area where sedimentary rocks of mudstone and sandstone are distributed

③ Area distributed by granitic rocks

In the valleys of sedimentary formations, good aquifers are formed and many boreholes to be used by handpumps are drilled around these areas. However, the residents using these handpumps have reported that, compared to spring water, the water has a slight odor and the taste is not as good, and therefore, if another water source is available nearby, they tend to avoid using the handpump.

Areas of metamorphic formations are hilly slope areas where annual rainfall is comparatively high to infiltrate into the groundwater, but rain which cannot penetrate deep into layers formed in older ages and recrystallized geology appear as springs on the surface. Many gravity water schemes using springs are found in this area.

In areas distributed with granitic rocks, hills are formed and the surface soil is thin to resist penetration of rain. Therefore, since trees in the area cannot survive, the area is covered with grass and groundwater is found only in limited areas along the valley floor. Not only groundwater, but surface water is also difficult to procure in this area. This is because granitic rocks and metamorphic rocks are of the Precambrian system, which are the oldest layers formed on the earth, and therefore, since these are compacted very tightly, they have the quality of not being able to let water pass through.

The above characteristics are summarized in the following figure.

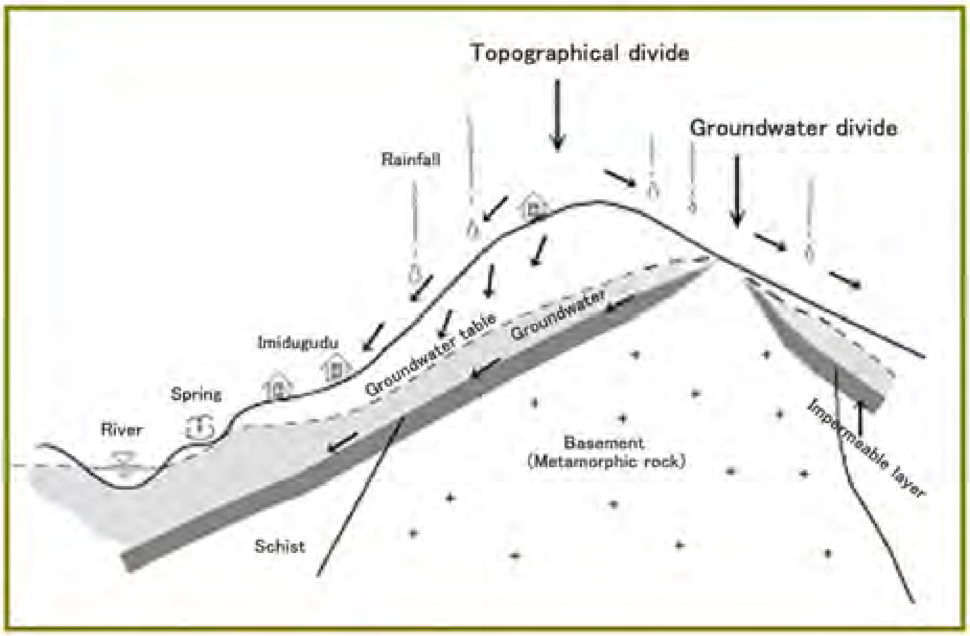


Figure S3-7 Cross Section Model of Groundwater Existence

From these circumstances, at topographically high areas, bedrocks frequently appear directly on the surface. As shown in Figure S3-7, since rainwater cannot penetrate deep into the ground, it flows down towards the talus cones and alluviums in valleys where it appears on the surface as springs.

From the achievements of past groundwater development projects, the following can be pointed out.

a) At topographically high areas, possibilities for formation of good aquifers are low.

b) In the lowlands (including bottoms of mountainsides) along valleys where talus cone layers and alluviums are sedimented, since openings in weathered zones of bedrocks, fractures and unconsolidated layers are filled with groundwater flowing down from mountainous areas, conditions for existence of groundwater is better as compared to the highlands.

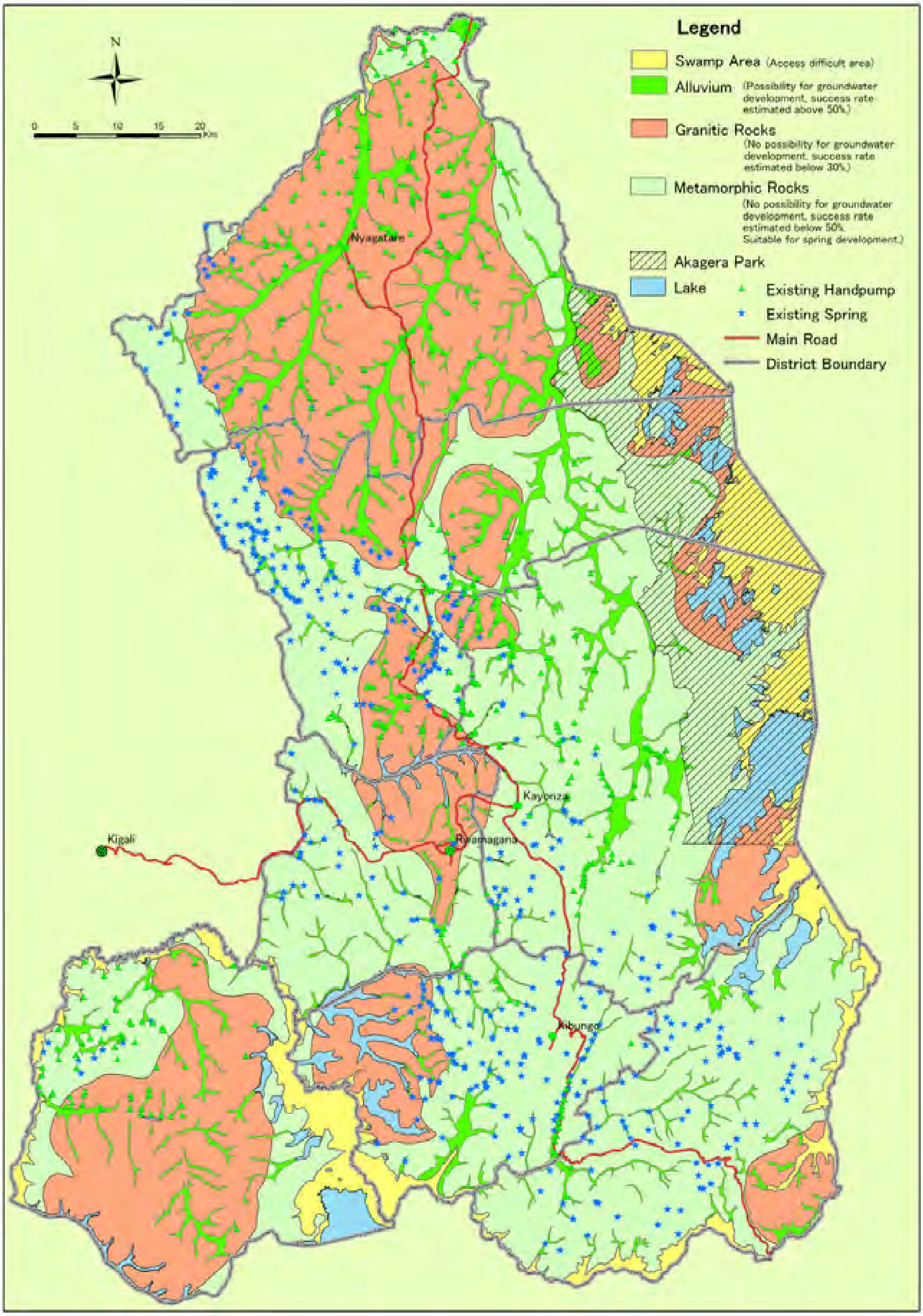


Figure S3-8 Summarized Hydrogeological Map of Eastern Province

2) Surface Water

Rivers found in the Eastern Province belong to the Akagera River system. When the Nyabarongo River, which originates from the western mountainous area of the country, changes its flow direction from a southern route to an eastern route near Lake Rweru at the Burundi border, the river name changes to Akagera River. This river is an international river that flows along the Burundi border down to the Tanzanian border and changes its flow to the north around Rusumo, and where it reaches the Ugandan border, the flow changes to the eastern direction and enters Lake Victoria in Tanzania.

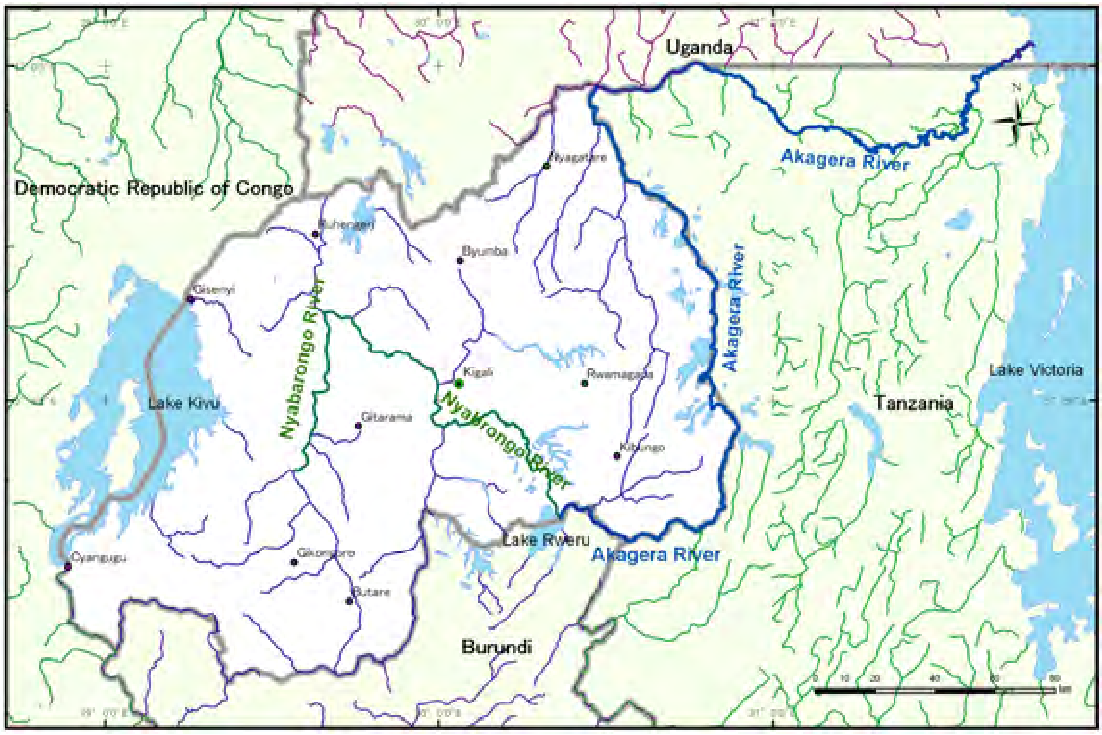


Figure S3-9 Water System Map of Rwnada

The rivers in the Eastern Province belonging to the Akagera River system can be roughly divided into the following five basin groups: 1. Northern basin group; 2. Central (Muhazi Lake) basin group; 3. Eastern lake basin group; 4. Western basin group; and 5. Southern basin group.

