No.

Ministry of Agriculture and Animal Resource

The Republic of Rwanda

STUDY REPORT
ON
THE PREPARATORY STUDY FOR FORMULATION OF THE PROGRAM FOR RURAL DEVELOPMENT IN EASTERN PROVINCE IN THE REPUBLIC OF RWANDA (IRRIGATED AGRICULTURE)

JULY 2009

JAPAN INTERNATIONAL COOPERATION AGENCY

SANYU CONAULTANTS INC.

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PREFACE

In response to a request from the Government of the Republic of Rwanda, the Government of Japan decided to conduct a preparatory study on the Project for Formulation of the Program for Rural Development in Eastern Province and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Rwanda a study team from February 27th to May 6th, 2009.

The team held discussions with the officials concerned of the Government of Rwanda, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, the present report was finalized.

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

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Rwanda for their close cooperation extended to the teams.

July 2009

Yoshihisa Ueda
Vice-president,
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

We are pleased to submit to you the study report on the Preparatory Study for Formulation of the Program for Rural Development in Eastern Province in Rwanda (Irrigated Agriculture).

This study was conducted by Sanyu Consultants Inc., under a contract to JICA, during the period from February to June 2009. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Rwanda and formulated the most appropriate basic design for the project under Japan's Grant Aid Scheme.

Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

Nobuaki Chiba

Project manager,

Preparatory study team on
the Preparatory Study for Formulation of
the Program for Rural Development in
Eastern Province in Rwanda (Irrigated
Agriculture).

Sanyu Consultants Inc.

SUMMARY

1 Objective of the Study

The Ministry of Agriculture (MINAGRI) of the Government of Rwanda has promoted Land-husbandry, Water harvesting and Hilliside-irrigation Project (LWH), which is to establish 101 sites of commercialized agriculture practices through land improvement, securing farmlands, and hillside irrigation in order to effectively contribute to practicing the Strategic Plan for Agricultural Transformation(SPAT). Then MINAGRI has requested the Government of Japan to assist in implementing four (4) sites among the 101. This Study is a preparatory study for the implementation of the Project based on the above request and the following are the objectives of the Study:

① To Study the relevance and feasibility f the four (4) sites of LWH requested to the Government of Japan from the viewpoints of technology, economy, natural and socio-economical conditions such as social, economical, cultural, institutional, financial, technical, agronomical, O&M aspects, etc., and environmental consideration.

② To assist JICA to prepare for the terms of reference of the subsequent study (Basic Design Level), which includes study scope, contents, required experts, etc. if such study was decided to conduct (confirmation of priority on facilities and equipments, collection of basic data for designing facilities, and recommendations for conducting basic design study)

③ To study on the cooperation program of JICA (this Study is a part of the preparatory study of the cooperation program of JICA and therefore, relation between this Study and the preparatory study of the cooperation program should be taken into consideration. Hence, the Study should clarify the position of LWH Project within the frame / strategies of the cooperation program.

④ To collect information to examine the relevance and necessity on implementing the Technucal Cooepration Project in Eastern Province (“Agricuture Development in the Southern Part of Eastern Province” (provisional title))

⑤ To study the possibility of collaboration and contents of the cooperation in order to make synergy effects with the LWH Project and Technical Cooperation Project

2 The Study Area

The Study Area consists of originally four (4) Project sites, which are located in Bugesera, Ngoma and Gatsibo Districts. The four (4) sites are named Bugesera 2 Gashora, Ngoma 21 Remera, Ngoma 22 Rurenge, and Gatsibo 31 Rugarama. After the Study Team finished the field work, MINAGRI requested JICA to study additional two (2) sites called Bugesera 3 Ririma and Bugesera 4 Museni. These two (2) sites were studied using existing data and documents and a brief field visit made by the Study Team during the field work.

Bugesera 2 Gashora site is located in the southern part of the Eastern Province, 33km south-southwest of Kigali. About 500m away from the main road is the planned dam axis site. There is a lake called Rumira about 3km downstream the dam axis and the rainfall in the catchments flow into the lake. Bugesera 3 site is planned just next valley to Bugesera 2 site and the streams at the bottom of the valleys of both sites meet on the way to the lake. Ngoma 21 Remera and Ngoma 22 Rurenge sites are located 57km east-southeast of Kigali and both sites are adjacent each other. The streams of both sits flow into the lake Mugesera located 10km downstream the planned dam axis site. Gatsibo 31 Rugarama is located 45km east-northeast of Kigali, on the foot of a mountain with the elevation of around 1668m. Rainfall in the catchments flow into river Rwagitima, which is a branch of river

Acagera. Bugesera 4 sites is located 23km south of Kigali and the rainfall in the catchments goes through marshlands into river Akanyaru.

Following tables show the administration jurisdiction of the Project sites, population of potential beneficiary Imidugudu, present cropping patterns based on the socio-economic survey. Because the bottom of the valley for Ngoma 22 Riurenge site is a boundary of Rurenge Sector and Remera Sector, one Cell each from the two Sectors are included in the beneficiary area. Bugesera 3 is also located with the same situation with Ngoma 22 Rurenge. The data of Bugesera 3 Ririma and Bugesera 4 are quoted from detailed design reports of LWH.

Potential beneficiary imidugudu are from two (2) to six (6) per site. The number of household in the Imidugudu varies from 280 to 1,090. Share of woman headed family counts around 20% to 30%. Major crops grown at present are drought tolerant crops such as sorghum, cassava, sweet potato, and haricot beans. There are farmers growing vegetable in some part of the field. Maize and banana are also observed to grow as staple food. There are paddy field in Ngoma 22 Rurenge site though it is a small-scale.

Table 1 Administrations in the Project Sites

Site	District	Sector	Cell	Imidugudu
Bugesera 2 Gashora	Bugesera	Gashora	Kagomashi	(3) Akagako, Kuwuruganda, Kagomashi
Ngoma 21 Remera	Ngoma	Remera	Bugera	(4) Rweso, Gisumuzu, Mumini I, Mumini II
Ngoma 22 Rurenge	Ngoma	Rurenge	Rujambara	(4) Nyabaganza, Gitobe, Mbonwa, Masyoza
		Remera	Ndekwe	(2) Gikomero, Rugando
Gatsibo 31 Rugarama	Gatsibo	Rugarama	Gihuta	(2) Gashenvi I, Agatare
Bugesera 3 Ririma	Bugesera	Ririma Gashora		(2) Gasarwe, Nyabagendwa
Bugesera 4 Museni	Bugesera	Museni		(3) Bishinge, Gakurazo, Kijuli

Table 2 Population in the Project Sites

Site		No. of HH	Male	Female	Total	Ave. Family size	Woman headed (%)
Bugesera 2		279	483	654	1,137	4.1	91 (33%)
Ngoma 21		409	710	944	1,654	4.0	106 (26%)
Ngoma 22	Rurenge	684	978	1,379	2,357	3.4	150 (22%)
	Remera	405					
	Total	1.089					
Gatsibo 31		301	912	1,399	2,311	7.7	66 (22%)

Table 3 Present Crop (from Socio-economic Survey)

Bugesera 2	Share of Farmers who grow crops (%)									
Surveyed HH	haricot bean	cCassava	sorghum	maize	sweet potato	banana				
40 HH	93%	83%	80%	80%	50%	35%				
Ngoma 21	Share of Farmers who grow crops (%)									
Surveyed HH	cassava	sorghum	s. potato	bean	tomato	maize	cabbage	carrot	onion	banana
39 HH	62%	56%	51%	41%	23%	15%	15%	13%	8%	3%
Ngoma 22	Share of Farmers who grow crops (%)									
Surveyed HH	sorghum	haricot bean	maize	rice	cassava	s. potato	banana	cabbage		
37 HH	68%	46%	32%	19%	19%	11%	8%	3%		
Gatsibo 31	Share of Farmers who grow crops (%)									
Surveyed HH	maize	Sorghum	Haricot bean	banana	rice	cassava	s. potato	Cabbage		
38 HH	63%	42%	37%	16%	11%	5%	5%	5%		
Bugesera 3	Share of Farmers who grow crops (%)									
Surveyed HH	beans	Cassava	sorghum	maize	s. potato	soybean	ground nut	Banana		
33 HH	100%	94%	91%	85%	82%	39%	18%	9%		
Bugesera 4	Share of Farmers who grow crops (%)									
Surveyed HH	beans	Cassava	ground nut	sorghum	cash crop	maize	s. potato	Iish potato		
33 HH	97%	97%	73%	67%	58%	48%	45%	27%		

3 Plan of Dam Construction

Upon planning the dam construction, the Team carried out a series of natural condition surveys mainly in the upstream reaches of the planned dam axis points. Items of the surveys were metrological and hydrologic survey, river and catchments conditions, survey for selecting the dam axis, boring survey at the dam axis, survey for materials of dam body, in outline survey of fault, survey on earthquake, and location survey. Following table summarizes the results of the surveyes:

Table 4 Situation Analysis on Planning Dam

Item	Bugesera 2 Gashora
Site	The catchments are spread across main road in the middle. Because the upper side of the main road is a military owned forest, dam axis shall be planned to locate avoiding the military land and also designed as the full water level of the dam reservoir does not reach to the military land.
Dam Axis	The point around 400 m downstream from the road is deemed suitable for dam axis as it will cause less dam embankment volume judging from the topographic condition of both banks which is narrowed. Upstream therefrom may result in shallower storage pocket. In downstream from the 400 m point, right bank side is widely opened causing much larger embankment volume. An alternative to cover the neighboring valley on the east side was considered, but because the irrigable area becomes small, the efficiency of this alternative was considered low.
Geological condition	As confirmed in the field survey, the surface layer of both banks is covered by those soils derived from weathered granite compositions. As the material for the dam embankment, this can be used as impervious material. In the center of the valley, there is a low land but no river is observed. The land surface is covered by alluvium deposit containing much sandy nature. During considerable floods, there can be seen a surface flow and silt and clay are to be flown away to further downstream. In the downstream conjunction point with the western right bank valley, no surface flow can be seen. The area is covered by sand and borrow pits of sand are found with having the sand layer thickness of

	about 3 m. The sand layer is considerably hard and the permeability is seemed to be low. Gravels are found in the upland field on the sloping land. These gravels are of quartz rich derived from the weathered granite but the quantity of gravels is not much. For the embankment material, such weathered silt and sand originated mainly from granite will be used. As per the boring survey results, both banks have solid foundation at the depth 3 m or deeper and at the river bed it is solid at the depth of 6 m or deeper. Permeability of foundation is judged to be impervious with about 3 Lugeons.
Others	Flood water from Bugesera 2 Gashora and the nearby catchments are to pass through the beneficiary area of Bugesera 3 and secondary pipelines as irrigation facilities are to be installed at the river bed. In this case, the said flood water and pipeline embedded below river bed cross each other. Even in the case Bugesera 2 Gashora would not be built, the same crossing may occur and cause operation and maintenance problem in future. MINAGRI official confirmed that it is possible to modify the plan of Bugesera 3 transferring the subject beneficiary area.

Table 5 Situation Analysis on Planning Dam

Item	Ngoma 21 Remera
Site	The site indicated in the LWH project report was different from the actual site. The Study Team confirmed the location through tracing by use of GPS and due confirmation by the officer in charge at the site. On the right bank side the topography is rather steep with natural bush while the left bank side gently sloping land used as upland field.
Dam Axis	There are springs at the right bank river bed in immediate downstream from the dam axis as requested, being the water source for the local people and concrete structures as installed with pipes are existing there. In the river there is some surface flow though a little and never dried up even in the dry season as per the information at the site. According to the local people, here had been some springs at about 100 m upstream in the past, though presently being abandoned field. At the said upstream spring point, no water intake facilities are existing and further upstream area is topographically raised up sharply without any surface flow or streams. In a distance of 180 m from the requested dam axis, the ground elevation is up by 10 m implying that the storage depth reduced by 10 m and therefore the site is judged not suitable for building a dam. It is also considered if including the spring site in the reservoir area, a reverse flow may happen or stored water may leak through spring due to the high pressure by stored water. Accordingly, it is necessary to locate the dam axis at further upstream of the spring site located upstream. The longitudinal profile of the valley is quite steep at 1/20 and a dam axis with comparatively favorable reservoir pocket can be found at around 580 m upstream from the requested dam axis point. At this site, a storage of 442,000 m3 can be expected with 16.6 m dam height and crest length of 400 m (In case dam embankment material be secured inside the reservoir area). The requested dam axis case, the crest length may be shorter at 370 m but due to the topography the storage capacity much less than the new site.
Geological condition	The ground surface is covered with soils as derived from weathering of granite and sandy-muddy sedimentary rocks and it is considered suitable in this case to use the impervious material taken from the weathered granite soils at the left bank abutment. In the river bed there found no much sand and it can be considered that river bed deposits are retained due to the higher groundwater table at the right bank test pit site. As the impervious embankment material, heavily weathered zone can be used. Though it can not be clarified in case of sandy nature soil, but small gravels can be found at the higher elevated locations and therefore it can be considered the weathered soil material is originated from conglomerate. For the rock materials, conglomerate and granite can be considered available. On the ridges of both banks there found some outcrops and rock material can be availed for dam construction though it may require some distance for transportation.

Table 6　Situation Analysis on Planning Dam

Item	Ngoma 22 Rurenge
Site	The site indicated in LWH report is actually a different site. The study team, therefore, fixed the correct location through confirming the site with the officer in charge at the site and fixing by using GPS. Both banks are upland fields with rather gentle slope. Over the river nearby the requested dam axis, there is a box-culvert bridge. In some years ago there had been a plan to provide a crossing of both bank roads at this location, but there have been no any substantial progress for the plan. The river with the width of only 1 m has surface flow and even in dry season flow does not disappear according to the local people. In the area as far as 1,140 m upstream from the requested dam axis, there are springs as equipped with pipe intake facilities for use of local people.
Dam Axis	The requested dam axis is the site where topographically both banks narrowing and seems possible to select a dam axis to cause the minimum dam embankment volume. The existing culvert structures at the dam axis area shall be removed and the dam crest will be used as a substitute facility to connect the both banks. To maintain the subject water intake facilities to be fully utilized by the people, the full water level of reservoir shall be fixed at lower than the intake. As is the case, the full water level is recommended to be fixed at 1 m lower than the crest of intake facility so as to avoid such negative effect.
Geological condition	The ground surface at the site is considered derived from weathering of granite and/or sandy-muddy sedimentary rocks and as the impervious materials for dam embankment the weathered granite zone on the left abutment is assumed possible for use. There is no much sand in the river bed and from the observation at the test pit it is considered that there are some clayey river bed deposits retained at the river bed. On the right bank abutment, there found shallow layer of weathered sandy-muddy mica schist. As the rock materials, there is a possibility to find them at the steep sloping area nearby. On the ridges of both banks, outcrops of rocks are found here and there.

Table 7　Situation Analysis on Planning Dam

Item	Gatsibo 31 Rugarama
Site	As many as 3 gullies with having steep mountain at the back join together at around the requested site and flows down further as a single gully. Being gullies, the both banks are of bluff ones and the cross section is not suitable for any dam construction. The difference of elevations between the flat bank ground and the river bed surface is observed at about 15 m and if the flat ground of both banks be used as reservoir area, then the dam height should exceed 15 m at the minimum. There found some low ridges stretched over both banks and if fix the dam axis to contact with those ridges, dam construction might be possible but careful attention shall be paid on the possible difference in subsidence on the part of dam body inside the gully and the transition part to connect with the dam body of flat ground on the bank. The gully flows down gradually scaling down its cross section area and changes the direction before crossing the road and further flows down to the north along the road. After flowing down by 700 m the gully crosses with under the road by culvert. After crossing, there is no water way in the vicinity. During the flooding time, the drained water inclusive of silt and sand intrudes into paddy fields causing lodging of rice plants and considerable soil and sand deposits in the paddy fields.
Dam Axis	The longitudinal gradient of gully type river is comparatively steep and storage in the gully section is quite limited. The requested dam axis is located at immediate downstream of the conjunction point by 3 gullies and the dam axis is lined from the hill with outcrop of rocks on the left bank to the gently stretched ridge on the right bank. In this case, the right bank elevation is high enough and the dam body can be connected with the flat ground at the downstream. If the dam axis is located at the downstream of the conjunction point, there would be some advantage in the reservoir storage capacity, but the elevation difference from the ground of both banks to the river bed of gully is about

	15 m only and the storage will e decisively in sufficient due to the water storage only within the gully section.
Geological condition	It is assumed that a rapid flow penetrated into the foot of mountain, where sandy-muddy sedimentary rocks and granites had been largely transformed, and eroded the ground to create the gully shaped river. Both banks of the gully maintains vertical cliff of 15 m in height. The cliff has some strength but subject to erosion by rapid flow. Though it is of complex metamorphic rocks, the geology is not of the pervious one and there is a possibility to have a reservoir. In the layer a little higher than the river bed, some gravels are exposed and some scoops can be observed at the lower position of gravel layer. Such gravel or sand material for filter can be available as they can be seen on the bed of gully or drains. In the upstream of dam axis test pits are excavated to judge the availability of embankment materials, and it was found out that the impervious material is available only up to the depth of 4 m.
Others	According to the inception report prepared for the detailed design of eight (8) sites of preceding LWH Project sites, Gatsibo 32 site is designed to cover the beneficial area of Gatsibo 31. Paddy fields in the downstream reaches of the site across the main road are to be covered by the RSSP project, which started in April 2009 to construct the dam to irrigate the paddy fields. Then at the time of interim reporting on the field survey, MINAGRI has confirmed no justification for Gastibo 31 and informed the Study Team to give up the planning. Accordingly the Study Team cancelled the planned boring survey for GATSIBO 31 site with due confirmation by JICA.

Table 8 Situation Analysis on Planning Dam

Item	Bugesera 3 Ririma
Site	Bugesera 3 Ririma is located in the valley neighboring with Bugesera 2 Gashora having the northern ridge of Gashora in between. The upstream of road in the catchments is the forest of military area same as Bugesera 2. The present slope of both banks at the vicinity of dam axis is about 1:7 on both left and right banks.
Dam Axis	Location of Bugesera 3 dam axis is so decided that the stored water would not reach to the military area at the full water level at 400m downstream from the main road. 16.2 m of dam height is planned. For the standard cross section of dam body, an impervious blanket zone will be provided at the upstream side so as to reduce the possible seepage from the dam body foundation. The blanket shall be I m thickness and the length must be 5 times of the maximum water depth.
Geological condition	The local geology of Bugesera 3 is characterized by an igneous intrusion of granite composition. Road cuts and local excavations show that the rock has undergone high to complete degree of weathering. It is quartz rich with significant mica minerals. The granite at the site is affected by high degree of weathering that it is transformed into sand to gravelly sand soil. The depth of weathering is large (More than 5 m) as seen from the nearby road cuts and the test pits. In 50 m stretch on the river bed along the dam axis, there are clayey soils originated from complete weathering of granite or river bed deposits though quite a little. Further in the stretch of 150 m on the river bed it is assumed that the 15-20 m depth weathered zone includes a variation from silt/sand to weathered rock with cracks. Further on the surface layer of both banks, it is assumed to have coarse sands as derived from weathering of granites. Embankment materials can be available within the vicinity area of the site and the impervious core material within the reservoir area. While such semi-pervious (sandy), filter material and rock material can be availed in the vicinity.
Others	Flood water from the spillway to be designed in Bugesera 2 and drain water from the neighboring catchments will cross the pipeline of Bugesera 3 designed to be laid underground at the bottom of the river bed. It is, therefore, required to re-design the irrigation service area of Bugesera 3 in order to avoid the affect from the flood and drain water to the structure of Bugesera 3.

Table 9　Situation Analysis on Planning Dam

Item	Bugesera 4 Museni
Site	Bugesera4Museni is located in comparatively flat topography with the elevation of about 1,400 m and as per the 1/50,000 topo-map there are high and steep mountains ranging at about 1,500 m elevation in the upstream basin. The lower moving down the basin, the gentler the gradient of both banks. At about 2 km downstream from the site there extends wet lands and at about 5 km point to north-west from the site, the flow empties into Akanyaru river, a tributary of Nyabarongo. Both at the upstream and downstream of the reservoir area, there are springs existing. The upstream one is situated higher than the reservoir full water level and the downstream one is on the mid slope of the mountain being 300 m distant from the reservoir and expected no influence on the reservoir. The slope gradients are confirmed lower than 16 % for 98 % area of both catchments area and beneficiary area.
Dam Axis	Upstream basin is quite steep but getting down to lower stream the valley shape gradually opened and the gradient of both banks become gentler too. Accordingly, the storage capacity becomes larger when the dam site moving to further downstream due to the wider river width and the gentler gradient of both banks, but at the same time the dam crest length and the embankment volume becomes larger too. In fixing the subject dam axis, the followings are the key points: there are houses of local resident in and around the reservoir area and the full water level be restricted to some level. Further, it is considered necessary to select either the foundation treatment by cement-milk grouting or adopting a homogeneous type dam with the dam height lower than 15 m, when considering the major dimensions as derived from the detailed design as the followings: scale of dam: Dam height: 26.5 m=crest EL144.5 m – Impervious zone EL118.0 m, 30.5 m of core zone bottom width, and deep fractured zone along the fault surface.
Geological condition	The base rock foundation in general is of pre-Cambrian and in and around the site is covered by metamorphic rocks predominantly consisting of mica-schist including quartz. On the slopes of both banks of reservoir, there found outcrops of mica-schist and the same is highly weathered. These rocks form sloped foundation both to up and down stream directions and is considered that the same indicate both joint and surface of discontinuity. The rocks are featured by quartz vein crossing the mother rock and are hydro-thermally altered. The mother rocks are widely covered by residual silt and highly weathered up to considerable depth. The valley portion is covered by dark-brown color and non-organic silt clay with about 4 m thickness. The both banks are covered by thick silt/sand layer derived from the weathered base rocks. Geology at the upstream of spillway is of highly-medium weathered rocks and the layer is measured at about 5 m in thickness. Of the result of resistivity imaging survey conducted on the dam axis, the detailed design report describes the following reference as [On the left bank of dam axis firm rock foundation is found on shallower level and on the right bank also no problem in the foundation though the weathered rock surface is thick, while an existence of fault is assumed at the river bed portion.] From the analysis it is not definitely clarified how to deal geo-technically with the possible existence of fault at the dam axis and it is noted that under the present planning boring survey on fault existence is necessary prior to the construction works and in some case additional survey including the dam axis at the time of pre-feasibility phase shall be made.

4　Plan of Cropping Pattern with Project

Cropping pattern with the Project is proposed corresponding the aspiration of the farmers (crops they wish to grow with irrigation) recognized by the socio-economic survey, and also considering the technical conditions such as the capacity of the proposed dam and the policy of LWH Project.

Especially in all the sites except for Gatsibo 31 Rugarama, most of the farmers wish to grow rice if there was enough irrigation water. Therefore, cropping pattern with rice will also be considered. Tables below shows the farmer's aspiration on crops to grow with irrigation.

Table 10 Aspiration of Farmers with Irrigation (from Baseline Survey)

Crop	Bugesera 2	Ngoma 21	Ngoma 22	Gatsibo 31
No. of Sample HH	40	39	37	38
Maize	55%	79%	16%	82%
Cabbage	55%	41%	59%	-
Tomato	30%	28%	41%	3%
Carrot	33%	28%	30%	3%
Other Vegetables	53%	26%	57%	84%

Other Vegetables: onion, eggplant, leek etc.

Table 11 Intention of Rice Crop of the Sample Farmers

Crop	Bugesera 2	Ngoma 21	Ngoma 22	Gatsibo 31
No. of Sample HH	40	39	37	38
Rice	100%	100%	84%	24%

Source: Result of the Baseline Survey by JICA Study Team

5 Plan for O&M

Based on the decentralized policy of the government of Rwanda, practices of the on-going projects and the economic activities in the rural areas, it is a basis that farmer beneficiaries are primarily responsible for the O&M of irrigation facilities to be constructed by the Project. Farmer beneficiaries are therefore organized to become a cooperative through the Project. Farmers organization (Cooperative) will manage the irrigation facilities by their own responsibility and when the issue arisen is beyond the capacity of the cooperative, Sector office will intervene the cooperative and if the issue is beyond the capacity of the Sector, the issue is carried forward to the District. This is the basic framework of O&M of irrigation facilities.

The central government, MINAGRI and MINALOC are implementing programs such as poverty reduction and promotion of chemical fertilizers and improved seeds through the set-up of the local administration – cooperative. For example, MINALOC is providing subsidy to the poor for compensation of water fee for boreholes through District and Sector. MINAGRI is providing subsidy for fertilizers and hybrid seeds of maize through the local administration for modernization of agriculture. The O&M of the irrigation facilities to be constructed by the Project will follow this basic framework of the set-up, namely establishment of cooperative for primary O&M body and issues arisen beyond the capacity of the cooperative will be forwarded to the local administration.

In Rwanda, "Cooperative" is defined as a group of people engaged in economic activities. As for the group engaged in non-economic activities it is defined as "Association". Cooperative is registered to the Rwanda Cooperative Agency (RCA) under the Ministry of Trade and Industry, while association is registered to the Ministry of Justice. The Government of Rwanda has been promoting the establishment of cooperatives to achieve the targets of Vision 2020, MDGs and EDPRS, as the cooperative is recognized as a viable tool for poverty reduction and economic growth.

In Rwanda, it is common that agriculture cooperative organizes water management committee within the cooperative and manages the irrigation facilities. Donor assisted project such as RSSP or

Lux-development are also following the same way as they assist in establishing agriculture cooperative by the farmer beneficiaries, which will be the body of O&M of the facilities. On the other hand, the officer in charge of LWH told the Study Team in a meeting that MINAGRI has made a policy that cooperative to manage the irrigation facilities should be separated from agriculture cooperative in order for the cooperative to concentrate on the O&M of the irrigation facilities.

As mentioned above, the government of Rwanda has been promoting cooperative to realize the economic growth and poverty reduction and the establishment of agriculture cooperative would be effective to activate the irrigated agriculture in the Project site. It is, therefore, proposed that the Project would assist in both establishing water users association as a cooperative and agriculture cooperative. Then it is suggested that the government side and farmer beneficiaries should have a consultation on farmer organization and decide whether to establish water users association solely dealing with irrigation water management and agriculture cooperative separately or integrate both bodies (agriculture cooperative and water management committee in its institutional set-up) or other ways based on the intention of the farmer beneficiaries.

6 The Study on Environmental and Social Consideration

This study was conducted for the legal framework of the relevant laws and regulations on the environmental and social considerations, environmental administration, the process on environmental impact assessment in Rwanda and the site survey of the proposed project sites, and followed by preparation of future schedule for the EIA process on the proposed project and the recommended mitigation measures. The proposed irrigation project including dam reservoir will require the process of full EIA.

The requirements on EIA process for the proposed project are summarized as follows;

1. As a first step, a Project Developer in Rwandan side should be decided for the implementation of the proposed Japan's Grant Aid project
2. After the Project Developer is decided in Rwandan side, the Japanese side will assist the Project Developer's EIA works during Basic Design Study through identifying the basic dimensions and the affected areas by the proposed project.
3. The project Developer will apply for the EIA process by submitting a Project Brief to REMA who is an examination body, and a TOR for the proposed project will be decided after the screening of REMA.
4. After the TOR is decided, the project developer will appoint a registered EIA Expert for the actual work for EIA study.
5. After the EIA Expert is appointed, the JICA Basic Design Team will assist his EIA study based on the results of the Basic Design Study.
6. It will take 4 to 6 months from the Project Developer's application for EIA process to the approval by REMA (it took four (4) months in case of RSSP project). Then, there will be an agreed E/N between the Japanese Government and Rwandan government. After E/N agreed in both sides, the project developer will decide the approved implementation of the proposed project and proceed to land expropriation.

The appropriate survey / study or mitigation measures will be necessary for the potential adverse impacts or unknown impacts which will be anticipated by the proposed project.

The following results were identified as important issues in relation to the implementation of the project;

The land expropriation and its compensation for the submerged agricultural lands:

> The resettlement will not be caused by the project since there was no dwelling house in the upstream side of the project sites. However, some agricultural lands were identified in the upstream reservoir of the proposed project and also some agricultural lands in the downstream sides will be affected by the development of irrigation facilities such as canals and spillways.

Appropriate measures for landless farmers:

> Landless farmers were identified. Some possibilities are recommended that they can be employed as the staffs for operation and maintenance of the irrigation facilities in the newly introduced water users association or the land reallocation to them after the reallocation of existing farm lands for earning their livelihood through crop production.

Environmental issues during construction:

> Some impacts of noise and vibration are estimated at the access roads which will reach the project sites since some dwelling houses were facing the roads which are located on steep slopes.

7 Technical Assistance

Technical assistance of the Project is considered not only implementing as a component of the Grant Aid Project but also collaborating with other schemes of Japanese Official Development Assistance (ODA) such as technical cooperation project and Japanese Overseas Cooperation Volunteer (JOCV). Technical assistance as a component of the Grant Aid is planned to implement at the end period of the construction work. As for the collaboration with other schemes, a technical cooperation project in the Eastern Province for agriculture development is scheduled to commence in 2009 and this project could be a candidate to collaborate with the Grant Aid Project during and after the construction period. Dispatching JOCV could be considered when the irrigation facilities are constructed and start for use probably around mid 2011. JOCV could work together with the Sector and Cell officers for effective use of the facilities to be constructed.

1) Technical Assistance as a Component of the Grant Aid Project

The technical assistance, which will be implemented by the Japan's Grant Aid Project, is planned to consist of following three categories: 1) assistance for farmers organization for irrigation water management, 2) trainings on the operation and maintenance of irrigation facilities, and 3) trainings on irrigated farming (on-farm irrigation of upland crops and paddy irrigation). The primary target is to assist in organizing farmer beneficiaries to agriculture cooperative or water users association (cooperative), which will manage the water distribution among the beneficiaries. Secondly, trainings to the farmer beneficiaries on the operation and maintenance of the irrigation facilities, which will be constructed by the Project, will be required. Then irrigated farming (on-farm irrigation) trainings will be required for farmers to utilize irrigation water efficiently and effectively.

2) Collaboration with Technical Cooperation Project

After the relevance of the Project is confirmed and decision is made to implement the Project, collaboration with the Japan's technical cooperation project in Eastern Province for the establishment and operation of the farmers organization (agriculture cooperative) is considered. The technical cooperation project in Eastern Province is scheduled to commence within 2009 ahead of the Grant Aid Project. Considering the schedule, it is expected that the technical cooperation project would assist in establishing agriculture cooperative in the sites in which the establishment of agriculture cooperative is decided. Technical assistance by the Grant Aid Project will follow at the end period of the construction work to support to establish water management committee within the agriculture cooperative or water users association as a cooperative.

After the completion of the construction work, the technical cooperation project will be engaged in monitoring and evaluation activities of the farmers organization. Physical inputs would be proposed to provide equipments like PC to the cooperative and also it would be effective to promote the cooperative activities if the technical cooperation project could construct the office of the cooperative at local standard. Furthermore, introducing Nerica rice can be carried out as pilot basis at the sites of the Grant Aid Project

3) Collaboration with JOCV

There are even now JOCV who are working near the Project areas such as Ruha Sector in Bugesera District, Kibungo Sector in Ngoma District, Karangazi Sector in Nyagatare District etc. Their assignments are food crop cultivation, rice cultivation, horticulture crop and rural development. The conditions in the Project areas to dispatch JOCV will have no problem. However, means of transportation for JOCV have to be taken into consideration.

Installing irrigation system by the Project will enable to expand rice and vegetable cultivation, which are more profitable. However, farmers in the Project sites are currently depending on rain fed farming with drought tolerant crops such as sorghum and cassava. It would, therefore, be required a technical assistance for agriculture extension. In Ngoma 22 Rurenge site, some farmers have already been cultivating paddy and paddy crop would be expanded after the Project. It would therefore be suggested to dispatch JOCV with expertise of vegetable and rice cultivation. As for assisting agriculture cooperative, it should be carefully considered that the activity of JOCV and the work of the above mentioned technical cooperation project does not overlap. For example, JOCV in charge of rural development could be attached to the agriculture cooperative to assist in engaging in agro-processing.

8 Relevance of the Site

Based on the results of the series of surveys such as naturial condition survey, socio-economic survey, environmental survey, and O&M survey, relevance of the site for implementation of the Project is examined.

Followig table summarizes the volume of the reservoir and irrigable area in each site. All the site except for Gatsibo 31 can secure more than 50ha of the irrigabel area.

Table 12 Basic Data of Dam in Each Site

Site	Buggesera2 Gashora	Ngoma21 Remera	Ngoma22 Rurenge	Gatsibo31 Rugarama	Bugesera3 Rilima	Bugesra4 Musenyi
Catchment Area(km2)	3.24	2.06	8.81	0.53	3.05	3.83
Dam Height (m)	15.2	16.6	15	16	16.2	20
Crest Elevation (EL.m)	1367	1431	1368	1436	1373	1404.5
Crest Length	367	400	200	220	297	429
Full Water Level (EL m)	1365	1429	1366	1434	1371	1402
Total Capacity (m3)	456,500	442,000	1,371,000	23,000	487,000	901,472
Effective Capacity (m3)	375,000	396,300	1,132,900	14,600	419,600	812,500
Dam Volume (m3)	111,000	140,000	65,000	35,000	121,500	241,700
Ground Level (EL m)	1352	1414	1353	1422	1357	1384.5
Irigable Area Case 1 (ha)	102	48	314	1	149	72
	Pineapple, Banana	Avocado, Banana	Paddy, Pineapple	Coffee, Banana	Pineapple, Banana	Mango, Banana
Irigable Area Case 2 (ha)	67	61	165	2	75	146
	Maize, Vegetables, Banana	Maize, Vegetables, Banana	Paddy, Maize, Vegetables,	Maize, Vegetables, Banana	Maize, Vegetables, Banana	Maize, Vegetables, Banana
Irigable Area Case 3 (ha)	51	49	—	—	57	110
	Paddy, Maize, Vegetables,	Paddy, Maize, Vegetables,	—	—	Paddy, Maize, Vegetables,	Paddy, Maize, Vegetables,

With the costs and benefits estimated above, IRR, B/C and NPV are calculated. Discount rate of 12% is applied to calculate B/C and NPV. When economic internal rate of return (EIRR) exceeds 12%, which is the opportunity cost of capital in Rwanda, and B/C rates more than one (1), and NPV is positive, it means that the benefit exceeds the investment (Project cost). The result does not include the inputs from Japan. Table 13 summarizes the results of the calculation by site and by case.

