MINISTRY OF AGRICULTURE AND ANIMAL RESOURCES
THE REPUBLIC OF RWANDA

THE PREPARATORY SURVEY REPORT ON LAND-HUSBANDRY, WATER-HARVESTING AND HILLSIDE-IRRIGATION PROJECT IN THE REPUBLIC OF RWANDA

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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

SANYU CONSULTANTS INC.

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PREFACE

Japan International Cooperation Agency (JICA) decided to conduct the “Preparatory Survey on Land-husbandry, Water-harvesting and Hillside-irrigation Project in the Republic of Rwanda” and entrust the survey to Sanyu Consultants Inc.

The survey team held a series of discussions with the officials concerned of the government of the Republic of Rwanda, and conducted a field investigation. As a result of further studies in Japan, 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.

Finally, 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 survey team.

June, 2014

Makoto KITANAKA
Director General,
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SUMMARY

1. Background of the Project

The Republic of Rwanda is a landlocked country located in the central Africa region right on the equator surrounded by four countries, namely, Uganda, Congo, Tanzania and Burundi. The altitude of the country ranges from 900m to 4,500m, and it is called "a country with thousand hills" because of hilly land. In the year of 2010, as many as 10.41 million populations live in the 26,338km^2 land area. The density of population is highest in African countries as many as 395 people per km^2.

According to World Bank report, GDP in Rwanda in the year of 2012 is 7.1 billion dollars and GNI per person amounts to 600 dollars. Although Rwandan economy, industries and human resources were heavily damaged by civil war broken out from 1990, Rwanda has revived rapidly economic development owing to international assistance and strong leadership of government so that its economic growth rate has reached 7 % in 2013, a report issued by World Bank says. Furthermore, Rwanda settled on "Rwanda Vision 2020" in 2000 aiming the per capita income of a nation will rise up to 900 dollars until 2020 and will become medium income country.

Agriculture and rural development is placed one of the important field of industry which can drive economic growth and reduction of poverty. According to governmental medium-term 5 year development plan, "Economic Development and Poverty Reduction Strategy (EDPRS), 2008-12", GDP composition rate of agriculture sector occupies 36.4 % which is ranked second place to service industry of 43.8%. Moreover, "Strategic Plan for Agricultural Transformation in RWANDA 2004 (SPAT)" reported that agriculture is major industry in Rwanda which occupies about 90% of labour population, creates 47% of GNP and takes 71% of export amount.

On the other hand, Rwanda has serious problem such as low agricultural productivity and shortage of food caused by hilly land, soil erosion during rainy season, land degradation and undeveloped irrigation system on hillside. In order to carry out "SPAT" effectively, Rwandan government has planned "LWH, Land-husbandry, Water-harvesting and Hillside-irrigation Project" and attempting agricultural production growth, sustainable development, market oriented commercialization and diversification of agricultural products by means of farm land reclamation, soil improvement, water-harvesting and hillside irrigation projects.

The Ministry of Agriculture and Animal Resources (MINAGRI), which is responsible for agriculture and irrigation development in Rwanda, plans to construct about 100 reservoirs for agriculture and irrigate 10,000 ha land based on "LWH" plan.

From the background mentioned above, GOR requested of grant aid assistance from Japan regarding construction of reservoir and irrigation facilities amounting 21 million USD with 5 project sites planned based on "LWH" in August 2009.

Project Components requested originally (August 2009)

Name of Site	Bugesera2	Bugesera3	Bugesera4	Ngoma21	Ngoma22
Cost requested	3.5Mill USD	2.9Mill USD	5.1Mill USD	4.4Mill USD	5.1Mill USD
Volume of dam embankment	111,000m^3	114,612m^3	224,905m^3	140,000m^3	65,000m^3
Spillway and Spillway canal	160m	210m	180m	250m	160m
Intake facilities	1 set	1 set	1 set	1 set	1 set
Irrigation canal (Pipeline)	2,700m	1,930m	4,108m	3,500m	8,000m

Through several surveys implemented by the Japan International Cooperation Agency (JICA) in response to the request, constructing reservoir or irrigation facilities at four candidate sites out of five has been evaluated as improbable. Only "Ngoma22 site" which is the target site of this survey has evaluated promising for irrigation development.

2. Outlines of Survey Results and Components of the Project

1) Survey Schedule

Following two times of field survey were conducted.

(1) First Field Survey

Survey for collecting general information and specific items necessary for compilation of the project components preparation of draft final report and their analysis were carried out.

August 22, 2013 - November 25, 2013 (96 days)

(2) Domestic Survey

Following the first field survey, the data and information were brought to Japan and analyzed and the project components were structured.

(3) Second Field Survey

Second field survey was implemented to obtain the basic acceptance to the draft final preparatory survey report by the Rwanda side through explanation and discussion on the components of project.

May 10, 2014 - May 18, 2014 (9 days)

2) Basic Concept of the Project

The Project is one of LWH sub-projects, as-called "Ngoma22 sub-project", which is located at Ngoma District, Eastern Province. The Project will cover construction of a reservoir and irrigation facilities, procurement of necessary materials, implementation of soft component and plot construction of the existing paddy field. The overall goal, project purpose and Project Design Matrix are as shown below:

Project Purpose: Agricultural productivity in the Project area is stabled and increased.
Overall Goal: Income of the target group is increased.

After completion of the first filed survey which was done from August to November 2013 as indicated above, JICA survey team continued its analysis as a domestic survey. The team finally compiled the project components as the table below.

Project Components

Item	Contents
1. Dam pond and Regulating tank	- Dam structure (Embankment) - Regulating tank
2. Irrigation facilities	- Main irrigation canals and secondary canals for hillside irrigation - Distribution boxes and canals/drainages for existing paddy field
3. Materials	- Solar panels - Pump facilities - Horse pipes

Item	Contents
4. Soft components	- Establishment of a Water Users Organization (WUO) and organization strengthening of the WUO（including inland aquaculture training）
	- Technical support for O&M of irrigation facilities, water management and farming
	- Test filling of the reservoir
5. Plot construction of existing paddy field	- Plot construction of paddy field in the downstream

As to the component item-1, -2, -3, and -4, the project plan have been established through the discussions made by both parties of Irrigation and Mechanization Taskforce of MINAGRI and JICA Survey Team and the following domestic survey in Japan.

Concerning the component item-5, “Plot construction of existing paddy field”, was requested newly by MINAGRI after commencement of the survey and then it was finally decided to be incorporated in the project. The plot construction works are to be shared by the both parties. The targeted area of plot construction is planned about 35ha so that Japanese side will cover demo-plot construction of about 2 ha and overall irrigation/drainage canal development including O&M road construction of around 3.8 km, while Rwandan side will be responsible for plot construction of remaining area.

It was also agreed that the plot construction would be done as a parts of technology transfer from the Japanese side to the Rwandan staff and also the heavy equipment are to be provided after finishing the model construction at demo-plots.

With introduction of pump irrigation, which is planned to apply the solar generating system, extension of the three faces power line is needed from the existing power grid 6km away from the project site as a supplemental power source for operation of the pumps. Through the discussion made by Permanent Secretary of MINAGRI and the persons concerns of Japanese side on November 23, 2013, Rwandan side and Japan side confirmed that the cost for extending the power line will be borne as a part of Japans’ Grant Aide of the projet.

3) Outline Design of the Japanese Assistance

(1) Design Policy

a) Observed data at the Gahororo observatory station in Ngoma district near the Project site is applied basically for meteorological conditions necessary for the survey of irrigation water requirement and so on such as temperature, rainfall and humidity. However, humidity, wind velocity and sunshine hours which are not observed at the station were alternated with the data of Kigali airport observatory station. Topographical and geological conditions at the sites of reservoir and irrigation facilities apply the results of topographic survey and geological survey including boring investigation and soil tests conducted on this survey referring topographic and geographic map collected in Rwanda.

b) Specification, quality and verification of materials and construction works of the Project will be based on the Japanese Industrial Standards (JIS) and the International Organization for Standardization (ISO), given that any standard concerning design and construction control has yet been established in Rwanda.

c) Banking materials, aggregates, stones, cement, pipes, pumps, solar panels and pump control panels can be procured in Rwanda. On the other hand, valves, ultrasonic current meters, low pressure power panels will be procured in Japan. General construction machines such as backhoe

and dump truck can be rented from some construction companies in Rwanda. However, it is planned to procure tractor, laser-leveler and so on in Rwanda and Japan.

d) Crops with high demand and high profitability are proposed as a policy for the agricultural plan of the project, and the ones that have already cultivated by farmers in the site due to adaptability to the soil and temperature are introduced. Increase of yield by year-round irrigation combined with improved farming technologies is also planned. At the marshland, paddy farming shall be continued in accordance with the national policy. At the hillside, cabbage, eggplant, carrot etc., with high consumption and higher preference are introduced along with tree tomatoes and coffee.

(2) Basic Plan

a) Available water quantity which is the fundamental value of irrigation plan is studied applying the runoff model (Tank Model) that can calculate the daily river flow rates through analyzing the relationship between the rainfall record and the river flow rate record that have been being observed since February 2012, ranging from 22nd of February 2012 to 5th of August 2013. While the expected flow rate with the 1/5 probability occurrence (Return period) is calculated 1,142,000m^3, the annual flow rate close to which is 1,111,000m^3 of the year 1974 from the result of analysis by Tank Model. Therefore, 1974 is defined to be the reference year for design and the calculated value of 1,111,000m^3 is treated to be the expected annual flow rate. Then, the available annual flow rate is estimated to be 1,063,000m^3 which comes from the subtraction of ecological river discharge 48,000m^3 estimated from the expected annual flow rate 1,111,000m^3.

b) Since terracing works shall be implemented on the hillside command area, the farm land area after terrace construction will be reduced compared to present area. Moreover, some lands which cannot be included as irrigation area such as tree planting area, rocky area, roads and canals and O&M road which will be constructed in the Project. Assuming that these reduction rates shall be about 20 % of gross area, net upland command area is estimated 265 ha for both sides of the hillside.

c) Irrigation water conveyance method from reservoir to command area is divided into using natural heads type and using pumps type. If the height of dam is lifted up to secure dead water volume adding available water volume, irrigation water can be supplied by natural gravity using lifted up head. However, using pumps is required to distribute irrigation water to higher area of hillside since the command area by using gravity shall be limited in a certain area according to topographical conditions. As the result of comparative study, the case of constructing 14.9m-height dam (lifted up height is 9.0m) has the advantage in construction cost as well as maintenance cost. For the reasons stated above, irrigation method with using gravity and pumps by lifting up the dam by 9m is adopted in this Project.

d) Land husbandry is comprehensive slope land conservation project integrated with leveling of farm land by terracing works, soil amelioration by calcium hydroxide or compost, countermeasures for landslide by planting grasses or trees and drainage works for turbid water by constructing catch drain. Since secondary canals of PVC ϕ 50 and drainage canal (B=300mm) are planned to be constructed at 100m intervals each other along the direction of hillside slope, terraces shall be independently constructed.

e) The homogeneous type shall be adopted as the dam body based on the following reasons, (i) wide bottom of the homogeneous dam body can contribute to increase the seepage length and decrease the length of the horizontal blanket, (ii) earth materials good and much enough in quality and quantity can be obtained from the borrow area close to the dam site and (iii) the dam height is less than 15m, which assures the stability of the embankment constructed adequately and requests the

simple structural composition.

f) The foundation of the dam body is composed of the upper pervious to semi-pervious earthen layer, and the lower semi-pervious weathered rock layer. In the case of Ngoma22, the grouting method cannot be applied because of the foundation being composed of earthen to highly weathered rock formation and having no cracks/room for cement milk to be injected. The blanket method is the only applicable method for the foundation treatment of the dam of Ngoma22.

g) The width of the dam crest is provided with 6m as the safety treatment considering the additional dam height being not so high and the water surface coming up near the dam crest. The upstream slope and the downstream slope is provide with the inclination of 1:3.0 and 1:2.5 respectively considering the stability of the dam body and the bottom width of the embankment being effective to reduce the seepage quantity. A berm of 2.5m wide is provided at EL.1385.0m on the upstream slope and the downstream slope of the dam body considering its contribution to the embankment stability and maintenance works.

h) The alignment of the spillway is designed at the right bank taking account of some conditions such as topographical and geological conditions and relation with other facilities. The basic structure of spillway is open canal type with rectangle shape.

i) As the result of comparative study, installing a pump station at the dam site using solar power generation mainly and commercial power subsidiary is selected plan. The location of installing the panels is near the pump station and gathering one place is better for operation and maintenance. Though it is possible to install the panels on the ground directory, they shall be installed on the top of regulating tank which will be constructed to store irrigation water with its size is 3m high and surface area of 600m^2 so as not to be stolen or broken. Moreover the fence will be installed around the tank for safety. Installing the panels on the top pf the tank is reasonable from the view point of decreasing land expropriation and compensation.

j) Main canal consists of lower canal which conveys irrigation water by natural gravity using lifted head at the reservoir and upper canal which conveys pumped up water. In consideration of characteristics of both types, open channel type is adopted basically for economical reason. While constructing regulating tank shall be adopted for lower main canal and pipeline type which can be laid regardless of topographical conditions shall be selected for downstream from the tank because the discharge is little and the difference of construction cost with open channel type may be also small. Secondary canals which are diverted from main canal and convey irrigation water to each farm plots shall be pipeline because they are arranged along the slope of a hillside and required to supply pressured water through hydrant.

k) As per plot construction in existing paddy field, alignment of main canal/drainage and O&M road basically follow the current lines so as not to disturb present paddy plots taking account of water management the farmers have practiced so far. Along the main canal of around 3.9 km, 12 division boxes are to be constructed with around 300 m interval to deliver the irrigation water to paddy plots spreading both sides of the main canal by raising water level in the canal. Prior to commencement of the plot construction works, road for construction shall be installed along the canal existed flowing in the center of the targeted paddy area. After completion of all construction works planned, the road will be used for maintenance activities for project sustainability.

l) Construction works of the project are shared by Japan and Rwanda as the table below.

Construction, Procurement and Installation Plan

Facilities	Japan side	Rwanda side
Whole	- Gravel pavement of approach road (L=2.2km) - Construction road	- Land acquisition - Removal of obstacles in the site and leveling - Preparing temporary yard
Dam	- Dam, Intake, Spill way	
Pump station	- Pump station, Regulating tank (No.1), Conduit pipe - Pump equipment, Electric equipment, Solar panel - Safety fence of Regulating tank (No.1) with solar panel	- Extension of grid line (Outsourcing to EWSA)
Main canal, Secondary canal, On farm facilities	- Main canal (open canal, pipe line), Regulating tank (No.2, No.3), Secondary canal, Hydrant	- Terracing - Safety fence of regulating tank (No.2, No.3) and Discharge tank (No.1, No.2 and No.3)
Plot construction of existing paddy filled	- Irrigation and drainage canal, O&M road, diversion box - Land leveling of paddy plots as technical transfer (2 ha)	- Land leveling of paddy plots (28 ha)

(3) Soft Component (Technical Assistance) Plan

In order to sustain effectiveness of irrigation agriculture at the Project site, it is proposed to integrate 1) Water Users Organization (WUO) establishment and strengthening including aquaculture training, 2) O&M of irrigation facilities, water management and farming technology, and 3) test filling of the dam into the soft component of the Project. Fig. 2.2.4.1 indicated in the main report shows a positive cycle aiming at income improvement through proper WUO management and irrigation farming.

Necessary Resources for the Soft Component Plan

Field	Japanese	Rwandan	Target
1. WUO Strengthening Inland fisheries (Aquaculture)	1 person x 3 months	1 person x 3 months 1 person x 2months	WUO representatives Cooperative representatives Agronomists of District, Sector Offices Representatives of farmers Representatives of DISC
2. O&M of facilities and water management Improved farming technologies	1 person x 3 months - Horticulture agronomist: 1 person x 3 months - Paddy agronomist: 1 person x 3 months	1 person x 3 months - Horticulture: 1 person x 3 months - Paddy: 1 person x 6 months	WUO representatives Cooperative representatives Agronomists of District, Sector Offices Representatives of farmers Representatives of DISC
3. Test filling	Dam engineer: 1 person x 1 month	Dam engineer: 1 person x 1 month	MINAGRI staff WUO representatives Cooperative representatives Representatives of DISC

4) Environmental and Social Considerations

Main structures/facilities to be constructed by the Project are a dam (dam's capacity; 960,000m^3) supported by the dam embankment (H=14.9m), main irrigation canals (L=28km) with appurtenant

facilities e.g. the spill way, the pumping station, solar generation facilities, the bottom conduit, discharge facilities, etc. The Project site is located on Remara Sector and Rurenge Sector in Ngoma District. It is planned that 21.73ha will be submerged by the proejct, which will lead to land expropriation, however, no involuntary resettlement is expected. Moreover, the area of paddy field in the downstream will be decreased due to the plot construction.

The lands to be expropriated are farmlands where the proposed dam and irrigation facilities will be constructed. Furthermore, no existing structure will be affected by the Project and all the affected persons are farmers who cultivated in the proposed construction sites. The number of PAPs is 1,120 households in total.

Land for land compensation is desirable according to the laws in Rwanda, however, due to shortage of available lands in the district, it is difficult for Ngoma District to arrange new alternative lands for the affected persons. Therefore, it is proposed to apply cash compensation based on the law (Ministerial order on land prices outside Kigali city, MINIRENA, 2010).

Compensation for marshland expropriation is not needed in Rwanda, however, some farmers will be damaged due to the Project. Therefore, it is planned to provide agricultural technical support through the soft component not only for the private land owners but also farmers in the marshland. On the other hand, there are some households who depend on the marshland for farming, and they will be influenced by the Project significantly, even though the proposed supports mentioned above are implemented. Therefore, it is proposed to redistribute of paddy filed in the downstream to such people.

5) Project Implementation Schedule and Estimated Project Cost

Since dam banking is a part of component of the Project, construction works of irritation facilities shall be carries out efficiently in dry season. While embankment works are executed, the other components such as pump, canal and plot construction for existing paddy field will be implemented. overall implementation schedule is planned as the table shown below.

- Detail design : 4.0 months
- Biding and Contract : 3.0 months
- Construction : 15.0 months (from contract to completion on construction)

The total cost to be incurred by the subject project implementation is about *** Million Yen (Japanese side ***Million Yen and Rwanda side 58 Million Yen).

3. Project Evaluation

1) Relevance

Despite agriculture sector is positioned as the key industry in Rwanda, it have been facing with low productivity and small-scale farming size scale, which have been closely linked with the issues of nationwide such as poverty of the people, food shortage and so on. Under such circumstances, the project is responsible for promotion of irrigation development of 10,000 ha by reservoir construction of about 100 sites based on the policy to LWH project so that urgency to implement the project is higher in the policy.

According to the feasibility study report formulated in 2012, average monthly expenditure per house hold in the project site is estimated at Rwf 13,775, which is equivalent to only a half of the living standard of the national average of Rwf 27,500/HH/month. In addition to this, the wages of casual labor in the area is around Rwf 800/capita/day - Rwf 1,000/capita/day only. It is a level of less than 2

USD/capita/day, which is referred to as the poverty line.

Farm sizes per household of hillside farm land and existing paddy plots in the project area are 34 are/HH and 11.7 are/HH respectively, which is much smaller than that of the average farming scale of the national level of 0.76 ha/HH. In addition, irrigation facilities contributing to improvement of agricultural productivity have been undeveloped so far so that WUO has also not established on the project site.

As described above, there is no room for expansion of farmland and being a small-scale farming on the project site so that it is a good idea for promoting crop production increase through improvement of the yield per unit area, but the cultivation state is extensive and the irrigation facilities are not developed. Furthermore, the living standard of the targeted beneficiaries in the project area is lower than that of the national level. In order to improve the livelihood of the beneficiaries and make the consumer stable, the urgency of the implementation of the project is high.

Based on the LWH policy, this project aims to improve the livelihood of farmers through increase of crop production by development of a reservoir and irrigation facilities at Ngoma22 site in Ngoma District so that it can be said that the consistency is high as a project that will contribute to the goal of national development plan.

2) Effectiveness

Expected effects of the implementation of the soft components and the construction of irrigation facilities in the Project are as follows.

(1) Quantitative Effect

- As per effectiveness of irrigated area expansion, irrigated area of hillside farm land is expanded to 265 ha from 26 ha of current,
- As per effectiveness of cropping acreage increase, the total cropping acreage of hillside farm land is expanded to 610 ha from 99 ha of current,
- As per effectiveness of crop yield increase, the yield per unit area of planned crops is increased as shown in the table below,
- As per effectiveness of irrigation time savings, irrigation time for paddy cultivation is saved to 50 man-day from 100 man-day of current, and
- As per effectiveness of shipping rate enhancement, the rate of shipment planning of planned crops is increased as shown in the table below.

Project Quantitative Effect (Increase of Crop Unit Production)

Index	Reference Value (2013)		Target Value (2019) (After 3 years of construction completion)	
Effect of Crop Unit Production Increase (kg/ha)	Paddy：	4,000	Paddy：	6,000
	Maize：	2,000	Maize：	5,000
	Beans：	1,000	Beans：	2,000
	Cabbage：	8,000	Cabbage：	12,000
	Carrot：	10,000	Carrot：	25,000
	Tomato：	10,000	Tomato：	20,000
	Egg plant：	3,500	Egg plant	7,400
	Tree tomato：	2,500	Tree tomato	3,500
	Coffee：	3,500	Coffee：	5,500

(2) Qualitative Effect

- With introduction of terminal irrigation method that incorporates the hose irrigation and development of key irrigation facilities including reservoir, farming conversion can be performed as individual farmer level by growing more profitable crops than that of traditional crops such as maize, beans and so on,
- Through organizing WUO composed of different community peoples and managing the irrigation facilities as common property of WUO members, the project contributes to stabilization of residents living and to the stabilization of the consumer. In addition, cooperativeness between paddy farmers and hillside farmers is increased, and
- Through practicing soft component activities, the ownership which considers the irrigation facilities as a common property of the community is built up, which leads the farmers to high transparency of financial management of WUO. In addition, farming management sense of the farmers is fostered through appropriate water management realizing appropriate amount and on-time water distribution and equitable water sharing, which takes the farmers to increase of high management sense of farming.

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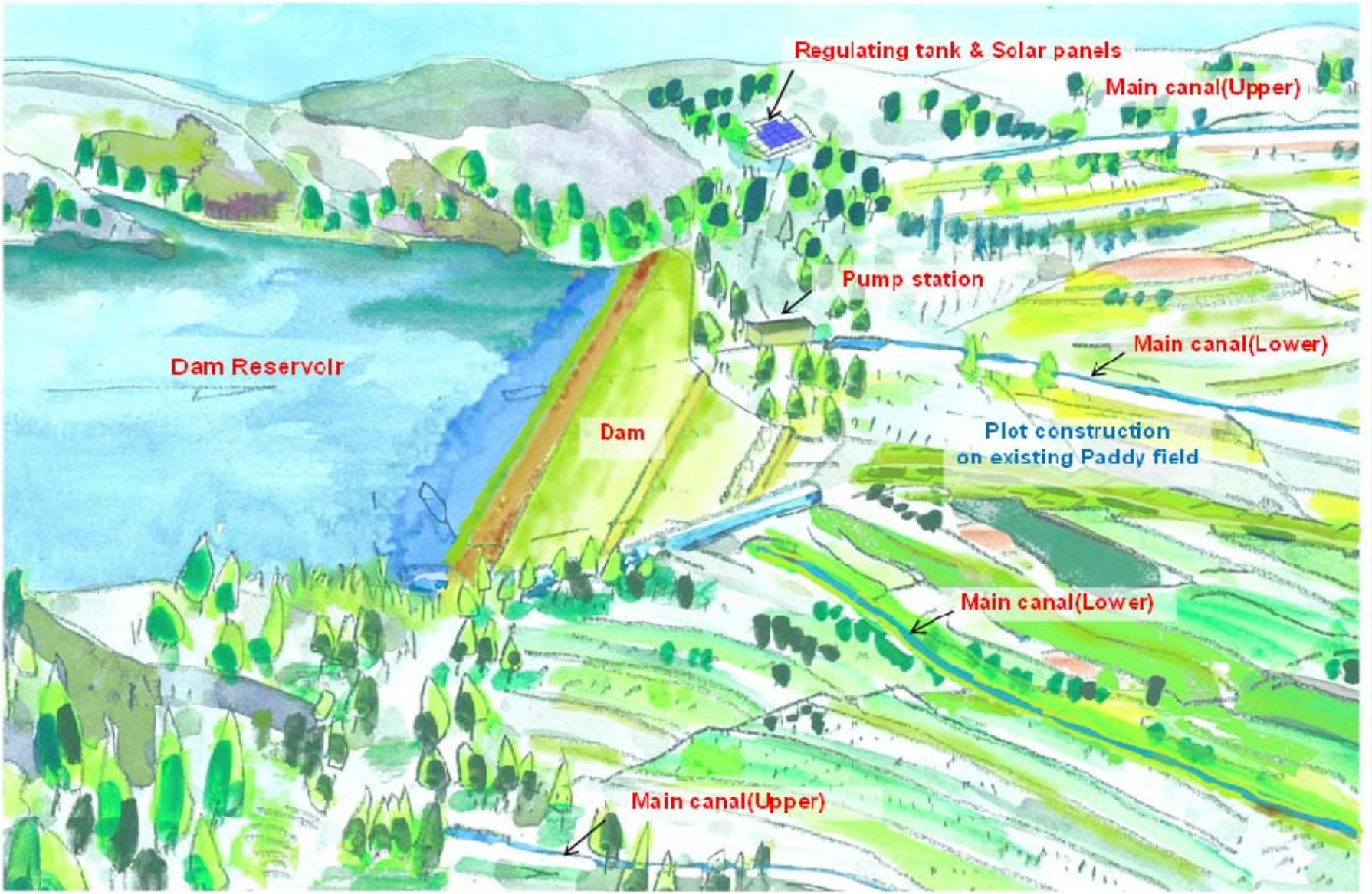
Bandazi
Nyarugenge
Karama
Kicukiro
Gahengele
RWAMAGANA
KAYONZA
TANZANIA
Nawe
Proiect Site
Bihembe
Kanzenze
No. 22
Nguzi
BUGESERA
Jenda
NGOMA
KIREHE
Gashoba
Birenga
RWANDA
Gakamba
Gasenyi
Lugarama
BURUNDI
LEGEND
Study Area
National Boundary
Provincial Boundary
District Boundary
Road
0
10
20
kilometers
Sources: UNHCR, Rwanda National Institiute of Statistics, Global Insight digital mapping - 1998 Europa Technologies Ltd
Democratic Republic of the CONGO
UGANDA
United Republic of TANZANIA
EASTERN PROVINCE
RWANDA
NGOMA DISTRICT
Study Area:
NGOMA District,Eastern Province
BURUNDI

Perspective

Land-husbandry, Water-harvesting and Hillside-irrigation Project in Ngoma22



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ABBREVIATIONS

CARD	Coalition for African Rice Development
C/P	Counterpart
DISC	District Irrigation Steering Committee
EAC	East African Committee
EIA	Environmental Impact Assessment
EIACA	Environmental Impact Assessment Certificate of Authorization
FAO	Food and Agriculture Organization
GoJ	Government of Japan
GoR	Government of Rwanda
JICA	Japan International Cooperation Agency
LWH	Land-husbandry, Water-harvesting and Hillside-irrigation Project
M/D	Minutes of Discussions
MINICOM	Ministry of Trade and Industry
MINAGRI	Ministry of Agriculture and Animal Resources
MINIRENA	Ministry of Natural Resources
NAEB	Rwanda National Agricultural Development Board
OD	Outline Design
OP	Operation Policy
OJT	On the Job Training
O&M	Operation and Maintenance
PAP	Project Affected Persons
PDM	Project Design Matrix
RAB	Rwanda Agriculture Board
RAP	Resettlement Action Plan
RDB	Rwanda Development Board
REMA	Rwanda Environment Management Authority
RNRA	Rwanda Natural Resources Authority
RPF	Resettlement Policy Framework
RSSP	Rural Support Sector Project
Rwf	Rwanda Franc
SPAT	The Strategic Plan for the Transformation of Agriculture
SPIU	Single Project Implementation Unit
TOR	Terms of Reference
WB	World Bank
W/S	Workshop
WUO	Water Users Organization

UNIT CONVERSION

1 meter (m)	=	3.28 feet
1 kilometer (km)	=	0.62 miles
1 hectare (ha)	=	2.47 acres
1 acre	=	0.405 ha
1 inch (in.)	=	2.54 cm
1 foot (ft.)	=	12 inches (30.48 cm)
1 ac-ft	=	1,233.4 cum
1 a	=	100 m^2

CURRENCY EQUIVALENTS (AS OF NOVEMBER 2013）

US$ 1.00	=	99.27 Japanese Yen
RWF 1.00	=	0.148 Japanese Yen

RWANDA FISCAL YEAR

From January 1 to December 31

CHAPTER 1 BACKGROUND OF THE PROJECT

1-1 Background and Outline of the Project

MINAGRI requested to Government of Japan in August 2009 to establish irrigation schemes implying facility construction as a Japan Grant Aid, which was planned as a part of LWH Project (Land husbandry, Water harvesting and Hillside irrigation Project) being promoted by MINAGRI. The request at that time is summarized as follows.

Table 1.1.1.1 Project Components requested originally (August 2009)

Name of Site	Bugesera2	Bugesera3	Bugesera4	Ngoma21	Ngoma22
Cost requested	3.5Mill USD	2.9Mill USD	5.1Mill USD	4.4Mill USD	5.1Mill USD
Volume of dam embankment	111,000m^3	114,612m^3	224,905m^3	140,000m^3	65,000m^3
Spillway and Spillway canal	160m	210m	180m	250m	160m
Intake facilities	1 set	1 set	1 set	1 set	1 set
Irrigation canal (Pipeline)	2,700m	1,930m	4,108m	3,500m	8,000m

In respond to the request, JICA conducted a series of survey, namely, 1) "Preparatory Survey on Project for LWH in Republic of Rwanda (No.1)" conducted in April 2010 and 2) "Data Collection Survey on Irrigation Development in Ngoma District of Eastern Province in Rwanda" executed in July 2012.

The former survey investigated 5 candidate sites in Ngoma and Bugesera Districts and then the survey found that 4 sites out of them were not suitable to further promotion as Japan Grant Aid Project because the size of water catchments of those sites were quite small for collection of irrigation water necessary. The latter survey targeted the remained site, where was Ngoma22 site, and then it was finally found the feasibility from the size of command area and water catchment area points of view. Because of the results on these processes mentioned so far, JICA decided to formulate an outline design of irrigation project on Ngoma22 site through execution of this preparatory survey which had been conducted from September 2013 to June 2014.

During the period of the survey 1) indicated above, both parties of JICA and Rwandan side confirmed checklist as below.

Table 1.1.1.2 Checklist confirmed in the Past Survey (April 2010)

Checklist confirmed	Outline
Project purpose	The project aims to realize increment of crop production through sustainable irrigation agriculture.
Target site	Through implementation of a series of survey, it was found that only Ngoma22 is suitable site for irrigation development as Japan Grant Aid Project.
Soil erosion	As to Ngoma22 site, it was judged that the possibility of soil erosion is low from the view point of soil conservation. Terracing will be investigated in next stage in detail.

Prior to commencement of this survey, the project components to achieve the project purpose and overall goal were examined and agreed between MINAGRI and the JICA mission through a series of discussions. On the 5th September 2013, the both parties made signatures on the Minute of Discussions (M/D) based on the discussion above. The Project components are as shown below. As for the project component items of 1, 2, and 3 indicated in the table below, it was confirmed that all would be integrated into the proposed soft component.

Table 1.1.1.3 Project Components confirmed in Minutes of Discussion (September 2013)

Item	Contents
1. Dam and water reservoir	・ Dam ・ Supplementary water reservoir (Regulating tank)
2. Irrigation facilities	・ Main and secondary canals for hillside ・ Intake gate and canals for paddy filed
3. Equipment	・ Solar panel ・ Pump ・ Hose
4. Technical assistance (Soft components)	・ Technical assistance to WUOs ・ Water management

After the field survey conducted from August to November 2013, the survey team analyzed the data and information to establish the outline design of the project. The design was discussed by MINAGRI and JICA mission team on May 15, 2014 and then it was agreed by the both parties.

Table 1.1.1.4 Project Components confirmed in Minutes of Discussion (May 2014)

Item	Contents
1. Dam pond and Regulating tank	・ Dam structure (Embankment) ・ Regulating tank
2. Irrigation facilities	・ Main irrigation canals and secondary canals for hillside irrigation ・ Distribution boxes and canals/drainages for existing paddy field
3. Materials	・ Solar panels ・ Pump facilities ・ Horse pipes
4. Soft components	・ Establishment of a Water Users Organization (WUO) and organization strengthening of the WUO（including inland aquaculture training） ・ Technical support for O&M of irrigation facilities, water management and farming ・ Test filling of the reservoir
5. Plot construction of existing paddy field	・ Plot construction of paddy field in the downstream

1-2 Natural Conditions

1-2-1 Hydrological and Meteorological Conditions

1) Temperature

Although Rwanda is a country which is located just under equator crossing the 2 degrees south latitude, it is said that "a country of everlasting spring" because of its altitude of about 1500m in average. The daily average temperature in capital Kigali is around 21 ^{o}C and it has little annual fluctuation with about 2 ^{o}C. Daily fluctuation is also constant with 16 ^{o}C at lowest and 28 ^{o}C at highest. Since the temperature depends on altitude, the difference of daily average temperature between Gahororo located in altitude of 1700m and Kigali located in altitude of 1450m is 2-4 ^{o}C. From the view point of long-range change, the temperature tends to be rising.

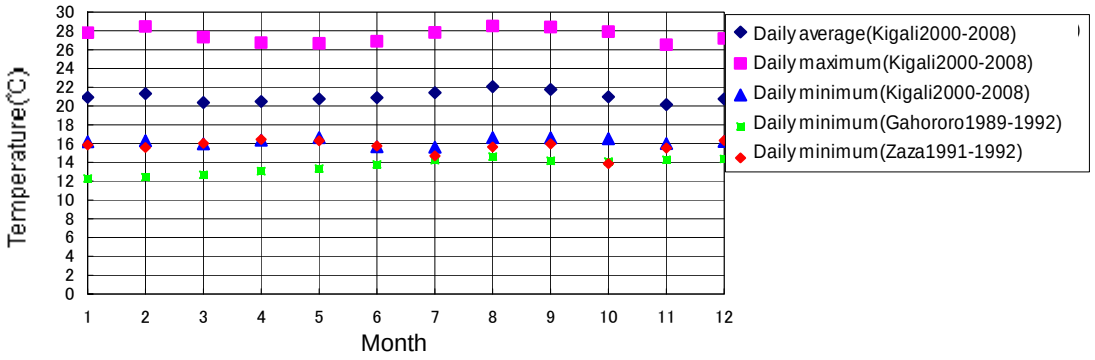


Figure 1.2.1.1 Temperature in Rwanda

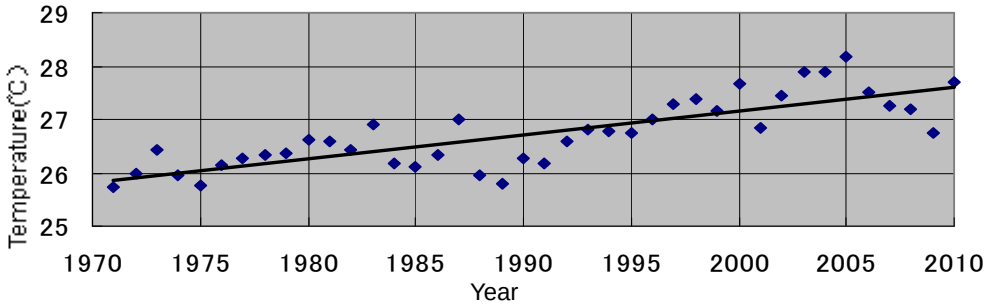


Figure 1.2.1.2Daily Maximum Temperature in Past 40 years

2) Precipitation

Annual precipitation in Rwanda is about 1500mm in western and northern mountainous area and about 700mm in eastern low hillside area. Annual rainfall of about 1000mm is expected in the project site of Ngoma area. It rains usually in a few hours intensively like a squall.

Following figure shows daily average precipitation in ten years from 1983 to 1993 at Gahororo observatory station in the vicinity of Ngoma district. The amount of rainfall is high in rainy season, from March to May, and it rains around 100mm on monthly basis from October to February thoroughly. On the contrary, there are few rains from June to August in dry season. From the view point of long-range change, the precipitation tends to be decreasing.

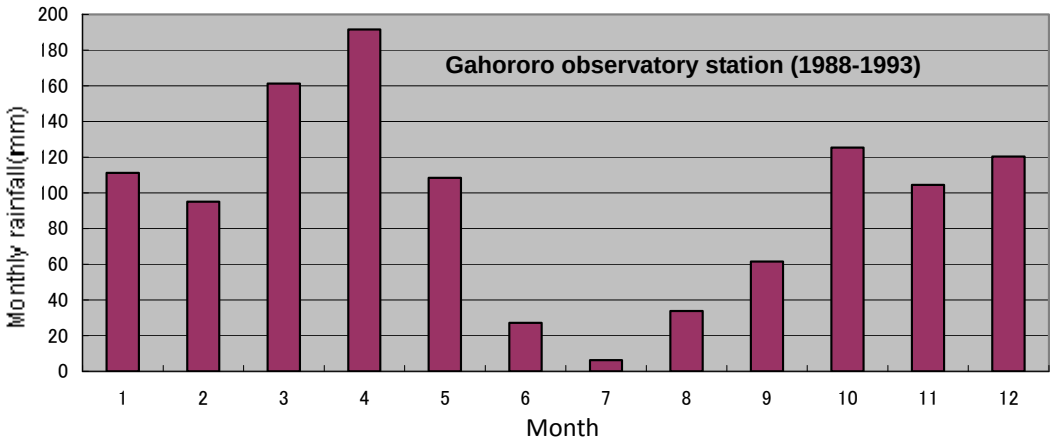


Figure1.2.1.3 Monthly Average of Daily Rainfall in Past 10 Years (Gahororo)

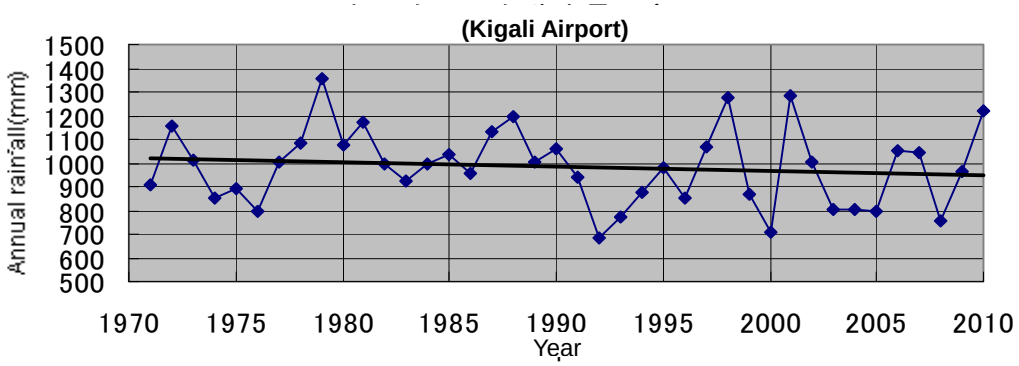


Figure1.2.1.4 Annual Rainfall in Past 40 Years

1-2-2 Geological Condition

1) Physiographic condition

Rwanda is a land-locked, rather small country in central Africa but it has grand landscapes everywhere as it called as "a country with thousand hills".

Relief of the country is generally classified into two zones by the divide of Lake Kive and the Nile drainage basin. The Nile Basin consisted of the central plateau (altitude from 2,000m to 1,500m) and the eastern low plains with elevation less than 1,500m cover the most of the country area and descend their averaged elevation toward the east to the swamps and lakes on the eastern border with Tanzania. On the course of descending their elevation, the land forms numerous wave undulations in NW-SE to N-S direction. Each hill in the plateau and plains has remarkable features; extremely prolonged and flat top and quite gentle side slopes.

Topography near around the Dam site is roughly classified into two categories; to the east, quite large rolling high hills with flat top and prolonged N-S direction, and to the west, rather low-lying very gentle hills with flat top also. Lineaments of the high hills are quite sharp, and their hill tops are quite flat keeping their elevation around 1,700m. In between the rolling hills, several drainages cut the hill slops forming very sharp valleys in parallel with the hills. While, the western portion of the site is a catchment area of the Lake Mugesera. An irregular, dendritic drainage system forms somewhat wide and flat valley bottom, covering most of the western low-lying hills area. These low-lying hills have also quite flat tops and their lineaments are unclear because they are wide and have branch ridges to some deferent directions.

Ngoma 22 Dam site is set at the small stream in Rwabishanyi valley, at its upstream. At the dam-axis, the stream has small but flat river bed with the width of some tens meter. The small river pours into the Lake Mugesera at its downstream, converged many small tributaries. Right bank of the dam is a gentle slope of NE-SW trend low-lying secondary hill, which is a branch from pretty wide primary low-lying hill extended to NW direction from Remera. Left bank is also a gentle slope of another prime low-lying hill with E-W to NW trend, extended from the end of sub-main hill split from the main high hill from Kigarama.

2) Geological condition

The target site, Ngoma 22 dam-site, is located in the southeast of Rwanda, and included in the 1:100,000 scale Local Geological Map of Rwanda, "Kibungo Sheet". Basic geology underlying in the sheet is mainly metasediments sequence belonging to "Mesoproterozoic", major facies are Quartzite, Mmetasandstone, and Shists. The sequence is heavily folded along with the axis of NEN-SWS direction, and faulted along same direction; there are many cross-cutting faults though. This main axis

is nearly same with the prolonging direction of the main high hills.

As one of remarkable geological feature in this area, almost all tops of the hills are covered by Laterite formation, mostly weathered but sometime fresh. When it is heavily weathered, only small, very hard, and spherical gravels of reddish brown are remaining in residual soil.

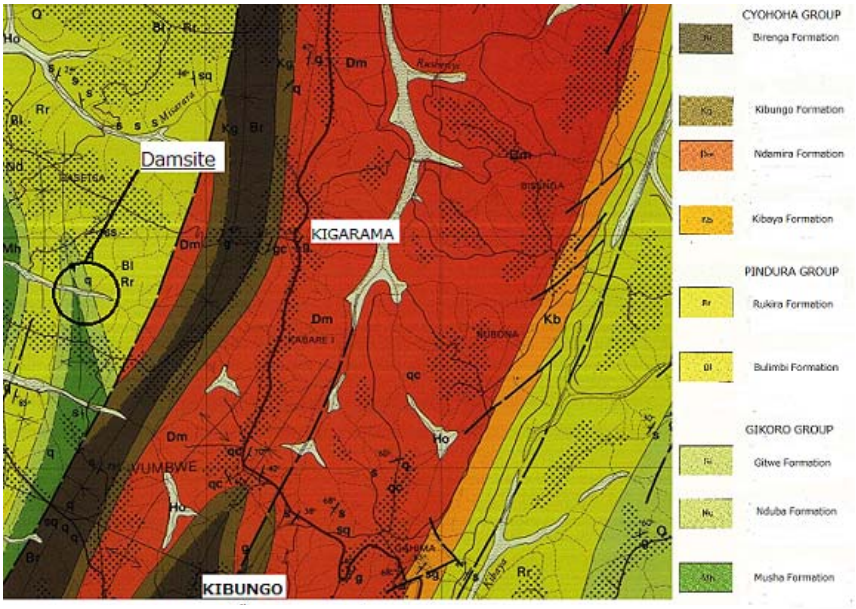


Figure1.2.2.1 Abstracted Geological Map around the Dam Site

The upper figure is a geological map near around the Dam site, abstracted from the Kibungo Sheet of 1:100,000 scale Geological Map. As shown in the figure, a thick syncline belt consisted of {Dm}, {Br}, and {Kg} formations runs across the area in NE-SW direction, and the belt is cut by faults at its both side. The zone near around the Dam site is underlain by far old formations than the ones composing the syncline belt, cut by the fault.

The geological map suggests that a small scale syncline axis passes through the just Dam site and Musha Formation {Mh} exposes as a narrow belt intercalated by Nduba Formation {Nd}. Field reconnaissance survey by the geologist of Study Team revealed there is quite a few outcrops of the bedrock at and near the Dam site. However, based on a few outcrops found in up and down-stream slopes, along cutting of small path, and boring cores obtained through the investigation boring, it could be supposed that the Dam site is underlain by pelitic rocks (mainly Schists), and some isolated Sandstone layers with several meters thickness are intercalated, Because Nduba Formation is to be consisted of Quartzite and Sandstones in accordance with the Geological Map, so the formation underlying Dam site shall be Musha Formation {Mh} which composed of mainly pelitic (Schists, Slate or Siltstone) rocks.

Schists distributing near around the site is pinkish to reddish brown, having heavy schistosity. It is generally weathered and soft, heavily disturbed sometimes. Sandstones are gray to pale yellow, hard, and sedimentation is not so clear. Because of its hardness, Sandstones are cropped out on the hill slopes like stone blocks, or shown at cuttings along the local roads. On the hill tops of both abutments, Laterite cover is observed widely. Surface of Laterite is usually weathered but subsurface is still remaining hard laterite crust texture, cropping out as a road base somewhere. In the heavily weathered portion of laterite layer, small, hard, ferric spheres are remained like small gravels.

It is said more than 3/4 of river flow stems from groundwater. In the Dam site also, the small stream runs down the Rwabisharyi valley is sourced by several small springs. Low-lying hills forming both abutments of the planed dam are consisted of very old and metamorphosed sedimentary rocks and covered by laterite cap on their tops. Because of their quite old age, they are already weathered and degenerated to rather pervious property, including a laterite cap. Rainfall in this area is easily infiltrates into the ground and recharges groundwater. Because of the topographic property that the slope inclination is highest at the base of slope, the spring out points are fixed at the bottom of the slope. Rainfall in the both side of the valley rises up the elevation of groundwater table in the hill, and

thus increased groundwater storage in the both side hills supplies spring water throughout the year, gradually reducing their groundwater table through dry seasons.

As the results of all investigation borings, the left abutment was covered by thick Lateritic soil and it became weathered Sandstone from the depth of 13m. In the riverbed, 3 to 5m thickness of overburden (mainly Talus deposits) covered the bedrock. Bedrocks were Sandstone/Schist alternation along the dam-axis, and Schist in slightly upstream. N-value of Lateritic soil was less than 30, Talus deposits were from 3 to 20, but rock formations were rebounded (more than 50). Permeability of soils (Lateritic soil and Talus) was 2 - 3 x 10^{-4} cm/sec, but 10^{-5} cm/sec order in fresh rock formation.

1-3 Environmental and Social Considerations

1-3-1 Environmental Impact Evaluation

1-3-1-1 Project Components which Cause Environmental Impacts

Main structures/facilities to be constructed by the Project are a dam (dam's capacity; 960,000m^3) supported by the dam embankment (H=14.9m), main irrigation canals (L=28km) with appurtenant facilities e.g. the spill way, the pumping station, solar generation facilities, the bottom conduit, discharge facilities, etc. The structure of the dam is proposed as illustrated in following figure. Two lines of main irrigation canal will be constructed on each bank and the total length of the main open canals and pipeline canals are around 20km and 8km respectively. The Project site is located on Remara Sector and Rurenge Sector in Ngoma District. It is planned that 21.73ha will be sumbered by the proejct, which will lead to land expropriation, however, no involuntary resettlement is expected. Moreover, the the area of paddy field in the downstream will be decreased due to the plot construction. The locations of those structures are as illustrated in the following figures:

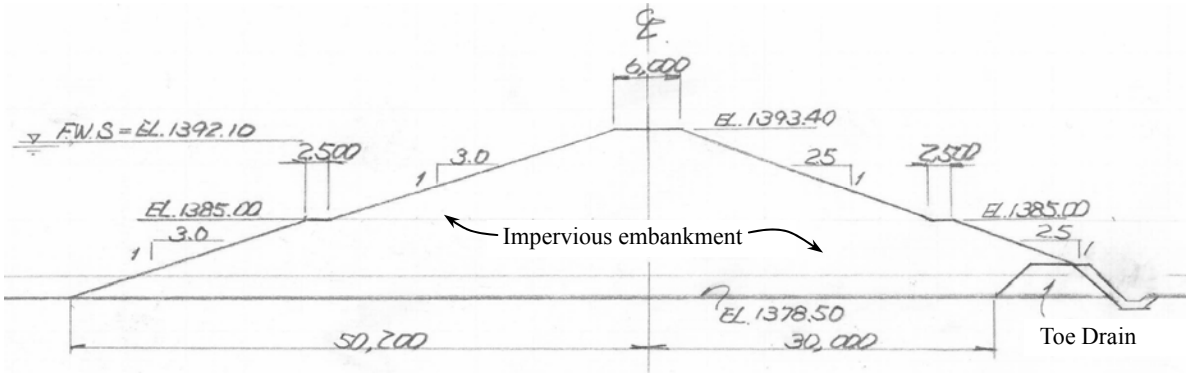


Figure 1.3.1.1 Structure of the Proposed Dam

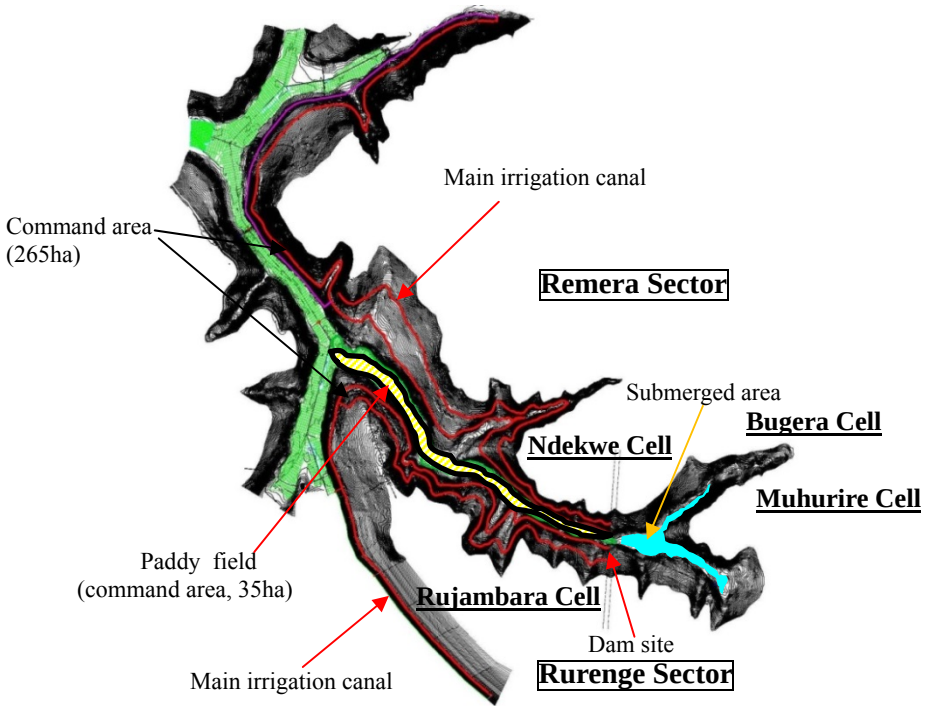


Figure 1.3.1.2 Locations of the Proposed Dam and Irrigation Canals

1-3-1-2 General Conditions of the Project Area

1) Location of Command Area

The Survey Area is located in Ngoma District of Eastern Province, the proposed irrigation command area is located on Ndekwe Cell and Rujambara Cell as shown in following figure. Not only people from those Cells mentioned above but also residents of Rugese Cell, Bugera Cell and Muhurire Cell cultivate in the command area. Beneficial areas are 265ha of upland crop field in the hillside and 35ha of paddy field along the Rwabishanyi River, which flows between Ndekwe Cell and Rujambara Cell.

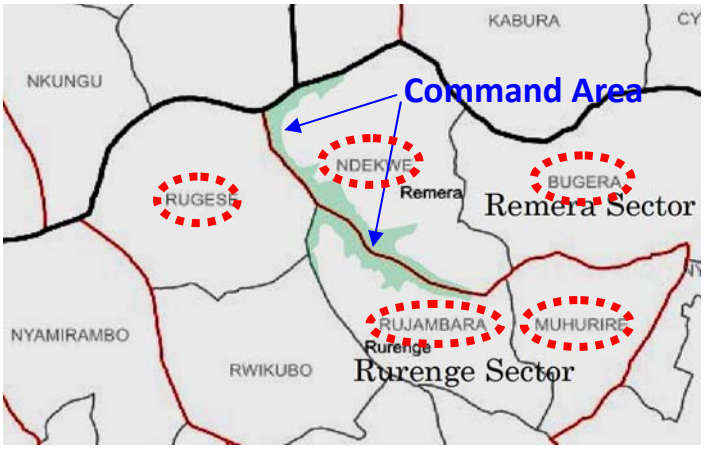


Figure 1.3.1.3 Locations of Command Area and Cells Concerned

2) Rainfall

Mean annual rainfall in Ngoma District is 1,148 mm, which was measured from 1984 to 2012 in Zaza Sector, and it is relatively more compared with other areas in Rwanda. There are two rainy seasons and the rainfall reaches to peak in April. The annual rainfall pattern is illustrated as shown in the following figure.

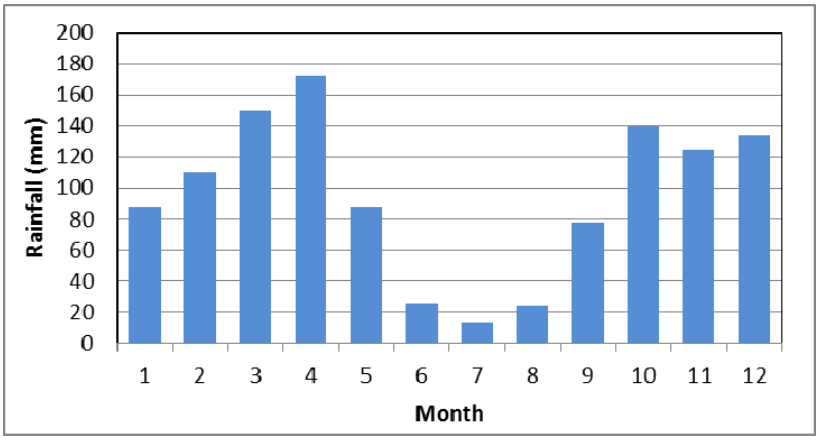


Figure 1.3.1.4 Annual Rainfall in Ngoma District

3) Land Use

In the valley where the proposed dam will be constructed, the lower portions of the hill slopes are steep with the inclination of about 20 degree including the maximum inclination of about 25 degree except the gentle slopes at the valley mouths or the end of hills. The height of such steep slopes is about 20m from the river bed. The upper portion of


Hillside and marshland in the beneficiary area

the slopes is gentle with the inclination of about 10 to 15 degree. The Rwabishanyi River flows in the valley, the stream will be merged into other rivers in the downstream and finally flows into the Mugesera Lake. The paddy field is owned by the government. In and around the proposed project sites are farmlands, which paddy, cabbage, sweet potato, tomato, casaba, bean, coffee, maize, carrot and so on are cultivated. Main land use of the target area is agricultural purpose, on the other hand, there are some plots of Eucalyptus forest.

4) Fauna and Flora

The proposed dam site is located on upstream of a marshland where Rwabishanyi River flows. The marshland and surrounding hillside area have been exploited for farming purpose and its major flora is dominated by agricultural crops such as sweet potato, trees and bushes e.g. *Lantana Camara*. It is guessed that native flora in the marshland has been already lost due to the farming activities.

Some small wildlife is identified in the marshland. They are African common toad (*Amietophrynus Gutturalis*), African dwarf frog (*Hymenochirus Boettgeri*), boomslang (*Dispholidus Typus*), naked mole rats (Heterocephalus Glaber), African pygmy mouse (*Mus Minutoides*), Goliath Heron (*Ardea Goliath*), African lungfish (*Protopterus Annectens*) and so on. They are common species and categorised as the least concerned in terms of extinction according to the International Union for Conservation of Nature and Natural Resources, they are not registered as protected animals in the law of Rwanda.

There are some conservation areas, a wetland and forest reserves in Rwanda such as Akagera National Park, there are no such protected area in and around the proposed project site as illustrated in following figure[1].