1) Northern Basin Group

The northern basin group covers the former Umutara Province. This basin extends from Rugarama and Kageyo Secteurs of Gatsibo District to the northern part of Nyagatare District. Three basins, a. Muvumba basin, b. Karangaza basin and c. Ntemde basin, make up this basin group.

Some water sources for schemes supplying areas in the southern part of Nyagatare District are taken from Ngoma River in the most upper stream of Muvumba River. Also, Musheri and Matimba Secteurs use underflow water of the Mvumba River as their water source.

2) Central (Muhazi Lake) Basin Group

This basin group is a small-scale basin surrounding Muhazi Lake and covers the southwestern part of Gatsibo District, a western part of Kayonza District and the northern part of Rwamagana District. Muhazi Lake is located near the central part of the Eastern Province and extends narrowly for about 26km from east to west forming an arborescent shape. The eastern side is a stagnant lake, but narrows its flow around Rwankuba in Murambi Secteur to flow westward. The rivers that enter into this lake from the eastern part are, starting from the north, a. Nyamarebe River, b. Gakenyeri River, c. Cyabatanzi River, d. Gashogoshogo River, and e. Ntaruka River. These rivers are not perennial and the basin lowlands form a wetlands zone.

Intake for schemes supplying water to secteurs around Rwamagana is Muhazi Lake.

3) Eastern Basin Group (Ihema Lake and Hago Lake Basins)

This basin group is composed of rivers entering the lakes and marshes distributed in the Akagera National Park which covers the eastern part of Gatsibo District and the eastern part of Kayonza District. The Akagera River has formed many groups of lakes and marshes in the basin while flowing from the Tanzanian border to the Ugandan border. The typical lakes of this group include Hago Lake and Ihema Lake in Kayonza District and Nasho Lake in Kireha District, but the scale of these rivers entering into this basin group is small.

4) Western Basin Group

This basin group comprises of the Nyabarongo River basin flowing south through Kigali to form the basin in Bugesera District. The Nyabarongo River originates from the western mountainous zone of this country and flows to the north once, but then changes its flow to the south going through Kigali and changes its name to Akagera River at the southern part of Bugesera District. Many lakes and marshes are formed in the downstream area. The water scheme for Bugesera District intakes water from Lake Cyohoha Sud located in this basin.

5) Southern Basin Group

This basin group is composed of the Rugende River basin in the southern part of Rwamagana District as well as the basins in the southern part of Ngoma District (Mugesera, Gahondo) and Kirehe District (former Rusumo District). Perennial rivers cannot be found in Ngoma District. The Matongo River (Gahondo basin) flows along the boundaries of Sake-Jarama Secteurs and Kazo-Mutenderi Secteurs and the basin is a wetlands zone. Cyunuzi River and Gahezi River (Rwagitugusa basin) are typical rivers in Kirehe District and both rivers are flowing. The Cyunuzi River joins the Gahezi River on the way flowing south from the former Rukira District and changes its name to Rwagitugusa River at the downstream area, and then flows into the Akagera River. The Gahezi River flows from east to west inside Kirehe District. The junction area of the 2 rivers is being used as rice fields. The Akagera River flows to the east along the southern part of the border with Tanzania, and changes its flow to the north in the vicinity of Rusumo. Small to medium-sized rivers can be observed in this basin.

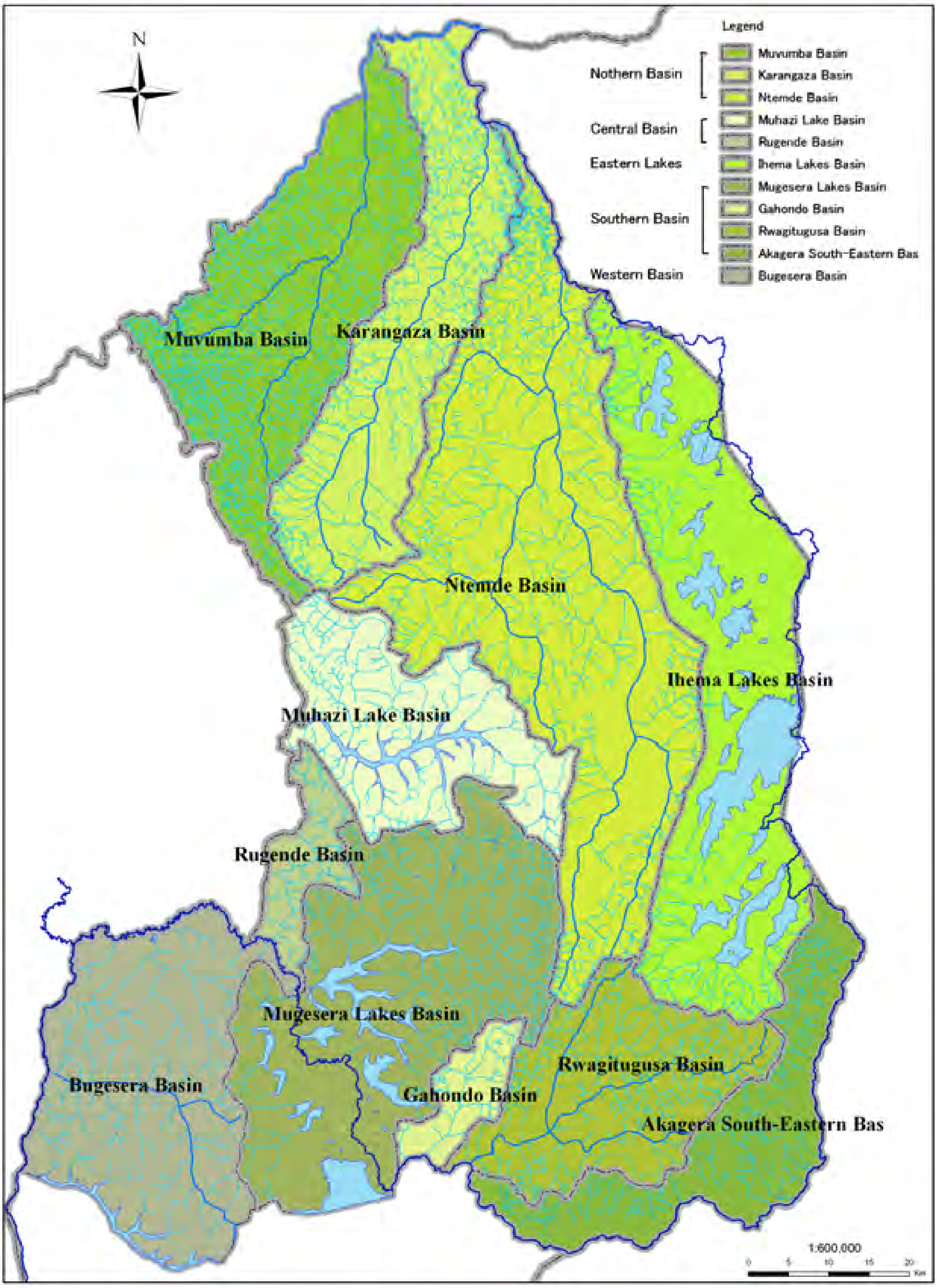
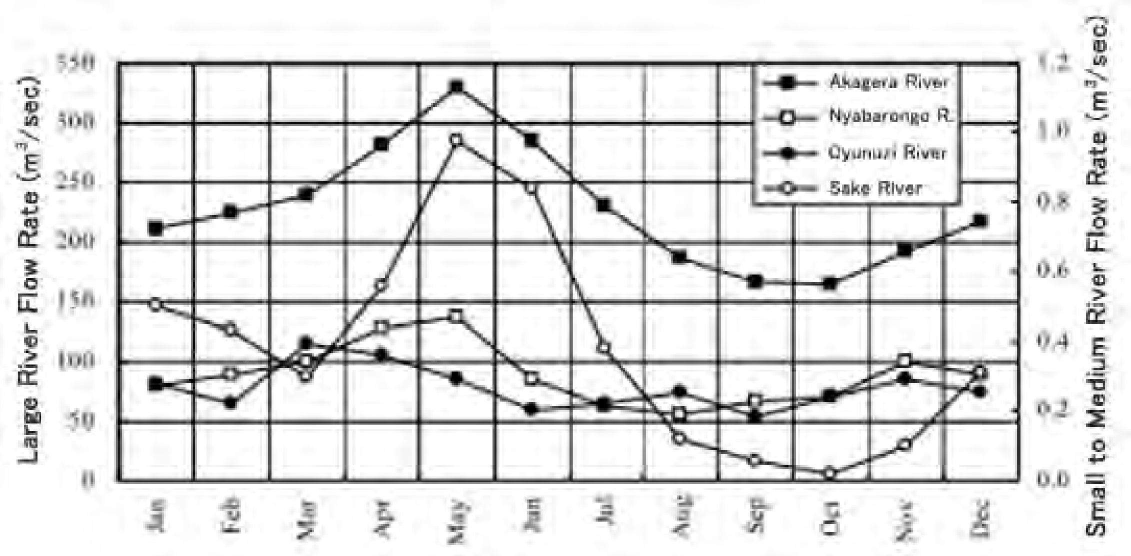


Figure S3-10 Water System Distribution Map

3) River Flow and Outflow Rate

Many rivers of the Akagera River system can be found in this province, but only a few rivers are perennial. According to past reports, although Akagera, Nyabarongo, Cyunuzi and Sake Rivers are mentioned, at the time of this survey, observation data of Cyunuzi river only were remaining. However, in the "Basic Design Report for Rural Water Supply in the Republic of Rwanda" implemented in 2006, observation data for Akagera, Nyabarongo, Cyunuzi and Sake Rivers were collected and analyzed. The results are as follows.



Source: Basic Design Report for Rural Water Supply in the Republic of Rwanda, JICA, 2006

Figure S3-11 River Flow Rates of Project Area

From March when the rainy season starts, flow rate increases and approaching the dry season around May, the flow begins to decrease. For large rivers of Akagera and Nyabarondo Rivers, October is when the river flow is lowest and for small rivers, August to September is the period of lowest flow. The fluctuation in flow of small rivers is assumed to affect the flow of large rivers one to two months later. Since rainfall during the dry season is almost nil, the flow rate during August to September can be considered to correspond to the base flow rate of small rivers, and rivers are recharged by groundwater outflow from the river basin.

Figure S3-12 shows the relationship between rainfall and outflow rates in the Cyunuzi River basin[1]. According to this data, about 15%-20% of rainfall makes up the riverflow during the rainy season (February, March, October and November). Also, we can assume that, since the riverflow becomes deficit with no rainfall during the dry season in July and August, groundwater outflow is available.