Table 13 Results of Evaluation by Site and by Case

Site	Case	IRR (%)		B/C (i=12%)		NPV (000 Rwf) (i=12%)	
		Economic	Financial	Economic	Financial	Economic	Financial
Bugesera 2	1	15.4	16.4	1.29	1.38	380,563	524,149
	2	**8.6**	**9.5**	**0.77**	**0.83**	**-255,393**	**-203,513**
	3	8.4	7.7	0.76	0.71	-227,945	-291,594
Bugesera 3	1	24.3	25.9	2.20	2.34	1,337,807	1,603,678
	2	**12.6**	**13.8**	**1.04**	**1.12**	**37,538**	**118,544**
	3	12.1	11.3	1.01	0.95	6,722	-42,666
Bugesera 4	1	12.0	12.9	1.00	1.07	4,509	88,774
	2	**15.9**	**17.2**	**1.27**	**1.36**	**435,934**	**615,268**
	3	13.8	12.9	1.13	1.06	175,285	89,985
Ngoma 21	1	4.8	4.4	0.45	0.42	-701,114	-797,259
	2	**4.4**	**4.8**	**0.51**	**0.53**	**-680,516**	**-697,459**
	3	4.8	3.8	0.53	0.48	-566,755	-676,374
Ngoma 22	1	23.8	22.5	2.10	1.97	2,888,640	2,741,268
	2	**18.2**	**16.9**	**1.44**	**1.34**	**699,874**	**591,913**
Gatsibo 31	1	n.a.	n.a.	0.002	0.005	-526,147	-562,857
	2	**n.a.**	**n.a.**	**0.04**	**0.04**	**-505,937**	**-541,206**

Following Table 14 summarizes the overall evaluation of the relevance of the Project. It is judged that all the sites have no considerable environmental impacts. In Bugesera 2 Gashora and Ngoma 22

Rurenge, the existing cooperatives could be the management body of O&M of the irrigation facilities. Ngoma 22 Rurenge is considered as the highest priority site with very high economic efficiency since the irrigable area is much wider than other sites and the volume of reservoir is large compared to the volume of the dam body. On the other hand, it is judged that the relevance of Gatsibo 31 is very low because of: large-scale measure for the gulley is required but the volume of reservoir and irrigable area are very small, and the beneficial area can be covered by the neighboring site of Gatsibo 32. Ngoma 21 Remera site requires studying methods of preventing leakage by blanket etc. due to some high permeable part in the river bed. In Bugesera 4 Museni, as the design height of the dam in LWH Project is as high as 26.5m and there is a fault on the river bed, it is required to conduct a comparative study on the position of dam axis, height of the dam, volume of reservoir and irrigable area. It is expected that the dam volume, reservoir capacity and construction cost will be reduced largely and also irrigable area will be reduced.

Table 14　Summary of Evaluation of Each Site (1)

	Bugesera 2 Gashora	Ngoma 21 Remera	Ngoma 22 Rurenge	Gatsibo 31 Rugarama	Bugesera 3 Ririma	Bugesera 4 Museni
Outline of the Reservoir	Catchment Area : 3.24km2 Total Capacity : 456,000m3 Effective Capacity : 375,000m3 Height : 15.2m Crest Length : 367m Dam Volume : 111,000m3	Catchment Area : 2.06km2 Total Capacity : 442,000m3 Effective Capacity : 376,300m3 Height : 16.6m Crest Length : 400m Dam Volume : 140,000m3	Catchment Area : 8.81km2 Total Capacity : 1,371,000m3 Effective Capacity : 1,132,900m3 Height : 15.0m Crest Length : 180m Dam Volume : 65,000m3	Catchment Area : 0.53km2 Total Capacity : 23,000m3 Effective Capacity : 14,600 Height : 16m Crest Length : 220m Dam Volume : 35,000m3	Catchment Area : 3.05km2 Total Capacity : 487,000m3 Effective Capacity : 419,600m3 Height : 16.2m Crest Length : 297m Dam Volume : 121,500m3	Catchment Area : 3.83km2 Total Capacity : 912,600m3 Effrective Capacity : 812,500m3 Height : 26.5m Crest Length : 429m Dam Volume : 241,700m3 The location of dam axis and the scale of the dam need to be reconsidered. Big change is expected.
Technical view	Needs to consider: coordinate with the design of pipeline and beneficial area of Bugesera 3, and affects to the main road. Needs turbid water treatment during the construction to avoid affect to the lake. Volume of Reservoir / Dam body ＝ 4.1	Consider: existing springs and high permeable part of river bed. Requires relatively high dam body due to the gradient of river bed. Volume of reservoir is small to the volume of the dam body, less economical. Needs turbid water treatment during the construction to avoid affect to the stream. Volume of Reservoir / Dam body ＝ 3.2	Consider existing springs. Existing bridge of box culvert should be removed. Consider temporary drainage during the construction. Volume of reservoir is big to the volume of dam body, economical. Needs turbid water treatment during the construction to avoid affect to the paddy field. Volume of Reservoir / Dam body ＝ 21.1	Dam height is high due to gulley. Large-scale measure for gulley is required. Irrigable area is very small. Gatsibo 32 can cover the area. Flood mitigation is expected. Silting of paddy fields in the downstream reaches can be prevented. Volume of Reservoir / Dam body ＝ 0.7	Needs to coordinate with the plan of Bugesera2 on the design of pipeline and beneficial area. Needs turbid water treatment during the construction to avoid affect to the lake. Volume of Reservoir / Dam body ＝ 4.0	Possibility of fault in the river bed. The deign dam height is 26m far beyond the standard of 15m. needs comparative study on the dam axis position, volume of reservoir etc. to make the dam height around 15m. Needs turbid water treatment during the construction to avoid affect to the stream. Volume of Reservoir / Dam body ＝ 3.7
	○	○	○	×	○	○
Farming, O&M	Existing agriculture cooperative could engage in O&M. Currently, main crop is sorghum. Increasing production value is expected with conversion of crops to maize, vegetables / rice and unit yield increase.	Needs to establish cooperative for O&M. Currently, main crop is sorghum. Increasing production value is expected with conversion of crops to maize, vegetable and unit yield increase.	Existing agriculture cooperative could engage in O&M. Expansion of rice crop is expected. On the slope, main crop is maize. Increasing production value is expected with conversion of crops to maize, vegetable and unit yield increase.	Needs to establish cooperative for O&M. Currently, main crops are sorghum and banana. Increasing production value is expected with conversion of crops to vegetables and unit yield increase. But the beneficial area is limited.	Existing agriculture cooperative could engage in O&M. Currently, main crops are sorghum and banana. Increasing production value is expected with conversion of crops to vegetables / rice and unit yield increase.	Existing agriculture cooperative could engage in O&M. Currently, main crops are sorghum and banana. Increasing production value is expected with new development of marsh land, conversion of crops to vegetables / rice and unit yield increase.
	○	○	○	△	○	○

Table 14 Summary of Evaluation of Each Site (2)

	Bugesera 2 Gashora	Ngoma 21 Remera	Ngoma 22 Rurenge	Gatsibo 31 Rugarama	Bugesera 3 Ririma	Bugesera 4 Museni
Social and environmental view	Needs turbid water treatment during the construction to avoid affect to the lake. Most of the catchment area and reservoir area is developed farm land and there is very few environmental impacts by the construction. There will be no re-settlement. Most of the reservoir area is farmland for compensation.	Most of the catchment area and reservoir area is developed farm land and there is very few environmental impacts by the construction. There will be no re-settlement. Most of the reservoir area is farmland for compensation.	Most of the catchment area and reservoir area is developed farm land and there is very few environmental impacts by the construction. There will be no re-settlement. Most of the reservoir area is state owned marshland. The number of beneficiaries is the most.	No significant environmental impacts. There will be no re-settlement.	Needs turbid water treatment during the construction to avoid affect to the lake. Most of the catchment area and reservoir area is developed farm land and there is very few environmental impacts by the construction. There will be 4 households which might require re-settlement.	Most of the catchment area and reservoir area is developed farm land and there is very few environmental impacts by the construction. There will be 3 households which might require re-settlement. Most of the reservoir area is farmland for compensation.
	○	○	◎	○	○	○
Socio-economic view	Irrigable area can be more than 50 ha. Not so economical.	Irrihgable area can be more than 50 ha. Large dam body makes economic efficiency low. Crest makes easier traffic of both sides of river.	Irrigable area is large, 165ha Most economical site. Crest makes easier traffic of both sides of river.	Irrigable area is too small. Economic efficiency is extremely low. Crest makes easier traffic of both sides of river.	Irrigable area can be more than 50 ha. Economic efficiency depends on the kind of crop.	It is expected that the scale of the reservoir will be as small as Bugesrra2 and 3 as a result of reconsideration. In that case, economic efficiency will be as same as Bugesera2 and 3.
	Irrigable Area, Cost, EIRR,B/C	Irrigable Area, Cost, EIRR,B/C	Irrigable Area, Cost, EIRR,B/C	Irrigable Area, Cost, EIRR,B/C	Irrigable Area, Cost, EIRR,B/C	Irrigable Area, Cost, EIRR,B/C
Case1	102ha、4.1M、10.3%、0.86	48ha、4.1M、1.9%、0.30	314ha、8.3M、16.7%、1.4	1ha、1.7M、－、0.002	149ha、3.5M、17.3%、1.47	72ha、3.7M、7.6%、0.67
	Pineapple, Banana	Avocado, Banana	Pineapple, Paddy	Coffee, Banana	Pineapple, Banana	Mango, Banana
Case2	67ha、3.5M、4.4%、0.51	61ha、4.4M、1.1%、0.34	165ha、5.1M、11.4%、0.96	2ha、1.7M、－、0.03	75ha、2.9M、7.4%、0.69	146ha、5.1M、9.8%、0.85
	Maize, Vegetable, Banana	Maize, Vegetable, Banana	Paddy, Maize, Vegetable, Banana	Maize, Vegetable, Banana	Maize, Vegetable, Banana	Maize, Vegetable, Banana
Case3	51ha、3.0M、4.3%、0.51	49ha、3.8M、1.4%、0.36	－	－	57ha、2.5M、7.4%、0.67	110ha、4.3M、8.3%、0.75
	Paddy, Maize, Vegetable, Banana	Paddy, Maize, Vegetable, Banana	－	－	Paddy, Maize, Vegetable, Banana	Paddy, Maize, Vegetable, Banana
	△	△	◎	×	○	△
Overall	There is no significant technical problem. Though the irrigable area is not so big, increasing agriculture production contributes to poverty reduction.	There is no significant technical problem. Though the irrigable area is not so big, increasing agriculture production contributes to poverty reduction.	Irrigable area is big enough and the number of beneficiary is high. Economic efficiency is high. Considered the most effective site.	Irrigable area is extremely small and beneficiary is less. Least effective site. The area can be covered by Gatsibo 32.	Though the irrigable area is not so big, increasing agriculture production contributes to poverty reduction. Construction cost is the lowest except Gatsibo31.	Needs reconsideration of the reservoir. It is expected that the scale of the reservoir will be as small as Bugesrra2 and 3 as a result of reconsideration. Increasing agriculture production contributes to poverty reduction.
Priority	3	5	1	－	2	4

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Abbreviations

1	**AfDB**	Africa Development Bank
2	**CAADP**	Common African Agricultural Development Program
3	**CARD**	Coalition for Africa Rice Development
4	**CDC**	Community Development Committee
5	**CDF**	Common Development Fund
6	**CDP (PDC)**	Community Development Plan
7	**DDP**	District Development Plan
8	**DFID**	Department for International Development
9	**EDPRS**	Economic Development and Poverty Reduction Strategy
10	**EIA**	Environmental Impact Assessment
11	**GDP**	Gross Domestic Product
12	**ICT**	Technology of Information and Cmmunication
13	**IEE**	Initial Environmental Examination
14	**IFAD (FIDA)**	International Fund for Agricultural Development
15	**IOC / IOO**	Implementation and Operation Order
16	**ISAR**	Institute of Agronomical Sciences in Rwanda
17	**JOCV**	Japan Overseas Cooperation Volunteers
18	**KIST**	Kigali Institute of Science and Technology
19	**LWH**	Land-hasbandry, Water-harvesting and Hillside-irrigation Project
20	**M&E**	Monitoring & Evaluation
21	**MINAGRI**	Ministry of Agriculture and Animal Resources
22	**MINALOC**	Ministry of Local Government, Community Development and Social Affairs
23	**MINECOFIN**	Ministry of Finance and Economic Planning
24	**MINICOM**	Ministry of Commerce, Industry, Investment Promotion, Tourism and Cooperatives
25	**MININFRA**	Ministry of Infrastructure
26	**MINITERE**	Ministry of Land, Environment, Forestry, water and Mines
27	**MTEF**	Medium Term Expenditure Framework
28	**NAP**	National Agricultural Policy
29	**NRP**	National Rice Program
30	**OCIR CAFE**	Office Des Cultures Industrielles du Rwanda-Café
31	**OCIR THE**	Office Des Cultures Industrielles du Rwanda-Thé
32	**PGNRE**	National Management of the Water Resources Project
33	**PRSP**	Poverty Reduction Strategy Papers
34	**PSCU**	Project Support and Coordination Unit
35	**PSTA (SPAT)**	The Strategic Plan for Agricultural Transformation
36	**RAB**	Rwamda Agricultural Development Board
37	**RAEDB**	Rwanda Agricultural Export Development Board
38	**RADA**	Rwanda Agricultural Development Authority
39	**RARDA**	Rwanda Animal Resources Development Authority
40	**RCA**	Rwanda Cooperative Agency
41	**REMA**	Rwanda Environment Management Authority
42	**RHODA**	Rwanda Horticulture Development Authority
43	**RNE**	Royal Netherland Embassy
44	**RSSP**	Rural Sector Support Project
45	**Rwf**	Rwanda Franc
46	**SWG**	Sector Working Group
47	**TICAD**	Tokyo International Conference on African Development
48	**USAID**	United States Agency for International Development
49	**WARDA**	West Africa Rice Development Association
50	**WB**	World Bank

Project Location Map

Construction model of Valley-Dam

● Requested Sites for Implementation of Land-husbandary, Water harvesting and Hillside-irrigation (LWH) Project

No.	Location
No.2	Gashora Sector in Bugesera District
No.3	Rilima Sector in Bugesera District
No.4	Musenyi Sector in Bugesera District
No.21	Remera Sector in Ngoma District
No.22	Rurenge Sector in Ngoma District
No.31	Rugaranma Sector in Gatsibo District

* Number of the request site corresponds with the request letter.

Uganda
Nyagatare
Gatsibo
Kayonza
Rwamagana
Ngoma
Kirehe
Bugesera
Eastern Province
United Republic of Tanzania
Burundi
KIGALI
Burera
Gicumbi
Rulindo
Gasabo
Kamonyi
Ruhango
Nyanza
Nyarugenge
Kicukiro
Gakenke
PROVINCE DU NORD
Kakitumba
Gazinga
Kabale
Kikungiri
Lubirizi
Maziba
Nyakatale
Kadjumo
Rwenjara
Bwishya
Bibale
Kyerwa
Itera
Murore
Ryandinzi
Tandalukara
Byumba
Nyarugumba
Muti
Kabale
Kivuba
Budjumu
Bugoya
Kirwa
Gashinia
Bulimba
Kanyoni
Tanda
Rusiga
Butale
Janjagiro
Bugaragara
Giko
Bandazi
Gahengele
Karama
Bugobagoba
Nawe
Bihembe
Kanzenze
Gitarama
Nguzi
Gashoba
Birenga
Butari
Gakamba
Lugarama
Gasenyi
Bugali
Mont Mugusa
Ngara
Kanazi
Dahwe
Nyabugombe
No.31
No.21
No.22
No.4
No.3
No.2

Legend
- Study Area
- National Boundary
- Provincial Boundary
- District Boundary
- Road

0 15 30
kilometers

Sources: UNHCR, Rwanda National Institute of Statistics, Global Insight digital mapping © 1998 Europa Technologies Ltd

Photographs

	Bugesera2 Upstream end of the reservoir. Main road on the right side.
	Bugesera2 Beneficiary Area. There is the confluence with Bugesera3 in the center back.
	Bugesera2 Village road at downstream. The left side is upstream side. There is no drain canal. The road is overflowed a few times a year. There is Lake Rumira about 200m in the right side.

	Ngoma21 Spring at downstream of the dam axis. It was constructed by an NGO.
	Ngoma21 Upstream view from downstream beneficiary area. Proposed dam axis is located about200m upstream of the banana field.
	Ngoma21 Riverbed at proposed dam axis. Sorghum field.

	Ngoma21 Sorghum field and banana field in the river bed.
	Ngoma22 The proposed dam axis is located at just downstream of the small bridge. Paddy fields are in the downstream
	Ngoma22 The view of upstream from right abutment.

	Ngoma22 Upstream view from right side slope at 3km downstream of the da axis. Paddy fields in the river bed area and Sorghum on the slope area.
	Gatsibo31 The view from the top of the mountain of catchment area. There is a large gully. The proposed dam axis is located at downstream of the confluence.
	Gatsibo31 Gully near the dam axis. The depth about 15m, width about 15m.

	Gatsibo 31 Downstream view from the proposed dam axis.
	Bugesera4 The view of proposed dam axis from upstream.
	Bugesera4 Field in the river bed area.

	Kanyanyanba Dam. Constructed by RSSP Project. Parapet on the dam crest. Front overflow type spillway.
	Pump station under construction by assistance of Luxemburg. Diesel engine type.
	Soil conservation project by Wotld Vision. Gashora Sector, Bugesera District. Excavating ditch along the contour line. Reducing the velocity of run off water. Infiltration and storage is also expected. It was done as Food for Work.

Chapter 1 Background of the Project

1.1 Background of the Project

Republic of Rwanda is called as “the land of thousand of hills” due to many hills and wetlands in the country. There is 9 million population in the land of 26,000km^2 and more than 90% of people in the rural area stay in the mountain ridges in accordance with the policy of assemble settlement (Imidugudu) after the civil war.

Farming is the major industry, which employs 87% of total labor force and accounts for 47% of GDP in Rwanda. Major produces are coffee and tea, which are exported to other countries, however, the conditions of these crop sale and its benefits depend on the external factors such as climate change or international price fluctuation and are unstable. On the other hand, most of farmers are engaged in harvest of sorghum, maize, various potatoes for self-support. The national average of land holding area per a household in Rwanda is relatively small, 0.76ha/household. This status seems to results from some unfavorable factors such as soil erosion, unstable rain fed farming and soil deterioration. Moreover, recent droughts have caused significant damages to the people like food shortage and dystrophic children.

It is necessary to solve these issues by taking countermeasures such as farming technology improvement in the hilly areas, soil conservation, wetland development, and activation of rural communities, which leads to poverty reduction and livelihood improvement.

1.2 Contents of LWH Project

(1) Summary of LWH Project

The Water harvesting and Hill-side irrigation (hereinafter referred to as LWH) project, which directly triggered and promoted this project implementation, aims at farming production increase and commercialization/diversification of farm produces through land management, water harvesting and irrigation in the land in hilly areas. These attempts can be considered to contribute to the food security, livelihood improvement in the target area and socio economic development. In addition, it aims for reinforcement of the governmental institutions and private sector organizations to promote participatory development involving local administrations.

According to the LWH project, 101 reservoir dams in the 17 Districts in the country are due to be constructed until 2012. The 32 reservoir dams in the 1st phase (2009-2010) and remaining 69 reservoir dam in the 2nd phase (2011 - 2012) will be constructed, which will enable to develop around 10,000ha land by irrigation (3,100ha in the 1st phase and 6,900ha in the 2nd phase construction). Moreover, around 30,250ha land can be developed based on the intensive and advanced land management technology. The beneficiaries will be able to work on for commercial farming. In addition to that, it is needed to promote capacity development of staff of the central government, District and Sector, and it is essential to strengthen the cooperation with local communities. For the achievement of this target, following five

items are to be implemented.

- Improvement of farm production system against soil erosion and soil infertilization will be implemented in a sustainable manner.
- Diversification of exports through the development of value-added crops, fruits, forest management and forage crops will be promoted.
- Soil conservation, soil fertilization, water harvesting and reservoir dam managemnet will be implemented to promote irrgation in the hilly areas by the beneficiaries.
- Establishment of model farmers organizations will be supported through land resource management, water harvesting, hilly area irrigation and distribution system improvement.
- Environment is protected through watershed management and soil erosion prevention and water resource development.

(2) The request to Japanese Govenment

LWH project will cover construction of 101 valley dam reservoirs across the whole country. The Japanese Government is requested to construct the four reservoir dams which are located on southern part of the Eastern Province out of the 101 as described above and its procurement of equipments through the grant aid project.

1.3 Objectives and tragert area of the project

(1) Obejectives

The objectives of the project are as follows:

① Feasibility study on the four reservoir dam construction which are requeted to Japanese Government is implemented in terms of techinical aspects, relevance, natural conditions, socio-economic conditions (including social system, budget, techinical level, farming skill and so on) and social and environmental consideration.

② Based on the study results above, planning of the second study including study area, scope of work and necessary personnel/staff is assisted by the Japanese side. This second study will be implemented in the basic design level. In this stage, it is needed to confirm the priority of each facility and eqcuipment, and get neccesary materials for facility design. In addition, important points for the basic design study are compiled.

③ Technical cooperation programme which will be implemented by JICA will be reviewed (This study is a part of the aid programme which will be implemented by JICA. It is needed to consdier the relationship between the study and the technical cooperation project by aid programme and to cralify the position of the LWH project under the framework of aid programme.)

④ Neccesary data and information is acquired to examine necessity and relevance of the techinical copperation project on technical assistance/support for sustainable rice production development in Bugesera District in Rwanda.

⑤ Based on the frame of aid programme, the possibility of cooperation between LWH project and the JICA technical cooperation project is examined. Moreover, proper cooperation scopes are studied for the purpose of synergetic effect.

(2) Sutdy Area

The study area is located in the Eastern Province, which covers the Bugesera District where the

locations of reservoir dams are shown in the request letter, the Ngoma District and the Gatsibo District.

District	Bugesera	Ngoma	Gatsibo	Kayonza	Kirehe	Rwamagana	Nyagatare	Total
Area (km^2)	1,334.0	738.0	1,585.3	1,954.0	1,225.4	691.6	1,741.0	9,269.3
Population	281,232	271,585	283,456	234,106	292,215	255,630	328,658	1,946,882
Sector	15	14	14	12	12	14	14	95
Cell	72	64	69	50	60	82	106	503
Umdugudu	581	473	603	422	612	474	628	3,793
Requested site No.	No.2	No.21 No.22	No.31	-	-	-	-	

1.4 Contents of project

The project consists of preparatory work in Japan, site survey, analysis, and reporting including compilation of the study results. The preparatory work covers examination of the request by the Rwandan government and analysis of existing data and preliminary assessment of the four sites for reservoir dam construction. In addition, the study team reviews any matters to be discussed with the relevant agencies/institutions in Rwanda, schedule and contents.

In the site survey, the JICA study team confirms the present conditions of agriculture/irrigation sector in Rwanda, general situation in the study area, project objectives, background, scope of works and implementation structure. The relevance and feasibility of the project are examined based on the results of natural condition study, socio-economic survey, social/environmental study and the other information/data.

After return to Japan, the team prepares “Report on summary of the field survey” and assesses the impacts of the project based on the data analysis in terms of technical aspects, economic conditions, and social and environmental consideration. The team examines the necessary facilities, equipments, design regarding soft component, project cost, operation and maintenance plan and so on. Moreover, the team proposes terms of reference for the second cooperation study (basic design level). A final report of “The Preparatory Study for formulation of the Program for Rural Development in southern part of Eastern Province in Rwanda (Irrigated Agriculture)” is complied based on the examination and analysis as stated above.

1.5 Process of relevance examination on the 4 sites for reservoir dam

At first, relevance of the four sites for reservoir construction is examined. After the feasibility of project is confirmed based on the scheme of Japanese project, the JICA team proposes terms of reference for the second study (basic design level) and any points to be kept in mind. Therefore, it is needed to study national policies, other donors’ aid trend/activities, socio-economic conditions, social and environmental consideration, interest and concern of the people toward the project in addition to technical examination.

Chapter 2 The Result of the Study

2.1 The Main result of the Study

2.1.1 Current Situationj of Each Site

(1) Bugesera2 Gashora

1) Site

The detailed design report for LWH Bugesera 3 site could be obtained during the field survey and it was confirmed that those basic data for Bugesera 2 are quite similar to those of Bugesera 3 as No.2 and No.3 are located nearby with each other. Further, the catchment for the No.2 extends over the main road including the forest area belonging to the Military Department as similar to the No. 3. Accordingly, through due consultation with the officer in charge of the Sector, it was so decided that the dam body should locate at outside of the military area and full water level of the reservoir not reach to the said military area.

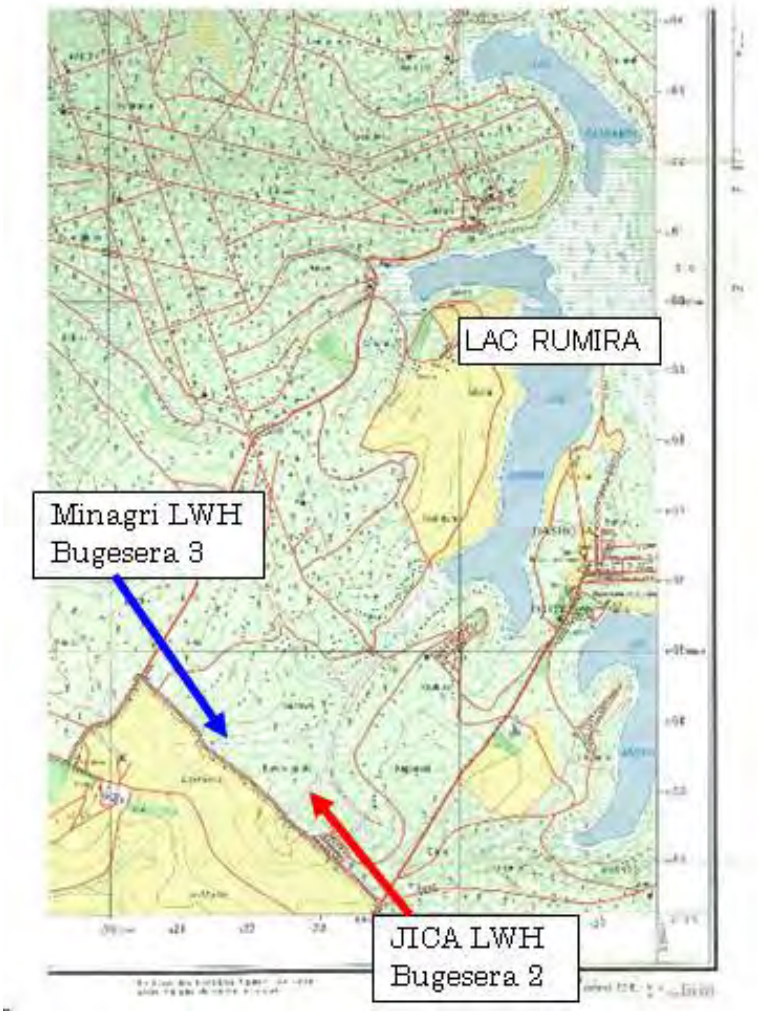


Figure 2.1.1 LocationMap of Bugesera2 Gashora

In case of Bugesera 3 site, the reservoir is located at the downstream of the road so that the stored water will not affect on the military area. The catchment is not so large, however, the dam axis shall be fixed at the place where does not cause water reach to the military area but with the possibly maximum storage capacity with in due consideration of the dam crest height and reservoir water level.

2) Geology

The local geology in and around the dam site is underlain by an igneous intrusion of granite composition and the foundation is of the thick layer of highly weathered. Topographically, there is a river flowing through the lowest portion at the center of the valley, however, there is surface water flowing not all the time as Wadi. As can be seen from the Figure 2.1.2, geological map in and around Bugesera 2 and 3 as referred from the geological map prepared by the Geological Institute, Belgium,

the river bed is covered y such alluvium deposits as clay, sand, and gravel.

3) Socio-Economy

Three (3) imidugudus of Akagako, Kuwuruganda and Kagomasi which belongs to Kagomasi cell of Gashora sector are located near the project site. All houses of above imidugudus are located in the downstream of the proposed project and no dwelling houses are submerged by the project.

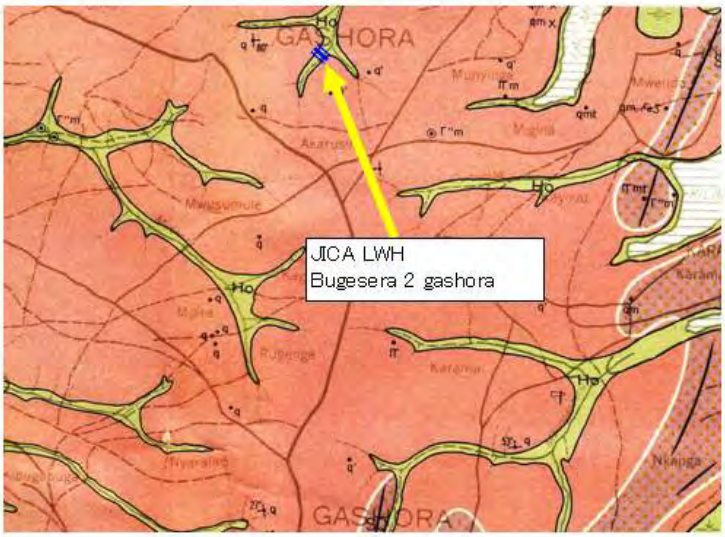


Figure 2.1.2 Geological Map of Bugesera2 Gashora

a. Population, Family Structure and Number of Household

Table 2.1.1 shows the population and number of household by imidugudu. The residents of 78 to 116 dwells in three imidugudus and the average size of the households is 4.1 persons. The rate of the number of the household headed by woman to the total household number exceeds 25 percent and it indicates the maximum rate of 42.4 percent in Kagomasi imidugudu. All the households are located in the downstream of the project site.

Table 2.1.1 Population and Number of Household by Imidugudu

		Imidugudu		
		Akagako	Kuwuruganda	Kagomasi
2002	Number of household	66	89	65
	Male	122	211	132
	Female	221	172	189
	Population	343	383	321
2008	Number of household	78	116	85
	Male	147	192	144
	Female	231	218	205
	Population	378	410	349
	Number of households headed by women (%)	21 (26.9)	34 (29.3)	36 (42.4)

Source: Interview by JICA study team

b. Land Tenure

Table 2.1.2 shows the current state on land tenure by imidugudu. Landless farmers make up the largest parts of the households near the project site, and followed by leased lands and private lands. About half of the whole households is landless farmers in Akagako and Kagomasi imidugudu and about 72 % of the whole households are landless, which shows the surrounding area of the project site has plenty of landless farmers. The farmers farming by leasing lands pay 4,000 to 15,000 Rwf/year as a tenancy rate.

Table 2.1.2 Land Tenure by Imidugudu

Imidugudu	Number of Households					Total
	Landless Farmers	Leases Land	Leases Land + Owned Lands	Owned Lands	Absentee Landowner	
Akagako	39	21	9	9	-	78
Kuwuruganda	84	20	11	1	-	116
Kagomasi	42	28	10	5	-	85

Source: Interview by JICA study team

c. Land Size

The number of households by size of agricultural land is shown in Table 2.4.3. The number of household farming the land below 0.5 ha is largest and that of farming over 2 ha smallest. The number of households owing the lands with the size 0.5 to 2 ha varies in each imidugudu.

Table 2.1.3 Number of Household by Land Size

Imidugudu	0 ha	0 < 0.5 ha	0.5 < 1.0	1.0 < 1.5	1.5 < 2.0	<2.0 ha
Akagako	39	12	9	8	10	0
Kuwuruganda	84	19	4	6	2	1
Kagomasi	42	20	6	9	6	2

Source: Interview by JICA study team

d. Land Use

Table 2.4.4 shows the land use in each imidugudu. The agricultural land is largest and there is no paddy filed near the project site. Most of the farmers farms the crops of sorghum, maize and beans.

Table 2.1.4 Land use in Each Imidugudu

Imidugudu	Total Area (ha)	Agricultural Land (ha)			Forest (ha)	Others (ha)
		Paddy	Upland Field	Perennial Crops		
Akagako	60	0	40	18.8	1.2	0
Kuwuruganda	72	0	60	11	1.0	0
Kagomasi	72	0	62	7	3.0	0

Source: Interview by JICA study team

e. Community Life

Almost no households use electricity but firewood and the use the kerosene lamp for lighting. There is one public tap in Kagozamsi imidugudu and it is located maximum at 2.5 km from the center of the communities. The community complains that the tap water is good in quality but it does not supply enough quantity. As for public health, there is no hospital but only one clinic. There is no doctor and few nurses take treatment for patients. The major diseases are malaria and parasite infection. As for education facilities, there are four (4) primary schools and two (2) middle/high schools and nursery schools.

f. Community Problems and Its Solution

According the interviews with the sector officers and farmers, the following are the problems that they are currently holding:

- No irrigation water is secured at dry seasons
- Marshlands are not utilized for agricultural development
- Not enough processing facilities of agricultural crops for raizing their marketability

- Land inheritance

For the issues of conflicts among the farmers, the sector chief takes action for settlement through the mutal discussions among the concerned parties. They can appeal to a court based on laws including penalty provisions.

g. Farming Practice

Rain-fed farming is common in the study area. The crops requring much water are not cultivated near the project site since Bugesera district has comparatively less rainfall in Eastern province. The vally of the project site is not deep with no water flow at its bottom. The crops of cold resistance such as sorghum are cultivated. According to the results of the farmers economy survey targeting at fourty (40) households, the major crops were cassava, sorghum, haricot bean and maize. Table 2.4.5 shows the household percentage by type of farming crops.

Table 2.1.5 Major Crops in Gashora 2 of Bugesera District

Farmers to be studied (Effective Response)	Percentage of Farmers Farming by Type of Crops (%)					
	Haricot Beans	Cassaba	Sorghum	Maize	Sweet Potato	Banana
40 Households	93%	83%	80%	80%	50%	35%

Source: Interview by JICA study team

With the result of the baseline survey and also considering the filed visit of the sites, present cropping pattern in the site is described. At present, inter-cropping of several crops such as sorghum, bean, maize, cassava and sweet potato are common.