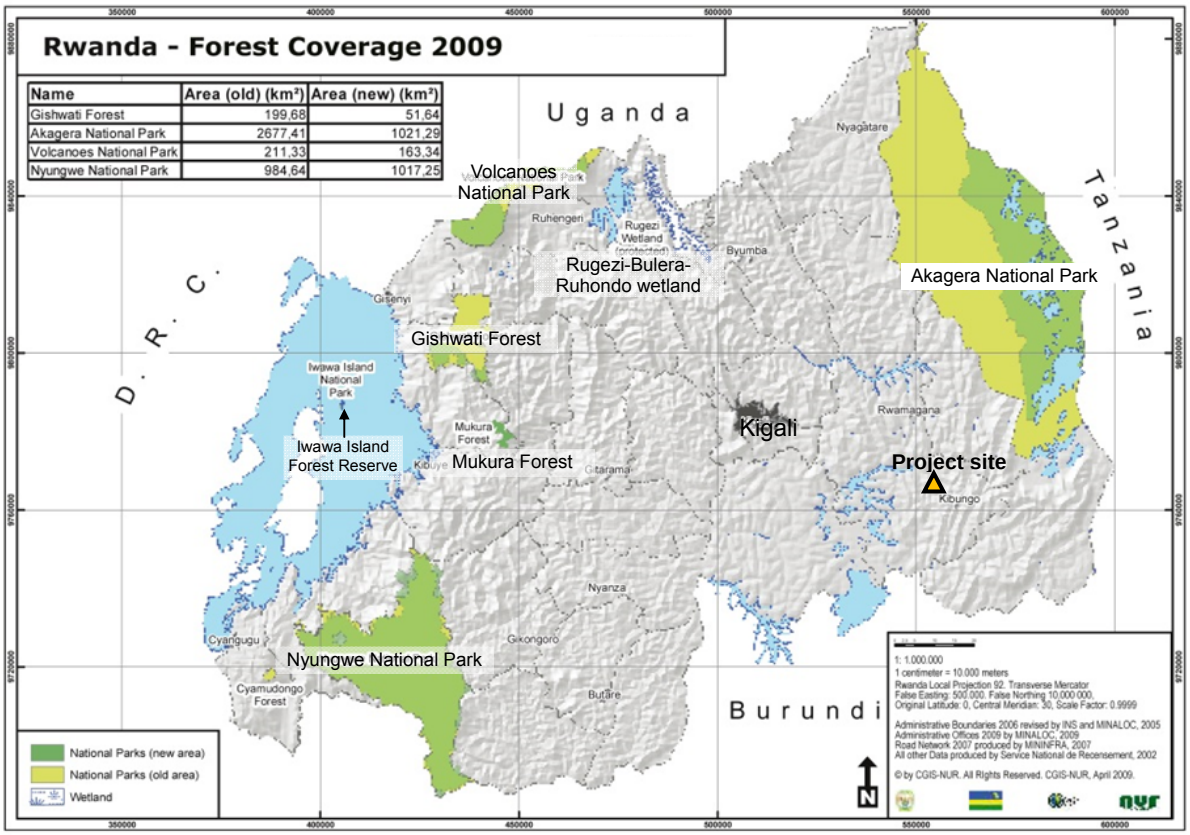


Figure 1.3.1.5 Distributions of Conservation Areas in Rwanda

[1]Source: Rwanda State of Environment and Outlook, 2009, REMA

5) Population and Number of Households of Related Cells

All of these villages are located on hilly area and the elevation of the residential area is higher than 1,400m. These villages are not located in the part of valley where the construction of the dam is planned, therefore, no house will be sunk under water of the planned dam. Following table shows population of concerned cell concerned. Average number of family members is 4.1 per household.

Table 1.3.1.1 Population of Concerned Cells

Sector	Cell	Village	No. of households	No. of population
Rurenge	MUHURIRE	NYAMATA	304	1,369
		GITOBE	168	784
		GISUNZU	169	696
		GASHINYA	77	353
		AGATONERIO	88	422
	Sub Total		806	3,624
Rurenge	Rugese	KAJEVUBA	188	547
		KAMWIRU	310	1,225
		KUMUNINI	92	412
		NYAMIGENDE	198	585
		RUGARIKA	185	813
		RWAKANUMA	176	714
		KIYANJA	443	1,726
	Sub Total		1,592	6,022
Rurenge	RUJAMBARA	AKARAMBARAYE	142	620
		MASHYOZA	196	803
		KABEZA	119	497
		MBONWA	139	610
		NYABANGA	119	517
		URUSAGARA	315	1,326
	Sub Total		1,030	4,373
Remera	NDEKWE	RUKORE	322	1,216
		GIKOMERO	163	661
		RUGANDO	285	1,154
		RWAMUTABAZI	335	1,425
		RUHUHA	237	979
		ICYAKABIRI	296	1,194
	Sub Total		1,638	6,629
Remera	BUGERA	GASEBEYA	130	580
		KABEZA	134	672
		MUNINI I	134	502
		NKENKE	87	377
		RWESERO	114	540
		KUMUKIZA	156	657
		RUBUMBA	187	748
		GATARE	178	770
		GISUNZU	157	743
		MUNINII	126	540
		KIYOVU	195	863

Sector	Cell	Village	No. of households	No. of population
	Sub Total		1,598	6,992
Total			6,664	27,640

Source: Remera Sector Office, 2012

1-3-1-3 Institutional and Legislative Framework of Environmental Consideration in Rwanda

1) Institutions concerned to environment conservation

(1) Ministry of Natural Resource (MINIRENA)

The Ministry of Natrual Resorce (MINIRENA) covers overall environmental administration in Rwanda and the ministry is in charged of promotion of the laws regarding environmental conservation at national level. It consists of three main units: the lands and mines unit, the environment and forestry unit, and the planning, monitoring and evaluation unit. The Rwanda Environmental Management Authority (REMA) and the Rwanda Natural Resources Authority (RNRA) are authorities under the MINIRENA.

(2) Rwanda Environment Management Agency (REMA)

REMA is directly responsible for environmental administration in Rwanda. Followings are main tasks of the REMA:

- To implement Government environmental policy and advise the Government on legislative and other measures for the management of the environment;
- To conduct comprehensive environmental audits and investigations, to prepare and publish biannual reports on the state of natural resources in Rwanda;
- To undertake research, investigations, surveys and such other relevant studies in the field of environment and disseminate the findings;
- To ensure monitoring and evaluation of development programs in order to control observance of proper safeguards;
- To set up of procedures and safeguards for the prevention of accidents;
- To render advice and technical support to entities engaged in natural resource management and environmental protection; and
- To publish and disseminate manuals, codes or guidelines relating to environmental management and prevention or abatement of environmental degradation.

(3) Rwanda Development Board (RDB)

Rwanda Development Board (RDB) is responsible for procedure of Environmental Impact Assement (EIA) in Rwanda. Environmental Compliance Department, which is one of departments of the RDB, is directly in charge of some procedures such as approval of EIA reports. RDB plays the following roles:

- To review Project Briefs so as to advise on Terms of Reference;
- To provide information or advice to developers and EIA experts when consulted during EIA process;
- To review EIA reports and provide comments to the developers;
- Organizing public hearings; and
- To issue certificate of approval.

2) Legislative framework

(1) EIA procedure in Rwanda

"Organic Law N° 04/2005 of 08/04/2005 Determining the Modalities of Protection, Conservation and

Promotion of Environment in Rwanda" stipulates basic principles for environmental conservation in Rwanda. Moreover, "General Guidelines and Procedures for Environmental Impact Assessment (2006)", which unifies the legal requirements with the practical conduct of EIA, meets a need in the pursuit for sustainable development in Rwanda, was prepared. It is needed to follow the guidline for EIA report preparation. "N° 004/2008 of 15/08/2008 Ministerial Order establishing the list of works, activities and projects that have to undertake an environment impact assessment" stipulates public works which need to undertake EIA. Those public works are as follows:

I. Infrastructure :

1. Construction and repair of international roads, national roads, district roads and repair of large bridges;
2. Construction of industries, factories and activities carried out in those industries;
3. Construction of hydro- dams and electrical lines;
4. Construction of public dams for water conservation, rain water harvesting for agricultural activities and artificial lakes;
5. Construction of oil pipelines and its products, gases and storage tanks;
6. Construction of terminal ports and airports, railways and car parks;
7. Construction of hotels and large public buildings which house more than a hundred people per day;
8. Water distribution activities and sanitation;
9. Construction of public Land fills;
10. Construction of slaughter houses;
11. Construction of hospitals;
12. Construction of Stadiums and large markets;
13. Initial installation of communication Infrastructures.

II. Agriculture and Animal Husbandry

1. Agricultural and breeding activities which use chemical fertilizers and pesticides in wetlands and large scale monoculture agricultural practices such as tea, coffee, flowers and pyrethrum, etc.
2. Works and Activities that use bio-technology to modify seeds and animals

EIA process in Rwanda consists of the four phases as illustrated in Figure 1.3.1.6. As a first step in the EIA process, a developer proposing to start a project shall notify RDB in writing by submission of a Project Brief. The purpose of a Project Brief is to provide information on the proposed activity. Screening refers to the process that RDB makes a decision as to whether an EIA is required or not, based on information in the Project Brief. Proposed projects are classified as either of impact level (IL) 1, 2 or 3[2].

Based on the Broject Brief submited, RDB issues the Terms of Reference (TOR) that would be used for carrying out the environmental impact study. The Project proponent will entrust EIA study and EIA report preparation to one of registrated EIA consultants on the REMA. An EIA report shall include environmental evaluation, results of consultation meeting and annex. Withinn 45 days after an EIA report submission to RDB, the EIA report will be reviewed. If it is approved, Environmental Impact Assessment Certificate of Authorization (EIACA) will be issued within 30 days after approval.

[2] IL-1 Project: any projects which do not need EIA, IL-2 Project: any projects which do not need EIA and need environmental consideration and IL-3 Project: Any projects which need full EIA implementation

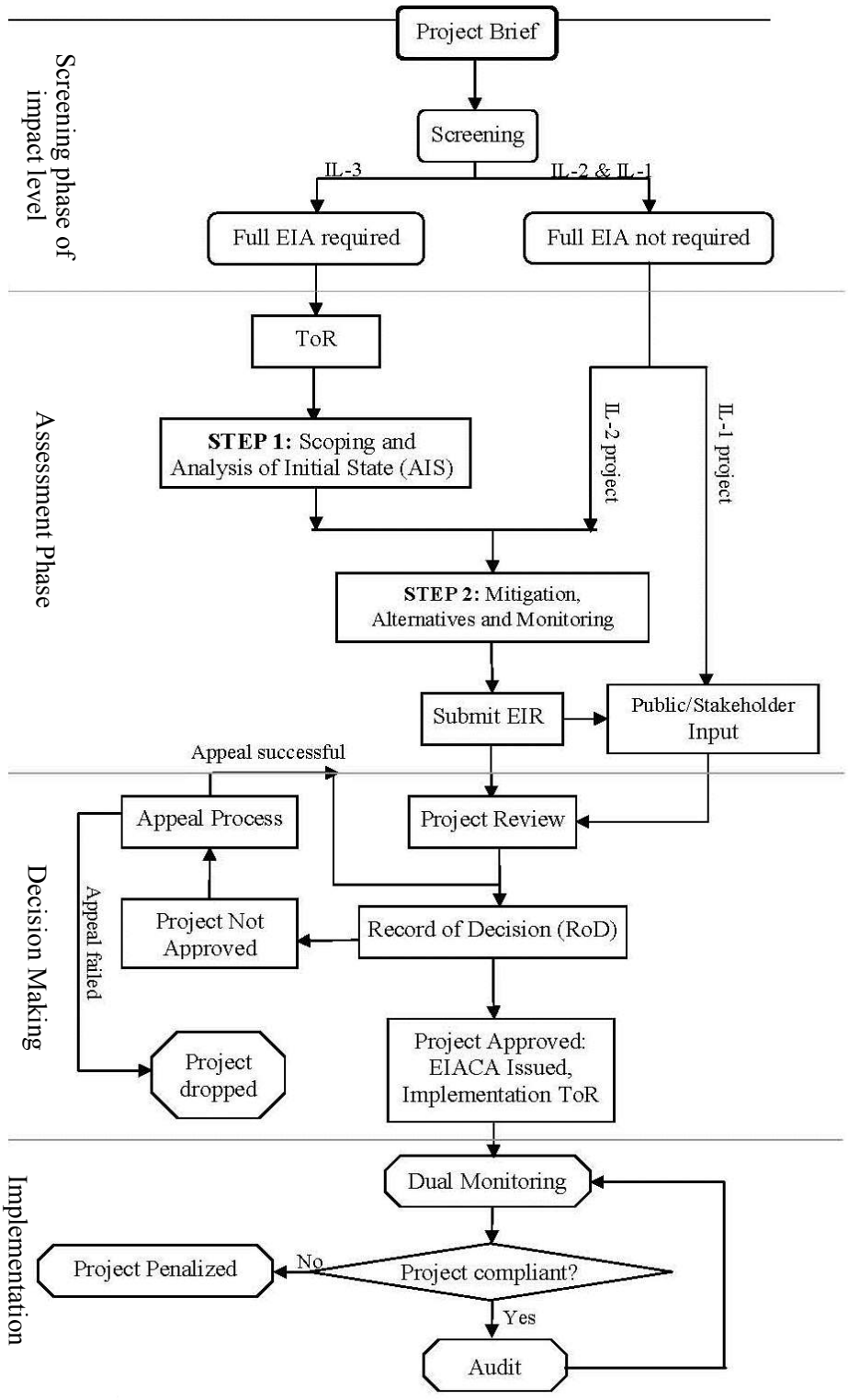


Figure 1.3.1.6 EIA Implementation Flow

The Project requires EIA report preparation according to the Guidelines mentioned above. MINAGRI prepared an EIA report based on a TOR, which was issued by RDB in November 2013. In February 2014, the EIA certificate for the project was issued by the RDB. The TOR and EIA report are attached in Appendix 6.1 and 6.2, respectively.

(2) Environmental standards in Rwanda

The ambient air quality tolerance limits is stipulated in the "Ministerial Order N°003/16.01 of

15/07/2010 Preventing Activities that Pollute the Atmosphere". The standard values do not deviate very much from the international standards such as International Finance Corporation (IFC) as illustrated in the following table:

Table 1.3.1.2 Ambient Air Quality Tolerance Limits

	Pollutant	Time weighted Average	Industrial area	Residential, Rural & Other area	Controlled areas	International Guideline*
1	Sulphur oxides (SOx);	Annual Average	80 µg/m^3	60µg/m^3	15 µg/m^3	
		24 hours	125 µg/m^3	80 µg/m^3	30 µg/m^3	20µg/m^3(SO_2)
		Annual Average		0.019 ppm 50µg/ m^3		
		24 Hours		0.048ppm 125µg/m^3		
		Instant Peak		500µg/m^3		
		Instant Peak (10 min)		0.191 ppm		
2	Oxides of Nitrogen (NOx);	Annual Average	80µg/ m^3	60µg/m^3	15µg/ m^3	40µg/m^3
		24 hours	150µg/ m^3	80µg/m^3	30µg/ m^3	
		8 hours				
		Annual Average		0.2 ppm		
		Month Average		0.3 ppm		
		24 hours		0.4 ppm		
		1 hour		0.8 ppm		200µg/m^3
		Instant Peak		1.4 ppm		
3	Nitrogen Dioxide	Annual Average	150µg/m^3	0.05 ppm		
		Month Average		0.08 ppm		
		24 hours	100µg/m^3	0.1 ppm		
		1 hour		0.2 ppm		
		Instant Peak		0.5ppm		
4	Suspended particulate matter (SPM)	Annual Average	360µg/m^3	140µg/m^3	70µg/m^3	
		24 hours	500µg/m^3	200µg/m^3	100µg/m^3	
		Annual Average		100µg/m^3		
		24 hours		180µg/m^3		
5	Respirable particulate matter (<10m) (RPM)	Annual Average*	70µg/m^3	50µg/m^3	50µg/m^3	
		24 hours	150µg/N m^3	100µg/N m^3	75µg/N m^3	
6	PM2.5	Annual Average	35µg/m^3			10µg/m^3
		24 hours	75µg m^3			25µg/m^3
7	Lead (Pb)	Annual Average	1.0µg/N m^3	0.75µg/N m^3	0.50µg/m^3	
		24 hours	1.5µg/m^3	1.00µg/m^3	0.75µg/m^3	
		Month average		2.55µg/Nm^3		
8	Carbon monoxide (CO)/ carbon dioxide (CO_2)	8 hours	5.0 mg/m^3	2.0 mg/m^3	1.0 mg/m^3	
		1 hour	10.0 mg/m^3	4.0 mg/m^3		
		24 hours				
9	Non-methane hydrocarbons					
		Instant peak	700ppb			
10	Total VOC	6 mg/m^3				
11	Ozone	1 hour	200µg/m^3	0.12 ppm		
		8 hour (instant Peak)	120µg/m^3	1.25 ppm		100µg/m^3

Source: Annex to the Ministerial Order N°003/16.01 of 15/07/2010 Preventing Activities that Pollute the Atmosphere

*EHS (Environmental, Health and Safety) General Guideline (April 2007, IFC)/ World Health Organization (WHO) Guideline

The waste water quality standard from houses and offices in Rwanda is established based on the WHO Guidelines for Wastewater Reuse (2006) and there is no big difference between the standard values and IFC's ones except BOD and COD. The standard is as shown below:

Table 1.3.1.3 Tolerance limits of Discharged Domestic Wastewater

Parameter	Limits in Rwanda	International guideline*
TDS	≤1500mg/l	-
TSS	≤50mg/l	≤50mg/l
pH	5.0-9.0	6.0-9.0
Total Nitrogen	≤30mg/l	≤10mg/l
Nitrite	≤2mg/l	-
Ammonium	≤5mg/l	-
Total phosphorus	≤5mg/l	≤2mg/l
Temperature variation of treated water compare to ambient temperature of water °C	≤3	
BOD	≤50mg/l	≤30mg/l
COD	≤400mg/l	≤125mg/l
Coli forms number/100ml	≤400	≤400
Oil and grease m	≤10mg/l	≤10mg/l
Chlorine	≤2mg/l	-
Sulfate	≤500mg/l	-
Color TCU	≤50	-
Turbidity NTU	≤30	-

Source: Directives on Minimum Requirements for Liquid Wastes Disposal and Treatment, Rwanda Utilities Regulatory Agency, 2009

*EHS General Guideline (April 2007, IFC)/ WHO Guideline

There is no specific irrigation water quality standard in Rwanda, therefore, the FAO water quality guideline is applied. The standard is as shown below:

Table 1.3.1.4 Guidelines for Interpretations of Water Quality for Irrigation (FAO)

Potential Irrigation Problem				Units	Degree of Restriction on Use		
					None	Slight to Moderate	Severe
Salinity*(affects crop water availability)*							
	EC_w			dS/m	< 0.7	0.7 – 3.0	> 3.0
	(or)						
	TDS			mg/l	< 450	450 – 2000	> 2000
Infiltration*(affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)*							
SAR	= 0 – 3	and EC_w	=		> 0.7	0.7 – 0.2	< 0.2
	= 3 – 6		=		> 1.2	1.2 – 0.3	< 0.3
	= 6 – 12		=		> 1.9	1.9 – 0.5	< 0.5
	= 12 – 20		=		> 2.9	2.9 – 1.3	< 1.3
	= 20 – 40		=		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity *(affects sensitive crops)*							
	Sodium (Na)						
	surface irrigation			SAR	< 3	3 – 9	> 9
	sprinkler irrigation			me/l	< 3	> 3	
	Chloride (Cl)						
	surface irrigation			me/l	< 4	4 – 10	> 10
	sprinkler irrigation			me/l	< 3	> 3	
	Boron (B)			mg/l	< 0.7	0.7 – 3.0	> 3.0

	Trace Elements (see Table 21)				
Miscellaneous Effects *(affects susceptible crops)*					
	Nitrogen (NO_3 - N)	mg/l	< 5	5 – 30	> 30
	Bicarbonate (HCO_3)				
	(overhead sprinkling only)	me/l	< 1.5	1.5 – 8.5	> 8.5
	pH		Normal Range 6.5 – 8.4		

Wildlife and plants to be protected in Rwanda are listed up in the Ministerial Order N°007/2008 of 15/08/2008. The list is as follows:

Table 1.3.1.5 Protected Wildlife and Plants

Category	Species
Mammal	Gorilla (*Gorilla gorilla beringei*), Chimpanzee (*Pan troglodydes*), Black rhinoceros (*Diceros bicornis*), Elephant (*Loxodonta Africana*), Roan antelope (*Hippotagus equinus*), Sitatunga (*Tragelaphus spekei*), Lions (*Panthera Leo*), Leopard (*Panthera pardus*), Klipspringer (*Oreotragus oretragus*), Buffalo (*Syncerus caffer*), Cheetah (*Acinonyx jubatus*), Zool mongoose (*Felis aurata (Temminck)*), Cephalophus (*Cephalophus nigrifrons*), Zoolserval (*Felis aurata (Temminck)*), Wild dog (*Lycaon pictus*), Bushbuck (*Tragelaphus (Pallas)*), Hippopotamus (*Hippopotamus*), Burchell's zebra (*Equus burcheli (Gray)*)
Birds	Black-headed Heron (*Ardea melanocephala*), Cattle Egret (*Bubulcus ibis*), Grauer's Swamp Warbler (*Bradypterus graueri*), Owls (*Strigidae*), All Lemoroids (*Lemuroide*), Grey Crowned-Crane (*Balearica regulorum*), Swallow (*Hirundinidae*), Arrow-marked Babbler (*Turdoides jardineii*), Cape Robin- Chat (*Cossypha caffra*), All pangolins (*Manis SP*), Vulture (*Aegypiidae*), Bee-eater (*Meropidae*), Scimitar bills (*Phoniculudae*), Hamer kop (*Scopus umbretta*) and Sunbirds(*Nectarinidae*)
Reptile	Tortoises (all species), Python, Crocodile, Viper
Plants	*Ficusthonningii, Prunus Africana, Pentadesma reindersii, Myrianthus holstii, Thonningia sanguine, Hypoestes trifolia, Aloe sp., Syzygium guineense, Erythrina abyssinica, Fagara chalybea, Kagelia africana, Orchidaceae, Eulophia streptopetala, Eulophia horsafalli, Diaphananthe bilosa, Disa emili, Disperis kilimanjarica, Euggelingia ligulifolia, Polystachyia hastate, Tridactyle anthomaniaca, Entandrophragma sp, Podocarpus usambarensis, Albizziasasa, Piptadenia africana, Podocarp usambarensis, Albizzia sasa, Piptadenia Africana, Podocarpus milinjianus, Carapa grandiflora, Strombosia scheffleri*

1-3-1-4 Examination of Alternatives

The head work construction plan is examined as one of alternatives of the dam construction plan. The main structure is a weir, and it is made of wet masonry. The structure has 2m height and about 30m length with aprons and the inclined retaining wall manufactured by wet masonry. The head works construction is not difficult in terms of technical matter and its construction cost is cheaper than that of the dam construction. However, the facility does not have the water storage function but only diverts the river flow for irrigation use, so that the flood water cannot be utilized and the beneficiary area would be very limited. In other words, cost-effectiveness of this alternative is relatively low. Therefore, the head work construction plan cannot be proposed as an irrigation scheme in the area. Following table shows the examination of alternatives including zero-option.

Table 1.3.1.6 Examination of Alternative Structures

Environmental items	Option 0 (no project)	Option 1 Headwork construction	Option 2 Dam construction
Irrigation command area	-	145ha	300ha
Available water volume	None	500,000m^3	1,100,000m^3
Possibility of fish aquaculture	None	None	Possible
Environmental impact	None	Proposed submerged area is farmland, which will not cause big environmental issues	Ditto
Submerged area	-	0.3ha	21.73ha

Resettlement and Land Expropriation	-	No resettlement and very limited land Expropriation	No resettlement while compensation and supports for the affected persons is needed
Project cost	Zero	8 million US$	13 million US$
Selection	-	-	Recommended

1-3-1-5 Scoping and TOR for Environmental Examination

Examination of degree of environmental impacts by those constructions, so called as "Scoping" is done, and some environmental parameters, on which negative impacts are likely to be caused, are to be identified. For those parameters, terms of reference (TOR) to identify study method of environmental impacts are prepared. Scoping of environmental impacts and TOR are presented as follows:

Table 1.3.1.7 Scoping

Environmental Parameters	Evaluation		Reasons
	Construction phase	Operational phase	
1. Air Pollution	B^-	D	Due to the construction works, air quality deterioration such as dust generation and gas emission from construction vehicles is expected. However, after the completion of works, no air pollution is anticipated.
2. Water Pollution	B^-	B^-	Murky water from the construction site is expected. In the operational phase, there is possibility that agrochemical will be discharged more than before, which will result in water quality deterioration.
3. Waste	B^-	D	Construction waste is generated during the construction phase. But, the period is limited to the construction phase.
4. Soil Contamination	B^-	D	Oil leakage from construction vehicles can be caused, however, it is tentative and the degree is not significant.
5. Noise and Vibration	B^-	D	Noise due to construction works and transportation of construction vehicles is anticipated. However, there are few houses, no hospital, no school in and around the construction sites, and the area to be affected is very limited.
6. Ground Subsidence	D	D	Ground subsidence is not expected both during and after works.
7. Offensive Odor	D	D	Offensive odor is not expected both during and after works.
8. Bottom sediment	D	D	Bottom sediment is not expected both during and after works.
9. Protected area/Eco-system	D	B^+	There is no protected area or conservation reserve in and around the Project site. Due to filling of the reservoir, bio-diversification can be promoted.
10. Ground water	D	D	The works does not give any impacts on ground water.
11. Hydrological Situation	B^-	B^+/B^-	Due to dam construction works, hydrological situations will be changed. It is needed to keep minimum discharge to the downstream during both construction and operation

Environmental Parameters	Evaluation		Reasons
	Construction phase	Operational phase	
			phase. On the other hand, irrigation farming in the command can be promoted.
12. Topography and Geographical features/Soil erosion	B^-	D	Soil excavation can cause soil erosion, however, the scale is not very significant.
13. Involuntary Resettlement	D	D	No households will be requested to resettle their houses.
14. Land Expropriation	B^-	D	Farmland that is located on the proposed dam construction will be submerged. Moreover, parts of other farmland in hillside will be expropriated for the open irrigation canal and other facility construction. The area of paddy field in the downstream will be reduced due to the plot construction.
15. Cultural heritage	D	D	There is no cultural heritage in and around sites.
16. Landscape	D	D	Due to dam construction work, landscape can be changed, however, there is no special or aesthetic zone in and around the construction site. Therefore, no adverse effect on landscape is anticipated.
17. Indigenous and ethnic people	D	D	There is no ethnic minority in and around construction sites.
18. Livelihood/ Local economy	B^+/B^-	B^+	Farmers who cultivate in the Project site will lose parts of their farmlands. On the other hand, the Project can provide opportunity for such persons to work as labors. After the Project completion, the beneficiaries will access to irrigation water and technical supports.
19. Existing social infrastructures and services	B^-	D	During construction works, traffic jam can be caused by the increase of traffic volume. However, the period is limited to construction phase, and the magnitude is negligible.
20. Misdistribution of benefit and damage	D	D	Those who cultivate in the Project site will be expropriated their farmlands, however, they will be provided with chance to work as labors of the Project and to take technical training. Therefore, severe misdistribution of benefit and damage is not expected.
21. Social institutions	D	B^+	Damages to existing social institutions are not caused by the Project. An Water Users Organization will be established and trained by the Project. Positive impact is expected in terms of social institutions.
22. Water Usage or Water Rights and Rights of Common	D	B^+/B^-	At present, the people can use spring water for irrigation free of charge, however, they will have to pay water charge and shoulder maintenance cost while they can access to irrigation water constantly.
23. Gender	D	D	No negative impact in terms of gender is expected.
24. Children rights	D	D	Damage to children rights is not anticipated.

Environmental Parameters	Evaluation		Reasons
	Construction phase	Operational phase	
25. Infectious diseases such as HIV/AIDS and water borne disease	D	B^-	The possibility of infectious disease such as HIV is low, since construction labors will be recruited among the people in the area. However, water borne disease can be brought due to dam and irrigation canal construction.
26. Accidents	B^-	D	During construction, there is a possibility that number of accident will be increased due to increase of traffic vehicles for construction works.
27. Global Warming	D	D	No global warming by the works is anticipated.

A+/-: Significant positive/negative impact is expected.
B+/-: Positive/negative impact is expected to some extent.
C: Extent of positive/negative impact is unknown. (A further examination is needed, and the impact could be clarified as the study progresses)
D: No impact is expected.

For those parameters which are evaluated as negative or unknown, namely, A^-, B^- and C mentioned above, study methods are proposed as shown below:

Table 1.3.1.8 Terms of Reference

Environmental Parameters	Study Contents	Study Method
Air pollution	• Information collection of other similar cases	• Data collection in other similar projects • Examination of number of construction vehicle to be used for the Project
Water pollution	• Information collection of other similar cases	• Examination of drainage from construction sites
Waste	• Waste disposal method	• Data collection in other similar projects
Noise/Vibration	• Current conditions of the Project sites • Confirmation of the Project components	• Current conditions in and around the Project sites • Period, location components of the construction works
Soil erosion	• Current conditions of the Project sites • Confirmation of the Project components	• Confirmation of situations in other similar projects • Hearing from organizations concerned
Soil Contamination/ salinization	• Oil leakage from construction vehicles	• Confirmation of situations in other similar projects
Water Usage or Water Rights and Rights of Common	• Governmental policy • Current water source for life, irrigation and so on in the area	• Confirmation of governmental policy • Confirmation of current water use conditions
Hydrological conditions	• Impacts on the field in the downstream of the Project sites	• Confirmation of the discharge to the downstream
Water borne diseases	• Examination of outbreak of water borne disease	• Information collection in other project sites
Land expropriation	• Current conditions in the area to be expropriated	• Confirmation of land recovery area • Implementation of census survey and socio-economic survey targeting the Project affected persons • Cost estimation of compensation for land expropriation

Environmental Parameters	Study Contents	Study Method
Existing social infrastructures and services	• Traffic jam due to the Project	• Confirmation of number of project vehicles and routes
Accidents	• Possibility of accident	• Confirmation of situations in other similar plans
Stakeholder meeting	• Organization of stakeholder meeting	• Organization of stakeholder meeting

Following the TOR mentioned above, environmental examination based on the existing data and census survey was implemented.

1-3-1-6 Results of Environmental Examination

The results of the environmental examination based on the TOR are as follow:

Air pollution:

A large amount of soil is likely to be displaced by heavy machines for site clearing, excavation and site leveling. As a result, dust will be generated from the works, however, it will not be significant issue, since residential area is not located in and around the dam construction site and the period is limited to only the construction phase.

Noise/Vibration:

Probably, foundation excavation, site leveling, increase of traffic will cause noise and vibration. However, the construction area is located on around farmlands and the period will be only construction phase.

Water pollution:

During the construction term, excavation works are inevitable, embankment surfaces and mound surfaces of spoil bank can cause murky water. This impact is estimated to be low in terms of significance, since treatment pond is installed. The impact duration is expected to be only the construction phase. On the other hand, water pollution due to increase of consumption of chemical and fertilizer is anticipated in the operation phase.

Soil contamination:

Oil leakage from construction vehicles, however, it will be negligible. Such impact can be minimized by proper and regular management of construction vehicles.

Waste:

Garbage from construction lodging houses and construction works will be generated, the impact will be avoidable, as far as waste is disposed properly. Excavated soil can be reused for other construction works. As a whole, severe impact will not be expected.

Hydrological conditions:

During the virgin storage phase, the greater part of the river flow shall be caught and stored in the dam to make the dam full, which will reduce the river flow to the downstream. Due to this, the downstream water users might experience temporary shortfall (until the reservoir fills up) of available irrigation water. The Project could influence on the hydrological conditions in the downstream marshland areas extending from Rwabishanyi, Murugando to Rwakanuma (refer to the following topography map). Therefore, even during period for filling of the reservoir, a certain amount of water shall be discharged from the dam site to the downstream to avoid spoiling the paddy cultivation.

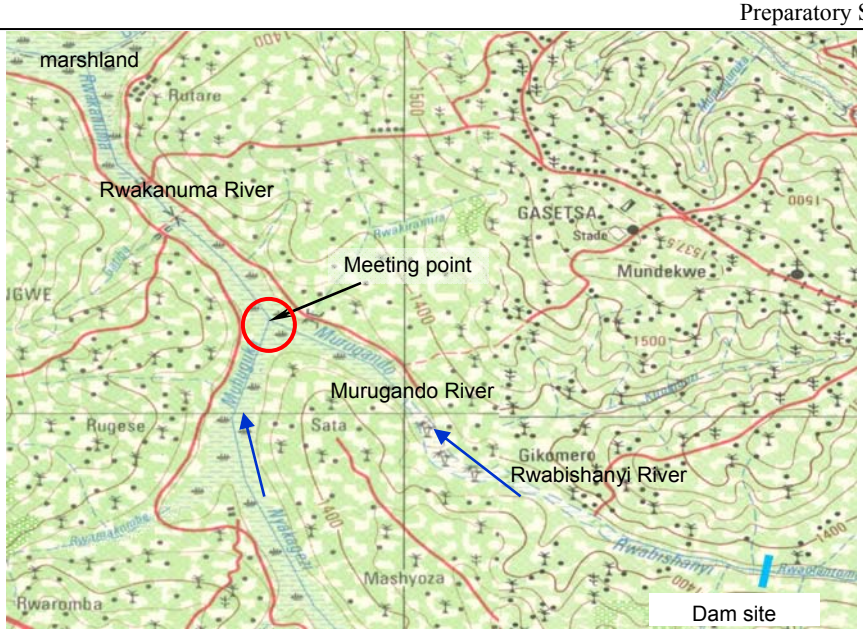


Figure 1.3.1.7 Meeting point of Murugando River and Rwakanuma River

Hydrological conditions at the dam site and in the downstream valley extending from Rwabishanyi to Murugando depend on the spring water and groundwater in dry season and on surface water in rainy season, respectively. According to the flow rate measurement of the river, shown on the following table, done in 2012 (JICA), the flow rate just before the meeting point is about three times larger than the one at the dam site in dry season, and about two times in rainy season. Considering the catchment area of the dam site being 8.8 km^2 and the one between the dam site and the meeting point being 9.2 km^2, the downstream valley can catches more water from spring than from the dam site and also receives the surface water in rainy season. Therefore, it can be thought that the impact caused by storage of water in the reservoir is not very crucial.

Table 1.3.1.9 Flow Rate at Murugando River and Dam Site

Date	Flow rate (little/sec)		
	(1) At the dam site	(2) Just before meeting point	(2)/(1)
2/3/2012	23	69.8	3.0
1/4/2012	23	71.3	3.1
8/4/2012	45	73.5	1.6
19/4/2012	26	68.3	2.6
25/4/2012	103	236	2.3
1/5/2012	104	218	2.1
20/5/2012	88	223	2.5

Source: JICA, 2012

In terms of the flow from Murugando to Rwakanuma, the influence of storing the river water at the dam site seems to be scarce, because the catchment area of 8.8 km^2 at the dam site is very small compared with the catchment area of about 61.4 km^2 at the meeting point, moreover, this marshland has its own catchment area of about 6 km^2 and three branch valleys with springs.

Amount of irrigation water supplied in a drought year with 1/5 probability occurrence shall reach 203,000 m^3 according to the irrigation plan for paddy field spreading over downstream of the dam, which corresponds to 18 % of the estimated total annual flow, namely, 1,111,000 m^3, will be discharged once to the river before being led into the paddy fields, and most of the irrigated water is expected to flow into the river again as the return-flow from the paddy fields. Moreover, river maintenance water, which is 48,000 m^3, shall be discharged from the reservoir to preserve the river conditions. Here, it would be said that the hydrological conditions might not be changed significantly,

the river conditions would be preserved and irrigation for paddy field in the downstream would be secured.

Water usage or water right:

At this moment, the farmers in the command area can utilize water free of charge for irrigation, however, after the Project completion, the beneficiaries have obligation to pay water charge. The amount of charge is still under discussion between MINAGRI and MINIRENA and it is needed to pay attention to the situations.

Soil erosion:

Borrow areas are planned to be set on the gentle slopes at both the right and the left bank of the reservoir and they will be submerged in the reservoir, Therefore, negative impacts from the borrow areas are anticipated within only construction stage.

Land expropriation:

Due to the construction of dam and irrigation canals, a part of the cultivable lands will be submerged under the water or replaced with the irrigation canal, which will influence agricultural activities /productions in the area. The areas to be submerged and replaced by the canals and other structures are 21.73ha and 13.98ha, respectively. It means that in total, 35.71ha will be affected by the Project. Regarding the submerged cultivable lands, there are two types; one is the titled lands on hill sides (6.56ha) and the other is the marshland owned by the Government (15.17ha). The former shall be compensated according to the law. The latter is not entitled for compensation following the law in Rwanda. Due to plot construction in the paddy field in the downstream, around 1.6 ha of the paddy area will be affected while it can be useful for even water distribution.

Impact on livelihood/local economy:

Due to the Project, the beneficiaries can enjoy stable irrigation water for agriculture, consequently, farming productivity will be increased, and more profitable and marketable crops will be cultivated in the area. In addition, some income generation activities such as fish aquaculture as soft components of the Project are proposed. During the construction phase, job opportunities as labor will be increased. On the other hand, farmers who cultivate the farmlands to be submerged will lose parts of their farmlands.

Impact on the existing infrastructure:

During the construction works, traffic jam can be caused by the increase of traffic volume. However, the number of construction vehicles is around 10 per day and the route to be used is neither important nor busy road. Therefore, it can be judged that the negative impact on the infrastructure is very significant. However, it is needed to examine efficient schedule of construction vehicle operation.

Infectious diseases:

The possibility of HIV infection will be limited considering that the local people will be mainly hired as labors of the construction works. On the other hand, there could be an increase in the incidences of malaria because the water reservoir would serve as a breeding ground for mosquitoes.

Accident:

Fence construction surrounding the site will be difficult, since the people will come to fetch water from the spring which is located on near the proposed reservoir. There must be assigned somebody who will not to allow the residents to enter the construction site. Moreover, there is a possibility of traffic accident due to the increase of traffic volumes.

1-3-1-7 Evaluation Result

Based on the results mentioned above, evaluation regarding environmental impacts is shown.

Table 1.3.1.10 Environmental Evaluation

Environmental parameters	Evaluation at Scoping		Evaluation based on IEE		Reasons
	Construction phase	Operation phase	Construction phase	Operation phase	
1. Air Pollution	B^-	D	B^-	D	Due to the construction works, air quality deterioration such as dust generation and gas emission from construction vehicles is expected, however it will be temporal. Moreover, there are few houses in and around the construction site. After the completion of works, no air pollution is anticipated.
2. Water Pollution	B^-	B^-	B^-	B^-	Murky water from the construction site is expected and it can be mitigated by the sedimentation pond and plant system. In the operational phase, there is a possibility that agrochemical will be discharged more than before.
3. Waste	B^-	D	B^-	D	Construction waste is generated and it shall be gathered, transported and processed adequately and promptly during construction phase. But, the period is limited to the construction phase.
4. Soil Contamination/ salinization	B^-	D	B^-	D	Oil leakage from construction vehicles can be caused, however, it is tentative and not very severe.
5. Noise and Vibration	B^-	D	B^-	D	Noise due to construction works and transportation of construction vehicles is anticipated. However, there are few houses, no hospital, no school in and around the construction site, and the impact is very limited.
6. Ground Subsidence	D	D	N/A	N/A	No negative impact is expected.
7. Offensive Odor	D	D	N/A	N/A	No negative impact is expected.
8. Bottom sediment	D	D	N/A	N/A	No negative impact is expected.
9. Protected area	D	B^+	N/A	N/A	There is no protected area or conservation reserve in and around the Project site. Due to dam construction, bio-diversification can be promoted.

Environmental parameters	Evaluation at Scoping		Evaluation based on IEE		Reasons
	Construction phase	Operation phase	Construction phase	Operation phase	
10. Ground water	D	D	N/A	N/A	No negative impact is expected.
11. Hydrological Situation	B^-	B^+/B^-	B^-	B^+/B^-	Due to the dam construction, hydrological situations will be changed, however, it will not be significant. Paddy cultivation will be possible even during the period for filling the reservoir while it cannot be done during the plot construction. In the operation phase, irrigation farming in the command can be promoted.
12. Topography and Geographical features/ Soil erosion	B^-	D	B^-	D	Soil will be excavated on the gentle slope. Moreover, borrow pit will be submerged after the construction. It means impact by the borrow pit will be limited only in the construction stage.
13. Involuntary Resettlement	D	D	N/A	N/A	No negative impact is expected.
14. Land Expropriation	B^-	D	B^-	D	21.73ha farmland is to be submerged for the dam construction work. Parts of farmland in the hillside, 13.98 ha, will be expropriated for the main irrigation canal construction. Area of paddy field in the downstream will be reduced by around 1.6ha due to the plot construction.
15. Cultural heritage	D	D	N/A	N/A	No negative impact is expected.
16. Landscape	D	D	N/A	N/A	No negative impact is expected.
17. The indigenous and ethnic people	D	D	N/A	N/A	No negative impact is expected.
18. Livelihood/local economy	B^+/B^-	B^+/B^-	B^+/B^-	B^+	Farmers who cultivate in the Project site will lose parts of their farmlands. On the other hand, the Project can provide opportunity for the persons to work as labors. After the Project completion, the beneficiaries will access to irrigation water.
19. Existing social infrastructures and services	B^-	D	B^-	D	During construction works, traffic jam can be caused by the increase of traffic volume. However, the period is limited to construction phase, and the magnitude is negligible.
20. Misdistribution of benefit and damage	D	D	N/A	N/A	No negative impact is expected.

Environmental parameters	Evaluation at Scoping		Evaluation based on IEE		Reasons
	Construction phase	Operation phase	Construction phase	Operation phase	
21. Social institutions	D	B^+	N/A	N/A	No negative impact is expected.
22. Water Usage or Water Rights and Rights of Common	D	B^+/B^-	D	B^+/B^-	At present, the people can use spring water for irrigation free of charge, however, they will have to pay water charge and shoulder maintenance cost while they can access to irrigation water constantly in the operation phase.
23. Gender	D	D	N/A	N/A	No negative impact is expected.
24. Children rights	D	D	N/A	N/A	No negative impact is expected.
25. Hazards (Risk), Infectious diseases such as HIV/AIDS	D	D	N/A	N/A	No negative impact is expected.
26. Accidents	B^-	D	B^-	D	During construction, there is a possibility that number of accident will be increased due to increase of traffic increase for construction works.
27. Global Warming	D	D	N/A	N/A	No negative impact is expected.

Source: JICA Survey Team

1-3-1-8 Mitigation Measures

Some adverse effects by the Project are anticipated, however, the period of air pollution, water pollution (mud water), waste and noise is limited to construction phase only, those impacts will be recoverable, considering scale of the impacts. At the same time, proper and regular management of construction vehicles, drained water treatment and so on shall be implemented to minimize the impacts, and such mitigation measures are to be covered by construction contractors mainly.

Regarding hydrological change, countermeasures depending on the phase are shall be done. During the filling of a reservoir, the first priority of water use shall be given to the paddy fields in the downstream at the same time, the farmers of paddy field are requested to conduct strict management of irrigation water. However, they cannot cultivate during the plot construction. During operation period, as mentioned before, it is necessary to keep certain discharge into the downstream, namely, 20 % of the base flow in dry season, 4ℓ/sec from the reservoir to preserve the river. A WUO will be established and it will play an important role for sustainable water management in collaboration with MINAGRI.

During operation phase, infection of malaria and water pollution due to increase of chemical and fertilizer can be anticipated after the construction completion. Awareness of malaria prevention, distribution of mosquito net by Ministry of Health will be needed. Technical training through the proposed soft component to minimize chemical and fertilizer also is necessary. Concerning water charge, since it has yet to be fixed, continuous discussion between MINAGRI and MINIRENA will be done and it is needed to pay attention to the result.

MINAGRI is responsible for the implementation of those mitigation measures and it is requested to collaborate with other organizations such as Ngoma District, MINIRENA and Ministry of Health in both construction and operation phases.

Table 1.3.1.11 Mitigation Measures

Environmental Parameters	Proposed Mitigation Measures		Implementing organization	Monitoring /responsible organization
	Construction phase	Operation phase		
Air Pollution	• Regular check and full maintenance of construction vehicles • Water spray in and around entrances of construction sites	None	Construction contractor	MINAGRI
Water Pollution	• Waste water treatment before discharge into rivers	• Proper application of chemical and fertilizer	Construction contractor	MINAGRI
Waste	• Classification waste dumping, recycle, reduction of waste • Entrustment of Proper disposal of waste which cannot be reused to dismantling operator	None	Construction contractor	MINAGRI
Topography and Geographical features/ Soil erosion	• To submerge burrow pits under the dam	None	Construction contractor	MINAGRI
Hydrological conditions	• To give priority on paddy field in the downstream	• To keep minimum discharge, 20% of base flow in dry season	Construction contractor, WUO, MINAGRI	MINAGRI
Soil Contamination/ salinization	• Proper management of construction vehicles	None	Construction contractor	MINAGRI
Noise and Vibration	• Not to work during nighttime and to use detour in the residential area	None	Construction contractor	MINAGRI
Land expropriation	• Pipelined canal construction to minimize damage to surrounding houses and forests • Compensation for the submerged area of the private lands • Employment of affected persons as labors with high priority	Agricultural technical training for both beneficiaries and affected persons	District and Resettlement/ Compensation committee	MINAGRI
Soil erosion	Submersion of burrow pit after the construction	None	Construction contractor	MINAGRI
Social infrastructure	Proper management of construction vehicle operation to minimize centralization	None	Construction contractor	MINAGRI
Water Usage or Water Rights and Rights of Common Water usufruct	None	Follow-up of the decision of amount of water charge	MINIRENA	MINAGRI /MINIRENA
Infectious diseases	None	• Mosquito net distribution • Awareness of malaria prevention and sanitation	Ministry of Health	Ministry of Health and MINAGRI
Accidents	• Proper management of construction vehicle operation to minimize centralization • Instruction on compliance with prescribed routes, speed, to	None	Construction contractor	MINAGRI

Environmental Parameters	Proposed Mitigation Measures		Implementing organization	Monitoring /responsible organization
	Construction phase	Operation phase		
	drivers of construction vehicles • Guidance to the people about off-limit area due to the construction works • Instruction to the residents about off-limit area for construction • Working environment			

Source: JICA Survey Team

1-3-1-9 Monitoring Plan

It is effective to prepare a monitoring plan and a monitoring form by phase for sustainable environmental management and project implementation. The responsible organization for monitoring is MINAGRI. The proposed monitoring plans for construction and operation phase are as follows:

Table 1.3.1.12 Recommended Monitoring Plan (Construction Phase)

Environmental Parameter	Monitoring Item	Survey point	Frequency	Implementer	Responsible Organization
Air pollution	Degree of dust by observation	Construction site	Once per week	Construction contractor	MINAGRI
Water pollution	Water turbidity check by measurement equipment	Drainage outlet	Once per week	Construction contractor	MINAGRI
Soil contamination	Management of vehicle to prevent oil leakage	Construction site	Once per week	Construction contractor	MINAGRI
Noise and vibration	Number of complaint from the neighboring residents	Construction site	Once per week	Construction contractor	MINAGRI
Waste	Condition of waste management	Construction site	Once per week	Construction contractor	MINAGRI
Soil erosion	Soil erosion	Around construction site	Once per week	Construction contractor	MINAGRI
Social infrastructure	Road conditions	Around construction site	Once per week	Construction contractor	MINAGRI
Accident	• Working environment • Accident	-	Once per week	Construction contractor	MINAGRI
Land expropriation	Compensation condition of project affected persons	-	Monthly	District (Resettlement and compensation committee)	MINAGRI

Table 1.3.1.13 Recommended Monitoring Plan (Operation Phase)

Environmental Parameter	Monitoring Item	Survey point	Frequency	Implementer	Responsible Organization
Water pollution	Water turbidity check by observation Chemical and fertilizer application	Drainage outlet Farmland	Once per month	Sector offices	MINAGRI
Infectious diseases	Number of Malaria patients	Health center in the	Bi-annually	Sector/Cell offices and health mobilizer	Ministry of Health and

Environmental Parameter	Monitoring Item	Survey point	Frequency	Implementer	Responsible Organization
		Project area			MINAGRI
Land expropriation	Conditions of the Project affected persons, times of complaint etc.	-	Bi-annually	District (Resettlement and compensation committee)	MINAGRI

Monitoring formats for construction period and operation period, respectively, are to be prepared. Comments obtained from the people through the monitoring and response by the government also are needed to be recorded. Draft monitoring forms of the Project are shown in the following table, and proposed monitoring plan and format for land expropriation are shown in next sub-chapter.

Table 1.3.1.14 Draft Monitoring Form (Construction Period)

(1) Response and actions by the government

Comments and response	Monitoring results
Number and contents of comments from the people	
Number and response to the comments from the government	

(2) Pollution (a) Air pollution, noise, soil contamination

Environmental Parameter	Monitoring Item	Survey point	Frequency
Air pollution	Dust	Construction site	Once per week
Noise and vibration	Complaint from the people	Construction site	Once per week
Soil contamination	Oil leakage	Construction site	Once per week

(2) Pollution (b) Water pollution

Environmental Parameter	Monitoring Item	Measured value (max)	Survey point	Frequency
Water pollution	Tributary	30NTU	Drainage outlet	Once per week

(3) Natural Environment

Environmental Parameter	Monitoring item	Monitoring results	Measures taken
Waste	Disposal of construction waste		
Soil erosion	Occurrence of soil erosion		

(4) Social Environment

Environmental Parameter	Monitoring item	Monitoring results	Measures taken
Expropriation*	Progress of compensation, complaints from the affected persons		
Social service	Traffic condition		
Accident	Number of accidents	Incidence per 1000 residents	

Table 1.3.1.15 Draft Monitoring Form (Operation Period)

(1) Response and actions by the government

Comments and response	Monitoring results	Measures taken	Frequency
Number and contents of comments from the people			
Number and response to the comments from the government			

(2) Natural Environment

Environmental Parameter	Monitoring results	Measures taken	Frequency
Water pollution			

(3) Social Environment

Environmental Parameter	Monitoring results	Measures taken	Frequency
Infectious diseases			

1-3-2 Resettlement and Land Expropriation

1-3-2-1 Necessity of Land Expropriation

1) Project components which need resettlement and land expropriation

There are very few structures in and around the proposed constructions sites and involuntary resettlement will not be caused. However, land expropriation will be caused due to dam and irrigation canal construction. The affected area by the dam construction is 21.73ha, consisting of 15.17ha of governmental land and 6.56ha private land. Moreover, the area to be expropriated for the canal and other facilities construction in the hillside will be 13.98ha. Furthermore, canal/drainage, O&M road and plot constructions will be implemented in the paddy field in the downstream, which will result in around 1.6ha decrease of the cultivable area.

2) Alternatives to minimize the land expropriation

There are a few houses and some forests consisting of hundreds of Eucalyptus around the proposed canal construction sites. If the canals are constructed linearly in the area, the works could give damages to the houses and forests. Therefore, it is proposed to construct pipeline canals in such area to avoid giving damages to them. Moreover, if there are some other valuable trees when canals are constructed, it is necessary to adjust the route to minimize adverse effects on them as much as possible.

1-3-2-2 Rwandan Legislation Related to Land Tenure, Land Use, Resettlement, Expropriation and Land Valuation

The Rwandan Land Policy ensures equal right to land use for all Rwandan citizens. The following list comprises the existing legislation that relates to land and resettlement issues in Rwanda:

- The Rwandan Constitution, promulgated in 2003;
- Organic Land law N° 08/2005 of 14/07/2005 determining the use and management of land in Rwanda;
- Organic law determining legislation around environmental management and protection
- Land Valuation Law promulgated in 2007;
- Land Expropriation Law promulgated N° 18/2007 of 19/04/2007 (hereinafter mentioned "Exprorpiation Law");
- Presidential Order N° 54/01 of 12/10/2006 determining the structure, the responsibilities, the functioning and the composition of Land Commissions; and
- Ministerial Order N° 001/2006 of 26/09/2006 determining the structure of Land Registers, the responsibilities and the functioning of the District Land Bureau.

Laws on property are found in various legal texts of Rwanda including the Rwandan Constitution which recognizes every person's right to private property (Article 29). Consequently, private property, whether individually or collectively owned is inviolable. Exceptionally, the right to property may be overruled in the case of public interest. In these cases, circumstances and procedures are determined

by the law and subject to fair and prior compensation (Article 29). In addition, the present Organic Land Law sets a legal framework for property law under articles 5 and 6 which provides for full ownership of land and permits any person that owns land (either through custom or otherwise), to be in conformity with the provisions of this law.

Eligibility for compensation is enshrined under the Rwandan constitution (Article 29) and the Expropriation Law. The two laws regulate and give entitlement to those affected, whether or not they have written customary or formal tenure rights. The person to be expropriated is defined under article 2 (7) of the Expropriation Law describing that any person who has his or her private property transferred due to public interest, in which case they shall be legally entitled to payment of compensation.

In case an individual suffers any loss, Article 3 of the Expropriation Law stipulates that he or she should receive just compensation for it, although it is not clear what comprises fair and just compensation, this being left to the judgment of independent valuers. Through mutual arrangement, both parties can determine the mode of payment. Article 22 (2) of the of the Expropriation Law provides that through an agreement between the person to expropriate and the one to be expropriated, just compensation may either be monetary, alternative land or a building equivalent as long as either option equates to fair and just monetary compensation. In case the determination of 'just' compensation exceeds in value the alternative land given to the expropriated person, the difference will be paid to the expropriated person.

A land holder whose holding has been expropriated shall be entitled to payment of compensation for land and other assets. For movable assets, compensation relates to inconveniences and other transition costs caused in the process of relocation. Immovable assets include: crops, forests, any building or other activity aimed at efficient use of the land, the value of land, and the activities thereon that belong to the person expropriated.

The law provides for public sensitization on the importance of the Project to be established and the need for expropriation. In addition to sensitization, the Expropriation Law requires prior consultative meetings and examination of the Project proposal involving expropriation, with a view to avoid eventual prejudice on the person or entity subject to expropriation. Normally, a consultative meeting is held within 30 days after receipt of the application for expropriation. Based on these consultations, the relevant Land Commission or Committee (from the Cell level to the National level) takes a decision to approve the Project within a period of 15 days. It is possible for the affected persons who are unsatisfied with poposed compensation to institute a lawsuit.

In Rwandan regulations, there is no mention about definition of cut-off-date. However, land owner of the land is not allowed to carry out any activities after the start of land survey and the inventory of the properties. In case he or she carries out any activities, they shall not be valued in the process of expropriation. Threfore, the date that the final census begins is regarded as the cut-off date for eligibility for compensation. On the other hand, if compensation to the Project Affected Persons (PAPs) cannot be done within 120 days after the census survey, the result will be invalid, another census survey should be implemented to update the reusult. At this moment, therfore, it is very difficult to set the cut-off-date of the Project. After the final decision for the Project implementation by the Japanese Goverrment and Rwandan Government, it is needed to conduct final census survey.

According to the Expropriation Law, affected people are to be fully informed of expropriation issues. As a whole, it can be said that Rwandan legal system concerning land expropriation has already been established to some extent. However, those who cultivate in the national lands cannot be targeted for compensation and there are some differneces between the "JICA Guideline for Social and Environmental consideration (April 2004)" (hereinafter refer to "JICA Guideline") and Rwandan

regulations. Following table illustlates the differences of those two regulations.