[1] Monthly average flow rate: Cyunuzi River Rukira Observatory (1996-1999), Rainfall: Kibungo Observatory (2007-2009)

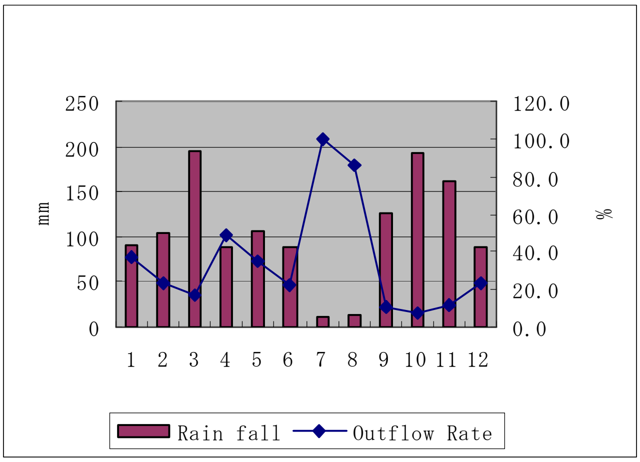


Figure S3-12 Relationship between Rainfall and Outflow Rate (Cyunuzi River Basin)

Table S3-4 Rainfall and Outflow rate

Month	1	2	3	4	5	6	7	8	9	10	11	12
Rainfall(mm)	90.2	104.8	195.3	89.2	106	87.6	11.5	14.1	125.9	191.4	161.7	89.6
Outflow Rate(%)	37.3	23.4	17.3	49.1	35.0	22.0	100<	86.3	10.4	7.6	11.4	22.9

4) Water Balance in Cyunuzi River Basin

Figure S3-13 shows the water balance relationship for each month in the Cyunuzi River basin. Rainfall (measured value) and maximum evaporation (calculated value) data are for Kibungo which is near this river and outflow height is the value obtained when riverflow is divided by the catchment area (80 km^2). Evaporation + outflow height largely exceeds rainfall especially during the dry season in July and August. The total for the year of this value is almost same as the amount of rainfall, but recharge into groundwater is not included in this amount. This means that, in terms of water balance, recharge into groundwater is very low. From this view, we can presume that recharge into groundwater by rainfall will not increase more than the present.

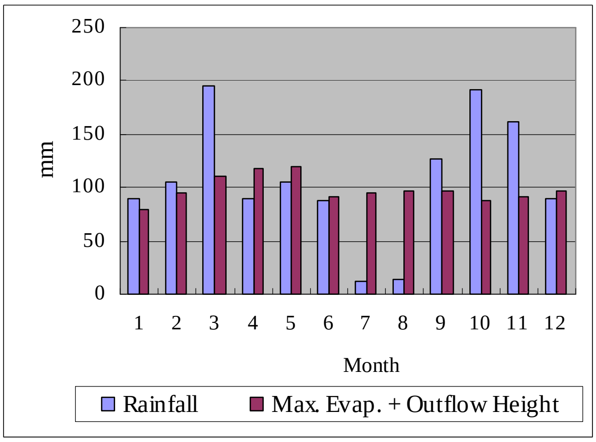


Figure S3-13 Water Balance of Cyunuzi River Basin

Figure S3-5　Rainfall (mm), Maximum Evaporation (mm) and Outflow Height (mm)

Month	1	2	3	4	5	6	7	8	9	10	11	12	年
Rainfall	90.2	104.8	195.3	89.2	106.0	87.6	11.5	14.1	125.9	191.4	161.7	89.6	1,267.3
Evaporation	76.3	70.4	76.4	75.0	82.7	72.3	79.9	84.6	84.5	74.9	72.6	76.7	926.3
Outflow height	33.6	24.6	33.8	43.8	37.0	19.3	14.5	12.1	13.0	14.4	18.4	20.4	284.9
Evap.+Outflow ht.	79.9	95.0	110.2	118.8	119.7	91.6	94.4	96.7	97.5	87.3	91.0	97.1	1,211.2

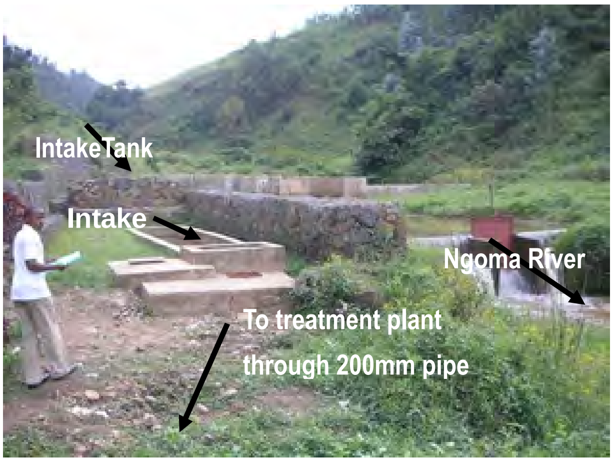
(2)　Existing Water Source Conditions

Water sources used for water supply in Eastern Province are summarized in the table below.

Table S3-6　Summary of Water Sources for Water Supply

Water Source		Intake Rate $m^{3/}$day	Suppy Area
Lake	Muhazi	1,200	Rwamagana District
	Mugesera	1,600	Rwamagana District (also, 11,000m^3 intake for Kigali city)
	Cyohoha Sud	2,900	Bugesera District
	Sub-total	5,700	
River	Ngoma	900	Nyagatare District
	Muvumba	600	Nyagatare District
	Sub-total	1,5005	
Groundwater	Spring	13,000	Nyagatare, Gatsibo, Kayonza, Rwamagana, Ngoma, Kirehe Districts
	Submersible Pump	200	Kayonza district
	Handpump	3,000	Nyagatare, Gatsibo, Kayonza, Ngoma Districts
	Sub-total	16,200	
Grand Total		23,400	

The total amount of intake from water sources to be supplied to Eastern Province is about 23,400 m^3/day. These water sources are not evenly distributed in the province but rather limited to certain areas only. Using rivers as water source in Eastern Province is limited to Nyagatare District where only water from the Muvumba River system originating from mountainous areas along the border with the Northern Province can be used. At upstream, water can be taken directly, but at the lowest stream, since the turbidity increases from 24.3NTU to 200 NTU, culvert pipes are used to intake water from the underground flow along the river.



Ngoma River Tovu Intake Point

Muvumba River Downstream Matimba Intake

Springs are concentrated in areas where metamorphic rocks are distributed. This area has topography of rough slopes formed by erosion after being forced up by external metamorphic actions. Also, due to the easily weathered geology, surface soil can be secured and moisture is stored near the surface to flourish plants. Therefore, springs having stable volume of water were being developed for many years in the mountainous western part of Nyagatare and Gatsibo Districts as well as Kayonza, Ngoma and Kirehe Districts. However, according to inquiries to district offices and local residents, they are reporting that recently spring flow rates are decreasing, but records showing annual flow rate changes are not kept to confirm this situation. Recently, mountainous areas above 2,000m altitudes are being developed and land is being cultivated on slopes reaching 30° to decrease forestry area.

The distribution of these existing facilities is shown in Figure S3-14.

(3) Water Sources and Estimated Potential

The potentials of springs, groundwater, lake water and river water, which are possible water sources in Eastern Province, were calculated.

1) Springs

As shown in Figures S3-15, spring is rainwater which becomes groundwater and appears on the surface. Since springs flow down in shallow layers, retention time is short and they are easily influenced by seasonal fluctuation of rainfall. Therefore, by measuring the present spring yield and calculating the spring ratio between the yield and rainfall rate of the catchment area, the spring potential was estimated.