Table 2.1.6 Present Cropping Pattern in Bugesera 2 Gashora

Crop	Area	Inter/ Mono	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sorghum	22%	Inter crop												
Maize	12%	Inter crop												
Sweet potato	7%	Inter crop												
Haricot bean	30%	Inter crop												
Cassava	24%	Inter crop												
Banana	4%	Mono crop												

h. Farm Household Income

Average annual farm household income in Gashora is estimated at 146,000Rwf. Out of them income from crop production occupies 81%. Farmers allocates significant amount of farm produce for their self-consumption. The monetary value of produce for the self-consumption was also estimated. The value of the annual self-consumption in Gashora is 158,000Rwf. Total annual farm household income and self-consumption value is estimated at 304,000Rwf

Table 2.1.7 Average annual income

Item	Gashora	
	Rwf	(%)
Crop	118,521	81%
Livestock	17,008	12%
Fishery	0	0%
Forest	1,625	1%
Farm labor	7,710	5%
Other	1,550	1%
Total	146,414	100%
Home Cosumption Value	157,813	
Total Value	304,227	
Crop + Home Consumption	276,334	91%

Table 2.1.8 No. of Households by income group

Annual Income + Home consumption Value (Rwf)	Gashora		
	No.	Share	Acc.
< 100,000	8	20%	20%
100,000 < 200,000	7	18%	38%
200,000 < 300,000	8	20%	58%
300,000 < 400,000	6	15%	73%
400,000 < 500,000	7	18%	90%
500,000 < 600,000	0	0%	90%
600,000 < 700,000	2	5%	95%
700,000 < 800,000	0	0%	95%
800,000 < 900,000	0	0%	95%
900,000 < 1,000,000	1	3%	98%
1,000,000 <	1	3%	100%
Total	40	100%	

i. Farmers Organization

Two farmers cooperatives are identified in Kagomasi cell and both of them are registered in the central government. One of the cooperatives has about 2,500 members and their activities are cooperation activities for production of maize, cassava and soaps and some of the members are setting out dyeing. A membership of 16,000 Rwf is collected as entry fee. Another cooperative is that of vegetable production which was established by the pumping irrigation project supported by Luxemburg government, and its members are 232 personnels.

(2) Ngoma21 Remera

1) Site

The site was indicated to locate in Remera 2 Sector in the LWH project report but in fact the site is located at Remera Sector. The study team confirmed the location through tracing by use of GPS and due confirmation by the officer in charge at the site. The name of the site is Remera but not Remera 2 as confirmed and also Ngoma 22 Remera be called Rurenge as confirmed also by the officer in charge at the site. It was found out that on the right bank side the topography is rather steep with natural bush while the

Figure 2.1.3 Location Map of Ngoma21 Remera

left bank side gently sloping land used as upland field.

2) Geology

The ground surface is covered with soils as derived from weathering of granite and sandy-muddy sedimentary rocks and it is considered suitable in this case to use the impervious material taken from the weathered granite soils at the left bank abutment. In the river bed there found no much sand and it can be considered that river bed deposits are retained due to the higher groundwater table at the right bank test pit site. As the impervious embankment material, heavily weathered zone can be used. Though it can not be clarified in case of sandy nature soil, but small gravels can be found at the higher elevated locations and therefore it can be considered the weathered soil m

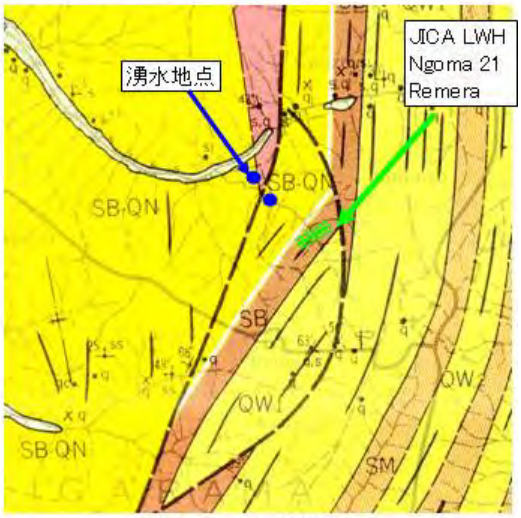


Figure 2.1.4 Geology at Ngoma21

3) Socio-Economy

Four (4) imidugudus of Rweso, Gisunzu, Mumini I and Mumini II which belongs to Bugera cell of Remera sector are located near the project site. No houses are submerged by the proposed project and they are located in remote areas from the proposed project.

a. Population, Family Structure and Number of Household

Table 2.4.6 shows the population and number of household by imidugudu. The residents of 95 to 110 dwells in the above imidugudus and the average size of the households is 4.0 persons. The rate of the number of the household headed by woman to the total household number in each imidugudu exceeds 19 percent and it indicates the maximum rate of 32.6 percent in Mumini II imidugudu.

Table 2.1.9 Population and Number of Household by Imidugudu

		Imidugudu			
		Rweso	Gisunzu	Mumini I	Mumini II
2002	Number of household	N/A	87	N/A	N/A
	Male	N/A	152	N/A	N/A
	Female	N/A	211	N/A	N/A
	Population	N/A	363	N/A	N/A
2008	Number of household	96	110	108	95
	Male	198	192	201	119
	Female	232	241	233	238
	Population	430	433	434	357
	Number of households headed by women (%)	27 (28.1)	27 (24.5)	21 (19.4)	31 (32.6)

Source: Interview by JICA study team

b. Land Size

The number of households by size of agricultural land is shown in Table 2.1.10 The number of household farming the land of 0.5 to 1.0 ha is largest and followed by the household farming the land below 0.5 ha though the data was not available from the all households. The farmers farming the land above 2.0 ha is only 8 %.

Table 2.1.10 Number of Household by Land Size

Imidugudu	0 ha	0 < 0.5 ha	0.5 < 1.0	1.0 < 1.5	1.5 < 2.0	<2.0 ha
Rweso	N/A	N/A	N/A	N/A	20	N/A
Gisunzu	13%	25%	29%	15%	10%	8%
Mumini I	N/A	N/A	N/A	N/A	N/A	N/A
Mumini II	N/A	N/A	N/A	N/A	N/A	N/A

Source: Interview by JICA study team

c. Community Life

As same as Gashora 2 site, almost no households use electricity but firewood and the use the kerosene lamp for lighting. There is one spring at 3.0 km from the center of the communities and two(2) public taps for their drinking. The community complains that the tap water does not supply enough water volume, while the spring water has enough quantity. As for public health, there is no hospital except two clinics. The major diseases are malaria and parasite infection.

d. Community Problems and Its Solution

According to the interview surveys, they have no problems in the community. However, they answered that the imidugudu leader will settele a prblem when it occur.

e. Farming Practice

Rain-fed farming is common in the study area as same as Gashora 2. However, the weed vegetation is identified at the project site since Ngoma district has more rainfall compared to Bugesera district. The farmers seems to go to the farming fields at the vally bottom for their farming management not frequently since the vally of the project site is deep with its remote distance from their communities. According to the results of the farmers socio-economy survey, the major crops were cassava, sorghum, sweet potato and haricot bean, etc. Some farmers are farming vegetables. Table 2.1.11 shows the household percentage by farming the crop types.

Table 2.1.11 Major Crops in Remera Sector of Ngoma 21

Farmers to be studied (Effective Response Number)	Percentage of Farmers Farming by Type of Crops (%)									
	Cassaba	Sorghum	Sweet Potato	Haricot Bean	Tomato	Maize	Cabbage	Carrot	Onion	Banana
39 Households	62%	56%	51%	41%	23%	15%	15%	13%	8%	3%

Source: Interview by JICA study team

With the result of the baseline survey and also considering the filed visit of the sites, present cropping pattern in the site is described. At present, inter-cropping of several crops such as sorghum, bean, maize, cassava and sweet potato are common.

Table 2.1.12 Present Cropping Pattern in Ngoma 21 Remera

Crop	Area	Inter/ Monc	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sorghum	29%	Inter crop												
Maize	7%	Inter crop												
Sweet potato	17%	Inter crop												
Haricot bean	16%	Inter crop												
Vegetable (1)	4%	Mono crop												
Vegetable (2)	4%	Mono crop												
Cassava	18%	Inter crop												
Banana	5%	Mono crop												

f. Farm Household Income

Average annual farm household income in Remera is estimated at 425,000Rwf. Out of them income from crop production occupies 50%. Income level in Remera is the highest among the 4 sites and also income from toher than crop is high in Remera. Table 2.1.13 below shows the average annual income of the site.

Farmers allocates significant amount of farm produce for their self-consumption. The monetary value of produce for the self-consumption was also estimated. The value of the annual self-consumption in Remera is 155,000Rwf. Total annual farm household income and self-consumption value are estimated at 580,000Rwf in Remera.

Table 2.1.13 Average Annual Income

Item	Remera	
	Rwf	(%)
Crop	211,351	50%
Livestock	44,282	10%
Fishery	7,692	2%
Forest	82,538	19%
Farm labor	0	0%
Other	79,231	19%
Total	425,094	100%
Home Cosumption Value	155,333	
Total Value	580,427	
Crop + Home Consumption	366,684	63%

Table 2.1.14 No. of Households by IncOome Group

Annual Income + Home consumption Value (Rwf)	Remera		
	No.	Share	Acc.
< 100,000	6	15%	15%
100,000 < 200,000	5	13%	28%
200,000 < 300,000	4	10%	38%
300,000 < 400,000	6	15%	54%
400,000 < 500,000	3	8%	62%
500,000 < 600,000	3	8%	69%
600,000 < 700,000	1	3%	72%
700,000 < 800,000	3	8%	79%
800,000 < 900,000	0	0%	79%
900,000 < 1,000,000	1	3%	82%
1,000,000 <	7	18%	100%
Total	39	100%	

g. Farmers Organization

The residents of the imidugudus participates in the farmers cooperatives for cofee and banana production which are established locally. The number of the members of the coffee cooperative and that of banana is 400 and 115 persons, respectively. The entry fee of above cooperatives is 20,000 and 5,000 Rwf, respectively.

(3) Ngoma22 Rurenge

1) Site

The Remera site indicated in LWH report is actually a different site. The study team, therefore, fixed the correct location through confirming the site with the officer in charge at the site and fixing by using GPS. It was finally confirmed that the right bank of the site is Remera and the left bank is Rurenge.

Figure 2.1.5 Location Map of Ngoma22 Rurenge

For this site, both banks are upland fields with rather gentle slope. Over the river nearby the requested dam axis, there existed a box-culvert bridge. In some years ago there had been a plan to provide a crossing of both bank roads at this location, but there have been no any substantial progress for the plan. The river with the width of only 1 m has surface flow and even in dry season flow does not disappear according to the local people. In the area as far as 1,140 m upstream from the requested dam axis, there existed springs as equipped with pipe intake facilities for use by the local people.

2) Geology

The ground surface at the site is considered derived from weathering of granite and/or sandy-muddy sedimentary rocks and as the impervious materials for dam embankment the weathered granite zone on the left abutment is assumed possible for use. There is no much sand in the river bed and from the observation at the test pit it is considered that there are some clayey

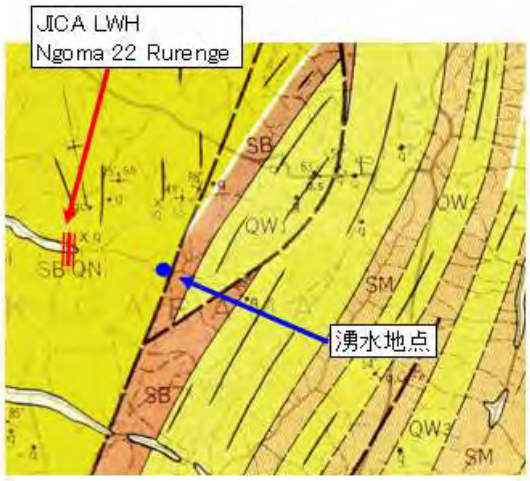


Figure2.1.6 Geological Map of Ngoma22 Rurenge

river bed deposits retained at the river bed. On the right bank abutment, there found shallow layer of weathered sandy-muddy mica schist. As the rock materials, there is a possibility to find them at the steep sloping area nearby. On the ridges of both banks, outcrops of rocks are found here and there.

3) Socio-Economy

The project site is the administrative border of Rurenge sector and Remera sector at its valley bottom. Rujambara and Ndekeme cell have jurisdiction over the project site. Foure (4) imidugudus of Nyabaganza, Gitobe, Mbonwa and Masyoza were identified in Rujambara cell, and two (2) imidugudus of Gikomero and Rugando in Ndekeme cell, which shows that total number of siz (6) imidugudus were identified. No houses are submerged by the proposed project and they are located in the upland remote areas from the proposed project and they are not located at the valley bottom nearby the project site.

a. Population, Family Structure and Number of Household

Table 2.1.15 shows the population and number of household by imidugudu. 684 residents dwell in Rurenge sector, and its average size of the households is 3.4 persons which is rather smaller compared to other sites. The rate of the number of the household headed by woman to the total household number in each imidugudu exceeds 20 percent. The number of households in Gikemero and Rugando was 171 and 234, respectively. However, other data were not vailable.

Table 2.1.15 Population and Number of Household by Imidugudu

Rurenge Sector		Imidugudu			
		Nyabaganza	Gitobe	Mbonwa	Masyoza
2008	Number of household	170	169	172	173
	Male	245	243	246	244
	Female	350	345	348	336
	Population	595	588	594	580
	Number of households headed by women（%）	42（24.7）	38（22.5）	36(20.9)	44（25.4）

Source: Interview by JICA study team

b. Community Life

Almost no households use electricity but firewood and they use the kerosene lamp for lighting. The communities take water from a stream and use it for their drinking by boiling. There are nine (9) springs near the project site, but only five (5) springs can be utilized for their drinking. As for public health, there is no hospital but one clinic. The major diseases are malaria, parasite infection, respiratory organs illness and typhoid fever. There are 17 nusery schools, 4 primary schools and 1 middel/high school in the sector.

c. Community Problems and Its Solution

The communities near the project site have the weather problems and the problems of crops distribution. The farmers cooeprative basically settle the farmers' conflicts but the court and police take actions when the cooperative cannot solve it.

d. Farming Practice

The project site is a adjacent valley of that of Remera sector of Ngoma 21 and its cropping is similar of that of Remera sector. The valley bottom has a marshland and rice cropping has been practiced in the developed paddy field of about 15 ha since 2006. However, the land-leveling was not carried out sufficiently and the unit yield is estimated to be small by taking the plenty of deaf ears into considerations, while the harvested rice ears were put on beside the paddy fields. According to the results of the farmers economy survey, the major crops were sorghum, haricot bean, maize and rice,etc. Table 2.1.16 shows the household percentage by farming the crop types.

Table 2.1.16 Major Crops in Rurenge Sector of Ngoma 22

Farmers to be studied (Effective Response Number)	Percentage of Farmers Farming by Type of Crops (%)							
	Sorghum	Haricot Bean	Maize	Rice	Cassaba	Sweet Potato	Banana	Cabbage
37 Households	68%	46%	32%	19%	19%	11%	8%	3%

Source: Interview by JICA study team

With the result of the baseline survey and also considering the filed visit of the sites, present cropping pattern in the site is described. At present, inter-cropping of several crops such as sorghum, bean, maize, cassava and sweet potato are common.

Table 2.1.17 Present Cropping Pattern in Ngoma 22 Rurenge

Crop	Area	Inter/ Mono	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rice	15%	Mono crop												
Sorghum	24%	Inter crop												
Maize	20%	Inter crop												
Sweet potato	5%	Inter crop												
Haricot Bean	24%	Inter crop												
Vegetable (Cabbage)	2%	Mono crop												
Cassava	5%	Inter crop												
Banana	5%	Mono crop												

e. Farm Household Income

Average annual farm household income in Rurenge is estimated at 241,000Rwf. Out of them income from crop production occupies 91%. Table 2.1.18 below shows the average annual income of the site.

Farmers allocates significant amount of farm produce for their self-consumption. The monetary value of produce for the self-consumption was also estimated. The value of the annual self-consumption in Rurenge is 118,000Rwf. Total annual farm household income and self-consumption value are estimated at 359,000Rwf in Rurenge.

Table 2.1.18 Average Annual Income Rurenge

Item	Rurenge	
	Rwf	(%)
Crop	219,297	91%
Livestock	8,703	4%
Fishery	0	0%
Forest	0	0%
Farm labor	0	0%
Other	13,108	5%
Total	241,108	100%
Home Cosumption Value	118,068	
Total Value	359,176	
Crop + Home Consumption	337,365	94%

Table 2.1.19 No. of Household by Income Group

Annual Income + Home consumption Value (Rwf)	Rurenge		
	No.	Share	Acc.
< 100,000	3	8%	8%
100,000 < 200,000	7	19%	27%
200,000 < 300,000	10	27%	54%
300,000 < 400,000	4	11%	65%
400,000 < 500,000	3	8%	73%
500,000 < 600,000	5	14%	86%
600,000 < 700,000	3	8%	95%
700,000 < 800,000	0	0%	95%
800,000 < 900,000	1	3%	97%
900,000 < 1,000,000	0	0%	97%
1,000,000 <	1	3%	100%
Total	37	100%	

f. Farmers Organization

A farmers cooperative named “TWIFATANYE” established by the paddy farmers at the valley bottom of the project site was identified. However, its registration in the central government has not been completed. The number of the members of the cooperative is 180, of which 100 members belongs to Rurenge sector and 80 members to Remera sector. The total size of the paddy field is about 15 ha and it means that the paddy size per member is 0.08 ha. The percentage of farmers who cannot access to the paddy field is estimated to be as 15 % and 20 % in Rurenge and Remera sector, respectively, when the relationship between the number of households of each imidufudu and the number of members in above cooperatives is considered.

In addition to above cooperative activities, some group activitities at community level are widely practiced through investing, reparing works of houses, and using for funerals by receiving the collected money from the members. In Rurenge sector, for instance, one group of 90 members collect the money of 100 Rwf per person every week and they use them for private investment. Similar activity exists in Remera sector. It seems that a organization of mutal aid exists in the rural areas of Rwanda and the tradition of bearing the expenses in coopearation takes roots there. Above tradition will be a merit for the establishment of future farmers organization

(4) Gatsibo31 Rugarama

1) Site

As many as 3 gullies with having steep mountain at the back join together at around the requested site and flows down further as a single gully. Being gullies, the both banks are of bluff ones and the cross section is not suitable for any dam construction. The difference of elevations between the flat bank ground and the river bed surface (No water flow but sand and gravel can be seen.) is observed at about 15 m and if the flat ground of both banks be used as reservoir area, then the dam height should exceed

15 m at the minimum. There found some low ridges stretched over both banks and if fix the dam axis to contact with those ridges, dam construction might be possible but careful attention shall be paid on the possible difference in subsidence on the part of dam body inside the gully and the transition part to connect with the dam body of flat ground on the bank.

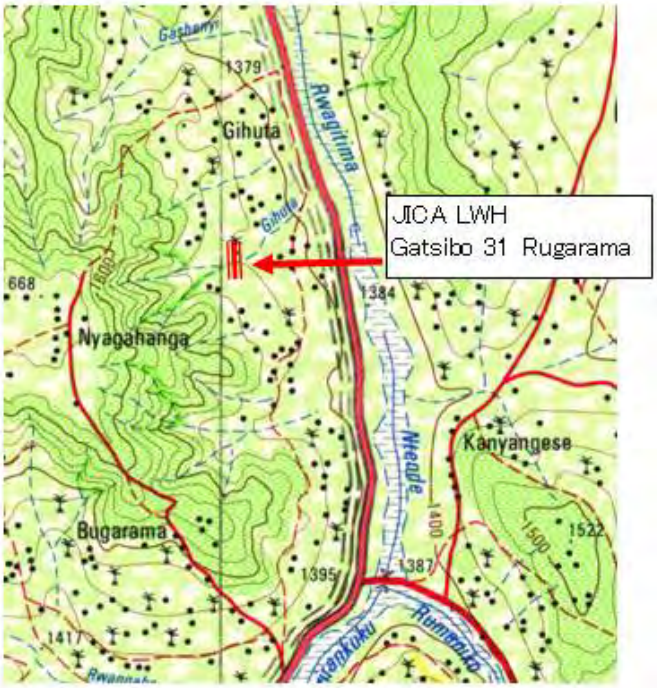
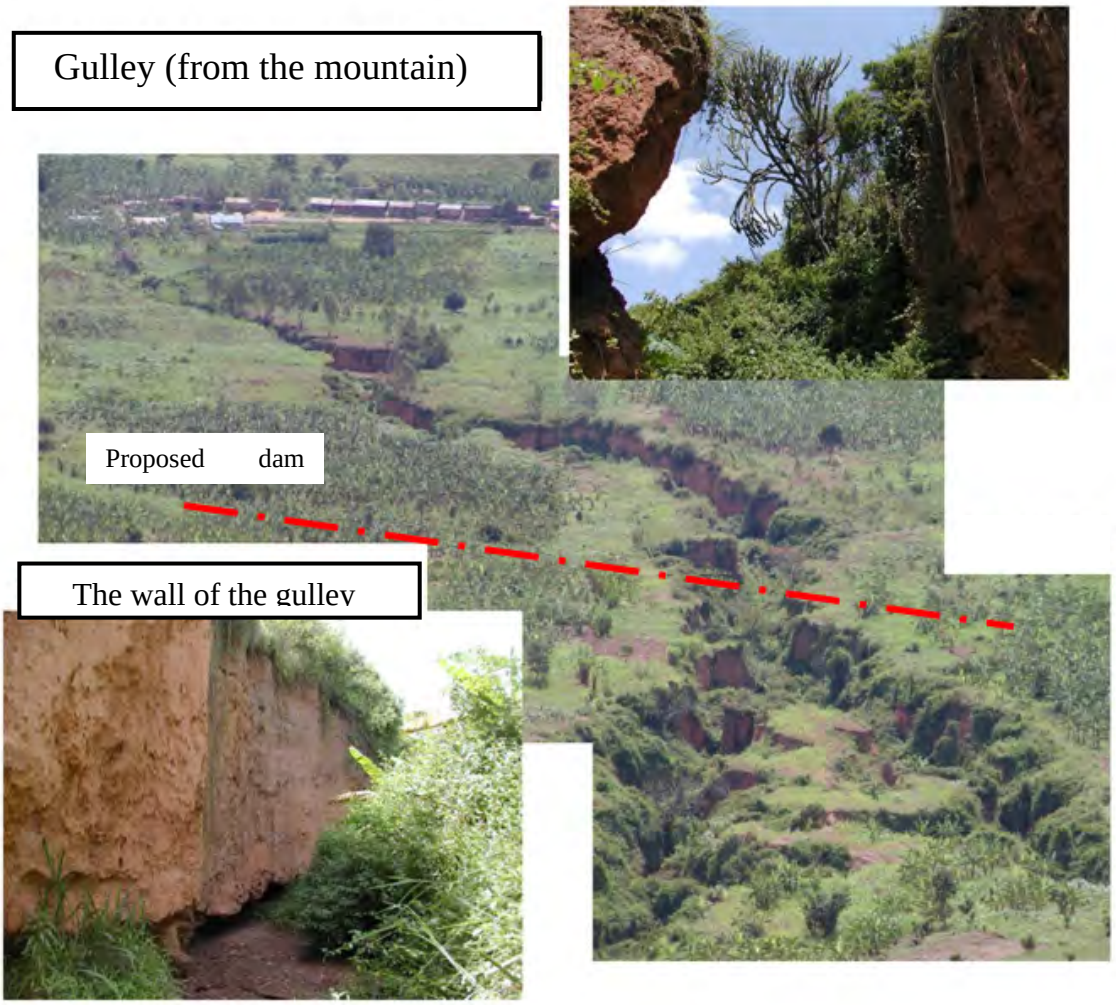


Figure 2.1.7 Location Map of Gatsibo31



Gulley of Gatsibo 31 Rugarama

2) Geology

It is assumed that a rapid flow penetrated into the foot of mountain, where sandy-muddy sedimentary rocks and granites had been largely transformed, and eroded the ground to create the gully shaped river. Both banks of the gully maintains vertical cliff of 15 m in height. The cliff has some strength but subject to erosion by rapid flow. Though it is of complex metamorphic rocks, the geology is not of the pervious one and there is a possibility to have a reservoir. In the layer a little higher than the river bed, some gravels are exposed and some scoops can be observed at the lower position of gravel layer.

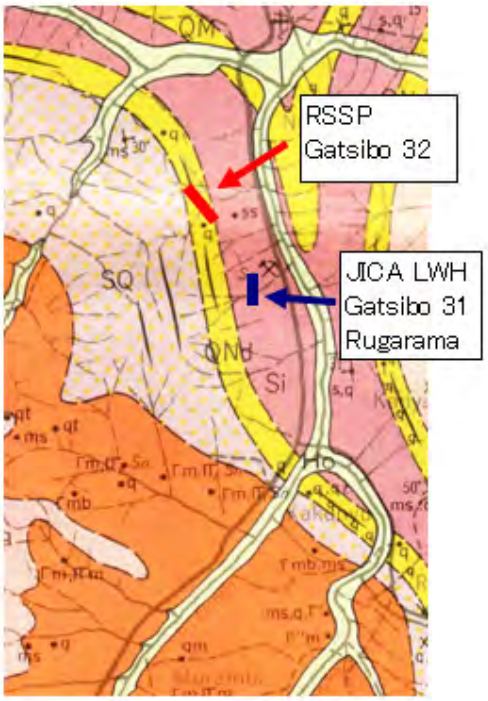


Figure 2.1.8 Geological Map of Gatsibo 31

3) Socio-Economy

There are two (2) imidugudus of Gashenyi I and Agatare at the project site which belongs to Gihuta cell of Rugarama sector. No houses are submerged by the proposed project.

a. Population, Family Structure and Number of Household

Table 2.1.20 shows the population and number of household by imidugudu. 125 and 176 households dwell in each imidugudu, and its average size of the households is 7.7 persons which is larger fcompared to other sites. The rate of the number of the household headed by woman to the total household number in each imidugudu exceeds 20 percent.

Table 2.1.20 Population and Number of Household by Imidugudu

		Imidugudu	
		Gashenyi I	Agatare
2008	Number of household	125	176
	Male	405	507
	Female	721	678
	Population	1,126	1,185
	Number of households headed by women (%)	30 (24.0)	36 (20.5)

Source: Interview by JICA study team

b. Community Life

Some households use electricity for lighting but most of the farmers use firewood for cooking and the

kerosene lamp for lighting. There are ten (10) public taps and wells locating in lowlands for their drinking. As for public health, there is no hospital but one clinic. The major diseases are malaria, TB (Tubercle Bacillus), parasite infection, typhoid fever and HIV. There are five (5) primary schools, one (1) middle/high school and nusery schools. The church staffs take care of the children at the nursery schools.

c. Community Problems and Its Solution

There are some conflicts among the farmers over the boundaries of their agricultural lands. The farmers cooeprative basically settle their conflicts but a court take actions when the cooperative cannot solve it.

d. Farming Practice

The project site consists of upland hill with steep slopes and the paddies in the downstream marshlands which is facing a trunk road. Maize, sorghum, beans and banana,etc. are cultivated in the upland hill, and paddy is practiced in above marshland. Maize production is the most common farming practice here since its hybrid variety was distributed by a MINAGRI program in 2008.

Table 2.1.21 Major Crops in Rugarama Sector of Gatsibo 31

Farmers to be studied (Effective Response Number)	Percentage of Farmers Farming by Type of Crops (%)							
	Maize	Sorghum	Haricot Bean	Banana	Rice	Cassaba	Sweet Potato	Cabbage
38 Households	63%	42%	37%	16%	11%	5%	5%	5%

With the result of the baseline survey and also considering the filed visit of the sites, present cropping pattern in the site is described. At present, inter-cropping of several crops such as sorghum, bean, maize, cassava and sweet potato are common.

Table 2.1.22 Present Cropping Pattern in Gatsibo31 Rugarama

Crop	Area	Inter/ Monc	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sorghum	24%	Inter crop												
Maize	34%	Inter crop												
Sweet potato	2%	Inter crop												
Haricot bean	15%	Inter crop												
Cassava	4%	Inter crop												
Banana	21%	Monocrop												

e. Farm Household Income

Average annual farm household income in Rugarama is estimated at 135,000Rwf. Out of them income from crop production occupies 75%. Table 2.1.23 below shows the average annual income of the site.

Farmers allocates significant amount of farm produce for their self-consumption. The monetary value of produce for the self-consumption was also estimated. The value of the annual self-consumption in Rugarama is 73,000Rwf. Total annual farm household income and self-consumption value are estimated at 209,000Rwf.

Table 2.1.23 Average Annual Income Rugarama

Item	Rugarama	
	Rwf	(%)
Crop	101,493	75%
Livestock	18,283	13%
Fishery	0	0%
Forest	0	0%
Farm labor	1,389	1%
Other	14,278	11%
Total	135,443	100%
Home Cosumption Value	73,181	
Total Value	208,624	
Crop + Home Consumption	174,674	84%

Table 2.1.24 No. of Households by Income Group

Annual Income + Home consumption Value (Rwf)	Rugarama		
	No.	Share	Acc.
< 100,000	13	36%	36%
100,000 < 200,000	12	33%	69%
200,000 < 300,000	5	14%	83%
300,000 < 400,000	1	3%	86%
400,000 < 500,000	2	6%	92%
500,000 < 600,000	1	3%	94%
600,000 < 700,000	1	3%	97%
700,000 < 800,000	0	0%	97%
800,000 < 900,000	0	0%	97%
900,000 < 1,000,000	0	0%	97%
1,000,000 <	1	3%	100%
Total	36	100%	

f. Farmers Organization

There is one rice cooperative named “COPRORIZ-Ntende” in the downstream marshland which was established by the assistance of ADRA (NGO) in 2003. The member number of the cooperative is 916 and the beneficiery area is about 180 ha. The cooperative has an office of solitary house with four (4) rooms and it was honored as an excellent cooperative by the Ministry of Trade and Industry. The farmers not holding agricultural lands is practicing various group activities such as handicrafts (production of baskets by women groups), cow raising, beekeeping and sewing.

(5) Bugesera 3 Rilima

1) Site

Bugesera3Ririma is located in the valley neighboring with Bugesera2Gashora having the northern ridge of Gashora in between. In the downstream this joins with Bugesera 2 and empties into Rumira lake. Similar to Bugesera 2, there is surface flow in the river bed not all the time. The upstream of road in the catchment is the forest of military area as same as bugesera 2. The present slope of both banks at the vicinity of dam axis is about 1:7 on both left and right banks (reffer to Figure 2.3.1).

2) Geology

The local geology of Bugesera 3 is characterized by an igneous intrusion of granite composition as part of the intrusions covering areas of significant size southeast and southwest of Kigali. Such intrusions have been observed in the eastern portion of Bugesera and central Nyanza districts. During the field survey, however, fresh outcrops of the intrusion have not been observed in many of the places including Bugesera 3 site. Road cuts and local excavations show that the rock has undergone high to complete degree of weathering. It is quartz rich with significant mica minerals. The granite at the site is affected by high degree of weathering that it is transformed into sand to gravelly sand soil. The depth of weathering is large (More than 5 m) as seen from the nearby road cuts and the test pits. On the left-hand side of the valley, the granite has been affected by higher degree of weathering that it exhibits almost equal proportions of fine and coarse fraction.

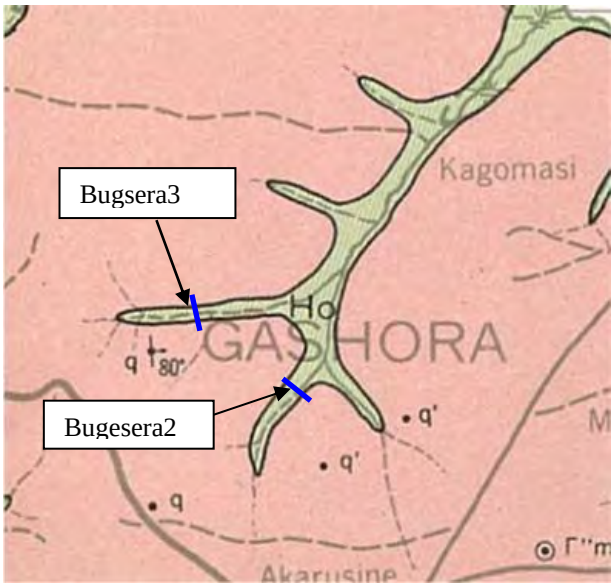


Figure 2.1.9 Geological Map of Bugesera3

As far as geological structures are concerned, the rock has been affected only by joints that are filled with late coming veins of quartz. In most of the weathered outcrops, these veins are seen as strong and resistant bodies and reveal dendritic patterns. It is free from other geological structures like deep seated open joints, faults and folds.

3) Socio-Economy

The site area includes Gasarwe imidigudu in Gashora sector and Nyabagendwa imidugudu in Rilima sector in Bugesera district.

a. Population, Familiy Structure and Numbr of Household

According to the socio-economical survey conducted by MINAGRI, 91% of households in the area is headed by male and 9% is headed by female. Average of number of family members is 6.1 persons and 88% of heads are married, 9% of them are widows or widowers and 3% of them are unmarried.

b. Land Tenure

61% of farmers don't have legal certification for land owner and 15% of them have. 24% of farmers were allocated farmland by the government but they don't have the right to sell it.

c. Land Size

Average farm land area per household is 1.16ha, 33% of the households own less than 0.5ha, 18% of them own 0.5 to 1.0ha and 49% of them own average 0.7ha. 15% of households rent average 0.3ha of farm land.. the farmers grow various crops in scattered farm land. The farm land is sold at RWF650,000/ha without crops and RWF1,2000,000/ha with bananas.

d. Land Use

The land in the area is used for growing cassava, sorghum, maize and other upland crops and there is no paddy field. According to the LWH report, there is no house in the reservoir area, however, 4 houses close to the reservoir needs to be moved.

e. Community Life

There is a deep well in the imidugudu and one household convey average 80lit/day and it takes one hour for 20lit/once. Water from the well is sold at the price 10RWF/20lit. No houshold uses elecricity and most of households use fire wood for fuel and kerosene for lighting. 61% of households had at least ome basic education, with 58% having attained some primary school education, 3% having attained lower secondary level of education respectively. 39% of the households heads had no formal education.

f. Farming Practice

Farmers in the area grow various crops. Major crops are shown in the Table Below. Beans, cassava, sorghum, maize and sweet potato is grown by many of farmers, followed by ground nuts and plantain. There are some of the constrains that hindered farmers from attaining optimal yields. These included lack of enough water throughout the growing season as a result of insufficient rainfall during the rainy period and a dry spell after the rainy season thus causing drying of crops before maturity, pests and diseases, inadequate soil fertility replenishment resources and poor crop management practices.

Table 2.1.25 Major Crops in Bugesera3

Farmers to be studied (Effective Response Number)	Percentage of Framers Farming by Type of Crops(%)								
33 households	Bans	Cassava	Sorghum	Maize	Sweet Potato	Soy Beans	Ground Nuts	Plantain	Other Crops
	100%	94%	91%	85%	82%	39%	18%	9%	3%

source：”Detailed Survey and Design Study - Volume 4-5 Bugesera - 4: Socioeconomics”, MINAGRI 2008

The nearest village market to the project site is in Rwibikara. The distance from the project site to the market is abouit 1km non-paved dirt road whose condition is rated as bad by the respondents but passable by trucks all year round. The nearest main market is Gashora, which is 3km away from the project site. The road to this market is a paved dirt road which is rated as good and passable by trucks all year round.

g. Farm Household Income

Average annual income of the area is RWS336,076 and the source of it is shown in the table below.