Table 1.3.2.1 Gap between Rwandan Laws and JICA Guideline

JICA Guideline (2004)	Rwandan regulation	Remarks
▪ Involuntary resettlement and loss of means of livelihood are to be avoided when feasible by exploring all viable alternatives. (JICA GL) ▪ When population displacement is unavoidable, effective measures to minimize impact and to compensate for losses should be taken. (JICA Guideline)	▪ Resettlement is acceptable for public interest. Affected persons are fully informed of expropriation issues. The law prohibits any opposition to the expropriation (Expropriation Law, Article 3). ▪ Affected person receive fair and just compensation (Expropriation Law).	▪ No resettlement is planned by the project, however, land expropriation is unavoidable. It is planned to compensate for private land loss in accordance with the law and to provide supports to those who cultivate in national land to minimize the losses.
▪ People to be resettled involuntarily and people whose means of livelihood will be hindered or lost must be sufficiently compensated and supported by project proponents, etc., in a timely manner. Project proponents must make efforts to enable people affected by projects to improve their standard of living, income opportunities and production levels, or at least to restore them to pre-project levels.	▪ There is no mention in laws to restore or improve living standard of the affected persons. Just compensation may be monetary or an alternative land and a building equivalent to the determination of just monetary compensation (Article 23 of the Expropriation Law). The persons who cultivate in national lands are not qualified for compensation.	▪ Monetary compensation will be provided to the persons to be expropriated their private lands. Those who cultivate in national lands are not compensated. It is proposed to provide technical supports and to employ them as labors for construction works with high priority, aiming at minimization of the impact on their livelihood.
▪ Appropriate participation by affected people and their communities must be promoted in the planning, implementation, and monitoring of RAPs and measures to prevent the loss of their means of livelihood (JICA Guideline)	▪ Public consultation is needed to be organized and the result must be included in Environmental Impact Assessment process (General Guidelines and Procedures for Environmental Impact Assessment, 2006).	▪ A series of consultation meetings to explain negative impacts and mitigation measures to the affected persons has already been organized and the participants agreed on the proposed plan. Representatives of the affected persons will participate in monitoring activities.
▪ Particular attention must be paid to the needs of the vulnerable groups among those displaced, especially those below the poverty line, landless, elderly, women and children, ethnic minorities, etc.	▪ It is general to pay consideration to vulnerable group according to the Rwandan context, even though there is no mention in the Expropriation Law.	▪ Vulnerable and project affected people have high priority to be employed for the construction works.

Resettlement Policy Framework (RPF) has been prepared for RSSP projects in Rwanda, while RPF of LWH is under revision. Therefore, Resettlement Action Plans (RAP) of other LWH projects have been prepared based on the RPF of RSSP. The project is one of LWH projects, therefore, a RAP has been prepared as Appendix 6.3.

1-3-2-3 Scope of the Land Expropriation

The lands to be expropriated are farmlands where the proposed dam and irrigation facilities planned will be constructed. Furthermore, No existing structure will be affected by the Project and all the affected persons are farmers who cultivated in the proposed construction sites. The number of PAPs is 1,220 households in total as shown following figure and table:

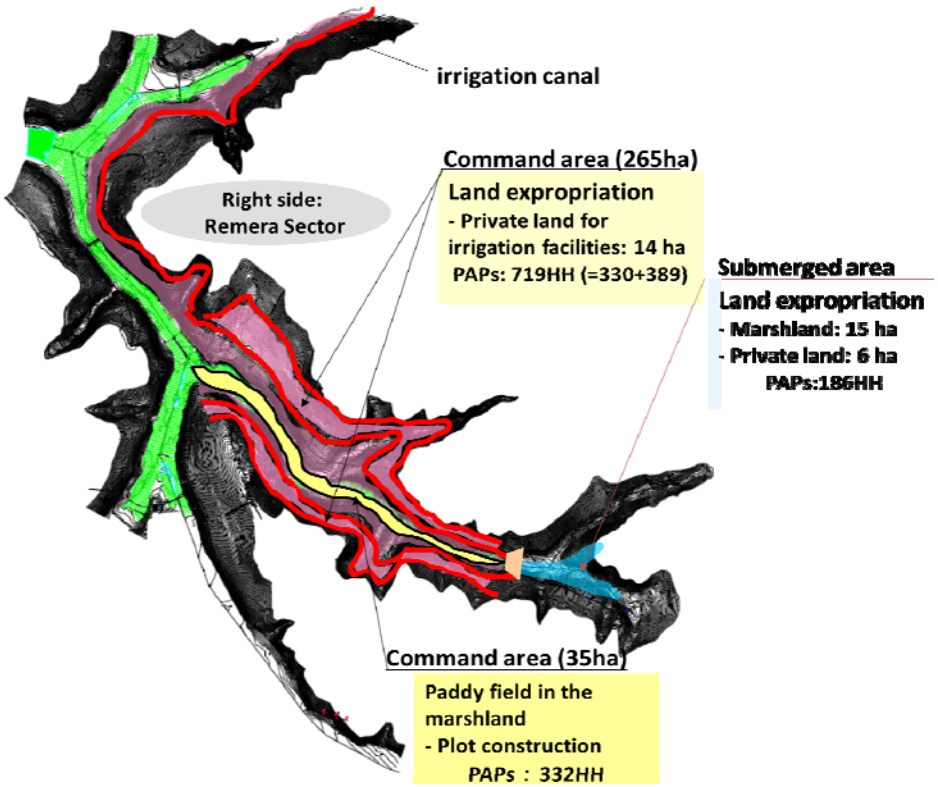


Figure 1.3.2.1 Project Affected Areas and Persons

Table 1.3.2.2 Type of Loss and Affected Persons

Type of loss	No, of Affected households*
1. Loss of farmlands in the dam site (private land)	53
2. Loss of cultivation right in the marshlands	160 households (HHs) (27HHs are overlapped with 1.)
1.+2. Loss of farmland and cultivation rights due to dam construction	186（=53+160-27）
3. Loss of farmlands due to main canal construction (hillside in the beneficial area)	389HHs (1HH is overlapped with 1.+ 2.)
4. Decrease of area in the paddy field in the downstream due to plot construction (governmental land)	332HHs
5. Loss of farmlands due to secondary canal (hillside in the beneficial area)	330HH[3]
Total	1,220HHs （excluding overlapped households' number）

At this moment, the Project stage is outline design, a provisional census survey covering the 186 households (15% of all PAPs mentioned above) who cultivate in the area to be submerged, was conducted[4]. They live in mainly five Cells, namely, in Ndekwe, Muhurire, Rujambara, Rugese and Bugera[5]. Most of villages in Remera Sector and Rurenge Sector have 500 - 1,000 populations and the people earn their living by farming. The affected farmlands are located on along the Rwabishanyi River which flows between Remera Sector and Rurenge Sector, which means that meteorological and geological conditions are very similar. Moreover, agricultural conditions are almost same due to no irrigation system in the area. Therefore, it can be judged that bias will not be caused even if only the

[3] It was counted on the map and there is a possibility that one household owns plural plots. However, the number of plots is regarded as the number of households to be affected for safety.

[4] One household who stays in Kigali was not surveyed due to absence.

[5] Only one household who lives in Musha Cell will be affected by the project.

186 households are targeted as the census survey. The questionnaire and the results are attached in Appendix - 6.4 (1) (2) and 6.5 (1) (2), respectively.

1) Population

The affected 186 households is composed of 489 men and 500 women (in total 989 persons) and average number of family member is 5.3 per household. It can be estimated that the total population of all PAPs (1,220 households) is 6,466, if the mean value of number of family member mentioned above is applied. It includes number of affected persons by plot construction in the paddy field.

2) Household income and living conditions

Annual household cash income of the surveyed families is around Rwf 400,000 on average. The amounts vary widely, from around Rwf 10,000 to more than Rwf 1,000,000. Major income source of them is farming, while some households earn incomes from livestock, carpentry, labor works and so on. Average annual cash income of the affected persons is as shown below:

Table 1.3.2.3 Annual Cash Income of PAPs due to Dam Construction (Unit: Rwf/year/HH)

Item	PAPs who cultivate in the marshland (160HH)	PAPs who cultivated in the hillside (53 HH)**	Average (186HH)
Farm income	345,963	442,516	366,173
Other income	38,325	49,471	37,484
Total	384,288	491,587	403,657
Mean farmland area (ha/HH)	0.79	1.27	0.90

* There is a big scale farmer who owns 7.9ha land and the household was excluded from the average calculation.

** It includes overlapped households who cultivate in marshland and hillside to be submerged.

Source: JICA Survey Team, 2013

The mean land holding area of the PAPs is 0.9ha and major crops in the hillside are maize, sweet potato, cabbage, carrot, tomato, coffee, soy bean, cassava and so on. On the other hand, sweet potato is mainly cultivated in the marshland. In general, the farmers harvest twice per year in both marshland and hillside. The affected persons have stayed in the area for many years, only 10 households out of 186 have stayed less than 20 years. 37% of household in the Project area has enjoyed the rural electrification program and have access to electricity. Most of the people utilize rain water and public piped water in rainy season, while they use public tube wells or shallow wells in dry season. Most of heads of families could not have education opportunities, 76 households out of 186 answered that they have never been to school.

In the marshland to be submerged, 11.3ha out of 15.17ha is cultivated actually, average cultivation area per household is 0.07ha. Degrees of reliance on the farming in the marshland vary depending on the families, and the farming areas in the marshland accounts for less than 10% of total farmlands for most of the PAPs (refer to Table 1.3.2.4). The area of farmlands in the marshland accounts for 12% of their total farmlands on average. In other words, the extent of damage due to the farmlands loss in the marshland is relatively small for most of the affected households, however, some families will be influenced significantly by the Project. Therefore, it is needed to provide some support to such households.

Table 1.3.2.4 Ratio of Farmlands in the Marshland to All the Farmland and its Distribution

Ratio of farmlands in the Marshland to All the Farmland	No. of HH
0 - 10%	106
10 - 20%	26
20 - 30%	11
30 - 40%	10

Ratio of farmlands in the Marshland to All the Farmland	No. of HH
40 - 50%	1
50 - 60%	4
60 - 70%	1
70 - 80%	0
80 - 90%	1
Total	160

3) Asset survey results

The areas to be submerged consist of 6.56 ha of private lands in four Cells, namely, Bugera, Ndekwe, Muhurire, and Rujambara Cell and farmlands in the marshland whose area is 15.17ha[6]. 13.98ha of private land in Ndekwe and Rujambara Cell will be expropriated for canal construction. In addition to that, fruit trees and timber trees will be lost due to the construction works. In the paddy field, 1.6ha will be expropriated for the plot construction. The assets to be affected by the Project are summarized in following table:

Table 1.3.2.5 Lands and Assets to be Expropriated

Assets to be expropriated	Total
Trees	One set
Private land for dam construction Muhurire Cell : 0.93ha Bugera Cell : 0.23ha Ndekwe Cell : 3.24ha Rujambara Cell : 2.16ha	6.56ha
Private land for canal and other facilities Ndekwe Cell : 7.65ha Rujambara Cell : 6.33ha	13.98ha
Governmental land for dam construction	15.17ha
Paddy field for plot construction (national land)	1.6ha

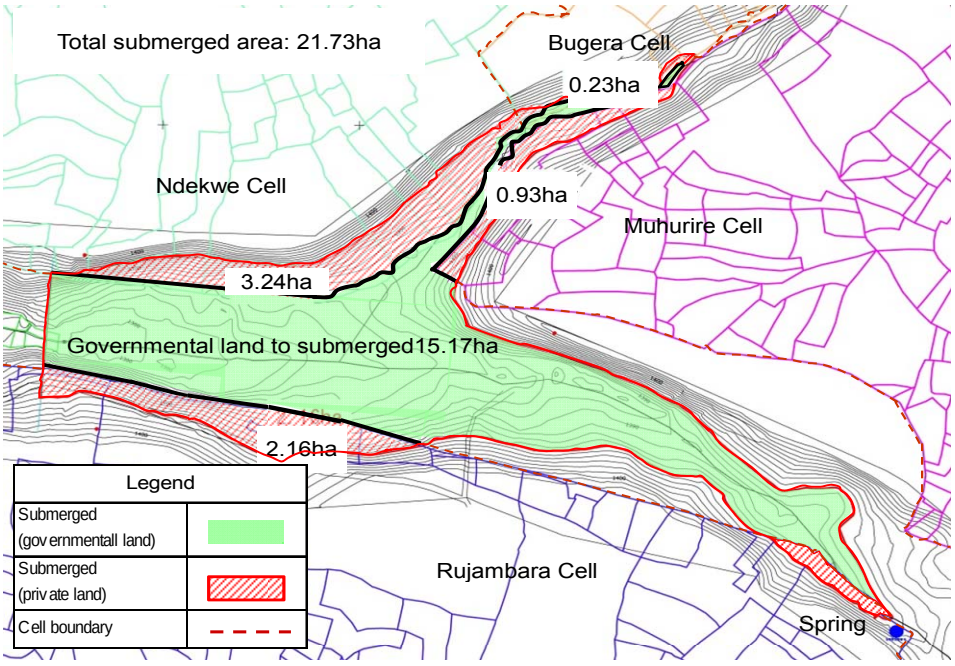


Figure 1.3.2.2 Location of the Submerged Areas

As mentioned before, the cut-off-date has yet to be fixed, since the census survey result is effective

[6] Actual cultivated area is 11.3ha out of 15.17ha according to the survey (JICA Survey Team, 2013)

within 120 days for compensation. After the official approval by both of Government of Rwanda and Government of Japan, it will be set on the date that the final census survey including asset survey and household survey will be started.

Prior to the Project implementation, it is necessary to request suspension of farming to the affected persons at least one crop season before. In such case, compensation for the standing annual crops will not be needed, while compensation for perennial crops to be damaged will be necessary. In Rwanda, compensation for land, which belongs to the government, is not approved, however, it is needed to provide compensation for the standing crops to be lost as well as in private lands. It means that targets of compensation of the Project are perennial crops and farmlands to be lost.

4) Vulnerable people

According to the survey result, 22 households have one and more handicapped persons in their families. When the final census survey will be conducted, it will be needed to request to the Cell officers and village heads concerned to specify vulnerable people among the PAPs. In Rwanda, there is no documented regulation for the vulnerable people in the process of land expropriation or resettlement. However, it is general to take consideration into such people according to Rwandan context and it is possible to obtain cooperation from local leaders to specify vulnerable people among the affected persons.

1-3-2-4 Compensation Measures

The Project will be funded by Government of Japan through JICA and it is very important to pay attention to the JICA Guideline in preparation and implementation of the RAP. The key principle of JICA's policy on involuntary resettlement is summarized below:

a. Involuntary resettlement and loss of means of livelihood are to be avoided when feasible by exploring all viable alternatives.

b. When population displacement is unavoidable, effective measures to minimize the impact and to compensate for losses should be taken.

c. People who must be resettled involuntarily and people whose means of livelihood will be hindered or lost must be sufficiently compensated and supported, so that they can improve or at least restore their standard of living, income opportunities and production levels to pre-project levels.

An entitlement matrix of the Project is prepared as illustrated in Table 1.3.2.6 below, which indicates compensation measures to mitigate the loss of land and crops and to restore their livelihoods.

Table 1.3.2.6 Entitlement Matrix

Type of Loss	No of PAPs	Qty	Eligibility Criteria	Entitlement
Loss of private lands in the dam site	53	6.56ha	Owners of land where the dam will be constructed	Cash compensation for loss of land
Loss of private lands along canals	719 (=389+330)	13.98 ha	Owners of land where the dam will be constructed	Cash compensation for loss of land
Loss of Government land in marshlands	160	15.17ha	Current users of affected marshlands	Support e.g. training implementation of agriculture, employment as labors during construction, redistribution of paddy field in the downstream
Loss of	332	1.6ha	Current users of affected	Employment as labors during

Type of Loss	No of PAPs	Qty	Eligibility Criteria	Entitlement
Government land in the paddy field			paddy field	construction and implementation of technical training
Loss of perennial crops	Not identified	One set	Those who grow the perennial crops to be lost	Cash compensation for loss of perennial crops
Vulnerable people	Not identified	-	Older, handicapped, marginal and others	Employment as labors during construction and implementation of technical training

Source: JICA Survey Team

1) Compensation for private land

Land for land compensation is desirable according to the laws in Rwanda, however, due to shortage of available lands in the district, it is difficult for Ngoma District to arrange new alternative lands for the affected persons. Therefore, it is proposed to apply cash compensation based on the law (Ministerial order on land prices outside Kigali city, MINIRENA, 2010). According to the district office, there are some unused farmlands in the district, and it is possible for the officers to facilitate the PAPs to purchase such farmlands after the cash payment as compensation. Moreover, it is planned to provide agricultural technical support through the soft component.

2) Compensation for perennial crops

The PAPs will be encouraged to harvest all of their produce before land expropriation. In order to ensure that this is possible, there needs to be sufficient consultation with the PAPs beforehand so that harvesting can be properly planned. According to the implementation schedule, final census survey will be done in December 2014 (harvest season), at that time, the farmers will be requested not to plant next crops. Concerning compensation unit price of crops, Ngoma District applies the unit prices described in the previous Expropriation Law even now. Therefore, it is possible to refer the same regulation for the compensation of the Project.

3) Support for PAPs who cultivate in the marshland to be submerged

Compensation for marshland expropriation is not needed in Rwanda, however, some farmers will be damaged due to the Project. Therefore, it is planned to provide agricultural technical support through the soft component not only for the private land owners but also farmers in the marshland. It is expected to mitigate their loss by improvement of their farming techniques and benefit increase[7] in their remaining farmlands. In addition, it is planned to employ from 6,000 to 7,000 persons as labors for construction works. It is proposed to give high priority to the vulnerable people to be affected and those who cultivate in the marshland to be submerged. Daily wage per person is from Rwf 1,000 to Rwf 2,000, if they are employed for 20 days per month, they will gain Rwf 240,000 to 480,000 for the construction period. It means that such job opportunity can alleviate the impact due to land loss on the PAPs to some extent.

On the other hand, there are some households who depend on the marshland for farming, and they will be influenced by the Project significantly, even though the proposed supports mentioned above are implemented. Therefore, it is proposed to redistribute of paddy filed in the downstream to such people. It is needed to get consensus from the current users of the paddy field. After the detail design, target farmers who will be able to access the paddy field distribution will be identified.

[7] According to the output by "Project for Increasing Crop Production with Quality Extension Services in the Eastern Province" (PiCROPP), which was implemented from 2010 to 2013, net income of crop per ha was increased by 43%. Many PAPs cultivate horticulture crops such as bean, tomato, cabbage, carrot and so on, therefore, they can apply the new techniques.

4) Support for PAPs who cultivate in the paddy field

Plot construction in the paddy field, which is located on the downstream, is planned. Due to the work, the area of paddy field will be reduced by around1.6ha. However, it is expected that the yield will be increased from 4tons/ha to 6tons/ha by the technical support mentioned above. Therefore, the paddy production will not be decreased even if the around 1.6ha of paddy field area is reduced. When "Data Collection Survey on Irrigation Development in Ngoma District of Eastern Province in Rwanda" (JICA, 2012) was conducted, the farmers of the paddy field requested to the JICA Team to implement plot construction for even water distribution. The proposed plot construction could contribute to proper water management and production increase.

During the plot construction works, the farmers will not be able to harvest paddy at least one season, which will result in loss of around Rwf 360,000/ha (Rwf 10,890,000 in total for all cultivated area: 30.25ha). Therefore, it is proposed to employ the affected farmers as labors of terracing works of the 265ha beneficiary area, to be shouldered by the Government of Rwanda. Considering there is a case that Rwf 1,000 was paid for $10m^2$ terracing works (10 to 20 m^2/day/person) in other LWH sub-projects and the beneficiary area of the Project is 265ha to be terraced, 265,000 labors in total will be needed for the works. Therefore, it is possible to offset the loss due to farming suspension for one season in the paddy area, if the affected persons are hired as labors. Terracing works will be done during the period the farmers cannot cultivate due to the plot construction, and the affected people can access to job as labor forces.

5) Support for the vulnerable

Out of the project affected persons, vulnerable persons shall be provided with special consideration. It is planned to employ them as labors during construction with high priority and to implement technical training.

1-3-2-5 Grievance Handling

The Ngoma District is an acknowledged institution to communicate with some PAPs expressing discontent with the proposed compensation process, if any. Article 26 of the Expropriation Law N° 18/2007 of 19/04/2007 provides a series of complaints procedures for individuals who are dissatisfied with the value of their compensation. The discontented person should file his/her grievance, relating to any issue associated with the resettlement process or compensation, in writing to a Resettlement and Compensation Committee, which is planned to be established by the Project. The grievance note should be signed and dated by the discontented person.

The appointed MINAGRI officer and the Resettlement and Compensation Committee will consult to determine the validity of claims. If valid, the Committee will notify the complainant and he/she will be assisted. The Resettlement and Compensation Committee will respond within 14 days during which time any meetings and discussions to be held with the discontented person will be conducted. If the grievance relates to valuation of assets, a second or even a third valuation will be undertaken, until it is accepted by both parties. These should be undertaken by separate independent valuers than the person who assessed the initial valuation.

If the discontented person does not receive a response or is not satisfied with the outcome within the agreed time, he/she may lodge his/her grievance to the relevant municipal administration such as the District Land Bureau. If requested, or deemed necessary by the Committee, the District Project Coordination officer will assist the discontented person in this matter. The relevant local administration will attempt to resolve the problem (through dialogue and negotiation) within 30 days of the complaint being lodged.

If no agreement is reached at this stage (in the administrative system), the complaint will be dealt with judicial system, at first, he/she will be supported by the local courts (*Abunzi*) where it is possible. When the matters cannot be resolved through the local mediation system, the grievance will be referred to higher authorities, to the primary court or high court. The process will be different depending on the nature of complaints. If the value of asset is more than three million Rwandan Francs, the process will be started from intermediate courts, and if it is not settled, it will be transferred to high court and to Supreme Court, since *Abunzi*/local mediator can manage land dispute whose value is less than three million Rwanda francs.

The Resettlement and Compensation Committee will provide assistance at all stages to the discontented persons to facilitate resolution of their complaint and ensure that the matter is addressed in the optimal way as much as possible. The proposed grievance redress system is as illustrated follows:

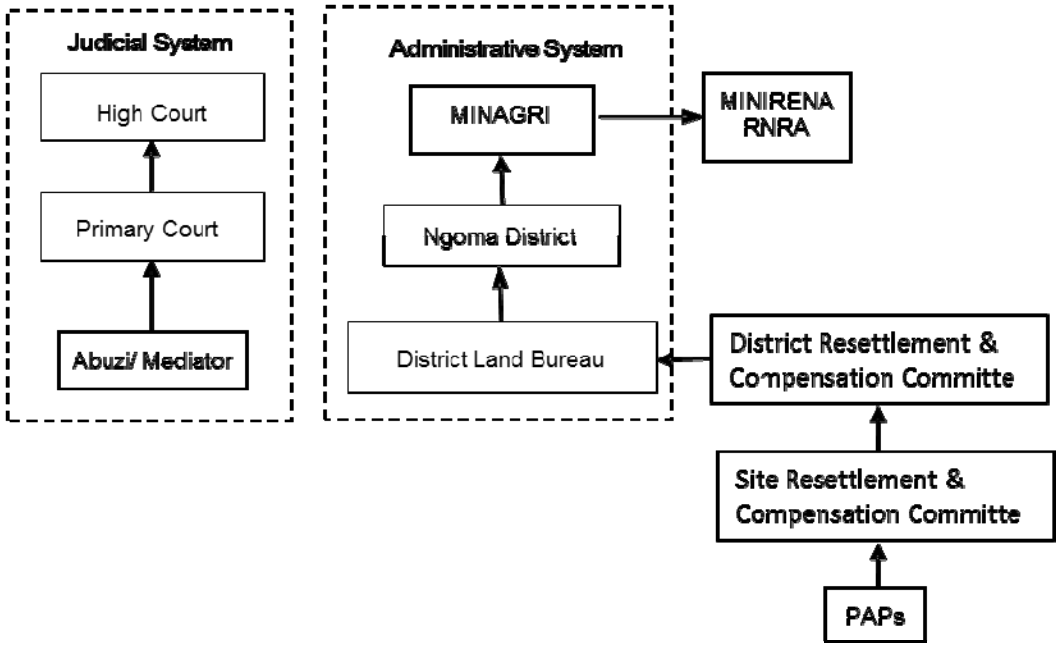


Figure 1.3.2.3 Proposed Grievance Redress Mechanism

1-3-2-6 Implementation Structure

1) MINAGRI

MINAGRI is the main agency involved in implementation of the proposed RAP of the Project. The ministry will take overall responsibility for implementation of the RAP and will provide required funds and skills. Moreover, it is suggested to assign one member of Single Project Implementation Unit (SPIU) of other LWH sub-projects to the Project.

2) MINIRENA

MINIRENA is a responsible organization for policy formulation and guidance as well as monitoring and evaluation. It ensures that the RAP is consistent with the national land use plan and international legislation such as OP 4.12.

3) Designated SPIU for the implementation of RAP

For better RAP implementation, it is recommended that MINAGRI to assign one of its SPIU to coordinate the RAP implementation of this Project as mentioned before. The roles of the SPIU member are implementation of the RAP, coordination of monitoring activities, keeping monitoring

results, analysis of monitoring data and capacity building of other stakeholders. Monitoring activities will be done during and post project implementation. The SPIU will be the focal point RAPs implementation and will liaise with other stakeholders. The SPIU will ensure that the procedures of the Rwandan laws and the JICA Guideline as well as the OP 4.12.

4) RNRA

RNRA is responsible for overall management and coordination of all activities related to land administration, land use planning and management in Rwanda. The role of RNRA in the RAP implementation process will be to give some advices for any matters related to land ownership and expropriation. It will supervise the District Land Bureau to check surveys and various maps before the land expropriation.

5) REMA

REMA will give some advices to MINAGRI for the RAP implementation to ensure that all policies and regulations related to resettlement in the better manner, especially provide some support for monitoring.

6) Ngoma District

The District will play a key role such as assessment of the land tenure rights of PAPs, grievance handling, facilitation of unused land purchase by the persons to be expropriated. In general, their major roles in RAP implementation are as follows:

- To monitor compliance with construction plans
- To monitor and approve valuation of land, assets and other immovable property;
- To demarcate and approve land cadastral;
- Establishing project level Resettlement and Compensation Committees at District (project level) and Sector/ Cell (site level);
- Clarifying the policies and operational guidelines of Resettlement and Compensation Committees;
- Establishing standards for unit rates of affected assets and compensation estimates, according to the standard units, adjusted for local conditions where necessary; and
- Coordinating and supervising RAP implementation by Resettlement and Compensation Committees as planned, and ensuring national/district guidelines.

The District Land Bureau will play an important role in a series of activities mentioned above, and the District office will monitor the activities done by the District Land Bureau.

7) District resettlement and compensation committee

The Ngoma district will organize the district level Resettlement and Compensation Committee. The committee consists of the District Community Development Officer, a civil Engineer, District Land Bureau officer, SPIU member, and executive secretaries of affected sectors and PAPs representatives. It will ensure that the RAP is properly implemented. The committee will be supported by the SPIU member.

8) Resettlement and compensation committees at site level

It is recommended to establish the site level Resettlement and Compensation Committee. It is

expected that the Ngoma District Land Bureau will be responsible for electing members of the site level committee. The committee will plan, coordinate and monitor the proposed compensation activities, as well as supervise compensation payments to the PAPs. A large part of their responsibility will be consultation with PAPs. The committee members would comprise the following:

- Representative from two Sectors (Remera and Rurenge)
- Representative of five Cells concerned to the Project
- Representative from the District Development Committee;
- Representative from any other key sector office involved in the Project;
- Key stakeholder's representative from the implementing organization;
- Two representatives of PAP by cells (equal gender representation); and

The Resettlement and Compensation Committee would have responsibility for:

- Verifying PAPs
- To validate inventories of PAPs and affected assets;
- To monitor the disbursement of funds;
- To facilitate conflict resolution and addressing grievances; and
- To provide support and assistance to vulnerable groups including handicapped people, widows, orphans, and the old persons among PAPs.

This committee should meet on a regular basis (as determined by the needs of the Project) to ensure that compensation activities are appropriately designed and executed. It is recommended to appoint one officer who would act as the key contact with PAPs and facilitate implementation of consultation, public participation and grievance mechanisms.

9) Mediators/Abunzi

At the Cell, there are mediators (*Abunzi*) whose work is to resolve disputes, especially land disputes. The A*bunzi*, or mediation committees, have mandatory jurisdiction less than three million Rwanda Francs. The *Abunzi* will be used in the Project as the first stop for resolving disputes and grievances following land acquisition. They will be involved in the compensation process from the beginning to the end.

10) Project affected persons

The PAPs will assist implementation of the final census survey and asset survey. Moreover, they are requested to participate in a series of consultation meeting for giving their opinions, views and concerns related to project implementation.

Table 1.3.2.7 Summary of Institutional Responsibilities RAP implementation

Institutions	Responsibilities
MINAGRI	• Collection of information regarding the Projects, including RAP documentation. • Review and approval of related documentation (RAP reports etc.) to ensure consistency and compliance with Resettlement Policy Framework; • Overall monitoring and evaluation of expropriation (i.e., annual audits and review of project level monitoring undertaken by District authorities), ensuring that RAPs are implemented in accordance with Rwandan laws and OP 4.12.
Appointed SPIU	• To initiate the expropriation process and compensation requirements

Institutions	Responsibilities
	• Preparation and signature of Compensation Grant agreement with the District • To establish Resettlement and Compensation Committee in consultation with District Land Bureau • To have a representation in the Project Resettlement and Compensation Committee • Provision of capacity building and technical support relating to expropriation and compensation activities; • Appropriate fund allocation for compensation following the RAP.
MINIRENA	• To ensure that the expropriation sites has sustainable programs including environmental protection measures, national land use plan and international guidelines such as OP4.12 • To describe the boundaries of the relocation area; • Assessment of the environmental impacts of the proposed expropriation, mitigation measures and environmental management plan.
RNRA	• To advise on matters related to land ownership and expropriation activities; • To support verification of land ownership and land titles.
REMA	• To support for monitoring and to give some advices to MINAGRI
Ngoma District	• To verify land owners based on the records of land registration • To issue construction permits and monitor compliance with construction plans • To supervise valuation of land and other immovable property • To approve results of asset survey • Work in collaboration with the Resettlement and Compensation Committees to ensure that 'fair and just' compensation is reached in accordance with the law and the requirements of this RAP • To facilitate the PAPs who will lose their farmlands to purchase new lands which are not cultivated well in the district
District Resettlement and Compensation Committee	• Verification of the PAPs • To validate inventories of PAPs and affected assets; • To facilitate the PAPs who will lose their farmlands to purchase new lands which are not cultivated well in the district • To facilitate conflict resolution and addressing grievances
Site resettlement and Compensation Committee	• To help in creating awareness on expropriation process • Monitoring of the expropriation; • Conflicts and grievance resolution • To help identification of land, • To serve as witnesses in compensation
Mediators/ Abunzi	• Resolving disputes • Provide grievances mechanism following land acquisition. • Help in designing RAP at the community level.
Project Affected Persons	• To be present when the land survey and inventory is being implemented • Provision of all required information in regards to expropriation • Participate in expropriation activities

Proposed RAP implementation structure is as shown below:

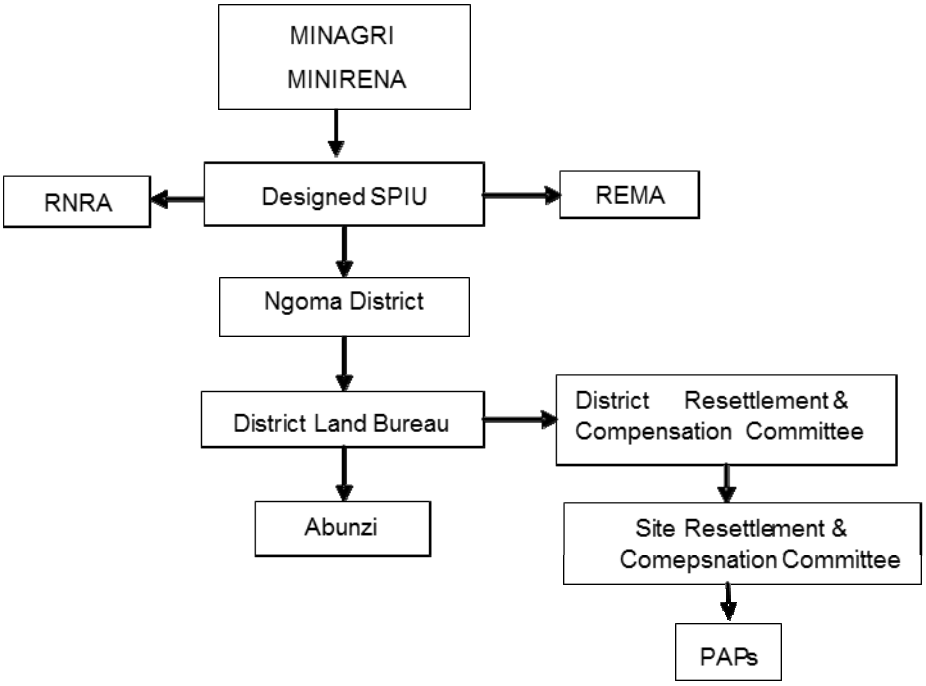


Figure 1.3.2.4 Proposed RAP Implementation Structure

1-3-2-7 Implementation Schedule

Implementation schedule has not been fixed yet at this moment, however, after the approval of official agreement between Government of Rwanda and Government of Japan, the Project will be started soon. There will be several steps to be followed during the preparation and construction. The proposed implementation schedule of RAP after the project approval is as shown in the following table:

Table 1.3.2.8 Implementation Schedule

Year	2014					2015									
Month	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10
Official approval of the Project	x	x													
D/D, Tender			x	x	x	X	X	X	x						
Establish of Resettlement & Compensation Committee				x											
Cut-off date				x											
Final census					x	X									
Disclosure of final census result						X									
Compensation agreement						X	X								
Compensation							X	X							
Land expropriation								X	x						
Project implementation										x	x	x	x	x	x
Monitoring and grievance redress (bi-annual for 2 years in the operation phase)							X	X	x	x	x	x	x	x	x

1-3-2-8 Cost and Fund

Based on the impacts described earlier, this section presents the budget estimates according to the aforementioned valuation methodologies and unit value rates. The estimated budget of compensation for loss of lands and trees is summarized in following table while for RAP implementation monitoring is presented in Table 1.3.2.11. The compensation cost shall be shouldered by the Government of Rwanda, while soft component cost such as technical training agriculture for PAPs, especially, those who cultivate in the marshland, will be covered by the Government of Japan.

Table 1.3.2.9 Cost Estimation for Compensation by Rwandan Side

Impact Description	Qty	Unit cost (Rwf)	Total Cost (Rwf)
Loss of Land (Bugera Cell)	0.23ha	122/m^2	280,600
Loss of Land (other cells)	20.31ha	107/m^2	21,731,700
Loss of Trees	1 set	(see Table 1.3.2.10)	11,102,208
Sub-total of compensation			33,114,508

Source:
1) Unit price of land: Ministerial Order No 002/16.01 of 2010 on Determining the Reference Land Price Outside Kigali City
2) Area to be affected: JICA Survey Team, 2013

Table1.3.2.10 Estimated Compensation Cost for Tree

Tree species	Age of trees	Quantity	Unit Price (Rwf)	Total Cost (Rwf)
Avocado	0-1 Year	32	4,005	128,160
	1-3 Years	63	13,020	820,260
	More than 3 Years	39	24,060	938,340
Grevillea	5-10 Years	237	1,716	406,692
	Under 5 Years	266	715	190,190
Eucalyptus/Inturusu		726	5,005	3,633,630
Acacia/Umunyinya		52	2,145	111,540
Erythrina Abyssinica/Umuko		93	715	66,495
Umusave (Timber Tree)		587	5,005	2,937,935
Acassia / Imisebeya		78	2,145	167,310
Dracaenas / Imihati		851	575	489,325
Spurge		98	920	90,160
Cyprus		7	858	6,006
Pinus		16	4,290	68,640
Medical trees		13	2,800	36,400
Mango		41	9,000	369,000
Ficus/Umuvumu		32	3,575	114,400
Other trees		27	450	12,150
Ricin/Ikibonobono		143	715	102,245
Sisal		26	250	6,500
Ornemental tree / Jakaranda		22	5,720	110,110
Euphorbes/Imiyenzi		166	920	152,720
Guava		16	9,000	144,000
Total				**11,102,208**

Source: 1) Unit price of trees: Previous Expropriation Law (the unit prices of trees are applied

in Ngoma District for compensation)

2) Quantity of trees: JICA Survey Team, 2013

Table1.3.2.11 Estimated Monitoring Cost

Activity	Indicator	Qty	Unit cost (Rwf)*	Total Cost (Rwf)
Meeting for set up resettlement committees	Established committee	1	120,000	120,000
Meeting for displaying PAPs asset.	Meeting	2	120,000	240,000
Follow up compensation process	Meeting	2	120,000	240,000
Meetings for grievance redress	Meetings/grievance resolved	16	120,000	1,920,000
Total				**2,520,000**

* Unit cost Rwf120,000 consists of Rwf 80,000 for vehicle and Rwf 5,000 mission allowances times 8 staffs (allowances guidelines for Government officers)

Table1.3.2.12 Total Cost for Compensation

Activity	Total Cost (Rwf)
1.Compensation for crops and lands	33,114,508
2. Final census survey (5% of sub-total of compensation for loss)*	1,655,725
3. Training of local level officers for grievance settlement	856,000
4.Monitoring	2,520,000
5. Sub-total (1.+2.+3.+4.)	38,146,233
6.Contingency (10% of sub-total)*	3,814,623
Grand total (5.+6.)	41,960,856

* Percentage of other LWH project is applied.

Governmental unit prices of land are fixed by Cell taking consideration into some conditions such as access to road and planted crops. On the other hand, market prices of land are fixed based on the negotiation between buyers and seller, on a case-by-case basis. Based on the interview to some farmers in the cells concerned, market prices and official price of lands were compared as shown in the following table. There are some differences between them to some extent, however, they are not very significant.

Table 1.3.2.13 Comparison of Market Price and Official Price

Land Use	Cell	Official unit price (Rwf/m^2) *1	Market price (Rwf/m^2) *2	Result
No crop and near to paved road	Ndekwe	161	166	Almost same
Banana cultivation	Ndekwe	107：land only 220：for banana *3 Total：327	256	Official rate is higher than that of private by 27%
No crop	Rwikubo	107	100	Almost same

Source *1 : Nº002/16.01 of 26/04/2010 Ministerial Order determining the reference land price outside the Kigali City
*2 : JICA Survey Team, 2013
*3 : Previous Expropriation Law

1-3-2-9 Monitoring Structure and Monitoring Form

In the monitoring process, following indicators could be used:

- Consultation with the PAPs for announcement of the Project and positive/negative impacts

- Implementation of the final census survey including asset survey and socio-economic survey
- Compensation to the PAPs based on the results of final census survey and the RAP
- Number of people raising grievances in relation to Project and number of unresolved grievances; and
- Support to recover livelihoods of the PAPs after the Project completion.

It is needed to check whether the proposed RAP is implemented as planned through the monitoring. During the compensation and construction stage, the monitoring will be practiced on monthly basis and it will be done bi-annually in the operation stage including period for filling of the reservoir.

Table 1.3.2.14 Sample Format for Monitoring

Responsible organization: MINAGRI

Work	Planned in total	Progress in quantity	Progress in percentage
Announcement to the affected people			
Identification of final PAPs			
Cost estimation for expropriation			
Consultation meeting			
Revise of the RAP and signing based on the feedback at the consultation meeting			
Compensation in cash			
Social supports such as job training			
Number of unresolved grievances.			

Announcement to the affected people		
Date:	Sector:	Cell
Date:	Sector:	Cell
Date:	Sector:	Cell
Consultation meeting with the affected people		
Date:	Sector:	Cell
Date:	Sector:	Cell
Date:	Sector:	Cell
Date:	Sector:	Cell

1-3-2-10 Consultation Meeting

1) First consultation meeting

The first consultation meeting to inform the Project outline to the people concerned was organized on September 2, 2013 and the Project stakeholders were invited at this meeting. The participants of the meeting were MINAGRI staff, JICA Headquarter Officers, JICA Rwanda Office staff, MINAGRI irrigation advisor, JICA team members, Sector and Cell official personnel, village heads in the beneficiary and affected areas and so on.

In the opening remarks, the Vice-Mayor in charge of Economic affairs of Ngoma District presented his recognition that the proposed irrigation project was very important considering its impact, and the farmers concerned would receive benefits for farming even without depending on rainfall. He called on the farmers for sufficient cooperation during the Project implementation and the good maintenance of facilities in the operation stage. The representative of MINAGRI, Mr. Jean Claude requested the farmers and local authorities to understand the importance of the Project and to collaborate for the Project implementation.

On behalf of JICA, Mr. Suzuki, Head of JICA HQs Mission, explained the purpose of the Project and informed the participants what was going on and discussed on the Project so far. He said that feasibility of the Project has already been clarified. He informed the participants that environmental and social matters to be caused by the Project would be discussed later. He introduced the JICA Survey Team members and asked for their cooperation for smooth activities. After the presentation, the participants were given opportunities to ask questions and to clarify as shown below:

Table 1.3.2.15 Outcome of the First Consultative Meeting

Speaker	Issues/Comments by Participants	Explanation by MINAGRI and JICA
Mr. Safari, the District Agronomist	He appreciated the Project that would irrigate both marshland and hillside. He said that in Ngoma District, it was the first time to have such kinds of Project. He also said that normally marshland area is a government property and asked if the land that would be used for canals or other project activities would be compensated or not.	About the land that would be affected by the Project, Mr. Jean Claude said that it was very clear in the land law. He explained that for public activities, they made expropriation for the land and compensation depending on the conditions such as standing crops.
Mr. Erick, a farmer from Muhurire cell	He welcomed the Project that would allow them to make cultivation in two seasons, but said that it was taking so long time to start implementation.	Mr. Suzuki said that so many preparatory actions are required in general prior to Project implement.
Mr. Justin, a farmer but also farmer mobilizer from Ndekwe cell	He expressed the need of giving notice before the construction so that they could avoid any damage of their crops. He wished to be notified 1 or 2 seasons before the commencement of construction works.	A notice will be given to users of the Project area once the cut-off date is fixed
Mr. Habimana Anastase, a farmer from Bugera,	He welcomed the Project that would allow them to cultivate all through the year and asked if stored water was only for irrigation or if it could also serve for domestic use.	Mr. Suzuki replied that the purpose of the dam was to store water for irrigation not for domestic use. The quality standard of irrigation water and the one of domestic water are different and the stored water was not suitable for domestic use. He added that the Project would not affect the springs.
Mr. Jean Marie Vianey, a farmer from Bugera	He asked if farms in the command area will be moved to other place of kept in the same place	Mr. Jean Claude replied that it was too early to comment on question in terms of farms in command area but added that if the area was for cattle, it would be taken into consideration. He said that there was a policy on land use and the RAP would clarify the real situation of the field.

Speech by the Ngoma Vice-Mayor

Participants listening to project introduction

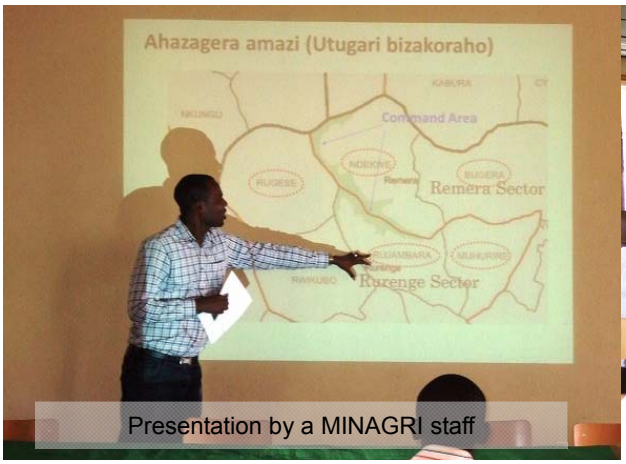
As a whole, the participants welcomed the Project, since they can access to irrigation water which leads to crop production increase, some of them presented their concerns about compensation and

timing they have to stop cultivation, though. The attendance list is attached in Appendix - 6.11.

2) Second public consultative meeting

The second public consultation meeting to present anticipated environmental impacts by the Project was organized on November 14, 2013, at Ngoma district. Village heads concerned, official personnel of Cells and Sector concerned, Ngoma District Agronomist, the Mayor of Ngoma District, MINAGRI staff, private environmental consultants, and the JICA Survey Team members participated in the meeting. The meeting was supported by Green and Clean Solution Ltd. consultants. MINAGRI staff also participated in the meeting. The specific objectives of the meeting were:

- Create awareness of the Project for the people
- To explain social and environmental impacts and proposed mitigation measures
- To obtain stakeholders' responses, feedback and concerns on the Project;



Presentation by a MINAGRI staff


Participants listening to the presentation

The environmental consultants and MINAGRI staffs explained that positive and negative impacts of the Project, and presented mitigation measured against the anticipated negative impacts and compensation measures based on the entitlement matrix. After the presentations, the participants were given opportunity to express their views, comments and questions. They are summarized as shown below:

Table 1.3.2.16 Outcome of the Second Consultative Meeting

Speaker	Issues/Comments by Participants	Explanation by MINAGRI and CGS Ltd Representatives
The Mayor of Ngoma District	He request Local Authorities to assist all donor who join them in any development program. Specifically for this Project for dam construction the Local leader must very well understand the Project and sensitized again famers to own the Project	Village leaders and PAPs representative are willing to support the Project
Mr. Gaspard NZAHABWANAYO, The Social, Economic and Development Officer at RUJAMBARA Cell	He asked whether private land that the proposed irrigation canal will cross will be compensated in consideration of all plot size or the area to be affected	The compensation will cover only the affected area not all plot size. Other remaining land will be also part of beneficiaries' of the irrigation scheme
Mr. Jean Claude SINGIRANKABO, The Executive Secretary at	He welcomed the Project because after installation of irrigation canal, the farmers will cultivate 3 times per year. He also asked more explanation about fish	There will be no conflict of interest between irrigation process and fish farming, since it is not planned to drain all water in dam. Fish farming will be

Speaker	Issues/Comments by Participants	Explanation by MINAGRI and CGS Ltd Representatives
NDEKWE Cell	farming in order to understand how to combine with irrigation in paddy.	done by using cage in the dam. Water Users Organization will be established to manage and handle all issues related to proper use of water resources.
Mr. RURANGIRWA SHABANI. The RMERA Acting Executive Secretary at Sector level	How is the Budget of this Project? We need also to now if in the Project package they are a budget for monitoring of activities in Project period and also after phase out project.	The facilitator explained the purpose of today's meeting is to get comments and additional input focused on environmental and social impacts. All concerns will be included in final project studies and budget.
Mr. UWIMANA JMV, The RURENGE Acting Executive Secretary at Sector level	Do you consider the affected people who will be compensated? If yes please also make attention about the proper time of compensation period because it's must be done before all construction activities.	Compensation will be done based on the law before starting dam construction activities
Emmanuel, Consultants from Green and clean Solution ltd	He wants to know if the local leader are ready to assist MINAGRI in this Project and what would be their Roles	Local leaders are willing to attend usually in evaluation practice of asset for each affected people. They will also take prior to sensitized farmers to own the Project activities
Ms. UFITIKIREZI Colletta, The Executive Secretary of BUGERA Cell	She emphasized on considering the rights of all beneficiaries by law on cash compensation while making payment by transfer on account because sometimes men do not give accountability to their wives.	All beneficiaries must approve the cost of their asset and the allocation account by mutual consent. During compensation, all family members will be present to avoid family conflict
Mr. NZABIRINDA Damien, Rurenge Sector Agronomist	Existing water collection point will be damaged during construction. There is a possibility that the people will collect water from the dam for domestic water consumption and it is dangerous for them. If it possible, please put a hand pump for them to prevent from accident.	The people can use other water sources such as water canal. MINAGRI agrees with his idea and it will be considered for design.
Ditto	It is needed to protect dam from soil erosion.	It is recommended to plant trees to protect dam from erosion in the area within 50m from the dam lake limitation.

The participants appreciated the proposed project in general, since it is expected that the Project will boost local economy due to increased productivity while they presented concerns regarding compensation method and timing. Some of village heads committed to collaborate with MINAGRI for the smooth project implementation.

3) Third public consultative meeting

The third public consultation meeting to present outline of the project and activities to be done by the beneficiaries was organized on March 21st, 2014, at Ngoma district. Village heads concerned, official personnel of Cells and Sector concerned, Ngoma District Agronomist, the staff of Ngoma District, MINAGRI staff, JICA Rwanda office staff and the JICA Survey Team member participated in the meeting. Official personnel of Ngoma District requested to the participants to share the information with general farmers. The specific discussions of the meeting are as follows:

Table 1.3.2.17 Outcome of the Third Consultative Meeting

Speaker	Issues/Comments by Participants	Explanation by MINAGRI and Japanese
Executive Secretary of Ndekwe Cell	Are there any constraints with the project of terraces construction, which has been already started at hillside? Where is coordination?	No negative impact with terrace project is expected. There is coordination between the terracing work and the project.
Mr. Arcade MURAGIJEMUNGU, Executive Secretary of Rurenge Sector	Before implementation, the Local Government Authority needs at least three months for population mobilization. Please inform them the schedule when the project plan is approved.	The Local Government Authorities will be informed around six months before of activities, when the final census will be implemented.
Mr. Arcade MURAGIJEMUNGU, Executive Secretary of Rurenge Sector	The project team and the Local Government Authorities are recommended to go on field together and to explain to the beneficiaries (not their representatives) about the project activities, compensation, implementation schedule, etc.	The farmers knows where are placed the pegs. The Local Government Authorities have to start the mobilization in order to prevent some losses like the construction in affected area or cultivation of perennial crops.
Executive Secretary of Ndekwe Cell	It is difficult to regroup farmers for different activities. It is better to form different cooperatives and to let WUO manage irrigation water.	It is better to get advices from RCA's experts. Usually, when farmers share the resources, they have to form one cooperative. According to the experience of MINAGRI, the coordination is not a problem. An integrated cooperative is important in terms of organization.
Executive Secretary of Ndekwe Cell	The management of agriculture cooperatives is not limited on the water resource but also on objectives, activities, needs, inputs, issues. It is better to create different cooperatives. Farmers who have same activities and problems have to form one cooperative. We have to debate with farmers and we will decide this issue taking account of profit of the farmers.	The WUO will manage water issues. According to the experience, it is difficult to manage many cooperatives. For instance, one farmer may be member of many cooperatives because some farmers cultivate in marshland and at hillside. Therefore, it is recommended to form an integrated cooperative. (It was concluded that the stakeholders will consult RCA experts）.
Social and Economic Development Officer, Rujambara Cell	The project will provide irrigation equipment like hosepipes to WUO and eventually to cooperatives. What about their storage facilities?	These facilities are not provided by the project. But, the project will construct a boathouse to store the boats for the WUO, where farmers can keep some equipment. We hope to create a strong cooperative(s) which are able to construct their own office by members' contribution or loan from banks. MINAGRI and Local Government Authorities are ready to support them.
Social and Economic Development Officer, Rujambara Cell	It is better to include study tours in project activities to enhance farmers' understanding.	Yes, this kind of activities will be included in the soft component.
Mr. Eric NSABIYUMVA, Village Head, and Executive Secretary of Ndekwe Cell	Farmers are already informed that the marshland is the government property which means that the farmers will lose the cultivation plots in marchland. Population is ready to resign. We have to inform them before and give them enough time for harvesting.	It is recommendable to take time to discuss within community on this point because some farmers who are not satisfied with compensation strategies may exist. The success will depend on a good communication and cooperation between Local Government Authorities and the people.

The participant lists of the series of public consultation meeting are attached in Annex 6.6(1), (2) and (3).

4) Fourth public consultative meeting

The fourth public consultation meeting to present outline of the project and activities, targeting general farmers, was organized on May 14th, 2014, at the field of Ngoma District. Around 200 farmers participated in the meeting. Two Executive Secretaries of Rurenge and Remera Sector, JICA project team, JICA Rwanda office and MINAGRI staff assisted the meeting. In general, the farmers welcomed

the project and promised a good collaboration.

1-3-3 Checklist

Category	Environmental Item	Main Check Items	Yes (Y) No (N)	Confirmation of Environmental Considerations
1. Permits and Explanation	(1) EIA and Environmental Permits	(a) Has EIA report been officially completed? (b) Has EIA report been approved by authorities of the host country's government? (c) Has EIA report been unconditionally approved? If conditions are imposed on the approval of EIA report, are the conditions satisfied? (d) In addition to the above approvals, have other required environmental permits been obtained from the appropriate regulatory authorities of the host country's government?	(a) Y (b) Y (c) N (d) N	a) and b EIA report has been completed and approved by RDB. c) It was approved under the conditions that the developer shall conform minimum basic safety, health, operational and environmental protection and to present its commitment. d) No other permit is needed. However, water use permit shall be gotten.
	(2) Explanation to the Public	(a) Are contents of the Project and the potential impacts adequately explained to the public based on appropriate procedures, including information disclosure? Is understanding obtained from the public? b) Are proper responses made to comments from the public and regulatory authorities?	1) Y 2) Y	1) Affected persons have been already informed of the Project. They welcome the Project. 2) MINAGRI officers responded to their questions properly.
	(3) Examination of alternatives	(a) Have alternative plans of the Project been examined with social and environmental considerations?	1) Y	At first, head works construction was examined as an alternative for irrigation program. However, it cannot be recommended in terms of cost-effectiveness. At next stage, locations of irrigation canal construction were examined considering Eucalyptus forests and houses located in the area. It is proposed to avoid constructing canal nearby such forests and houses to minimize damages to assets of the people.
2. Mitigation measures	(1) Water Quality	(a) Does water quality of dam pond/reservoir comply with the country's ambient water quality standards? Is there a possibility that proliferation of phytoplankton and zooplankton will occur? (b) Does the quality of water discharged from the dam pond/reservoir comply with the country's ambient water quality standards? (c) Are adequate measures, such as clearance of woody vegetation from the inundation zone prior to flooding planned to prevent water quality degradation in the dam pond/reservoir? (d) Is there a possibility that reduced the river flow downstream will cause water quality degradation resulting in areas that do not comply with the country's ambient water quality standards? (e) Is the discharge of water from the lower portion of the dam pond/reservoir (the water temperature of the lower portion is generally lower than the water temperature of the upper portion) planned by considering the impacts to downstream areas?	(a) Y (b) Y (c) Y (d) N (e) Y	The water source of the proposed dam is spring, which is used for drinking water of the people at present. Therefore, the dam water will comply with irrigation water quality standard (FAO). There is no source of eutrophication around the proposed, and no eutrophication is expected. (d) Water springs from the ground in and around the site, no severe water deterioration is expected. (e) It is not thought that water temperature of lower part of dam is very lower than others. The water temperature will be confirmed at the detail design stage.
	(2) Waste	(a) In the case of that large volume of excavated/dredged materials are generated, are the excavated/dredged materials properly treated and	(a) Y	The generated waste by the construction will be reused for other purposes.

Category	Environmental Item	Main Check Items	Yes (Y) No (N)	Confirmation of Environmental Considerations
		disposed of in accordance with the country's standards?		
3. Natural Environment	(1) Protected Areas	(a) Is the Project site located in protected areas designated by the country's laws or international treaties and conventions? Is there a possibility that the Project will affect the protected areas?	(a) N	Protected areas are far away from the construction sites and no damage is expected to such protected areas.
	(2) Ecosystem	(a) Does the Project site encompass primeval forests, tropical rain forests, ecologically valuable habitats (e.g., coral reefs, mangroves, or tidal flats)? (b) Does the Project site encompass the protected habitats of endangered species designated by the country's laws or international treaties and conventions? (c) Is there a possibility that the Project will adversely affect downstream aquatic organisms, animals, plants, and ecosystems? Are adequate protection measures taken to reduce the impacts on the ecosystem? (d) Is there a possibility that installation of structures, such as dams will block the movement of the migratory fish species (such as salmon, trout and eel that move between rivers and sea for spawning)? Are adequate measures taken to reduce the impacts on these species?	(a) N (b) N (c) – (d) N	(d) There is no migratory fish.
	(3) Hydrology	(a) Is there a possibility that hydrologic changes due to the Project will adversely affect surface water and groundwater flows?	(a) N	Since 20% of basic flow will be discharged into the downstream, no significant impact for surface water and ground water is expected.
	(4) Topography and Geology	(a) Is there a possibility that reductions in sediment loads downstream due to settling of suspended particles in the reservoir will cause impacts, such as scouring of the downstream riverbeds and soil erosion? Is there a possibility that sedimentation of the reservoir will cause loss of storage capacity, water logging upstream, and formation of sediment deposits at the reservoir entrance? Are the possibilities of the impacts studied, and adequate prevention measures taken?	(a) N	Proposed burrow pit will be submerged in the dam. No big-scale geological change is expected.
4. Social Environment	(1) Resettlement and Land expropriation	(a) Is involuntary resettlement/land expropriation caused by Project implementation? If involuntary resettlement is caused, are efforts made to minimize the impacts caused by the resettlement? (b) Is adequate explanation on compensation and resettlement assistance given to affected people prior to resettlement? (c) Is the resettlement plan, including compensation with full replacement costs, restoration of livelihoods and living standards developed based on socio-economic studies on resettlement? (d) Is the compensations going to be paid prior to the resettlement and land expropriation? (e) Is the compensation policies prepared in document? (f) Does the resettlement plan pay particular attention to vulnerable groups or people, including women, children, the elderly, people below the poverty line, ethnic minorities, and indigenous peoples? (g) Are agreements with the affected people obtained prior to resettlement? (h) Is the organizational framework established to properly implement resettlement? Are the capacity and budget secured to implement the plan?	(a) Y (b) Y (c) Y (d) Y (e) Y (f) Y (g)N/Y (h) Y (i) Y (j) N	(a) No resettlement will be caused while land expropriation will be done. It was examined to minimize the land to be expropriated and to avoid relocation. (b) Consultation meeting to explain basic compensation package for the affected persons was done. (c) Compensation cost for land and standing crops is estimated following the governmental regulations, which considers market price. In addition, support for livelihood recovery for farmers who cultivated in the marshland is proposed. (d) Prior to land expropriation, compensation shall be paid. (e) It is included in the report. (f) It is planned to give high priority to vulnerable groups for employment of labors.