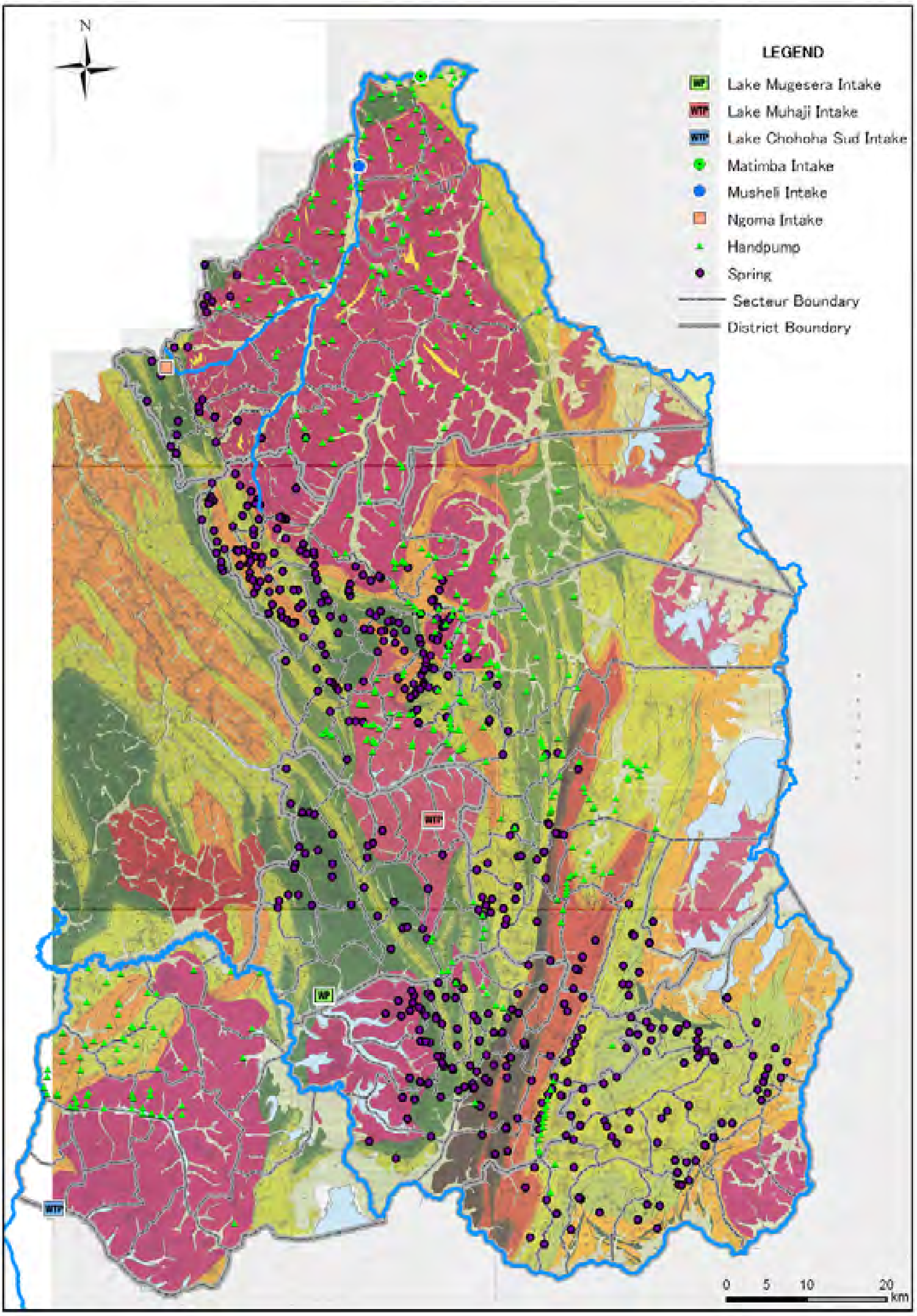


Table S3-14 Location Map of Existing Water Sources

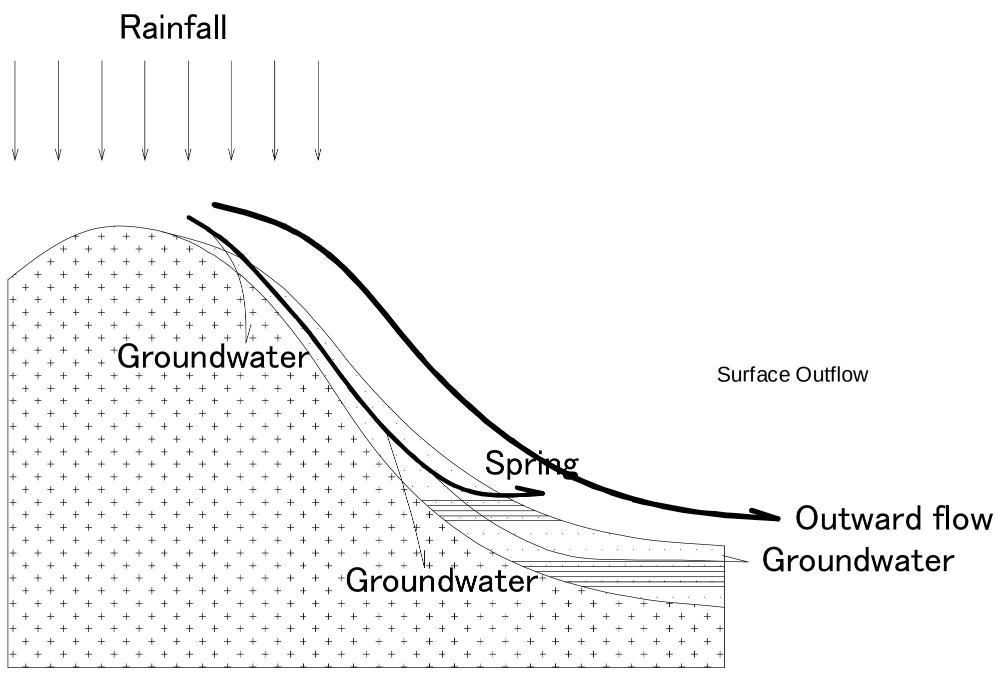


Figure S3-15 Cross Section of Model Spring

To determine this ratio, 16 spring points were selected from spring developed areas in Eastern Province and spring yields were measured at the sites. The catchment area was calculated using 1/50,000 topographic maps. The volume of water flowing out from the protected spring was measured using a vessel of fixed volume and spring yield per unit time was calculated.

The result of the above measurements, catchment area of each spring point and calculation results of spring ratio to annual rainfall are shown in Table S3-7. Also, locations of spring measurements and their catchment areas are shown in Figure S3-16. For annual rainfall, annual average rainfall data between 1986 and 1990 of Ngarama observatory (Gatsibo District) was used.

Table S3-7　Ratio of Spring to Rainfall in Catchment

District	Sector	Name of Spring	Spring yieid		Catchment area	Annual Rainfall		Spring Ratio to annual Rainfall
			Field Measurement	Converted to Annual Spring Yield	(Measured from map)	Average in Eastern Prov.	Annual Average	
			①(l/min)	①x60x24x365/1000= ②(m^3/year)	③(m^2)	④(m)	③x④=⑤(m^3)	②/⑤x100(%)
Gatsibo	Kiramuruzi	Kagina	60	31,536	3,006,810.34	0.8953	2,691,997	1.17%
	Muhura	Nyakagezi	41	21,550	6,082,742.45		5,445,879	0.40%
Kayonza	Kabare	Kiburara	64	33,638	48,241,890.87		43,190,965	0.08%
	Kabarondo	Mubugazire	180	94,608	6,663,765.26		5,966,069	1.59%
	Murama	Gicaca	92	48,355	5,629,659.93		5,040,235	0.96%
	Murama	Nyaruriba	68	35,741	8,988,071.14		8,047,020	0.44%
Kirehe	Kigarama	Nyagashagara	110	57,816	2,251,530.91		2,015,796	2.87%
	Kigina	Rwakiriba	108.5	57,028	3,030,663.13		2,713,353	2.10%
	Nasho	Mutsindo	62	32,587	3,431,077.86		3,071,844	1.06%
Ngoma	Kibungo	Nyamuganda	162	85,147	3,826,708.75		3,426,052	2.49%
	Kibungo	Rwasaburo	260	136,656	9,370,985.49		8,389,843	1.63%
	Mugesera	Nyakagezi	40.5	21,287	1,895,828.13		1,697,335	1.25%
	Murama	Kabashima	65	34,164	15,070,534.67		13,492,650	0.25%
Rwamagana	Kigabiro	Kabura	67.9	35,688	3,133,499.75		2,805,422	1.27%
	Kigabiro	MKM	60	31,536	16,034,346.27		14,355,550	0.22%
	Muyumbu	Kwairivera	32.4	17,029	11,881,678.97		10,637,667	0.16%
				774,366			132,990,079	**0.58%**

Since spring structure and catchment characteristics differ for each spring, the spring ratio to rainfall varies from 2.87% to 0.08%, but the weighted average becomes 0.58%. By using this weighted average as the annual spring ratio of the target area, and if the catchment area is multiplied to this value, then the result is the annual potential.

Since springs are not developed in granite areas and flat areas, these areas were excluded to calculate the catchment area on a map (refer to Figure S317). The calculation result is as follows.

Catchment Area × Average Rainfall Rate × Spring Ratio ＝ Annual Potential
(Usable Spring Yield)

3,237,000,000m^2 × 0.896m × 0.58% ＝ **16,822,000m^3**

Since spring yield measurements were made in January and February, and this period is not necessarily the base outflow period for river flow, the calculations have possibilities of becoming higher in value than actual. Therefore, in this report, 70% of the above calculation results which is **11,775,000m^3** will be used.