Table 2.1.26　Income source

Farmers to be studied (Effective Response Number)	Percentage of households that gains income from each item（example: 94% of 33 households gain an income from crop and the average amount is RWF230,116）								
Item	Crop	Livestock	Labor (except farm labor)	Temporary farm labor	Temporary labor (except farm labor)	Farm labor for long period	Business	remittance	Selling wood
Percentage	94%	55%	3%	39%	12%	3%	3%	6%	6%
Average Income	230,116	60,417	168,000	139,231	45,100	156,000	360,000	75,000	22,500

出典：”Detailed Survey and Design Study - Volume 4-5 Bugesera - 4: Socioeconomics”, MINAGRI 2008

h. Farmers Organization

42% of farmers belong to a farmers organization. 63% of their activity is production, marketting, saving and credit.

(6) Bugesrra4 Musenyi

1)　Site

Bugesera4Museni is located in Musenyi Sector where is about 23 km south of Kigali and about 18 km west from Bugesera 3 and Bugesera 2. At present the site is found comparatively flat topography with the elevation of about 1,400 m and as per the 1/50,000 topo-map there are high and steep mountains ranging at about 1,500 m elevation in the upstream basin. The lower moving down the basin, the gentler the gradient of both banks. At about 2 km downstream from the site there extends wet lands and at about 5 km point to north-west from the site, the flow empties into Akanyaru river, a tributary of Nyabarongo. Both at the upstream and downstream of the reservoir area, there are springs existing. The upstream one is situated higher than the reservoir full water level and the downstream one is on the mid slope of the mountain being 300 m distant from the reservoir and expected no influence on the reservoir. The slope gradients are confirmed lower than 16 % for 98 % area of both catchment area and beneficiary area.

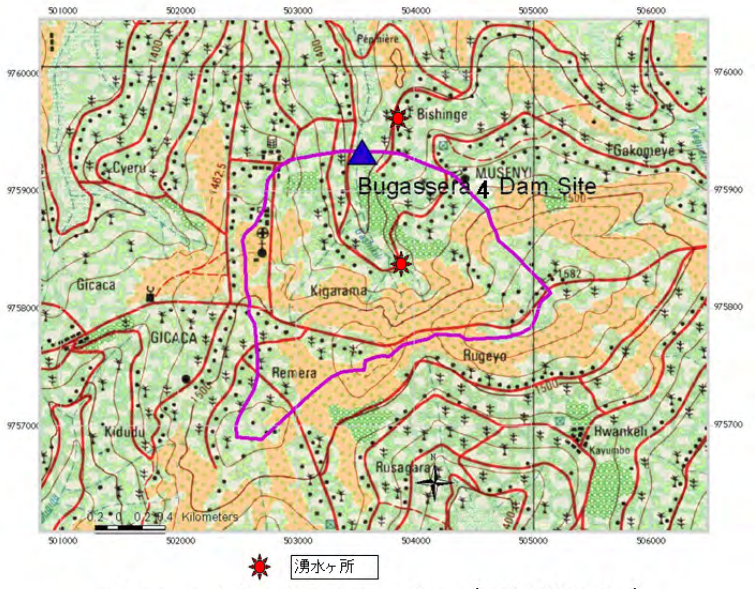


Figure 2.1.10　Location Map of Bugesera4

2) Geology

The base rock foundation in general is of pre-Cambrian and in and around the site is covered by metamorphic rocks predominantly consisting of mica-schist including quartz. On the slopes of both banks of reservoir, there found outcrops of mica-schist and the same is highly weathered. These rocks form sloped foundation both to up and down stream directions and is considered that the same indicate both joint and surface of discontinuity. The rocks are featured by quartz vein crossing the mother rock and are hydro-thermally altered. The mother rocks are widely covered by residual silt and highly weathered up to considerable depth.

The valley portion is covered by dark-brown color and non-organic silty clay with about 4 m thickness.

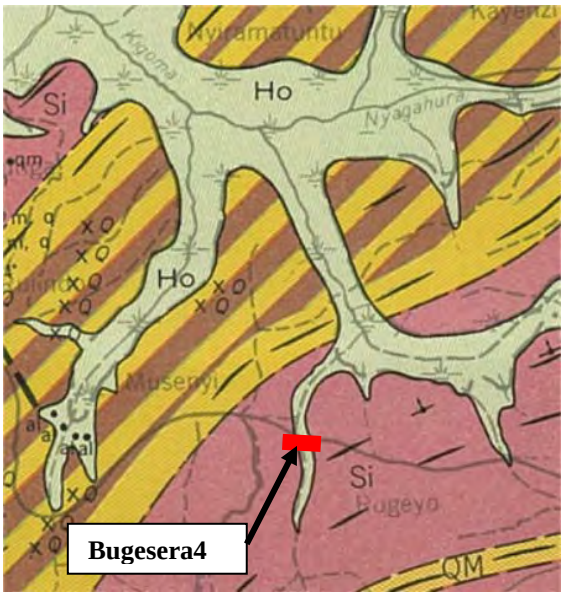


Figure 2.1.11 Geological Map of Bugesera4

3) Socio-Economy

The project site includes Bishinge, Gakurazo and Kijuli imidugudu in Mesenyi sector in Bugesera district.

a. Ppopulation, Family Structure and Number of Household

According to the socio-economical survey conducted by MINAGRI, 64% of households in the area is headed by male and 36% is headed by female. Average of number of family members is 5.1 persons and 61% of heads are married, 27% of them are widows or widowers and 6% of them are unmarried.

b. Land Tenure

81% of the households own land but only 3% of them have the certificate. 16% of farmers were allocated farmland by the government but they don't have the right to sell it. According to the LWH report, there is no house in the reservoir area, however, 3 houses close to the reservoir needs to be moved.

c. Land Size

Average farm land area per household is 1.5ha, 18% of the households own less than 0.5ha, 31% of them own 0.5 to 1.5ha and 51% of them own 2 to 4.5ha. Additionally, 27% of the households own additional land parcels elesewhere, with an average farm size of 0.25ha, while 12% further supplemented their farming by renting land, of an average farm size of 0.04ha.

d. Land Use

The land in the area is used for growing cassava, sorghum, maize and other upland crops and there is no paddy field. There is a forest of eucalyptus at the downstream of proposed dam axis.

e. Community Life

No houshold uses elecricity and most of households use fire wood for fuel and kerosene for lighting. There is a spring at upstream of the site and downstream of the site respectively and many of the peaple living the area use for drinking water. The spring at upstream was improved by an NGO and the people drink boiled water. 70% of households had at least ome basic education, with 52% having attained some primary school education, 9% having attained lower secondary level of education respectively. 30% of the households heads had no formal education.

f. Farming Practice

Farmers in the area grow various crops. Major crops are shown in the Table Below. Beans, cassava is grown by many of farmers, followed by ground nuts and sorghum. There are some of the constrains that hindered farmers from attaining optimal yields. These included lack of enough water throughout the growing season as a result of insufficient rainfall during the rainy period and a dry spell after the rainy season thus causing drying of crops before maturity, pests and diseases, inadequate soil fertility replenishment resources and poor crop management practices.

Table 2.1.27 Major Crops in Bugesera4

Farmers to be studied (Effective Response Number)	Percentage of Framers Farming by Type of Crop (%)								
33 Households	Beans	Cassava	Ground nuts	Sorghum	Commercial Crops	Maize	Sweet potato	Irish Potato	Other Crops
	97%	97%	73%	67%	58%	48%	45%	27%	<24%

source：”Detailed Survey and Design Study - Volume 4-5 Bugesera - 4: Socioeconomics”, MINAGRI 2008

The nearest village market to the project site which could be provide an outlet for farmers’ produce that may not meet the first quality/grade requirements of the buyer is Musenyi market, located about 1km from the project site and Gichacha market located about 2km away. The road to the markets is a paved dirt road whose condition is rated as good to the Musenyi market and bad to the Gichacha market.

g. Farm Household Income

The households in the project area had an annual average gross income of RWF199,419, obtained from different sources. The income from crop sales is the largest followed by business and livestock/product sales.

h. Farmers Organization

59% of households are members of groups, where 85% belong to farmers’ associations whose main functions are crop production, produce marketing or savings and credit. An assessment of the willingness of farmers to become members of producer marketing groups is impressive since 82% of the farmers indicated that they are willing to become members.

2.1.2 Planning for Each Dam Site

(1) Bugesera2 Gashora

1) Site

The detailed design report for LWH Bugesera 3 site could be obtained during the field survey and it was confirmed that those basic data for Bugesera 2 are quite similar to those of Bugesera 3 as No.2 and No.3 are located nearby with each other. Further, the catchment for the No.2 extends over the main road including the forest area belonging to the Military Department as similar to the No. 3. Accordingly, through due consultation with the officer in charge of the Sector, it was so decided that the dam body should locate at outside of the military area and full water level of the reservoir not reach to the said military area.

In case of Bugesera 3 site, the reservoir is located at the downstream of the road so that the stored water will not affect on the military area. The catchment is not so large, however, the dam axis shall be fixed at the place where does not cause water reach to the military area but with the possibly maximum storage capacity with in due consideration of the dam crest height and reservoir water level.

Figure 2.1.12 Location of Dam Axis

2) Selection of dam axis

The point around 400 m downstream from the road is deemed suitable for dam axis as it will cause less dam embankment volume judging from the topographic condition of both banks which is narrowed. Upstream therefrom may result in shallower storage pocket. In downstream from the 400 m point, right bank side is widely opened causing much larger embankment volume. In further downstream, the left bank side is opened at the junction with the downstream of Bugesera 3. Again at the most downstream the topography is an open area with gently undulating and not suited to dam site.

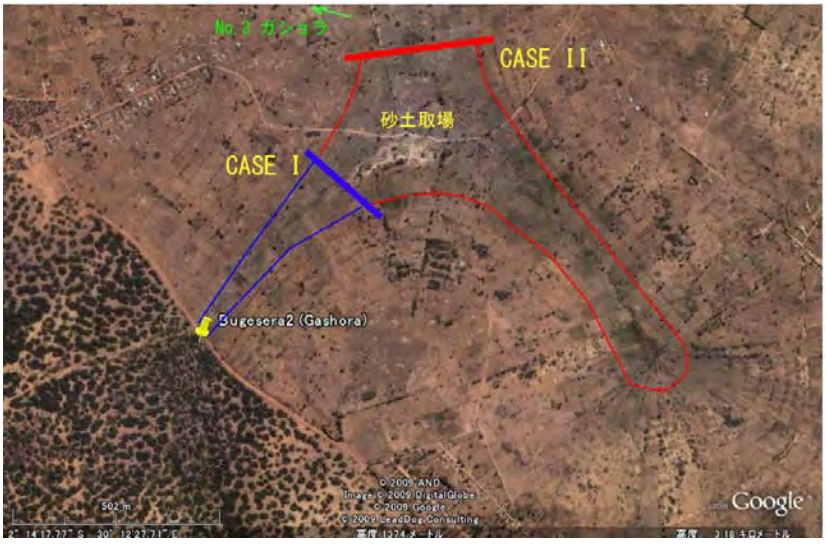


Figure 2.1.13 Location of Bugesra 2 Case I and Case II

There has been a request that for this planning the storage capacity of reservoir be fixed as large as

possible, and therefore, it was intended to locate the dam axis at the lower-most stream within the limit of reasonable technical justification. This is the case for Case I alternative.

While the Case II is an alternative including the valley on eastern side and considered that the plan is provided with high technical feasibleness. The representative of the Sector also requested the study team to pay due attention on the Case II study. Due to the complication of beneficiary areas, however the plan was abandoned as the result of careful study and it was decided to adopt the Case I in due consideration to the planning concept of LWH.

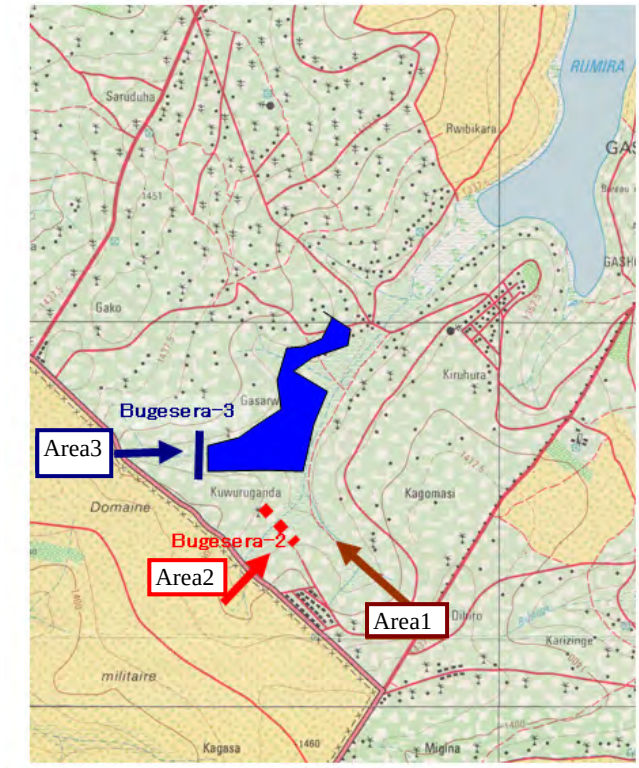


Figure 2.1.14 Catchment Area of Bugesera2 and Bugesera3

[Technical note 1: Re. Dam axis alternative Case II]

i) Alternatives for Bugesera 2

Under the LWH project, Bugesera 2 dam is to be provided in the catchment No. 2 located neighboring with the catchment No. 3 of Bugesera 3 for which the detailed design has been completed.

As the matter of course, the storage capacity would be decided based on the scale of dam, the size of catchment area and etc. and the beneficiary area be fixed as per the irrigation plan. The catchment No.1 neighboring the Bugesera 2 site is not cultivated as the beneficiary area and depending on the necessity it can be combined together with Bugesera 2. This case is an alternative as Case 2 of Bugesera 2 where the storage

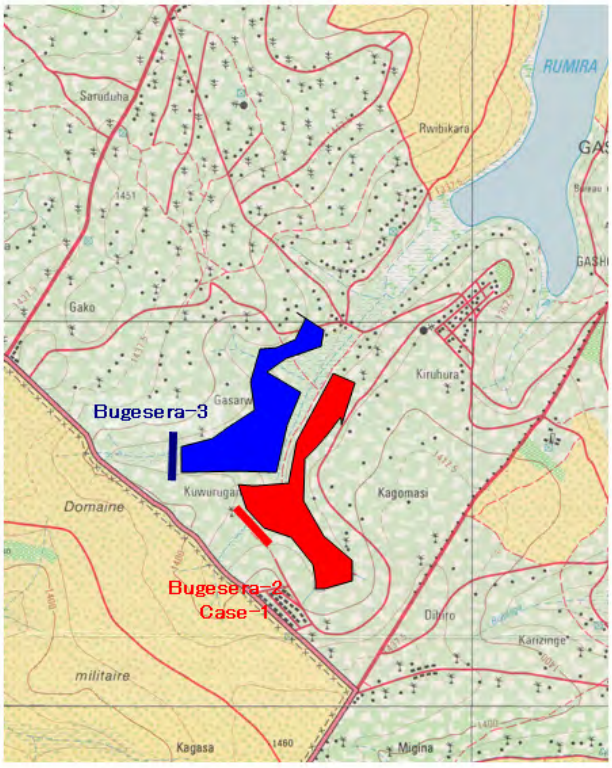


Figure2.1.15 Beneficiary Area of Bugesera2 and Bugesera3

capacity becomes about double of Bugesera 2.

ii) Bugesera 3

Bugesera 3 under the LWH project is planned to irrigate the left bank beneficiary area extending downstream from the conjunction point of catchment No. 1, 2, and 3. The beneficiary area in total is 55 Ha. The catchment extends further and reaches to Rumira lake by about 500 m distance.

iii) Original Case II of Bugesera 2

While in the case of original Bugesera 2, it is possible to include the catchment No. 1 as the beneficiary area, being located at the opposite side bank of Bugesera 3 and it is possible to combine within right bank beneficiary area. The Figure 2.1.15 shows the layout of the beneficiary areas as mentioned.

iv) Alternative Case II of Bugesera 2

Examining the case combining the catchment No. 1 under Bugesera 2, the storage capacity would be about double of the original plan, making it possible to increase the beneficiary area accordingly as shown in the Figure 2.1.16. As can be seen from the Figure, the beneficiary area can not be expanded sufficiently even though the area be extended up to Rumira lake. As is the case, it is questionable if the plan may secure enough benefits to meet the construction cost.

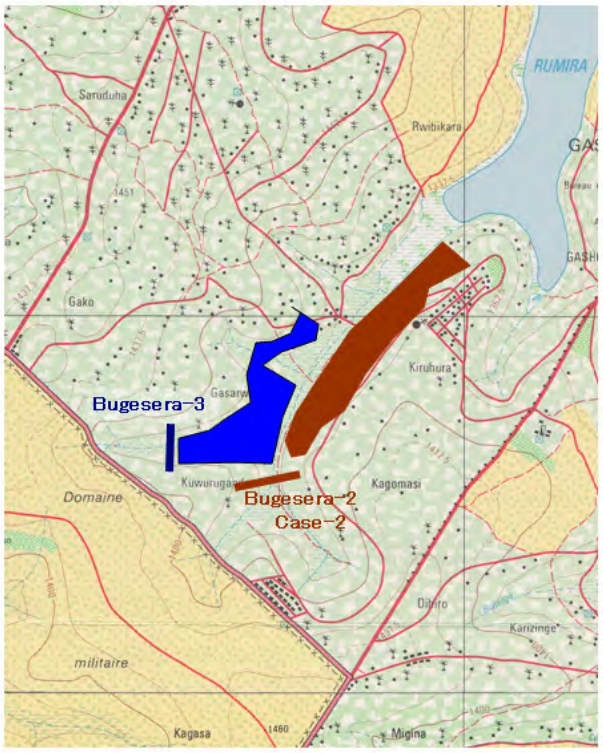


Figure 2.1.16 Beneficiary Area of Bugesera3

While it can be said that in case the water level in Rumira lake could not be raised up due to some reasons, the lake functions as regulating pond and it is meaningful to secure larger storage capacity.

Under the present circumstances however, there is no particular advantage in having a regulating pond, and it is considered that Bugesera 2 is planned to have the catchment No. 2 as drainage area and the catchment No. 1 as the

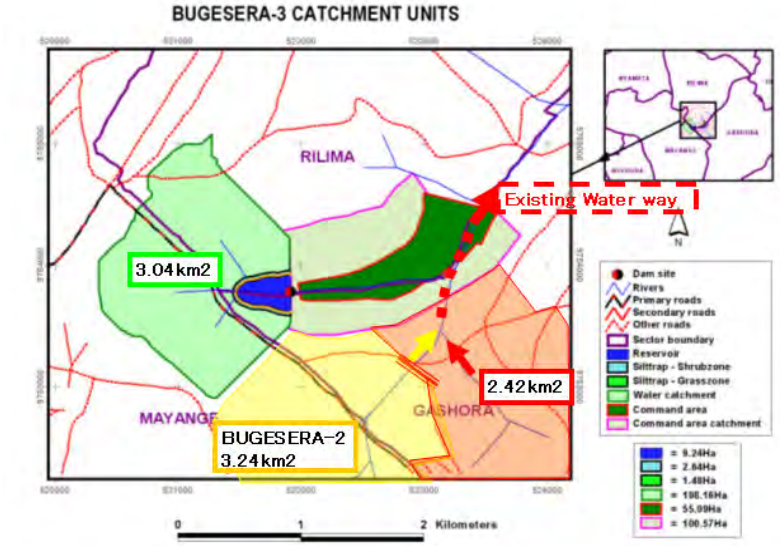


Figure2.1.17 The location of Bugesera2 and Bugesera3

beneficiary area.

[Technical note 2: Re. Transfer of right bank beneficiary area along the existing water way, Bugesera 3]

MINAGRI requested plans that will not affect on Bugesera 3 under the LWH project. In fact, however, some effects to Bugesera 3 by the present planning is unavoidable. Reasons for this point are as follows. Under the LWH project, the flood water from Bugesera2Gashora and the nearby catchment is to pass trough the beneficiary area by Bugesera 3 and secondary pipelines as irrigation facilities are to be installed at the river bed. In this case, the said flood water and pipeline embedded below river bed cross each other. Even in the case Bugesera2Gashora would not be built, the same crossing may happen causing operation and maintenance problem in future. (As per the opinion of the MINAGRI official who accompanied with the study team, it is possible to modify the plan during the construction work so as to transfer the subject beneficiary area, no problem may happen when JICA proceeded to implementation of Bugesera2Gashora as confirmed.)
Further, it is noted that the river water way could be safely secured and cause no problem if beneficiary area be transferred as shown in the Figure 2.1.18.
Further, it is noted that the river water way could be safely secured and cause no problem if beneficiary area be transferred as shown in the following Figure.

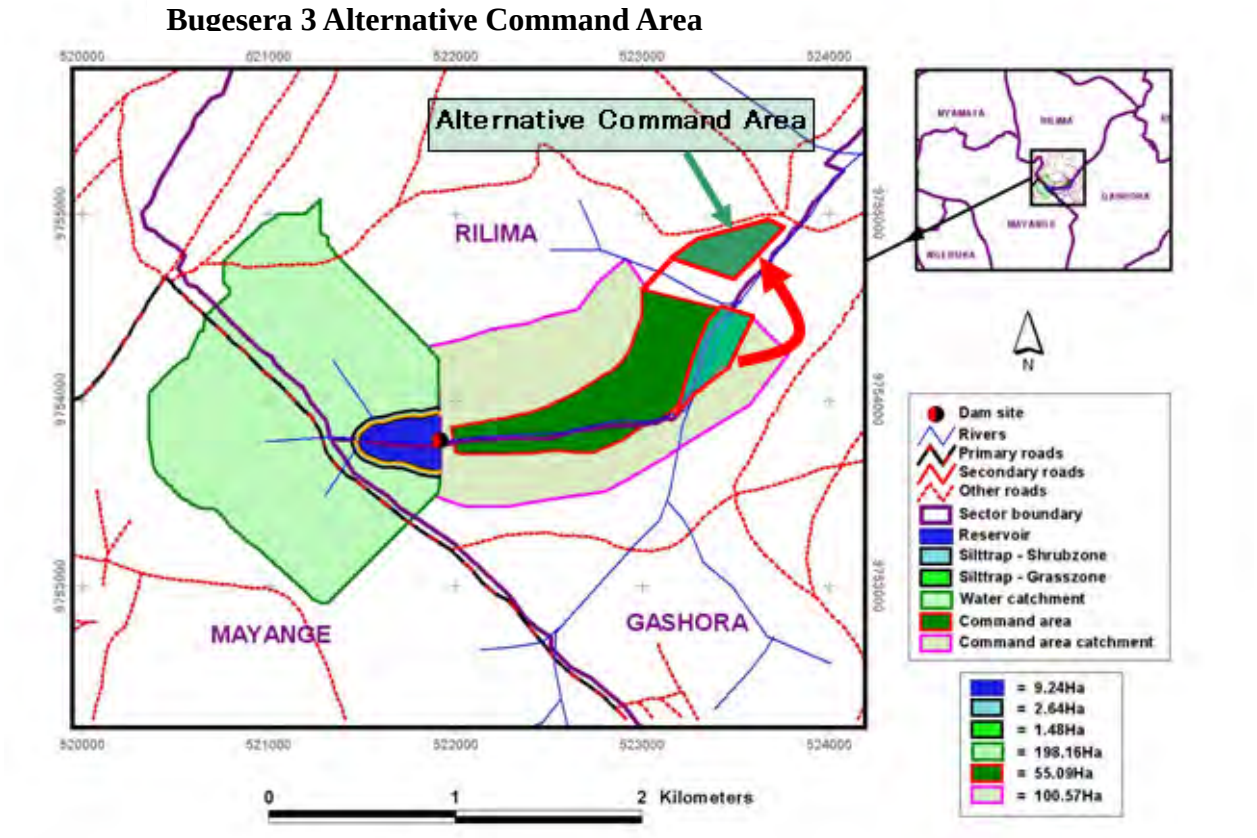


Figure2.1.18　Alternative for Beneficiary Area of Bugesera3

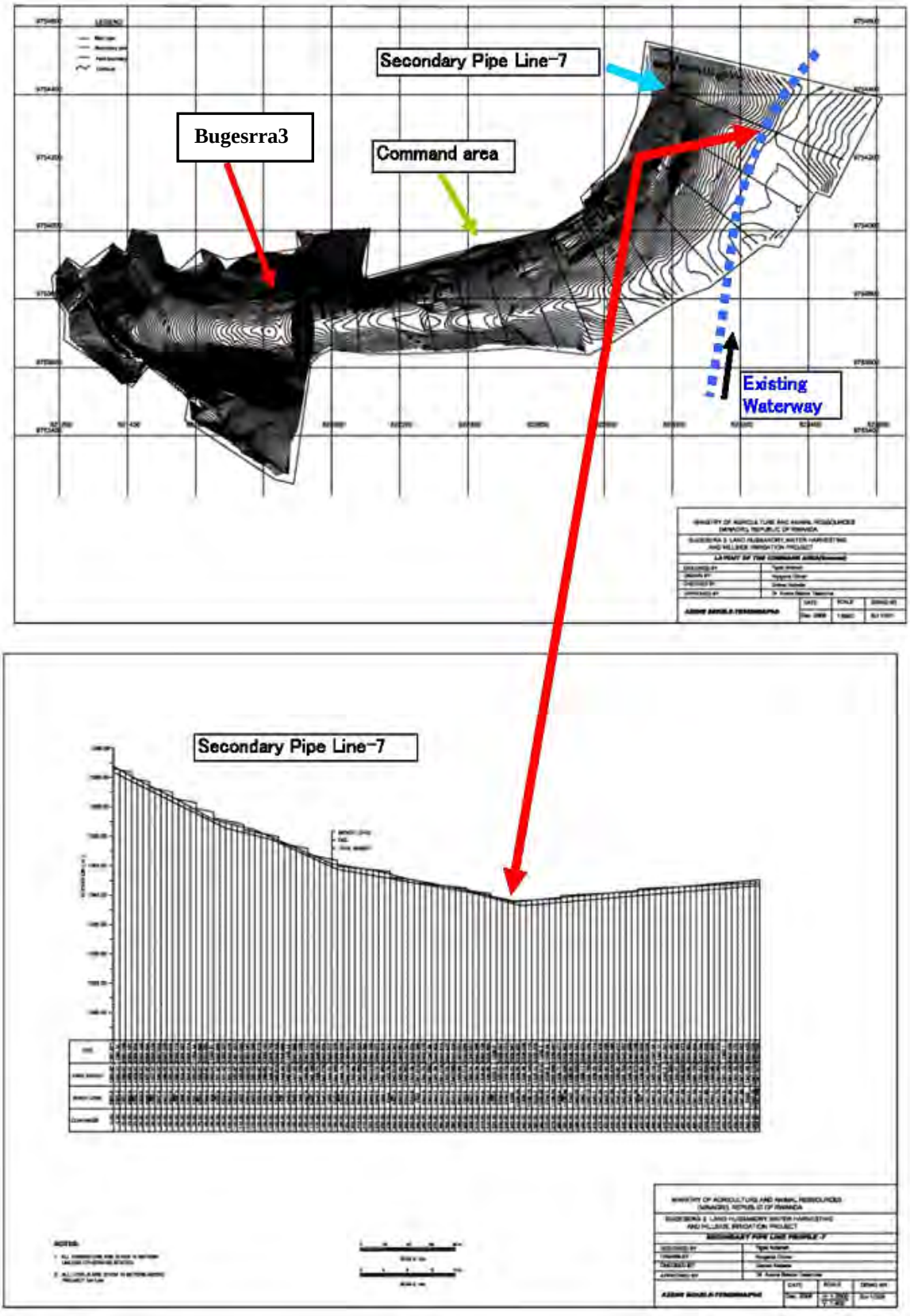


Figure2.1.19 Location of Drain Canal

Further to mention, Bugesera 3 has been included in the subject study as per the additional request made by MINAGRI after the completion of the field survey and the study team's return to Japan. As Bugesera 3 be included in the subsequent study(Basic design) by JICA, the solution for crossing over problem and/or collaboration between ongoing LWH and JICA project could be attained in due course.

3) Geology

The local geology in and around the dam site is underlain by an igneous intrusion of granite composition and the foundation is of the thick layer of highly weathered. Topographically, there is a river flowing through the lowest portion at the center of the valley, however, there is surface water flowing not all the time as Wadi. As can be seen from the Figure 2.1.20, geological map in and around Bugesera 2 and 3 as referred from the geological map prepared by the Geological Institute, Belgium, the river bed is covered y such alluvium deposits as clay, sand, and gravel.

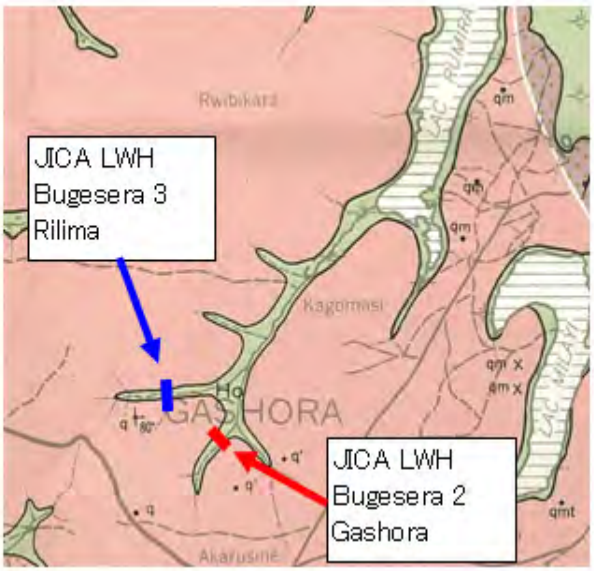


Figure 2.1.20 Geological Map of Bugesera2 and Bugesera3

As confirmed in the field survey, the surface layer of both banks is covered by those soils derived from weathered granite compositions. As the material for the dam embankment, this can be used as impervious material. In the center of the valley, there is a low land but no river is observed. The land surface is covered by alluvium deposit containing much sandy nature. During considerable floods, there can be seen a surface flow and silt and clay are to be flown away to further downstream. In the downstream conjunction point with the western right bank valley, no surface flow can be seen. The area is covered by sand and borrow pits of sand are found with having the sand layer thickness of about 3 m. The sand layer is considerably hard and the permeability is seemed to be low. Gravels are found in the upland field on the sloping land. These gravels are of quartz rich derived from the weathered granite but the quantity of gravels is not much. For the embankment material, such weathered silt and sand originated mainly from granite will be used.

—Geological Survey at Dam Axis—

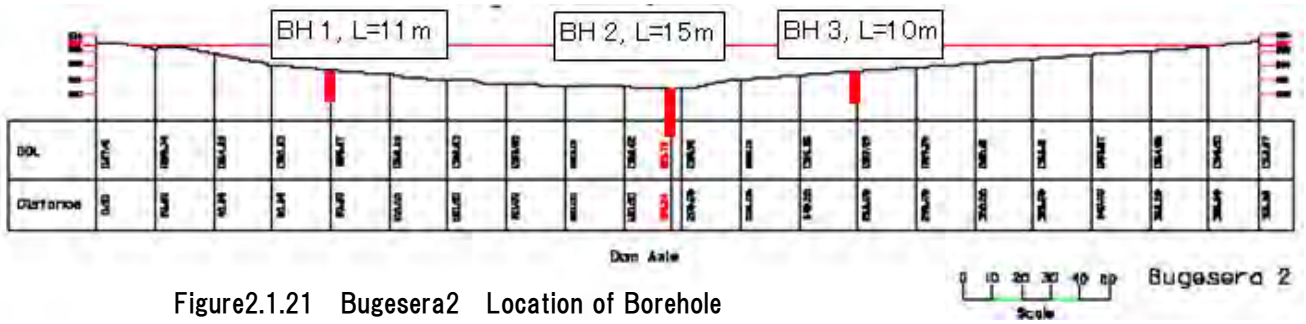


Figure2.1.21 Bugesera2 Location of Borehole

BH 1: From the surface to the depth 3 m, clayey soil mixed with sand and gravel in reddish brown color. Between the depth 3-11 m, weathered sand stone with N-value
larger than 50. (According to the test pit, weathered sand stone is observed at the depth 4 m and deeper.) Permeability test showed 0-5 m: 1.5 Lugeon, 5-10 m: 1 Lugeon to confirm the impervious foundation.

BH 2: From the surface to the depth 7.5 m, clayey soil mixed with sand and gravel in yellow brown color. At the depth 1.5 m, N-value 12, at 4.5 m, 15 and at 6 m,N-value 38. Deeper than 7.5 m, weathered sand stone with N-value larger than 50. Permeability test showed 0-5 m: 3.2 Lugeon, 5-10 m: 1 Lugeon, 10-15 m: impervious with lower than 1 Lugeon

BH 3: From the surface to the depth 4.5 m, clayey soil mixed with gravel in yellowish brown. At the depth of 1.5 m, N-value 17 and at 3 m, N-value 58. At the depth of 4.5 m or deeper, weathered sand stone.

As per the boring survey results as above, both banks have solid foundation at the depth 3 m or deeper and at the river bed it is solid at the depth of 6 m or deeper. Permeability of foundation is judged to be impervious with about 3 Lugeons or smaller under the condition of water pressure at 30 m with the depth of 5 m from the surface. However, it is noted that careful attention shall be paid during the excavation of cutoff taking into account the possible water path as the N-value is only 15 at te depth 4.5 m at the river bed.

4) Survey for embankment materials

In order to avail the embankment materials within the reservoir area, test pits were provided on both banks of the upstream area of dam axis. Laboratory tests were conducted on the samples collected and studied the possibility to use them as impervious core material for dam embankment.

The test result showed that the material can be used as impervious core material.

The materials tested on both right and left banks showed the similar result and can be used as impervious material except the material from the river bed portion. The impervious material is, however,

found with rather low moisture content and it is necessary to pay due attention to add some water during the embankment construction works.

5) Longitudinal section and plan of dam axis

The following Figure shows the longitudinal section and plan of dam axis as assumed as the most probable.