Category	Environmental Item	Main Check Items	Yes (Y) No (N)	Confirmation of Environmental Considerations
		(i) Are any plans developed to monitor the impacts of resettlement? (j) Is the grievance redress mechanism established?		(g) At the consultation meeting, the representatives of affected people welcomed the Project. It is Outline Design stage of the Project, therefore, after official approval of the Project by both government, final census and asset survey will be done. After that, final agreement on the compensation will be exchanged. (h) Resettlement and Compensation Committee will be established based on the regulations. Training cost of the committee and monitoring cost by the committee are included in the budget. (i) A proposed monitoring plan is documented in the report. (j) Resettlement and Compensation Committee will handle complaints in collaboration with traditional mediator.
	(2) Living and Livelihood	(a)Is there a possibility that the Project will adversely affect the living conditions of inhabitants? Are adequate measures considered to reduce the impacts, if necessary? (b) Is there a possibility that the Project will adversely affect the downstream land uses? In particular, is there a possibility that reductions in the supply of fertile soils to downstream areas will adversely affect agricultural production? (c) Is sufficient infrastructure (e.g., hospitals, schools, roads) available for project implementation? If existing infrastructure is insufficient, is a plan developed to construct new infrastructure or improve existing infrastructure? (d) Is there a possibility that diseases, including communicable diseases, such as HIV will be introduced due to immigration of workers associated with the Project? Are adequate considerations given to public health, if necessary? (e) Is there a possibility that the existence of the dam will cause impacts on water navigation, such as limitations of vessel traffic and water area uses by local inhabitants? (f) Is the minimum flow required for maintaining downstream water uses secured? (g) Is there a possibility that reductions in water flow downstream or seawater intrusion will cause impacts on downstream water uses and land uses? (h) Is there a possibility that water-borne or water-related diseases (e.g., schistosomiasis, malaria, filariasis) will be introduced?	(a) Y (b)Y and N (c) N (d) N (e) N (f) Y (g) N (h) Y	(a) It was examined to minimize the land to be expropriated and to avoid relocation. (b) Farmers who cultivate in the downstream can access to the stable irrigation water while some of them will be expropriated. (c) The Project site is located on farmland, there is no hospital or school. (d) It is planned to employ local residents as much as possible, such adverse effect will be limited. (e) There is no navigation in and around the site. (f) 20% of basic flow shall be discharged into the downstream. (g) There is no sea in the country. (h) Probably, it can be caused, Ministry of Health has a program to reduce Malaria by distribution of mosquito net free of charge.
	(3) Heritage	(a) Is there a possibility that the Project will damage the local archeological, historical, cultural, and religious heritage sites? Are adequate measures considered to protect these sites in accordance with the country's laws?	(a)N	There is no heritage in and around the site.
	(4) Land scape	(a) Is there a possibility that the Project will adversely affect the local landscape? Are necessary measures	(a)N	There is no special and esthetic land scape in and around the site.

Category	Environmental Item	Main Check Items	Yes (Y) No (N)	Confirmation of Environmental Considerations
		taken?		
	(5) Ethnic Minorities and Indigenous Peoples	(a)Does the Project comply with the country's laws for rights of ethnic minorities and indigenous peoples? (b) Are considerations given to reduce impacts on the culture and lifestyle of ethnic minorities and indigenous peoples?	(a) (b) N	There is no minority people.
5. Others	(1) Impacts during Construction	(a) Are adequate measures considered to reduce impacts during construction (e.g., noise, vibrations, turbid water, dust, exhaust gases, and wastes)? (b) If construction activities adversely affect the natural environment (ecosystem), are adequate measures considered to reduce impacts? (c) If construction activities adversely affect the social environment, are adequate measures considered to reduce impacts? (d) In the case of the Projects including borrow sites, if construction activities adversely affect the natural environment (ecosystem), are adequate measures considered to reduce impacts? (e) If necessary, is health and safety education (e.g., traffic safety, public health) provided for Project personnel, including workers?	(a) Y (b) - (c) Y (d) – (e) Y	(a) Some mitigation measures such as water spray to reduce dust are proposed. (b) Severe negative impact on the natural environment is not expected. (c) Due to land expropriation, some damages to social environment are expected, however, supports to restore their living standard are proposed. (d) The Project site has been already developed for farming. There is no primordial nature. (e) It is planned to provide as needed.
	(2) Accident	(a) Are adequate contingency plans and mitigation measures developed to cover both the soft and hard aspects of the Project, such as accident prevention programs, installation of prevention facilities and equipment, and safety education for workers? Are adequate measures for emergency response to accidental events considered? (b) Is a warning system established to alert the inhabitants to water discharge from the dam?	(a) Y (b) N	(a) It is planned to present safety instruction and practice regular maintenance of equipment and vehicles. (b) Warning system has yet to be established, however, WUO will be responsible for the water management.
	(3) Monitoring	(a) Does the proponent develop and implement monitoring program for the environmental items that are considered to have potential impacts? (b) Are the items, methods and frequencies of the monitoring program adequate? (c) Does the proponent establish an adequate monitoring framework (organization, personnel, equipment, and adequate budget to sustain the monitoring framework)? (d) Are any regulatory requirements pertaining to the monitoring report system identified, such as the format and frequency of reports from the proponent to the regulatory authorities?	(a) Y (b) Y (c) Y (d) Y	(a) Monitoring parameters are proposed. (b) Practical methods are proposed. (c) It is included in the report. (d) Draft monitoring format is attached in the report.
6. Note	Note on Using Environmental Checklist	(a) If necessary, the impacts to trans-boundary or global issues should be confirmed (e.g., the Project includes factors that may cause problems, such as trans-boundary waste treatment, acid rain, destruction of the ozone layer, or global warming).	(a) N	(a) Such big scale of environmental impact is not anticipated and the construction site is enough far away (longer than 30km) from the international boundary.

CHAPTER 2 CONTENTS OF THE PROJECT

2-1 Basic Concept of the Project

2-1-1 Overall Goal and Project Purpose

Agriculture is one of the most important industries in Rwanda, however, various constraints, namely, small-scale farming, dominance of hilly area, primitive agricultural techniques, poor infrastructure and so on hinder agricultural productivity development. "Rwanda Vision 2020", a mid- and long-term development plan, emphasizes the promotion of high-value/high-productive farming and market oriented agriculture. On the other hand, the Strategic Plan for the Transformation of Agriculture III (SPAT III) stipulates the importance of irrigation in the agriculture, and irrigation development is one of sub-programs in the plan.

The Ministry of Agriculture and Animal Resources (MINAGRI), which is responsible for agriculture and irrigation development in Rwanda, has prepared the Rural Sector Support Project (RSSP) plans for marshlands development and the Land-husbandry, Water-irrigation and Hillside-harvesting (LWH) project plans for hillside farmlands. The ministry aims at agricultural development in the country through promotion of irrigation and soil conservation.

The Project is one of LWH sub-projects, as-called "Ngoma22 sub-project", is located on Ngoma District, Eastern Province. The Project will cover construction of a reservoir and irrigation facilities, procurement of necessary materials, implementation of soft component and plot construction of the existing paddy field. The overall goal, project purpose and Project Design Matrix (PDM) are as shown below:

Project Purpose： Agricultural productivity in the Project area is stabled and increased.

Overall Goal： Income of the target group is increased.

Table 2.1.1.1 Project Design Matrix（PDM）

Project name:
Project period: August 2013 to July 2016
Project area: Ngoma22 site in Ngoma District, Eastern Province
Target group: around 1,100 households in the Project area
Beneficiary area: upland filed 265ha, paddy field 35ha as of May 2014

Narrative Summary	Indicator	Means of Verification	Important Assumption
Overall Goal Income of the target group is increased.	Benefits of main crop production	1. Record of household income 2. Statics data of Ngoma District	・ Severe natural disaster is not caused. ・ Policy of Rwandan agricultural development is not changed extremely.
Project Purpose Agricultural productivity in the Project area is stabilized and increased	Production area and yield of main crops	1. Water management record 2. Farming extension report of District/Sector 3. Statistic data of Ngoma District	・ Unit prices of agricultural products and materials are not changed.
Outputs 1. Necessary irrigation facilities for hillside irrigation are established 2. Irrigation agriculture can be implemented in the	1. Intake volume 2. (1) Planted area (2) Cost of O&M	1. Discharge measurement 2. (1) Statics data of Ngoma District (2) O&M report (3) WUO financial report	・ Roles and responsibilities of MINAGRI and WUO for O&M of irrigation facilities are not changed.

Project area			
Activities 1. Basic design of dam and other appurtenant facilities is done. 2. Detailed design of dam and other appurtenant facilities is done. 3. Dam and other appurtenant facilities are constructed. 4. WUO is established and technology transfer of O&M of irrigation facilities is implemented.	Inputs （Japanese side） 1. Preparatory survey 2. Detailed design survey 3. Construction of irrigation facilities 4. Implementation of soft component 5. Model project implementation of plot construction, canal/drainage and O&M road construction in the existing paddy field	（Rwandan side） 1. Provision of information and data 2. Implementation of obligation to be shouldered by Rwandan side 3. Plot construction of the existing paddy field	Pre-condition ・ Policy of Rwandan agriculture and irrigation is not changed extremely.

2-1-2 Project Brief

After completion of the filed survey which was done from August to November 2013, JICA survey team continued its analysis as a domestic survey. The team finally compiled the project components as in the table below.

Table 2.1.2.1 Project Components

Facilities	Dimension / Contents
1. Dam reservoir	・reservoir capacity ：960,000m^3 ・Dam height：14.9m ・dam type：Homogeneous type ・Spill way：RC type, Rectangular open canal ・Discharge facility for low water level：1set ・Intake facilities on both banks：1 set ・Other ancillaries：1set
2. Pump station	・Pump house：RC type、Direct foundation ・Pump equipment：horizontal centrifuge pump 1kw×5nos Solar panel 280W、24V、153nos
3. Main irrigation canal Open canal, Pipeline)	・Open canal：Concrete lining, Length 18.7km ・Pipeline ：Length 8.1km ・Diversion box, Drainage facilities：1set
4. Discharge tank	・No. 1 Discharge tank：3.75m×2.0m ・No. 2 Discharge tank：3.75m×2.0m ・No. 3 Discharge tank：2.0m×2.0m
5. Regulating tank	・No.1 Regulating tank ：RC type, Capacity 1,500m^3 ・No.2 Regulating tank ：RC type, Capacity 330m^3 ・No.3 Regulating tank ：RC type, Capacity 120m^3
6. Drainage box	・Drainage collection box 185nos, Drain canal
7. Secondary canal and on-farm facilities	・Pipeline：Length 26.7km ・Hydrant：1 set
8. Plot Construction for existing paddy field	・Plot construction：1 set ・Diversion box：12 place ・irrigation canal/drain and O&M road：3.85km

2-2 Outline Design of the Japanese Assistance

2-2-1 Design Policy

2-2-1-1 Basic Policy

2-2-1-1-1 Targeted Site of the Project

Although the requested site from the Government of the Republic of Rwanda (hereinafter referred to as "GoR") was five sites, four sites among them have found out not to be suitable for Japan's grand aid project because of low feasibility for storing water in consideration of the size of catchment area as the results of investigations conducted before, and this fact was understood by GoR. On the survey conducted in 2012 that detail information about the one site which had requested from the beginning was collected and feasibility was evaluated, the site concerned, namely Ngoma22 was found out prospective site for irrigation development. From these backgrounds, only the Ngoma22 is selected for the targeted site of grant aid project.

2-2-1-1-2 Scope of Work of the Project

Among the components requested which consist of construction of facilities such as water reservoir and irrigation canal, farm land reclamation work on hillside which is called land husbandry or terracing work is supposed to be implemented by GoR. On the other hand, study for arrangement of on-farm facilities in order to function farm land and irrigation facilities as integrated such as arrangement of hydrants installed on the secondary canals and the outline design of terracing necessary for this survey are supposed to be conducted by Japanese side.

The items of facilities requested by GoR are as follows.

- Dam and reservoir (dam body, spillway, spillway canal and intake and outlet facility)
- Main and secondary canals
- Pump and solar panel
- On-farm irrigation equipment (Hose, etc.)
- Paddy plot construction

Establishment and strengthening of Water Users Organization (WUO) including aquaculture training, O&M of irrigation facilities/water management/farming technique, and test filling of the reservoir shall be studied as soft components.

2-2-1-1-3 Basic Policy on Studying on Facility Design

1) Available water amount

Available water amount or design flood discharge on the study of water resource facility shall be calculated through the runoff analysis using the latest observed stream flow data at the site for more than a year. Expected inflow from the river shall be estimated on the dry year of occurrence probability 1/5 as reference to other LWH project.

2) Irrigation water for paddy field

After the construction of dam, irrigation water for paddy field shall be supplied by the dam reservoir because the present river flow will be interrupted. Water requirement for paddy field is estimated in consideration of returned water in the downstream area which is supplied from surrounding catchment basin as surface water and ground water. Moreover, river maintenance

water should be examined taking into account of influences over water users at the downstream and conservation of river environment. Necessary volume of this water is released as the relation with irrigation water requirement for paddy field.

3) Irrigation water for farmland

Irrigation water for farmland on hillside is calculated by meteorological data such as rainfall or temperature based on cropping schedule recommended. Meteorological conditions applied are observed data on the reference dry year determined on water resource study as well as average data for past thirty years for reference of examining the facility size based on the irrigation water obtained on the condition.

4) Beneficiary area size of farmland

Since terracing works will be implemented on the command area of hillside, the size of farm land after the construction will be reduced compared to current one. Moreover, because there exists unsuitable land for irrigation such as present road or rocky area, the size of command area as well as facilities should be estimated in consideration of these reductions.

5) Pump irrigation

The power sources of pump facilities are supposed to utilize commercial electricity or solar generation. Appropriate power source facilities should be examined taking into considerations of present condition of power grid development and technical level in Rwanda as well as construction and O&M cost.

6) Canal type

Since canal type will affect function of whole canal network and construction cost, it is selected through the study of economy, water management system and O&M condition.

On other LWH projects have adopted two types of canal system, namely, open channel type for main canal and pipeline type for secondary canal. Comparative study should be conducted taking account of each characteristic.

7) On-farm irrigation facilities

Other LWH project sites now under developing in Rwanda adopting the on-farm earth canal where irrigation water flows from hydrant have a problem that irrigation water can not reach to the end of the farm land because of high permeability of soil. Since the soil in this Project area are proved to having high permeability too, on-farm irrigation facilities should be considered saving of irrigation water amount and faming labor as well as realization of effective farm work.

8) Paddy field improvement plan

On the paddy field of 35 ha in the downstream area from dam which is subject of command area of the Project, unbalanced irrigation water distribution or low workability are pointed currently. Therefore, countermeasures against these issues such as rearrangement of plots, development of irrigation and drainage canals and construction of management facilities like O&M road shall be planned.

2-2-1-2 Considerations on Natural/Environmental Conditions

2-2-1-2-1 Meteorological Conditions

Observed data at the Gahororo observatory station in Ngoma district near the Project site is applied

basically for meteorological conditions necessary for the study of irrigation water requirement and so on such as temperature, rainfall and humidity. However, humidity, wind velocity and sunshine hours which are not observed at the station apply the data at Kigali airport observatory station. It is noted that data of rainfall vary widely by years.

Figure 2.2.1.1 Location Map of Major Meteorological Stations in Rwanda

Table 2.2.1.1 Average Climate Conditions near the Project Site

Month	Rain mm	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours
January	96.6	12.8	25.4	78	173	5.6
February	100.9	12.7	25.5	76	173	5.6
March	147.8	12.7	25.5	79	173	5.3
April	192.5	12.6	25.0	83	156	5.2
May	111.3	12.8	25.2	80	173	5.6
June	20.1	13.0	25.8	69	181	7.1
July	10.8	13.2	26.4	61	207	7.5
August	30.8	12.7	26.7	61	225	6.9
September	69.5	12.7	26.5	69	216	6.0
October	109.1	12.7	25.8	76	216	5.7
November	142.5	13.2	25.0	81	190	5.1
December	110.9	12.9	25.0	80	181	5.3
Average	1142.8	12.8	25.6	74	189	5.9

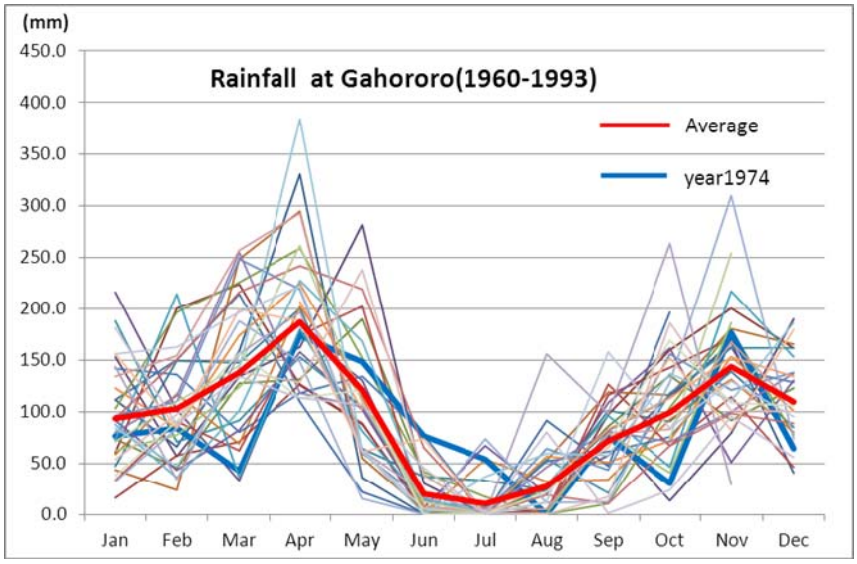


Figure 2.2.1.2 Rainfall Data at Gohororo Meteorological Station (1960 - 1993)

2-2-1-2-2 Topographical and Geological Conditions

Topographical and geological conditions at the sites of reservoir and irrigation facilities apply the results of topographic survey and geological survey including boring investigation and soil tests conducted on this survey referring topographic and geographic map collected in Rwanda.

2-2-1-2-3 River Discharge and Others

The observed data such as stream flow or ground water level at the site collected by JICA expert from February in 2012 have been accumulated. These data for more than one year should be utilized as fundamental conditions for analyzing runoff connected to rainfall, planning of water source and studying irrigation facility design.

Photo 2.2.1.1 Stream-flow Observation Facility

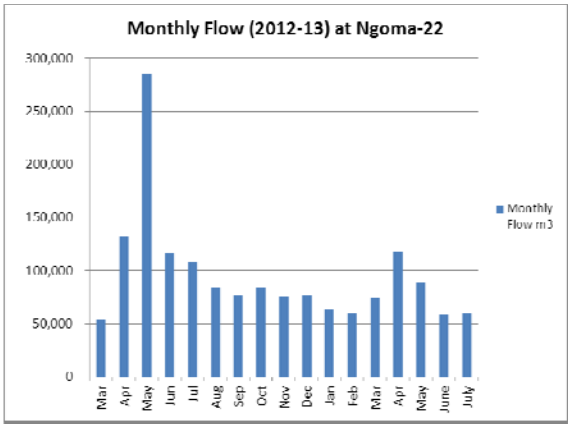


Figure 2.2.1.3 Observed Monthly River Flow

2-2-1-3 Policy for Socio-Economic Conditions

The beneficial area of the Project is composed of five villages in Rurenge Sector and four villages in Remera Sector in Ngoma District located at the eastern part of the country. There is an existing rice cooperative at the Project site, which is Kigarama Rice Farmers Cooperative organized by those who from nine villages. The members of the planned WUO will be consisting from the same

people of the Cooperative and the beneficiaries who cultivate horticulture crop on the hillside though they are belonging to different administratively. Taking into consideration easier O&M, however, only one WUO will be organized in a marshland as a matter of policy of the Project.

Regular maintenance such as dredging and weeding is required for planned canals and others but Umganda, which is traditional mutual work for public project, can work effectively for this matter. By making use of Umganda, it is expected that beneficiaries will maintain main and secondary canals, drainage canal and O&M road and so on, which will foster ownership of the constructed irrigation facilities and lead to sustainable use of the facilities to be constructed.

For the cropping pattern of the Project, maize, beans/pulses, carrot and eggplant and so on are proposed considering current crops that farmers are cultivating at the site and the dietary habit of the people is assumed not to change so significantly in future too. Farming practices for those crops are done both men and women from plowing to harvesting by manual.

As to agricultural benefit generating from irrigation, increase of yield by applying improved agricultural technologies combined with availability of water is proposed as an agricultural policy of the Project taking into account site condition of valley, small farm size, lack of farmland for expansion.

2-2-1-4 Basic Policy on Construction and Procurement Conditions

1) Laws

Basic wage and labor hours of the Project are determined taking consideration into the Labor Standard Act in Rwanda.

2) Standards

Specification, quality and verification of materials and construction works of the Project will be based on the Japanese Industrial Standards (JIS) and the International Organization for Standardization (ISO), given that any standard concerning design and construction control has yet to be established in Rwanda.

3) Construction conditions

East African Community (EAC), which Rwanda has affiliated in 2007, has five signatory states at present, namely, Kenya, Tanzania, Uganda, Bunge and Rwanda. Within the EAC, physical distribution and personal exchange have been accelerated so far, many materials and technologies have been imported to Rwanda, especially, from Kenya, which results in technology and performance improvement for Rwanda. Major construction companies in Kigali have some experiences of high-rise building construction and road expansion. Sale of freshly mixed concrete including concrete production and delivery have been operated by using concrete pump vehicles. Such construction companies own major construction machines.

4) Construction materials

Banking materials, aggregates, stones, cement, pipes, pumps, solar panels and pump control panels can be procured in Rwanda. On the other hand, valves, ultrasonic current meters, low pressure power panels will be procured in Japan.

General construction machines such as backhoe and dump truck can be rented from some construction companies in Rwanda. However, it is planned to procure tractor, laser-leveler and so on in Rwanda and Japan.

5) Policy on utilization of Rwandan construction companies

RSSP sub-projects and LWH sub-projects have already been implemented, and some Rwandan construction companies have enough experiences of reservoir construction, irrigation canal establishment, plot construction and so on. It is proposed to utilize such construction companies, which have head offices in Kigali, for the project implementation.

6) Policy on determination of facility and material grade

Grade of facilities and materials are determined at the same level of as actual performance in Rwanda so far. In terms of maintenance, commonly used and durable grade will be applied for the Project.

7) Policy on construction methods, procurement and time management

It is necessary to discuss with MINAGRI to confirm about procedures of customs, tax exemption and so on for smooth construction as planned. Rainy season is from March to May (main rainy season), especially, April has large amount of rainfall in general. Therefore, the construction works will not be implemented basically in April and dam body banking works will be implemented from June to September.

8) Policy on construction control system

A resident supervisor will be in charge of overall construction works during the construction period, and construction supervisor will be assisted at the beginning and end of construction works. For the purpose of schedule, quality and safety control, a responsible civil engineer for reservoir construction will confirm situations of excavation for dam body, banking and setting of buried instrument, while electricity and machine engineer will check setting of electricity materials, trial operation of pump and solar system to be installed in the pump station and solar system.

2-2-1-5 Policy of Agricultural Plan

1) Crop selection

Crops with high demand and high profitability are proposed as a policy for the agricultural plan, and the ones that have already cultivated by farmers in the site due to adaptability to the soil and temperature are introduced. Increase of yield by year-round irrigation combined with improved farming technologies is also planned. At the marshland, paddy farming shall be continued in accordance with the national policy. At the hillside, cabbage, eggplant, carrot etc., with high consumption and higher preference are introduced along with tree tomatoes and coffee.

Table 2.2.1.2 Reasons for Crop Selection

Crops	Reasons for Selection
Paddy	Imported crop due to lack of domestic production. Crop being promoted in marshland as the national policy.
Maize	Highest demand (16.7kg/capita) in a cereal group than rice and sorghum. Many beneficiaries want to cultivate maize on hillside according to the baseline survey.
Bean/pulses	High demand (29.3kg/capita). Cultivating widely on hillside with mono and mixed cropping system with maize and other crops. Good for maintaining soil fertility.
Cabbage	Can harvested 3times a year, and high demand for consumption.
Tomatoes	High consumption(4.3kg/person/year), and higher profitability, higher demand in markets.
Carrot	High preference and higher demand in market
Eggplant	Sector agronomist recommended due to preference by farmers
Tree Tomato	Selling not only local market but also Kigali city at higher price, higher demand, higher profitability, processable for juice and jam.
Coffee	Exporting crop with higher profit, suitable for sloped areas of the valley of the site

2) Proposed cropping pattern

Present irrigable area of 64 ha (paddy: 35ha + hillside: 29ha) will be expanded to 300 ha by implementing project. The cropping pattern with higher cropping intensity considering more dryly season crops in response to availability of water is proposed as the figure shown below. Paddy is indispensable to substitute importing rice, and areas for other crops will be maximized to expand as much as possible depending on capacity of water availability of the planned dam. According to the District agronomist, proposed crops have been already cultivating by beneficial farmers in the site, and adapted to local climate and soil conditions, and have higher demand at local markets nearby.

Stable production with higher land use ratio can be expected by improvement of irrigation condition. As for tomato production, beans/pulses will be introduced between two crops of it to prevent damage due to continuous cropping of tomatoes.

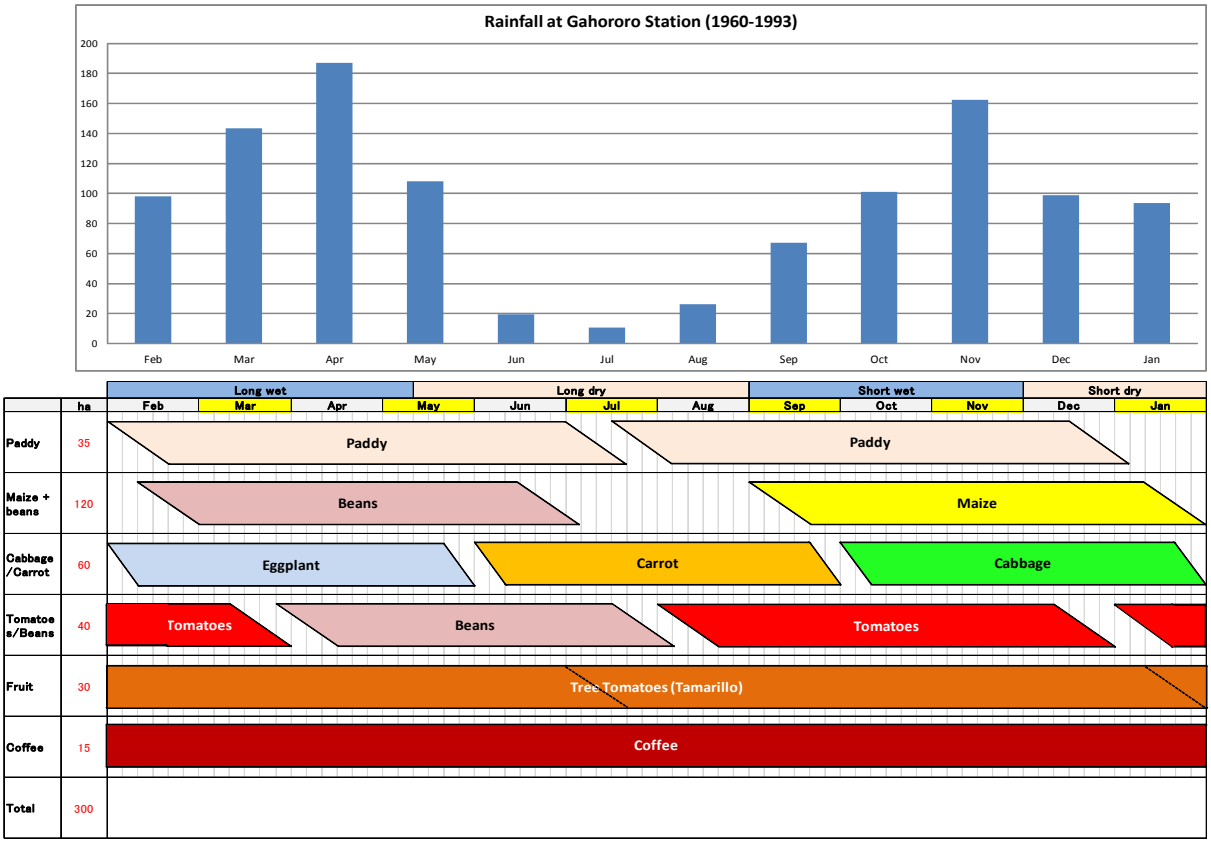


Figure 2.2.1.4 Proposed Cropping Pattern and Climate Conditions

3) Present yields and targeted yields

By applying improved farming technologies combined with developed irrigation water source increase of crop yields can be expected within projected three years. Targeted yields is projected as shown below based on field survey and discussion with agronomists of District and Sector Officers, NAEB, RAB, and MINAGRI, in this manner, 70% at 1st year, 80% at 2nd year and 100% at 3rd year respectively are expected.

Table 2.2.1.3 Target Yields (kg/ha)

	Without Project	With Project
Paddy	4,000	6,000
Maize	2,000	5,000
Beans	1,000	2,000
Cabbage	8,000	12,000
Carrot	10,000	25,000
Tomatoes	10,000	20,000
Eggplant	3,500	7,400
Tree tomatoes	2,500	3,500
Coffee	3,500	5,500
Plantain	12,000	-
Sorghum	12,00	-
Cassava	10,000	-

Source. District, Sector agronomists, farmers, and other projects

2-2-1-6 Policy of O&M

1) Executing agency

MINAGRI is the main office responsible for implementation of the Project, however, WUO will be transferred management of facilities from the government according to the ministers' order on December 2011. Considering implementation of the soft component of the Project, establishment of WUO should be given utmost priority. Temporarily as of February 2014, starting mobilization is planned on February 2015 and WUO will be established on May 2015, taking into consideration construction work of facilities.

In order to support establishment of WUO, WUOs Supporting Unit has been set up under Irrigation and Mechanization Task Force of MINAGRI. It is necessary for WUO to acquire juridical personality and water right to get approval of the management transfer of the irrigation facilities in the Project area from the government. Then as the matter of policy of the Project, soft component will start to train WUO and its members on WUO management, O&M of the facilities, water management and so on to build up their capability necessary for sustainable use of the facilities.

2) Technical level

This is the first time for the WUO members to operate and maintain the irrigation facilities since there have been no facilities at the Ngoma22 site so that they have no technologies necessary for O&M of dam, pumps, gate, water division, solar panel and so on. It is necessary to acquire necessary technologies for water management and use such as water-saving irrigation, equitable water distribution, on-time and on-demand irrigation, repairing facilities. As to WUO management, they need to acquire technologies on water charge collection, suitable management of WUO, transparent financial management and so on. Trainings on those matters shall be provided in the soft component of the Project.

The technology on water storage test of the constructed dam is also needed for MINAGRI staff and representatives of WUO.

Paddy farming technologies are to be trained to secure and expand improved technologies for more members though some representatives of Kigarama Rice Farmer's Cooperative who were trained under the Technical Cooperation of JICA, which was PiCROPP. Similarly, farming technologies on upland crops shall be provided to improve traditional and extensive technologies in order to increase yield as seen in tomato cultivation.

Technologies on aquaculture at the constructed dam shall be transferred to the representatives of beneficiaries through the training in the soft component, too.

3) Initial guidance on handling and operation

Initial guidance and O&M of the pumps and other equipment shall be done in a part of installment when those equipments are set up by contractor and makers apart from the soft component of the Project. WUOs' board members and operators who will operate equipment shall be trained on the following subjects during installment stage;

- Practical training on installment of pump and electric equipment,
- Practical training on test operation of the pump and other equipment,
- Practical training on operation method of the pump equipment, and
- Practical training on maintenance of the pump and other electric equipment

4) Budget

The necessary costs for O&M of the irrigation facilities pump operation, canal repairing and WUO management after the completion of the construction works shall be managed by water charge to be collected from WUO members.

It is estimated that O&M cost of the irrigation facilities in the WUO to be newly established will account for 40% of the total budget, and 30 % for WUO management (salary for accountant and gate-keepers etc.), 20% for saving for depreciation and 10% for the Irrigation Trust Fund as surveyed at APIISAMAK WUO (Kanyonyomba Dam) which will be spent for other irrigation project in marshlands. It is considered that O&M cost will be spent mostly at the same allocation in the new WUO of Ngoma22.

5) Organization and staff

Though WUO has not been established yet at the site, the members of existing Kigarama Rice Farmers Cooperative and the beneficiaries of hillside farmers shall join into the WUO to manage irrigation facilities as beneficiaries according to the Minister's order on December 2011. Actual staffing of the WUO shall be decided when it is organized in response to the site condition and facilities. The WUO, however, shall be organized as shown below according to the preceding WUOs. Though board members are volunteers, water manager and his staff will be gainfully.

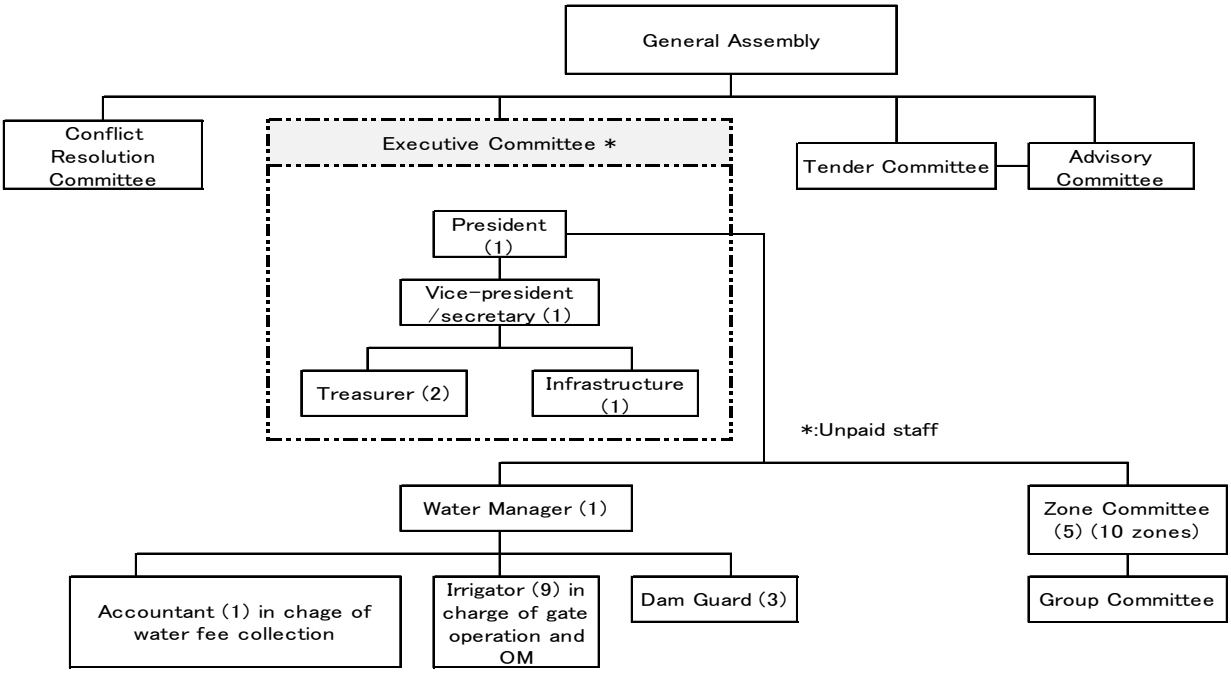


Figure 2.2.1.5 WUO Organization Structure of Kanyonyamba Marshland

**: all staff is hired

2-2-2 Basic Plan (Construction Plan / Equipment Plan)

2-2-2-1 Irrigation Designing

2-2-2-1-1 Studying of Available Water Quantity

1) Methodology

The runoff model that can calculate the daily river flow rates through inputting the daily rainfalls shall be obtained by analyzing the relationship between the rainfall record and the river flow rate record that have been being observed since February 2012, ranging from 22nd of February 2012 to 5th of August 2013.

The Tank Model Method shall be applied as the analysis method considering the following conditions.

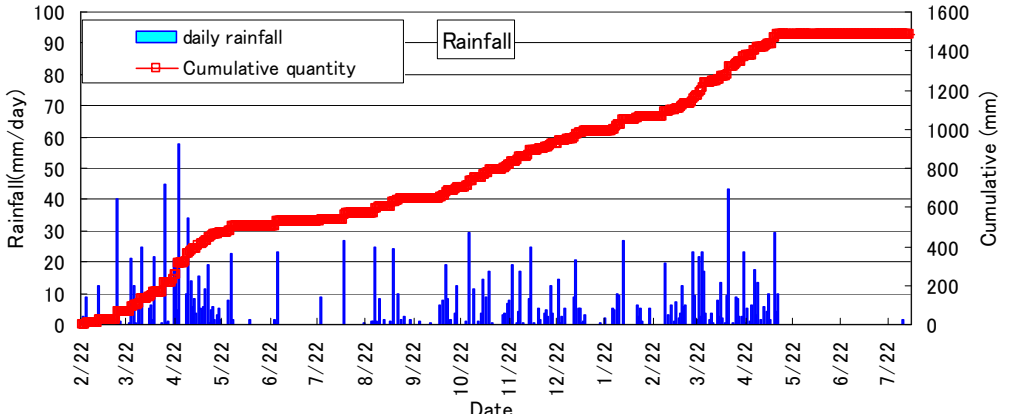
- The target is to estimate the long-term river flow rate such as the annual cumulative river flow rate,
- The river flow rate in this area is much affected by the degree of saturation in the ground brought from previous rainfalls, and
- The Tank Model Method is appropriate to such analysis conditions.

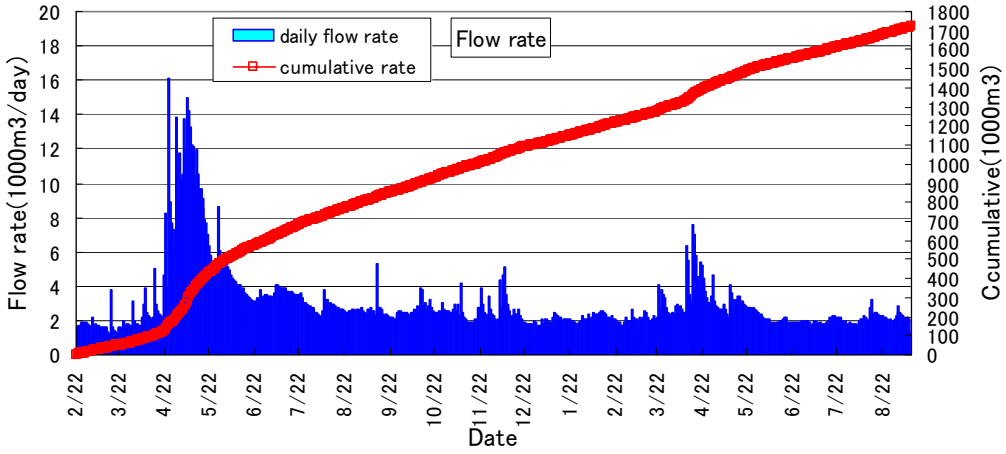
2) Examination to the observation data

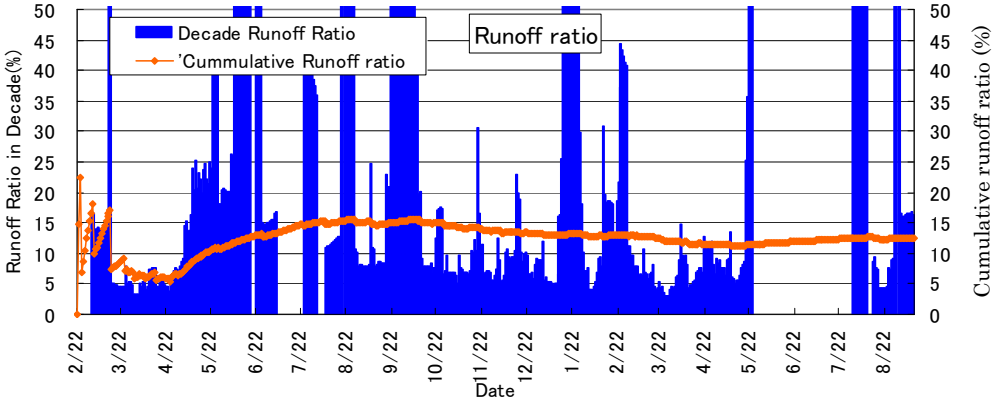
The data observed through the period mentioned above shall be summarized in daily records (decade records in runoff's case) and in cumulative records since its beginning time. The record diagrams are indicated below.

Based on these diagrams, followings would be pointed out.

- In 2012, it rained much from the beginning of March till mid April though it did not cause the increase of flow rate.
- From 20th of April 2012, the runoff appeared with little delay of time to the rain and the river flow rate increased remarkably.
- Such phenomena as mentioned above would be explained by the difference of saturation ratio of the ground. This high saturated condition of the ground kept its influence through June, July and August, where the river flow rate increased and decreased repeatedly to occasional rains under a totally descending tendency.
- It rained relatively much in October, November and December; but the river flow rate kept its descending tendency though reacted to each rain, and reached the minimum at the end of December.
- From the beginning of January on, the river flow rate changed from descending to the gradual increase and reached its peak around 20th of April, 2013 and behaved in the same way as in 2012.
- The base flow rate seems to be around 1,800m^3/day - 2,000m^3/day, of which condition appears from January to mid March and its timing/duration differs according to the rainfall quantity.
- The runoff ratio is quite low to be 5 % or so during the period of the rainfall being consumed to saturate the ground even if it rains much; but it reaches 12.5% all through the observation period. This observed runoff ratio coincides with the ratio of the total flow rate to the total precipitation in the catchment area.







Examination to the observation record

Period 2012/2/22-2013/9/10	
Correlation factor	1.000
Cumulative flow rate	1,720 ×1000 m3
Ccumulative rainfall	1,564 mm
Converted flow rate	13,763 ×1000 m3
Runoff ratio	12.5%

Converted flow rate= (rainfall(mm)×8.8km2)

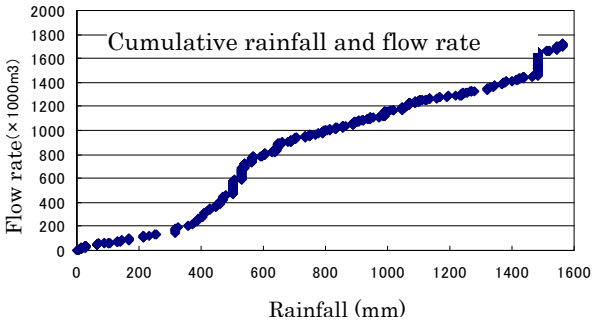


Figure 2.2.2.1 Analysis to the Record of Rainfall and River Flow Rate

3) Building of the Tank Model

(1) Evapo-transpiration

The amount of evapo-transpiration from the ground surface in the catchment area shall be taken into account in the runoff analysis by the Tank Model. The main crops being planted on the site are Sorghum, Maize, Beans, Banana and coffee in the catchment area which don't contain the command area. Here, given Sorghum is represented by Maize and fruit trees by coffee and the planting ratio between Maize/Beans and coffee shall be 50% to 50% considering the increase of plantation area of fruit trees in future, the amount of evapo-transpiration in decades of each month is estimated as follows.

Table 2.2.2.1 Estimated Evapo-transpiration of the Major Crops

Mon.	Dec.	Maize (Cultivation: 50%)			Beans (Cultivation: 50%)			Coffee (Cultivation: 50%)			Weighed Mean
1	1				1.86	1.86	1.86	3.38	3.91	3.89	2.79
	2				1.86	1.86	1.86	3.61	3.61	4.18	2.83
	3				1.86	1.86	1.86	3.67	3.67	3.67	2.77
2	1	1.24	1.24	1.24				3.72	3.72	3.72	2.48
	2	1.26	1.26	1.26				3.78	3.78	3.78	2.52
	3	1.30	1.23	1.23				3.70	3.70	3.71	2.48
3	1	2.00	1.26	1.21				3.62	3.62	3.62	2.56
	2	2.87	1.95	1.23				3.53	3.53	3.53	2.77
	3	3.65	2.77	1.90				3.37	3.37	3.37	3.07
4	1	4.25	3.51	2.68				3.20	3.20	3.20	3.34
	2	4.15	4.03	3.32				3.04	3.04	3.04	3.44
	3	4.08	4.08	3.96				2.99	2.99	2.99	3.52
5	1	4.01	4.01	4.01				2.98	2.94	2.94	3.48
	2	3.94	3.94	3.94				2.99	2.92	2.89	3.44
	3	3.43	3.89	3.89				3.03	2.96	2.89	3.35
6	1	2.42	3.34	3.84				3.06	3.00	2.93	3.10
	2	1.49	2.39	3.29				3.09	3.03	2.96	2.71
	3	1.54	1.54	2.47				3.26	3.20	3.13	2.52
7	1	1.55	1.55	1.55				3.32	3.30	3.24	2.42
	2	1.55	1.55	1.55				3.40	3.40	3.38	2.47
	3	1.55	1.55	1.55				3.91	3.91	3.92	2.73
8	1				1.87	1.87	1.87	4.53	4.53	4.55	3.20
	2				1.87	1.87	1.87	5.05	5.05	5.06	3.46
	3				1.87	1.87	1.87	4.95	4.96	4.97	3.42
9	1				1.87	1.87	1.87	4.83	4.83	4.84	3.35
	2				1.85	1.85	1.85	4.77	4.77	4.78	3.31
	3				2.53	1.86	1.86	4.79	4.79	4.81	3.44
10	1				3.83	2.57	1.89	4.88	4.88	4.90	3.83
	2				5.15	3.85	2.60	4.93	4.94	4.95	4.40
	3				4.21	4.69	3.55	4.50	4.50	4.51	4.33
11	1				4.58	4.54	4.16	3.96	3.96	3.97	4.20
	2				4.08	4.04	4.02	3.52	3.52	3.53	3.79
	3				4.00	3.97	3.96	3.47	3.47	3.48	3.73
12	1				3.01	3.86	3.86	3.38	3.38	3.39	3.48
	2				1.64	2.88	3.70	3.26	3.26	3.70	3.07
	3					1.78	3.06	3.50	3.55	3.56	2.58

The evapo-transpiration depth shall be deduced from the first tank, and only when the water depth in the first tank is not enough also deduced from the second tank with the limitation of less than 50% of the shortage.

(2) Constant of the tank model

The constants of the Tank Model shown in the illustration below are decided through trial calculations aiming to obtain higher than 90% the correlation coefficient between observed values and calculated

ones and to get approximately same values of runoff ratio between the observed and the calculated. The final river flow rate calculated by the adopted model is shown as Fig 2.2.2.2. Here, the obtained correlation coefficient is 0.924 and the runoff ratios by the model is 12.5% as same as the observed.

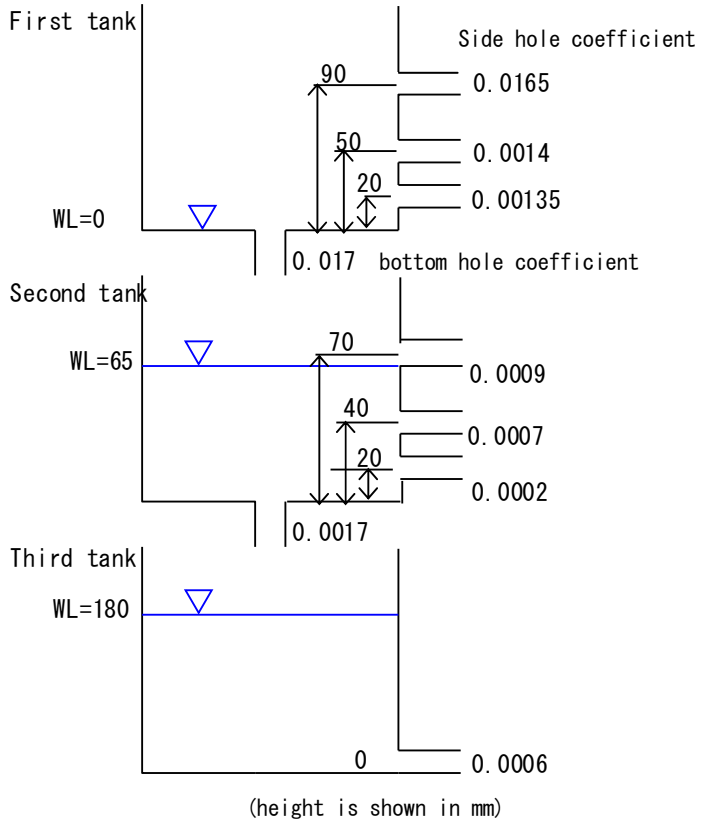
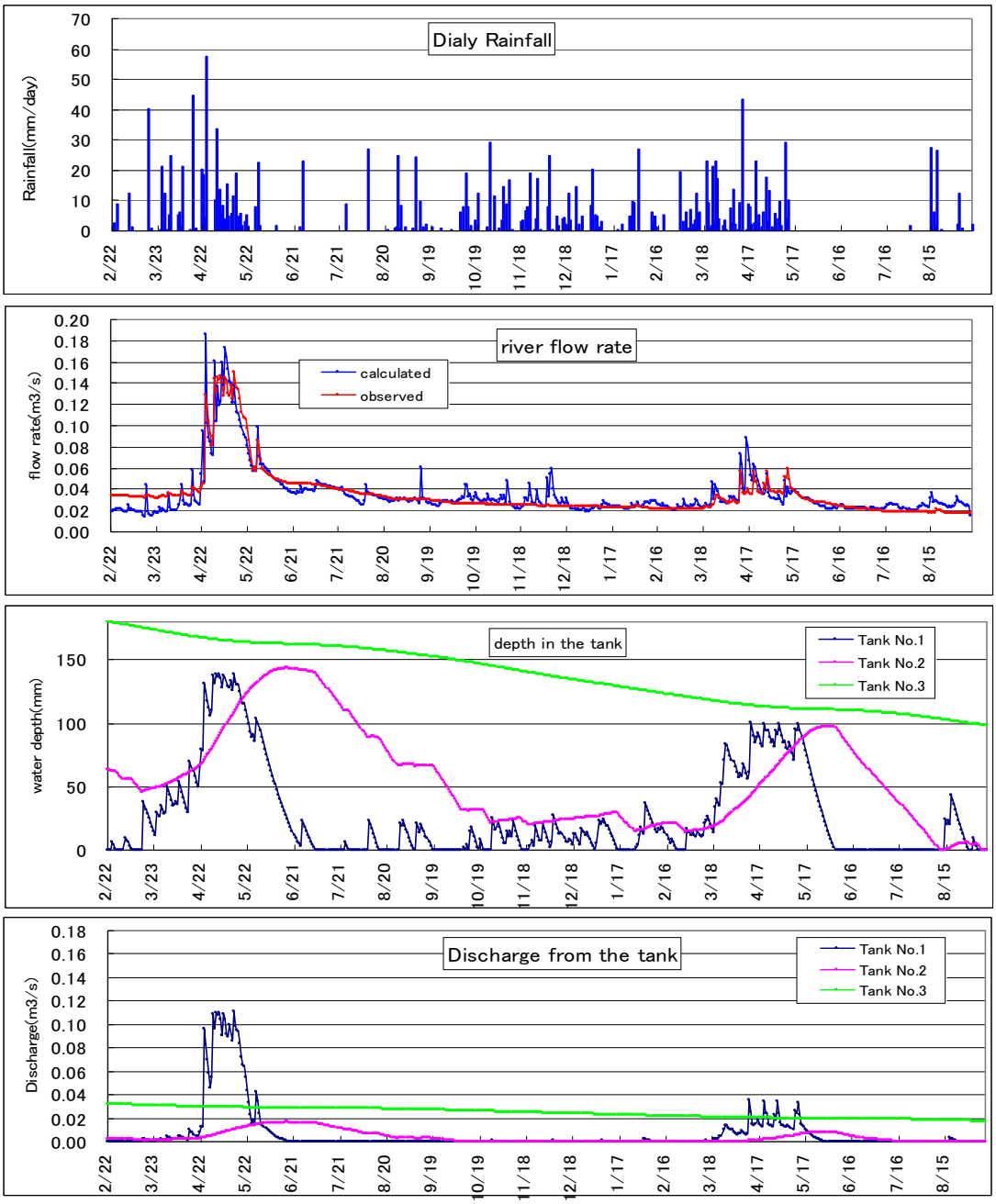


Figure 2.2.2.2 Illustration of the Adopted Tank Model

In addition, the flow rate estimation of each year done in the following section by applying the model above shall be operated year by year, i.e. the water depths in each tank shall be treated to be the depths above on 1st of January, considering that the observed record is not the one ranging wide span of years so that calculation errors might become cumulative in case of the operation being done continuously. This manner of operation corresponds to the observed flow rate showing the minimum at the beginning of the year.



Result of simulation analysis

period	22/2/2012～10/9/2013	
Correlation coefficient	0.924	Runoff ratio (%)
Cumulative flow rate calculated	1,714 ×1000m3	Calculated; 12.5%
Cumulative flow rate observed	1,720 ×1000m3	Observed; 12.5%
Cumulative rainfall observed	1,564 mm	

Figure 2.2.2.3 Result of Simulation Analysis to Runoff by Tank Model built

4) Estimation of the cumulative quantity of annual river flow rate

The daily rainfall record of Gahororo Meteorological Station is applied to the analysis based on the following view points.

- Short distance to the dam site
- Daily rainfall record of 34 years from 1960 to 1993
- KIBUNGO Meteorological Station is also close to the dam site and has the daily rainfall records of 63 years from 1931 to 1994; but there are lacks of the recent records from 1981 to 1989. It is appropriate to adopt Gahororo Station with recent records considering the tendency of the annual rainfall decreasing in these years.

Figure 2.2.2.4 Location Map of the Dam Site and Gahororo Meteorological Station

The tank model built through the process in the previous section can produce the daily river flow rates corresponding to the each daily rainfall record of 34 years from 1960 to 1993. The following table and figures show the estimated quantity of annual river flow rate that is the accumulation of these daily values.