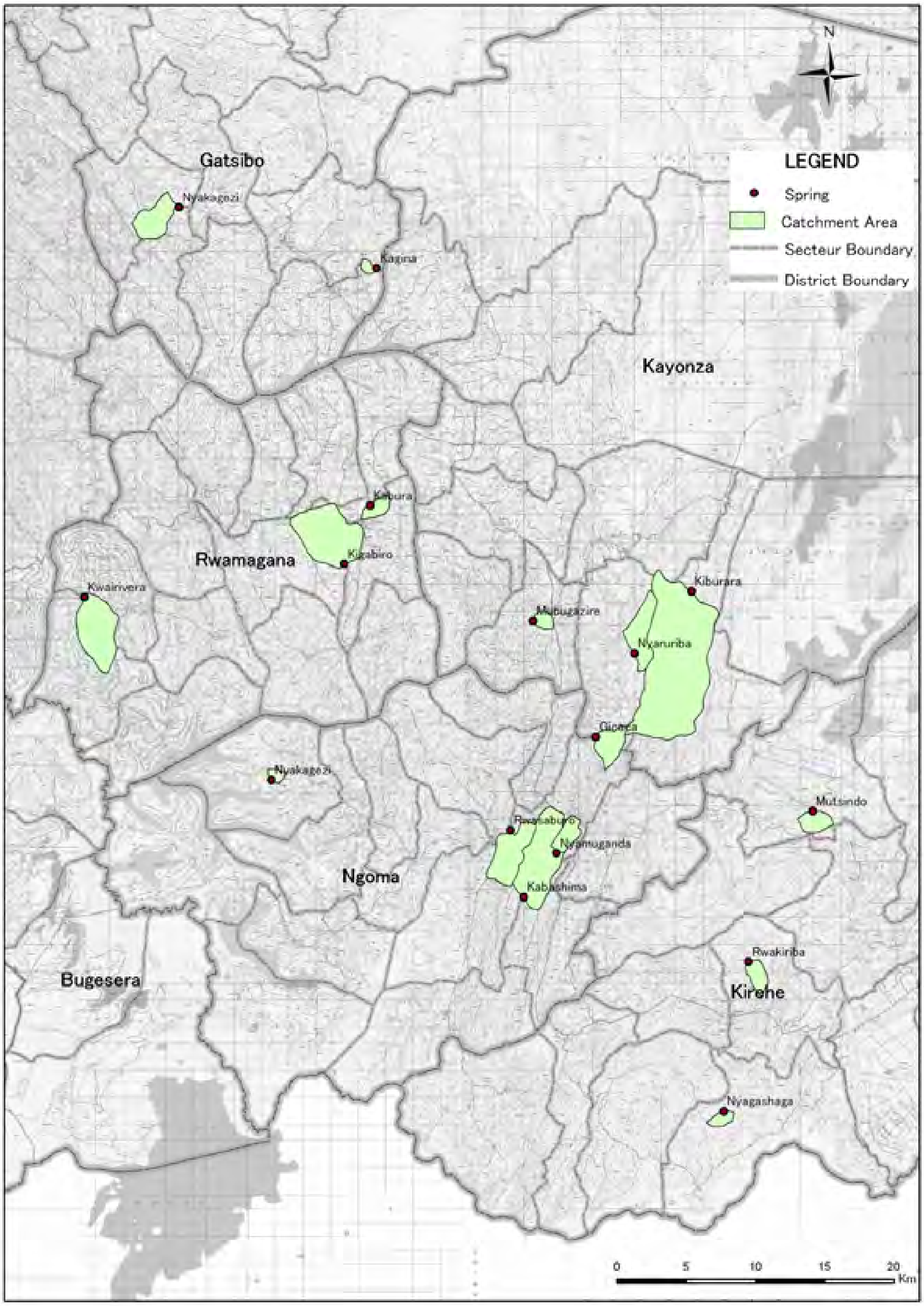


Figure S3-16 Spring Location Map for Calculations

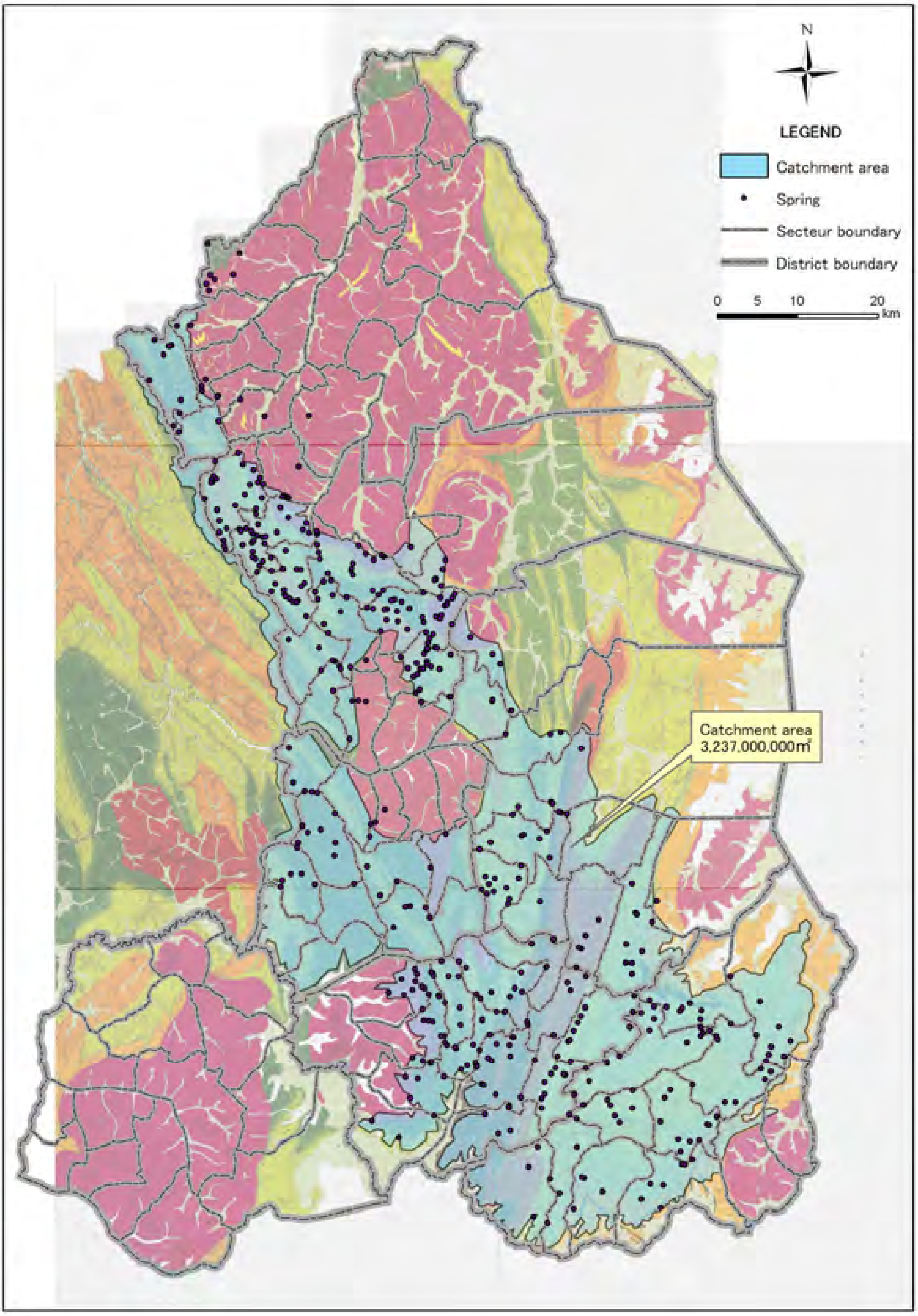


Figure S3-17 Spring Distribution Map

2) Groundwater

Alluvial plains developed along valleys have highest potential for groundwater development. Groundwater potential is estimated by finding suitable areas on a map and multiplying their areas and aquifer thicknesses by aquifer opening ratios. Geoelectrical prospecting results confirmed that weathered zones expected to be aquifers are distributed above basement rock layers with average layer thickness of 21m and average depths of 24 to 45m. However, weathered zones which become aquifers are of either strong weathered band or weak weathered band, but the strength is difficult to determine by resistivities of geoelectric prospecting. Therefore, information on existing borehole drillings and inquiries to contractors were analyzed and confirmed that, successful boreholes are distributed mostly in lowlands along valleys; water is taken from the lower section of strong weathered zones above basement rocks; and installed screen lengths are less than 6m. In consideration that, screens are generally installed with some reserve since they are manufactured with fixed lengths and screens cannot be processed at pipe joint portions, aquifer layers are assumed to exist as strong weathered zones of 5m thicknesses above basement rocks.

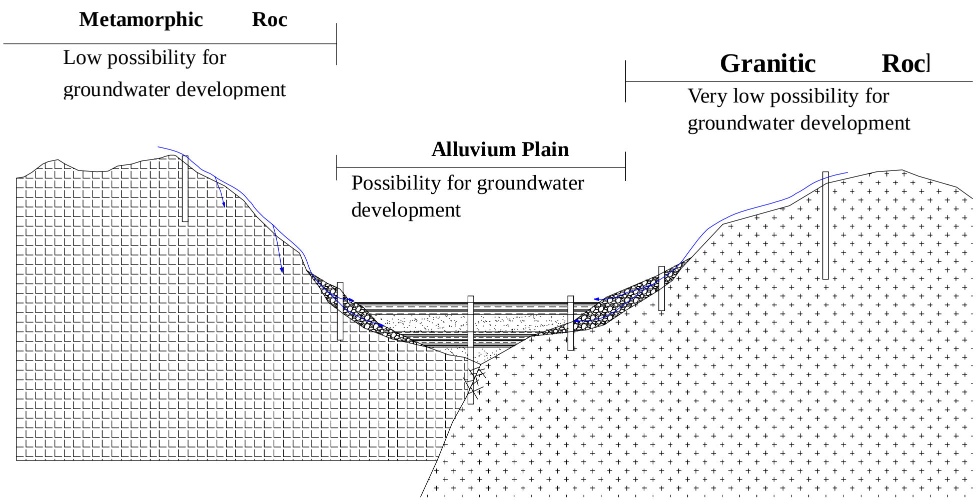


Figure S3-18 Possible Groundwater Development Zones in Target Area

According to "Physical and Chemical Hydrogeology, 1st edition, Patrick A. Domenico and Franklin W. Schwartz", effective porosity is more than 1 digit less than the porosity as listed in the following table. From this table, effective porosities of weathered granitic rocks are between 3.4% and 5.7% and from resistivities of geoelectrical prospecting results and component structure, if this is considered as a sand layer (fine sand), then it is between 2.6% and 5.3%. In this report, we will consider it as fine sand layer with an effective porosity of 3%.

Table S3-8 Porosity of Materials

Material	Porosity (%)	Material	Porosity (%)
Sediment		Crystalline Rock	
Pebble	24-36	Fractured crystalline rock	0-10
Granule	25-38	Dense crystalline rock	0-5
Coarse sand	31-46	Basalt	3-35
Fine sand	26-53	Weathered granite	34-57
Silt	34-61	Weathered gabbro	42-45
Clay	34-60		
Sedimentary Rock			
Sandstone	5-30		
Siltstone	21-41		
Limestone, Dolomite	0-20		
Karst limestone	5-50		
Shale	0-10		

Source: Physical and Chemical Hydrogeology, 1st edition, 1990

Possible Borehole Drilling Area × Aquifer Thickness × Porosity = Groundwater Potential

561,498,000m^2 × 5m × 3% = **84,224,000 m^3**

Possible Borehole Drilling Area: Alluvium area calculated from geological map

Aquifer Thickness: Assumed from existing borehole data and geophysical prospecting results

Effective Porosity: Considered as sand layer, assume 3%

3) Lake Water

Lakes presently used as water sources are Lake Muhazi, Lake Mugesera and Lake Cyohoha Sud. The water levels of these lakes are not measured, but according to inquiries to persons in charge at treatment plants which intake water from these lakes, annual lowering of the lake water level is not seen. Also, they have reported that the annual maximum water level fluctuation is less than 1m and intake is stable. However, since calculation of lake water potential is difficult without water level measurement data, intake rate at the time of the survey as shown below will be taken as the usable volume.

Table S3-9 Intake Rate from Lakes

Lake Name	Intake Rate (m^3)	
	Daily	Annual
Lake Muhazi	1,200	438,000
Lake Mugesera	1,600	584,000
Lake Cyohoha Sud	2,900	1,058,500
Total	5,700	2,080,500

4) River Water

Perennial rivers useable for water supply are those of the Muvumba River system originating from the mountains along the border between Gicumbi District and Nyagatare District. Presently water is being taken from 3 locations within this system and flow is stable. The present intake rates at intake points are as follows.

Table S3-10 Intake Rate from Rivers

Intake Point	Intake Rate (m^3)	
	Daily	Annual
Ngoma	900	328,500
Musheli	200	73,000
Matimba	400	146,000
Total	1,500	547,500

Simple river flow measurements were carried out in September at 2 points along the upstream of the Muvumba River system. The results showed 0.552 m^3/sec at Kiyombe Secteur measurement point (Ngoma intake point) and 0.95 m^3/sec at Nyagihanga Secteur measurement point.

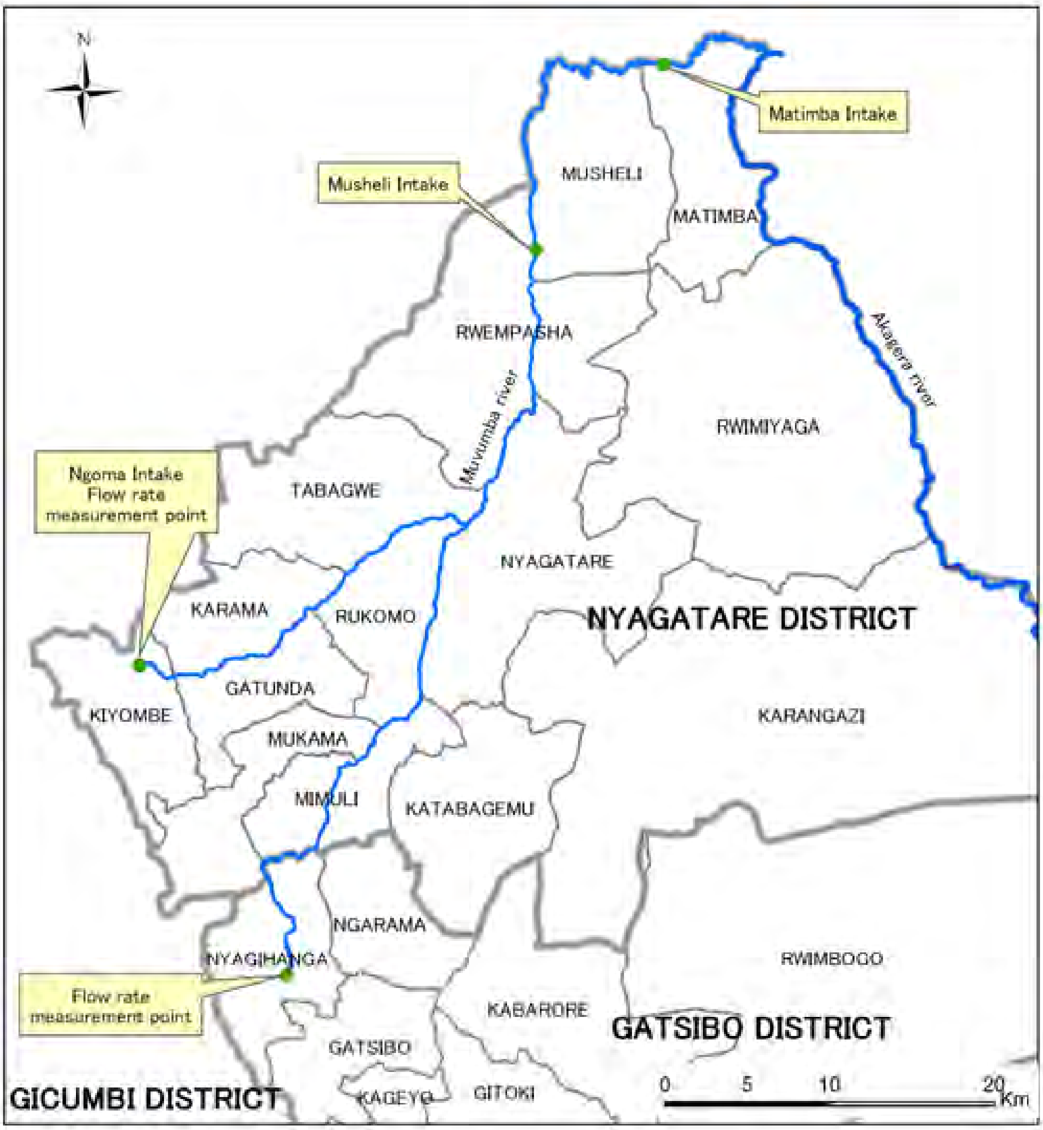


Figure S3-19 Muvumba River System Flow Measurement Points

If water resources potentials of Eastern Province explained in 1) to 4) above are compiled, the annual total is about **99 million m^3** (about 270 thousand m^3/day) as shown below.