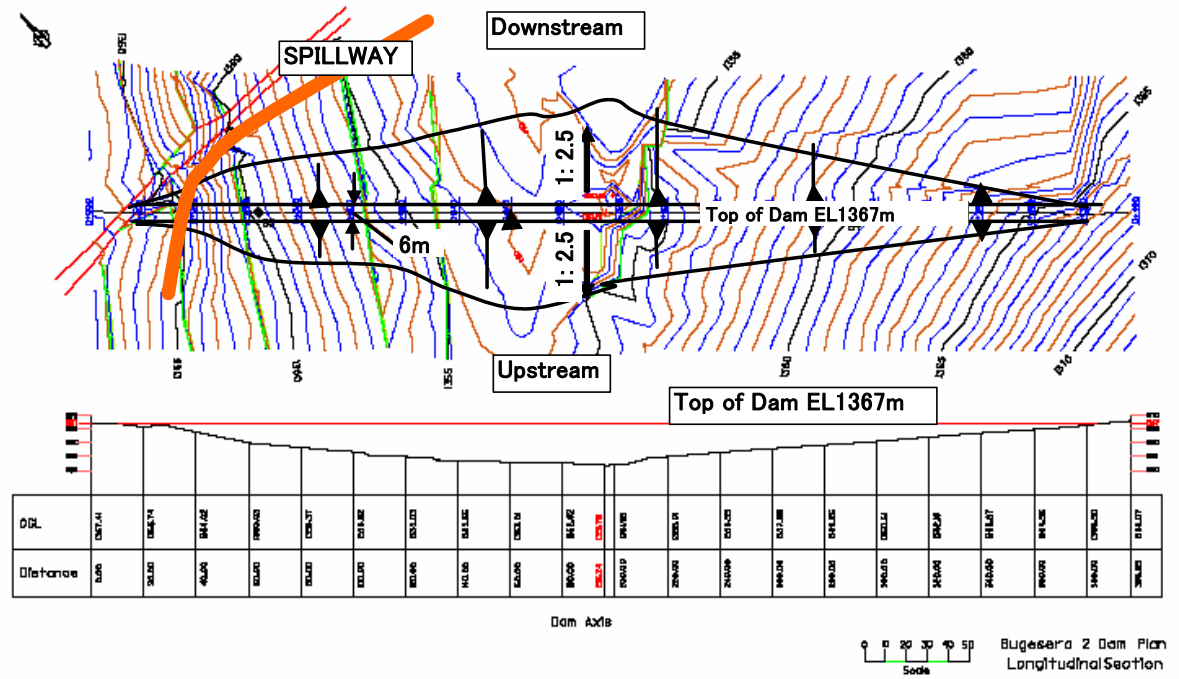


Figure 2.1.22 Bugesera2 Longitudinal Section and Plan

6) Image of completed dam body and surroundings

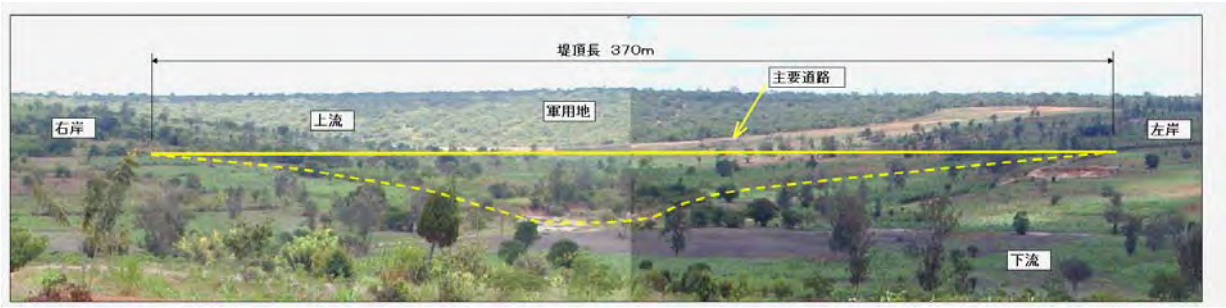


Figure 2.1.23 Image of completed dam body and surroundings, Bugesera 2

(2) Ngoma21Remera

1) Site

The site was indicated to locate in Remera 2 Sector in the LWH project report but in fact the site is located at Remera Sector. The study team confirmed the location through tracing by use of GPS and due confirmation by the officer in charge at the site. The name of the site is Remera but not Remera 2 as confirmed and also Ngoma 22 Remera be called Rurenge as confirmed also by the officer in charge at the site. It was found out that on the right bank side the topography is rather steep with natural bush while the left bank side gently sloping land used as upland field.

2) Selection of dam axis

There are springs at the right bank river bed in immediate downstream from the dam axis as requested, being the water source for the local people and concrete structures as installed with pipes are existing there. In the river there is some surface flow though a little and never dried up even in the dry season as per the information at the site. According to the local people, here had been some springs at about 100 m upstream and cultivated paddy in the past, though presently being abandoned field. At the said upstream spring point, no water intake facilities are existing and further upstream area is topographically raised up sharply without any surface flow or streams. In a distance of 180 m from the requested dam axis, the ground elevation is up by 10 m implying that the storage depth reduced by 10 m and therefore the site is judged not suitable for building a dam. It is also considered if including the spring site in the reservoir area, a reverse flow may happen or stored water may leak through spring due to the high pressure by stored water. Accordingly, it is necessary to locate the dam axis at further upstream of the spring site located upstream.

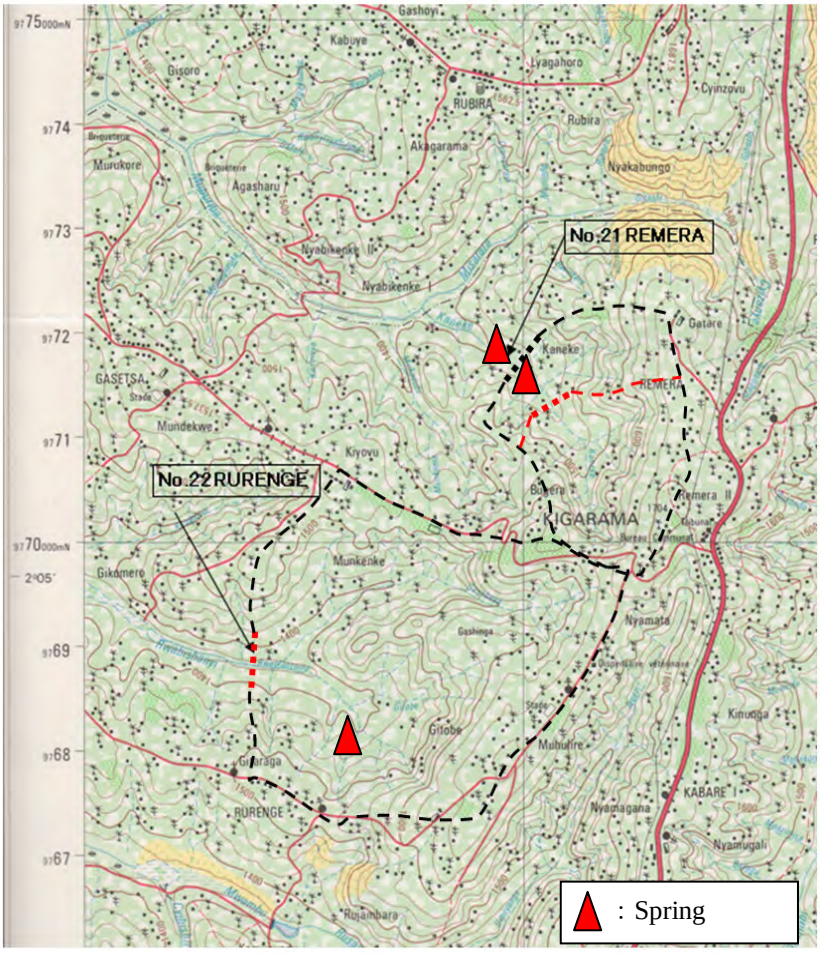


Figure 2.1.24 Catvhment Area of Ngoma21 Remera and Ngoma22 Rurenge

The longitudinal profile of the valley is quite steep at 1/20 and a dam axis with comparatively favorable reservoir pocket can be found at around 580 m upstream from the requested dam axis point. At this site, a storage of 442,000 m3 can be expected with 16.6 m dam height and crest length of 400 m (In case dam embankment material be secured inside the reservoir area). The requested dam axis case, the crest length may be shorter at 370 m but due to the topography the storage capacity much less than the new site.

3) Geology

The ground surface is covered with soils as derived from weathering of granite and sandy-muddy sedimentary rocks and it is considered suitable in this case to use the impervious material taken from the weathered granite soils at the left bank abutment. In the river bed there found no much sand and it can be considered that river bed deposits are retained due to the higher groundwater table at the right bank test pit site. As the impervious embankment material, heavily weathered zone can be used. Though it can not be clarified in case of sandy nature soil, but small gravels can be found at the higher elevated locations and therefore it can be considered the weathered soil material is originated from conglomerate.

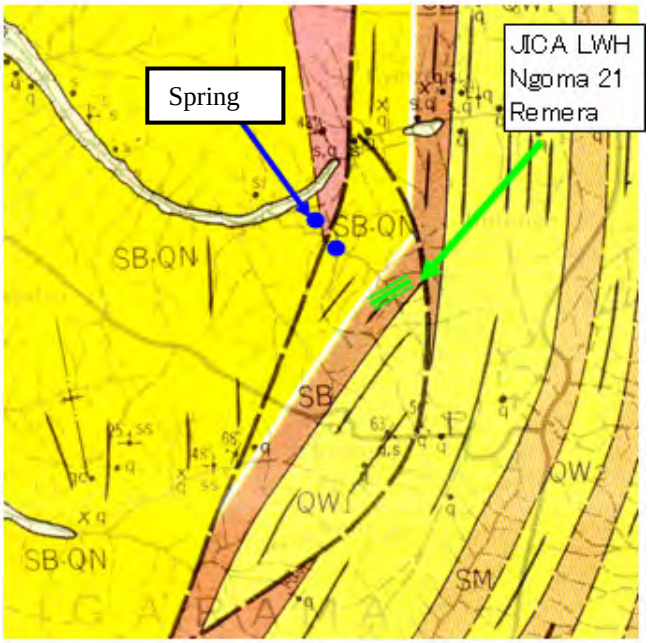


Figure 2.1.25 Geology of Ngoma21

For the rock materials, conglomerate and granite can be considered available. On the ridges of both banks there found some outcrops and rock material can be availed for dam construction though it may require some distance for transportation.

—Geological Survey at Dam Axis—

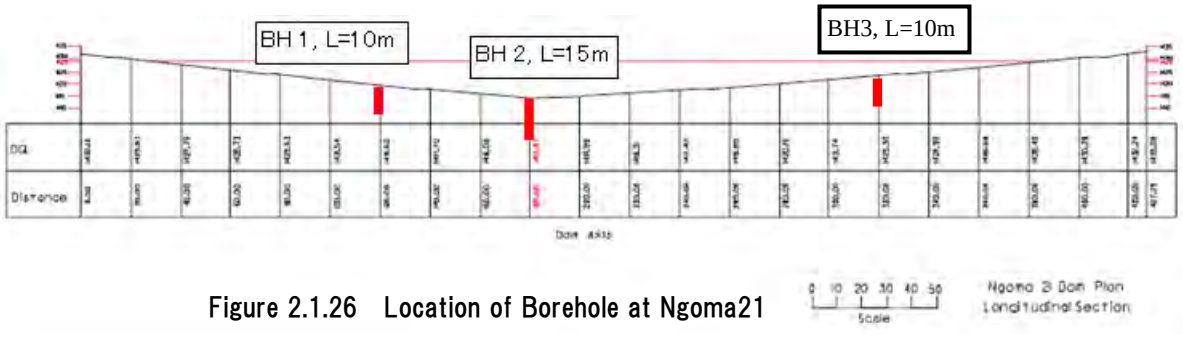


Figure 2.1.26 Location of Borehole at Ngoma21

BH 1: From the surface to the depth of 7.5 m, silty clay in reddish brown color. Between the depth 7.5-10 m, color changes to yellowish gray being silty clay mixed with gravel. N-value 5 for 0-1.5 m, 12 for 3 m, 8 for 4.5 m 21 for 7 m and 54 for 9 m. (As per the test pit observation, below the ground surface there found clayey silt and sand mixed with gravel being different from the result of boring survey.)

BH 2: From the surface to the depth of 1.5 m, dark brown silty clay.
Between the depth 1.5-9 m, reddish brown silty clay. From 9m, reddish brown tuff.
N-value is 5 at 1.5 m, 12 at 3 m, 15 at 5 m, 20 at 7 m and larger than 50 at 9 m.
Permeability is 0.3 Lugion at 0-5m, 27 Lugion at 5-10m and 40 Lugion at10-15m.

BH3: From the surface to the depth of 6m, stiff clay in reddish brown color. 6 to 10m, reddish brown stiff clay with gravel.
N-value is 13 at 0-1.5m, 17 at 3m, 26 at 4.5m, 36 at 6m, 35 at 7m and 33 at 9m.
Permeability is 1.5 Lugion at 0-5m and less than 1 Lugion at 5-10m

It is judged that if N-value of clayey soil is 12 at 3 m depth, there is no problem on the safety as the foundation for the homogeneous dam with 16 m dam height.

On both abutments the topographical inclinations are gentle with having the similar results both for left bank and river bed. It can be considered as the secondary sediments of weathered rocks too as river bed from silty clay to weathered rock without mixture of gravel while for the left bank with the mixture of gravel. At the river bed weathered rock can be found at the 9 m depth but there is a possibility that the rock surface line is not elevated on the abutment sides. In the river bed portion, basement of cutoff may be fixed at 4.5 m depth.

According to the permeability test, at the river bed, the foundation is impervious up to 5m depth. However, it is pervious in the depth under 5m. If the impounded water does not affect the pervious zone directly, the reservoir can be constructed. However, it is necessary to survey its impact in the upper stream area. On the other hand, it is important that the reservoir will be designed that cut off shall be within the depth of thin impervious foundation and the thickness of remaining impervious foundation shall be ensured. Therefore, it is recommended to lay impervious blanket at upstream of the embankment to ensure seepage control.

Additional geological survey is required; 2 bore holes at river bed and one at 25m upstream from dam axis and one at 50m from dam axis, total 4 bore holes (10m x 4 = 40m).
Permeability test at short section (each 1m) is required to grasp detail of high permeability zone in the

foundation. A large capacity pump is required to measure accurately.

4) Survey for embankment materials

It is planned the embankment materials be taken inside of the reservoir area, and test pits were provided on both banks of the upstream area of dam axis. Laboratory tests were conducted on the samples collected and studied the possibility to use it as impervious core material for dam embankment.
The test result showed that the material can be used as impervious core material.
The materials tested on both right and left banks showed the similar result and can be used as impervious material except those from the river bed.

5) Longitudinal section and plan of dam axis

The following Figure shows the longitudinal section and plan of dam axis as assumed as the most probable under the present study result.

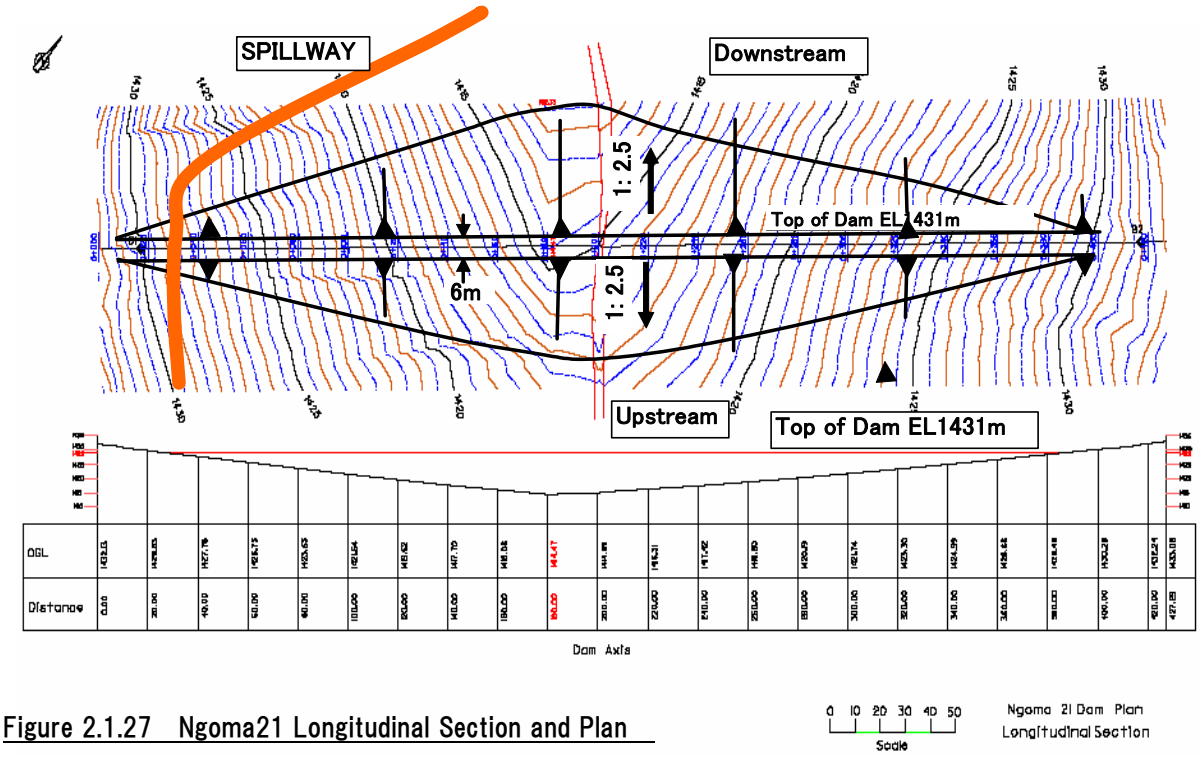


Figure 2.1.27 Ngoma21 Longitudinal Section and Plan

6) Image of completed dam body and surroundings

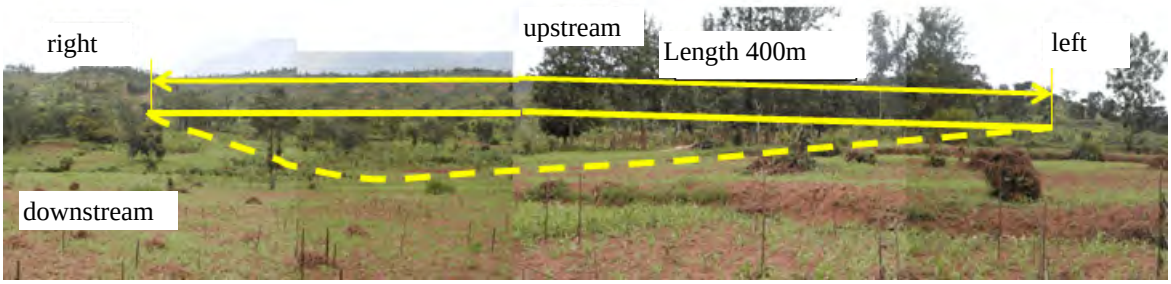


Figure 2.1.28 Image of completed dam body and surroundings, Ngoma21

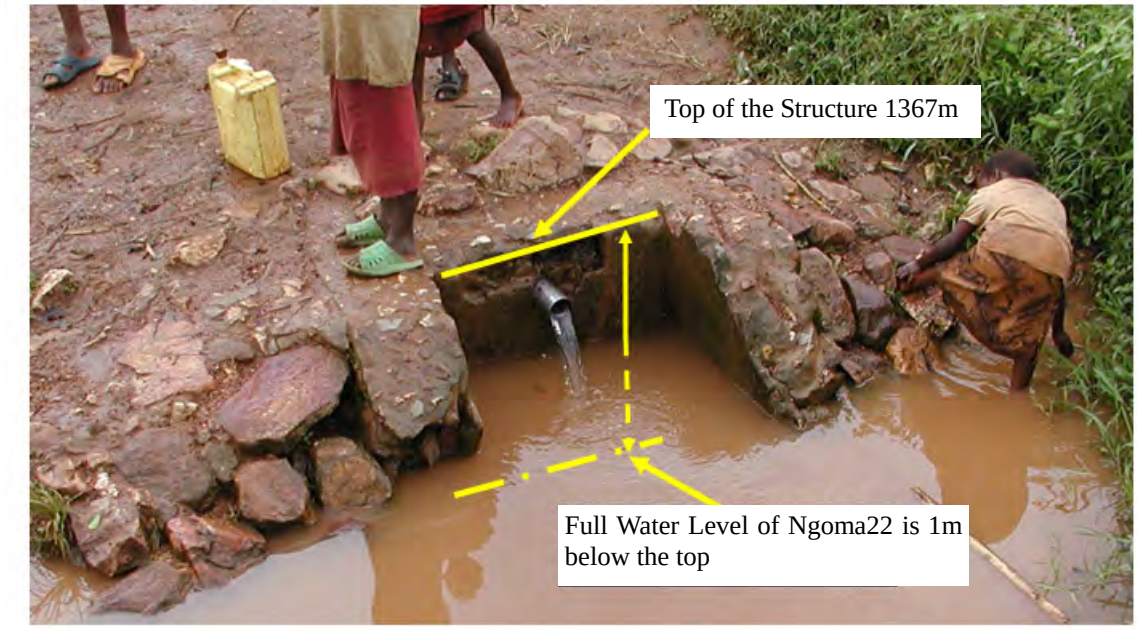
(3) Ngoma22Rurenge

1) Site

The Remera site indicated in LWH report is actually a different site. The study team, therefore, fixed the correct location through confirming the site with the officer in charge at the site and fixing by using GPS. It was finally confirmed that the right bank of the site is Remera and the left bank is Rurenge.

For this site, both banks are upland fields with rather gentle slope. Over the river nearby the requested dam axis, there existed a box-culvert bridge. In some years ago there had been a plan to provide a crossing of both bank roads at this location, but there have been no any substantial progress for the plan. The river with the width of only 1 m has surface flow and even in dry season flow does not disappear according to the local people. In the area as far as 1,140 m upstream from the requested dam axis, there existed springs as equipped with pipe intake facilities for use by the local people.

Even after the completion of dam construction the subject water intake facilities are to be fully utilized by the people, the full water level of reservoir shall be fixed at lower than the intake. As is the case, the full water level is recommended to be fixed at EL 1366 m, 1 m lower than the crest of intake facility which is confirmed as 1367 m so as to avoid such negative effect as mentioned above.



2) Selection of dam axis

The requested dam axis is the site where topographically both banks narrowing and seems possible to select a dam axis to cause the minimum dam embankment volume. The existing culvert structures at the dam axis area shall be removed and the dam crest will be used as a substitute facility to connect the both banks.

3) Geology

The ground surface at the site is considered derived from weathering of granite and/or sandy-muddy sedimentary rocks and as the impervious materials for dam embankment the weathered granite zone on the left abutment is assumed possible for use. There is no much sand in the river bed and from the observation at the test pit it is considered that there are some clayey river bed deposits retained at the river bed. On the right bank abutment, there found shallow layer of weathered sandy-muddy mica schist. As the rock materials, there is a possibility to find them at the steep sloping area nearby. On the ridges of both banks, outcrops of rocks are found here and there.

—Geological Survey at Dam Axis—

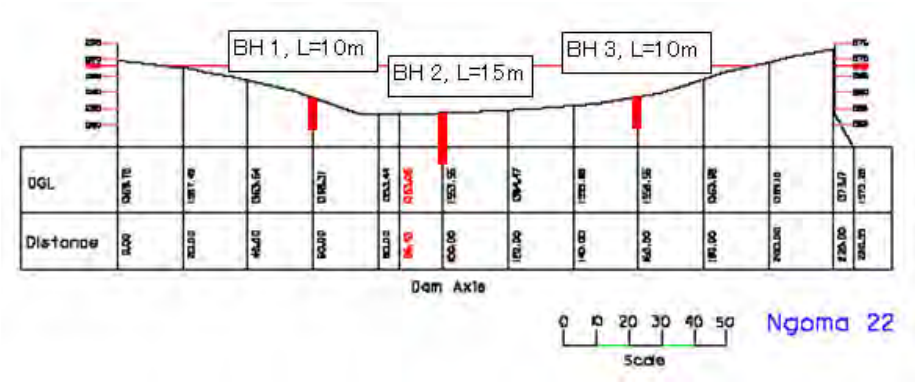


Figure 2.1.29 Location of Boreholes

BH1: From the surface to the depth of 6m, reddish brown stiff clay. 6-7m and 7.8-9m, yellowish brown stiff clay with gravel. Greyish brown stiff clay under 10m.

At he depth of 1.5m, N-value 7, at 3m 8, at 4.5m 12, at 6m 12, at 7m 21 and at 9m 54.

Permeability is less than 3 Lugion at 0-5m and less than 2 Lugion at 5-10m.

BH2: From the surface to the depth of 3m, dark grayish clay with sand. 3 to 10m. coarse grained fragmented Granite. 10 to 11.5m, coarse grained Basalt. 11.5 to 15m, reddish highly weathered Granite.

At the depth of 1.5m, N-value 4 and the depth below 3m, N-value more than 50.

Permeability is less than 7 at 0-5m, less than 4 at 5-10m and less than 4 at 10-15m.

BH3: From the surface to the depth of 1.5m, dark brown clay. 1.5 to 4.5m yellowish brown clay. 4.5 to 7.5m, dark brown clay. At the depth deeper 7.5m, reddish brown stiff clay.

At the depth of 1.5m, N-value 8, at 3m 9, at 4.5m 9, at 6m 33 and at 7.5m 70.

Permeability is less than 2 Lugion at 0-5m and less than 1 Lugion at 5-10m.

Permeability of river bed is less than 4 at the depth deeper than 5m. Lugion value of left side abutment is less than 3 and the thickness of impervious layer is expected more than 10m.

4) Embankment materials

To avail the embankment materials within the reservoir area, test pits were provided on both banks of the upstream area of dam axis. Laboratory tests were conducted on the samples collected and examined the possibility to use them as impervious core material for dam embankment..

As the results, it was confirmed that the material can be used as impervious core material.

For this case, the condition is different by left bank and right bank. In the right bank, clayey soil layer extends up to 5 m depth, while in right bank the natural moisture content shows higher ratio with having mixture of gravel and deeper than 5 m weathered rock foundation is observed. In this case it is preferable to fix the borrow pit on the left bank side.

4) Longitudinal section and plan of dam axis

The following Figure shows the longitudinal section and plan of dam axis as assumed as most probable under the present study.

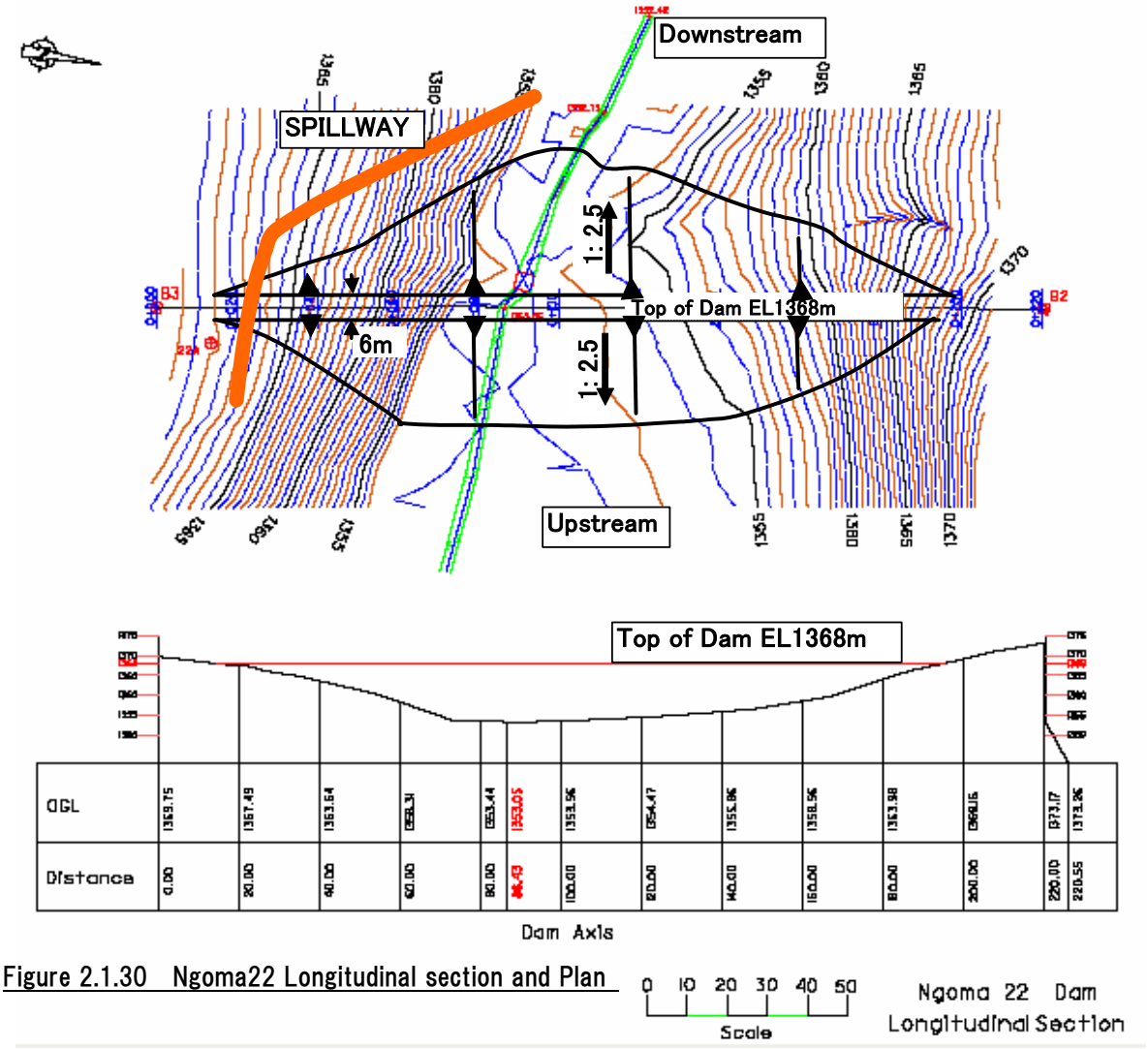


Figure 2.1.30 Ngoma22 Longitudinal section and Plan

5) Image of completed dam body

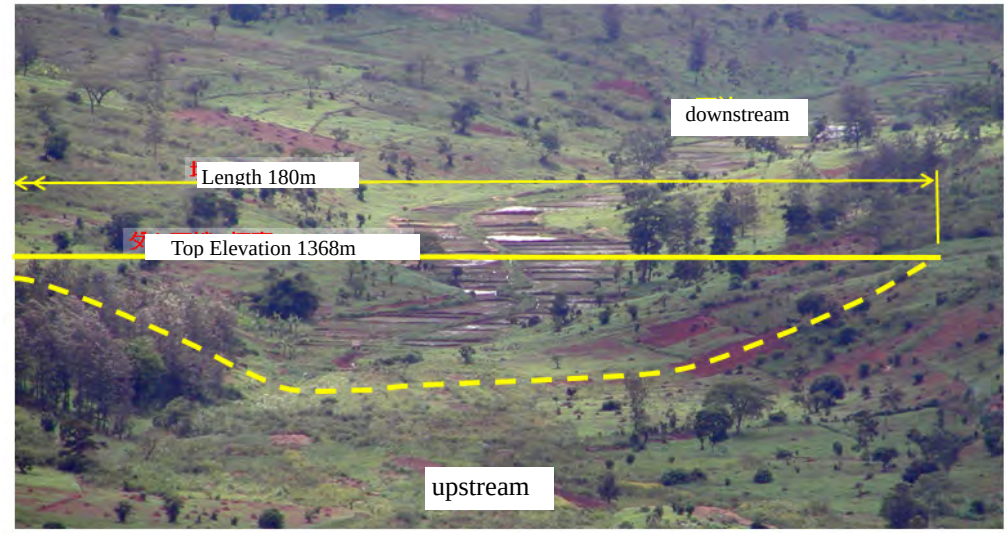
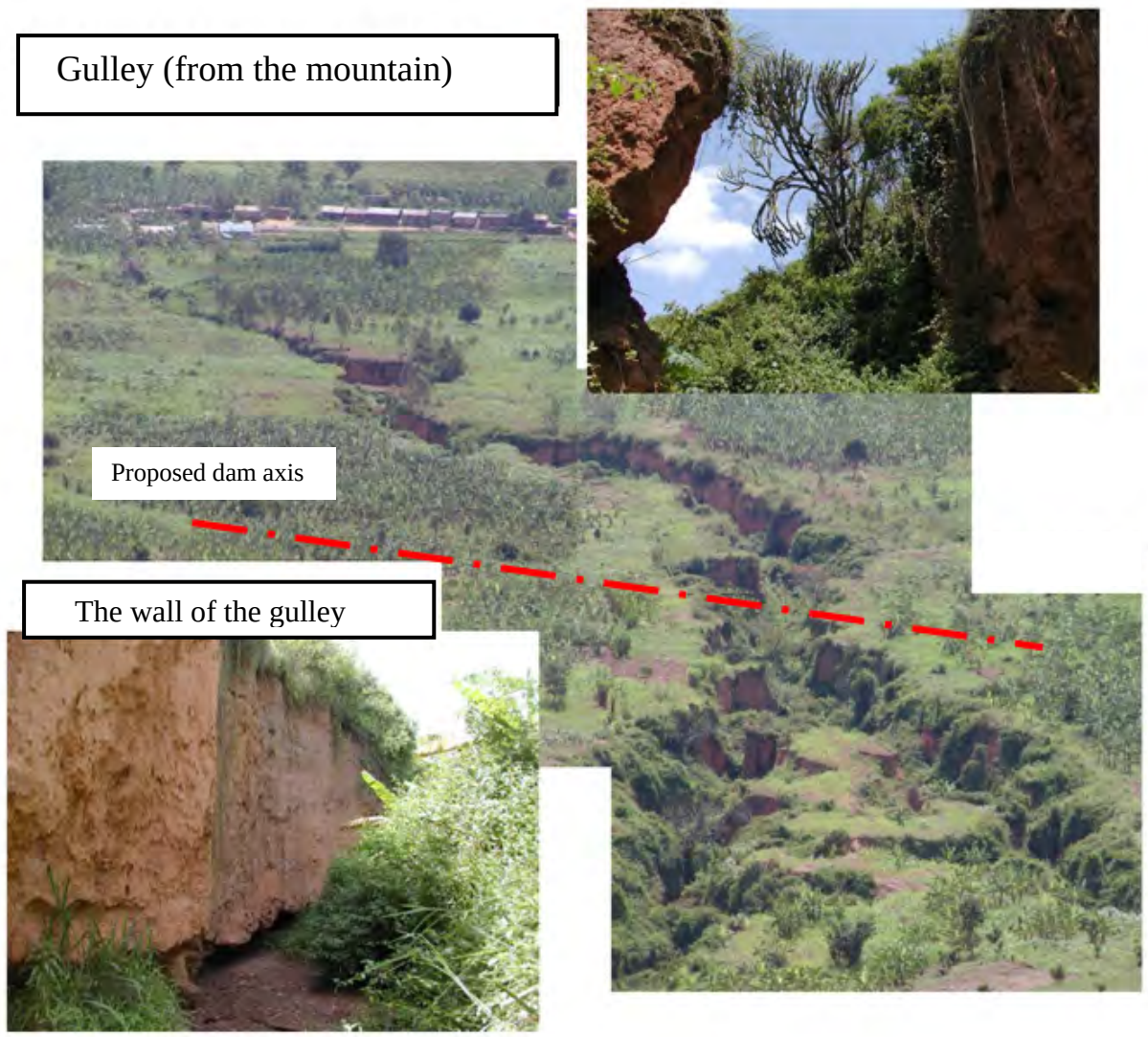


Figure 2.1.31 Image of completed dam body

(4) Gatsibo31Rugarama

1) Site

As many as 3 gullies with having steep mountain at the back join together at around the requested site and flows down further as a single gully. Being gullies, the both banks are of bluff ones and the cross section is not suitable for any dam construction. The difference of elevations between the flat bank ground and the river bed surface (No water flow but sand and gravel can be seen.) is observed at about 15 m and if the flat ground of both banks be used as reservoir area, then the dam height should exceed 15 m at the minimum. There found some low ridges stretched over both banks and if fix the dam axis to contact with those ridges, dam construction might be possible but careful attention shall be paid on the possible difference in subsidence on the part of dam body inside the gully and the transition part to connect with the dam body of flat ground on the bank.