Table 2.2.2.2 Estimated Annual Flow Rate by Tank Model

Year	Flow rate (×1000m3)	Rainfall (mm)	Runnoff ratio	Ranking from max.	Ranking from min.	Ranking in annual flow rate
1960	1,856	1,133	18.6	10	25	
1961	2,030	1,320	17.5	6	29	
1962	1,196	1,067	12.7	26	9	
1963	1,728	1,183	16.6	12	23	
1964	1,283	1,094	13.3	22	13	
1965	1,953	1,304	17.0	8	27	
1966	2,101	1,366	17.5	5	30	including modified data
1967	835	856	11.1	34	1	
1968	2,814	1,349	23.7	1	34	
1969	1,459	1,095	15.1	16	19	
1970	1,274	1,134	12.8	23	12	
1971	1,056	984	12.2	30	5	
1972	1,247	1,147	12.4	24	11	
1973	1,057	918	13.1	29	6	
1974	1,111	1,002	12.6	28	7	
1975	926	1,022	10.3	33	2	
1976	1,295	1,145	12.9	21	14	
1977	1,687	1,166	16.4	13	22	
1978	1,965	1,268	17.6	7	28	
1979	2,774	1,269	24.8	3	32	
1980	1,122	883	14.4	27	8	including missing data
1981	1,633	1,124	16.5	15	20	
1982	1,246	637	22.2	25	10	including missing data
1983	968	822	13.4	31	4	including missing data
1984	1,416	1,077	14.9	17	18	
1985	2,784	1,349	23.4	2	33	
1986	1,648	1,046	17.9	14	21	including missing data
1987	1,410	1,161	13.8	18	17	including missing data
1988	1,888	1,306	16.4	9	26	
1989	1,770	1,270	15.8	11	24	
1990	2,182	1,283	19.3	4	31	
1991	1,327	1,100	13.7	20	15	
1992	967	994	11.1	32	3	
1993	1,371	927	16.8	19	16	
平均	1,547	1,105	15.7			
最小	835	637	10.3			
最大	2,814	1,366	24.8			

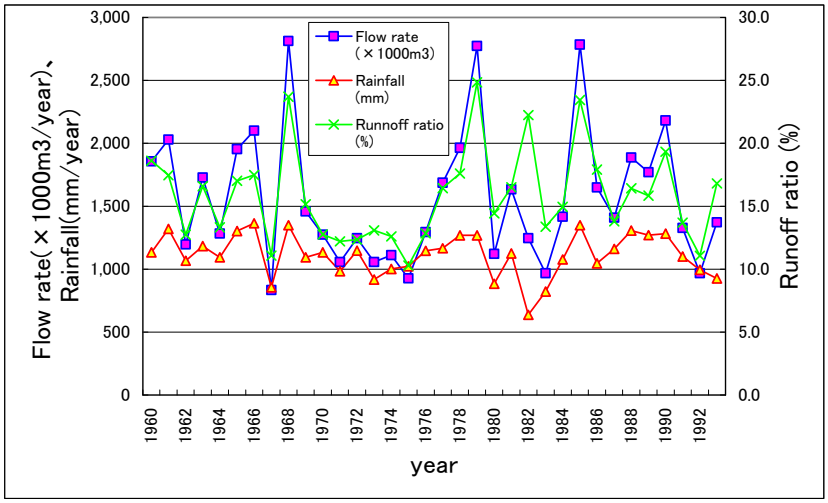


Figure 2.2.2.5 Summary of Estimated Annual Flow Rate

5) Reference year for design and the available annual river flow rate

The probability occurrence is examined to the annual river flow rates obtained by the Tank Model Analysis and the dry year with the probability occurrence of 1/5 approximately is adopted as the reference year for design, which is as same as in Nyanza-23 and others of the LWH project, and the annual river flow rate of this base year is considered to be the available quantity.

While the expected flow rate with the 1/5 probability occurrence (Return period) is calculated 1,142,000m^3, the annual flow rate close to which is 1,111,000m^3 of the year 1974 so that 1974 is defined to be the reference year for design and 1,111,000m^3 is treated to be the expected annual flow rate. Then, the available annual flow rate is estimated to be 1,063,000m^3 which comes from the subtraction of ecological river discharge 48,000m^3 from the expected annual flow rate 1,111,000m^3.

Table 2.2.2.3(1) Calculation Result of Expected Probability Flow Rate

Data number in 10% range at both edges of distribution	Constant of lower limit
3	-336.3

xl Max	xs Min	xg $\log_{10}$xg $=\Sigma\log_{10}$xi	xl･xs−xg^2	2xg−(xl+xs)	bs xl･xs−xg^2 /2xg−(xl+xs)	b 平均bs	
2,813.777	834.517	1518.3638	42716.06	−611.57	−69.85	−69.8	
2,783.726	925.606	1518.3638	271205.10	−672.60	−403.22	−236.5	
2,773.611	967.242	1518.3638	377325.18	−704.13	−535.88	−336.3	◎
2,182.269	1,056.166	1518.3638	−590.34	−201.71	2.93	−251.5	
2,029.902	1,057.017	1518.3638	−159787.27	−50.19	3183.54	435.5	
1,964.706	1,111.135	1518.3638	−122375.11	−39.11	3128.75	884.4	
1,952.958	1,196.379	1518.3638	31047.90	−112.61	−275.72	718.7	
1,887.797	1,247.365	1518.3638	49342.74	−98.43	−501.28	566.2	
1,856.152	1,273.535	1518.3638	58446.01	−92.96	−628.73	433.4	
1,769.876	1,282.552	1518.3638	−35469.93	−15.70	2259.12	616.0	

standard deviation Sx	1/a
0.18382	0.26473

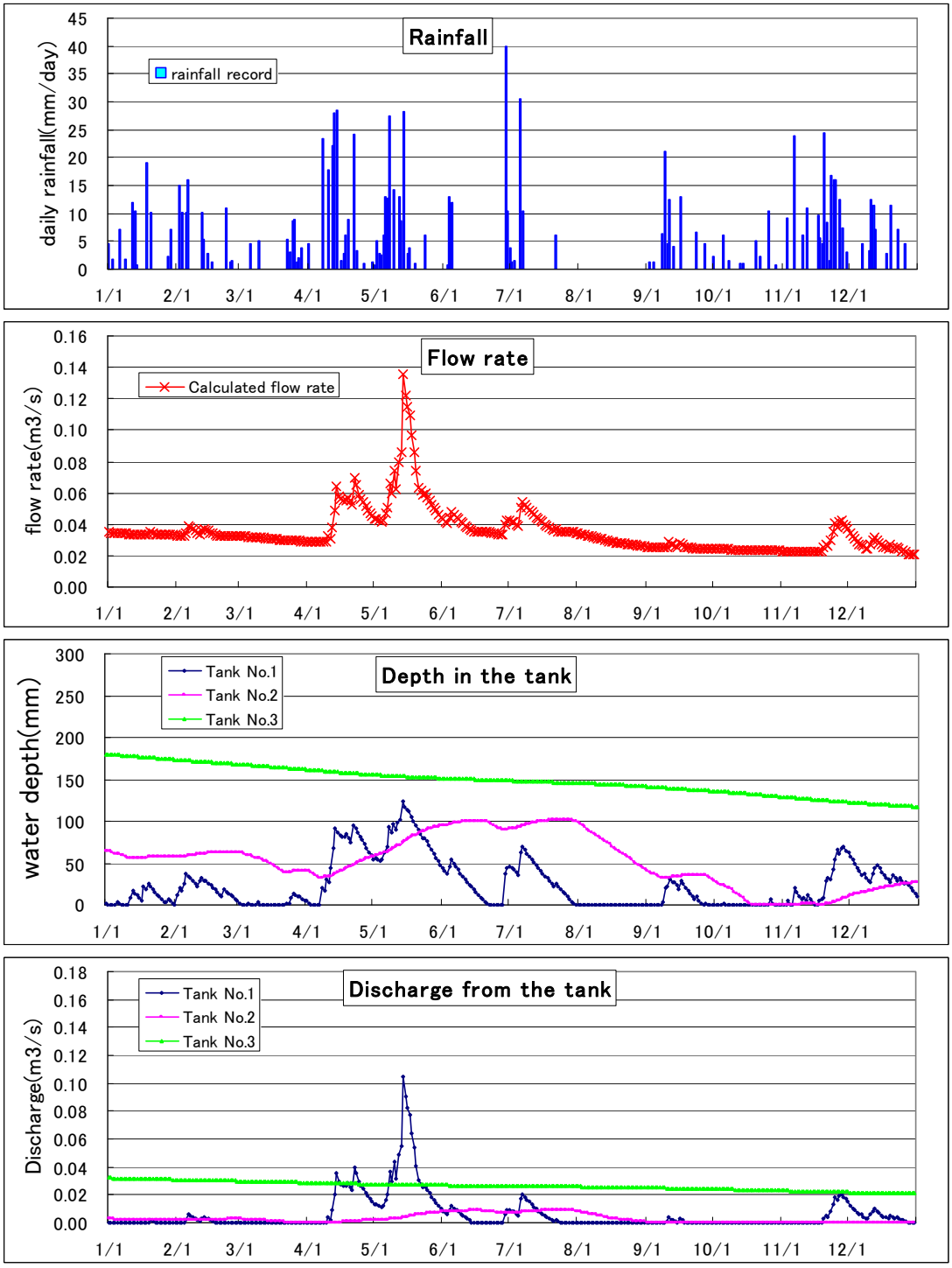
Unit ×1000 m3/yea

occurrence period of year T year	ξ	1/a･ξ	mean(Y) +1/a･ξ	x+b	Probability prediction to the occurrence x
1	0.0000	0.0000	3.0639	1158.6	1494.945
2	0.0000	0.0000	3.0639	1158.6	1494.945
3	0.3045	0.0806	2.9833	962.4	1298.666
4	0.4769	0.1263	2.9377	866.4	1202.665
5	0.5951	0.1575	2.9064	806.1	1142.438
6	0.6858	0.1816	2.8824	762.8	1099.079
7	0.7547	0.1998	2.8642	731.4	1067.707
8	0.8134	0.2153	2.8486	705.7	1041.999
9	0.8634	0.2286	2.8354	684.5	1020.815
10	0.9062	0.2399	2.8240	666.9	1003.187

Table 2.2.2.3(2) Calculation Result of Expected Probability Flow Rate

			②	③	④	⑤	⑥	⑦	⑧	⑨	⑩					
Effective samp	計	Tatal	0.00		89.079		85.790	263.803	80,216,632.1	158,824,392,426.8						
N=28	計/N	Total/N	0.00		3.181		3.064	9.422	2,864,879.7	5,672,299,729.5						
											※ In case of R.P. being less than 2.0, R.P.=1.0					
①			②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪				
Ranking	YEAR		xi	Fn(%)	$log_{10}xi$	xi+b	Y= log(xi+b)	Y^2	x^2	x^3	ξ	$period_1$	$period_2$	$ξ_1$	$ξ_2$	Repeat period (year)
1	1967		834.517	96.55	2.92144	498.203	2.69741	7.27600	696,418.701	581,173,277.8	1.3846	39	40	1.3782	1.3860	39.8
2	1975		925.606	93.10	2.96643	589.292	2.77033	7.67473	856,746.880	793,010,244.1	1.1091	17	18	1.1065	1.1263	17.1
3	1992		967.242	89.66	2.98554	630.929	2.79998	7.83989	935,557.776	904,911,107.4	0.9971	12	13	0.9780	1.0084	12.6
4	1971		1056.166	86.21	3.02373	719.852	2.85724	8.16384	1,115,486.205	1,178,138,383.8	0.7808	7	8	0.7547	0.8134	7.4
5	1973		1057.017	82.76	3.02408	720.703	2.85776	8.16677	1,117,285.056	1,180,989,360.2	0.7789	7	8	0.7547	0.8134	7.4
6	1974		1111.135	79.31	3.04577	774.821	2.88920	8.34749	1,234,621.460	1,371,831,378.1	0.6601	5	6	0.5951	0.6858	5.7
7	1962		1196.379	75.86	3.07787	860.065	2.93453	8.61147	1,431,321.524	1,712,402,303.0	0.4888	4	5	0.4769	0.5951	4.1
8	1972		1247.365	72.41	3.09599	911.051	2.95954	8.75889	1,555,918.770	1,940,798,197.0	0.3944	3	4	0.3045	0.4769	3.5
9	1970		1273.535	68.97	3.10501	937.222	2.97184	8.83185	1,621,892.217	2,065,537,026.5	0.3479	3	4	0.3045	0.4769	3.3
10	1964		1282.552	65.52	3.10808	946.239	2.97600	8.85658	1,644,940.717	2,109,722,701.0	0.3322	3	4	0.3045	0.4769	3.2
11	1976		1294.558	62.07	3.11212	958.244	2.98148	8.88920	1,675,880.058	2,169,523,705.1	0.3115	3	4	0.3045	0.4769	3.0
12	1991		1326.877	58.62	3.12283	990.564	2.99588	8.97531	1,760,603.284	2,336,104,474.6	0.2571	2	3	0.0000	0.3045	2.8
13	1993		1370.997	55.17	3.13704	1,034.683	3.01481	9.08906	1,879,631.529	2,576,968,334.2	0.1856	2	3	0.0000	0.3045	2.6
14	1984		1415.558	51.72	3.15093	1,079.245	3.03312	9.19982	2,003,805.826	2,836,504,340.8	0.1164	2	3	0.0000	0.3045	2.4
15	1969		1459.234	48.28	3.16412	1,122.920	3.05035	9.30463	2,129,363.605	3,107,239,579.6	0.0514	2	3	0.0000	0.3045	2.2
16	1981		1633.470	44.83	3.21311	1,297.156	3.11299	9.69072	2,668,223.433	4,358,462,272.1	-0.1853	1	2	0.0000	0.0000	1.0
17	1977		1687.112	41.38	3.22714	1,350.798	3.13059	9.80060	2,846,346.631	4,802,105,330.5	-0.2517	1	2	0.0000	0.0000	1.0
18	1963		1727.644	37.93	3.23745	1,391.330	3.14343	9.88115	2,984,754.426	5,156,593,625.6	-0.3002	1	2	0.0000	0.0000	1.0
19	1989		1769.876	34.48	3.24794	1,433.562	3.15642	9.96297	3,132,460.786	5,544,066,926.7	-0.3493	1	2	0.0000	0.0000	1.0
20	1960		1856.152	31.03	3.26861	1,519.838	3.18180	10.12383	3,445,298.655	6,394,996,511.8	-0.4452	1	2	0.0000	0.0000	1.0
21	1988		1887.797	27.59	3.27596	1,551.483	3.19075	10.18087	3,563,777.291	6,727,687,868.0	-0.4790	1	2	0.0000	0.0000	1.0
22	1965		1952.958	24.14	3.29069	1,616.644	3.20861	10.29521	3,814,043.341	7,448,664,884.3	-0.5465	1	2	0.0000	0.0000	1.0
23	1978		1964.706	20.69	3.29330	1,628.392	3.21176	10.31540	3,860,067.736	7,583,896,346.4	-0.5583	1	2	0.0000	0.0000	1.0
24	1961		2029.902	17.24	3.30748	1,693.589	3.22881	10.42520	4,120,503.198	8,364,218,767.1	-0.6227	1	2	0.0000	0.0000	1.0
25	1990		2182.269	13.79	3.33891	1,845.956	3.26622	10.66820	4,762,299.427	10,392,619,978.1	-0.7641	1	2	0.0000	0.0000	1.0
26	1979		2773.611	10.34	3.44305	2,437.297	3.38691	11.47115	7,692,916.349	21,337,155,147.9	-1.2200	1	2	0.0000	0.0000	1.0
27	1985		2783.726	6.90	3.44463	2,447.412	3.38871	11.48334	7,749,127.843	21,571,445,035.1	-1.2267	1	2	0.0000	0.0000	1.0
28	1968		2813.777	3.45	3.44929	2,477.463	3.39401	11.51928	7,917,339.418	22,277,625,320.0	-1.2468	1	2	0.0000	0.0000	1.0

6) Estimated flow rate in 1974 as the reference year for design



Summary of the estimation

period	1974, 1/1-12/31
Cumulative flow rate calculated	1,111,000 m3
Cumulative rainfall observed	1,002 mm
Annual runoff ratio	12.60%

Figure 2.2.2.6 Estimated Flow Rate in 1974

2-2-2-1-2 Water Requirement for the Paddy Fields

1) Necessity of water supply and methodology of estimation

35 ha of paddy fields are expanding on the downstream marshland about 4 km long from the dam site to the confluence with the main river. It is usual for the river flow to be cut by the dam construction and for the downstream paddy fields to depend on the dam/reservoir regarding the irrigation water. In case of these paddy fields, however, the downstream marshland has its own catchment area summed up to be about 9 km^2 extending from the dam site to the confluence point.

Accordingly, after the river flowing down for a proper distance the irrigation water shall be supplied sufficiently as surface water and ground water from the both hill sides. Actually, more than 10 springs can be seen at the foot of the hill slopes from the dam site to the exit of the valley. These spring waters are used as the villagers' domestic water and led to the paddy fields as the irrigation water.

According to the Tank Model Analysis, the runoff ratio between the estimated annual river flow rate at the dam site and the annual precipitation in 1974, which is reference year for design, is 12.6 %. The expected water supply inflowing from the hillside at the given location on the downstream river is calculated by applying the precipitation of 1974 and runoff ratio to the catchment area ranging from the dam site to the given location.

The water requirement for paddy irrigation shall be estimated based on the size of paddy field area from the dam site to the given location and the monthly irrigation water requirement calculated by CROPWAT-8.

The balance sheet becomes as follows. In case of counting the whole precipitation including floods that are counted in the runoff ratio 12.6 % together with the base flow, the downstream paddy fields are satisfied with expected in-flow coming from hillside only.

Table 2.2.2.4 Balance between the Expected In-Flow and the Water Requirement in the downstream paddy fields

Item \ Location	1km from the dam site	2km from the dam site	3km from the dam site	Confluence Point
Catchment area (km2)	1.7	3.7	7.4	9.2
Annual precipitation (mm)	1,002	1,002	1,002	1,002
Runoff ratio (%)	12.6	12.6	12.6	12.6
Expected in-flow from hill side (m3)	214,628.4	467,132.4	934,264.8	1,161,518.4
Paddy field area (ha)	3.6	10.3	19.6	35
Unit water requirement (mm)	1,172	1,172	1,172	1,172
Water requirement (m3)	42,192.0	120,716.0	229,712.0	410,200.0

Though paddy fields are able to store rainfalls to some extent, they can not keep water of whole rainfalls actually. According to the runoff analysis by the Tank Model, the river flow rate is 0.02m^3/sec or so from October to November. It is, therefore, necessary to confirm the circumstances in the downstream paddy fields during such period. In addition, the paddy fields lying in just downstream area to the dam site don't have much catchment area expected flowing surface and ground water into the paddy area so that the irrigation water must be supplied all through a year.

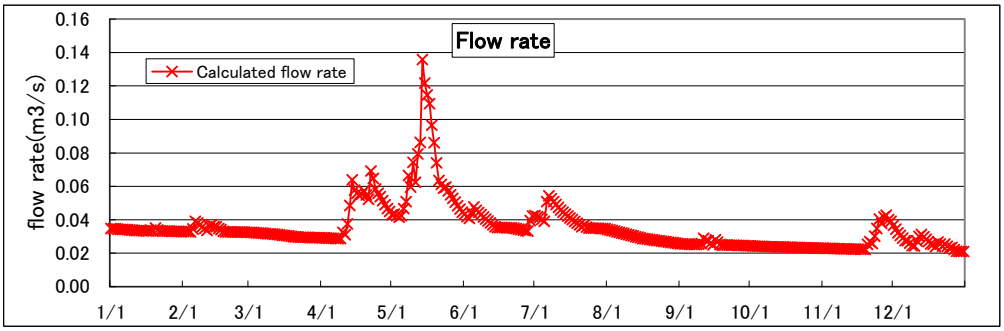


Figure 2.2.2.7 Estimated River Flow Rate in 1974

Based on the recognition above, the cumulative calculations at every 50 m interval ranging from the dam site to the exit of the valley are carried out monthly to confirm the circumstances between supply and demand in irrigation water, i.e. the relationship among the irrigation water requirement, the in-flow rate from the catchment area, and the water supply to the paddy fields immediate downstream of the reservoir. The calculations are done under the following assumptions.

- The intake mouths are set up at 100 m interval near the starting point and the end point, and at 200 m interval through the other portion.
- The calculation interval is 50 m composed of two lots of paddy fields between which the ridge-through irrigation and horizontal leakage is considered. The in-flow of surface/ground water is estimated to this section where the specific discharge from the runoff analysis on the base year 1974 by Tank Model is applied.
- The required water supply to the paddy fields is composed of the ETc, the vertical percolation 13.6 mm and the horizontal leakage 5 mm. The ETc (mm/day)/irrigation water requirement is evaluated as follows.

Table 2.2.2.5 Irrigation Water Requirement per Month

Month	1	2	3	4	5	6	7	8	9	10	11	12
Etc (mm)	156.1	183.1	170.4	12.7	22.0	44.4	69.9	261.4	196.6	151.7	12.6	37.8

- Except for ETc, the vertical percolation and the horizontal leakage are circularly used by 100 %. (return-flow rate; 100%, refer to the comments below.) In this Ngoma22 valley, more than 10 springs seep out at the foot of the right and the left hills from the dam site to the exit of the valley. These springs are brought by the shallow ground water, which flows into the river, appearing on the ground surface here and there.
- The water surface in the paddy field has the higher seepage potential than the paddy field surface so that the vertical percolation occurs; but this percolated water meets with and ride on the ground water flowing into the river. Therefore, the return-flow rate of the percolation water is considered to be 100 %. Nevertheless around the exit of the valley, this rate is estimated to be 90% to 80% as the return flow might appear into the downstream river bed.

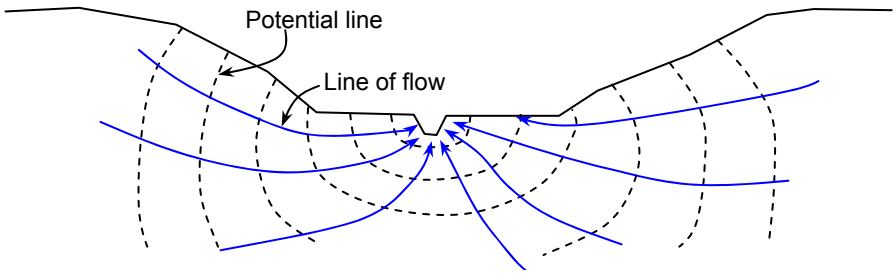


Figure 2.2.2.8 Return Mechanism of the Percolated Water

- Regarding the ratio of seepage composed of percolation and leakage, the seepage out ratio to the river is 1/3 and the seepage out ratio to the adjacent paddy field is 2/3.
- At the intake mouth, the whole seepage out quantity to the river is caught and taken as the return flow. In case of this whole quantity being smaller than the irrigation water requirement at that intake point, the insufficient amount of water is discharged from the reservoir.

2) Study result

The results of simulation analyses are summarized as follows.

Table 2.2.2.6 Water Requirement in Downstream Paddy Fields

Mon.	Sections requesting for water supply	Requested quantity	Cumulative quantiry
1	0m - 400m, 3km - 4km	15,914.1m^3	15,914.1m^3
2	0m - 400m, 2.5km - 4km	26,225.0m^3	42,139.1m^3
3	0m - 400m, around downstream edge	24,185.8m^3	66,324.9m^3
4	0m - 100m	1,061.5m^3	67,386.4m^3
5	0m - 100m	1,077.5m^3	68,463.9m^3
6	0m - 400m, around downstream edge	1,410.4m^3	69,874.3m^3
7	0m - 400m	1,621.6m^3	71,495.9m^3
8	0m - 400m, 3km - 4km	52,487.0m^3	123,982.9m^3
9	0m - 400m, 1km - 4km	38,235.6m^3	162,218.5m^3
10	0m - 400m, 3km - 4km	29,951.1m^3	192,169.6m^3
11	0m - 400m, around downstream edge	2,061.1m^3	194,230.7m^3
12	0m - 400m, around downstream edge	8,419.6m^3	202,650.3m^3

Water supply quantity to the downstream paddy fields is estimated to be 203,000m^3 in total; and the available water quantity for the hillside irrigation is to be 860,000m^3 (1,063,000m^3 − 203,000m^3=860,000m^3).

Table 2.2.2.7(1) Calculation of Water Quantity for Supplemental Supply to the Paddy Fields (January)

Jan. Water Re= 23.64 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×31	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67×(1.0～0.8)	⑬=⑪×0.33×(1.0～0.8)
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.)	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1318.9			333.8	0.085	28.373	2198.4	156.1	281.0	1917.4	1284.69	632.76
2	100.0	0.18	0.36	2637.7	632.8	720.3	333.8	0.085	28.373	4237.6	156.1	281.0	3956.6	2650.91	1305.67
3	150.0	0.18	0.54	2650.9		0.0	333.8	0.085	28.373	3530.5	156.1	281.0	3249.5	2177.16	1072.33
4	200.0	0.18	0.72	5275.4	2378.0	720.3	333.8	0.085	28.373	6155.0	156.1	281.0	5874.0	3935.60	1938.43
5	250.0	0.18	0.9	3935.6		0.0	333.8	0.085	28.373	4815.2	156.1	281.0	4534.2	3037.90	1496.28
6	300.0	0.18	1.08	3037.9		0.0	333.8	0.085	28.373	3917.5	156.1	281.0	3636.5	2436.44	1200.04
7	350.0	0.18	1.26	2436.4		0.0	333.8	0.085	28.373	3316.0	156.1	281.0	3035.0	2033.47	1001.56
8	400.0	0.18	1.44	7669.8	5636.3	0.0	333.8	0.085	28.373	8549.3	156.1	281.0	8268.4	5539.80	2728.56
9	450.0	0.18	1.62	5539.8		0.0	333.8	0.085	28.373	6419.4	156.1	281.0	6138.4	4112.72	2025.67
10	500.0	0.18	1.8	4112.7		0.0	333.8	0.085	28.373	4992.3	156.1	281.0	4711.3	3156.57	1554.73
11	550.0	0.18	1.98	3156.6		0.0	333.8	0.085	28.373	4036.1	156.1	281.0	3755.2	2515.95	1239.20
12	600.0	0.18	2.16	10064.1	7548.2	0.0	333.8	0.085	28.373	10943.7	156.1	281.0	10662.7	7144.00	3518.69
13	650.0	0.18	2.34	7144.0		0.0	333.8	0.085	28.373	8023.6	156.1	281.0	7742.6	5187.53	2555.05
14	700.0	0.18	2.52	5187.5		0.0	333.8	0.085	28.373	6067.1	156.1	281.0	5786.1	3876.70	1909.42
15	750.0	0.18	2.7	3876.7		0.0	333.8	0.085	28.373	4756.3	156.1	281.0	4475.3	2998.44	1476.84
16	800.0	0.18	2.88	12458.4	9460.0	0.0	333.8	0.085	28.373	13338.0	156.1	281.0	13057.0	8748.20	4308.82
17	850.0	0.18	3.06	8748.2		0.0	333.8	0.085	28.373	9627.8	156.1	281.0	9346.8	6262.35	3084.44
18	900.0	0.18	3.24	6262.3		0.0	333.8	0.085	28.373	7141.9	156.1	281.0	6860.9	4596.82	2264.11
19	950.0	0.18	3.42	4596.8		0.0	333.8	0.085	28.373	5476.4	156.1	281.0	5195.4	3480.92	1714.48
20	1000.0	0.18	3.6	14852.8	11371.8	0.0	333.8	0.085	28.373	15732.3	156.1	281.0	15451.4	10352.41	5098.95
21	1050.0	0.335	3.935	10352.4		0.0	333.8	0.1	33.38	11387.2	156.1	522.9	10864.3	7279.05	3585.20
22	1100.0	0.335	4.27	7279.0		0.0	333.8	0.1	33.38	8313.8	156.1	522.9	7790.9	5219.90	2570.99
23	1150.0	0.335	4.605	5219.9		0.0	333.8	0.1	33.38	6254.7	156.1	522.9	5731.7	3840.27	1891.48
24	1200.0	0.335	4.94	16986.9	13146.6	0.0	333.8	0.1	33.38	18021.7	156.1	522.9	17498.7	11724.15	5774.58
25	1250.0	0.335	5.275	11724.1		0.0	333.8	0.1	33.38	12758.9	156.1	522.9	12236.0	8198.12	4037.88
26	1300.0	0.335	5.61	8198.1		0.0	333.8	0.1	33.38	9232.9	156.1	522.9	8710.0	5835.67	2874.29
27	1350.0	0.335	5.945	5835.7		0.0	333.8	0.1	33.38	6870.5	156.1	522.9	6347.5	4252.84	2094.68
28	1400.0	0.335	6.28	19034.3	14781.4	0.0	333.8	0.1	33.38	20069.0	156.1	522.9	19546.1	13095.89	6450.22
29	1450.0	0.335	6.615	13095.9		0.0	333.8	0.1	33.38	14130.7	156.1	522.9	13607.7	9117.19	4490.55
30	1500.0	0.335	6.95	9117.2		0.0	333.8	0.1	33.38	10152.0	156.1	522.9	9629.0	6451.45	3177.58
31	1550.0	0.335	7.285	6451.5		0.0	333.8	0.1	33.38	7486.2	156.1	522.9	6963.3	4665.41	2297.89
32	1600.0	0.335	7.62	21081.6	16416.2	0.0	333.8	0.1	33.38	22116.4	156.1	522.9	21593.5	14467.64	7125.85
33	1650.0	0.335	7.955	14467.6		0.0	333.8	0.1	33.38	15502.4	156.1	522.9	14979.5	10036.25	4943.23
34	1700.0	0.335	8.29	10036.3		0.0	333.8	0.1	33.38	11071.0	156.1	522.9	10548.1	7067.23	3480.87
35	1750.0	0.335	8.625	7067.2		0.0	333.8	0.1	33.38	8102.0	156.1	522.9	7579.1	5077.98	2501.09
36	1800.0	0.335	8.96	23129.0	18051.0	0.0	333.8	0.1	33.38	24163.8	156.1	522.9	23640.9	15839.38	7801.49
37	1850.0	0.335	9.295	15839.4		0.0	333.8	0.1	33.38	16874.2	156.1	522.9	16351.2	10955.32	5395.91
38	1900.0	0.335	9.63	10955.3		0.0	333.8	0.1	33.38	11990.1	156.1	522.9	11467.2	7683.00	3784.17
39	1950.0	0.335	9.965	7683.0		0.0	333.8	0.1	33.38	8717.8	156.1	522.9	8194.8	5490.55	2704.30
40	2000.0	0.335	10.3	25176.4	19685.9	0.0	333.8	0.1	33.38	26211.2	156.1	522.9	25688.3	17211.13	8477.12
41	2050.0	0.465	10.765	17211.1		0.0	333.8	0.185	61.753	19125.5	156.1	725.9	18399.6	12327.74	6071.87
42	2100.0	0.465	11.23	12327.7		0.0	333.8	0.185	61.753	14242.1	156.1	725.9	13516.2	9055.86	4460.35
43	2150.0	0.465	11.695	9055.9		0.0	333.8	0.185	61.753	10970.2	156.1	725.9	10244.3	6863.71	3380.63
44	2200.0	0.465	12.16	29253.7	22390.0	0.0	333.8	0.185	61.753	31168.0	156.1	725.9	30442.2	20396.25	10045.91
45	2250.0	0.465	12.625	20396.2		0.0	333.8	0.185	61.753	22310.6	156.1	725.9	21584.7	14461.77	7122.96
46	2300.0	0.465	13.09	14461.8		0.0	333.8	0.185	61.753	16376.1	156.1	725.9	15650.2	10485.66	5164.58
47	2350.0	0.465	13.555	10485.7		0.0	333.8	0.185	61.753	12400.0	156.1	725.9	11674.1	7821.68	3852.47
48	2400.0	0.465	14.02	34007.6	26185.9	0.0	333.8	0.185	61.753	35921.9	156.1	725.9	35196.1	23581.37	11614.70
49	2450.0	0.465	14.485	23581.4		0.0	333.8	0.185	61.753	25495.7	156.1	725.9	24769.8	16595.80	8174.05
50	2500.0	0.465	14.95	16595.8		0.0	333.8	0.185	61.753	18510.1	156.1	725.9	17784.3	11915.47	5868.81
51	2550.0	0.465	15.415	11915.5		0.0	333.8	0.185	61.753	13829.8	156.1	725.9	13103.9	7901.68	3891.87
52	2600.0	0.465	15.88	37451.1	29549.4	0.0	333.8	0.185	61.753	39365.5	156.1	725.9	38639.6	23299.67	11475.96
53	2650.0	0.465	16.345	23299.7		0.0	333.8	0.185	61.753	25214.0	156.1	725.9	24488.2	14766.36	7272.98
54	2700.0	0.465	16.81	14766.4		0.0	333.8	0.185	61.753	16680.7	156.1	725.9	15954.8	9620.76	4738.59
55	2750.0	0.465	17.275	9620.8		0.0	333.8	0.185	61.753	11535.1	156.1	725.9	10809.2	6517.97	3210.35
56	2800.0	0.465	17.74	33215.8	26697.9	0.0	333.8	0.185	61.753	35130.2	156.1	725.9	34404.3	20745.81	10218.08
57	2850.0	0.465	18.205	20745.8		0.0	333.8	0.185	61.753	22660.1	156.1	725.9	21934.3	13226.37	6514.48
58	2900.0	0.465	18.67	13226.4		0.0	333.8	0.185	61.753	15140.7	156.1	725.9	14414.9	8692.16	4281.21
59	2950.0	0.465	19.135	8692.2		0.0	333.8	0.185	61.753	10606.5	156.1	725.9	9880.6	5958.02	2934.55
60	3000.0	0.465	19.6	29906.3	23948.3	0.0	333.8	0.185	61.753	31820.7	156.1	725.9	31094.8	18750.18	9235.16
61	3050.0	0.77	20.37	18750.2		0.0	333.8	0.09	30.042	19681.5	156.1	1202.0	18479.5	11143.15	5488.41
62	3100.0	0.77	21.14	11143.1		0.0	333.8	0.09	30.042	12074.4	156.1	1202.0	10872.5	6556.10	3229.13
63	3150.0	0.77	21.91	6556.1		0.0	333.8	0.09	30.042	7487.4	156.1	1202.0	6285.4	3790.12	1866.77
64	3200.0	0.77	22.68	23609.6	19819.5	0.0	333.8	0.09	30.042	24540.9	156.1	1202.0	23338.9	14073.37	6931.66
65	3250.0	0.77	23.45	14073.4		0.0	333.8	0.09	30.042	15004.7	156.1	1202.0	13802.7	8323.03	4099.40
66	3300.0	0.77	24.22	8323.0		0.0	333.8	0.09	30.042	9254.3	156.1	1202.0	8052.4	4855.58	2391.55
67	3350.0	0.77	24.99	4855.6		0.0	333.8	0.09	30.042	5786.9	156.1	1202.0	4584.9	2764.70	1361.72
68	3400.0	0.77	25.76	22567.2	14784.3	5018.1	333.8	0.09	30.042	23498.5	156.1	1202.0	22296.5	13444.78	6622.06
69	3450.0	0.77	26.53	13444.8		0.0	333.8	0.09	30.042	14376.1	156.1	1202.0	13174.1	7943.99	3912.71
70	3500.0	0.77	27.3	7944.0		0.0	333.8	0.09	30.042	8875.3	156.1	1202.0	7673.3	4627.01	2278.98
71	3550.0	0.77	28.07	4627.0		0.0	333.8	0.09	30.042	5558.3	156.1	1202.0	4356.3	2335.00	1150.08
72	3600.0	0.77	28.84	16298.8	13963.8	0.0	333.8	0.09	30.042	17230.1	156.1	1202.0	16028.2	8591.09	4231.43
73	3650.0	0.77	29.61	8591.1		0.0	333.8	0.09	30.042	9522.4	156.1	1202.0	8320.4	4459.75	2196.59
74	3700.0	0.77	30.38	11283.6	6428.0	395.8	333.8	0.09	30.042	12214.9	156.1	1202.0	11012.9	5902.92	2907.41
75	3750.0	0.77	31.15	5902.9		0.0	333.8	0.09	30.042	6834.2	156.1	1202.0	5632.3	3018.89	1486.91
76	3800.0	0.77	31.92	11283.6	4394.3	3870.4	333.8	0.09	30.042	12214.9	156.1	1202.0	11012.9	5902.92	2907.41
77	3850.0	0.77	32.69	5902.9		0.0	333.8	0.09	30.042	6834.2	156.1	1202.0	5632.3	3018.89	1486.91
78	3900.0	0.77	33.46	11283.6	4394.3	3870.4	333.8	0.09	30.042	12214.9	156.1	1202.0	11012.9	5902.92	2907.41
79	3950.0	0.77	34.23	5902.9		0.0	333.8	0.09	30.042	6834.2	156.1	1202.0	5632.3	3018.89	1486.91
80	4000.0	0.77	35	7413.2	4394.3	0.0	333.8	0.09	30.042	8344.5	156.1	1202.0	7142.5	3828.40	1885.63
				1318.9		14595.2									

Total water supply = 15914.1

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨(ETc mm/mon.)／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5mm)

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 2.2.2.7(2) Calculation of Water Quantity for Supplemental Supply to the Paddy Fields (February)

Feb. Water Re= 25.14 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×28	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67×(1.0～0.8)	⑬=⑪×0.33×(1.0～0.8)
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.)	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1267.0			333.8	0.085	28.373	2061.5	183.1	329.6	1731.9	1160.36	571.52
2	100.0	0.18	0.36	2534.0	571.5	802.2	333.8	0.085	28.373	4130.6	183.1	329.6	3801.1	2546.71	1254.35
3	150.0	0.18	0.54	2546.7		0.0	333.8	0.085	28.373	3341.2	183.1	329.6	3011.6	2017.75	993.82
4	200.0	0.18	0.72	5068.1	2248.2	802.2	333.8	0.085	28.373	5862.5	183.1	329.6	5532.9	3707.07	1825.87
5	250.0	0.18	0.9	3707.1		0.0	333.8	0.085	28.373	4501.5	183.1	329.6	4171.9	2795.20	1376.74
6	300.0	0.18	1.08	2795.2		0.0	333.8	0.085	28.373	3589.6	183.1	329.6	3260.1	2184.24	1075.82
7	350.0	0.18	1.26	2184.2		0.0	333.8	0.085	28.373	2978.7	183.1	329.6	2649.1	1774.90	874.20
8	400.0	0.18	1.44	6927.5	5152.6	0.0	333.8	0.085	28.373	7722.0	183.1	329.6	7392.4	4952.91	2439.49
9	450.0	0.18	1.62	4952.9		0.0	333.8	0.085	28.373	5747.4	183.1	329.6	5417.8	3629.91	1787.86
10	500.0	0.18	1.8	3629.9		0.0	333.8	0.085	28.373	4424.4	183.1	329.6	4094.8	2743.50	1351.27
11	550.0	0.18	1.98	2743.5		0.0	333.8	0.085	28.373	3537.9	183.1	329.6	3208.4	2149.60	1058.76
12	600.0	0.18	2.16	8787.0	6637.4	0.0	333.8	0.085	28.373	9581.4	183.1	329.6	9251.9	6198.74	3053.11
13	650.0	0.18	2.34	6198.7		0.0	333.8	0.085	28.373	6993.2	183.1	329.6	6663.6	4464.62	2198.99
14	700.0	0.18	2.52	4464.6		0.0	333.8	0.085	28.373	5259.1	183.1	329.6	4929.5	3302.75	1626.73
15	750.0	0.18	2.7	3302.8		0.0	333.8	0.085	28.373	4097.2	183.1	329.6	3767.6	2524.30	1243.31
16	800.0	0.18	2.88	10646.4	8122.1	0.0	333.8	0.085	28.373	11440.9	183.1	329.6	11111.3	7444.58	3666.73
17	850.0	0.18	3.06	7444.6		0.0	333.8	0.085	28.373	8239.0	183.1	329.6	7909.4	5299.33	2610.12
18	900.0	0.18	3.24	5299.3		0.0	333.8	0.085	28.373	6093.8	183.1	329.6	5764.2	3862.01	1902.18
19	950.0	0.18	3.42	3862.0		0.0	333.8	0.085	28.373	4656.5	183.1	329.6	4326.9	2899.00	1427.87
20	1000.0	0.18	3.6	12505.9	9606.9	0.0	333.8	0.085	28.373	13300.3	183.1	329.6	12970.8	8690.41	4280.35
21	1050.0	0.335	3.935	8690.4		0.0	333.8	0.1	33.38	9625.1	183.1	613.4	9011.7	6037.82	2973.85
22	1100.0	0.335	4.27	6037.8		0.0	333.8	0.1	33.38	6972.5	183.1	613.4	6359.1	4260.58	2098.49
23	1150.0	0.335	4.605	4260.6		0.0	333.8	0.1	33.38	5195.2	183.1	613.4	4581.8	3069.83	1512.01
24	1200.0	0.335	4.94	13934.5	10864.7	0.0	333.8	0.1	33.38	14869.2	183.1	613.4	14255.8	9551.38	4704.41
25	1250.0	0.335	5.275	9551.4		0.0	333.8	0.1	33.38	10486.0	183.1	613.4	9872.6	6614.66	3257.97
26	1300.0	0.335	5.61	6614.7		0.0	333.8	0.1	33.38	7549.3	183.1	613.4	6935.9	4647.07	2288.85
27	1350.0	0.335	5.945	4647.1		0.0	333.8	0.1	33.38	5581.7	183.1	613.4	4968.3	3328.77	1639.55
28	1400.0	0.335	6.28	15219.6	11890.8	0.0	333.8	0.1	33.38	16154.2	183.1	613.4	15540.8	10412.34	5128.47
29	1450.0	0.335	6.615	10412.3		0.0	333.8	0.1	33.38	11347.0	183.1	613.4	10733.6	7191.51	3542.09
30	1500.0	0.335	6.95	7191.5		0.0	333.8	0.1	33.38	8126.1	183.1	613.4	7512.8	5033.55	2479.21
31	1550.0	0.335	7.285	5033.6		0.0	333.8	0.1	33.38	5968.2	183.1	613.4	5354.8	3587.72	1767.09
32	1600.0	0.335	7.62	16504.6	12916.9	0.0	333.8	0.1	33.38	17439.2	183.1	613.4	16825.8	11273.30	5552.52
33	1650.0	0.335	7.955	11273.3		0.0	333.8	0.1	33.38	12207.9	183.1	613.4	11594.6	7768.36	3826.20
34	1700.0	0.335	8.29	7768.4		0.0	333.8	0.1	33.38	8703.0	183.1	613.4	8089.6	5420.04	2669.57
35	1750.0	0.335	8.625	5420.0		0.0	333.8	0.1	33.38	6354.7	183.1	613.4	5741.3	3846.67	1894.63
36	1800.0	0.335	8.96	17789.6	13942.9	0.0	333.8	0.1	33.38	18724.2	183.1	613.4	18110.8	12134.27	5976.58
37	1850.0	0.335	9.295	12134.3		0.0	333.8	0.1	33.38	13068.9	183.1	613.4	12455.5	8345.20	4110.32
38	1900.0	0.335	9.63	8345.2		0.0	333.8	0.1	33.38	9279.8	183.1	613.4	8666.5	5806.53	2859.93
39	1950.0	0.335	9.965	5806.5		0.0	333.8	0.1	33.38	6741.2	183.1	613.4	6127.8	4105.61	2022.17
40	2000.0	0.335	10.3	19074.6	14969.0	0.0	333.8	0.1	33.38	20009.3	183.1	613.4	19395.9	12995.23	6400.64
41	2050.0	0.465	10.765	12995.2		0.0	333.8	0.185	61.753	14724.3	183.1	851.4	13872.9	9294.84	4578.06
42	2100.0	0.465	11.23	9294.8		0.0	333.8	0.185	61.753	11023.9	183.1	851.4	10172.5	6815.58	3356.93
43	2150.0	0.465	11.695	6815.6		0.0	333.8	0.185	61.753	8544.7	183.1	851.4	7693.3	5154.48	2538.77
44	2200.0	0.465	12.16	22028.9	16874.4	0.0	333.8	0.185	61.753	23758.0	183.1	851.4	22906.5	15347.38	7559.16
45	2250.0	0.465	12.625	15347.4		0.0	333.8	0.185	61.753	17076.5	183.1	851.4	16225.1	10870.79	5354.27
46	2300.0	0.465	13.09	10870.8		0.0	333.8	0.185	61.753	12599.9	183.1	851.4	11748.5	7871.46	3876.99
47	2350.0	0.465	13.555	7871.5		0.0	333.8	0.185	61.753	9600.5	183.1	851.4	8749.1	5861.92	2887.21
48	2400.0	0.465	14.02	25539.6	19677.6	0.0	333.8	0.185	61.753	27268.6	183.1	851.4	26417.2	17699.54	8717.68
49	2450.0	0.465	14.485	17699.5		0.0	333.8	0.185	61.753	19428.6	183.1	851.4	18577.2	12446.73	6130.48
50	2500.0	0.465	14.95	12446.7		0.0	333.8	0.185	61.753	14175.8	183.1	851.4	13324.4	8927.35	4397.05
51	2550.0	0.465	15.415	8927.3		0.0	333.8	0.185	61.753	10656.4	183.1	851.4	9805.0	5912.42	2912.09
52	2600.0	0.465	15.88	28069.7	22157.3	0.0	333.8	0.185	61.753	29798.8	183.1	851.4	28947.4	17455.28	8597.38
53	2650.0	0.465	16.345	17455.3		0.0	333.8	0.185	61.753	19184.4	183.1	851.4	18332.9	11054.77	5444.89
54	2700.0	0.465	16.81	11054.8		0.0	333.8	0.185	61.753	12783.9	183.1	851.4	11932.4	7195.26	3543.93
55	2750.0	0.465	17.275	7195.3		0.0	333.8	0.185	61.753	8924.3	183.1	851.4	8072.9	4867.98	2397.66
56	2800.0	0.465	17.74	24851.8	19983.9	0.0	333.8	0.185	61.753	26580.9	183.1	851.4	25729.5	15514.89	7641.66
57	2850.0	0.465	18.205	15514.9		0.0	333.8	0.185	61.753	17244.0	183.1	851.4	16392.6	9884.71	4868.59
58	2900.0	0.465	18.67	9884.7		0.0	333.8	0.185	61.753	11613.8	183.1	851.4	10762.4	6489.72	3196.43
59	2950.0	0.465	19.135	6489.7		0.0	333.8	0.185	61.753	8218.8	183.1	851.4	7367.4	4442.53	2188.11
60	3000.0	0.465	19.6	22337.3	17894.8	0.0	333.8	0.185	61.753	24066.4	183.1	851.4	23215.0	13998.64	6894.85
61	3050.0	0.77	20.37	13998.6		0.0	333.8	0.09	30.042	14839.8	183.1	1409.9	13429.9	8098.26	3988.69
62	3100.0	0.77	21.14	8098.3		0.0	333.8	0.09	30.042	8939.4	183.1	1409.9	7529.6	4540.33	2236.28
63	3150.0	0.77	21.91	4540.3		0.0	333.8	0.09	30.042	5381.5	183.1	1409.9	3971.6	2394.89	1179.58
64	3200.0	0.77	22.68	21680.1	14299.4	4985.8	333.8	0.09	30.042	22521.3	183.1	1409.9	21111.4	12730.19	6270.09
65	3250.0	0.77	23.45	12730.2		0.0	333.8	0.09	30.042	13571.4	183.1	1409.9	12161.5	7333.38	3611.96
66	3300.0	0.77	24.22	7333.4		0.0	333.8	0.09	30.042	8174.6	183.1	1409.9	6764.7	4079.11	2009.11
67	3350.0	0.77	24.99	4079.1		0.0	333.8	0.09	30.042	4920.3	183.1	1409.9	3510.4	2116.78	1042.59
68	3400.0	0.77	25.76	21680.1	12933.8	6629.6	333.8	0.09	30.042	22521.3	183.1	1409.9	21111.4	12730.19	6270.09
69	3450.0	0.77	26.53	12730.2		0.0	333.8	0.09	30.042	13571.4	183.1	1409.9	12161.5	7333.38	3611.96
70	3500.0	0.77	27.3	7333.4		0.0	333.8	0.09	30.042	8174.6	183.1	1409.9	6764.7	4079.11	2009.11
71	3550.0	0.77	28.07	4079.1		0.0	333.8	0.09	30.042	4920.3	183.1	1409.9	3510.4	1881.58	926.75
72	3600.0	0.77	28.84	14699.5	12817.9	0.0	333.8	0.09	30.042	15540.7	183.1	1409.9	14130.8	7574.11	3730.53
73	3650.0	0.77	29.61	7574.1		0.0	333.8	0.09	30.042	8415.3	183.1	1409.9	7005.4	3754.90	1849.43
74	3700.0	0.77	30.38	12001.5	5580.0	2666.6	333.8	0.09	30.042	12842.7	183.1	1409.9	11432.8	6127.98	3018.26
75	3750.0	0.77	31.15	6128.0		0.0	333.8	0.09	30.042	6969.2	183.1	1409.9	5559.3	2979.78	1467.65
76	3800.0	0.77	31.92	12001.5	4485.9	4535.8	333.8	0.09	30.042	12842.7	183.1	1409.9	11432.8	6127.98	3018.26
77	3850.0	0.77	32.69	6128.0		0.0	333.8	0.09	30.042	6969.2	183.1	1409.9	5559.3	2979.78	1467.65
78	3900.0	0.77	33.46	12001.5	4485.9	4535.8	333.8	0.09	30.042	12842.7	183.1	1409.9	11432.8	6127.98	3018.26
79	3950.0	0.77	34.23	6128.0		0.0	333.8	0.09	30.042	6969.2	183.1	1409.9	5559.3	2979.78	1467.65
80	4000.0	0.77	35	7465.7	4485.9	0.0	333.8	0.09	30.042	8306.9	183.1	1409.9	6897.0	3696.79	1820.81
				1267.0		24958.0									

Total water supply = 26225.0

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨(ETc mm/mon.)／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5mm)

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 2.2.2.7(3) Calculation of Water Quantity for Supplemental Supply to the Paddy Fields (March)

Mar. Water Re= 24.10 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×31	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67×(1.0～0.8)	⑬=⑪×0.33×(1.0～0.8)
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.)	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1344.6			304.4	0.085	25.874	2146.7	170.4	306.7	1840.0	1232.78	607.19
2	100.0	0.18	0.36	2689.2	607.2	849.2	304.4	0.085	25.874	4340.5	170.4	306.7	4033.8	2702.65	1331.15
3	150.0	0.18	0.54	2702.6		0.0	304.4	0.085	25.874	3504.7	170.4	306.7	3198.0	2142.67	1055.35
4	200.0	0.18	0.72	5378.4	2386.5	849.2	304.4	0.085	25.874	6180.5	170.4	306.7	5873.8	3935.43	1938.35
5	250.0	0.18	0.9	3935.4		0.0	304.4	0.085	25.874	4737.5	170.4	306.7	4430.8	2968.64	1462.16
6	300.0	0.18	1.08	2968.6		0.0	304.4	0.085	25.874	3770.7	170.4	306.7	3464.0	2320.89	1143.12
7	350.0	0.18	1.26	2320.9		0.0	304.4	0.085	25.874	3123.0	170.4	306.7	2816.3	1886.90	929.37
8	400.0	0.18	1.44	7359.9	5473.0	0.0	304.4	0.085	25.874	8162.0	170.4	306.7	7855.3	5263.03	2592.24
9	450.0	0.18	1.62	5263.0		0.0	304.4	0.085	25.874	6065.1	170.4	306.7	5758.4	3858.13	1900.27
10	500.0	0.18	1.8	3858.1		0.0	304.4	0.085	25.874	4660.2	170.4	306.7	4353.5	2916.85	1436.66
11	550.0	0.18	1.98	2916.8		0.0	304.4	0.085	25.874	3718.9	170.4	306.7	3412.2	2286.19	1126.03
12	600.0	0.18	2.16	9341.4	7055.2	0.0	304.4	0.085	25.874	10143.5	170.4	306.7	9836.8	6590.63	3246.13
13	650.0	0.18	2.34	6590.6		0.0	304.4	0.085	25.874	7392.7	170.4	306.7	7086.0	4747.62	2338.38
14	700.0	0.18	2.52	4747.6		0.0	304.4	0.085	25.874	5549.7	170.4	306.7	5243.0	3512.81	1730.19
15	750.0	0.18	2.7	3512.8		0.0	304.4	0.085	25.874	4314.9	170.4	306.7	4008.2	2685.48	1322.70
16	800.0	0.18	2.88	11322.9	8637.4	0.0	304.4	0.085	25.874	12125.0	170.4	306.7	11818.3	7918.24	3900.03
17	850.0	0.18	3.06	7918.2		0.0	304.4	0.085	25.874	8720.3	170.4	306.7	8413.6	5637.12	2776.49
18	900.0	0.18	3.24	5637.1		0.0	304.4	0.085	25.874	6439.2	170.4	306.7	6132.5	4108.77	2023.72
19	950.0	0.18	3.42	4108.8		0.0	304.4	0.085	25.874	4910.9	170.4	306.7	4604.1	3084.78	1519.37
20	1000.0	0.18	3.6	13304.4	10219.6	0.0	304.4	0.085	25.874	14106.5	170.4	306.7	13799.8	9245.84	4553.92
21	1050.0	0.335	3.935	9245.8		0.0	304.4	0.1	30.44	10189.5	170.4	570.8	9618.6	6444.49	3174.15
22	1100.0	0.335	4.27	6444.5		0.0	304.4	0.1	30.44	7388.1	170.4	570.8	6817.3	4567.58	2249.70
23	1150.0	0.335	4.605	4567.6		0.0	304.4	0.1	30.44	5511.2	170.4	570.8	4940.4	3310.06	1630.33
24	1200.0	0.335	4.94	14918.2	11608.1	0.0	304.4	0.1	30.44	15861.8	170.4	570.8	15291.0	10244.94	5046.02
25	1250.0	0.335	5.275	10244.9		0.0	304.4	0.1	30.44	11188.6	170.4	570.8	10617.7	7113.89	3503.85
26	1300.0	0.335	5.61	7113.9		0.0	304.4	0.1	30.44	8057.5	170.4	570.8	7486.7	5016.08	2470.61
27	1350.0	0.335	5.945	5016.1		0.0	304.4	0.1	30.44	5959.7	170.4	570.8	5388.9	3610.55	1778.33
28	1400.0	0.335	6.28	16409.4	12798.8	0.0	304.4	0.1	30.44	17353.0	170.4	570.8	16782.2	11244.05	5538.11
29	1450.0	0.335	6.615	11244.0		0.0	304.4	0.1	30.44	12187.7	170.4	570.8	11616.8	7783.29	3833.56
30	1500.0	0.335	6.95	7783.3		0.0	304.4	0.1	30.44	8726.9	170.4	570.8	8156.1	5464.58	2691.51
31	1550.0	0.335	7.285	5464.6		0.0	304.4	0.1	30.44	6408.2	170.4	570.8	5837.4	3911.04	1926.33
32	1600.0	0.335	7.62	17900.6	13989.5	0.0	304.4	0.1	30.44	18844.2	170.4	570.8	18273.4	12243.15	6030.21
33	1650.0	0.335	7.955	12243.1		0.0	304.4	0.1	30.44	13186.8	170.4	570.8	12615.9	8452.69	4163.26
34	1700.0	0.335	8.29	8452.7		0.0	304.4	0.1	30.44	9396.3	170.4	570.8	8825.5	5913.08	2912.41
35	1750.0	0.335	8.625	5913.1		0.0	304.4	0.1	30.44	6856.7	170.4	570.8	6285.9	4211.54	2074.34
36	1800.0	0.335	8.96	19391.8	15180.2	0.0	304.4	0.1	30.44	20335.4	170.4	570.8	19764.6	13242.25	6522.30
37	1850.0	0.335	9.295	13242.3		0.0	304.4	0.1	30.44	14185.9	170.4	570.8	13615.1	9122.09	4492.97
38	1900.0	0.335	9.63	9122.1		0.0	304.4	0.1	30.44	10065.7	170.4	570.8	9494.9	6361.57	3133.31
39	1950.0	0.335	9.965	6361.6		0.0	304.4	0.1	30.44	7305.2	170.4	570.8	6734.4	4512.03	2222.34
40	2000.0	0.335	10.3	20883.0	16370.9	0.0	304.4	0.1	30.44	21826.6	170.4	570.8	21255.8	14241.36	7014.40
41	2050.0	0.465	10.765	14241.4		0.0	304.4	0.185	56.314	15987.1	170.4	792.4	15194.7	10180.47	5014.26
42	2100.0	0.465	11.23	10180.5		0.0	304.4	0.185	56.314	11926.2	170.4	792.4	11133.8	7459.68	3674.17
43	2150.0	0.465	11.695	7459.7		0.0	304.4	0.185	56.314	9205.4	170.4	792.4	8413.0	5636.74	2776.31
44	2200.0	0.465	12.16	24115.9	18479.1	0.0	304.4	0.185	56.314	25861.6	170.4	792.4	25069.3	16796.40	8272.85
45	2250.0	0.465	12.625	16796.4		0.0	304.4	0.185	56.314	18542.1	170.4	792.4	17749.8	11892.35	5857.43
46	2300.0	0.465	13.09	11892.3		0.0	304.4	0.185	56.314	13638.1	170.4	792.4	12845.7	8606.63	4239.09
47	2350.0	0.465	13.555	8606.6		0.0	304.4	0.185	56.314	10352.4	170.4	792.4	9560.0	6405.21	3154.80
48	2400.0	0.465	14.02	27929.4	21524.2	0.0	304.4	0.185	56.314	29675.1	170.4	792.4	28882.8	19351.44	9531.31
49	2450.0	0.465	14.485	19351.4		0.0	304.4	0.185	56.314	21097.2	170.4	792.4	20304.8	13604.23	6700.59
50	2500.0	0.465	14.95	13604.2		0.0	304.4	0.185	56.314	15350.0	170.4	792.4	14557.6	8778.23	4323.61
51	2550.0	0.465	15.415	8778.2		0.0	304.4	0.185	56.314	10524.0	170.4	792.4	9731.6	5868.16	2890.29
52	2600.0	0.465	15.88	29314.0	23445.8	0.0	304.4	0.185	56.314	31059.7	170.4	792.4	30267.3	18251.20	8989.40
53	2650.0	0.465	16.345	18251.2		0.0	304.4	0.185	56.314	19996.9	170.4	792.4	19204.6	11580.36	5703.76
54	2700.0	0.465	16.81	11580.4		0.0	304.4	0.185	56.314	13326.1	170.4	792.4	12533.7	7557.84	3722.52
55	2750.0	0.465	17.275	7557.8		0.0	304.4	0.185	56.314	9303.6	170.4	792.4	8511.2	5132.26	2527.83
56	2800.0	0.465	17.74	26075.8	20943.5	0.0	304.4	0.185	56.314	27821.5	170.4	792.4	27029.1	16298.57	8027.65
57	2850.0	0.465	18.205	16298.6		0.0	304.4	0.185	56.314	18044.3	170.4	792.4	17251.9	10402.92	5123.83
58	2900.0	0.465	18.67	10402.9		0.0	304.4	0.185	56.314	12148.7	170.4	792.4	11356.3	6847.85	3372.82
59	2950.0	0.465	19.135	6847.8		0.0	304.4	0.185	56.314	8593.6	170.4	792.4	7801.2	4704.14	2316.96
60	3000.0	0.465	19.6	23545.4	18841.3	0.0	304.4	0.185	56.314	25291.1	170.4	792.4	24498.8	14772.76	7276.14
61	3050.0	0.77	20.37	14772.8		0.0	304.4	0.09	27.396	15622.0	170.4	1312.1	14310.0	8628.90	4250.06
62	3100.0	0.77	21.14	8628.9		0.0	304.4	0.09	27.396	9478.2	170.4	1312.1	8166.1	4924.16	2425.33
63	3150.0	0.77	21.91	4924.2		0.0	304.4	0.09	27.396	5773.4	170.4	1312.1	4461.4	2690.20	1325.02
64	3200.0	0.77	22.68	23007.6	15276.5	5040.9	304.4	0.09	27.396	23856.9	170.4	1312.1	22544.8	13594.51	6695.80
65	3250.0	0.77	23.45	13594.5		0.0	304.4	0.09	27.396	14443.8	170.4	1312.1	13131.7	7918.42	3900.12
66	3300.0	0.77	24.22	7918.4		0.0	304.4	0.09	27.396	8767.7	170.4	1312.1	7455.6	4495.74	2214.32
67	3350.0	0.77	24.99	4495.7		0.0	304.4	0.09	27.396	5345.0	170.4	1312.1	4032.9	2431.86	1197.78
68	3400.0	0.77	25.76	23007.6	14008.0	6567.7	304.4	0.09	27.396	23856.9	170.4	1312.1	22544.8	13594.51	6695.80
69	3450.0	0.77	26.53	13594.5		0.0	304.4	0.09	27.396	14443.8	170.4	1312.1	13131.7	7918.42	3900.12
70	3500.0	0.77	27.3	7918.4		0.0	304.4	0.09	27.396	8767.7	170.4	1312.1	7455.6	4495.74	2214.32
71	3550.0	0.77	28.07	4495.7		0.0	304.4	0.09	27.396	5345.0	170.4	1312.1	4032.9	2161.65	1064.69
72	3600.0	0.77	28.84	16036.6	13874.9	0.0	304.4	0.09	27.396	16885.9	170.4	1312.1	15573.8	8347.55	4111.48
73	3650.0	0.77	29.61	8347.5		0.0	304.4	0.09	27.396	9196.8	170.4	1312.1	7884.7	4226.22	2081.57
74	3700.0	0.77	30.38	11503.8	6193.1	1084.5	304.4	0.09	27.396	12353.1	170.4	1312.1	11041.0	5917.97	2914.82
75	3750.0	0.77	31.15	5918.0		0.0	304.4	0.09	27.396	6767.2	170.4	1312.1	5455.2	2923.97	1440.16
76	3800.0	0.77	31.92	11503.8	4355.0	4224.8	304.4	0.09	27.396	12353.1	170.4	1312.1	11041.0	5917.97	2914.82
77	3850.0	0.77	32.69	5918.0		0.0	304.4	0.09	27.396	6767.2	170.4	1312.1	5455.2	2923.97	1440.16
78	3900.0	0.77	33.46	11503.8	4355.0	4224.8	304.4	0.09	27.396	12353.1	170.4	1312.1	11041.0	5917.97	2914.82
79	3950.0	0.77	34.23	5918.0		0.0	304.4	0.09	27.396	6767.2	170.4	1312.1	5455.2	2923.97	1440.16
80	4000.0	0.77	35	7279.0	4355.0	0.0	304.4	0.09	27.396	8128.2	170.4	1312.1	6816.2	3653.46	1799.46
				1344.6		22841.2									