Table S3-11 Water Source Potential of Eastern Province

Water Source	Potential		Remarks
	m^3/year	m^3/day	
Spring	11,775,000	32,000	
Groundwater	84,224,000	231,000	
Lake Water	2,080,500	5,700	Intake at time of survey
River Water	547,500	1,500	Intake at time of survey
Grand Total	98,627,000	270,200	

(4) Water Quality

Water service providers who are managing water supply schemes should periodically carry out water quality analyses. However, since only little information exists, in order to identify water qualities of existing water schemes and candidate water sources, simple water quality tests were conducted using “Pack Tests” (handy on-site water quality test kits). The results of water quality analyses made on existing piped water schemes and protected springs during the present study as well as past water quality analyses results provided during the preparatory study meet WHO guideline values.

However, for some handpumps, concentrations of iron, manganese and fluoride were higher than the standards. Iron and fluoride levels tend to be high in granitic rock areas of Nyagatare District (refer to Figure S3-21). Also, water pumped up from some handpumps in Bugesera District showed high electric conductivity values of 100 to 300 mS/m. These handpumps are located along the Umwago valley which includes Lake Kamdebell and Lake Cyohoha Nord, and electric conductivity of Lake Cyhoha Nord is also high at 137.2 mS/m. Therefore, groundwater along this valley has high electric conductivity and this area is not suitable for groundwater intake. Lakes such as Cyohoha Nord Lake in this valley do not have large flow outlets and meteorological conditions show evaporation is more than rainfall. These are probable reasons for this area to become a high electric conductivity area.

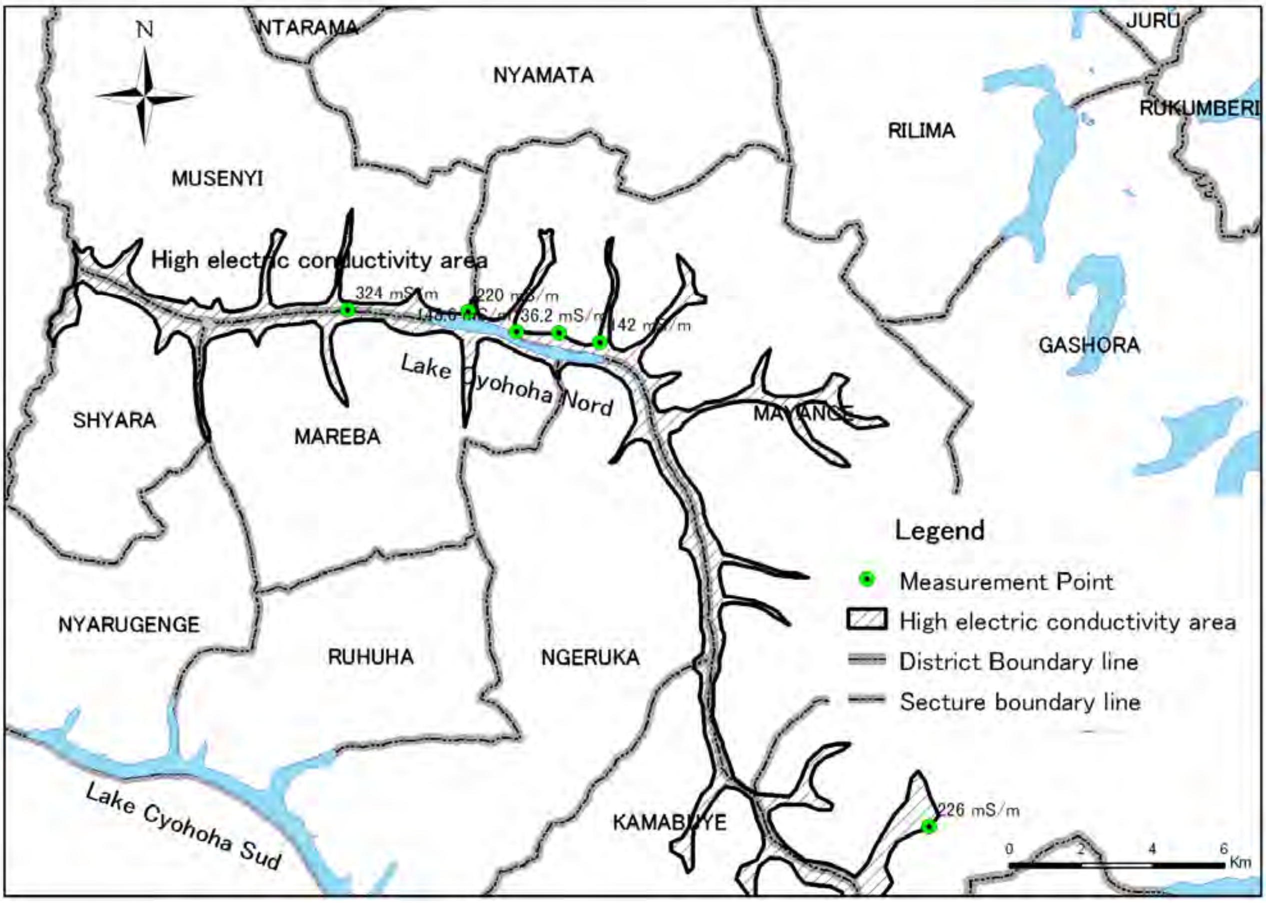


Figure S3-20 High Conductivity Area of Bugesera District

Generally, groundwater pumped up by handpumps is considered to be suitable for drinking. However, some handpumps are pumping up groundwater not satisfying WHO guideline values and therefore, water needs to be carefully used through continuous observations of influence on residents. Water quality analyses results are shown in the nest page.