Gulley of Gatsibo 31 Rugarama

In the upstream reaches, both banks are narrowed and dangerous due to the possibility of collapsing (Scooped sediments are deposited at the existing drains at the downstream.). When the dam body would

cross the gully, it is necessary to build the dam after excavating the both banks with a gentler slope than 1:1.0. For the transition part, it is necessary to provide further gentler slope so as to avoid sudden change in the magnitude of subsidence after the dam embankment construction.

The gully discussed above flows down gradually scaling down its cross section area and changes the direction before crossing the road and further flows down to the north along the road. After flowing down by 700 m the gully crosses with under the road by culvert (Tri-angle shape corrugate pipe, 1 m H x 1.5 m W). After crossing, there is no water way in the vicinity. During the flooding time, the drained water inclusive of silt and sand intrudes into paddy fields causing lodging of rice plants and considerable soil and sand deposits in the paddy fields. The beneficiary rice farmers requested only possible counter-measures under Gatsibo 31 dam for protection of silt and sand depositing, as irrigation water could be fully supplied by another new dam (RSSP-LWH Gatsibo 32). According to the detailed design report under the LWH, RSSP-LWH Gatsibo 32 will take more than 50% of catchment area of Gatsibo 31, and MINAGRI has given up the plan for Gatsibo 31 after the completion of JICA's field survey.

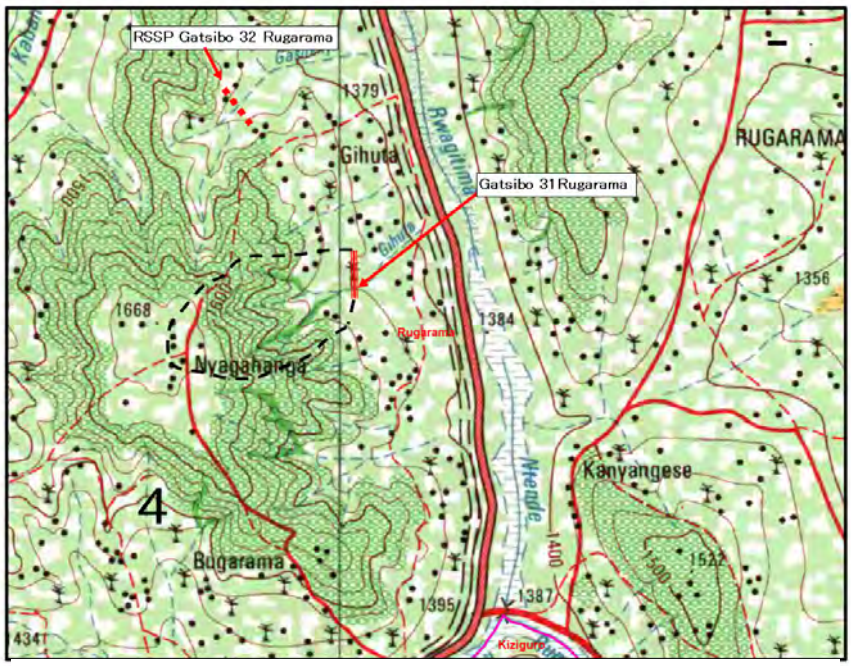


Figure 2.1.32 Location Map of Gatsibo 31 Rugarama

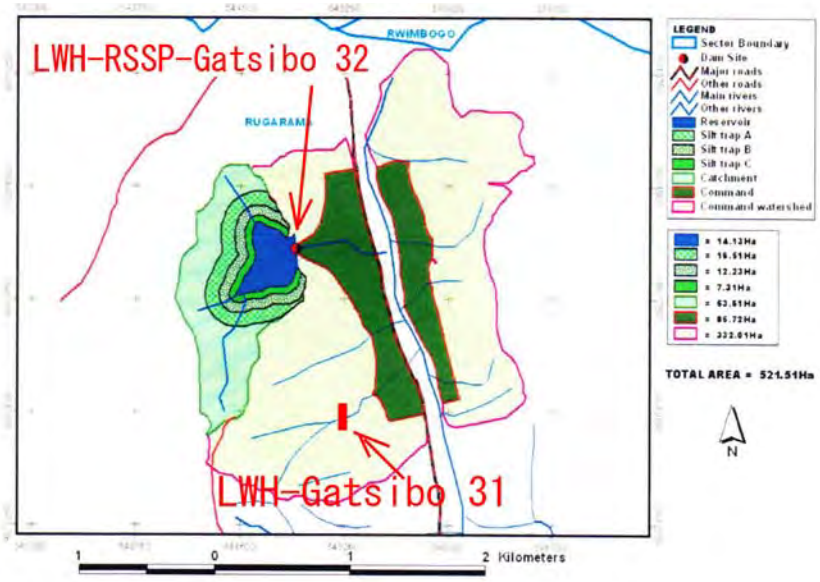


Figure 2.1.33 Gatsibo 31 and Gatsibo 32

2) Selection of dam axis

The longitudinal gradient of gully type river is comparatively steep and storage in the gully section is quite limited. The requested dam axis is located at immediate downstream of the conjunction point by 3

gullies and the dam axis is lined from the hill with outcrop of rocks on the left bank to the gently stretched ridge on the right bank. In this case, the right bank elevation is high enough and the dam body can be connected with the flat ground at the downstream. If the dam axis is located at the downstream of the conjunction point, there would be some advantage in the reservoir storage capacity, but the elevation difference from the ground of both banks to the river bed of gully is about 15 m only and the storage will e decisively in sufficient due to the water storage only within the gully section.

In addition, it is necessary in planning the spillway to pay due attention in layout/fixing plans, alignment, elevation, gradient to comply with the specific topography of gully.

3) Geology

It is assumed that a rapid flow penetrated into the foot of mountain, where sandy-muddy sedimentary rocks and granites had been largely transformed, and eroded the ground to create the gully shaped river. Both banks of the gully maintains vertical cliff of 15 m in height. The cliff has some strength but subject to erosion by rapid flow. Though it is of complex metamorphic rocks, the geology is not of the pervious one and there is a possibility to have a reservoir. In the layer a little higher than the river bed, some gravels are exposed and some scoops can be observed at the lower position of gravel layer.

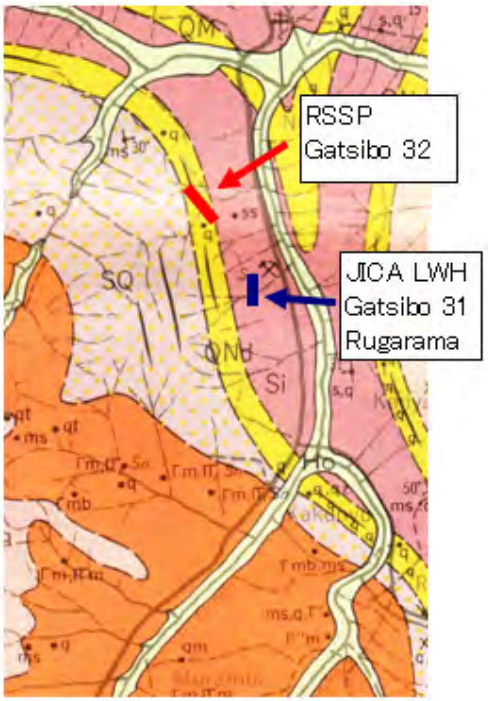


Figure 2.1.34 Geological Map of Gatsibo 31

Such gravel or sand material for filter can be available as they can be seen on the bed of gully or drains. There is an opinion that the left abutment be fixed on the mountain with outcrop of quartz, and there is a possibility of having the base rock at the shallower layer, though it is quite difficult to know the distribution. In the upstream of dam axis test pits are excavated to judge the availability of embankment materials, and it was found out that the impervious material is available only up to the depth of 4 m and deeper than 4 m is weathered rocks. The natural moisture content is measured at lower than 10% and during construction a careful moisture control is required. At the time of interim reporting on the field survey, MINAGRI has confirmed no justification for Gastibo 31 and informed the study team to give up the planning. Accordingly the study team cancelled the planned boring survey for GATSIBO 31 site with due confirmation by JICA.

4) Survey for embankment materials

In order to avail the embankment materials within the reservoir area, test pits were provided on both banks of the upstream of dam axis. Laboratory tests were conducted on the samples collected and studied the possibility to use them as impervious core material for dam embankment.

The natural moisture content is considerably low. Deeper than 4 m, weathered rocks and cause

difficulties in construction works.

Both test pit show weathered rock at depth deeper than 5m and it is not used for embankment material. Since natural water content is less than 10%, it is difficult to control water content during the construction of embankment.

5) Longitudinal section and plan of dam axis

The following Figure shows the longitudinal section and plan of dam axis as assumed as the most probable.

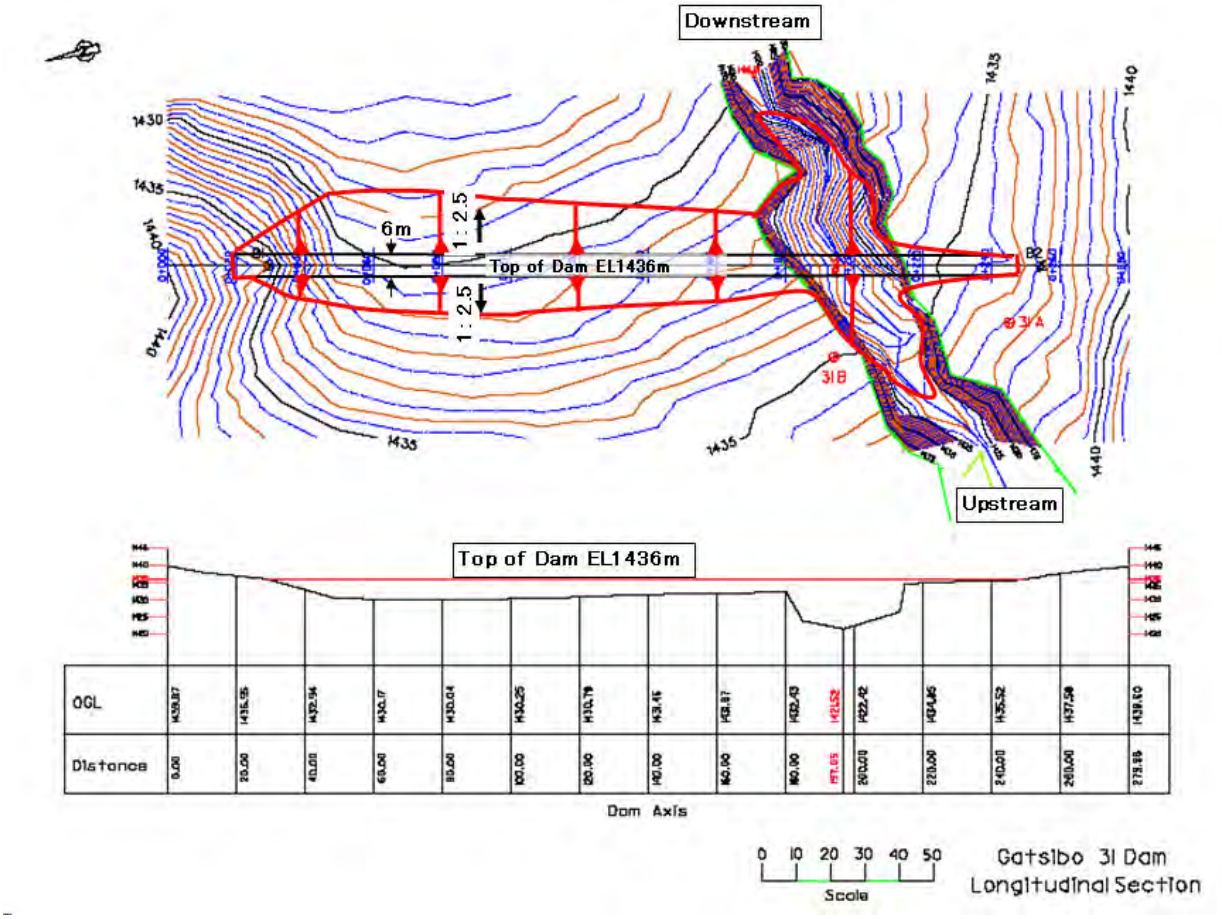


Figure 2.1.35 Longitudinal section and Plan of Gatsibo 31

6) Image of completed dam body

This is the case when fixing the dam height at 15 m for Gatsibo 31.

After the field survey by JICA study team, Gatsibo 31 was excluded from the subject study.

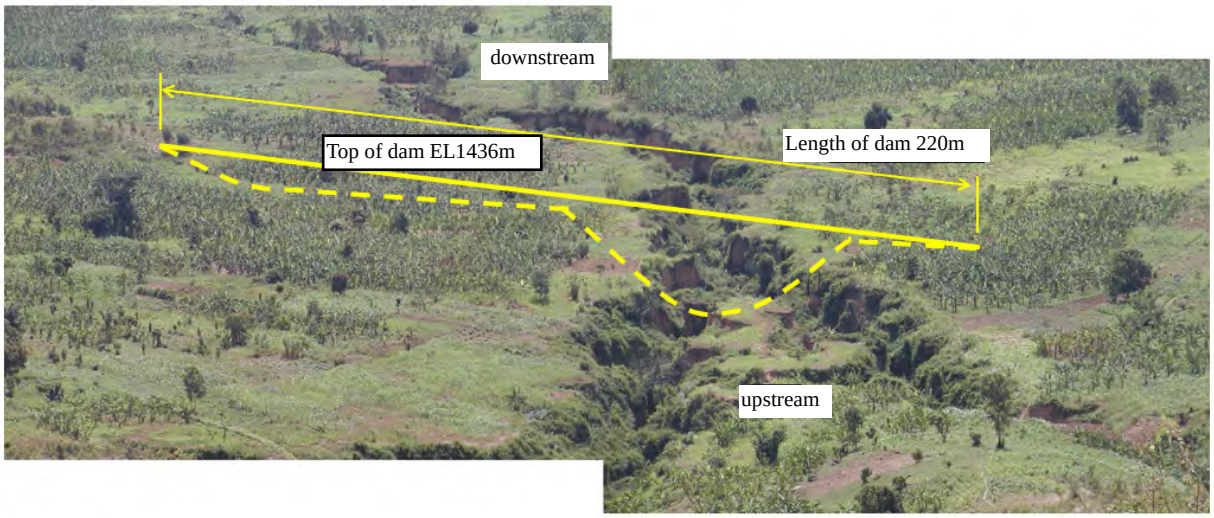


Figure 2.1.36 Image of completed dam body

(5) Bugesera3 Rilima

For Bugesera 3 under the LWH, the detailed design has been completed and the major dimensions are fixed already. Therefore, the following descriptions include some referred from the said LWH detailed design report.

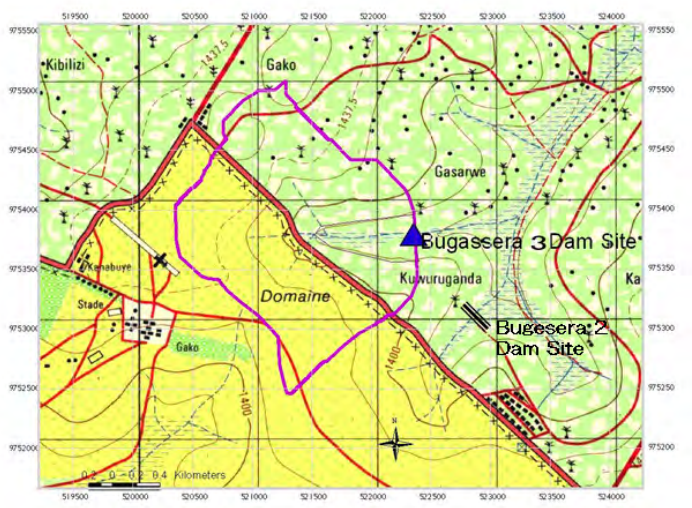


Figure 2.1.37 Location of Bugesra3 during initial stage

1) Site

Bugesera3Ririma is located in the valley neighboring with Bugesera2Gashora having the northern ridge of Gashora in between. In the downstream this joins with Bugesera 2 and empties into Rumira lake. Similar to Bugesera 2, there is surface flow in the river bed not all the time. The upstream of road in the catchment is the forest of military area as same as bugesera 2. The present slope of both banks at the vicinity of dam axis is about 1:7 on both left and right banks.

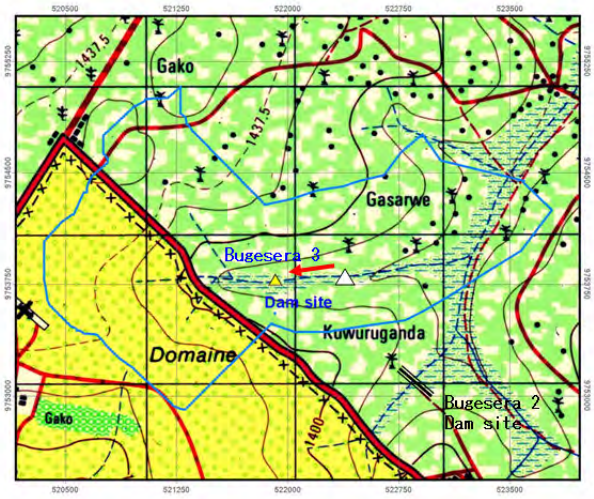


Figure 2.1.38 Final location of Bugesera3 dam axis

2) Selection of dam axis

As shown in the Figure 2.1.37, original location of Bugesera 3 dam axis, the catchment area includes forest-covered military area and those hilly areas in and around, and the full water level is so decided that the stored water would not reach to the military area. From the result of topographic survey conducted afterward, when fixing the full water level as high as possible within the limit not affecting to the military area, the dam height might exceed 20 m due to the low elevation of river bed. Therefore the idea was changed to fix the full water level to secure the beneficiary area first and moved the dam axis up, calculate the storage capacity and as the result 16.2 m of dam height was obtained, as assumed by the study team. In comparison with Bugesera 2, Bugesera 3 is featured with steeper river bed slope as well as the steeper topographic gradient of both banks.

3) Geology

The local geology of Bugesera 3 is characterized by an igneous intrusion of granite composition as part of the intrusions covering areas of significant size southeast and southwest of Kigali. Such intrusions have been observed in the eastern portion of Bugesera and central Nyanza districts. During the field survey, however, fresh outcrops of the intrusion have not been observed in many of the places including Bugesera 3 site. Road cuts and local excavations show that the rock has undergone high to complete degree of weathering. It is quartz rich with significant mica minerals. The granite at the site is affected by high degree of weathering that it is transformed into sand to gravelly sand soil. The depth of weathering is large (More than 5 m) as seen from the nearby road cuts and the test pits. On the left-hand side of the valley, the granite has been affected by higher degree of weathering that it exhibits almost equal proportions of fine and coarse fraction.

As far as geological structures are concerned, the rock has been affected only by joints that are filled with late coming veins of quartz. In most of the weathered outcrops, these veins are seen as strong and resistant bodies and reveal dendritic patterns. It is free from other geological structures like deep seated open joints, faults and folds.

Thee are clayey soil deposited in the center of the valley with the thickness of about 3 m, dark gray in color, non-organic, solid and impervious. On the left bank there found residual clayey sands derived from weathering of base rocks. The thickness of the layer is assumed at about 10 m. In the lower layer of the valley, there distributed some sandy soils with small gravel. For the portion of spillway, highly-medium weathered granites are found. The result of resistivity imaging survey is shown as in the following Figure.

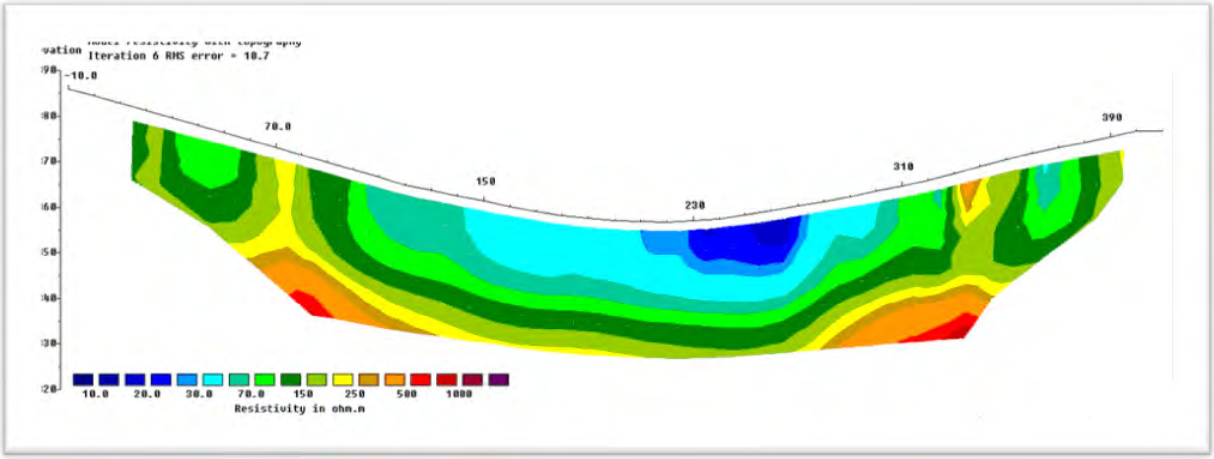


Figure 2.1.39 Bugesera3 Result of electrical exploration

In the 50 m stretch on the river bed along the dam axis, there are clayey soils originated from complete weathering of granite or river bed deposits though quite a little. Further in the stretch of 150 m on the

river bed it is assumed that the 15-20 m depth weathered zone includes a variation from silt/sand to weathered rock with cracks. Further on the surface layer of both banks, it is assumed to have coarse sands as derived from weathering of granites.

For the standard cross section of dam body, an impervious blanket zone will be provided at the upstream side so as to reduce the possible seepage from the dam body foundation. The blanket shall be I m thickness and the length must be 5 times of the maximum water depth.

Embankment materials can be available within the vicinity area of the site and the impervious core material within the reservoir area. While such semi-pervious (sandy), filter material and rock material can be availed in the vicinity. Borrow pits and quarry expected are as shown in the Figure below.

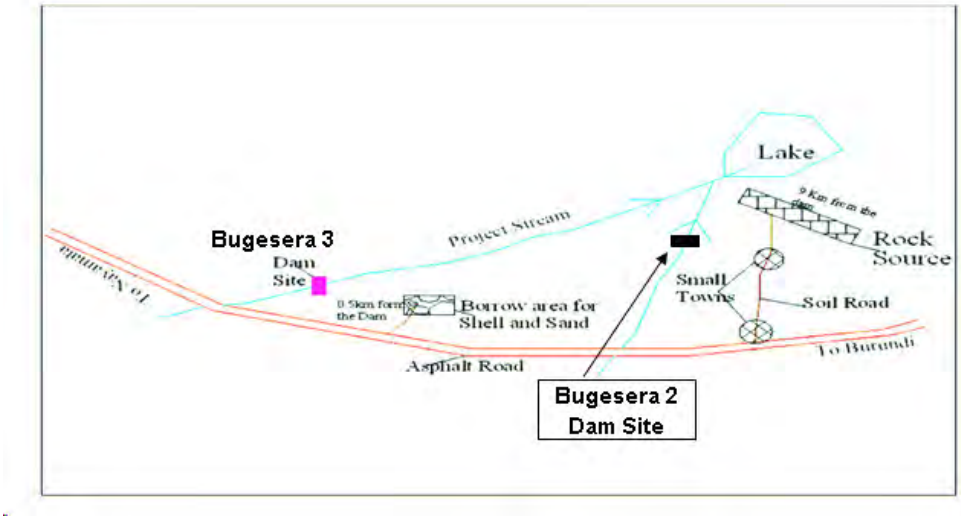


Figure 2.1.40 Borrow pit and quarry site for Bugesera2 and 3

4) Test on embankment material

Gradation curves were prepared for various materials, confirming the suitability to use them. For the impervious material, the plasticity index secures higher than 20 to be judged acceptable.

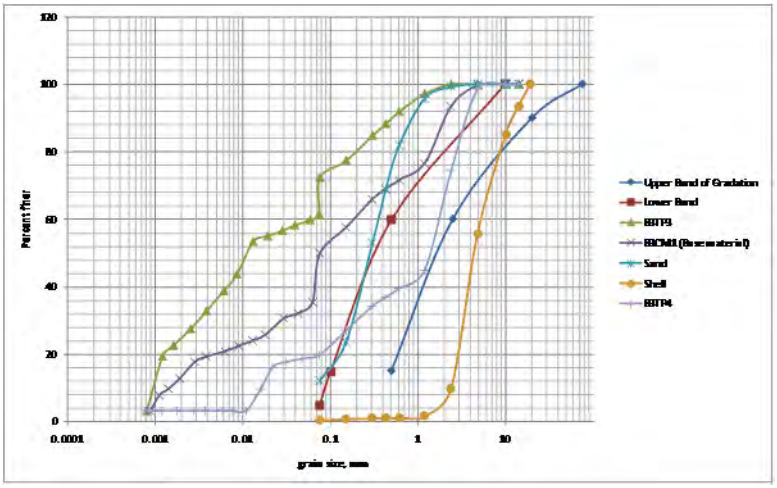


Figure 2.1.41 Sieve analysis of embankment material

5) Longitudinal section and plan of dam axis

The following Figure shows the longitudinal section and plan of dam axis as assumed as the most probable under the present study.

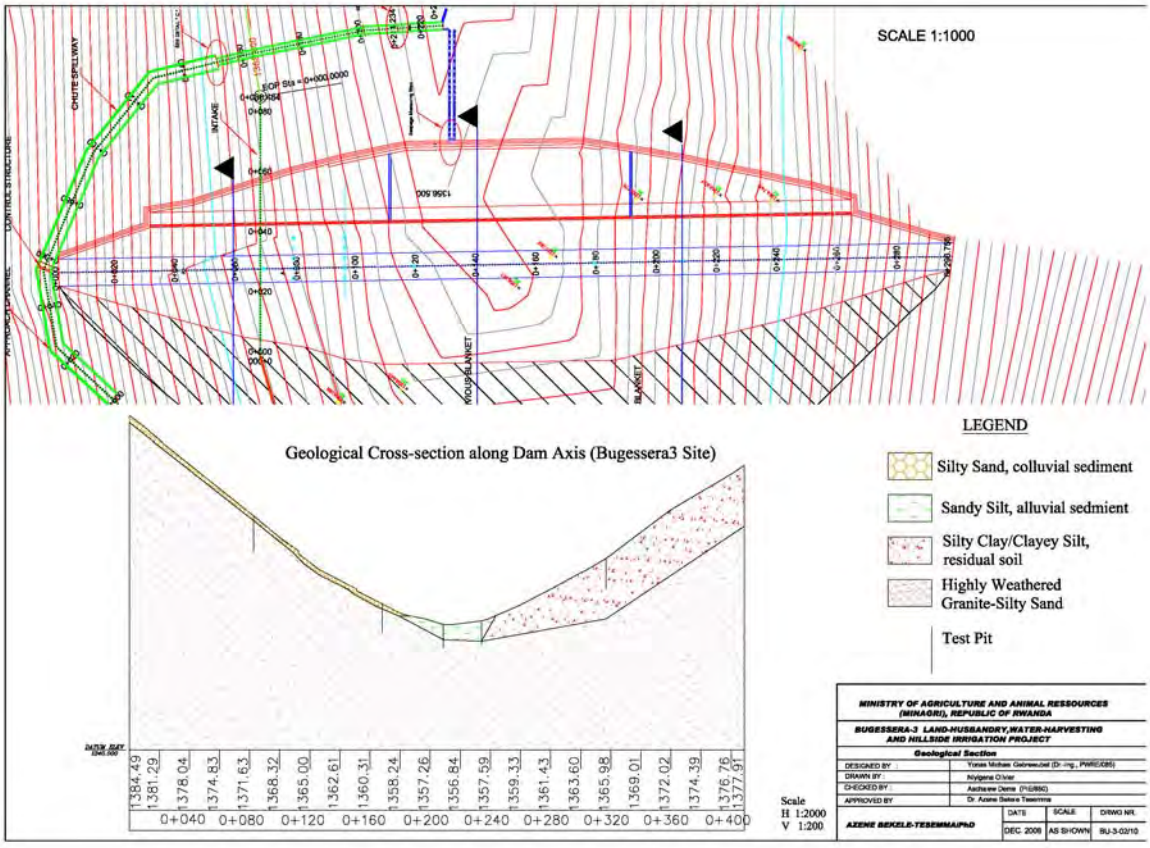


Figure 2.1.42 Longitudinal section and plan of dam axis (LWH design Report)

(6) Bugesera4 Musenyi

For Bugesera 4 under the LWH, the detailed design has been completed and the major dimensions are fixed by this time. Therefore, the following descriptions include some referred from the said LWH detailed design report.

1) Site

Bugesera4Museni is located in Museni Sector where is about 23 km south of Kigali and about 18 km west from Bugesera 3 and Bugesera 2. At present the site is found comparatively flat topography with the elevation of about 1,400 m and as per the 1/50,000 topo-map there are high and steep mountains ranging at about 1,500 m elevation in the upstream basin. The lower moving down the basin, the gentler the gradient of both banks. At about 2 km downstream from the site there extends wet lands and at about 5 km point to north-west from the site, the flow empties into Akanyaru river, a tributary of Nyabarongo.

Both at the upstream and downstream of the reservoir area, there are springs existing. The upstream one is situated higher than the reservoir full water level and the downstream one is on the mid slope of the mountain being 300 m distant from the reservoir and expected no influence on the reservoir. The slope gradients are confirmed lower than 16 % for 98 % area of both catchment area and beneficiary area.

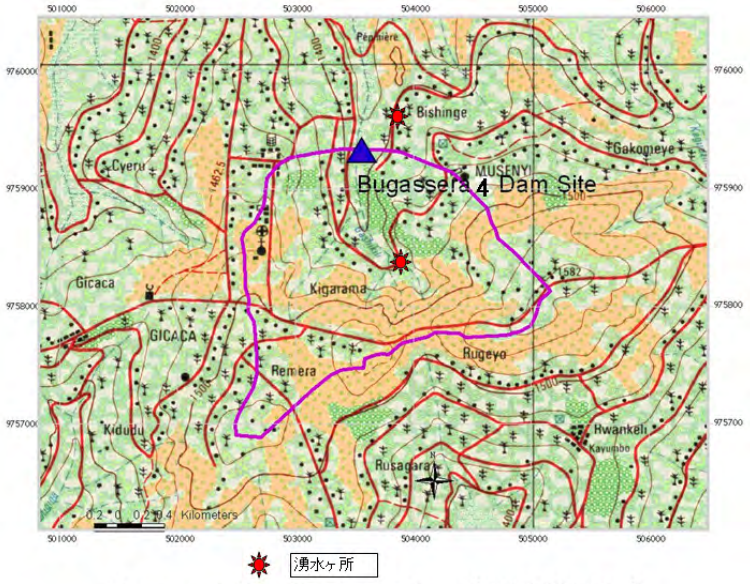


Figure 2.1.43 Location Map of Bugesera4

2) Selection of dam axis

As shown in the Figure 2.1.43 location for Bugesera 4, upstream basin is quite steep but getting down to lower stream the valley shape gradually opened and the gradient of both banks become gentler too. Accordingly, the storage capacity becomes larger when the dam site moving to further downstream due to the wider river width and the gentler gradient of both banks, but at the same time the dam crest length and the embankment volume becomes larger too.

In fixing the subject dam axis, the followings are the key points.

- There exist houses of local resident in and around the reservoir area and the full water level be restricted to some level.

- The water level for irrigation in the downstream beneficiary area is expected at about 1,390 m, similar to the pipeline alignment, then it is necessary to fix the reservoir full water level as high as possible.

- There exist the existing road crossing the subject valley at the downstream of the dam axis and the topography further downstream from the said road changes drastically to be opened and causing much longer crest length and larger dam embankment volume if dam axis be selected there.

It is considered that by having higher full water level the beneficiary area could be maximized, but higher full water level may cause resettlement of local resident's houses. Inception Report for LWH contains the following descriptions. [The dam axis was decided at the pre-feasibility phase but during the field survey on August 1, 2008 another decision was made that there is a better dam axis at about 100 m upstream from the former one. The new axis is situated on E0503520-N9759368 with the river bed elevation of EL1390 m. Taking into account all these as noted above, the dam height of about 17 m be fixed through topographic survey and hydrological survey during the detailed design phase.]

As per the subject detailed design report the dam axis location is fixed as same as the above indication but the river bed elevation is confirmed as 1382.57 m which is considerably different from 1390 m at the pre-F/S phase. Further there is a problem issue on the resettlement and the full water level was lowered down as much as possible within the limit to satisfy the downstream beneficiary area as assumed.

Also, as per the socio-economic repot under the detailed design phase, it is described [Resettlement is recommended for the 3 houses existing in and around the reservoir area.] and the cost for resettlement is estimated and included under detailed design.

The site layout for Bugesera 4 dam site is as shown below.
According to the above drawing, it is confirmed that the surveying was conducted based on the decided dam axis as in the Inception report but the dam height is maximized to the highest level as the topographic condition allows. Further to mention the subject dam is one of the four priority-given dams under LWH and it is assumed that there was no time enough for reviewing the plans for dam axis, scale of dam, comparative studies on full water levels and so on.

In case if the subject dam would be included in the following JICA's study, it may be necessary to make additional study on the dam axis plan located at about 100 m plus several ten meter upstream at the time of pre-feasibility phase so as to avoid the resettlement requirement, and further another comparative study among the following points.