Total water supply = 24185.8

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨(ETc mm/mon.)／days in month （ETc: calculated by CROPWAT-8）

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5mm)

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 2.2.2.7(4) Calculation of Water Quantity for Supplemental Supply to the Paddy Fields (April)

Apr. Water Re= 19.02 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×30	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67×(1.0～0.8)	⑬=⑪×0.33×(1.0～0.8)
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.)	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1061.5			441.8	0.085	37.553	2225.6	12.7	22.9	2202.8	1475.87	726.92
2	100.0	0.18	0.36	2202.8	726.9	0.0	441.8	0.085	37.553	3366.9	12.7	22.9	3344.1	2240.53	1103.54
3	150.0	0.18	0.54	2240.5		0.0	441.8	0.085	37.553	3404.7	12.7	22.9	3381.8	2265.81	1116.00
4	200.0	0.18	0.72	4485.4	2219.5	0.0	441.8	0.085	37.553	5649.5	12.7	22.9	5626.6	3769.84	1856.79
5	250.0	0.18	0.9	3769.8		0.0	441.8	0.085	37.553	4934.0	12.7	22.9	4911.1	3290.46	1620.67
6	300.0	0.18	1.08	3290.5		0.0	441.8	0.085	37.553	4454.6	12.7	22.9	4431.7	2969.26	1462.47
7	350.0	0.18	1.26	2969.3		0.0	441.8	0.085	37.553	4133.4	12.7	22.9	4110.5	2754.07	1356.48
8	400.0	0.18	1.44	9050.5	6296.4	0.0	441.8	0.085	37.553	10214.6	12.7	22.9	10191.8	6828.48	3363.28
9	450.0	0.18	1.62	6828.5		0.0	441.8	0.085	37.553	7992.6	12.7	22.9	7969.8	5339.74	2630.02
10	500.0	0.18	1.8	5339.7		0.0	441.8	0.085	37.553	6503.9	12.7	22.9	6481.0	4342.29	2138.74
11	550.0	0.18	1.98	4342.3		0.0	441.8	0.085	37.553	5506.4	12.7	22.9	5483.6	3673.99	1809.58
12	600.0	0.18	2.16	13615.6	9941.6	0.0	441.8	0.085	37.553	14779.8	12.7	22.9	14756.9	9887.12	4869.78
13	650.0	0.18	2.34	9887.1		0.0	441.8	0.085	37.553	11051.3	12.7	22.9	11028.4	7389.03	3639.37
14	700.0	0.18	2.52	7389.0		0.0	441.8	0.085	37.553	8553.2	12.7	22.9	8530.3	5715.31	2815.00
15	750.0	0.18	2.7	5715.3		0.0	441.8	0.085	37.553	6879.5	12.7	22.9	6856.6	4593.92	2262.68
16	800.0	0.18	2.88	18180.7	13586.8	0.0	441.8	0.085	37.553	19344.9	12.7	22.9	19322.0	12945.76	6376.27
17	850.0	0.18	3.06	12945.8		0.0	441.8	0.085	37.553	14109.9	12.7	22.9	14087.0	9438.32	4648.72
18	900.0	0.18	3.24	9438.3		0.0	441.8	0.085	37.553	10602.5	12.7	22.9	10579.6	7088.33	3491.27
19	950.0	0.18	3.42	7088.3		0.0	441.8	0.085	37.553	8252.5	12.7	22.9	8229.6	5513.84	2715.77
20	1000.0	0.18	3.6	22745.9	17232.0	0.0	441.8	0.085	37.553	23910.0	12.7	22.9	23887.2	16004.40	7882.76
21	1050.0	0.335	3.935	16004.4		0.0	441.8	0.1	44.18	17374.0	12.7	42.5	17331.4	11612.06	5719.37
22	1100.0	0.335	4.27	11612.1		0.0	441.8	0.1	44.18	12981.6	12.7	42.5	12939.1	8669.19	4269.90
23	1150.0	0.335	4.605	8669.2		0.0	441.8	0.1	44.18	10038.8	12.7	42.5	9996.2	6697.47	3298.76
24	1200.0	0.335	4.94	27868.3	21170.8	0.0	441.8	0.1	44.18	29237.8	12.7	42.5	29195.3	19560.85	9634.45
25	1250.0	0.335	5.275	19560.9		0.0	441.8	0.1	44.18	20930.4	12.7	42.5	20887.9	13994.88	6893.00
26	1300.0	0.335	5.61	13994.9		0.0	441.8	0.1	44.18	15364.5	12.7	42.5	15321.9	10265.69	5056.23
27	1350.0	0.335	5.945	10265.7		0.0	441.8	0.1	44.18	11635.3	12.7	42.5	11592.7	7767.12	3825.60
28	1400.0	0.335	6.28	33176.4	25409.3	0.0	441.8	0.1	44.18	34546.0	12.7	42.5	34503.4	23117.31	11386.14
29	1450.0	0.335	6.615	23117.3		0.0	441.8	0.1	44.18	24486.9	12.7	42.5	24444.3	16377.71	8066.63
30	1500.0	0.335	6.95	16377.7		0.0	441.8	0.1	44.18	17747.3	12.7	42.5	17704.7	11862.18	5842.57
31	1550.0	0.335	7.285	11862.2		0.0	441.8	0.1	44.18	13231.8	12.7	42.5	13189.2	8836.77	4352.44
32	1600.0	0.335	7.62	38484.5	29647.8	0.0	441.8	0.1	44.18	39854.1	12.7	42.5	39811.6	26673.76	13137.82
33	1650.0	0.335	7.955	26673.8		0.0	441.8	0.1	44.18	28043.3	12.7	42.5	28000.8	18760.53	9240.26
34	1700.0	0.335	8.29	18760.5		0.0	441.8	0.1	44.18	20130.1	12.7	42.5	20087.6	13458.67	6628.90
35	1750.0	0.335	8.625	13458.7		0.0	441.8	0.1	44.18	14828.3	12.7	42.5	14785.7	9906.42	4879.28
36	1800.0	0.335	8.96	43792.7	33886.3	0.0	441.8	0.1	44.18	45162.3	12.7	42.5	45119.7	30230.21	14889.51
37	1850.0	0.335	9.295	30230.2		0.0	441.8	0.1	44.18	31599.8	12.7	42.5	31557.2	21143.36	10413.89
38	1900.0	0.335	9.63	21143.4		0.0	441.8	0.1	44.18	22512.9	12.7	42.5	22470.4	15055.16	7415.23
39	1950.0	0.335	9.965	15055.2		0.0	441.8	0.1	44.18	16424.7	12.7	42.5	16382.2	10976.07	5406.13
40	2000.0	0.335	10.3	49100.8	38124.8	0.0	441.8	0.1	44.18	50470.4	12.7	42.5	50427.9	33786.67	16641.19
41	2050.0	0.465	10.765	33786.7		0.0	441.8	0.185	81.733	36320.4	12.7	59.1	36261.3	24295.09	11966.24
42	2100.0	0.465	11.23	24295.1		0.0	441.8	0.185	81.733	26828.8	12.7	59.1	26769.8	17935.74	8834.02
43	2150.0	0.465	11.695	17935.7		0.0	441.8	0.185	81.733	20469.5	12.7	59.1	20410.4	13674.97	6735.43
44	2200.0	0.465	12.16	57851.9	44176.9	0.0	441.8	0.185	81.733	60385.6	12.7	59.1	60326.5	40418.78	19907.76
45	2250.0	0.465	12.625	40418.8		0.0	441.8	0.185	81.733	42952.5	12.7	59.1	42893.4	28738.61	14154.84
46	2300.0	0.465	13.09	28738.6		0.0	441.8	0.185	81.733	31272.3	12.7	59.1	31213.3	20912.90	10300.38
47	2350.0	0.465	13.555	20912.9		0.0	441.8	0.185	81.733	23446.6	12.7	59.1	23387.6	15669.67	7717.90
48	2400.0	0.465	14.02	67750.5	52080.9	0.0	441.8	0.185	81.733	70284.3	12.7	59.1	70225.2	47050.89	23174.32
49	2450.0	0.465	14.485	47050.9		0.0	441.8	0.185	81.733	49584.6	12.7	59.1	49525.6	33182.12	16343.43
50	2500.0	0.465	14.95	33182.1		0.0	441.8	0.185	81.733	35715.8	12.7	59.1	35656.8	23890.05	11766.74
51	2550.0	0.465	15.415	23890.0		0.0	441.8	0.185	81.733	26423.8	12.7	59.1	26364.7	15897.92	7830.32
52	2600.0	0.465	15.88	75012.7	59114.8	0.0	441.8	0.185	81.733	77546.5	12.7	59.1	77487.4	46724.91	23013.76
53	2650.0	0.465	16.345	46724.9		0.0	441.8	0.185	81.733	49258.6	12.7	59.1	49199.6	29667.34	14612.27
54	2700.0	0.465	16.81	29667.3		0.0	441.8	0.185	81.733	32201.1	12.7	59.1	32142.0	19381.63	9546.18
55	2750.0	0.465	17.275	19381.6		0.0	441.8	0.185	81.733	21915.4	12.7	59.1	21856.3	13179.35	6491.32
56	2800.0	0.465	17.74	66842.9	53663.5	0.0	441.8	0.185	81.733	69376.6	12.7	59.1	69317.5	41798.48	20587.31
57	2850.0	0.465	18.205	41798.5		0.0	441.8	0.185	81.733	44332.2	12.7	59.1	44273.2	26696.71	13149.13
58	2900.0	0.465	18.67	26696.7		0.0	441.8	0.185	81.733	29230.4	12.7	59.1	29171.4	17590.34	8663.90
59	2950.0	0.465	19.135	17590.3		0.0	441.8	0.185	81.733	20124.1	12.7	59.1	20065.0	12099.20	5959.31
60	3000.0	0.465	19.6	60458.8	48359.6	0.0	441.8	0.185	81.733	62992.6	12.7	59.1	62933.5	37948.91	18691.25
61	3050.0	0.77	20.37	37948.9		0.0	441.8	0.09	39.762	39181.5	12.7	97.8	39083.7	23567.50	11607.87
62	3100.0	0.77	21.14	23567.5		0.0	441.8	0.09	39.762	24800.1	12.7	97.8	24702.3	14895.50	7336.59
63	3150.0	0.77	21.91	14895.5		0.0	441.8	0.09	39.762	16128.1	12.7	97.8	16030.3	9666.29	4761.01
64	3200.0	0.77	22.68	52063.0	42396.7	0.0	441.8	0.09	39.762	53295.6	12.7	97.8	53197.8	32078.30	15799.76
65	3250.0	0.77	23.45	32078.3		0.0	441.8	0.09	39.762	33310.9	12.7	97.8	33213.1	20027.52	9864.30
66	3300.0	0.77	24.22	20027.5		0.0	441.8	0.09	39.762	21260.1	12.7	97.8	21162.4	12760.90	6285.22
67	3350.0	0.77	24.99	12760.9		0.0	441.8	0.09	39.762	13993.5	12.7	97.8	13895.7	8379.13	4127.03
68	3400.0	0.77	25.76	44455.4	36076.3	0.0	441.8	0.09	39.762	45688.1	12.7	97.8	45590.3	27490.93	13540.31
69	3450.0	0.77	26.53	27490.9		0.0	441.8	0.09	39.762	28723.6	12.7	97.8	28625.8	17261.34	8501.85
70	3500.0	0.77	27.3	17261.3		0.0	441.8	0.09	39.762	18494.0	12.7	97.8	18396.2	11092.89	5463.66
71	3550.0	0.77	28.07	11092.9		0.0	441.8	0.09	39.762	12325.5	12.7	97.8	12227.7	6554.06	3228.12
72	3600.0	0.77	28.84	37288.0	30733.9	0.0	441.8	0.09	39.762	38520.6	12.7	97.8	38422.8	20594.64	10143.63
73	3650.0	0.77	29.61	20594.6		0.0	441.8	0.09	39.762	21827.3	12.7	97.8	21729.5	11647.00	5736.58
74	3700.0	0.77	30.38	27527.2	15880.2	0.0	441.8	0.09	39.762	28759.8	12.7	97.8	28662.0	15362.85	7566.78
75	3750.0	0.77	31.15	15362.9		0.0	441.8	0.09	39.762	16595.5	12.7	97.8	16497.7	8842.76	4355.39
76	3800.0	0.77	31.92	20764.9	11922.2	0.0	441.8	0.09	39.762	21997.5	12.7	97.8	21899.8	11738.27	5781.54
77	3850.0	0.77	32.69	11738.3		0.0	441.8	0.09	39.762	12970.9	12.7	97.8	12873.1	6899.98	3398.50
78	3900.0	0.77	33.46	16080.0	9180.0	0.0	441.8	0.09	39.762	17312.6	12.7	97.8	17214.8	9227.16	4544.72
79	3950.0	0.77	34.23	9227.2		0.0	441.8	0.09	39.762	10459.8	12.7	97.8	10362.0	5554.03	2735.57
80	4000.0	0.77	35	12834.3	7280.3	0.0	441.8	0.09	39.762	14066.9	12.7	97.8	13969.1	7487.46	3687.85
				1061.5		0.0									
					Total water supply =	1061.5									

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨(ETc mm/mon.)／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5mm)

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 2.2.2.7(5) Calculation of Water Quantity for Supplemental Supply to the Paddy Fields (May)

May Water Re= 19.31 mm/day

NO.	Distance (m)	① Paddy Area (ha)	Cumulative Area (ha)	② W.S./initial, return (m3/mon)	③ Intake quantity (m3/mon.)	④ Supplemental supply (m3/mon)	⑤ Specific discharge (m3/km2)	⑥ catchment area (km2)	⑦=⑤×⑥ Flow-in volume (m3/day)	⑧=②+⑦×31 Irrigation water (m3/mon)	⑨ ETc (mm/mon)	⑩=①×⑨×10000/1000 Water loss (m3/mon)	⑪=⑧-⑩ Residual water (m3/mon.)	⑫=⑪×0.67×(1.0～0.8) Horizontal leakage (m3/mon.)	⑬=⑪×0.33×(1.0～0.8) Return to the river (m3/mon.)
1	50.0	0.18	0.18	1077.5		0.0	657.8	0.085	55.913	2810.8	22.0	39.6	2771.2	1856.69	914.49
2	100.0	0.18	0.36	2771.2	914.5	0.0	657.8	0.085	55.913	4504.5	22.0	39.6	4464.9	2991.47	1473.41
3	150.0	0.18	0.54	2991.5		0.0	657.8	0.085	55.913	4724.8	22.0	39.6	4685.2	3139.07	1546.11
4	200.0	0.18	0.72	6158.6	3019.5	0.0	657.8	0.085	55.913	7891.9	22.0	39.6	7852.3	5261.04	2591.26
5	250.0	0.18	0.9	5261.0		0.0	657.8	0.085	55.913	6994.3	22.0	39.6	6954.7	4659.67	2295.06
6	300.0	0.18	1.08	4659.7		0.0	657.8	0.085	55.913	6393.0	22.0	39.6	6353.4	4256.76	2096.61
7	350.0	0.18	1.26	4256.8		0.0	657.8	0.085	55.913	5990.1	22.0	39.6	5950.5	3986.81	1963.65
8	400.0	0.18	1.44	12933.4	8946.6	0.0	657.8	0.085	55.913	14666.7	22.0	39.6	14627.1	9800.16	4826.94
9	450.0	0.18	1.62	9800.2		0.0	657.8	0.085	55.913	11533.5	22.0	39.6	11493.9	7700.89	3792.97
10	500.0	0.18	1.8	7700.9		0.0	657.8	0.085	55.913	9434.2	22.0	39.6	9394.6	6294.38	3100.22
11	550.0	0.18	1.98	6294.4		0.0	657.8	0.085	55.913	8027.7	22.0	39.6	7988.1	5352.01	2636.07
12	600.0	0.18	2.16	19708.2	14356.2	0.0	657.8	0.085	55.913	21441.5	22.0	39.6	21401.9	14339.28	7062.63
13	650.0	0.18	2.34	14339.3		0.0	657.8	0.085	55.913	16072.6	22.0	39.6	16033.0	10742.10	5290.89
14	700.0	0.18	2.52	10742.1		0.0	657.8	0.085	55.913	12475.4	22.0	39.6	12435.8	8331.99	4103.82
15	750.0	0.18	2.7	8332.0		0.0	657.8	0.085	55.913	10065.3	22.0	39.6	10025.7	6717.21	3308.48
16	800.0	0.18	2.88	26483.0	19765.8	0.0	657.8	0.085	55.913	28216.3	22.0	39.6	28176.7	18878.41	9298.32
17	850.0	0.18	3.06	18878.4		0.0	657.8	0.085	55.913	20611.7	22.0	39.6	20572.1	13783.31	6788.80
18	900.0	0.18	3.24	13783.3		0.0	657.8	0.085	55.913	15516.6	22.0	39.6	15477.0	10369.60	5107.42
19	950.0	0.18	3.42	10369.6		0.0	657.8	0.085	55.913	12102.9	22.0	39.6	12063.3	8082.41	3980.89
20	1000.0	0.18	3.6	33257.8	25175.4	0.0	657.8	0.085	55.913	34991.1	22.0	39.6	34951.5	23417.53	11534.01
21	1050.0	0.335	3.935	23417.5		0.0	657.8	0.1	65.78	25456.7	22.0	73.7	25383.0	17006.62	8376.39
22	1100.0	0.335	4.27	17006.6		0.0	657.8	0.1	65.78	19045.8	22.0	73.7	18972.1	12711.31	6260.79
23	1150.0	0.335	4.605	12711.3		0.0	657.8	0.1	65.78	14750.5	22.0	73.7	14676.8	9833.45	4843.34
24	1200.0	0.335	4.94	40848.0	31014.5	0.0	657.8	0.1	65.78	42887.2	22.0	73.7	42813.5	28685.02	14128.44
25	1250.0	0.335	5.275	28685.0		0.0	657.8	0.1	65.78	30724.2	22.0	73.7	30650.5	20535.83	10114.66
26	1300.0	0.335	5.61	20535.8		0.0	657.8	0.1	65.78	22575.0	22.0	73.7	22501.3	15075.88	7425.43
27	1350.0	0.335	5.945	15075.9		0.0	657.8	0.1	65.78	17115.1	22.0	73.7	17041.4	11417.71	5623.65
28	1400.0	0.335	6.28	48709.9	37292.2	0.0	657.8	0.1	65.78	50749.1	22.0	73.7	50675.4	33952.50	16722.88
29	1450.0	0.335	6.615	33952.5		0.0	657.8	0.1	65.78	35991.7	22.0	73.7	35918.0	24065.05	11852.93
30	1500.0	0.335	6.95	24065.0		0.0	657.8	0.1	65.78	26104.2	22.0	73.7	26030.5	17440.45	8590.07
31	1550.0	0.335	7.285	17440.5		0.0	657.8	0.1	65.78	19479.6	22.0	73.7	19405.9	13001.98	6403.96
32	1600.0	0.335	7.62	56571.8	43569.8	0.0	657.8	0.1	65.78	58611.0	22.0	73.7	58537.3	39219.99	19317.31
33	1650.0	0.335	7.955	39220.0		0.0	657.8	0.1	65.78	41259.2	22.0	73.7	41185.5	27594.27	13591.21
34	1700.0	0.335	8.29	27594.3		0.0	657.8	0.1	65.78	29633.4	22.0	73.7	29559.7	19805.03	9754.72
35	1750.0	0.335	8.625	19805.0		0.0	657.8	0.1	65.78	21844.2	22.0	73.7	21770.5	14586.24	7184.27
36	1800.0	0.335	8.96	64433.7	49847.5	0.0	657.8	0.1	65.78	66472.9	22.0	73.7	66399.2	44487.48	21911.74
37	1850.0	0.335	9.295	44487.5		0.0	657.8	0.1	65.78	46526.7	22.0	73.7	46453.0	31123.48	15329.48
38	1900.0	0.335	9.63	31123.5		0.0	657.8	0.1	65.78	33162.7	22.0	73.7	33089.0	22169.60	10919.36
39	1950.0	0.335	9.965	22169.6		0.0	657.8	0.1	65.78	24208.8	22.0	73.7	24135.1	16170.51	7964.58
40	2000.0	0.335	10.3	72295.7	56125.2	0.0	657.8	0.1	65.78	74334.8	22.0	73.7	74261.1	49754.96	24506.18
41	2050.0	0.465	10.765	49755.0		0.0	657.8	0.185	121.693	53527.4	22.0	102.3	53425.1	35794.85	17630.30
42	2100.0	0.465	11.23	35794.8		0.0	657.8	0.185	121.693	39567.3	22.0	102.3	39465.0	26441.57	13023.46
43	2150.0	0.465	11.695	26441.6		0.0	657.8	0.185	121.693	30214.1	22.0	102.3	30111.8	20174.88	9936.88
44	2200.0	0.465	12.16	85271.7	65096.8	0.0	657.8	0.185	121.693	89044.2	22.0	102.3	88941.9	59591.05	29350.82
45	2250.0	0.465	12.625	59591.1		0.0	657.8	0.185	121.693	63363.5	22.0	102.3	63261.2	42385.03	20876.21
46	2300.0	0.465	13.09	42385.0		0.0	657.8	0.185	121.693	46157.5	22.0	102.3	46055.2	30856.99	15198.22
47	2350.0	0.465	13.555	30857.0		0.0	657.8	0.185	121.693	34629.5	22.0	102.3	34527.2	23133.21	11393.97
48	2400.0	0.465	14.02	99952.4	76819.2	0.0	657.8	0.185	121.693	103724.9	22.0	102.3	103622.6	69427.14	34195.46
49	2450.0	0.465	14.485	69427.1		0.0	657.8	0.185	121.693	73199.6	22.0	102.3	73097.3	48975.21	24122.12
50	2500.0	0.465	14.95	48975.2		0.0	657.8	0.185	121.693	52747.7	22.0	102.3	52645.4	35272.41	17372.98
51	2550.0	0.465	15.415	35272.4		0.0	657.8	0.185	121.693	39044.9	22.0	102.3	38942.6	23482.39	11565.95
52	2600.0	0.465	15.88	110738.9	87256.5	0.0	657.8	0.185	121.693	114511.4	22.0	102.3	114409.1	68988.67	33979.50
53	2650.0	0.465	16.345	68988.7		0.0	657.8	0.185	121.693	72761.2	22.0	102.3	72658.9	43813.29	21579.68
54	2700.0	0.465	16.81	43813.3		0.0	657.8	0.185	121.693	47585.8	22.0	102.3	47483.5	28632.53	14102.59
55	2750.0	0.465	17.275	28632.5		0.0	657.8	0.185	121.693	32405.0	22.0	102.3	32302.7	19478.54	9593.91
56	2800.0	0.465	17.74	98734.2	79255.7	0.0	657.8	0.185	121.693	102506.7	22.0	102.3	102404.4	61749.85	30414.11
57	2850.0	0.465	18.205	61749.9		0.0	657.8	0.185	121.693	65522.3	22.0	102.3	65420.0	39448.28	19429.75
58	2900.0	0.465	18.67	39448.3		0.0	657.8	0.185	121.693	43220.8	22.0	102.3	43118.5	26000.43	12806.18
59	2950.0	0.465	19.135	26000.4		0.0	657.8	0.185	121.693	29772.9	22.0	102.3	29670.6	17891.38	8812.17
60	3000.0	0.465	19.6	89353.6	71462.2	0.0	657.8	0.185	121.693	93126.1	22.0	102.3	93023.8	56093.34	27628.06
61	3050.0	0.77	20.37	56093.3		0.0	657.8	0.09	59.202	57928.6	22.0	169.4	57759.2	34828.80	17154.48
62	3100.0	0.77	21.14	34828.8		0.0	657.8	0.09	59.202	36664.1	22.0	169.4	36494.7	22006.28	10838.91
63	3150.0	0.77	21.91	22006.3		0.0	657.8	0.09	59.202	23841.5	22.0	169.4	23672.1	14274.30	7030.63
64	3200.0	0.77	22.68	76926.4	62652.1	0.0	657.8	0.09	59.202	78761.6	22.0	169.4	78592.2	47391.13	23341.90
65	3250.0	0.77	23.45	47391.1		0.0	657.8	0.09	59.202	49226.4	22.0	169.4	49057.0	29581.36	14569.93
66	3300.0	0.77	24.22	29581.4		0.0	657.8	0.09	59.202	31416.6	22.0	169.4	31247.2	18842.08	9280.43
67	3350.0	0.77	24.99	18842.1		0.0	657.8	0.09	59.202	20677.3	22.0	169.4	20507.9	12366.29	6090.86
68	3400.0	0.77	25.76	65649.4	53283.1	0.0	657.8	0.09	59.202	67484.7	22.0	169.4	67315.3	40591.10	19992.63
69	3450.0	0.77	26.53	40591.1		0.0	657.8	0.09	59.202	42426.4	22.0	169.4	42257.0	25480.95	12550.32
70	3500.0	0.77	27.3	25480.9		0.0	657.8	0.09	59.202	27316.2	22.0	169.4	27146.8	16369.53	8062.60
71	3550.0	0.77	28.07	16369.5		0.0	657.8	0.09	59.202	18204.8	22.0	169.4	18035.4	9666.97	4761.34
72	3600.0	0.77	28.84	55033.9	45366.9	0.0	657.8	0.09	59.202	56869.1	22.0	169.4	56699.7	30391.05	14968.73
73	3650.0	0.77	29.61	30391.1		0.0	657.8	0.09	59.202	32226.3	22.0	169.4	32056.9	17182.51	8463.03
74	3700.0	0.77	30.38	40614.3	23431.8	0.0	657.8	0.09	59.202	42449.5	22.0	169.4	42280.1	22662.14	11161.95
75	3750.0	0.77	31.15	22662.1		0.0	657.8	0.09	59.202	24497.4	22.0	169.4	24328.0	13039.81	6422.59
76	3800.0	0.77	31.92	30624.4	17584.5	0.0	657.8	0.09	59.202	32459.6	22.0	169.4	32290.2	17307.56	8524.62
77	3850.0	0.77	32.69	17307.6		0.0	657.8	0.09	59.202	19142.8	22.0	169.4	18973.4	10169.75	5008.98
78	3900.0	0.77	33.46	23703.4	13533.6	0.0	657.8	0.09	59.202	25538.6	22.0	169.4	25369.2	13597.90	6697.47
79	3950.0	0.77	34.23	13597.9		0.0	657.8	0.09	59.202	15433.2	22.0	169.4	15263.8	8181.38	4029.63
80	4000.0	0.77	35	18908.5	10727.1	0.0	657.8	0.09	59.202	20743.7	22.0	169.4	20574.3	11027.85	5431.63
				1077.5		0.0									

Total water supply = 1077.5

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨(ETc mm/mon.)／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5mm)

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 2.2.2.7(6) Calculation of Water Quantity for Supplemental Supply to the Paddy Fields (June)

June Water Re= 20.08 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×30	⑨	⑩=①×⑨×10000/1000	⑪=⑧−⑩	⑫=⑪×0.67×(1.0～0.8)	⑬=⑪×0.33×(1.0～0.8)
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.)	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1120.5			373.1	0.085	31.7135	2103.6	44.4	79.9	2023.7	1355.85	667.81
2	100.0	0.18	0.36	2240.9	667.8	217.3	373.1	0.085	31.7135	3441.3	44.4	79.9	3361.4	2252.13	1109.26
3	150.0	0.18	0.54	2252.1		0.0	373.1	0.085	31.7135	3235.3	44.4	79.9	3155.3	2114.07	1041.26
4	200.0	0.18	0.72	4337.3	2150.5	72.7	373.1	0.085	31.7135	5320.4	44.4	79.9	5240.5	3511.12	1729.36
5	250.0	0.18	0.9	3511.1		0.0	373.1	0.085	31.7135	4494.2	44.4	79.9	4414.3	2957.59	1456.73
6	300.0	0.18	1.08	2957.6		0.0	373.1	0.085	31.7135	3940.7	44.4	79.9	3860.8	2586.73	1274.06
7	350.0	0.18	1.26	2586.7		0.0	373.1	0.085	31.7135	3569.8	44.4	79.9	3489.9	2338.25	1151.68
8	400.0	0.18	1.44	7950.1	5611.8	0.0	373.1	0.085	31.7135	8933.2	44.4	79.9	8853.3	5931.69	2921.58
9	450.0	0.18	1.62	5931.7		0.0	373.1	0.085	31.7135	6914.8	44.4	79.9	6834.9	4579.38	2255.51
10	500.0	0.18	1.8	4579.4		0.0	373.1	0.085	31.7135	5562.5	44.4	79.9	5482.6	3673.33	1809.25
11	550.0	0.18	1.98	3673.3		0.0	373.1	0.085	31.7135	4656.4	44.4	79.9	4576.5	3066.27	1510.25
12	600.0	0.18	2.16	11562.9	8496.6	0.0	373.1	0.085	31.7135	12546.0	44.4	79.9	12466.1	8352.26	4113.80
13	650.0	0.18	2.34	8352.3		0.0	373.1	0.085	31.7135	9335.4	44.4	79.9	9255.5	6201.16	3054.30
14	700.0	0.18	2.52	6201.2		0.0	373.1	0.085	31.7135	7184.3	44.4	79.9	7104.4	4759.92	2344.44
15	750.0	0.18	2.7	4759.9		0.0	373.1	0.085	31.7135	5743.0	44.4	79.9	5663.1	3794.29	1868.83
16	800.0	0.18	2.88	15175.7	11381.4	0.0	373.1	0.085	31.7135	16158.8	44.4	79.9	16078.9	10772.84	5306.02
17	850.0	0.18	3.06	10772.8		0.0	373.1	0.085	31.7135	11756.0	44.4	79.9	11676.0	7822.94	3853.09
18	900.0	0.18	3.24	7822.9		0.0	373.1	0.085	31.7135	8806.1	44.4	79.9	8726.1	5846.52	2879.63
19	950.0	0.18	3.42	5846.5		0.0	373.1	0.085	31.7135	6829.6	44.4	79.9	6749.7	4522.31	2227.41
20	1000.0	0.18	3.6	18788.5	14266.1	0.0	373.1	0.085	31.7135	19771.6	44.4	79.9	19691.7	13193.41	6498.25
21	1050.0	0.335	3.935	13193.4		0.0	373.1	0.1	37.31	14350.0	44.4	148.7	14201.3	9514.86	4686.42
22	1100.0	0.335	4.27	9514.9		0.0	373.1	0.1	37.31	10671.5	44.4	148.7	10522.7	7050.23	3472.50
23	1150.0	0.335	4.605	7050.2		0.0	373.1	0.1	37.31	8206.8	44.4	148.7	8058.1	5398.92	2659.17
24	1200.0	0.335	4.94	22715.3	17316.3	0.0	373.1	0.1	37.31	23871.9	44.4	148.7	23723.1	15894.50	7828.63
25	1250.0	0.335	5.275	15894.5		0.0	373.1	0.1	37.31	17051.1	44.4	148.7	16902.4	11324.59	5577.78
26	1300.0	0.335	5.61	11324.6		0.0	373.1	0.1	37.31	12481.2	44.4	148.7	12332.5	8262.75	4069.71
27	1350.0	0.335	5.945	8262.7		0.0	373.1	0.1	37.31	9419.4	44.4	148.7	9270.6	6211.31	3059.30
28	1400.0	0.335	6.28	26746.7	20535.4	0.0	373.1	0.1	37.31	27903.4	44.4	148.7	27754.6	18595.59	9159.02
29	1450.0	0.335	6.615	18595.6		0.0	373.1	0.1	37.31	19752.2	44.4	148.7	19603.5	13134.32	6469.14
30	1500.0	0.335	6.95	13134.3		0.0	373.1	0.1	37.31	14290.9	44.4	148.7	14142.2	9475.27	4666.92
31	1550.0	0.335	7.285	9475.3		0.0	373.1	0.1	37.31	10631.9	44.4	148.7	10483.1	7023.70	3459.44
32	1600.0	0.335	7.62	30778.2	23754.5	0.0	373.1	0.1	37.31	31934.8	44.4	148.7	31786.1	21296.68	10489.41
33	1650.0	0.335	7.955	21296.7		0.0	373.1	0.1	37.31	22453.3	44.4	148.7	22304.6	14944.05	7360.50
34	1700.0	0.335	8.29	14944.1		0.0	373.1	0.1	37.31	16100.7	44.4	148.7	15951.9	10687.79	5264.13
35	1750.0	0.335	8.625	10687.8		0.0	373.1	0.1	37.31	11844.4	44.4	148.7	11695.7	7836.09	3859.57
36	1800.0	0.335	8.96	34809.7	26973.6	0.0	373.1	0.1	37.31	35966.3	44.4	148.7	35817.6	23997.77	11819.80
37	1850.0	0.335	9.295	23997.8		0.0	373.1	0.1	37.31	25154.4	44.4	148.7	25005.6	16753.78	8251.86
38	1900.0	0.335	9.63	16753.8		0.0	373.1	0.1	37.31	17910.4	44.4	148.7	17761.7	11900.31	5861.35
39	1950.0	0.335	9.965	11900.3		0.0	373.1	0.1	37.31	13056.9	44.4	148.7	12908.2	8648.48	4259.70
40	2000.0	0.335	10.3	38841.2	30192.7	0.0	373.1	0.1	37.31	39997.8	44.4	148.7	39849.1	26698.87	13150.19
41	2050.0	0.465	10.765	26698.9		0.0	373.1	0.185	69.0235	28838.6	44.4	206.5	28632.1	19183.53	9448.60
42	2100.0	0.465	11.23	19183.5		0.0	373.1	0.185	69.0235	21323.3	44.4	206.5	21116.8	14148.26	6968.54
43	2150.0	0.465	11.695	14148.3		0.0	373.1	0.185	69.0235	16288.0	44.4	206.5	16081.5	10774.62	5306.90
44	2200.0	0.465	12.16	45648.9	34874.2	0.0	373.1	0.185	69.0235	47788.6	44.4	206.5	47582.1	31880.03	15702.10
45	2250.0	0.465	12.625	31880.0		0.0	373.1	0.185	69.0235	34019.8	44.4	206.5	33813.3	22654.91	11158.39
46	2300.0	0.465	13.09	22654.9		0.0	373.1	0.185	69.0235	24794.6	44.4	206.5	24588.2	16474.08	8114.10
47	2350.0	0.465	13.555	16474.1		0.0	373.1	0.185	69.0235	18613.8	44.4	206.5	18407.3	12332.92	6074.42
48	2400.0	0.465	14.02	53381.9	41049.0	0.0	373.1	0.185	69.0235	55521.7	44.4	206.5	55315.2	37061.19	18254.02
49	2450.0	0.465	14.485	37061.2		0.0	373.1	0.185	69.0235	39200.9	44.4	206.5	38994.5	26126.28	12868.17
50	2500.0	0.465	14.95	26126.3		0.0	373.1	0.185	69.0235	28266.0	44.4	206.5	28059.6	18799.90	9259.65
51	2550.0	0.465	15.415	18799.9		0.0	373.1	0.185	69.0235	20939.6	44.4	206.5	20733.2	12502.10	6157.75
52	2600.0	0.465	15.88	59041.7	46539.6	0.0	373.1	0.185	69.0235	61181.4	44.4	206.5	60975.0	36767.90	18109.56
53	2650.0	0.465	16.345	36767.9		0.0	373.1	0.185	69.0235	38907.6	44.4	206.5	38701.2	23336.80	11494.25
54	2700.0	0.465	16.81	23336.8		0.0	373.1	0.185	69.0235	25476.5	44.4	206.5	25270.1	15237.85	7505.21
55	2750.0	0.465	17.275	15237.9		0.0	373.1	0.185	69.0235	17377.6	44.4	206.5	17171.1	10354.19	5099.82
56	2800.0	0.465	17.74	52563.0	42208.8	0.0	373.1	0.185	69.0235	54702.8	44.4	206.5	54496.3	32861.27	16185.40
57	2850.0	0.465	18.205	32861.3		0.0	373.1	0.185	69.0235	35001.0	44.4	206.5	34794.5	20981.11	10333.98
58	2900.0	0.465	18.67	20981.1		0.0	373.1	0.185	69.0235	23120.8	44.4	206.5	22914.4	13817.37	6805.57
59	2950.0	0.465	19.135	13817.4		0.0	373.1	0.185	69.0235	15957.1	44.4	206.5	15750.6	9497.63	4677.94
60	3000.0	0.465	19.6	47500.5	38002.9	0.0	373.1	0.185	69.0235	49640.3	44.4	206.5	49433.8	29808.58	14681.84
61	3050.0	0.77	20.37	29808.6		0.0	373.1	0.09	33.579	30849.5	44.4	341.9	30507.6	18396.11	9060.77
62	3100.0	0.77	21.14	18396.1		0.0	373.1	0.09	33.579	19437.1	44.4	341.9	19095.2	11514.39	5671.27
63	3150.0	0.77	21.91	11514.4		0.0	373.1	0.09	33.579	12555.3	44.4	341.9	12213.5	7364.72	3627.40
64	3200.0	0.77	22.68	40406.0	33041.3	0.0	373.1	0.09	33.579	41446.9	44.4	341.9	41105.1	24786.35	12208.20
65	3250.0	0.77	23.45	24786.4		0.0	373.1	0.09	33.579	25827.3	44.4	341.9	25485.4	15367.71	7569.17
66	3300.0	0.77	24.22	15367.7		0.0	373.1	0.09	33.579	16408.7	44.4	341.9	16066.8	9688.27	4771.83
67	3350.0	0.77	24.99	9688.3		0.0	373.1	0.09	33.579	10729.2	44.4	341.9	10387.3	6263.56	3085.04
68	3400.0	0.77	25.76	33897.8	27634.2	0.0	373.1	0.09	33.579	34938.8	44.4	341.9	34596.9	20861.92	10275.27
69	3450.0	0.77	26.53	20861.9		0.0	373.1	0.09	33.579	21902.9	44.4	341.9	21561.0	13001.27	6403.61
70	3500.0	0.77	27.3	13001.3		0.0	373.1	0.09	33.579	14042.2	44.4	341.9	13700.3	8261.31	4069.00
71	3550.0	0.77	28.07	8261.3		0.0	373.1	0.09	33.579	9302.3	44.4	341.9	8960.4	4802.76	2365.54
72	3600.0	0.77	28.84	27916.2	23113.4	0.0	373.1	0.09	33.579	28957.1	44.4	341.9	28615.3	15337.78	7554.43
73	3650.0	0.77	29.61	15337.8		0.0	373.1	0.09	33.579	16378.7	44.4	341.9	16036.8	8595.75	4233.73
74	3700.0	0.77	30.38	20383.9	11788.2	0.0	373.1	0.09	33.579	21424.9	44.4	341.9	21083.0	11300.47	5565.91
75	3750.0	0.77	31.15	11300.5		0.0	373.1	0.09	33.579	12341.4	44.4	341.9	11999.5	6431.75	3167.88
76	3800.0	0.77	31.92	15165.5	8733.8	0.0	373.1	0.09	33.579	16206.5	44.4	341.9	15864.6	8503.43	4188.26
77	3850.0	0.77	32.69	8503.4		0.0	373.1	0.09	33.579	9544.4	44.4	341.9	9202.5	4932.54	2429.46
78	3900.0	0.77	33.46	11550.3	6617.7	0.0	373.1	0.09	33.579	12591.2	44.4	341.9	12249.3	6565.64	3233.82
79	3950.0	0.77	34.23	6565.6		0.0	373.1	0.09	33.579	7606.6	44.4	341.9	7264.7	3893.88	1917.88
80	4000.0	0.77	35	9045.6	5151.7	0.0	373.1	0.09	33.579	10086.5	44.4	341.9	9744.7	5223.14	2572.59
				1120.5		290.0									

Total water supply = 1410.4

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨(ETc mm/mon.)／days in month （ETc: calculated by CROPWAT-8）

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5mm)

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 2.2.2.7(7) Calculation of Water Quantity for Supplemental Supply to the Paddy Fields (July)

July Water Re= 20.85 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×31	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67×(1.0～0.8)	⑬=⑪×0.33×(1.0～0.8)
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.)	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1163.7			402.5	0.085	34.2125	2224.3	69.9	125.8	2098.5	1405.97	692.49
2	100.0	0.18	0.36	2327.4	692.5	228.9	402.5	0.085	34.2125	3616.9	69.9	125.8	3491.1	2339.04	1152.06
3	150.0	0.18	0.54	2339.0		0.0	402.5	0.085	34.2125	3399.6	69.9	125.8	3273.8	2193.45	1080.36
4	200.0	0.18	0.72	4654.8	2232.4	228.9	402.5	0.085	34.2125	5715.4	69.9	125.8	5589.6	3745.01	1844.56
5	250.0	0.18	0.9	3745.0		0.0	402.5	0.085	34.2125	4805.6	69.9	125.8	4679.8	3135.45	1544.33
6	300.0	0.18	1.08	3135.5		0.0	402.5	0.085	34.2125	4196.0	69.9	125.8	4070.2	2727.05	1343.17
7	350.0	0.18	1.26	2727.0		0.0	402.5	0.085	34.2125	3787.6	69.9	125.8	3661.8	2453.42	1208.40
8	400.0	0.18	1.44	8393.9	5940.5	0.0	402.5	0.085	34.2125	9454.5	69.9	125.8	9328.6	6250.19	3078.45
9	450.0	0.18	1.62	6250.2		0.0	402.5	0.085	34.2125	7310.8	69.9	125.8	7185.0	4813.92	2371.04
10	500.0	0.18	1.8	4813.9		0.0	402.5	0.085	34.2125	5874.5	69.9	125.8	5748.7	3851.62	1897.07
11	550.0	0.18	1.98	3851.6		0.0	402.5	0.085	34.2125	4912.2	69.9	125.8	4786.4	3206.88	1579.51
12	600.0	0.18	2.16	12132.9	8926.1	0.0	402.5	0.085	34.2125	13193.5	69.9	125.8	13067.7	8755.36	4312.34
13	650.0	0.18	2.34	8755.4		0.0	402.5	0.085	34.2125	9816.0	69.9	125.8	9690.1	6492.39	3197.74
14	700.0	0.18	2.52	6492.4		0.0	402.5	0.085	34.2125	7553.0	69.9	125.8	7427.2	4976.19	2450.96
15	750.0	0.18	2.7	4976.2		0.0	402.5	0.085	34.2125	6036.8	69.9	125.8	5911.0	3960.34	1950.62
16	800.0	0.18	2.88	15872.0	11911.7	0.0	402.5	0.085	34.2125	16932.6	69.9	125.8	16806.8	11260.54	5546.24
17	850.0	0.18	3.06	11260.5		0.0	402.5	0.085	34.2125	12321.1	69.9	125.8	12195.3	8170.86	4024.45
18	900.0	0.18	3.24	8170.9		0.0	402.5	0.085	34.2125	9231.4	69.9	125.8	9105.6	6100.77	3004.86
19	950.0	0.18	3.42	6100.8		0.0	402.5	0.085	34.2125	7161.4	69.9	125.8	7035.5	4713.81	2321.73
20	1000.0	0.18	3.6	19611.1	14897.3	0.0	402.5	0.085	34.2125	20671.7	69.9	125.8	20545.8	13765.72	6780.13
21	1050.0	0.335	3.935	13765.7		0.0	402.5	0.1	40.25	15013.5	69.9	234.2	14779.3	9902.13	4877.17
22	1100.0	0.335	4.27	9902.1		0.0	402.5	0.1	40.25	11149.9	69.9	234.2	10915.7	7313.53	3602.19
23	1150.0	0.335	4.605	7313.5		0.0	402.5	0.1	40.25	8561.3	69.9	234.2	8327.1	5579.17	2747.95
24	1200.0	0.335	4.94	23586.6	18007.4	0.0	402.5	0.1	40.25	24834.4	69.9	234.2	24600.2	16482.13	8118.06
25	1250.0	0.335	5.275	16482.1		0.0	402.5	0.1	40.25	17729.9	69.9	234.2	17495.7	11722.13	5773.58
26	1300.0	0.335	5.61	11722.1		0.0	402.5	0.1	40.25	12969.9	69.9	234.2	12735.7	8532.93	4202.78
27	1350.0	0.335	5.945	8532.9		0.0	402.5	0.1	40.25	9780.7	69.9	234.2	9546.5	6396.16	3150.35
28	1400.0	0.335	6.28	27640.9	21244.8	0.0	402.5	0.1	40.25	28888.7	69.9	234.2	28654.5	19198.53	9455.99
29	1450.0	0.335	6.615	19198.5		0.0	402.5	0.1	40.25	20446.3	69.9	234.2	20212.1	13542.12	6670.00
30	1500.0	0.335	6.95	13542.1		0.0	402.5	0.1	40.25	14789.9	69.9	234.2	14555.7	9752.32	4803.38
31	1550.0	0.335	7.285	9752.3		0.0	402.5	0.1	40.25	11000.1	69.9	234.2	10765.9	7213.16	3552.75
32	1600.0	0.335	7.62	31695.3	24482.1	0.0	402.5	0.1	40.25	32943.0	69.9	234.2	32708.9	21914.94	10793.93
33	1650.0	0.335	7.955	21914.9		0.0	402.5	0.1	40.25	23162.7	69.9	234.2	22928.5	15362.11	7566.41
34	1700.0	0.335	8.29	15362.1		0.0	402.5	0.1	40.25	16609.9	69.9	234.2	16375.7	10971.72	5403.98
35	1750.0	0.335	8.625	10971.7		0.0	402.5	0.1	40.25	12219.5	69.9	234.2	11985.3	8030.15	3955.15
36	1800.0	0.335	8.96	35749.6	27719.5	0.0	402.5	0.1	40.25	36997.4	69.9	234.2	36763.2	24631.35	12131.86
37	1850.0	0.335	9.295	24631.3		0.0	402.5	0.1	40.25	25879.1	69.9	234.2	25644.9	17182.11	8462.83
38	1900.0	0.335	9.63	17182.1		0.0	402.5	0.1	40.25	18429.9	69.9	234.2	18195.7	12191.11	6004.58
39	1950.0	0.335	9.965	12191.1		0.0	402.5	0.1	40.25	13438.9	69.9	234.2	13204.7	8847.15	4357.55
40	2000.0	0.335	10.3	39804.0	30956.8	0.0	402.5	0.1	40.25	41051.7	69.9	234.2	40817.5	27347.76	13469.79
41	2050.0	0.465	10.765	27347.8		0.0	402.5	0.185	74.4625	29656.1	69.9	325.0	29331.1	19651.81	9679.25
42	2100.0	0.465	11.23	19651.8		0.0	402.5	0.185	74.4625	21960.1	69.9	325.0	21635.1	14495.53	7139.59
43	2150.0	0.465	11.695	14495.5		0.0	402.5	0.185	74.4625	16803.9	69.9	325.0	16478.8	11040.81	5438.01
44	2200.0	0.465	12.16	46767.5	35726.6	0.0	402.5	0.185	74.4625	49075.8	69.9	325.0	48750.8	32663.01	16087.75
45	2250.0	0.465	12.625	32663.0		0.0	402.5	0.185	74.4625	34971.3	69.9	325.0	34646.3	23213.03	11433.28
46	2300.0	0.465	13.09	23213.0		0.0	402.5	0.185	74.4625	25521.4	69.9	325.0	25196.3	16881.54	8314.79
47	2350.0	0.465	13.555	16881.5		0.0	402.5	0.185	74.4625	19189.9	69.9	325.0	18864.8	12639.45	6225.40
48	2400.0	0.465	14.02	54700.7	42061.2	0.0	402.5	0.185	74.4625	57009.0	69.9	325.0	56684.0	37978.26	18705.71
49	2450.0	0.465	14.485	37978.3		0.0	402.5	0.185	74.4625	40286.6	69.9	325.0	39961.6	26774.25	13187.32
50	2500.0	0.465	14.95	26774.2		0.0	402.5	0.185	74.4625	29082.6	69.9	325.0	28757.5	19267.56	9489.99
51	2550.0	0.465	15.415	19267.6		0.0	402.5	0.185	74.4625	21575.9	69.9	325.0	21250.9	14238.08	6311.51
52	2600.0	0.465	15.88	61932.6	47694.5	0.0	402.5	0.185	74.4625	64240.9	69.9	325.0	63915.9	38541.29	18983.02
53	2650.0	0.465	16.345	38541.3		0.0	402.5	0.185	74.4625	40849.6	69.9	325.0	40524.6	24436.33	12035.80
54	2700.0	0.465	16.81	24436.3		0.0	402.5	0.185	74.4625	26744.7	69.9	325.0	26419.6	15931.04	7846.63
55	2750.0	0.465	17.275	15931.0		0.0	402.5	0.185	74.4625	18239.4	69.9	325.0	17914.3	10802.35	5320.56
56	2800.0	0.465	17.74	54988.4	44186.0	0.0	402.5	0.185	74.4625	57296.7	69.9	325.0	56971.7	34353.91	16920.58
57	2850.0	0.465	18.205	34353.9		0.0	402.5	0.185	74.4625	36662.3	69.9	325.0	36337.2	21911.34	10792.15
58	2900.0	0.465	18.67	21911.3		0.0	402.5	0.185	74.4625	24219.7	69.9	325.0	23894.6	14408.47	7096.71
59	2950.0	0.465	19.135	14408.5		0.0	402.5	0.185	74.4625	16716.8	69.9	325.0	16391.8	9884.24	4868.36
60	3000.0	0.465	19.6	49562.0	39677.8	0.0	402.5	0.185	74.4625	51870.4	69.9	325.0	51545.3	31081.84	15308.97
61	3050.0	0.77	20.37	31081.8		0.0	402.5	0.09	36.225	32204.8	69.9	538.2	31666.6	19094.95	9404.98
62	3100.0	0.77	21.14	19095.0		0.0	402.5	0.09	36.225	20217.9	69.9	538.2	19679.7	11866.86	5844.87
63	3150.0	0.77	21.91	11866.9		0.0	402.5	0.09	36.225	12989.8	69.9	538.2	12451.6	7508.32	3698.13
64	3200.0	0.77	22.68	41765.3	34256.9	0.0	402.5	0.09	36.225	42888.2	69.9	538.2	42350.0	25537.05	12577.95
65	3250.0	0.77	23.45	25537.1		0.0	402.5	0.09	36.225	26660.0	69.9	538.2	26121.8	15751.44	7758.17
66	3300.0	0.77	24.22	15751.4		0.0	402.5	0.09	36.225	16874.4	69.9	538.2	16336.2	9850.72	4851.85
67	3350.0	0.77	24.99	9850.7		0.0	402.5	0.09	36.225	10973.7	69.9	538.2	10435.5	6292.59	3099.33
68	3400.0	0.77	25.76	34579.9	28287.3	0.0	402.5	0.09	36.225	35702.9	69.9	538.2	35164.6	21204.28	10443.90
69	3450.0	0.77	26.53	21204.3		0.0	402.5	0.09	36.225	22327.3	69.9	538.2	21789.0	13138.78	6471.34
70	3500.0	0.77	27.3	13138.8		0.0	402.5	0.09	36.225	14261.8	69.9	538.2	13723.5	8275.29	4075.89
71	3550.0	0.77	28.07	8275.3		0.0	402.5	0.09	36.225	9398.3	69.9	538.2	8860.0	4748.98	2339.05
72	3600.0	0.77	28.84	28079.1	23330.2	0.0	402.5	0.09	36.225	29202.1	69.9	538.2	28663.9	15363.85	7567.27
73	3650.0	0.77	29.61	15363.8		0.0	402.5	0.09	36.225	16486.8	69.9	538.2	15948.6	8548.44	4210.43
74	3700.0	0.77	30.38	20326.1	11777.7	0.0	402.5	0.09	36.225	21449.1	69.9	538.2	20910.9	11208.23	5520.47
75	3750.0	0.77	31.15	11208.2		0.0	402.5	0.09	36.225	12331.2	69.9	538.2	11793.0	6321.04	3113.35
76	3800.0	0.77	31.92	14954.9	8633.8	0.0	402.5	0.09	36.225	16077.8	69.9	538.2	15539.6	8329.23	4102.45
77	3850.0	0.77	32.69	8329.2		0.0	402.5	0.09	36.225	9452.2	69.9	538.2	8914.0	4777.89	2353.29
78	3900.0	0.77	33.46	11233.6	6455.7	0.0	402.5	0.09	36.225	12356.6	69.9	538.2	11818.4	6334.65	3120.05
79	3950.0	0.77	34.23	6334.7		0.0	402.5	0.09	36.225	7457.6	69.9	538.2	6919.4	3708.80	1826.72
80	4000.0	0.77	35	8655.6	4946.8	0.0	402.5	0.09	36.225	9778.5	69.9	538.2	9240.3	4952.81	2439.44
				1163.7		457.9									
					Total water supply =	1621.6									