Table S3-12 Water Quality Analyses Results

No.	Location			Water Source Name	Latitude	Longitude	Altitude (m)	Yield	Temp	pH	TDS	Conductivity	NO3	Fe	Mn	F	Total hardness	Chloride	SO4	Coliform group,cfg.
	District	Secteur	Cell					ℓ/min	℃		ppm	ms/m	ppm	ppm	ppm	ppm	ppm	ppm	ppm	
1		Bugarama	Gihuta	Spring Ntende	-01 42' 52.7″	30 24' 34.5″	1,355	52.9	23.9	5.9	277	56.5	10<	0.2>	0	0	50	150	0	
2		Gasange	Bibare	Gasigati	-01 46' 47.98"	30 18' 45.93"	1,594		24.6	4.6	380	79.4	5	0.2>	0.5>	0	30	100>	0	Detect little
3			Kigabiro	HP	-01 48' 15.16"	30 18' 37.28"	1,502		24.1	5.9	265	52.7	2	0.5	0	0	20	100>	0	
4			kabarore	HP	-01 37' 07.1″	30 23' 11.7″	1,471		25.5	6.6	42	8.4	1	0.2>	0	0	10	100>	0	
5			Kabeza	HP	-01 36' 44.0″	30 23' 52.6″	1,474		25	6.4	80	16.4	4	0.2>	0	0	10	100>	0	
6		Kabarore	Marimba	HP	-01 36' 17.5″	30 19' 14.2″	1,411		26.1	7.1	156	30.9	1>	0.2>	0	0	100	100>	0	
7			Nyabikiri	HP	-01 36' 09.4″	30 25' 25.7″	1,467		24.2	6.2	41	8.5	1	0.2>	0	0	10	100>	0	
8			Simbwa	HP	-01 32' 44.0″	30 21' 26.2″	1,380		26.6	6.8	131	25.8	2	0.2	0	0	50	100>	0	
9		Kageyo		Kaninga	-01 39' 30.71"	30 15' 58.95"	1,676	26	20.7	5.24		19.39	10	0.2	0	0	10	100>	0	
10		Kiramuruzi	Gakenke	HP	-01 48' 05.58"	30 25' 48.58"	1,466		22.8	6.3	257	51.2	5	0.5	0	0	20	100>	0	
11	Gatsibo			Kagina	-01 47' 11.50"	30 26' 39.37"	1,485	70	22.9	5.8	286	58.2	10	0.2>	0	0	30	100>	0	
12		Matunguru	Matungiro	HP	-01 40' 32.3″	30 27' 50.5″	1,338		25.6	7.1	574	115.2	1>	0.5	0	3	100	200<	0	
13			Rambura	HP	-01 40' 13.3″	30 27' 07.9″	1,349		26.6	7	26	5.3	0.3	0.5	0	0	10	100>	0	
14		Mufura		Kibir-Mpaza	-01 43' 20.60"	30 15' 19.80"	1,616	83.1	20.8	5.61		32.2	45	0	0	0	50	100>	0	
15		Muranbi	Muranbi	Byimana	-01 47' 31.21"	30 20' 59.43"	1,499		24.4	5.9	306	61.5	10	0.2>	0.5>	0	40	100>	0	
16		Nyagihanga	Kibari	Gashure	-01 32' 45.40"	30 11' 42.80"	1,639	41	21.3	5.19		29.4	20	0	0	0	50	100>	0.1	Not detect
17				Rwobe-1	-01 36' 00.46"	30 11' 25.39"	1,775	53.4	20.3	5.07		6.05	2	0	0	0	10	100>	0	Not detect
18		Rugarama	Gihuta	Spring Kanyangese	-01 41' 11.0″	30 24' 31.1″	1,364		24	6.6	311	61.6	45<	0.2>	0	0	30	100-150	0	
19			Matunguru Rutindo	HP	-01 40' 44.7″	30 26' 42.0″	1,351		25.7	7	91	18.1	0.2>	0.3	0	0	30	100>	0	
20			Rwikiniro	HP	-01 38' 48.5″	30 27' 24.4″	1,384		25	6.6	98	19.6	1	0.5	0	0	20	100>	0	
21		Rwimbogo	Kiburara	HP	-01 39' 55.3″	30 24' 39.41″	1,406		24.3	6.8	294	58.7	1	0.2>	0.5>	0	70	150	0	
22			Kiburara	HP	-01 40' 04.65″	30 24' 55.98″	1,386		24	6.9	287	57.6	10<	0.2>	0.5>	0	60	100>	0	
23		Gahini		Nyabombe	-01 49' 45.18"	30 33' 25.96"	1,456		23.8	6	57	11.4	5	0.2>	0	0	20	100>	0	Not detect
24		Murama		Gicaca	-02 05' 21.24"	30 35' 10.32"	1,400		24.3	5.6		30.7	10	0.2>	0	0	100	100>		
25				Kabonobono	-02 03' 14.28"	30 35' 47.76"	1,450		26.4	5.7		24.2	2	0.2>	0	0.4	75	100>		
26			Karambi	Gisagora	-01 43' 09.62"	30 28' 02.95"	1,374	20	24.5	5.8	40	7.9	5	0.2>	0	0	10	100>	0	Not detect
27		Murundi	Rukara	Ryakiramba	-01 48' 08.71"	30 30' 50.16"	1,482	20	24.3	6	50	10	2	0.2>	0	0	10	100>	0	
28			Ryamanyori	Nyamga	-01 45' 00.59"	30 30' 05.06"	1,389	15	28	5.9	64	16.7	3	0.2>	0	0	10	100>	0	Not detect
29			Migera	Rugege Ⅰ	-01 54' 25.93"	30 33' 35.75"	1,469	26	23.9	6	51	10.2	3	0.2>	0	0	10	100>	0	
30		Mwiri		HP:Rbonobono Ⅰ	-01 53' 32.18"	30 33' 42.72"	1,485		25	6.5	89	18.7	10	0.5	0.5>	0	20	100>	0	
31				HP	-01 54' 31.44"	30 40' 45.72"	1,330		22.1	6.2		23.2	1	0.2>	0	0	75	100>		
32		Kabarondo		Mubugazire	-02 00' 51.18"	30 32' 43.98"	1,420		23.3	5.3		21.3	10	0.2>	0	0	50	100>		Not detect
33			Rugarama	Cyatokue	-01 49' 44.97"	30 30' 26.30"	1,471		25	5.9	55	11.4	2	0.2>	0.5>	0	10	100>	0	Not detect
34		Rukara		Nyakariba	-01 47' 31.58"	30 29' 30.81"	1,503	8	24.1	6.1	122	24.5	10	0.2>	0	0	20	100>	0	
35				HP	-01 48' 50.54"	30 26' 39.21"	1,459		24.3	6.2	364	76.4	5	0.5	0	0	10	100>	0	
36			Bugambira	Rwanyakajyugo	-02 00' 32.11"	30 29' 09.35"	1,363	41	22.5	5.5	134	26.9	10	0.2>	0	0	20	100>	0	
37			Kabukara	Karaso	-01 59' 28.04"	30 29' 43.43"	1,444	11	22	5.7	129	25.8	10	0.2>	0	0	10	100>	0	
38	Kayonza		Nkamba	Rwanyakagobo	-02 00' 14.13"	30 28' 48.04"	1,367	15	23.8	5.1	138	37.5	10	0.2>	0.5>	0	15	100>	0	
39		Ruramira	Ruyonza	Gitoki	-01 59' 28.30"	30 31' 18.79"	1,478	95	22.5	5.7	135	27	10	0.2>	0.5>	0	30	100>	0	
40			Umubuga	Akabuye	-02 00' 50.69"	30 30' 41.92"	1,377	30	22.4	5.4	159	31.8	10	0.2>	0	0	20	100>	0	
41				Gatore	-01 58' 37.73"	30 31' 29.03"	1,507	32	24	5.3	134	27	10	0.2>	0	0	20	100>	0	
42				Rutaka	-02 00' 23.12"	30 29' 38.48"	1,399	27	23	5.6	145	24.5	6	0.2>	0	0	10	100>	0	
43				HP:Kiyapani-Karambo	-01 59' 41.13"	30 28' 29.54"	1,379		23.4	5.9	209	42	2	0.2>	0	0	20	100>	0	
44				HP	-01 57' 39.24"	30 35' 22.38"	1,370		27.1	5.2		27.3	0.5	0.2>	0	0	100	100>		
45		Rwinkwavu		Spring	-01 59' 17.64"	30 34' 47.22"	1,380		28.5	5.6		33.5	2	0.2>	0	0	100	100>		
46				HP	-01 59' 31.44"	30 34' 09.24"	1,440		21.9	5.6		26	10	0.2>	0	0	100	100>		
47		Gahini	Juru	HP	-01 49' 47.2″	30 33' 17.5″	1,466		24.8	6.5	72	13.9	1>	0.3	0	0	30	100>	0	
48			Karambi	HP	-01 41' 52.03″	30 27' 54.58″	1,364		24	6.9	84	16.9	0.2	0.5	0	0	20	100>	0	
49		Murundi	Karambi Nyamirama	HP	-01 42' 46.6″	30 28' 45.9″	1,355		25.7	7.2	93	18.5	1	0.2>	0	1	20	100>	0	
50			Karambi Rugunga	HP	-01 42' 04.6″	30 29' 03.5″	1,332		24.7	7.6	165	34	1>	0.2>	0	3	10	100>	0	
51			Ryamanyoni	HP	-01 44' 11.1″	30 30' 09.6″	1,347		23.9	6.7	83	17	1	0.2>	0	0.4	10	100>	0	
52		Mwiri	Kageyo	HP	-01 52' 40.0″	30 38' 05.8″	1,336		24.3	6.7	214	43.2	1>	0.5	0	3	20	100>	0	
53			Kageyo	HP	-01 51' 13.6″	30 38' 55.0″	1,317		27.9	10	219	44	1>	0.2	0	3	10	150	0.2	
54		Gatore		HP	-02 17' 16.32"	30 33' 57.66"	1,340		23.3	5.7		41.3	1	0.2>	0	0	75	100>		
55	Kirehe	Kirehe		River	-02 17' 19.14"	30 39' 28.80"	1,410		24.1	5.6		16.4	1	0.2>	0					
56				Spring	-02 15' 51.18"	30 38' 06.06"	1,500		25.5	5.6		24	1	0.2>	0					
57		Gashanda	Mutsindo	Kwamuhire	-02 08' 32.26"	30 30' 21.05"	1,394	43.5	22.3	6.3	58	11.6	10	0.2>	0	0	10	100>	0	Not detect
58		Kazo		Nyamuhinali	-02 11' 42.12"	30 30' 46.62"	1,500		24	6.8		16.5	2	0.2>	0	0	50	100>		
59		kibungo	Karama	Rwasaburo	-02 09' 10.61"	30 31' 53.04"	1,446		21.2	5.9	66	13.2	10	0.2>	0	0	10	100>	0	Not detect
60		Murama	Mvumba	HP	-02 11' 48.53"	30 33' 50.74"	1,377		22.5	6.6	194	38.8	0.5	0.2	0	0	50	100>	0	Not detect
61	Ngoma	Rukira	Kibatsi	Gasovo	-02 07' 18.66"	30 39' 04.62"	1,680		27	5.2		26	1	0.2>	0	0	50	100>		Detect little
62		Sake	Nyarurembo	Kiriko	-02 12' 44.82"	30 23' 37.80"	1,330		26.6	5.5		13.1	2	0.2>	0	0	50	100>		Detect little
63				Rukoma	-02 11' 53.22"	30 22' 50.76"	1,360		24.4	5.8		12.6	5	0.2>	0	0	50	100>		
64		Zaza	Ruhinga	Gisuma	-02 11' 50.57"	30 24' 50.62"	1,357	270	24.4	6.4	54	10.7	5	0.2>	0	0	10	100>	0	Not detect
65				Gisuma	-02 11' 47.34"	30 25' 12.06"	1,350		22.3	5.3		12	10	0.2>	0	0	50	100>		Detect little
66		Gishari		Muhazi lake	-01 54' 05.46"	30 25' 48.81"	1,449		26.4	8		55.3	1	0.2>	0	0	75	100>		Detect little
67		Kigabiro		HP	-02 02' 10.02"	30 25' 33.12"	1,350		21.6	5.2		38	8	0.2>	0	0	75	100>		
68	Rwamagana	Musha		Kagarama	-01 55' 42.36"	30 21' 17.52"	1,470		27.3	5.5		41.7	1.5	0.2>	0	0	100	100>		Not detect
69		Muhazi		Kavura	-01 56' 28.98"	30 26' 23.20"	1,456	67.9	21.7	5.5		10.99	20	0	0	0	50	100>	0	Not detect
70		Fumbwe	Nyagasambu	Gahondohondo	-01 53' 35.49"	30 16' 52.40"	1,434	76.6	22.1	5.34		33.4	20	0	0	0	50	100>	0	
71		Mukara		Gihengeri	-01 31' 17.00"	30 10' 38.97"	1,540	220	20	7.26		6.5	10	0.2>	0	0	10	100>	0	
72		Kiyombi		River Water	-01 24' 43.75"	30 05' 26.73"	1,694	33600	17.4	6.53		5.52	1	0.2	0	0	10	100>	0	
73			Kamate	HP	-01 23' 00.7″	30 24' 54.0″	1,350		27	6.6	66	13	10	0.2>	0	0	10	100>	0	
74			Kizirakome	HP	-01 25' 11.8″	30 23' 42.1″	1,351		25.1	6.9	118	24.4	3	0.2>	0	1	20	100>	0	
75			Mbare	HP	-01 23' 39.1″	30 23' 00.9″	1,343		26.3	7.5	272	54.3	1	0.5	0	3	100	100-150	0	
76		Karangazi	Mbare Kajumo	HP	-01 25' 22.3″	30 21' 56.5″	1,350		26.3	7.4	100	19.8	2	5	0	1.5	50	100>	0	
77			Ndama	HP	-01 24' 51.8″	30 28' 07.2″	1,350		26.4	7.1	119	23.8	1>	2	0	3	50	100>	0	
78			Ndama	HP	-01 25' 44.1″	30 25' 52.2″	1,382		26.2	6.8	97	19	5	0.2>	0	3	30	100>	0	
79			Rwisirabo	HP	-01 23' 57.5″	30 24' 21.8″	1,361		27.3	7.2	285	57.1	1.5	0.2>	0	3	10	150	0	
80			Rwisirabo	HP	-01 24' 14.3″	30 23' 07.8″	1,332		25.7	7.8	287	57.9	1	1	0	3	50	100-150	0	
81		Matimba	Bwera	HP	-01 18' 44.6″	30 25' 45.0″	1,375		26	7.1	215	43.8	10	0.2	0	0.8	50	100>	0	
82			Rugarama Ⅰ Nyabyihur	HP	-01 08' 21.2″	30 23' 56.5″	1,390		26.4	7.4	220	44.2	2	2	0	1	60	100>	0	
83		Musheli	Musheli	HP	-01 07' 38.3″	30 24' 02.9″	1,371		26.3	7.2	244	49.8	2	1	0	0.4	70	100>	0	
84			Rugarama Ⅰ	HP	-01 07' 41.5″	30 25' 03.5″	1,364		26.3	7.4	433	86.5	2	0.2>	0	1.5	100	200<	0	
85	Nyagatare	Nyagatare	Kamagiri	HP	-01 19' 49.5″	30 24' 07.5″	1,351		26.2	7.4	327	65	5	0.2>	0	1.5	70	100>	0	
86			Rutaraka	HP	-01 18' 49.3″	30 21' 42.9″	1,377		26.8	7.8	175	35	0	0.2>	0	1	50	100>	0	
87			Gasenga	HP	-01 10' 59.8″	30 20' 55.0″	1,337		27.1	7.3	235	47.7	0	2	0	1	60	100>	0	
88			Kabare	HP	-01 14' 12.2″	30 21' 40.3″	1,358		27.5	7.8	201	40.6	2	2	0	3	30	100>	0	
89			Kabare gituro	HP	-01 14' 47.3″	30 22' 34.9″	1,374		26.5	7.6	204	40.5	7	0.2>	0	1	100	100>	0	
90		Rwempasha	Kabare gituro Ⅱ	HP	-01 14' 42.2″	30 23' 41.3″	1,384		27	7.4	104	20.8	2	1	0	0.8	50	100>	0	
91			Nyamenge	HP	-01 07' 45.8″	30 21' 01.0″	1,336		26.3	8.1	485	96.5	1>	0.2>	0	3	30	150	0	
92			Nyarupfubire	HP	-01 13' 49.9″	30 23' 05.7″	1,353		26.3	7.5	180	36.2	2	0.2>	0	1.5	50	100>	0	
93			Nyarupfubire Ⅱ	HP	-01 13' 23.7″	30 23' 58.7″	1,370		26	7.5	100	20.2	5	0.2>	0	0.8	50	100-150	0	
94			Ryeru	HP	-01 12' 33.7″	30 17' 35.5″	1,398		26.3	7.2	159	31.7	5	0.2>	0	0	70	100>	0	
95			Kabeza	HP	-01 15' 47.0″	30 25' 31.6″	1,349		25.7	6.7	73	14.6	2	0.2>	0	0.4	20	100>	0	
96			Kabeza	HP	-01 14' 27.3″	30 26' 02.9″	1,347		27.4	7.1	127	25.5	2	5	0	0.3	30	100>	0	
97		Rwimiyaga	Kamagiri	HP	-01 18' 23.0″	30 22' 25.9″	1,365		25.6	7.3	108	21.5	15	0.2>	0	1.5	30	100>	0	
98			Kirebe	HP	-01 18' 25.9″	30 26' 40.9″	1,335		27.6	7.3	330	66.1	1	10	0	3	10	150	0.1	
99			Ntoma	HP	-01 12' 41.3″	30 25' 34.9″	1,359		26	7	164	32.7	5	0.2>	0	0	50	100>	0	
100		Mayange		HP Gahwiji 1	-02 13' 38.78″	30 03'32.14″			24.7	6.67	1660	324	0.02	0.48	3.1	0	570	7.3		Detect little
101	Bugesera			HP Gahwiji 2	-02 21' 26.38″	30 12'18.50″			25	6.8	1153	226	0.04	0.48	3.5	1.18	1000	15.3		Detect little
102		Musenyi		HP Nyakajuli	-02 13' 40.58″	30 05'21.33″			23.7	6.74	1134	220	0.04	0.12	0.052	0.72	690	45.75		Not detect
WHO Guideline, 3rd Edition									-	-	1000	-	50	0.3	0.4	1.5	Acceptable	250	-	Not detected