- Lowering of full water level and decrease in beneficiary area (sloping upland field)

- Increase in new beneficiary area (paddy field) in swamp area

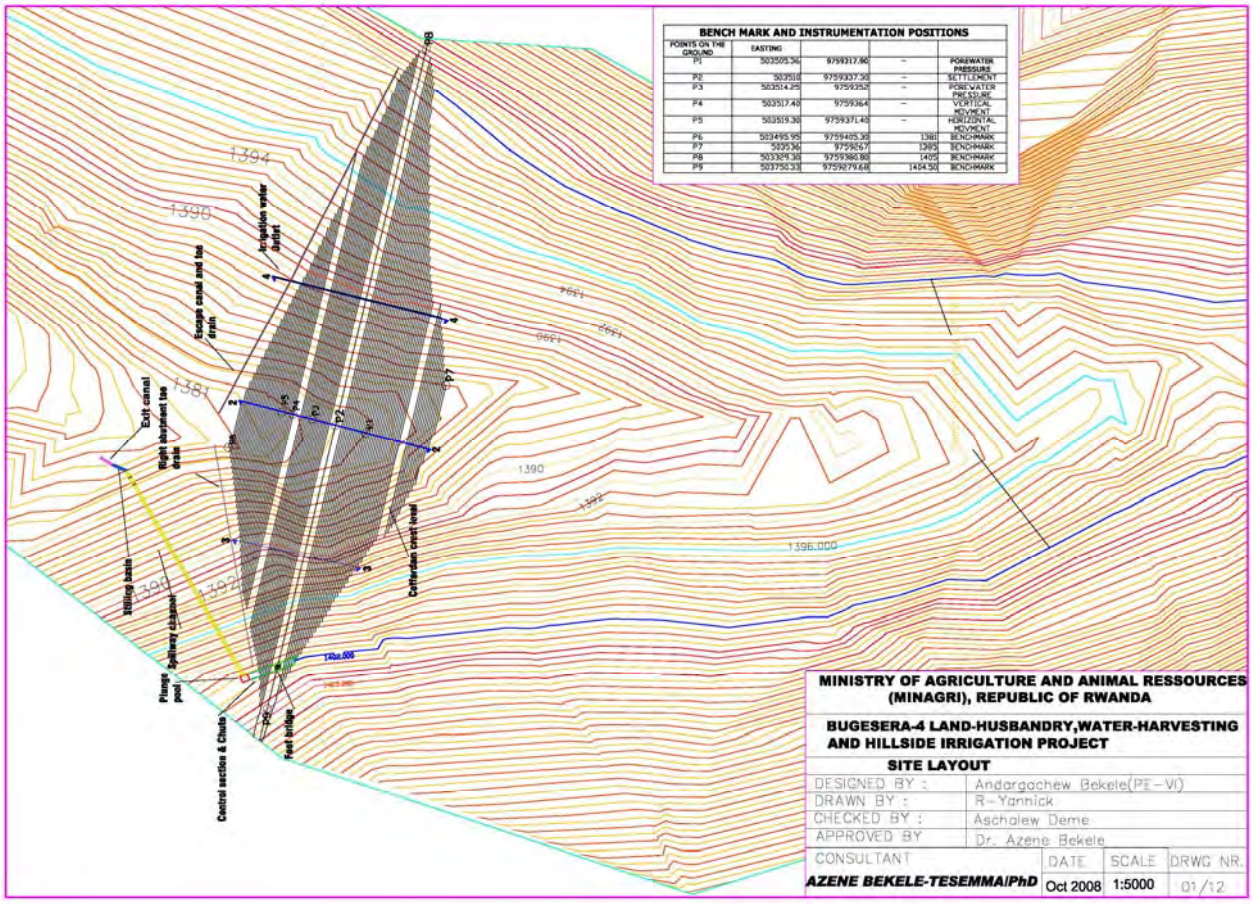


Figure 2.1.44　Plan of Bugesera4 (LWH Design Report)

3)　Geology

The base rock foundation in general is of pre-Cambrian and in and around the site is covered by metamorphic rocks predominantly consisting of mica-schist including quartz. On the slopes of both banks of reservoir, there found outcrops of mica-schist and the same is highly weathered. These rocks form sloped foundation both to up and down stream directions and is considered that the same indicate both joint and surface of discontinuity. The rocks are featured by quartz vein crossing the mother rock and are hydro-thermally altered. The mother rocks are widely covered by residual silt and highly weathered up to considerable depth.

The valley portion is covered by dark-brown color and

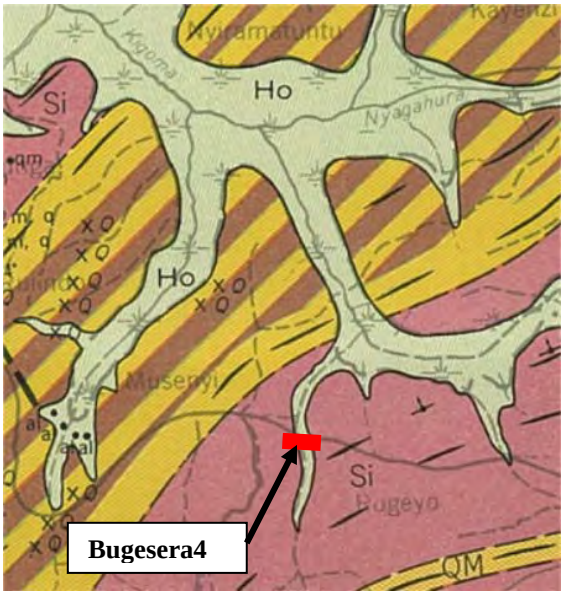


Figure 2.1.45　Geological Mapof Bugesera4

non-organic silty clay with about 4 m thickness. The both banks are covered by thick silt/sand layer derived from the weathered base rocks. Geology at the upstream of spillway is of highly-medium weathered rocks and the layer is measured at about 5 m in thickness.

The result of resistivity imaging survey conducted on the dam axis is shown as below.

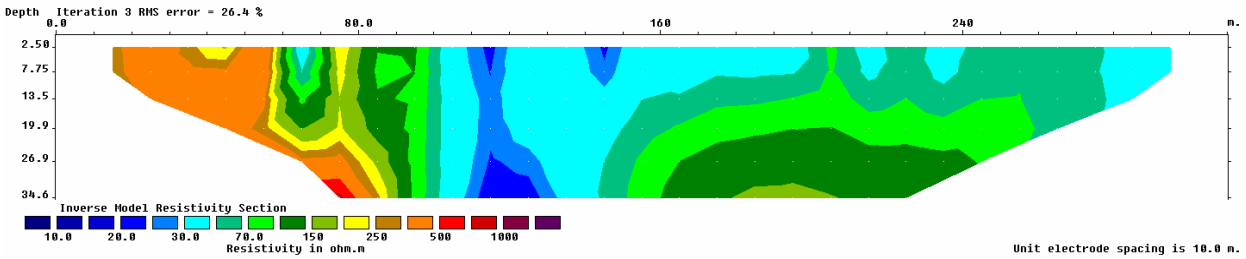


Figure 2.1.46 Electrical exploration at dam axis

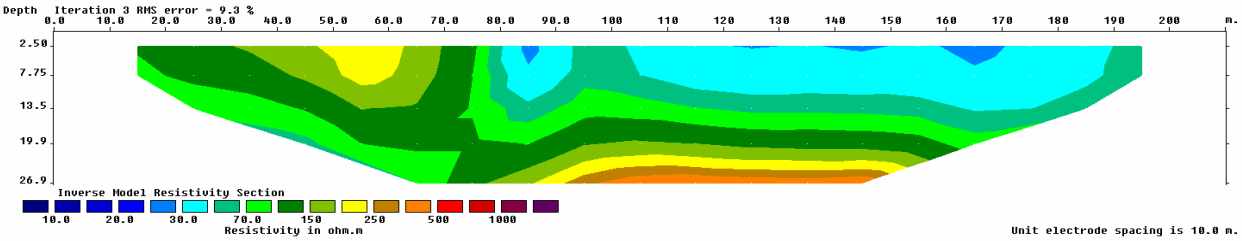


Figure 2.1.47 Electrical exploration at 140m upstream of dam axis

As the result , the detailed design report describes the following reference as [On the left bank of dam axis firm rock foundation is found on shallower level and on the right bank also no problem in the foundation though the weathered rock surface is thick, while an existence of fault is assumed at the river bed portion. At the upstream of dam axis in parallel with the axis, the survey was carried out to find a sort of fault as assumed. Though it is difficult to definitely judge the case as nothing is indicated on the geological map by the Belgium Institute for Geology, a careful attention shall be paid during the construction stage.]

From the analysis it is not definitely clarified how to deal geo-technically with the possible existence of fault at the dam axis and it is noted that under the present planning boring survey on fault existence is necessary prior to the construction works and in some case additional survey including the dam axis at the time of pre-feasibility phase shall be made.

Further, it is considered necessary to select either the foundation treatment by cement-milk grouting or

adopting a homogeneous type dam with the dam height lower than 15 m, when considering the major dimensions as derived from the detailed design as the followings.

- Dam height: 1404.5m – 1378m = 26.5m
- 30.5m of core zone bottom width
- Deep fractured zone along the fault

4) Survey for embankment materials

As per the detailed design report the results of tests on impervious material is as follows. The plasticity index
is rather small.

Table 2.1.28 Impervious material

Soil parameter	Result
Fine fraction	70%
LL of fine fraction	37.90%
PI of fine fraction	19.70%
Clay fraction	18%
Specific gravity	2.62
permeability	3.7e-8 m/s
ϕ°	28°
C'	0 kPa
Natural moisture content	8%
Bulk density	17 kN/m3

Dam embankment material can be taken from the vicinity of dam site and the impervious core material within the reservoir area. Semi-pervious(Sandy) material and filter and rock materials are to be availed from the vicinity of the dam site. Expected borrow pits are shown in the following Figure.

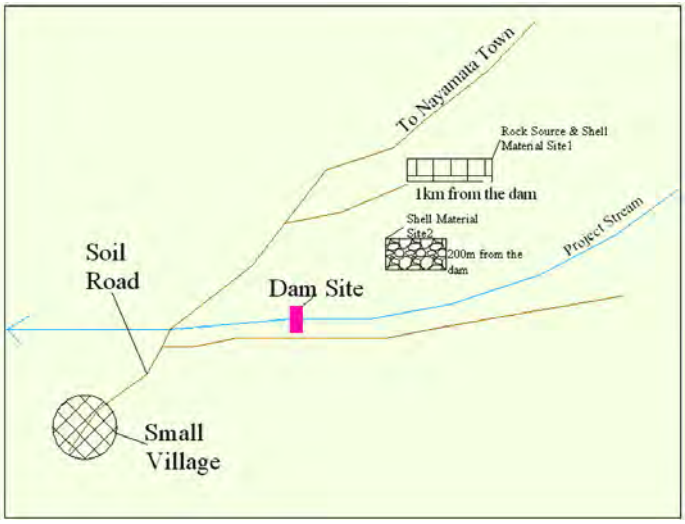


Figure 2.1.48 Borrow pit and quarry site for Bugesera 4

5) Layout plan of dam axis

Dam layout plan by the detailed design is shown as below.

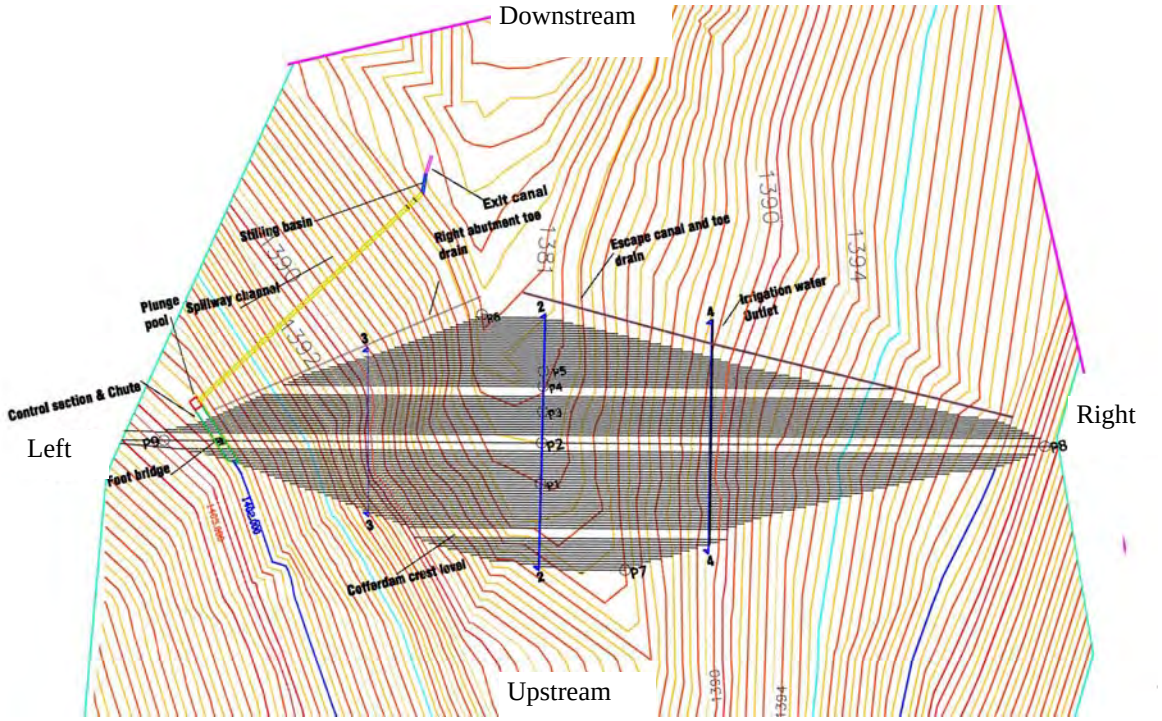


Figure 2.1.49 Plan pf dam (LWH Design Report)

The standard drawing of dam body under the detailed design is shown below.

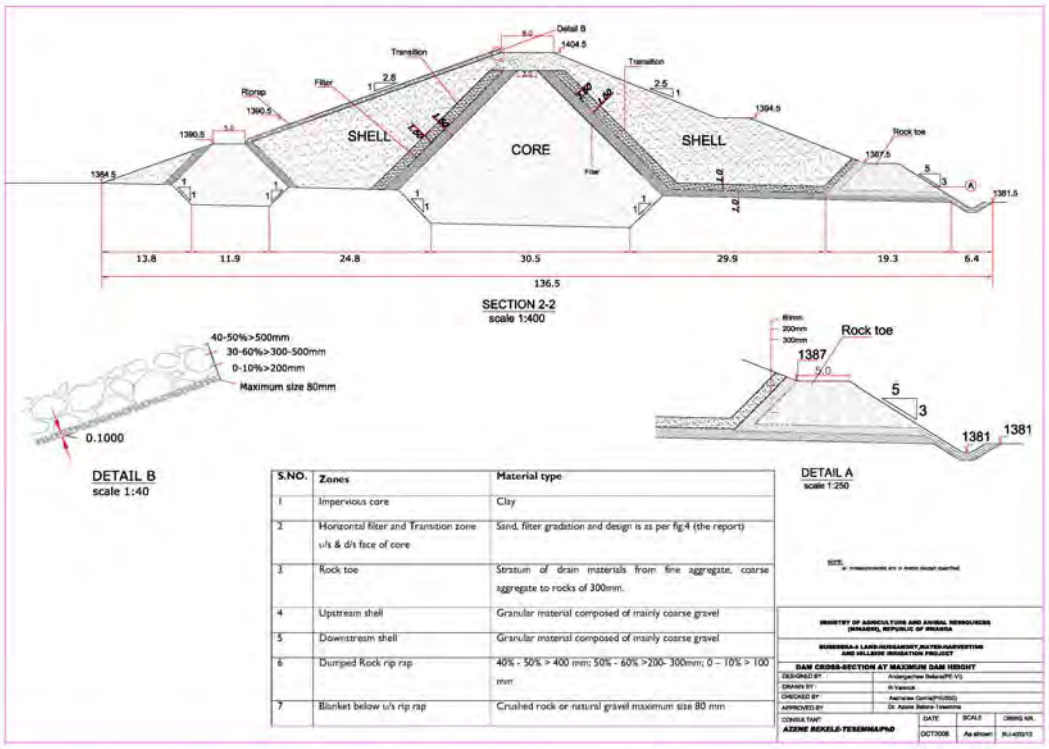


Figure 2.1.50 Standard Cross Section of Dam (LHW Design Report)

6) Image of completed dam body

Figure 2.1.51 Image of completed dam body

(7) Objective and result of Soil Test

1) Objective

The objective of the soil test in this study is to confirm the material in the site is useful as embankment material or not. The test is for impermeable material for homogeneous type dam.

2) Adequacy of Material

The laboratory test for impermeable material of each site was carried out. The impermeable material is basically weathered rock at present location and it contains less secondary sedimentation, less proper interfusion of gravel and a lot of fine fraction (clay, silt).

It is suitable for impermeable material. However, since its water content is small, it requires spraying water during the construction, and since it contains less gravel and a lot of fine fraction, its workability is low and cracks are easy to occur. With proper measure for those matter, it is enough useful as embankment material for homogeneous type dam.

As a result of investigation of latest constructed RSSP dams, they were constructed securely and water leakage was not observed. Since similar material is used for a construction of 30m height dam in Malaysia securely, it will be constructed without problem with proper work method.

3) The Result of Soil Test

The result of soil test and estimation is as follows;

① Permeability

According to sieve analysis, all the samples satisfy following condition and suitable for impermeable material.

To contain fine fraction (less than 0.075mm) more than 10％～15％

To contain clay (less than 0.005mm) more than 5%

② Deformation and Strength

The plasticity index was calculated from liquid limit and plasticity limit. All the samples are classified in CL or CM in the plasticity chart and they are confirmed to be suitable material as impermeable material.

③ Pore Water Pressure during the Construction

From the test result, 50% particle size was examined based on standard of USBR. The material from right abutment in Ngoma22 Rurenge is a material that has a possibility of slide. However, its thickness is thin and the material from left abutment will be used. Other samples show possibility of slide less than 20 %. All the material contain small water and they require spraying water during the construction.

④ High Crack Possibility Material

Almost all the samples are within the range of grain size of high crack possibility. However, cracks occur often when the water content is less than optimum water content and the plasticity index is less than 15. According to the test result, plasticity index of samples from deeper part of Bugesera 2 Gashora is small as 11.3 and 10.4. They need spraying water during the construction to make the water content more than optimum water content. Other materials show the plasticity index more than 15 and they will be used without problem.

Cracks often occur in exposed impermeable material. Top and downstream surface of embankment need to be covered with rock material, protection zone or vegetation.

⑤ Natural Water Content

Since natural water content of materials of every site is very small, water spraying is required for all the sites during the construction. Detailed treatment will be decided after future physical test.

4) Example of Other Sites of LWH Project

Detail design for 8 dams in LWH project had been completed. The summary of test result of embankment material is as follows;

① Bugesera3

In the detail design report of Bugesera3 which is neighboring to Bugesera2, core material is described as “According to United Soil Classification System, the soil is grouped as CL with the group name of sandy lean clay with comparable shear strength and lower permeability.” However, in Chapter4 Dam and reservoir design, it is described that “Soils having high compressibility and liquid limit are not suitable for core as they are prone to swelling and formation of cracks. The suitability of the borrow area material as collected and got tested for core material is discussed in detail in the geology/geotechnics report”. It is presumed because of small plasticity index 9.6% much less than 15%. In case of Bugesera2, 2 samples show plasticity index about 10% and similar result as Bugesera3.

In「4.17 Construction Schedule」in the report of Bugesera3, it is described “Since the dam is small, it is possible to construct in three to four months. The time should be set in such a way that it coincides

the driest period of the year. Hence, the dam is to be constructed starting from late June up to middle of September." However, even in rainy season, water flow is observed only when it rains heavily, rainy season is advantageous at the point of adding water to embankment material during the construction. It rains very few in the dry season and there is no water available in the site area.

② Bugesera4

In the detail design report, it is described "According to United Soil Classification System, the soil is grouped as CL with the group name of sandy lean clay. The values in the table show that the soil, when compacted, achieves low permeability, high density and good shear strength." Any notes on core material for this site is not described. It is presumed that, since zone type is adopted, only impermeability of core material was considered.

③ Gatsibo31

In the detail design report, it is described "According to the test result, values in the table show that the soil, when compacted, achieves low permeability, high density and good shear strength." Plasticity index shows 20% and no problem.

④ Karongi12

Classification ＣＬ, plasticity index 19.3％、fine fraction 89.5％、clay fraction 3.2％. It is suitable for impermeable material.

⑤ Karongi13

Clay fraction of the sample of the dam site shows 5% and another borrow pit was selected downstream. Classification CL. In the detail design report, it is described "According to the test result, values in the table show that the soil, when compacted, achieves low permeability, high density and good shear strength."

⑥ Kayonza15

Classification SC. It differs from other dams. Plasticity index 12.6%, clay fraction 4%. In the detail design report, it is described "According to the test result, values in the table show that the soil, when compacted, achieves low permeability, high density but low shear strength."

⑦ Nyanza23

Classification CL. According to the test result, it is useful as impermeable material. Dam height is 16.2m, however, the foundation is rock and grouting is planned.

5) Example of Malaysia

Material of a dam in Malaysia is weathered rock at present location in a long period, it does not contain gravel and it is weathered to the maximum. The water content of material in Rwanda is small, on the other hand, the material in Malaysia contains much water because of the difference of climate. However, percentage of fine fracture and plasticity is similar to Rwanda. The material in Rwanda is used for embankment material for 30m height dam.

6) Criterion for Decision

① Range of grain size

Adequate range of grain size of impermeable material is shown in the following figure. It shows also the range of grain size of material which often make cracks when its water content is less than optimum water content. This figure was made out from the result of investigation on 17 dams which made cracks in the permeable material. It is said that low to medium plasticity clay with plasticity index less than 15 often make cracks.

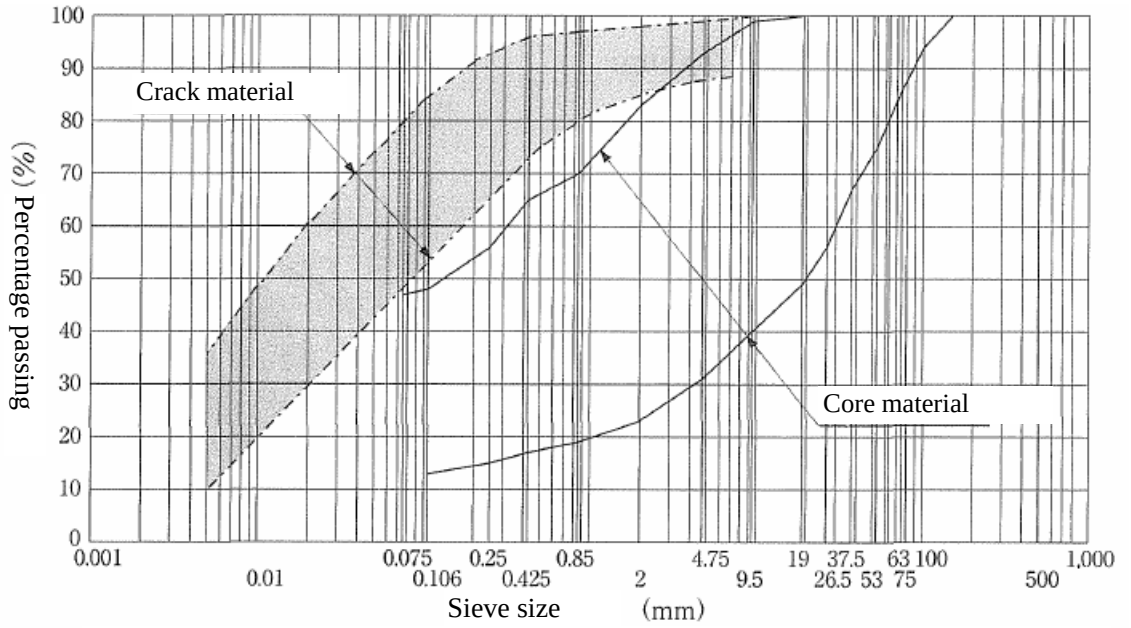


Figure 2.1.52　Appropriate grain size for impermeable material

② Grading

Rate of interfusion of soil particles is called grading. It is shown in percentage by weight. The figure with percentage passing in ordinate axis and grain size in transverse is called grain size accumulation curve. The sieve size of 50% percentage passing is defined D50. This is the typical grain size of the soil. Pore pressure will be produced under the condition of water content more than optimum water content and it affects stability. USBR investigated and found that slide during and after construction is closely linked to D50.

D_{50}＝less than 0.006 mm　　:　100 % of dams slid

D_{50}＝0.006mm～0.02mm（fine ）:　50 % of dams slid

D_{50}＝0.02mm～0.06mm（medium）:　10 ～20 % of dams slid

D_{50}＝more than 0.06mm　　:　0% of dams slid

③ Soil Classification

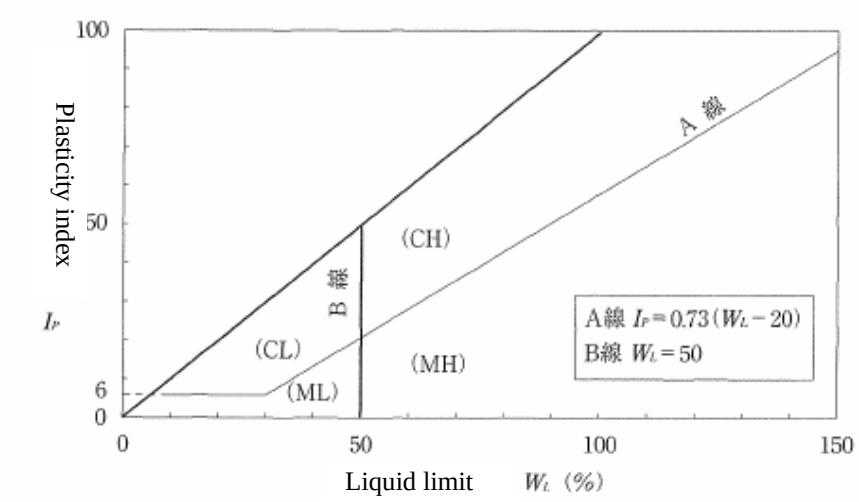


Figure 2.1.53 Plasticity chart

Plotting liquid limit and plasticity index in the Figure 2.1.53, soil classification is determined. If the material correspond to CL or CH in the Table 2.1.29, it is suitable for impermeable material.

Table 2.1.29 Standard Classification and properties for soil, gravel and sand

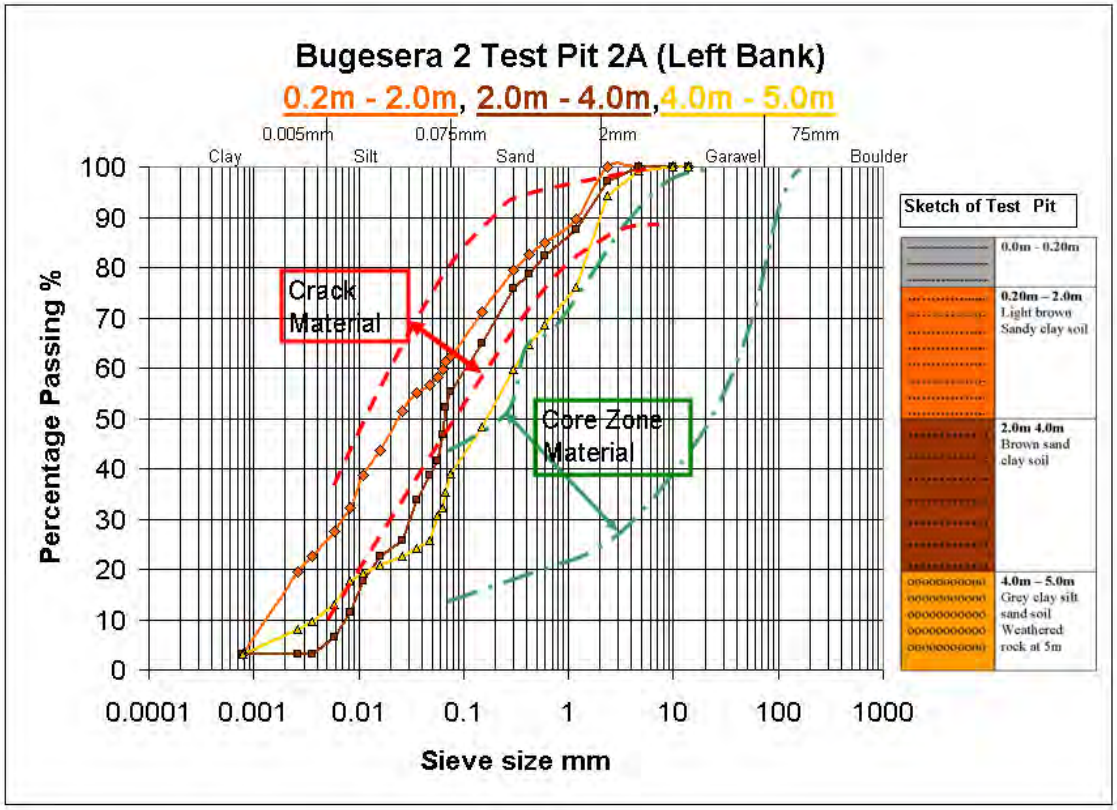
Standard Classification and properties for soil, gravel and sand

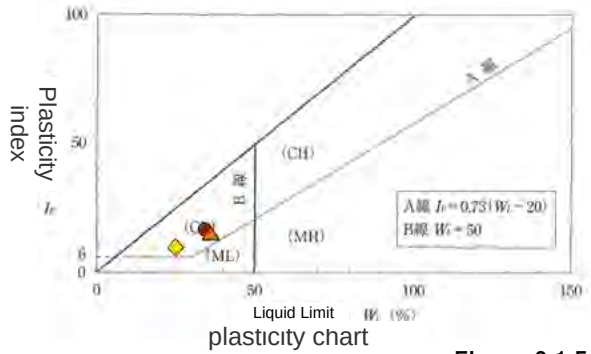
Symbol	Standard compaction		Void ratio e0	Piping resistance	Coeficient of permiability k(cm/sec)	Degree of permiability	Shearing strength			Shearing strength	Constructio n difficulty	No. of actual USBR examples	Suitability	Compression (%)	
	rd. max (t/m3)	Wopt					C0 (kg/cm2)	C sat (kg/cm2)	ϕ(8°)					1.4 kg/cm2	3.5 kg/cm2
GW	＞1.91	＜13.3	*	large	1^-8～1^-1 (2.7^-2±1.3^-2)	pervious	*	*	＞38	very large	very easy	–	suitable (pervious)	＜1.4	*
GP	＞1.76	＜12.4	*	large-medium	5^-3～1^-1 (6.4^-2±3.4^-2)	pervious-very pervious	*	*	＞36	large	very easy	–	suitable (pervious)	＜0.8	*
GM	＞1.83	＜14.5	*	large-medium	1^-7～1^-4(＞3^-7)	semi pervious	*	*	＞34	large	very easy	4	suitable (impervious	＜1.2	＜3.0
GC	＞1.84	＜14.7	*	very large	1^-8～1^-5(＞3^-7)	impervious	*	*	＞31	large	very easy	4	suitable (impervious	＜1.2	＜2.4
SW	1.91±0.08	13.3±2.5	0.37±*	large-medium	5^-5～5^-2(＊)	pervious	0.40±0.04	*	38±1	very large	very easy	–	suitable (pervious)	1.4±*	*
SP	1.76±0.03	12.4±1.0	0.50±0.03	small-very small	5^-4～5^-1(7.2^-4)	pervious-semi pervious	0.23±0.06	*	36±1	large	easy-medium	–	suitable (pervious)	0.8±0.3	*
SM	1.83±0.02	14.5±0.4	0.48±0.02	medium-small	1^-7～5^-4 (7.5^-6±4.8^-6)	semi pervious-	0.52±0.06	0.20±0.07	34±1	large	easy-medium	16	suitable (impervious	1.2±0.1	3.0±0.4
SM-SC	1.91±0.02	12.8±0.5	0.41±0.02	–	(8.0^-7±6.0^-7)	–	0.51±0.22	0.15±0.06	33±3	–	–	3	–	1.4±0.3	2.9±1.0
SC	1.84±0.02	14.7±0.4	0.48±0.01	large	1^-8～5^-5 (3.0^-7±2.0^-7)	impervious	0.76±0.15	0.11±0.06	31±3	large-medium	easy-medium	7	suitable (impervious	1.2±0.2	2.4±0.5
ML	1.65±0.02	19.2±0.7	0.63±0.02	small-very small	1^-8～5^-5 (5.9^-7±2.3^-7)	impervious	0.68±0.10	0.09±*	32±2	mewdium -large	medium-very	7	suitable (impervious	1.5±0.2	2.6±0.3
ML-CL	1.75±0.02	16.8±0.7	0.54±0.03	–	–(1.3^-7±0.7^-7)	–	0.64±0.17	0.22±*	32±3	–	–	–	–	1.0±0.2	2.2±0.0
CL	1.73±0.02	17.3±0.7	0.56±0.01	large	1^-8～1^-6 (8.0^-8±3.0^-8)	impervious	0.88±0.10	0.13±*	28±2	medium	medium-difficult	10	suitable (impervious	1.4±0.2	2.6±0.4
OL	*	*	*	medium	1^-8～1^-5(＊)	impervious	*	*		small	medium-difficult	–	unsuitable	*	*
MH	1.31±0.06	36.3±3.2	1.15±0.12	meidium-large	1^-9～1^-7 (1.6^-7±1.6^-7)	very impervious	0.73±0.30	0.20±0.01	25±2	small	very difficult	–	unsuitable	2.0±1.2	3.8±0.8
CH	1.50±0.03	25.5±1.2	0.80±0.04	very large	1^-10～1^-8 (5.0^-5±5.0^-8)	very impervious	1.04±0.34	0.11±0.06	19±5	small-medium	very difficult	1	suitable (impervious	2.6±1.3	3.9±1.5
OH	*	*	*	–	–(＊)					–	–	–	unsuitable	*	
Pt											compaction impossible		usable		

1. This table is prepared on the basis of data from USBR, US Army Civil Engineering and Earth and Earth-Rock Dams. Figures stated in the table show an average reliabilty of 90%
2. * indicate no data
3. C0: shearing strength at optimum moisture content, C sat: shearing strength at saturated condition
   Coefficient of permiability 1^-3～1^-1 indicates 1x10^-3 ～1x10^-1
   source: Engineering Manual for Irrigation and Drainage Fill Dam, The Japanese Institute of Irrigation and Drainage 1988

7) Test Result of Each Site

Table 2.1.30 Bugesera 2 Testpit 2A (Left Bank) Laboratory Test				
	Test performed	Test Results		
1	Left Bank Test Pit Depth (m)	Gashora 2A 0.20m-2.0m	Gashora 2A 2.0m-4.0m	Gashora 2A 4.0m-5.0m
2	Natural Moisture Content %	9.8	11.5	6.8
3	Atterberg i)Liquid Limit %	35.2	32.6	25.9
	ii)Plastic Limit %	18.9	15.7	14.6
	iii)Plasticity Index %	16.3	16.9	11.3
4	Specific Gravity	2.67	2.68	2.7



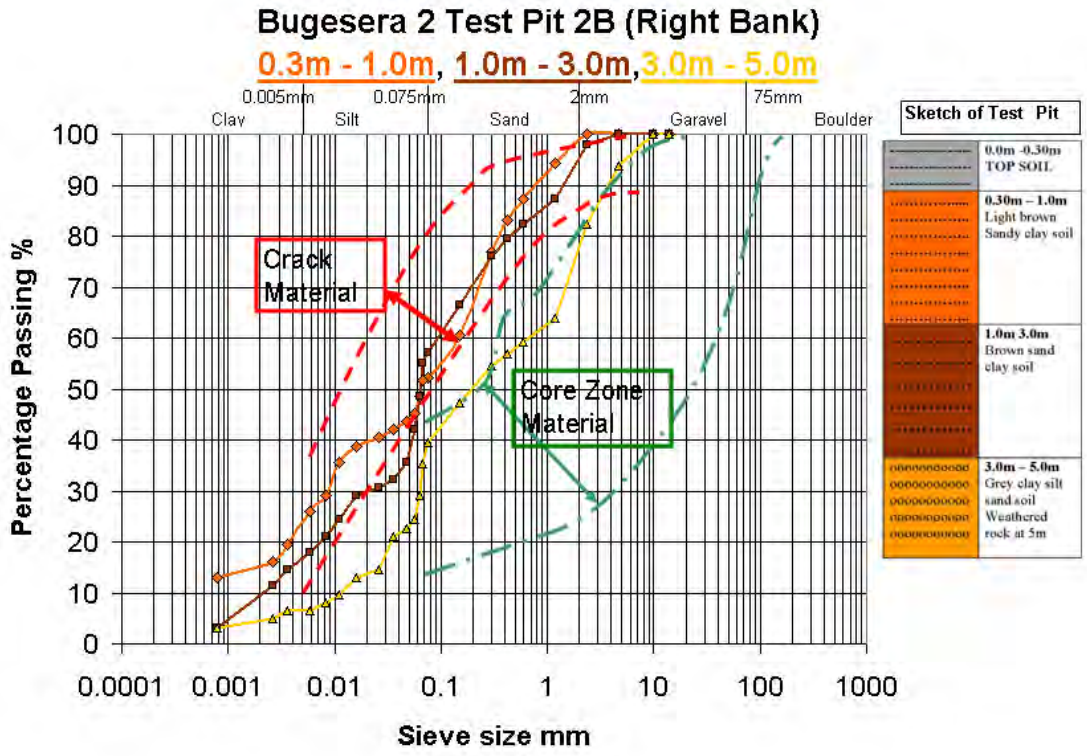


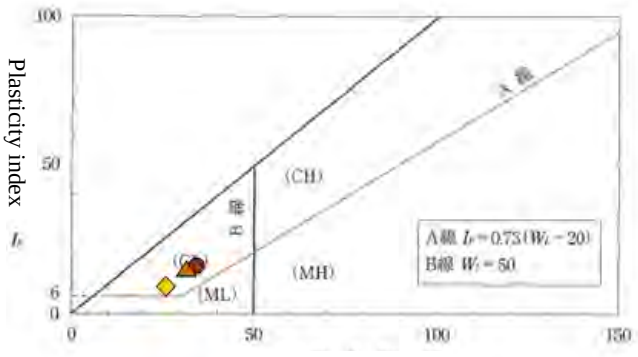
	0. 2m－2m	2m－4m	4m－5m
Liquid Limit	35.2	32.6	25.9
Plasticity index	16.3	16.9	11.3
Symbol	▲	●	◆
Soil Classification	CL	CL	CL
	Clay	Clay	Clay

Figure 2.1.54 Result of Soil Test (1), Bugesera 2

The test result showed that the material can be used as impervious core material.