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨(ETc mm/mon.)／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5mm)

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 2.2.2.7(8) Calculation of Water Quantity for Supplemental Supply to the Paddy Fields (August)

Aug. Water Re= 27.03 mm/day

NO.	Distance (m)	① Paddy Area (ha)	Cumulative Area (ha)	② W.S./initial, return (m3/mon)	③ Intake quantity (m3/mon.)	④ Supplemental supply (m3/mon)	⑤ Specific discharge (m3/km2)	⑥ catchment area (km2)	⑦=⑤×⑥ Flow-in volume (m3/day)	⑧=②+⑦×31 Irrigation water (m3/mon)	⑨ ETc (mm/mon)	⑩=①×⑨×10000/1000 Water loss (m3/mon)	⑪=⑧-⑩ Residual water (m3/mon.)	⑫=⑪×0.67×(1.0～0.8) Horizontal leakage (m3/mon.)	⑬=⑪×0.33×(1.0～0.8) Return to the river (m3/mon.)
1	50.0	0.18	0.18	1508.4			284.7	0.085	24.1995	2258.6	261.4	470.5	1788.1	1198.00	590.06
2	100.0	0.18	0.36	3016.8	590.1	1228.7	284.7	0.085	24.1995	4995.7	261.4	470.5	4525.2	3031.88	1493.32
3	150.0	0.18	0.54	3031.9		0.0	284.7	0.085	24.1995	3782.1	261.4	470.5	3311.5	2218.74	1092.81
4	200.0	0.18	0.72	6033.6	2586.1	1228.7	284.7	0.085	24.1995	6783.8	261.4	470.5	6313.3	4229.89	2083.38
5	250.0	0.18	0.9	4229.9		0.0	284.7	0.085	24.1995	4980.1	261.4	470.5	4509.6	3021.40	1488.15
6	300.0	0.18	1.08	3021.4		0.0	284.7	0.085	24.1995	3771.6	261.4	470.5	3301.1	2211.71	1089.35
7	350.0	0.18	1.26	2211.7		0.0	284.7	0.085	24.1995	2961.9	261.4	470.5	2491.4	1669.22	822.15
8	400.0	0.18	1.44	7152.3	5483.0	0.0	284.7	0.085	24.1995	7902.4	261.4	470.5	7431.9	4979.39	2452.53
9	450.0	0.18	1.62	4979.4		0.0	284.7	0.085	24.1995	5729.6	261.4	470.5	5259.1	3523.57	1735.49
10	500.0	0.18	1.8	3523.6		0.0	284.7	0.085	24.1995	4273.7	261.4	470.5	3803.2	2548.16	1255.07
11	550.0	0.18	1.98	2548.2		0.0	284.7	0.085	24.1995	3298.3	261.4	470.5	2827.8	1894.65	933.18
12	600.0	0.18	2.16	8270.9	6376.3	0.0	284.7	0.085	24.1995	9021.1	261.4	470.5	8550.6	5728.89	2821.69
13	650.0	0.18	2.34	5728.9		0.0	284.7	0.085	24.1995	6479.1	261.4	470.5	6008.6	4025.73	1982.82
14	700.0	0.18	2.52	4025.7		0.0	284.7	0.085	24.1995	4775.9	261.4	470.5	4305.4	2884.61	1420.78
15	750.0	0.18	2.7	2884.6		0.0	284.7	0.085	24.1995	3634.8	261.4	470.5	3164.3	2120.07	1044.21
16	800.0	0.18	2.88	9389.6	7269.5	0.0	284.7	0.085	24.1995	10139.8	261.4	470.5	9669.2	6478.39	3190.85
17	850.0	0.18	3.06	6478.4		0.0	284.7	0.085	24.1995	7228.6	261.4	470.5	6758.1	4527.90	2230.16
18	900.0	0.18	3.24	4527.9		0.0	284.7	0.085	24.1995	5278.1	261.4	470.5	4807.6	3221.07	1586.50
19	950.0	0.18	3.42	3221.1		0.0	284.7	0.085	24.1995	3971.3	261.4	470.5	3500.7	2345.49	1155.24
20	1000.0	0.18	3.6	10508.2	8162.7	0.0	284.7	0.085	24.1995	11258.4	261.4	470.5	10787.9	7227.89	3560.01
21	1050.0	0.335	3.935	7227.9		0.0	284.7	0.1	28.47	8110.5	261.4	875.7	7234.8	4847.30	2387.47
22	1100.0	0.335	4.27	4847.3		0.0	284.7	0.1	28.47	5729.9	261.4	875.7	4854.2	3252.30	1601.88
23	1150.0	0.335	4.605	3252.3		0.0	284.7	0.1	28.47	4134.9	261.4	875.7	3259.2	2183.65	1075.53
24	1200.0	0.335	4.94	11229.2	8624.9	420.7	284.7	0.1	28.47	12111.8	261.4	875.7	11236.1	7528.17	3707.91
25	1250.0	0.335	5.275	7528.2		0.0	284.7	0.1	28.47	8410.7	261.4	875.7	7535.1	5048.49	2486.57
26	1300.0	0.335	5.61	5048.5		0.0	284.7	0.1	28.47	5931.1	261.4	875.7	5055.4	3387.10	1668.27
27	1350.0	0.335	5.945	3387.1		0.0	284.7	0.1	28.47	4269.7	261.4	875.7	3394.0	2273.96	1120.01
28	1400.0	0.335	6.28	11256.7	8982.8	0.0	284.7	0.1	28.47	12139.3	261.4	875.7	11263.6	7546.61	3716.99
29	1450.0	0.335	6.615	7546.6		0.0	284.7	0.1	28.47	8429.2	261.4	875.7	7553.5	5060.84	2492.65
30	1500.0	0.335	6.95	5060.8		0.0	284.7	0.1	28.47	5943.4	261.4	875.7	5067.7	3395.37	1672.35
31	1550.0	0.335	7.285	3395.4		0.0	284.7	0.1	28.47	4277.9	261.4	875.7	3402.3	2279.51	1122.74
32	1600.0	0.335	7.62	11284.2	9004.7	0.0	284.7	0.1	28.47	12166.8	261.4	875.7	11291.1	7565.05	3726.07
33	1650.0	0.335	7.955	7565.1		0.0	284.7	0.1	28.47	8447.6	261.4	875.7	7571.9	5073.19	2498.74
34	1700.0	0.335	8.29	5073.2		0.0	284.7	0.1	28.47	5955.8	261.4	875.7	5080.1	3403.65	1676.42
35	1750.0	0.335	8.625	3403.6		0.0	284.7	0.1	28.47	4286.2	261.4	875.7	3410.5	2285.05	1125.47
36	1800.0	0.335	8.96	11311.8	9026.7	0.0	284.7	0.1	28.47	12194.3	261.4	875.7	11318.6	7583.49	3735.15
37	1850.0	0.335	9.295	7583.5		0.0	284.7	0.1	28.47	8466.1	261.4	875.7	7590.4	5085.55	2504.82
38	1900.0	0.335	9.63	5085.5		0.0	284.7	0.1	28.47	5968.1	261.4	875.7	5092.4	3411.93	1680.50
39	1950.0	0.335	9.965	3411.9		0.0	284.7	0.1	28.47	4294.5	261.4	875.7	3418.8	2290.60	1128.21
40	2000.0	0.335	10.3	14497.4	9048.7	3158.1	284.7	0.1	28.47	15380.0	261.4	875.7	14504.3	9717.87	4786.41
41	2050.0	0.465	10.765	9717.9		0.0	284.7	0.185	52.6695	11350.6	261.4	1215.5	10135.1	6790.53	3344.59
42	2100.0	0.465	11.23	6790.5		0.0	284.7	0.185	52.6695	8423.3	261.4	1215.5	7207.8	4829.21	2378.56
43	2150.0	0.465	11.695	4829.2		0.0	284.7	0.185	52.6695	6462.0	261.4	1215.5	5246.5	3515.12	1731.33
44	2200.0	0.465	12.16	15756.0	12240.9	0.0	284.7	0.185	52.6695	17388.8	261.4	1215.5	16173.3	10836.08	5337.18
45	2250.0	0.465	12.625	10836.1		0.0	284.7	0.185	52.6695	12468.8	261.4	1215.5	11253.3	7539.73	3713.60
46	2300.0	0.465	13.09	7539.7		0.0	284.7	0.185	52.6695	9172.5	261.4	1215.5	7957.0	5331.17	2625.80
47	2350.0	0.465	13.555	5331.2		0.0	284.7	0.185	52.6695	6963.9	261.4	1215.5	5748.4	3851.44	1896.98
48	2400.0	0.465	14.02	17425.0	13573.6	0.0	284.7	0.185	52.6695	19057.7	261.4	1215.5	17842.2	11954.30	5887.94
49	2450.0	0.465	14.485	11954.3		0.0	284.7	0.185	52.6695	13587.1	261.4	1215.5	12371.5	8288.93	4082.61
50	2500.0	0.465	14.95	8288.9		0.0	284.7	0.185	52.6695	9921.7	261.4	1215.5	8706.2	5833.14	2873.04
51	2550.0	0.465	15.415	5833.1		0.0	284.7	0.185	52.6695	7465.9	261.4	1215.5	6250.4	3768.98	1856.36
52	2600.0	0.465	15.88	18468.9	14699.9	0.0	284.7	0.185	52.6695	20101.7	261.4	1215.5	18886.2	11388.36	5609.19
53	2650.0	0.465	16.345	11388.4		0.0	284.7	0.185	52.6695	13021.1	261.4	1215.5	11805.6	7118.78	3506.27
54	2700.0	0.465	16.81	7118.8		0.0	284.7	0.185	52.6695	8751.5	261.4	1215.5	7536.0	4544.22	2238.20
55	2750.0	0.465	17.275	4544.2		0.0	284.7	0.185	52.6695	6177.0	261.4	1215.5	4961.5	2991.77	1473.56
56	2800.0	0.465	17.74	15819.0	12827.2	0.0	284.7	0.185	52.6695	17451.7	261.4	1215.5	16236.2	9790.44	4822.16
57	2850.0	0.465	18.205	9790.4		0.0	284.7	0.185	52.6695	11423.2	261.4	1215.5	10207.7	6155.24	3031.68
58	2900.0	0.465	18.67	6155.2		0.0	284.7	0.185	52.6695	7788.0	261.4	1215.5	6572.5	3963.21	1952.03
59	2950.0	0.465	19.135	3963.2		0.0	284.7	0.185	52.6695	5596.0	261.4	1215.5	4380.5	2641.41	1300.99
60	3000.0	0.465	19.6	23254.5	11106.9	9506.2	284.7	0.185	52.6695	24887.3	261.4	1215.5	23671.7	14274.06	7030.51
61	3050.0	0.77	20.37	14274.1		0.0	284.7	0.09	25.623	15068.4	261.4	2012.8	13055.6	7872.52	3877.51
62	3100.0	0.77	21.14	7872.5		0.0	284.7	0.09	25.623	8666.8	261.4	2012.8	6654.1	4012.40	1976.25
63	3150.0	0.77	21.91	4012.4		0.0	284.7	0.09	25.623	4806.7	261.4	2012.8	2793.9	1684.74	829.80
64	3200.0	0.77	22.68	25810.4	13714.1	10411.6	284.7	0.09	25.623	26604.7	261.4	2012.8	24591.9	14828.94	7303.80
65	3250.0	0.77	23.45	14828.9		0.0	284.7	0.09	25.623	15623.2	261.4	2012.8	13610.5	8207.11	4042.31
66	3300.0	0.77	24.22	8207.1		0.0	284.7	0.09	25.623	9001.4	261.4	2012.8	6988.6	4214.15	2075.63
67	3350.0	0.77	24.99	4214.2		0.0	284.7	0.09	25.623	5008.5	261.4	2012.8	2995.7	1806.40	889.72
68	3400.0	0.77	25.76	25810.4	14311.5	9692.5	284.7	0.09	25.623	26604.7	261.4	2012.8	24591.9	14828.94	7303.80
69	3450.0	0.77	26.53	14828.9		0.0	284.7	0.09	25.623	15623.2	261.4	2012.8	13610.5	8207.11	4042.31
70	3500.0	0.77	27.3	8207.1		0.0	284.7	0.09	25.623	9001.4	261.4	2012.8	6988.6	4214.15	2075.63
71	3550.0	0.77	28.07	4214.2		0.0	284.7	0.09	25.623	5008.5	261.4	2012.8	2995.7	1605.69	790.86
72	3600.0	0.77	28.84	15818.3	14212.6	0.0	284.7	0.09	25.623	16612.6	261.4	2012.8	14599.8	7825.51	3854.35
73	3650.0	0.77	29.61	7825.5		0.0	284.7	0.09	25.623	8619.8	261.4	2012.8	6607.0	3541.37	1744.26
74	3700.0	0.77	30.38	12905.2	5598.6	3765.2	284.7	0.09	25.623	13699.5	261.4	2012.8	11686.7	6264.09	3085.30
75	3750.0	0.77	31.15	6264.1		0.0	284.7	0.09	25.623	7058.4	261.4	2012.8	5045.6	2704.45	1332.04
76	3800.0	0.77	31.92	12905.2	4417.3	5783.4	284.7	0.09	25.623	13699.5	261.4	2012.8	11686.7	6264.09	3085.30
77	3850.0	0.77	32.69	6264.1		0.0	284.7	0.09	25.623	7058.4	261.4	2012.8	5045.6	2704.45	1332.04
78	3900.0	0.77	33.46	12905.2	4417.3	5783.4	284.7	0.09	25.623	13699.5	261.4	2012.8	11686.7	6264.09	3085.30
79	3950.0	0.77	34.23	6264.1		0.0	284.7	0.09	25.623	7058.4	261.4	2012.8	5045.6	2704.45	1332.04
80	4000.0	0.77	35	7121.8	4417.3	0.0	284.7	0.09	25.623	7916.1	261.4	2012.8	5903.3	3164.18	1558.48
				1508.4		50978.6									
					Total water supply =	52487.0									

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨(ETc mm/mon.)／days in month （ETc: calculated by CROPWAT-8）

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5mm)

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 2.2.2.7(9) Calculation of Water Quantity for Supplemental Supply to the Paddy Fields (September)

Sep. Water Re= 25.15 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×30	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67×(1.0～0.8)	⑬=⑪×0.33×(1.0～0.8)
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.)	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.144	1403.6			255.3	0.085	21.7005	2076.3	196.6	353.9	1722.4	1154.00	568.39
2	100.0	0.18	0.324	2807.1	568.4	1084.7	255.3	0.085	21.7005	4564.5	196.6	353.9	4210.7	2821.15	1389.52
3	150.0	0.18	0.504	2821.1		0.0	255.3	0.085	21.7005	3493.9	196.6	353.9	3140.0	2103.79	1036.19
4	200.0	0.18	0.684	5433.1	2425.7	903.6	255.3	0.085	21.7005	6105.8	196.6	353.9	5752.0	3853.81	1898.15
5	250.0	0.18	0.864	3853.8		0.0	255.3	0.085	21.7005	4526.5	196.6	353.9	4172.6	2795.67	1376.97
6	300.0	0.18	1.044	2795.7		0.0	255.3	0.085	21.7005	3468.4	196.6	353.9	3114.5	2086.72	1027.79
7	350.0	0.18	1.224	2086.7		0.0	255.3	0.085	21.7005	2759.4	196.6	353.9	2405.6	1611.72	793.83
8	400.0	0.18	1.404	6708.5	5096.7	0.0	255.3	0.085	21.7005	7381.2	196.6	353.9	7027.3	4708.29	2319.01
9	450.0	0.18	1.584	4708.3		0.0	255.3	0.085	21.7005	5381.0	196.6	353.9	5027.1	3368.17	1658.95
10	500.0	0.18	1.764	3368.2		0.0	255.3	0.085	21.7005	4040.9	196.6	353.9	3687.0	2470.30	1216.71
11	550.0	0.18	1.944	2470.3		0.0	255.3	0.085	21.7005	3143.0	196.6	353.9	2789.1	1868.72	920.41
12	600.0	0.18	2.124	7983.8	6115.1	0.0	255.3	0.085	21.7005	8656.5	196.6	353.9	8302.6	5562.77	2739.87
13	650.0	0.18	2.304	5562.8		0.0	255.3	0.085	21.7005	6235.5	196.6	353.9	5881.6	3940.67	1940.93
14	700.0	0.18	2.484	3940.7		0.0	255.3	0.085	21.7005	4613.4	196.6	353.9	4259.5	2853.87	1405.64
15	750.0	0.18	2.664	2853.9		0.0	255.3	0.085	21.7005	3526.6	196.6	353.9	3172.7	2125.71	1046.99
16	800.0	0.18	2.844	9259.1	7133.4	0.0	255.3	0.085	21.7005	9931.9	196.6	353.9	9578.0	6417.25	3160.73
17	850.0	0.18	3.024	6417.2		0.0	255.3	0.085	21.7005	7090.0	196.6	353.9	6736.1	4513.18	2222.91
18	900.0	0.18	3.204	4513.2		0.0	255.3	0.085	21.7005	5185.9	196.6	353.9	4832.0	3237.45	1594.56
19	950.0	0.18	3.384	3237.4		0.0	255.3	0.085	21.7005	3910.2	196.6	353.9	3556.3	2382.71	1173.57
20	1000.0	0.18	3.564	10534.5	8151.8	0.0	255.3	0.085	21.7005	11207.2	196.6	353.9	10853.3	7271.73	3581.60
21	1050.0	0.335	3.899	7271.7		0.0	255.3	0.1	25.53	8063.2	196.6	658.6	7404.5	4961.05	2443.50
22	1100.0	0.335	4.234	4961.0		0.0	255.3	0.1	25.53	5752.5	196.6	658.6	5093.9	3412.89	1680.98
23	1150.0	0.335	4.569	3412.9		0.0	255.3	0.1	25.53	4204.3	196.6	658.6	3545.7	2375.63	1170.08
24	1200.0	0.335	4.904	11251.8	8876.2	0.0	255.3	0.1	25.53	12043.2	196.6	658.6	11384.6	7627.68	3756.92
25	1250.0	0.335	5.239	7627.7		0.0	255.3	0.1	25.53	8419.1	196.6	658.6	7760.5	5199.54	2560.97
26	1300.0	0.335	5.574	5199.5		0.0	255.3	0.1	25.53	5991.0	196.6	658.6	5332.4	3572.68	1759.68
27	1350.0	0.335	5.909	3572.7		0.0	255.3	0.1	25.53	4364.1	196.6	658.6	3705.5	2482.68	1222.81
28	1400.0	0.335	6.244	11783.1	9300.4	0.0	255.3	0.1	25.53	12574.5	196.6	658.6	11915.9	7983.64	3932.24
29	1450.0	0.335	6.579	7983.6		0.0	255.3	0.1	25.53	8775.1	196.6	658.6	8116.5	5438.03	2678.43
30	1500.0	0.335	6.914	5438.0		0.0	255.3	0.1	25.53	6229.5	196.6	658.6	5570.8	3732.47	1838.38
31	1550.0	0.335	7.249	3732.5		0.0	255.3	0.1	25.53	4523.9	196.6	658.6	3865.3	2589.74	1275.55
32	1600.0	0.335	7.584	12314.3	9724.6	0.0	255.3	0.1	25.53	13105.8	196.6	658.6	12447.2	8339.60	4107.56
33	1650.0	0.335	7.919	8339.6		0.0	255.3	0.1	25.53	9131.0	196.6	658.6	8472.4	5676.52	2795.90
34	1700.0	0.335	8.254	5676.5		0.0	255.3	0.1	25.53	6468.0	196.6	658.6	5809.3	3892.26	1917.08
35	1750.0	0.335	8.589	3892.3		0.0	255.3	0.1	25.53	4683.7	196.6	658.6	4025.1	2696.80	1328.28
36	1800.0	0.335	8.924	12845.6	10148.8	0.0	255.3	0.1	25.53	13637.1	196.6	658.6	12978.4	8695.56	4282.89
37	1850.0	0.335	9.259	8695.6		0.0	255.3	0.1	25.53	9487.0	196.6	658.6	8828.4	5915.01	2913.36
38	1900.0	0.335	9.594	5915.0		0.0	255.3	0.1	25.53	6706.4	196.6	658.6	6047.8	4052.05	1995.78
39	1950.0	0.335	9.929	4052.0		0.0	255.3	0.1	25.53	4843.5	196.6	658.6	4184.9	2803.86	1381.01
40	2000.0	0.335	10.264	13376.9	10573.0	0.0	255.3	0.1	25.53	14168.3	196.6	658.6	13509.7	9051.51	4458.21
41	2050.0	0.465	10.729	9051.5		0.0	255.3	0.185	47.2305	10515.7	196.6	914.2	9601.5	6432.99	3168.49
42	2100.0	0.465	11.194	6433.0		0.0	255.3	0.185	47.2305	7897.1	196.6	914.2	6982.9	4678.57	2304.37
43	2150.0	0.465	11.659	4678.6		0.0	255.3	0.185	47.2305	6142.7	196.6	914.2	5228.5	3503.11	1725.41
44	2200.0	0.465	12.124	15159.6	11656.5	0.0	255.3	0.185	47.2305	16623.7	196.6	914.2	15709.5	10525.40	5184.15
45	2250.0	0.465	12.589	10525.4		0.0	255.3	0.185	47.2305	11989.5	196.6	914.2	11075.4	7420.49	3654.87
46	2300.0	0.465	13.054	7420.5		0.0	255.3	0.185	47.2305	8884.6	196.6	914.2	7970.4	5340.20	2630.25
47	2350.0	0.465	13.519	5340.2		0.0	255.3	0.185	47.2305	6804.3	196.6	914.2	5890.2	3946.40	1943.75
48	2400.0	0.465	13.984	17359.4	13413.0	0.0	255.3	0.185	47.2305	18823.6	196.6	914.2	17909.4	11999.28	5910.09
49	2450.0	0.465	14.449	11999.3		0.0	255.3	0.185	47.2305	13463.4	196.6	914.2	12549.2	8407.99	4141.25
50	2500.0	0.465	14.914	8408.0		0.0	255.3	0.185	47.2305	9872.1	196.6	914.2	8957.9	6001.82	2956.12
51	2550.0	0.465	15.379	6001.8		0.0	255.3	0.185	47.2305	7466.0	196.6	914.2	6551.8	3950.72	1945.88
52	2600.0	0.465	15.844	18904.1	14953.3	0.0	255.3	0.185	47.2305	20368.2	196.6	914.2	19454.0	11730.77	5777.84
53	2650.0	0.465	16.309	11730.8		0.0	255.3	0.185	47.2305	13194.9	196.6	914.2	12280.7	7405.28	3647.38
54	2700.0	0.465	16.774	7405.3		0.0	255.3	0.185	47.2305	8869.4	196.6	914.2	7955.2	4797.01	2362.70
55	2750.0	0.465	17.239	4797.0		0.0	255.3	0.185	47.2305	6261.2	196.6	914.2	5347.0	3224.22	1588.05
56	2800.0	0.465	17.704	16600.2	13376.0	0.0	255.3	0.185	47.2305	18064.3	196.6	914.2	17150.1	10341.53	5093.59
57	2850.0	0.465	18.169	10341.5		0.0	255.3	0.185	47.2305	11805.7	196.6	914.2	10891.5	6567.57	3234.77
58	2900.0	0.465	18.634	6567.6		0.0	255.3	0.185	47.2305	8031.7	196.6	914.2	7117.5	4291.87	2113.90
59	2950.0	0.465	19.099	4291.9		0.0	255.3	0.185	47.2305	5756.0	196.6	914.2	4841.8	2919.62	1438.02
60	3000.0	0.465	19.564	20940.2	11880.3	6140.2	255.3	0.185	47.2305	22404.3	196.6	914.2	21490.1	12958.53	6382.56
61	3050.0	0.77	20.334	12958.5		0.0	255.3	0.09	22.977	13670.8	196.6	1513.8	12157.0	7330.67	3610.63
62	3100.0	0.77	21.104	7330.7		0.0	255.3	0.09	22.977	8043.0	196.6	1513.8	6529.1	3937.07	1939.15
63	3150.0	0.77	21.874	3937.1		0.0	255.3	0.09	22.977	4649.4	196.6	1513.8	3135.5	1890.73	931.25
64	3200.0	0.77	22.644	23241.7	12863.6	8487.4	255.3	0.09	22.977	23954.0	196.6	1513.8	22440.1	13531.41	6664.72
65	3250.0	0.77	23.414	13531.4		0.0	255.3	0.09	22.977	14243.7	196.6	1513.8	12729.9	7676.12	3780.77
66	3300.0	0.77	24.184	7676.1		0.0	255.3	0.09	22.977	8388.4	196.6	1513.8	6874.6	4145.37	2041.75
67	3350.0	0.77	24.954	4145.4		0.0	255.3	0.09	22.977	4857.7	196.6	1513.8	3343.8	2016.34	993.12
68	3400.0	0.77	25.724	23241.7	13480.4	7745.0	255.3	0.09	22.977	23954.0	196.6	1513.8	22440.1	13531.41	6664.72
69	3450.0	0.77	26.494	13531.4		0.0	255.3	0.09	22.977	14243.7	196.6	1513.8	12729.9	7676.12	3780.77
70	3500.0	0.77	27.264	7676.1		0.0	255.3	0.09	22.977	8388.4	196.6	1513.8	6874.6	4145.37	2041.75
71	3550.0	0.77	28.034	4145.4		0.0	255.3	0.09	22.977	4857.7	196.6	1513.8	3343.8	1792.30	882.77
72	3600.0	0.77	28.804	15162.3	13370.0	0.0	255.3	0.09	22.977	15874.6	196.6	1513.8	14360.8	7697.38	3791.25
73	3650.0	0.77	29.574	7697.4		0.0	255.3	0.09	22.977	8409.7	196.6	1513.8	6895.8	3696.17	1820.50
74	3700.0	0.77	30.344	12008.2	5611.8	2700.3	255.3	0.09	22.977	12720.5	196.6	1513.8	11206.7	6006.77	2958.56
75	3750.0	0.77	31.114	6006.8		0.0	255.3	0.09	22.977	6719.1	196.6	1513.8	5205.2	2790.01	1374.18
76	3800.0	0.77	31.884	12008.2	4332.7	4885.4	255.3	0.09	22.977	12720.5	196.6	1513.8	11206.7	6006.77	2958.56
77	3850.0	0.77	32.654	6006.8		0.0	255.3	0.09	22.977	6719.1	196.6	1513.8	5205.2	2790.01	1374.18
78	3900.0	0.77	33.424	12008.2	4332.7	4885.4	255.3	0.09	22.977	12720.5	196.6	1513.8	11206.7	6006.77	2958.56
79	3950.0	0.77	34.194	6006.8		0.0	255.3	0.09	22.977	6719.1	196.6	1513.8	5205.2	2790.01	1374.18
80	4000.0	0.77	34.964	7122.8	4332.7	0.0	255.3	0.09	22.977	7835.0	196.6	1513.8	6321.2	3388.17	1668.80
				1403.6		36832.1									

Total water supply = 38235.6

Water re.＝Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨(ETc mm/mon.)／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5mm)

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 2.2.2.7(10) Calculation of Water Quantity for Supplemental Supply to the Paddy Fields (October)

Oct. Water Re= 23.49 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×31	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67×(1.0～0.8)	⑬=⑪×0.33×(1.0～0.8)
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.)	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1310.9			235.6	0.085	20.026	1931.7	151.7	273.1	1658.7	1111.32	547.37
2	100.0	0.18	0.36	2621.9	547.4	963.2	235.6	0.085	20.026	4205.9	151.7	273.1	3932.8	2634.99	1297.83
3	150.0	0.18	0.54	2635.0		0.0	235.6	0.085	20.026	3255.8	151.7	273.1	2982.7	1998.43	984.30
4	200.0	0.18	0.72	5243.8	2282.1	963.2	235.6	0.085	20.026	5864.6	151.7	273.1	5591.5	3746.31	1845.20
5	250.0	0.18	0.9	3746.3		0.0	235.6	0.085	20.026	4367.1	151.7	273.1	4094.1	2743.02	1351.04
6	300.0	0.18	1.08	2743.0		0.0	235.6	0.085	20.026	3363.8	151.7	273.1	3090.8	2070.81	1019.95
7	350.0	0.18	1.26	2070.8		0.0	235.6	0.085	20.026	2691.6	151.7	273.1	2418.6	1620.43	798.12
8	400.0	0.18	1.44	6634.7	5014.3	0.0	235.6	0.085	20.026	7255.6	151.7	273.1	6982.5	4678.27	2304.22
9	450.0	0.18	1.62	4678.3		0.0	235.6	0.085	20.026	5299.1	151.7	273.1	5026.0	3367.43	1658.58
10	500.0	0.18	1.8	3367.4		0.0	235.6	0.085	20.026	3988.2	151.7	273.1	3715.2	2489.17	1226.01
11	550.0	0.18	1.98	2489.2		0.0	235.6	0.085	20.026	3110.0	151.7	273.1	2836.9	1900.73	936.18
12	600.0	0.18	2.16	8025.7	6125.0	0.0	235.6	0.085	20.026	8646.5	151.7	273.1	8373.5	5610.23	2763.25
13	650.0	0.18	2.34	5610.2		0.0	235.6	0.085	20.026	6231.0	151.7	273.1	5958.0	3991.84	1966.13
14	700.0	0.18	2.52	3991.8		0.0	235.6	0.085	20.026	4612.6	151.7	273.1	4339.6	2907.52	1432.06
15	750.0	0.18	2.7	2907.5		0.0	235.6	0.085	20.026	3528.3	151.7	273.1	3255.3	2181.03	1074.24
16	800.0	0.18	2.88	9416.7	7235.7	0.0	235.6	0.085	20.026	10037.5	151.7	273.1	9764.5	6542.19	3222.27
17	850.0	0.18	3.06	6542.2		0.0	235.6	0.085	20.026	7163.0	151.7	273.1	6889.9	4616.26	2273.68
18	900.0	0.18	3.24	4616.3		0.0	235.6	0.085	20.026	5237.1	151.7	273.1	4964.0	3325.88	1638.12
19	950.0	0.18	3.42	3325.9		0.0	235.6	0.085	20.026	3946.7	151.7	273.1	3673.6	2461.33	1212.30
20	1000.0	0.18	3.6	10807.7	8346.4	0.0	235.6	0.085	20.026	11428.5	151.7	273.1	11155.4	7474.15	3681.30
21	1050.0	0.335	3.935	7474.1		0.0	235.6	0.1	23.56	8204.5	151.7	508.2	7696.3	5156.53	2539.78
22	1100.0	0.335	4.27	5156.5		0.0	235.6	0.1	23.56	5886.9	151.7	508.2	5378.7	3603.72	1774.97
23	1150.0	0.335	4.605	3603.7		0.0	235.6	0.1	23.56	4334.1	151.7	508.2	3825.9	2563.35	1262.54
24	1200.0	0.335	4.94	11821.9	9258.6	0.0	235.6	0.1	23.56	12552.3	151.7	508.2	12044.1	8069.55	3974.55
25	1250.0	0.335	5.275	8069.5		0.0	235.6	0.1	23.56	8799.9	151.7	508.2	8291.7	5555.45	2736.27
26	1300.0	0.335	5.61	5555.4		0.0	235.6	0.1	23.56	6285.8	151.7	508.2	5777.6	3871.00	1906.61
27	1350.0	0.335	5.945	3871.0		0.0	235.6	0.1	23.56	4601.4	151.7	508.2	4093.2	2742.42	1350.74
28	1400.0	0.335	6.28	12710.6	9968.2	0.0	235.6	0.1	23.56	13441.0	151.7	508.2	12932.8	8664.95	4267.81
29	1450.0	0.335	6.615	8665.0		0.0	235.6	0.1	23.56	9395.3	151.7	508.2	8887.1	5954.37	2932.75
30	1500.0	0.335	6.95	5954.4		0.0	235.6	0.1	23.56	6684.7	151.7	508.2	6176.5	4138.28	2038.26
31	1550.0	0.335	7.285	4138.3		0.0	235.6	0.1	23.56	4868.6	151.7	508.2	4360.4	2921.50	1438.95
32	1600.0	0.335	7.62	13599.3	10677.8	0.0	235.6	0.1	23.56	14329.6	151.7	508.2	13821.4	9260.35	4561.07
33	1650.0	0.335	7.955	9260.4		0.0	235.6	0.1	23.56	9990.7	151.7	508.2	9482.5	6353.29	3129.23
34	1700.0	0.335	8.29	6353.3		0.0	235.6	0.1	23.56	7083.6	151.7	508.2	6575.5	4405.55	2169.90
35	1750.0	0.335	8.625	4405.6		0.0	235.6	0.1	23.56	5135.9	151.7	508.2	4627.7	3100.57	1527.15
36	1800.0	0.335	8.96	14487.9	11387.3	0.0	235.6	0.1	23.56	15218.3	151.7	508.2	14710.1	9855.75	4854.33
37	1850.0	0.335	9.295	9855.8		0.0	235.6	0.1	23.56	10586.1	151.7	508.2	10077.9	6752.21	3325.71
38	1900.0	0.335	9.63	6752.2		0.0	235.6	0.1	23.56	7482.6	151.7	508.2	6974.4	4672.83	2301.54
39	1950.0	0.335	9.965	4672.8		0.0	235.6	0.1	23.56	5403.2	151.7	508.2	4895.0	3279.65	1615.35
40	2000.0	0.335	10.3	15376.6	12096.9	0.0	235.6	0.1	23.56	16106.9	151.7	508.2	15598.7	10451.16	5147.58
41	2050.0	0.465	10.765	10451.2		0.0	235.6	0.185	43.586	11802.3	151.7	705.4	11096.9	7434.94	3661.98
42	2100.0	0.465	11.23	7434.9		0.0	235.6	0.185	43.586	8786.1	151.7	705.4	8080.7	5414.07	2666.63
43	2150.0	0.465	11.695	5414.1		0.0	235.6	0.185	43.586	6765.2	151.7	705.4	6059.8	4060.08	1999.74
44	2200.0	0.465	12.16	17536.0	13475.9	0.0	235.6	0.185	43.586	18887.2	151.7	705.4	18181.8	12181.80	5999.99
45	2250.0	0.465	12.625	12181.8		0.0	235.6	0.185	43.586	13533.0	151.7	705.4	12827.6	8594.46	4233.09
46	2300.0	0.465	13.09	8594.5		0.0	235.6	0.185	43.586	9945.6	151.7	705.4	9240.2	6190.95	3049.27
47	2350.0	0.465	13.555	6191.0		0.0	235.6	0.185	43.586	7542.1	151.7	705.4	6836.7	4580.60	2256.11
48	2400.0	0.465	14.02	20119.1	15538.5	0.0	235.6	0.185	43.586	21470.2	151.7	705.4	20764.8	13912.44	6852.39
49	2450.0	0.465	14.485	13912.4		0.0	235.6	0.185	43.586	15263.6	151.7	705.4	14558.2	9753.99	4804.21
50	2500.0	0.465	14.95	9754.0		0.0	235.6	0.185	43.586	11105.2	151.7	705.4	10399.8	6967.83	3431.92
51	2550.0	0.465	15.415	6967.8		0.0	235.6	0.185	43.586	8319.0	151.7	705.4	7613.6	4591.00	2261.24
52	2600.0	0.465	15.88	21940.8	17349.8	0.0	235.6	0.185	43.586	23291.9	151.7	705.4	22586.5	13619.67	6708.19
53	2650.0	0.465	16.345	13619.7		0.0	235.6	0.185	43.586	14970.8	151.7	705.4	14265.4	8602.05	4236.83
54	2700.0	0.465	16.81	8602.1		0.0	235.6	0.185	43.586	9953.2	151.7	705.4	9247.8	5576.43	2746.60
55	2750.0	0.465	17.275	5576.4		0.0	235.6	0.185	43.586	6927.6	151.7	705.4	6222.2	3751.98	1847.99
56	2800.0	0.465	17.74	19291.6	15539.6	0.0	235.6	0.185	43.586	20642.8	151.7	705.4	19937.4	12022.23	5921.40
57	2850.0	0.465	18.205	12022.2		0.0	235.6	0.185	43.586	13373.4	151.7	705.4	12668.0	7638.80	3762.39
58	2900.0	0.465	18.67	7638.8		0.0	235.6	0.185	43.586	8990.0	151.7	705.4	8284.6	4995.59	2460.51
59	2950.0	0.465	19.135	4995.6		0.0	235.6	0.185	43.586	6346.8	151.7	705.4	5641.4	3401.73	1675.48
60	3000.0	0.465	19.6	20210.3	13819.8	2988.8	235.6	0.185	43.586	21561.5	151.7	705.4	20856.1	12576.22	6194.26
61	3050.0	0.77	20.37	12576.2		0.0	235.6	0.09	21.204	13233.5	151.7	1168.1	12065.5	7275.47	3583.44
62	3100.0	0.77	21.14	7275.5		0.0	235.6	0.09	21.204	7932.8	151.7	1168.1	6764.7	4079.12	2009.12
63	3150.0	0.77	21.91	4079.1		0.0	235.6	0.09	21.204	4736.4	151.7	1168.1	3568.3	2151.71	1059.80
64	3200.0	0.77	22.68	22431.6	12846.6	7433.3	235.6	0.09	21.204	23089.0	151.7	1168.1	21920.9	13218.29	6510.50
65	3250.0	0.77	23.45	13218.3		0.0	235.6	0.09	21.204	13875.6	151.7	1168.1	12707.5	7662.64	3774.13
66	3300.0	0.77	24.22	7662.6		0.0	235.6	0.09	21.204	8320.0	151.7	1168.1	7151.9	4312.58	2124.11
67	3350.0	0.77	24.99	4312.6		0.0	235.6	0.09	21.204	4969.9	151.7	1168.1	3801.8	2292.49	1129.14
68	3400.0	0.77	25.76	22431.6	13537.9	6601.3	235.6	0.09	21.204	23089.0	151.7	1168.1	21920.9	13218.29	6510.50
69	3450.0	0.77	26.53	13218.3		0.0	235.6	0.09	21.204	13875.6	151.7	1168.1	12707.5	7662.64	3774.13
70	3500.0	0.77	27.3	7662.6		0.0	235.6	0.09	21.204	8320.0	151.7	1168.1	7151.9	4312.58	2124.11
71	3550.0	0.77	28.07	4312.6		0.0	235.6	0.09	21.204	4969.9	151.7	1168.1	3801.8	2037.77	1003.68
72	3600.0	0.77	28.84	15450.2	13412.4	0.0	235.6	0.09	21.204	16107.5	151.7	1168.1	14939.4	8007.53	3944.01
73	3650.0	0.77	29.61	8007.5		0.0	235.6	0.09	21.204	8664.9	151.7	1168.1	7496.8	4018.27	1979.15
74	3700.0	0.77	30.38	11215.8	5923.2	1274.4	235.6	0.09	21.204	11873.1	151.7	1168.1	10705.1	5737.91	2826.13
75	3750.0	0.77	31.15	5737.9		0.0	235.6	0.09	21.204	6395.2	151.7	1168.1	5227.1	2801.75	1379.97
76	3800.0	0.77	31.92	11215.8	4206.1	4208.0	235.6	0.09	21.204	11873.1	151.7	1168.1	10705.1	5737.91	2826.13
77	3850.0	0.77	32.69	5737.9		0.0	235.6	0.09	21.204	6395.2	151.7	1168.1	5227.1	2801.75	1379.97
78	3900.0	0.77	33.46	11215.8	4206.1	4208.0	235.6	0.09	21.204	11873.1	151.7	1168.1	10705.1	5737.91	2826.13
79	3950.0	0.77	34.23	5737.9		0.0	235.6	0.09	21.204	6395.2	151.7	1168.1	5227.1	2801.75	1379.97
80	4000.0	0.77	35	7007.8	4206.1	0.0	235.6	0.09	21.204	7665.2	151.7	1168.1	6497.1	3482.44	1715.23
				1310.9		28640.1									
					Total water supply =	29951.1									

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨(ETc mm/mon.)／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5mm)

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 2.2.2.7(11) Calculation of Water Quantity for Supplemental Supply to the Paddy Fields (November)

Nov. Water Re= 19.31 mm/day

		①		②	③	④	⑤	⑥	⑦=⑤×⑥	⑧=②+⑦×30	⑨	⑩=①×⑨×10000/1000	⑪=⑧-⑩	⑫=⑪×0.67×(1.0～0.8)	⑬=⑪×0.33×(1.0～0.8)
NO.	Distance (m)	Paddy Area (ha)	Cumulative Area (ha)	W.S./initial, return (m3/mon)	Intake quantity (m3/mon.)	Supplemental supply (m3/mon)	Specific discharge (m3/km2)	catchment area (km2)	Flow-in volume (m3/day)	Irrigation water (m3/mon)	ETc (mm/mon)	Water loss (m3/mon)	Residual water (m3/mon.)	Horizontal leakage (m3/mon.)	Return to the river (m3/mon.)
1	50.0	0.18	0.18	1077.7			265.1	0.085	22.5335	1776.2	21.4	38.5	1737.7	1164.26	573.44
2	100.0	0.18	0.36	2155.4	573.4	417.7	265.1	0.085	22.5335	3271.6	21.4	38.5	3233.1	2166.14	1066.91
3	150.0	0.18	0.54	2166.1		0.0	265.1	0.085	22.5335	2864.7	21.4	38.5	2826.2	1893.53	932.63
4	200.0	0.18	0.72	4171.7	1999.5	278.6	265.1	0.085	22.5335	4870.2	21.4	38.5	4831.7	3237.24	1594.46
5	250.0	0.18	0.9	3237.2		0.0	265.1	0.085	22.5335	3935.8	21.4	38.5	3897.3	2611.16	1286.09
6	300.0	0.18	1.08	2611.2		0.0	265.1	0.085	22.5335	3309.7	21.4	38.5	3271.2	2191.69	1079.49
7	350.0	0.18	1.26	2191.7		0.0	265.1	0.085	22.5335	2890.2	21.4	38.5	2851.7	1910.65	941.06
8	400.0	0.18	1.44	6811.8	4901.1	0.0	265.1	0.085	22.5335	7510.3	21.4	38.5	7471.8	5006.09	2465.68
9	450.0	0.18	1.62	5006.1		0.0	265.1	0.085	22.5335	5704.6	21.4	38.5	5666.1	3796.29	1869.82
10	500.0	0.18	1.8	3796.3		0.0	265.1	0.085	22.5335	4494.8	21.4	38.5	4456.3	2985.73	1470.58
11	550.0	0.18	1.98	2985.7		0.0	265.1	0.085	22.5335	3684.3	21.4	38.5	3645.7	2442.65	1203.10
12	600.0	0.18	2.16	9451.8	7009.2	0.0	265.1	0.085	22.5335	10150.4	21.4	38.5	10111.8	6774.94	3336.91
13	650.0	0.18	2.34	6774.9		0.0	265.1	0.085	22.5335	7473.5	21.4	38.5	7435.0	4981.42	2453.54
14	700.0	0.18	2.52	4981.4		0.0	265.1	0.085	22.5335	5680.0	21.4	38.5	5641.4	3779.76	1861.67
15	750.0	0.18	2.7	3779.8		0.0	265.1	0.085	22.5335	4478.3	21.4	38.5	4439.8	2974.65	1465.13
16	800.0	0.18	2.88	12091.9	9117.2	0.0	265.1	0.085	22.5335	12790.4	21.4	38.5	12751.9	8543.79	4208.13
17	850.0	0.18	3.06	8543.8		0.0	265.1	0.085	22.5335	9242.3	21.4	38.5	9203.8	6166.55	3037.26
18	900.0	0.18	3.24	6166.5		0.0	265.1	0.085	22.5335	6865.1	21.4	38.5	6826.6	4573.80	2252.77
19	950.0	0.18	3.42	4573.8		0.0	265.1	0.085	22.5335	5272.3	21.4	38.5	5233.8	3506.66	1727.16
20	1000.0	0.18	3.6	14732.0	11225.3	0.0	265.1	0.085	22.5335	15430.5	21.4	38.5	15392.0	10312.64	5079.36
21	1050.0	0.335	3.935	10312.6		0.0	265.1	0.1	26.51	11134.4	21.4	71.7	11062.8	7412.05	3650.71
22	1100.0	0.335	4.27	7412.0		0.0	265.1	0.1	26.51	8233.9	21.4	71.7	8162.2	5468.65	2693.52
23	1150.0	0.335	4.605	5468.7		0.0	265.1	0.1	26.51	6290.5	21.4	71.7	6218.8	4166.58	2052.19
24	1200.0	0.335	4.94	17642.4	13475.8	0.0	265.1	0.1	26.51	18464.2	21.4	71.7	18392.5	12322.96	6069.52
25	1250.0	0.335	5.275	12323.0		0.0	265.1	0.1	26.51	13144.8	21.4	71.7	13073.1	8758.96	4314.12
26	1300.0	0.335	5.61	8759.0		0.0	265.1	0.1	26.51	9580.8	21.4	71.7	9509.1	6371.09	3138.00
27	1350.0	0.335	5.945	6371.1		0.0	265.1	0.1	26.51	7192.9	21.4	71.7	7121.2	4771.21	2350.00
28	1400.0	0.335	6.28	20642.8	15871.6	0.0	265.1	0.1	26.51	21464.6	21.4	71.7	21393.0	14333.28	7059.67
29	1450.0	0.335	6.615	14333.3		0.0	265.1	0.1	26.51	15155.1	21.4	71.7	15083.4	10105.88	4977.52
30	1500.0	0.335	6.95	10105.9		0.0	265.1	0.1	26.51	10927.7	21.4	71.7	10856.0	7273.52	3582.48
31	1550.0	0.335	7.285	7273.5		0.0	265.1	0.1	26.51	8095.3	21.4	71.7	8023.6	5375.84	2647.80
32	1600.0	0.335	7.62	23643.3	18267.5	0.0	265.1	0.1	26.51	24465.1	21.4	71.7	24393.4	16343.60	8049.83
33	1650.0	0.335	7.955	16343.6		0.0	265.1	0.1	26.51	17165.4	21.4	71.7	17093.7	11452.79	5640.93
34	1700.0	0.335	8.29	11452.8		0.0	265.1	0.1	26.51	12274.6	21.4	71.7	12202.9	8175.95	4026.96
35	1750.0	0.335	8.625	8176.0		0.0	265.1	0.1	26.51	8997.8	21.4	71.7	8926.1	5980.47	2945.60
36	1800.0	0.335	8.96	26643.8	20663.3	0.0	265.1	0.1	26.51	27465.6	21.4	71.7	27393.9	18353.92	9039.99
37	1850.0	0.335	9.295	18353.9		0.0	265.1	0.1	26.51	19175.7	21.4	71.7	19104.0	12799.71	6304.33
38	1900.0	0.335	9.63	12799.7		0.0	265.1	0.1	26.51	13621.5	21.4	71.7	13549.8	9078.39	4471.44
39	1950.0	0.335	9.965	9078.4		0.0	265.1	0.1	26.51	9900.2	21.4	71.7	9828.5	6585.10	3243.41
40	2000.0	0.335	10.3	29644.3	23059.2	0.0	265.1	0.1	26.51	30466.1	21.4	71.7	30394.4	20364.24	10030.15
41	2050.0	0.465	10.765	20364.2		0.0	265.1	0.185	49.0435	21884.6	21.4	99.5	21785.1	14596.01	7189.08
42	2100.0	0.465	11.23	14596.0		0.0	265.1	0.185	49.0435	16116.4	21.4	99.5	16016.8	10731.29	5285.56
43	2150.0	0.465	11.695	10731.3		0.0	265.1	0.185	49.0435	12251.6	21.4	99.5	12152.1	8141.92	4010.20
44	2200.0	0.465	12.16	34656.9	26515.0	0.0	265.1	0.185	49.0435	36177.3	21.4	99.5	36077.7	24172.09	11905.66
45	2250.0	0.465	12.625	24172.1		0.0	265.1	0.185	49.0435	25692.4	21.4	99.5	25592.9	17147.26	8445.67
46	2300.0	0.465	13.09	17147.3		0.0	265.1	0.185	49.0435	18667.6	21.4	99.5	18568.1	12440.63	6127.47
47	2350.0	0.465	13.555	12440.6		0.0	265.1	0.185	49.0435	13961.0	21.4	99.5	13861.5	9287.18	4574.28
48	2400.0	0.465	14.02	40340.3	31053.1	0.0	265.1	0.185	49.0435	41860.6	21.4	99.5	41761.1	27979.94	13781.16
49	2450.0	0.465	14.485	27979.9		0.0	265.1	0.185	49.0435	29500.3	21.4	99.5	29400.8	19698.52	9702.26
50	2500.0	0.465	14.95	19698.5		0.0	265.1	0.185	49.0435	21218.9	21.4	99.5	21119.4	14149.97	6969.39
51	2550.0	0.465	15.415	14150.0		0.0	265.1	0.185	49.0435	15670.3	21.4	99.5	15570.8	9389.20	4624.53
52	2600.0	0.465	15.88	44466.5	35077.3	0.0	265.1	0.185	49.0435	45986.9	21.4	99.5	45887.4	27670.09	13628.55
53	2650.0	0.465	16.345	27670.1		0.0	265.1	0.185	49.0435	29190.4	21.4	99.5	29090.9	17541.83	8640.01
54	2700.0	0.465	16.81	17541.8		0.0	265.1	0.185	49.0435	19062.2	21.4	99.5	18962.7	11434.49	5631.91
55	2750.0	0.465	17.275	11434.5		0.0	265.1	0.185	49.0435	12954.8	21.4	99.5	12855.3	7751.76	3818.03
56	2800.0	0.465	17.74	39470.3	31718.5	0.0	265.1	0.185	49.0435	40990.6	21.4	99.5	40891.1	24657.33	12144.66
57	2850.0	0.465	18.205	24657.3		0.0	265.1	0.185	49.0435	26177.7	21.4	99.5	26078.2	15725.14	7745.22
58	2900.0	0.465	18.67	15725.1		0.0	265.1	0.185	49.0435	17245.5	21.4	99.5	17146.0	10339.02	5092.35
59	2950.0	0.465	19.135	10339.0		0.0	265.1	0.185	49.0435	11859.4	21.4	99.5	11759.9	7091.20	3492.68
60	3000.0	0.465	19.6	35566.1	28474.9	0.0	265.1	0.185	49.0435	37086.5	21.4	99.5	36986.9	22303.13	10985.12
61	3050.0	0.77	20.37	22303.1		0.0	265.1	0.09	23.859	23042.8	21.4	164.8	22878.0	13795.42	6794.76
62	3100.0	0.77	21.14	13795.4		0.0	265.1	0.09	23.859	14535.0	21.4	164.8	14370.3	8665.27	4267.97
63	3150.0	0.77	21.91	8665.3		0.0	265.1	0.09	23.859	9404.9	21.4	164.8	9240.1	5571.79	2744.32
64	3200.0	0.77	22.68	30364.0	24792.2	0.0	265.1	0.09	23.859	31103.6	21.4	164.8	30938.8	18656.10	9188.83
65	3250.0	0.77	23.45	18656.1		0.0	265.1	0.09	23.859	19395.7	21.4	164.8	19231.0	11596.26	5711.59
66	3300.0	0.77	24.22	11596.3		0.0	265.1	0.09	23.859	12335.9	21.4	164.8	12171.1	7339.18	3614.82
67	3350.0	0.77	24.99	7339.2		0.0	265.1	0.09	23.859	8078.8	21.4	164.8	7914.0	4772.16	2350.47
68	3400.0	0.77	25.76	25637.9	20865.7	0.0	265.1	0.09	23.859	26377.5	21.4	164.8	26212.7	15806.27	7785.18
69	3450.0	0.77	26.53	15806.3		0.0	265.1	0.09	23.859	16545.9	21.4	164.8	16381.1	9877.81	4865.19
70	3500.0	0.77	27.3	9877.8		0.0	265.1	0.09	23.859	10617.4	21.4	164.8	10452.7	6302.96	3104.44
71	3550.0	0.77	28.07	6303.0		0.0	265.1	0.09	23.859	7042.6	21.4	164.8	6877.8	3686.50	1815.74
72	3600.0	0.77	28.84	21257.1	17570.5	0.0	265.1	0.09	23.859	21996.7	21.4	164.8	21831.9	11701.90	5763.62
73	3650.0	0.77	29.61	11701.9		0.0	265.1	0.09	23.859	12441.5	21.4	164.8	12276.7	6580.34	3241.06
74	3700.0	0.77	30.38	15585.0	9004.7	0.0	265.1	0.09	23.859	16324.6	21.4	164.8	16159.9	8661.69	4266.21
75	3750.0	0.77	31.15	8661.7		0.0	265.1	0.09	23.859	9401.3	21.4	164.8	9236.5	4950.78	2438.45
76	3800.0	0.77	31.92	11655.4	6704.7	0.0	265.1	0.09	23.859	12395.1	21.4	164.8	12230.3	6555.43	3228.80
77	3850.0	0.77	32.69	6555.4		0.0	265.1	0.09	23.859	7295.1	21.4	164.8	7130.3	3821.83	1882.39
78	3900.0	0.77	33.46	9220.2	5111.2	287.2	265.1	0.09	23.859	9959.8	21.4	164.8	9795.0	5250.14	2585.89
79	3950.0	0.77	34.23	5250.1		0.0	265.1	0.09	23.859	5989.8	21.4	164.8	5825.0	3122.19	1537.80
80	4000.0	0.77	35	7245.9	4123.7	0.0	265.1	0.09	23.859	7985.5	21.4	164.8	7820.7	4191.91	2064.67
				1077.7		983.4									
					Total water supply =	2061.1									

Water re.＝Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨(ETc mm/mon.)／days in month （ETc: calculated by CROPWAT-8）

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5mm)

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

Table 2.2.2.7(12) Calculation of Water Quantity for Supplemental Supply to the Paddy Fields (December)