*Values not meeting WHO guideline values are shown in yellow.

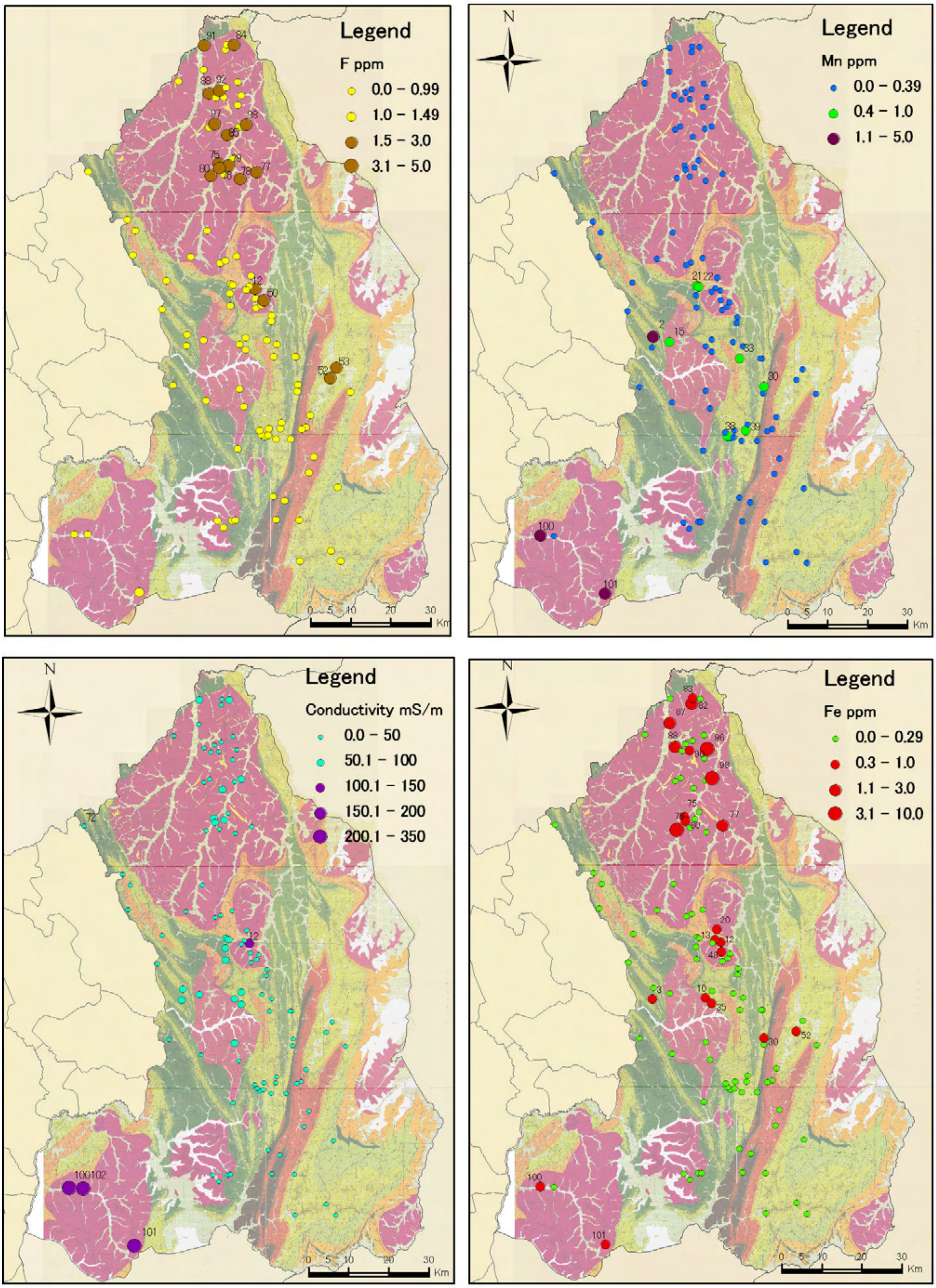


Figure S3-21 Water Quality Distribution Map (Fluoride, Manganese, Conductivity, Iron)

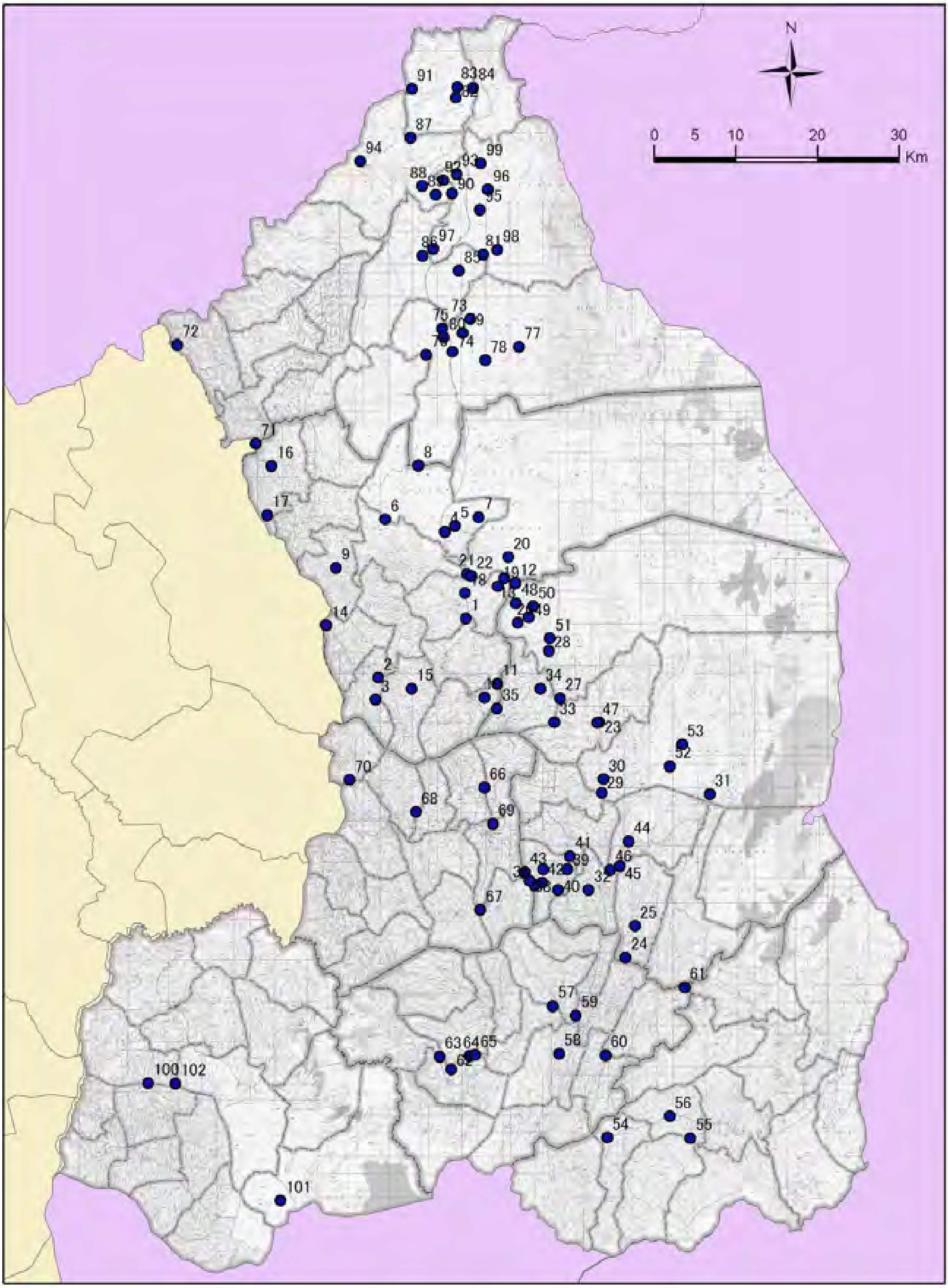


Figure S3-22 Water Quality Sampling Location Map