Table 2.1.31 Bugesera 2 Testpit 2B （ Right Bank ） Laboratory Test				
	Test performed	Test Results		
1	Right Bank Test Pit Depth (m)	Gashora 2B 0.30m-1.0m	Gashora 2B 1.0m-3.0m	Gashora 2B 3.0m-5.0m
2	Natural Moisture Content %	10.5	11.8	4.6
3	Atterberg i)Liquid Limit %	30.4	33.1	26.3
	ii)Plastic Limit %	15.6	17.6	15.9
	iii)Plasticity Index %	14.8	15.5	10.4
4	Specific Gravity	2.68	2.67	2.7





	0.3m－1m	1m－3m	3m－5m
Liquid limit	30.4	33.1	26.3
Plasticity	14.8	15.5	10.4
Symbol	▲	●	◆
classification	CL	CL	CL
	clay	clay	clay

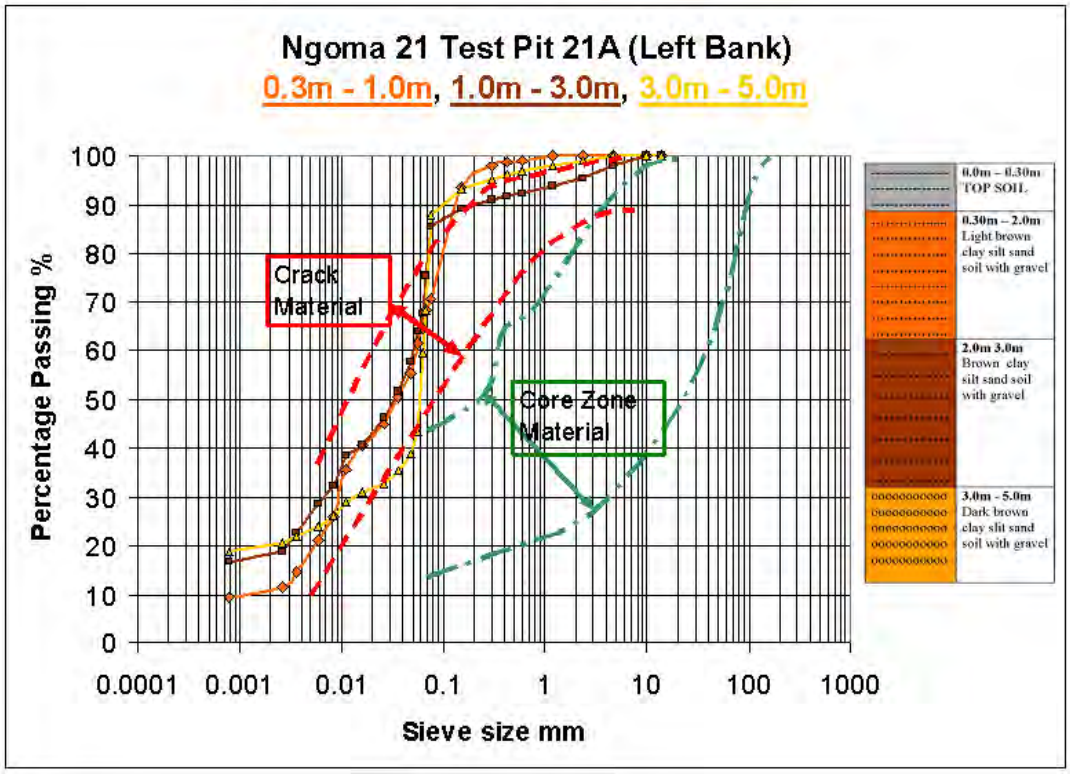
Figure 2.1.55 Soil Test Result Bugesera2 (2)

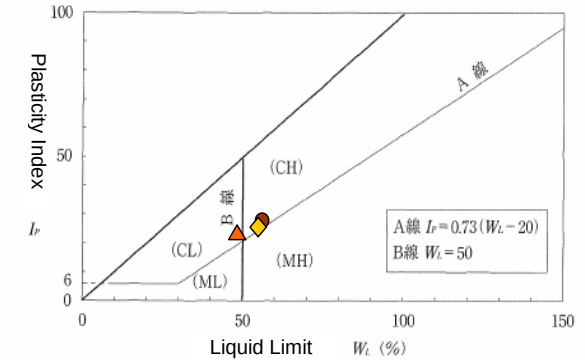
The test result showed that the material can be used as impervious core material.

The materials tested on both right and left banks showed the similar result and can be used as impervious material except the material from the river bed portion. The impervious material is, however, found with rather low moisture content and it is necessary to pay due attention to add some water

during the embankment construction works.

Table 2.1.32 Ngoma 21 Testpit 21A (Left Bank) Laboratory Test				
	Test performed	Test Results		
1	Left Bank Test Pit Depth (m)	Ngoma 21A 0.30m-1.0m	Ngoma 21A 1.0m-3.0m	Ngoma 21A 3.0m-5.0m
2	Natural Moisture Content %	12.5	10.8	13.6
3	Atterberg i)Liquid Limit %	48.9	56.6	54.9
	ii)Plastic Limit %	25.4	28.8	27.9
	iii)Plasticity Index %	23.5	27.8	27
4	Specific Gravity	2.65	2.66	2.65



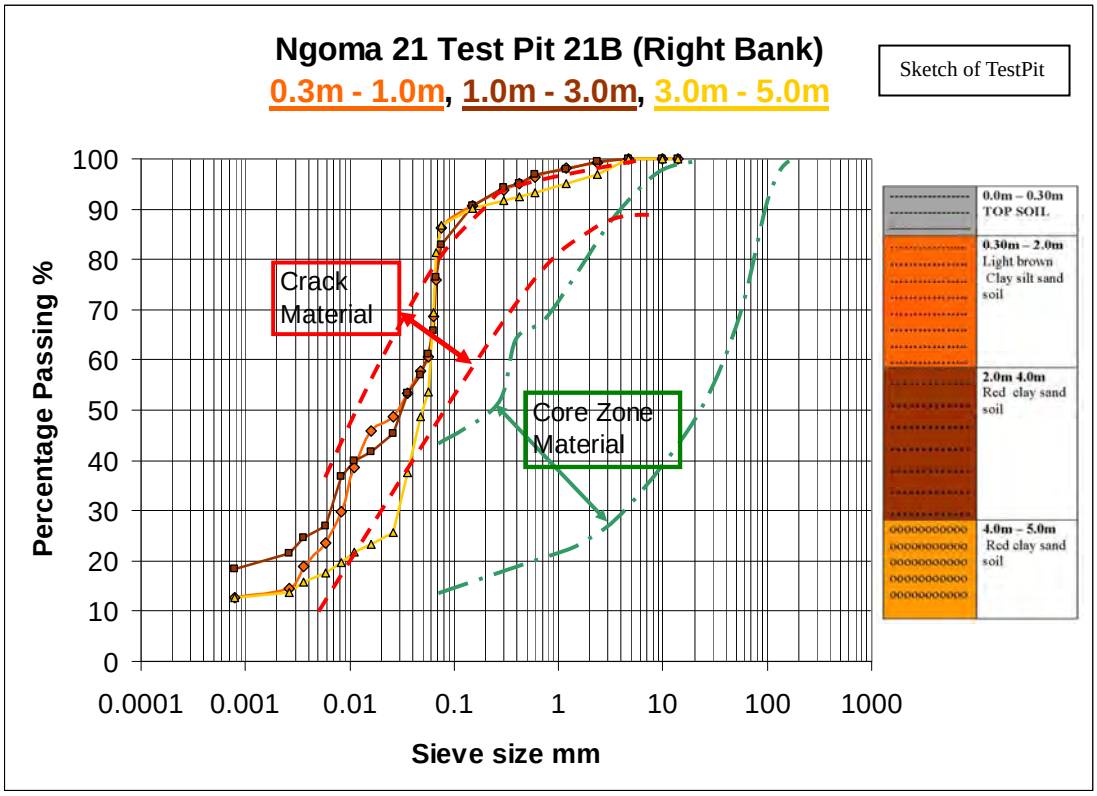


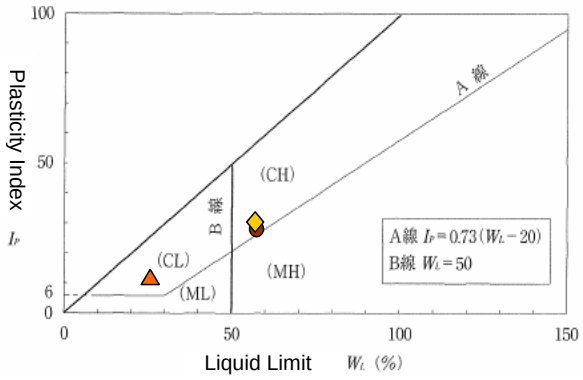
	0.3m－1m	1m－3m	3m－5m
Liquid Limt	48.9	56.6	54.9
Plasticity Index	23.5	27.8	27
Symbol	▲	●	◆
Classification	CL	CH	CH
	Clay	Clay	Clay

Figure 2.1.56 Soil Test Result Ngoma21 (1)

The test result showed that the material can be used as impervious core material.

Table 2.1.33 Ngoma 21 Testpit 21B (Right Bank) Laboratory Test				
	Test performed	Test Results		
1	Right Bank Test Pit Depth (m)	Ngoma 21B 0.30m-1.0m	Ngoma 21B 1.0m-3.0m	Ngoma 21B 3.0m-5.0m
2	Natural Moisture Content %	12.5	14.6	16.5
3	Atterberg i) Liquid Limit %	34.2	57.7	57.6
	ii) Plastic Limit %	19.7	29.3	28.9
	iii) Plasticity Index %	14.5	28.4	28.7
4	Specific Gravity	2.67	2.64	2.64





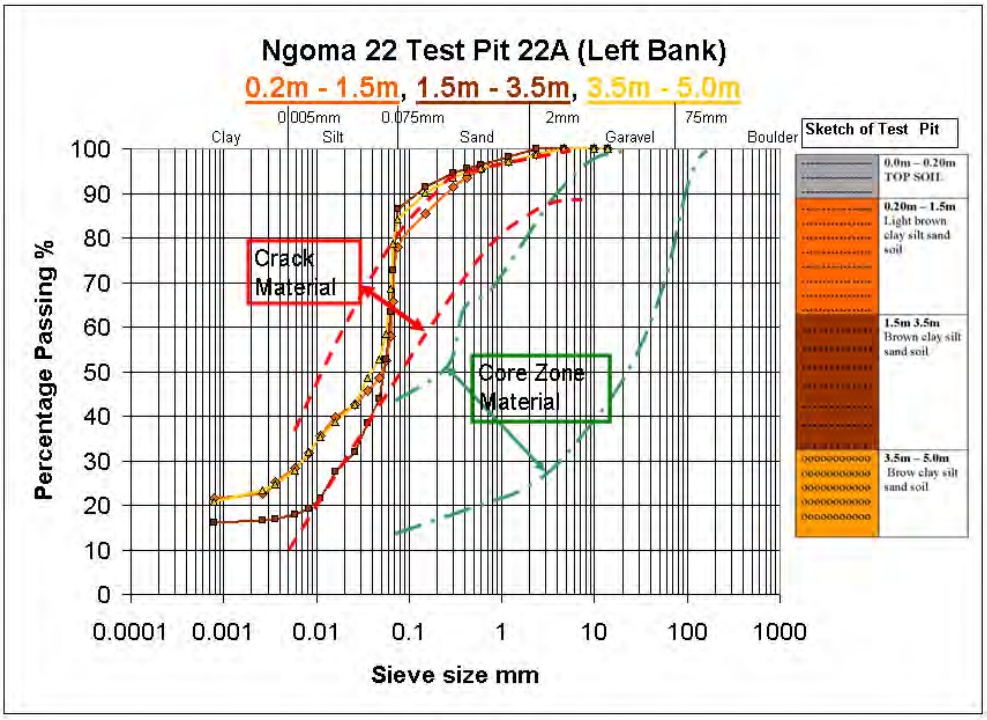
	0.3m－1m	1m－3m	3m－5m
Liquid Limt	34.2	57.7	57.6
Plasticity Index	14.5	28.4	28.7
Symbol	▲	●	◆
Classification	CL	CH	CH
	Clay	Clay	Clay

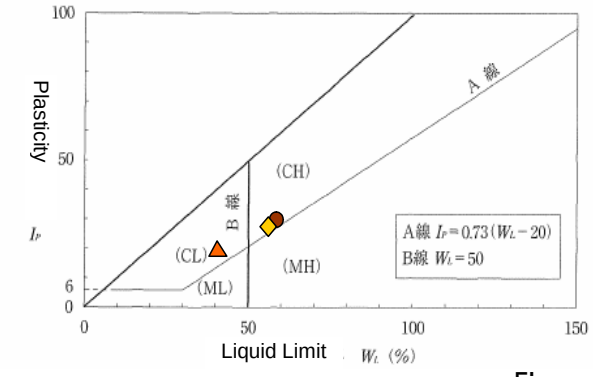
Figure 2.1.57 Soil Test Result Ngoma21 (1)

The test result showed that the material can be used as impervious core material.

The materials tested on both right and left banks showed the similar result and can be used as impervious material except those from the river bed.

Table 2.1.34 Ngoma 22 Test Pit 22A（Left Bank） Laboratory Test				
	Test performed	Test Results		
1	Left Bank Test Pit Depth (m)	Ngoma22A 0.20m-1.5m	Ngoma22A 1.5m-3.5m	Ngom 22A 3.5m-5.0m
2	Natural Moisture Content %	9.6	10.4	11.6
3	Atterberg i)Liquid Limit %	40.9	58.6	55.6
	ii)Plastic Limit %	19.2	28.7	27.9
	iii)Plasticity Index %	21.7	29.9	27.7
4	Specific Gravity	2.65	2.66	2.7



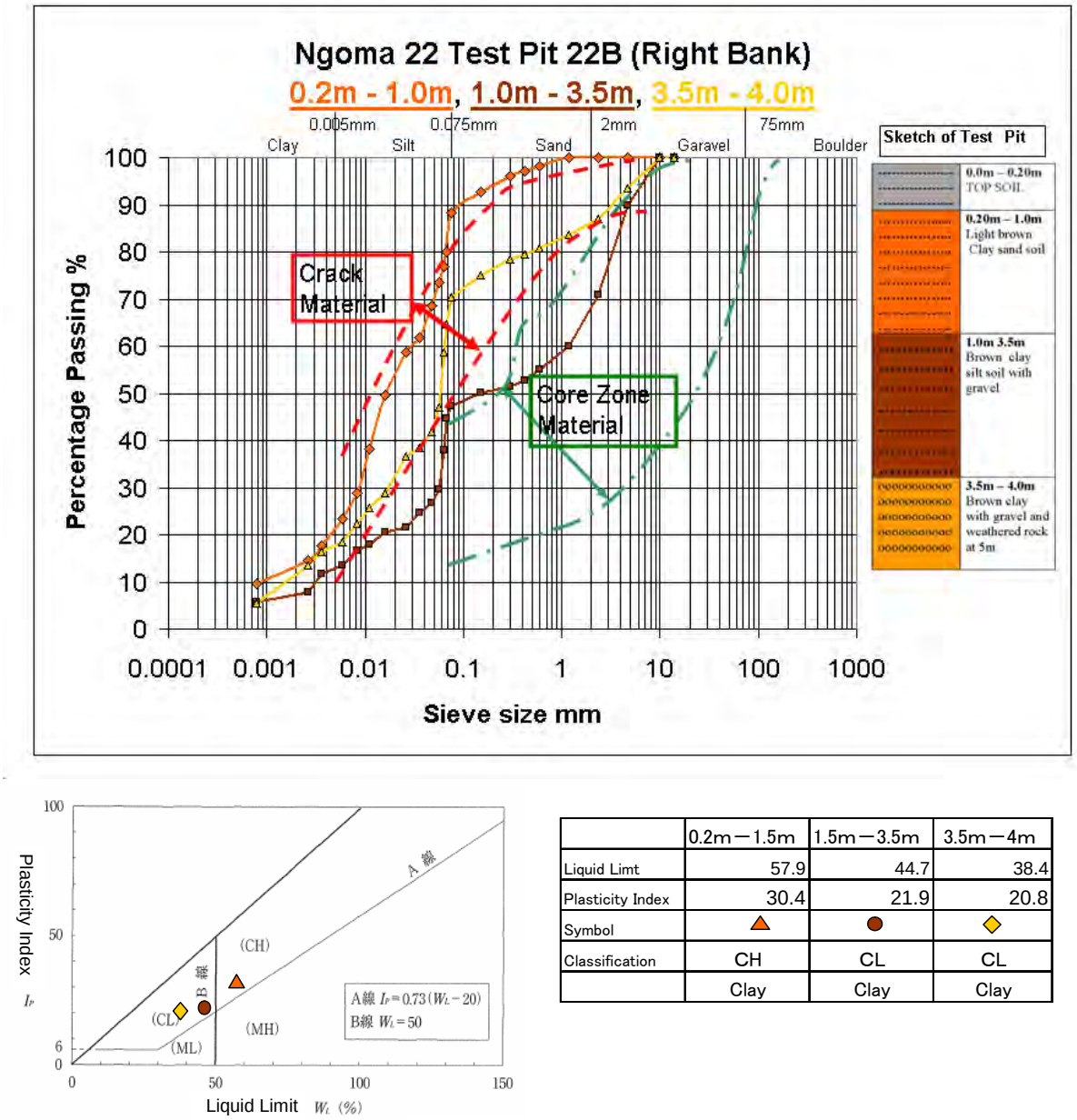


	0.2m－1.5m	1.5m－3.5m	3.5m－5m
Liquid Limt	40.9	58.6	55.6
Plasticity Index	21.7	29.9	27.7
Symbol	▲	●	◆
Classification	CL	CH	CH
	Clay	Clay	Clay

Figure 2.1.58 Ngoma22 Result of Soil Test(1)

As the results, it was confirmed that the material can be used as impervious core material.

Table 2.1.35 Ngoma 22 Test Pit 22B (Right Bank) Laboratory Test				
	Test performed	Test Results		
1	Right Bank Test Pit Depth (m)	Ngoma 22B 0.20m-1.0m	Ngoma 22B 1.0m-3.5m	Ngoma 22B 3.5m-4.0m
2	Natural Moisture Content %	7.6	9.6	6.8
3	Atterberg i)Liquid Limit %	57.9	44.7	38.4
	ii)Plastic Limit %	27.5	22.8	17.6
	iii)Plasticity Index %	30.4	21.9	20.8
4	Specific Gravity	2.65	2.63	2.7



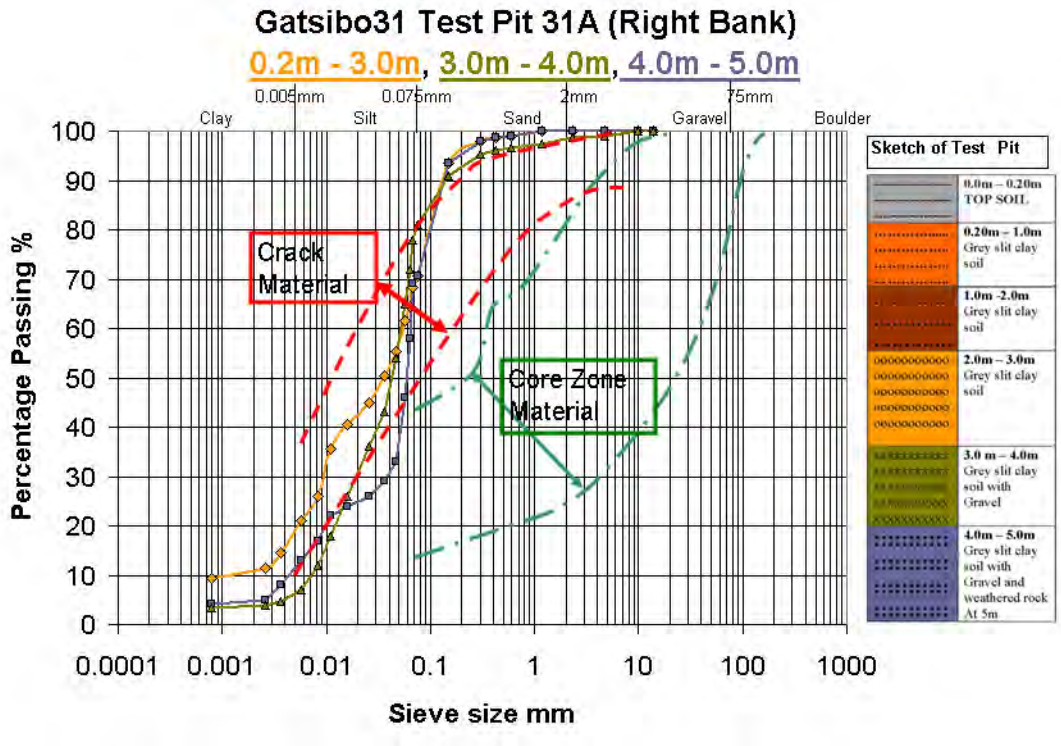
	0.2m－1.5m	1.5m－3.5m	3.5m－4m
Liquid Limt	57.9	44.7	38.4
Plasticity Index	30.4	21.9	20.8
Symbol	▲	●	◆
Classification	CH	CL	CL
	Clay	Clay	Clay

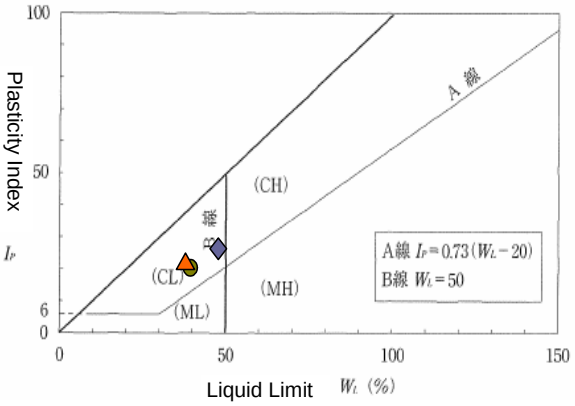
Figure 2.1.59 Ngoma22 Result of Soil Test(2)

For this case, the condition is different by left bank and right bank. In the right bank, clayey soil layer extends up to 5 m depth, while in right bank the natural moisture content shows higher ratio with having mixture of gravel and deeper than 5 m weathered rock foundation is observed. In this case it is

preferable to fix the borrow pit on the left bank side.

Table 2.1.36 Gatsibo 31 Test Pit 31A (Right Bank) Laboratory Test				
	Test performed	Test Results		
1	Right Bank Test Pit Depth (m)	Gatsibo31A 0.20m-3.0m	Gatsibo31A 3.0m-4.0m	Gatsibo31A 4.0m-5.0m
2	Natural Moisture Content %	8.6	10.4	7.5
3	Atterberg i)Liquid Limit %	38.8	39.5	47.9
	ii)Plastic Limit %	17.5	18.5	23.9
	iii)Plasticity Index %	21.3	21	24
4	Specific Gravity	2.7	2.68	2.64



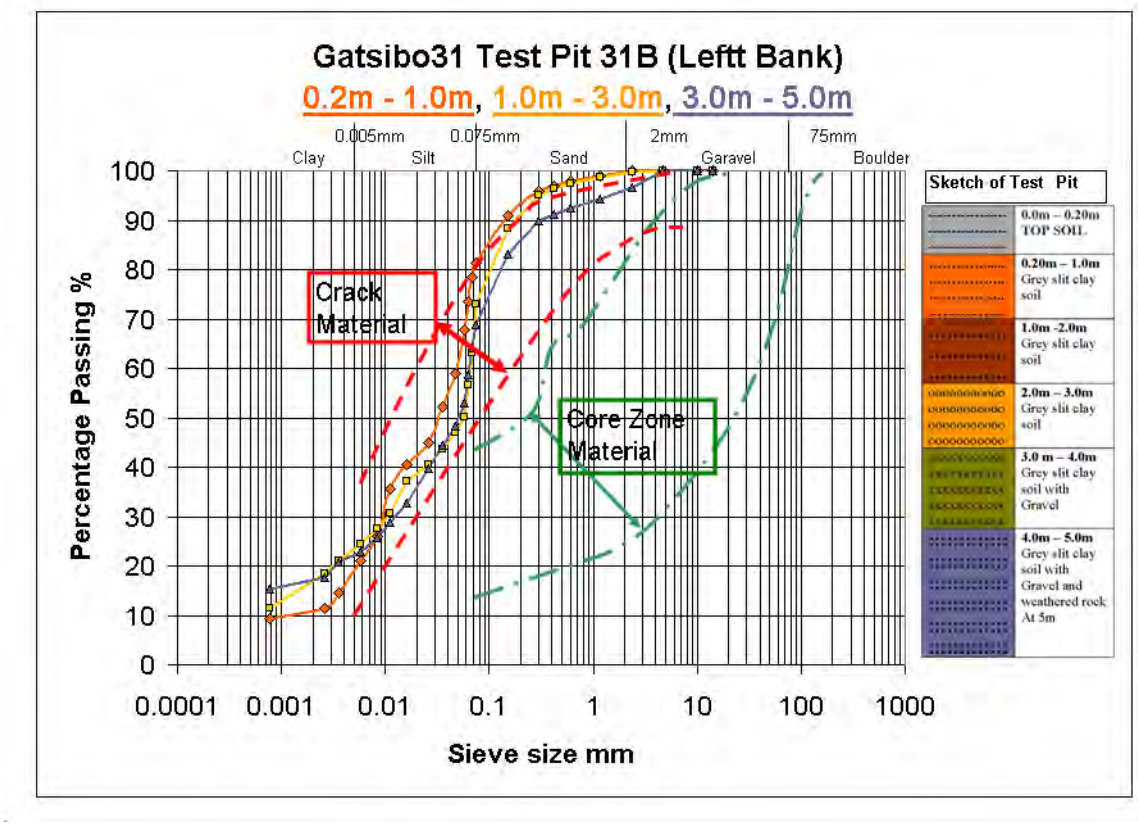


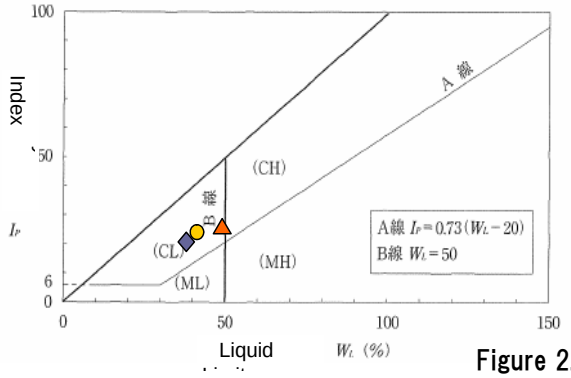
	0. 2m−3m	3m−4m	4m−5m
Liquid Limt	38.8	39.5	47.9
Plasticity Index	21.3	21	24
Symbol	▲	●	◆
Classification	CL	CL	CL
	Clay	Clay	Clay

Figure 2.1.60 Result of Soil Test(1) Gatsibo 31

The natural moisture content is considerably low. Deeper than 4 m, weathered rocks and cause difficulties in construction works.

Table 2.1.37 Gatsibo 31 Test Pit 31B (Left Bank) Laboratory Test				
	Test performed	Test Results		
1	Left Bank Test Pit Depth (m)	Gatsibo31B 0.20 -1.0m	Gatsibo31B 1.0m–3.0m	Gatsibo31B 3.0m–5.0m
2	Natural Moisture Content %	10.4	11.9	6.2
3	Atterberg i)Liquid Limit %	48.6	40.2	37.2
	ii)Plastic Limit %	24.8	17.6	16.7
	iii)Plasticity Index %	23.8	22.6	20.5
4	Specific Gravity	2.66	2.67	2.69





	0. 2m－1m	1m－3m	3m－5m
Liquid Limt	48.6	40.2	37.2
Plasticity Index	23.8	22.6	20.5
Symbol	▲	●	◆
Classification	CL	CL	CL
	Clay	Clay	Clay

Figure 2.1.61 Result of Soil Test (2) Gatsibo 31

Both test pit show weathered rock at depth deeper than 5m and it is not used for embankment material. Since natural water content is less than 10%, it is difficult to control water content during the construction of embankment.

Table 2.1.38 General Overview of Soil Test

Site	Bugesera2 Gashora	Gatsibo31 rugarama	Ngoma21 Remera	Ngoma22 Rurenge
Specific Gravity	The same as general value of soil particles 2.65～2.70. No specific nature of clay mineral or original mineral.			
Natural Water Content	Generally, the smaller the fine fraction is the smaller the water content is, and percentage of fine fraction is correlative with natural water content. To examine the result of soil test as soil in a tropical country, it was examined comparing to data of Malaysia. The result shows the same correlativity and the natural water content is considered as corresponding to grading of the sample. It is presumed that the natural water content depends on physicality of the soil. Based on general characteristics of compaction of clay soil, that optimum moisture content is 3 to 5% lower than plasticity index, optimum moisture content was estimated from water content of plasticity limit. As the result, natural water content varies from optimum moisture content to 15 % less than the optimum moisture content.			
	Natural water content is 5 to 12%. It is estimated that the water content is a few % less than optimum water content.	Natural water content is 7 to 12%. It is estimated that the water content is about 10 % less than optimum water content.	Natural water content is 11 to 17%. It is estimated that the water content is 2,3% to 15% less than optimum water content.	Natural water content is 7 to 12%. It is estimated that the water content is 5,6% to 15% less than optimum water content.
Grading	By tropical climate and tens of millions to a hundred million years long time, fine grained soil become clay to the maximum degree, and it consist of clay and silt without sand and gravel. The samples from three site except Gashora show this characteristics prominently and their percentage of clay or silt is 70 to 90%. Permeability of soil is dominated by content of clay and silt. Rough standard of impermeability of compacted soil is fine fraction 15%. According to this rough standard, all the tested materials are impermeable. Particle of clay is imaged as flaky, on the other hand, particle of silt is imaged as powder. Due to this, comparing to pore water in clay which is restricted by electricity, pore water in silt which is not restricted by electricity is more unstable. Therefore, the soil of which characteristic of silt is dominant, shear strength and workability is affected by water content largely. One sample shows rapid increase in silt range in the grading curve and it needs care.			
	Content of clay and silt is 40 to 60%. It is the fewest among the four sites. The grading curve is smooth and it contains fine gravel of a few mm diameter. It is presumed that it excels in strength in terms of grading.	Content of clay and silt is 70 to 80%. Content of clay varies 7 to 30%. The material from GatsiboA contains less clay and shows rapid increase in silt range in the grading curve and it needs care.	Content of clay and silt is 80 to 90%. Content of clay varies 20 to 30%. In terms of grading, it shows homogeneity. However, since the grading curve shows S curve and the content of particle larger than sand is small, shear strength is dominated by degree of compaction of fine fraction.	Content of clay and silt is 45 to 90%. Content of clay varies 17 to 30%. The sample from RurengeB shows well graded. It is presumed because the test pit reached to foundation rock.
Consistency	Overall result of the test, low plasticity and CL in the classification is prevailing. Low plasticity means high elasticity and it is presumed that comparatively excellent at shear strength.			
	The material is sandy clay with low plasticity index as much as 11 to 17. it is considered that the low plasticity is the result of influence of content of sand and silt. Classification CL （in the range under 0.42mm）	The material is medium plasticity silty clay with plasticity index 21 to 24. content of clay does not influence plasticity index. Classification CL （in the range under 0.42mm）	The plasticity index is 14 to 29. The material is silty clay mainly consist of material with high plasticity index about 30. Classification CH, partially CL （in the range under 0.42mm）	The plasticity index is 21 to 31. the material is silty clay consist of material with high plasticity index 30 and medium plasticity index 20. Classification CH and CL （in the range under 0.42mm）