Dec. Water Re= 20.95 mm/day

NO.	Distance (m)	① Paddy Area (ha)	Cumulative Area (ha)	② W.S./initial, return (m3/mon)	③ Intake quantity (m3/mon.)	④ Supplemental supply (m3/mon)	⑤ Specific discharge (m3/km2)	⑥ catchment area (km2)	⑦=⑤×⑥ Flow-in volume (m3/day)	⑧=②+⑦×31 Irrigation water (m3/mon)	⑨ ETc (mm/mon)	⑩=①×⑨×10000/1000 Water loss (m3/mon)	⑪=⑧-⑩ Residual water (m3/mon.)	⑫=⑪×0.67×(1.0～0.8) Horizontal leakage (m3/mon.)	⑬=⑪×0.33×(1.0～0.8) Return to the river (m3/mon.)
1	50.0	0.18	0.144	1169.1			255.3	0.085	21.7005	1841.8	72.9	131.2	1710.6	1146.10	564.50
2	100.0	0.18	0.324	2338.2	564.5	627.6	255.3	0.085	21.7005	3638.5	72.9	131.2	3507.3	2349.89	1157.41
3	150.0	0.18	0.504	2349.9		0.0	255.3	0.085	21.7005	3022.6	72.9	131.2	2891.4	1937.23	954.16
4	200.0	0.18	0.684	4676.4	2111.6	627.6	255.3	0.085	21.7005	5349.1	72.9	131.2	5217.9	3495.99	1721.91
5	250.0	0.18	0.864	3496.0		0.0	255.3	0.085	21.7005	4168.7	72.9	131.2	4037.5	2705.12	1332.37
6	300.0	0.18	1.044	2705.1		0.0	255.3	0.085	21.7005	3377.8	72.9	131.2	3246.6	2175.23	1071.38
7	350.0	0.18	1.224	2175.2		0.0	255.3	0.085	21.7005	2847.9	72.9	131.2	2716.7	1820.21	896.52
8	400.0	0.18	1.404	6842.4	5022.2	0.0	255.3	0.085	21.7005	7515.1	72.9	131.2	7383.9	4947.20	2436.68
9	450.0	0.18	1.584	4947.2		0.0	255.3	0.085	21.7005	5619.9	72.9	131.2	5488.7	3677.42	1811.27
10	500.0	0.18	1.764	3677.4		0.0	255.3	0.085	21.7005	4350.1	72.9	131.2	4218.9	2826.68	1392.24
11	550.0	0.18	1.944	2826.7		0.0	255.3	0.085	21.7005	3499.4	72.9	131.2	3368.2	2256.68	1111.50
12	600.0	0.18	2.124	9008.4	6751.7	0.0	255.3	0.085	21.7005	9681.1	72.9	131.2	9549.9	6398.41	3151.45
13	650.0	0.18	2.304	6398.4		0.0	255.3	0.085	21.7005	7071.1	72.9	131.2	6939.9	4649.73	2290.17
14	700.0	0.18	2.484	4649.7		0.0	255.3	0.085	21.7005	5322.4	72.9	131.2	5191.2	3478.12	1713.11
15	750.0	0.18	2.664	3478.1		0.0	255.3	0.085	21.7005	4150.8	72.9	131.2	4019.6	2693.14	1326.47
16	800.0	0.18	2.844	11174.3	8481.2	0.0	255.3	0.085	21.7005	11847.1	72.9	131.2	11715.8	7849.61	3866.23
17	850.0	0.18	3.024	7849.6		0.0	255.3	0.085	21.7005	8522.3	72.9	131.2	8391.1	5622.04	2769.07
18	900.0	0.18	3.204	5622.0		0.0	255.3	0.085	21.7005	6294.8	72.9	131.2	6163.5	4129.57	2033.97
19	950.0	0.18	3.384	4129.6		0.0	255.3	0.085	21.7005	4802.3	72.9	131.2	4671.1	3129.61	1541.45
20	1000.0	0.18	3.564	13340.3	10210.7	0.0	255.3	0.085	21.7005	14013.0	72.9	131.2	13881.8	9300.82	4581.00
21	1050.0	0.335	3.899	9300.8		0.0	255.3	0.1	25.53	10092.3	72.9	244.2	9848.0	6598.18	3249.85
22	1100.0	0.335	4.234	6598.2		0.0	255.3	0.1	25.53	7389.6	72.9	244.2	7145.4	4787.42	2357.98
23	1150.0	0.335	4.569	4787.4		0.0	255.3	0.1	25.53	5578.8	72.9	244.2	5334.6	3574.20	1760.43
24	1200.0	0.335	4.904	15523.5	11949.3	0.0	255.3	0.1	25.53	16314.9	72.9	244.2	16070.7	10767.36	5303.33
25	1250.0	0.335	5.239	10767.4		0.0	255.3	0.1	25.53	11558.8	72.9	244.2	11314.6	7580.76	3733.81
26	1300.0	0.335	5.574	7580.8		0.0	255.3	0.1	25.53	8372.2	72.9	244.2	8128.0	5445.75	2682.23
27	1350.0	0.335	5.909	5445.7		0.0	255.3	0.1	25.53	6237.2	72.9	244.2	5993.0	4015.28	1977.68
28	1400.0	0.335	6.244	17712.3	13697.0	0.0	255.3	0.1	25.53	18503.8	72.9	244.2	18259.5	12233.89	6025.65
29	1450.0	0.335	6.579	12233.9		0.0	255.3	0.1	25.53	13025.3	72.9	244.2	12781.1	8563.34	4217.77
30	1500.0	0.335	6.914	8563.3		0.0	255.3	0.1	25.53	9354.8	72.9	244.2	9110.6	6104.07	3006.48
31	1550.0	0.335	7.249	6104.1		0.0	255.3	0.1	25.53	6895.5	72.9	244.2	6651.3	4456.36	2194.93
32	1600.0	0.335	7.584	19901.2	15444.8	0.0	255.3	0.1	25.53	20692.6	72.9	244.2	20448.4	13700.43	6747.97
33	1650.0	0.335	7.919	13700.4		0.0	255.3	0.1	25.53	14491.9	72.9	244.2	14247.6	9545.92	4701.72
34	1700.0	0.335	8.254	9545.9		0.0	255.3	0.1	25.53	10337.4	72.9	244.2	10093.1	6762.40	3330.74
35	1750.0	0.335	8.589	6762.4		0.0	255.3	0.1	25.53	7553.8	72.9	244.2	7309.6	4897.44	2412.17
36	1800.0	0.335	8.924	22090.0	17192.6	0.0	255.3	0.1	25.53	22881.5	72.9	244.2	22637.3	15166.97	7470.30
37	1850.0	0.335	9.259	15167.0		0.0	255.3	0.1	25.53	15958.4	72.9	244.2	15714.2	10528.50	5185.68
38	1900.0	0.335	9.594	10528.5		0.0	255.3	0.1	25.53	11319.9	72.9	244.2	11075.7	7420.73	3654.99
39	1950.0	0.335	9.929	7420.7		0.0	255.3	0.1	25.53	8212.2	72.9	244.2	7967.9	5338.52	2629.42
40	2000.0	0.335	10.264	24278.9	18940.4	0.0	255.3	0.1	25.53	25070.3	72.9	244.2	24826.1	16633.50	8192.62
41	2050.0	0.465	10.729	16633.5		0.0	255.3	0.185	47.2305	18097.6	72.9	339.0	17758.7	11898.30	5860.36
42	2100.0	0.465	11.194	11898.3		0.0	255.3	0.185	47.2305	13362.4	72.9	339.0	13023.5	8725.72	4297.74
43	2150.0	0.465	11.659	8725.7		0.0	255.3	0.185	47.2305	10189.9	72.9	339.0	9850.9	6600.09	3250.79
44	2200.0	0.465	12.124	28201.6	21601.5	0.0	255.3	0.185	47.2305	29665.8	72.9	339.0	29326.8	19648.93	9677.83
45	2250.0	0.465	12.589	19648.9		0.0	255.3	0.185	47.2305	21113.1	72.9	339.0	20774.1	13918.64	6855.45
46	2300.0	0.465	13.054	13918.6		0.0	255.3	0.185	47.2305	15382.8	72.9	339.0	15043.8	10079.35	4964.46
47	2350.0	0.465	13.519	10079.3		0.0	255.3	0.185	47.2305	11543.5	72.9	339.0	11204.5	7507.02	3697.49
48	2400.0	0.465	13.984	32702.2	25195.2	0.0	255.3	0.185	47.2305	34166.4	72.9	339.0	33827.4	22664.36	11163.04
49	2450.0	0.465	14.449	22664.4		0.0	255.3	0.185	47.2305	24128.5	72.9	339.0	23789.5	15938.98	7850.54
50	2500.0	0.465	14.914	15939.0		0.0	255.3	0.185	47.2305	17403.1	72.9	339.0	17064.1	11432.97	5631.17
51	2550.0	0.465	15.379	11433.0		0.0	255.3	0.185	47.2305	12897.1	72.9	339.0	12558.1	7572.56	3729.77
52	2600.0	0.465	15.844	35947.1	28374.5	0.0	255.3	0.185	47.2305	37411.2	72.9	339.0	37072.2	22354.56	11010.45
53	2650.0	0.465	16.309	22354.6		0.0	255.3	0.185	47.2305	23818.7	72.9	339.0	23479.7	14158.27	6973.48
54	2700.0	0.465	16.774	14158.3		0.0	255.3	0.185	47.2305	15622.4	72.9	339.0	15283.4	9215.91	4539.18
55	2750.0	0.465	17.239	9215.9		0.0	255.3	0.185	47.2305	10680.1	72.9	339.0	10341.1	6235.66	3071.30
56	2800.0	0.465	17.704	31830.1	25594.4	0.0	255.3	0.185	47.2305	33294.2	72.9	339.0	32955.2	19872.01	9787.70
57	2850.0	0.465	18.169	19872.0		0.0	255.3	0.185	47.2305	21336.2	72.9	339.0	20997.2	12661.29	6236.16
58	2900.0	0.465	18.634	12661.3		0.0	255.3	0.185	47.2305	14125.4	72.9	339.0	13786.5	8313.23	4094.58
59	2950.0	0.465	19.099	8313.2		0.0	255.3	0.185	47.2305	9777.4	72.9	339.0	9438.4	5691.35	2803.20
60	3000.0	0.465	19.564	28613.0	22921.6	0.0	255.3	0.185	47.2305	30077.1	72.9	339.0	29738.2	17932.10	8832.23
61	3050.0	0.77	20.334	17932.1		0.0	255.3	0.09	22.977	18644.4	72.9	561.3	18083.1	10904.09	5370.67
62	3100.0	0.77	21.104	10904.1		0.0	255.3	0.09	22.977	11616.4	72.9	561.3	11055.0	6666.19	3283.35
63	3150.0	0.77	21.874	6666.2		0.0	255.3	0.09	22.977	7378.5	72.9	561.3	6817.1	4110.74	2024.69
64	3200.0	0.77	22.644	23621.7	19510.9	0.0	255.3	0.09	22.977	24334.0	72.9	561.3	23772.6	14334.90	7060.47
65	3250.0	0.77	23.414	14334.9		0.0	255.3	0.09	22.977	15047.2	72.9	561.3	14485.9	8734.97	4302.30
66	3300.0	0.77	24.184	8735.0		0.0	255.3	0.09	22.977	9447.3	72.9	561.3	8885.9	5358.22	2639.12
67	3350.0	0.77	24.954	5358.2		0.0	255.3	0.09	22.977	6070.5	72.9	561.3	5509.2	3322.03	1636.22
68	3400.0	0.77	25.724	20004.6	15638.1	1044.5	255.3	0.09	22.977	20716.9	72.9	561.3	20155.6	12153.80	5986.20
69	3450.0	0.77	26.494	12153.8		0.0	255.3	0.09	22.977	12866.1	72.9	561.3	12304.8	7419.77	3654.51
70	3500.0	0.77	27.264	7419.8		0.0	255.3	0.09	22.977	8132.1	72.9	561.3	7570.7	4565.15	2248.51
71	3550.0	0.77	28.034	4565.1		0.0	255.3	0.09	22.977	5277.4	72.9	561.3	4716.1	2527.83	1245.05
72	3600.0	0.77	28.804	15662.1	13134.3	0.0	255.3	0.09	22.977	16374.4	72.9	561.3	15813.1	8475.80	4174.65
73	3650.0	0.77	29.574	8475.8		0.0	255.3	0.09	22.977	9188.1	72.9	561.3	8626.8	4623.94	2277.46
74	3700.0	0.77	30.344	11076.1	6452.1	0.0	255.3	0.09	22.977	11788.3	72.9	561.3	11227.0	6017.68	2963.93
75	3750.0	0.77	31.114	6017.7		0.0	255.3	0.09	22.977	6730.0	72.9	561.3	6168.6	3306.39	1628.52
76	3800.0	0.77	31.884	10002.3	4592.5	2103.5	255.3	0.09	22.977	10714.6	72.9	561.3	10153.3	5442.15	2680.46
77	3850.0	0.77	32.654	5442.1		0.0	255.3	0.09	22.977	6154.4	72.9	561.3	5593.1	2997.90	1476.58
78	3900.0	0.77	33.424	10002.3	4157.0	2847.4	255.3	0.09	22.977	10714.6	72.9	561.3	10153.3	5442.15	2680.46
79	3950.0	0.77	34.194	5442.1		0.0	255.3	0.09	22.977	6154.4	72.9	561.3	5593.1	2997.90	1476.58
80	4000.0	0.77	34.964	7154.9	4157.0	0.0	255.3	0.09	22.977	7867.2	72.9	561.3	7305.9	3915.96	1928.76
				1169.1		7250.5									

Total water supply = 8419.6

Water re.=Virtical percolation 13.6mm+Horizontal leakage 5mm+⑨(ETc mm/mon.)／days in month (ETc: calculated by CROPWAT-8)

②;=upper one column in ⑫ row (2/3×Horizontal leakage), at the intake point, larger one between the former value and supply target area×(ETc+Virtical 13.6mm+ Horizontal 5mm)

③;intake quantity of the total return flow in ⑬row after the previous intake point

④;resupply quantity in case of the total return flow being less than irrigation water requirement at the relevant intake point

⑤;=total flow rate at the dam site per month (estimated by the Tank Model Analysis) devided by catchment area 8.8km2 and devided by the days' number of the relevant month

2-2-2-1-3 Hillside Irrigation Water Requirement

Hillside irrigation water requirement on hillside is calculated by meteorological data such as precipitation or temperature based on cropping pattern planned.

1) Conditions of Study

(1) Cropping pattern

Cropping pattern is studied in consideration of marketability, productivity, food security and result of discussions with local staffs. The crops which are recommended to be introduced to command area are Rice (double cropping), Maize and Beans, Vegetable-1 (Carrot, Cabbage and Eggplant), Vegetable-2 (Tomato and Beans), Vegetable-3 (Tomato Tree) and Coffee. The acreage ratio of vegetable should be enlarged at farmers' wish since it is profitable crop. On the contrary, the ratio of coffee shall be minimized since it is cultivated already in high land area of the hillside.

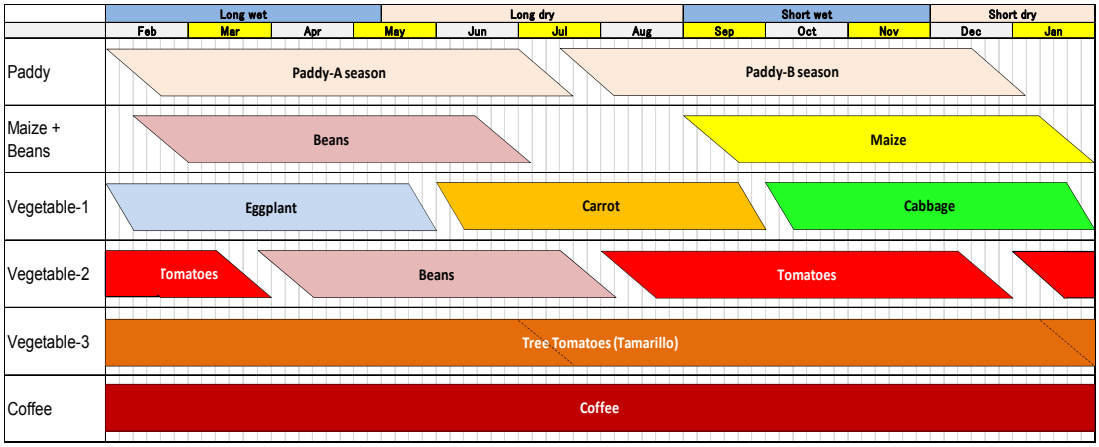


Figure 2.2.2.9 Planned Cropping Pattern

(2) Irrigation area of farm land

Since terracing works shall be implemented on the hillside command area, the farm land area after construction will be reduced compared to present area. Standard sectional profile of terrace on LWH project is as follows. Cutting gradient, filling gradient and step height according to hillside slope are provided.

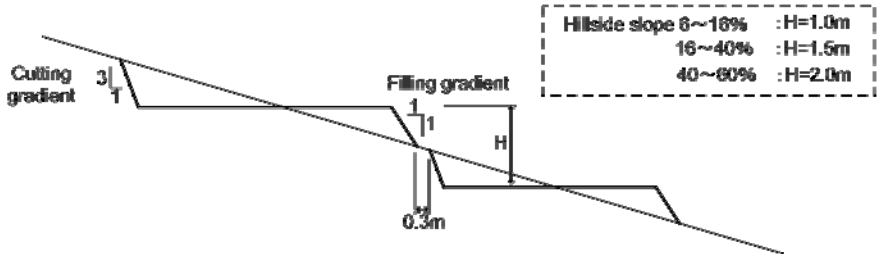


Figure 2.2.2.10 Standard Profile of Terrace

Moreover, some land which can not be included as irrigation area such as tree planting area, rocky area, roads and canals and O&M road which will be constructed in the Project. Since average gradient of command area of hillside is from 10 to 15% the area shall be reduced to 88% after terracing works.

And total area shall be reduced to 83% including other land such as roads which is estimated about 5 % of total. As the result of study, upland command area is decided as following table.

Table 2.2.2.8 Command Area and Breakdown of Cropping

	Right hill	Left hill	Total
Gross command area	200.6ha	120.9ha	321.5ha
Net command area	166.5ha≒165ha	100.3ha≒100ha	266.8ha≒265ha

Crop		Cropping Acreage		Remarks
Rice Paddy		35 ha	(12 %)	
Upland Cropping	Maize + Beans	120 ha	(40 %)	
	Vegetable-1	60 ha	(20 %)	Carrot + Cabbage +Eggplant
	Vegetable-2	40 ha	(13 %)	Tomato + Beans
	Vegetable-3	30 ha	(10 %)	Tomato Tree
	Coffee	15 ha	(5 %)	
	Sub-total	265 ha	(88 %)	
Total		300 ha	(100 %)	

(3) Meteorological data

In this study, rainfall and temperature observed at Gahororo station, the nearest meteorological station by command area, are adopted for calculation of irrigation water requirement. And other meteorological data such as relative humidity, wind velocity and sunshine hours observed at Kigali national airport station are adopted since these data are not observed at Gahororo. The following table shows meteorological conditions in 1974, the dry year with the probability occurrence of 1/5.

Table 2.2.2.9 Meteorological Conditions for Calculation of Irrigation Water Requirement (1974)

Month	Rain	Min Temp	Max Temp	Humidity	Wind	Sun	Rad	ETo
	mm	°C	°C	%	km/day	hours	MJ/m2/day	mm/day
January	76.8	9.7	26.2	77	324	6.1	18.6	4.16
February	84.4	9.7	26.4	77	297	6.2	19.2	4.21
March	42.8	9.9	26.6	77	257	4.9	17.2	3.93
April	173.3	10	25.4	84	188	5.2	17.0	3.37
May	148.3	10.2	25.0	82	206	5.6	16.5	3.27
June	76.2	10.1	25.9	84	197	5.4	15.6	3.14
July	53.4	9.8	25.0	77	222	4.7	14.8	3.25
August	0.0	10.9	27.9	64	292	7.7	20.1	4.93
September	75.2	10.6	26.9	72	307	6.0	18.5	4.42
October	30.5	10.8	28.0	74	336	6.7	19.9	4.73
November	176.1	10.7	25.5	83	242	4.7	16.5	3.45
December	64.5	12.4	24.2	85	226	5.4	17.3	3.29
Average	1001.5	10.4	26.1	78	258	5.7	17.6	3.85

Notes:

*1) Rainfall: Gahororo Station (Rurenge Sector, Ngoma District), 1974.01-12

*2) Minimum Temperature: Gahororo Station, 1974.01-12

*3) Maximum Temperature: Gahororo Station, 1974.01-12

*4) Humidity, Wind, and Sunshine: Kigali Station, 1974.01-12

*5) Radiation and RET (Reference Evapotranspiration) is calculated by CROPWAT8.0 based on other data.

2) Study of irrigation water requirement

Irrigation water requirement is studied as following procedures.

(1) Unit irrigation water requirement

Unit Irrigation Water Requirement for each crop is calculated by CROPWAT8.0, which is a decision support tool developed by the Land Water Development Division of FAO(Food and Agriculture Organization).

(2) Net irrigation water requirement

Net Irrigation Water Requirement for each crop is calculated taking into account cropping acreage and unit irrigation water requirement.

(3) Gross irrigation water requirement

Gross Irrigation Water Requirement is calculated based on net irrigation water requirement taking into account irrigation efficiency and wet area coefficient.

(4) Irrigation efficiency

Irrigation efficiency is subdivided into conveyance efficiency (Ec) and field application efficiency (Ea).

Conveyance efficiency and field application efficiency are shown as follows on "Irrigation Water Management Manual No.4: Irrigation Scheduling, FAO".

Table 2.2.2.10 Ec: Conveyance Efficiency

Description			Conveyance Efficiency (Ec)			
Canal Type			Earthen Canals			Lined Canals
Soil Type			Sand	Loam	Clay	-
Canal Length	Long	(> 2,000m)	60 %	70 %	80 %	95 %
	Medium	(200- 2,000m)	70 %	75 %	85 %	95 %
	Short	(< 200m)	80 %	85 %	90 %	95 %

Table 2.2.2.11 Ea: Field Application Efficiency

Irrigation Methods	Field Application Efficiency (Ea)
Surface Irrigation (Border, Furrow, Basin)	60 %
Sprinkler Irrigation	75 %
Drip Irrigation	90 %

In this study, 95% is applied as conveyance efficiency since concrete lining canal or pipeline is adopted for main and secondary canal. In addition, 90% is applied as field application efficiency since water saving irrigation method is adopted as on-farm irrigation system.

Therefore, irrigation efficiency is estimated at 85% as follows;

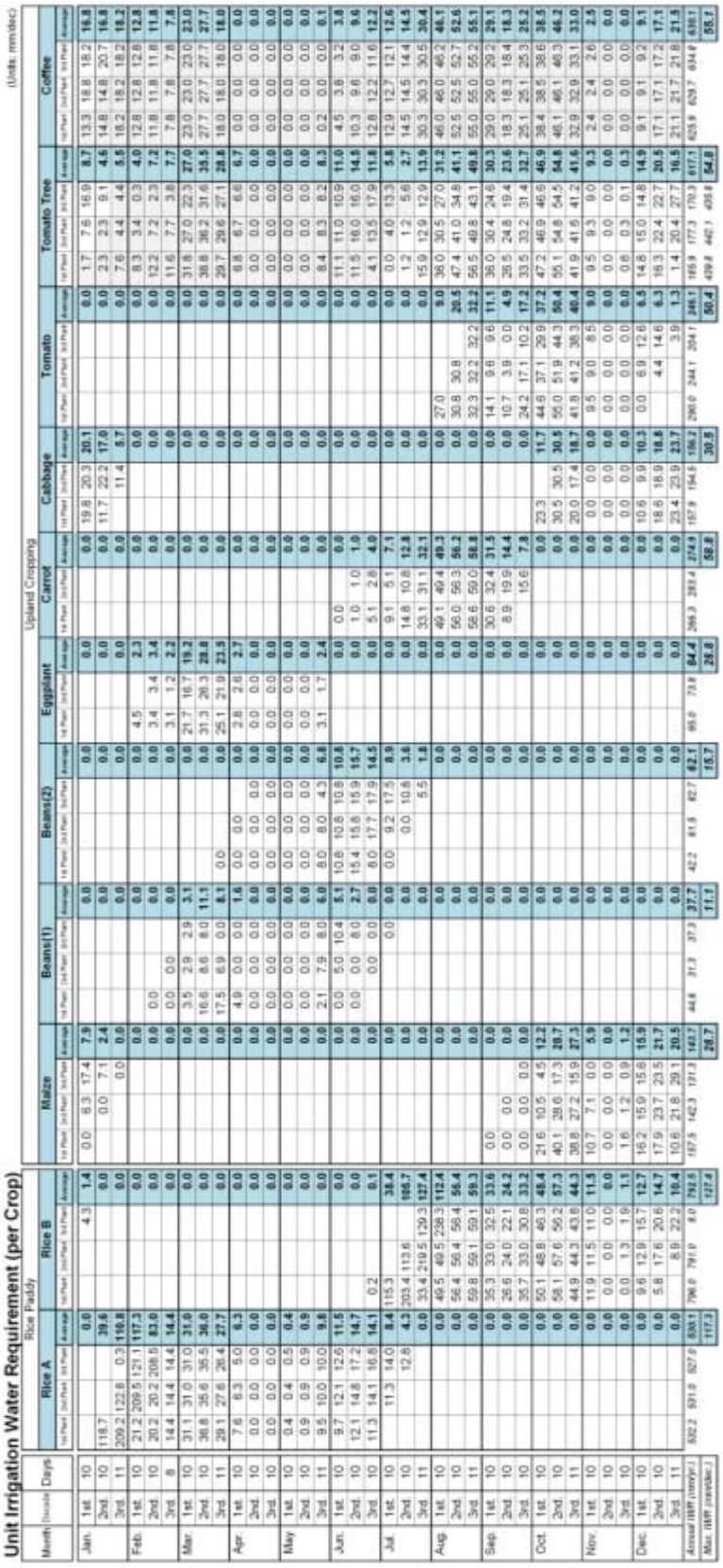
$$E = Ec \times Ea = 95\% \times 90\% = 85\%$$

(5) Wet area coefficient

Wet area coefficient (Kw) is different according to irrigation method. In case of surface irrigation and sprinkler irrigation, the coefficient of those is 100% since these method supply water to whole ground. Because water saving irrigation method shall be applied which supply water only to around the crop in this Project, the wet area coefficient applied from 40 to 70% generally. Therefore, comparative study is

conducted in four cases, such as Kw=40, 50, 60 and 70%.

Table 2.2.2.12 Unit Irrigation Water Requirement (per Crop)



Unit Irrigation Water Requirement (per Crop)

(Units: mm/dec)

Upland Cropping

Month	Decade	Days	Rice A	Rice B	Maize	Beans(1)	Beans(2)	Eggplant	Carrot	Cabbage	Tomato	Tomato Tree	Coffee
Jan.	1st.	10		4.3	0.0 6.3 17.4 7.9			0.0	0.0	19.8 20.3 20.1		1.7 7.6 16.9 8.7	13.3 18.8 18.2 16.8
	2nd.	10	118.7	39.6	0.0 7.1 2.4			0.0	0.0	11.7 22.2 17.0		2.3 2.3 9.1 4.5	14.8 14.8 20.7 16.8
	3rd.	11	209.2 122.8 0.3 116.8	0.0	0.0			0.0	0.0	11.4 5.7		7.6 4.4 4.4 5.5	18.2 18.2 18.2 18.2
Feb.	1st.	10	21.2 209.5 121.1 117.3		0.0			0.0 4.5 2.3	0.0	0.0		8.3 3.4 0.3 4.0	12.8 12.8 12.6 12.8
	2nd.	10	20.2 20.2 208.5 83.0		0.0 0.0			0.0 3.4 3.4 3.4	0.0	0.0		12.2 7.2 2.3 7.2	11.8 11.8 11.8 11.8
	3rd.	8	14.4 14.4 14.4 14.4		0.0 0.0 0.0			0.0 3.1 1.2 2.2	0.0	0.0		11.6 7.7 3.8 7.7	7.8 7.8 7.8 7.8
Mar.	1st.	10	31.1 31.0 31.0 31.0		0.0	3.5 2.9 2.9 3.1		0.0 21.7 16.7 19.2	0.0	0.0		31.8 27.0 22.3 27.0	23.0 23.0 23.0 23.0
	2nd.	10	36.8 35.6 35.5 36.0		0.0	16.6 8.6 8.0 11.1		0.0 31.3 26.3 28.8	0.0	0.0		38.8 36.2 31.6 35.5	27.7 27.7 27.7 27.7
	3rd.	11	29.1 27.6 26.4 27.7		0.0	17.5 6.9 0.0 8.1	0.0	25.1 21.9 23.5	0.0	0.0		29.7 29.6 27.1 28.8	18.0 18.0 18.0 18.0
Apr.	1st.	10	7.6 6.3 5.0 6.3		0.0	4.9 0.0 0.0 1.6	0.0 0.0	0.0 2.8 2.6 2.7	0.0	0.0		6.8 6.7 6.6 6.7	0.0 0.0 0.0 0.0
	2nd.	10	0.0 0.0 0.0 0.0		0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0	0.0		0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0
	3rd.	10	0.0 0.0 0.0 0.0		0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0	0.0		0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0
May	1st.	10	0.4 0.4 0.5 0.4		0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0	0.0		0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0
	2nd.	10	0.9 0.9 0.9 0.9		0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0	0.0		0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0
	3rd.	11	9.5 10.0 10.0 9.8		0.0	2.1 7.9 8.0 6.0	8.0 8.0 4.3 6.8	3.1 1.7 2.4	0.0	0.0		8.4 8.3 8.2 8.3	0.2 0.0 0.0 0.1
Jun.	1st.	10	9.7 12.1 12.6 11.5		0.0	0.0 5.0 10.4 5.1	10.8 10.8 10.8 10.8	0.0	0.0 0.0	0.0		11.1 11.0 10.9 11.0	4.5 3.8 3.2 3.8
	2nd.	10	12.1 14.8 17.2 14.7		0.0	0.0 0.0 8.0 2.7	15.4 15.8 15.9 15.7	0.0	0.0 1.0 1.0 1.0	0.0		11.5 16.0 16.0 14.5	10.3 9.6 9.0 9.6
	3rd.	10	11.3 14.1 16.8 14.1 0.2	0.1	0.0	0.0 0.0 0.0 0.0	8.0 17.7 17.9 14.5	0.0	5.1 2.6 4.0	0.0		4.1 13.5 17.9 11.8	12.8 12.2 11.6 12.2
Jul.	1st.	10	11.3 14.0 8.4 115.3	38.4	0.0	0.0	9.2 17.5 8.9	0.0	9.1 5.1 7.1	0.0		0.0 4.0 13.3 5.8	12.9 12.7 12.1 12.6
	2nd.	10	12.8 4.3 203.4 113.8	108.7	0.0		0.0 10.8 3.6	0.0	14.8 10.8 12.4	0.0		1.2 1.2 5.6 2.7	14.5 14.5 14.4 14.5
	3rd.	11	0.0 33.4 219.5 129.3	127.4	0.0		5.5 1.8	0.0	33.1 31.1 32.1	0.0		15.9 12.9 12.9 13.9	30.3 30.3 30.3 30.4
Aug.	1st.	10	0.0 49.5 49.5 238.3	112.4	0.0		0.0	0.0	49.1 49.4 49.3	0.0	27.0	38.0 30.5 27.0 31.2	46.0 46.0 46.0 46.2
	2nd.	10	0.0 56.4 56.4 56.4	56.4	0.0		0.0	0.0	56.0 56.3 56.2	0.0	30.8 30.8	47.4 41.0 34.8 41.1	52.5 52.5 52.7 52.6
	3rd.	11	0.0 59.8 59.1 59.1	59.3	0.0		0.0	0.0	58.6 59.0 58.8	0.0	32.3 32.2 32.2	56.5 49.8 43.1 49.8	55.0 55.0 55.2 55.1
Sep.	1st.	10	0.0 35.3 33.0 32.5	33.6	0.0		0.0	0.0	30.6 32.4 31.5	0.0	14.1 9.6 9.6 11.1	38.0 30.4 24.6 30.3	29.0 29.0 29.2 29.1
	2nd.	10	0.0 26.6 24.0 22.1	24.2	0.0 0.0		0.0	0.0	8.9 19.9 14.4	0.0	10.7 3.9 0.0 4.9	26.5 24.8 19.4 23.6	18.3 18.3 18.4 18.3
	3rd.	10	0.0 35.7 33.0 30.8	33.2	0.0 0.0 0.0 0.0		0.0	0.0	15.6 7.8	0.0	24.2 17.1 10.2 17.2	33.5 33.2 31.4 32.7	25.1 25.1 25.3 25.2
Oct.	1st.	10	0.0 50.1 48.8 46.3	48.4	21.6 10.5 4.5 12.2		0.0	0.0	0.0	23.3	11.7 44.6 37.1 29.9 37.2	47.2 46.9 46.6 46.9	38.4 38.5 38.6 38.5
	2nd.	10	0.0 58.1 57.6 56.2	57.3	40.1 28.6 17.3 28.7		0.0	0.0	0.0	30.5 30.5	55.0 51.9 44.3 50.4	55.1 54.8 54.5 54.8	46.1 46.1 46.3 46.2
	3rd.	11	0.0 44.9 44.3 43.6	44.3	38.6 27.2 15.9 27.3		0.0	0.0	0.0	20.0 17.4 18.7	41.8 41.2 38.3 40.4	41.9 41.6 41.2 41.6	32.8 32.9 33.1 33.0
Nov.	1st.	10	0.0 11.9 11.5 11.0	11.5	10.7 7.1 0.0 5.9		0.0	0.0	0.0	0.0 0.0 0.0 0.0	9.5 9.0 8.5 9.0	9.5 9.3 9.0 9.3	2.4 2.4 2.6 2.5
	2nd.	10	0.0 0.0 0.0 0.0	0.0	0.0 0.0 0.0 0.0		0.0	0.0	0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0	0.0 0.0 0.0 0.0
	3rd.	10	0.0 0.0 1.3 1.9	1.1	1.6 1.2 0.9 1.2		0.0	0.0	0.0	0.0 0.0 0.0 0.0	0.0 0.3 0.1 0.3	0.6 0.3 0.1 0.3	0.0 0.0 0.0 0.0
Dec.	1st.	10	0.0 9.6 12.9 15.7	12.7	16.2 15.9 15.6 15.9		0.0	0.0	0.0	10.6 9.9 10.3	6.9 12.6 6.5	14.8 15.0 14.8 14.9	9.1 9.1 9.2 9.1
	2nd.	10	0.0 5.8 17.6 20.6	14.7	17.9 23.7 23.5 21.7		0.0	0.0	0.0	18.6 18.9 18.8	4.4 14.6 6.3	16.3 22.4 22.7 20.5	17.1 17.1 17.2 17.1
	3rd.	11	0.0 8.9 22.2 10.4	10.4	10.6 21.8 29.1 20.5		0.0	0.0	0.0	23.4 23.9 23.7	3.9 1.3	1.4 20.4 27.7 16.5	21.1 21.7 21.8 21.5
Annual IWR (mm/yr.)			932.2 931.0 927.8 930.1	796.0 791.0 8.0 792.5	187.5 142.3 191.3 143.7	44.8 31.3 37.3 37.7	42.2 81.6 82.7 82.1	95.0 73.8 84.4	266.3 283.4 274.9	167.9 154.6 156.2 159.6	280.0 244.1 264.1 346.1	185.9 177.3 170.3 617.1	625.9 629.7 634.9 630.1
Max. IWR (mm/dec.)			177.3	127.4	28.7	11.1	15.7	26.8	58.8	30.5	50.4	439.8 442.1 408.8 54.8	55.1

Notes

*1) Irrigation Water Requirement : Calculated by CROPWAT8 based on cropping pattern for Ngoma22.

Table 2.2.2.13 Unit Irrigation Water Requirement (per Cropping Pattern)

Unit Irrigation Water Requirement (per Cropping Pattern)

(Units: mm/dec)

Month	Decade	Days	Rice Paddy			Upland Cropping												
						Maize + Beans			Vegetable 1				Vegetable 2			Vegetable 3		
			Rice A (Average)	Rice B (Average)	Total	Maize (Average)	Beans (Average)	Sub-total	Eggplant (Average)	Carrot (Average)	Cabbage (Average)	Sub-total	Tomato (Average)	Beans (Average)	Sub-total	Tomato Tree (Average)	Coffee (Average)	Total
Jan.	1st.	10	0.0	1.4	**1.4**	7.9	0.0	7.9	0.0	0.0	20.1	20.1	0.0	0.0	0.0	8.7	16.8	**53.5**
	2nd.	10	39.6	0.0	**39.6**	2.4	0.0	2.4	0.0	0.0	17.0	17.0	0.0	0.0	0.0	4.6	16.8	**40.7**
	3rd.	11	110.8	0.0	**110.8**	0.0	0.0	0.0	0.0	0.0	5.7	5.7	0.0	0.0	0.0	5.5	18.2	**29.4**
Feb.	1st.	10	117.3	0.0	**117.3**	0.0	0.0	0.0	2.3	0.0	0.0	2.3	0.0	0.0	0.0	4.0	12.8	**19.1**
	2nd.	10	83.0	0.0	**83.0**	0.0	0.0	0.0	3.4	0.0	0.0	3.4	0.0	0.0	0.0	7.2	11.8	**22.4**
	3rd.	8	14.4	0.0	**14.4**	0.0	0.0	0.0	2.2	0.0	0.0	2.2	0.0	0.0	0.0	7.7	7.8	**17.7**
Mar.	1st.	10	31.0	0.0	**31.0**	0.0	3.1	3.1	19.2	0.0	0.0	19.2	0.0	0.0	0.0	27.0	23.0	**72.3**
	2nd.	10	36.0	0.0	**36.0**	0.0	11.1	11.1	28.8	0.0	0.0	28.8	0.0	0.0	0.0	35.5	27.7	**103.1**
	3rd.	11	27.7	0.0	**27.7**	0.0	8.1	8.1	23.5	0.0	0.0	23.5	0.0	0.0	0.0	28.8	18.0	**78.4**
Apr.	1st.	10	6.3	0.0	**6.3**	0.0	1.6	1.6	2.7	0.0	0.0	2.7	0.0	0.0	0.0	6.7	0.0	**11.0**
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
	3rd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
May	1st.	10	0.4	0.0	**0.4**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
	2nd.	10	0.9	0.0	**0.9**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
	3rd.	11	9.8	0.0	**9.8**	0.0	6.0	6.0	2.4	0.0	0.0	2.4	0.0	6.8	6.8	8.3	0.1	**23.5**
Jun.	1st.	10	11.5	0.0	**11.5**	0.0	5.1	5.1	0.0	0.0	0.0	0.0	0.0	10.8	10.8	11.0	3.8	**30.8**
	2nd.	10	14.7	0.0	**14.7**	0.0	2.7	2.7	0.0	1.0	0.0	1.0	0.0	15.7	15.7	14.5	9.6	**43.5**
	3rd.	10	14.1	0.1	**14.1**	0.0	0.0	0.0	0.0	4.0	0.0	4.0	0.0	14.5	14.5	11.8	12.2	**42.5**
Jul.	1st.	10	8.4	38.4	**46.9**	0.0	0.0	0.0	0.0	7.1	0.0	7.1	0.0	8.9	8.9	5.8	12.6	**34.3**
	2nd.	10	4.3	105.7	**109.9**	0.0	0.0	0.0	0.0	12.8	0.0	12.8	0.0	3.6	3.6	2.7	14.5	**33.5**
	3rd.	11	0.0	127.4	**127.4**	0.0	0.0	0.0	0.0	32.1	0.0	32.1	0.0	1.8	1.8	13.9	30.4	**78.2**
Aug.	1st.	10	0.0	112.4	**112.4**	0.0	0.0	0.0	0.0	49.3	0.0	49.3	9.0	0.0	9.0	31.2	46.1	**135.5**
	2nd.	10	0.0	56.4	**56.4**	0.0	0.0	0.0	0.0	56.2	0.0	56.2	20.5	0.0	20.5	41.1	52.6	**170.3**
	3rd.	11	0.0	59.3	**59.3**	0.0	0.0	0.0	0.0	58.8	0.0	58.8	32.2	0.0	32.2	49.8	55.1	**195.9**
Sep.	1st.	10	0.0	33.6	**33.6**	0.0	0.0	0.0	0.0	31.5	0.0	31.5	11.1	0.0	11.1	30.3	29.1	**102.0**
	2nd.	10	0.0	24.2	**24.2**	0.0	0.0	0.0	0.0	14.4	0.0	14.4	4.9	0.0	4.9	23.6	18.3	**61.2**
	3rd.	10	0.0	33.2	**33.2**	0.0	0.0	0.0	0.0	7.8	0.0	7.8	17.2	0.0	17.2	32.7	25.2	**82.8**
Oct.	1st.	10	0.0	48.4	**48.4**	12.2	0.0	12.2	0.0	0.0	11.7	11.7	37.2	0.0	37.2	46.9	38.5	**146.5**
	2nd.	10	0.0	57.3	**57.3**	28.7	0.0	28.7	0.0	0.0	30.5	30.5	50.4	0.0	50.4	54.8	46.2	**210.5**
	3rd.	11	0.0	44.3	**44.3**	27.3	0.0	27.3	0.0	0.0	18.7	18.7	40.4	0.0	40.4	41.6	33.0	**161.0**
Nov.	1st.	10	0.0	11.5	**11.5**	5.9	0.0	5.9	0.0	0.0	0.0	0.0	9.0	0.0	9.0	9.3	2.5	**26.7**
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
	3rd.	10	0.0	1.1	**1.1**	1.2	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	**1.6**
Dec.	1st.	10	0.0	12.7	**12.7**	15.9	0.0	15.9	0.0	0.0	10.3	10.3	6.5	0.0	6.5	14.9	9.1	**56.7**
	2nd.	10	0.0	14.7	**14.7**	21.7	0.0	21.7	0.0	0.0	18.8	18.8	6.3	0.0	6.3	20.5	17.1	**84.4**
	3rd.	11	0.0	10.4	**10.4**	20.5	0.0	20.5	0.0	0.0	23.7	23.7	1.3	0.0	1.3	16.5	21.5	**83.5**
Annual IWR (mm/yr.)			*530.1*	*792.5*	***1,322.6***	*143.7*	*37.7*	*181.4*	*84.4*	*274.9*	*156.2*	*515.5*	*246.1*	*62.1*	*308.2*	*617.1*	*630.1*	***2,252.3***
Max. IWR (mm/dec.)			*117.3*	*127.4*	***127.4***	*28.7*	*11.1*	*28.7*	*28.8*	*58.8*	*30.5*	*58.8*	*50.4*	*15.7*	*50.4*	*54.8*	*55.1*	***210.5***

Table 2.2.2.14 Net Irrigation Water Requirement (per Cropping Pattern)

Net Irrigation Water Requirement (per Cropping Pattern)

(Unit: m^3/dec)

Month	Decade	Days	Rice Paddy			Upland Cropping													Grand Total
						Maize + Beans			Vegetable 1				Vegetable 2			Vegetable 3	Coffee	Total	
			Rice A	Rice B	Total	Maize	Beans	Sub-total	Eggplant	Carrot	Cabbage	Sub-total	Tomato	Beans	Sub-total	Tomato Tree			
			35.0 ha (12 %)			120.0 ha (40 %)			60.0 ha (20 %)				40.0 ha (13 %)			30.0 ha (10 %)	15.0 ha (5 %)	**265.0 ha (88 %)**	300.0 ha (100 %)
Jan.	1st.	10	0.0	501.7	**501.7**	9,480.0	0.0	9,480.0	0.0	0.0	12,030.0	12,030.0	0.0	0.0	0.0	2,620.0	2,515.0	**26,645.0**	27,146.7
	2nd.	10	13,848.3	0.0	**13,848.3**	2,840.0	0.0	2,840.0	0.0	0.0	10,170.0	10,170.0	0.0	0.0	0.0	1,370.0	2,515.0	**16,895.0**	30,743.3
	3rd.	11	38,768.3	0.0	**38,768.3**	0.0	0.0	0.0	0.0	0.0	3,420.0	3,420.0	0.0	0.0	0.0	1,640.0	2,730.0	**7,790.0**	46,558.3
Feb.	1st.	10	41,043.3	0.0	**41,043.3**	0.0	0.0	0.0	1,350.0	0.0	0.0	1,350.0	0.0	0.0	0.0	1,200.0	1,920.0	**4,470.0**	45,513.3
	2nd.	10	29,038.3	0.0	**29,038.3**	0.0	0.0	0.0	2,040.0	0.0	0.0	2,040.0	0.0	0.0	0.0	2,170.0	1,770.0	**5,980.0**	35,018.3
	3rd.	8	5,040.0	0.0	**5,040.0**	0.0	0.0	0.0	1,290.0	0.0	0.0	1,290.0	0.0	0.0	0.0	2,310.0	1,170.0	**4,770.0**	9,810.0
Mar.	1st.	10	10,861.7	0.0	**10,861.7**	0.0	3,720.0	3,720.0	11,520.0	0.0	0.0	11,520.0	0.0	0.0	0.0	8,110.0	3,450.0	**26,800.0**	37,661.7
	2nd.	10	12,588.3	0.0	**12,588.3**	0.0	13,280.0	13,280.0	17,280.0	0.0	0.0	17,280.0	0.0	0.0	0.0	10,660.0	4,155.0	**45,375.0**	57,963.3
	3rd.	11	9,695.0	0.0	**9,695.0**	0.0	9,760.0	9,760.0	14,100.0	0.0	0.0	14,100.0	0.0	0.0	0.0	8,640.0	2,700.0	**35,200.0**	44,895.0
Apr.	1st.	10	2,205.0	0.0	**2,205.0**	0.0	1,960.0	1,960.0	1,620.0	0.0	0.0	1,620.0	0.0	0.0	0.0	2,010.0	0.0	**5,590.0**	7,795.0
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
May	1st.	10	151.7	0.0	**151.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	151.7
	2nd.	10	315.0	0.0	**315.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	315.0
	3rd.	11	3,441.7	0.0	**3,441.7**	0.0	7,200.0	7,200.0	1,440.0	0.0	0.0	1,440.0	0.0	2,706.7	2,706.7	2,490.0	10.0	**13,846.7**	17,288.3
Jun.	1st.	10	4,013.3	0.0	**4,013.3**	0.0	6,160.0	6,160.0	0.0	0.0	0.0	0.0	0.0	4,320.0	4,320.0	3,300.0	575.0	**14,355.0**	18,368.3
	2nd.	10	5,145.0	0.0	**5,145.0**	0.0	3,200.0	3,200.0	0.0	600.0	0.0	600.0	0.0	6,280.0	6,280.0	4,350.0	1,445.0	**15,875.0**	21,020.0
	3rd.	10	4,923.3	23.3	**4,946.7**	0.0	0.0	0.0	0.0	2,370.0	0.0	2,370.0	0.0	5,813.3	5,813.3	3,550.0	1,830.0	**13,563.3**	18,510.0
Jul.	1st.	10	2,951.7	13,451.7	**16,403.3**	0.0	0.0	0.0	0.0	4,260.0	0.0	4,260.0	0.0	3,560.0	3,560.0	1,730.0	1,885.0	**11,435.0**	27,838.3
	2nd.	10	1,493.3	36,983.3	**38,476.7**	0.0	0.0	0.0	0.0	7,680.0	0.0	7,680.0	0.0	1,440.0	1,440.0	800.0	2,170.0	**12,090.0**	50,566.7
	3rd.	11	0.0	44,590.0	**44,590.0**	0.0	0.0	0.0	0.0	19,260.0	0.0	19,260.0	0.0	733.3	733.3	4,170.0	4,555.0	**28,718.3**	73,308.3
Aug.	1st.	10	0.0	39,351.7	**39,351.7**	0.0	0.0	0.0	0.0	29,550.0	0.0	29,550.0	3,600.0	0.0	3,600.0	9,350.0	6,910.0	**49,410.0**	88,761.7
	2nd.	10	0.0	19,740.0	**19,740.0**	0.0	0.0	0.0	0.0	33,690.0	0.0	33,690.0	8,213.3	0.0	8,213.3	12,320.0	7,885.0	**62,108.3**	81,848.3
	3rd.	11	0.0	20,766.7	**20,766.7**	0.0	0.0	0.0	0.0	35,280.0	0.0	35,280.0	12,893.3	0.0	12,893.3	14,940.0	8,260.0	**71,373.3**	92,140.0
Sep.	1st.	10	0.0	11,760.0	**11,760.0**	0.0	0.0	0.0	0.0	18,900.0	0.0	18,900.0	4,440.0	0.0	4,440.0	9,100.0	4,360.0	**36,800.0**	48,560.0
	2nd.	10	0.0	8,481.7	**8,481.7**	0.0	0.0	0.0	0.0	8,640.0	0.0	8,640.0	1,946.7	0.0	1,946.7	7,070.0	2,750.0	**20,406.7**	28,888.3
	3rd.	10	0.0	11,608.3	**11,608.3**	0.0	0.0	0.0	0.0	4,680.0	0.0	4,680.0	6,866.7	0.0	6,866.7	9,810.0	3,775.0	**25,131.7**	36,740.0
Oct.	1st.	10	0.0	16,940.0	**16,940.0**	14,640.0	0.0	14,640.0	0.0	0.0	6,990.0	6,990.0	14,880.0	0.0	14,880.0	14,070.0	5,775.0	**56,355.0**	73,295.0
	2nd.	10	0.0	20,055.0	**20,055.0**	34,400.0	0.0	34,400.0	0.0	0.0	18,300.0	18,300.0	20,160.0	0.0	20,160.0	16,440.0	6,925.0	**96,225.0**	116,280.0
	3rd.	11	0.0	15,516.7	**15,516.7**	32,760.0	0.0	32,760.0	0.0	0.0	11,220.0	11,220.0	16,173.3	0.0	16,173.3	12,470.0	4,945.0	**77,568.3**	93,085.0
Nov.	1st.	10	0.0	4,013.3	**4,013.3**	7,120.0	0.0	7,120.0	0.0	0.0	0.0	0.0	3,600.0	0.0	3,600.0	2,780.0	370.0	**13,870.0**	17,883.3
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	0.0	373.3	**373.3**	1,480.0	0.0	1,480.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	**1,580.0**	1,953.3
Dec.	1st.	10	0.0	4,456.7	**4,456.7**	19,080.0	0.0	19,080.0	0.0	0.0	6,150.0	6,150.0	2,600.0	0.0	2,600.0	4,460.0	1,370.0	**33,660.0**	38,116.7
	2nd.	10	0.0	5,133.3	**5,133.3**	26,040.0	0.0	26,040.0	0.0	0.0	11,250.0	11,250.0	2,533.3	0.0	2,533.3	6,140.0	2,570.0	**48,533.3**	53,666.7
	3rd.	11	0.0	3,628.3	**3,628.3**	24,600.0	0.0	24,600.0	0.0	0.0	14,190.0	14,190.0	520.0	0.0	520.0	4,950.0	3,230.0	**47,490.0**	51,118.3
Annual IWR (m^3/yr.)			*185,523.3*	*277,375.0*	***462,898.3***	*172,440.0*	*45,280.0*	*217,720.0*	*50,640.0*	*164,910.0*	*93,720.0*	*309,270.0*	*98,426.7*	*24,853.3*	*123,280.0*	*185,120.0*	*94,520.0*	***929,910.0***	*1,392,808.3*
Max IWR (m^3/dec.)			*41,043.3*	*44,590.0*	***44,590.0***	*34,400.0*	*13,280.0*	*34,400.0*	*17,280.0*	*35,280.0*	*18,300.0*	*35,280.0*	*20,160.0*	*6,280.0*	*20,160.0*	*16,440.0*	*8,260.0*	***96,225.0***	*116,280.0*

Notes

*1) Net Irrigation Water Requirement (m^3/dec) = Unit Irrigation Water Requirement (mm/dec) / 1,000 (mm/m) * Cropping Acreage (has) * 10,000 (m^2/ha)

Legend of Table

Crop Combination		
Crop	Crop	Total
Crop Acreage (ha) (Crop Acreage (%))		

Table 2.2.2.15(1) Gross Irrigation Water Requirement (per Cropping Pattern)

Case-1 : Wet Area Coefficient = 40%

Gross Irrigation Water Requirement (per Cropping Pattern)

(Unit: m^3/dec)

Month	Decade	Days	Rice Paddy: Rice A	Rice Paddy: Rice B	Rice Paddy: Total	Upland Cropping: Maize + Beans: Maize	Maize + Beans: Beans	Maize + Beans: Sub-total	Vegetable 1: Eggplant	Vegetable 1: Carrot	Vegetable 1: Cabbage	Vegetable 1: Sub-total	Vegetable 2: Tomato	Vegetable 2: Beans	Vegetable 2: Sub-total	Vegetable 3: Tomato Tree	Coffee	Upland Total	Grand Total
			35.0 ha (12 %)			120.0 ha (40 %)			60.0 ha (20 %)				40.0 ha (13 %)			30.0 ha (10 %)	15.0 ha (5 %)	265.0 ha (88 %)	300.0 ha (100 %)
Jan.	1st.	10	0.0	501.7	**501.7**	4,461.2	0.0	4,461.2	0.0	0.0	5,661.2	5,661.2	0.0	0.0	0.0	1,232.9	1,183.5	**12,538.8**	13,040.5
	2nd.	10	13,848.3	0.0	**13,848.3**	1,336.5	0.0	1,336.5	0.0	0.0	4,785.9	4,785.9	0.0	0.0	0.0	644.7	1,183.5	**7,950.6**	21,798.9
	3rd.	11	38,768.3	0.0	**38,768.3**	0.0	0.0	0.0	0.0	0.0	1,609.4	1,609.4	0.0	0.0	0.0	771.8	1,284.7	**3,665.9**	42,434.2
Feb.	1st.	10	41,043.3	0.0	**41,043.3**	0.0	0.0	0.0	635.3	0.0	0.0	635.3	0.0	0.0	0.0	564.7	903.5	**2,103.5**	43,146.9
	2nd.	10	29,038.3	0.0	**29,038.3**	0.0	0.0	0.0	960.0	0.0	0.0	960.0	0.0	0.0	0.0	1,021.2	832.9	**2,814.1**	31,852.5
	3rd.	8	5,040.0	0.0	**5,040.0**	0.0	0.0	0.0	607.1	0.0	0.0	607.1	0.0	0.0	0.0	1,087.1	550.6	**2,244.7**	7,284.7
Mar.	1st.	10	10,861.7	0.0	**10,861.7**	0.0	1,750.6	1,750.6	5,421.2	0.0	0.0	5,421.2	0.0	0.0	0.0	3,816.5	1,623.5	**12,611.8**	23,473.4
	2nd.	10	12,588.3	0.0	**12,588.3**	0.0	6,249.4	6,249.4	8,131.8	0.0	0.0	8,131.8	0.0	0.0	0.0	5,016.5	1,955.3	**21,352.9**	33,941.3
	3rd.	11	9,695.0	0.0	**9,695.0**	0.0	4,592.9	4,592.9	6,635.3	0.0	0.0	6,635.3	0.0	0.0	0.0	4,065.9	1,270.6	**16,564.7**	26,259.7
Apr.	1st.	10	2,205.0	0.0	**2,205.0**	0.0	922.4	922.4	762.4	0.0	0.0	762.4	0.0	0.0	0.0	945.9	0.0	**2,630.6**	4,835.6
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
May	1st.	10	151.7	0.0	**151.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	151.7
	2nd.	10	315.0	0.0	**315.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	315.0
	3rd.	11	3,441.7	0.0	**3,441.7**	0.0	3,388.2	3,388.2	677.6	0.0	0.0	677.6	0.0	1,273.7	1,273.7	1,171.8	4.7	**6,516.1**	9,957.7
Jun.	1st.	10	4,013.3	0.0	**4,013.3**	0.0	2,898.8	2,898.8	0.0	0.0	0.0	0.0	0.0	2,032.9	2,032.9	1,552.9	270.6	**6,755.3**	10,768.6
	2nd.	10	5,145.0	0.0	**5,145.0**	0.0	1,505.9	1,505.9	0.0	282.4	0.0	282.4	0.0	2,955.3	2,955.3	2,047.1	680.0	**7,470.6**	12,615.6
	3rd.	10	4,923.3	23.3	**4,946.7**	0.0	0.0	0.0	0.0	1,115.3	0.0	1,115.3	0.0	2,735.7	2,735.7	1,670.6	861.2	**6,382.7**	11,329.4
Jul.	1st.	10	2,951.7	13,451.7	**16,403.3**	0.0	0.0	0.0	0.0	2,004.7	0.0	2,004.7	0.0	1,675.3	1,675.3	814.1	887.1	**5,381.2**	21,784.5
	2nd.	10	1,493.3	36,983.3	**38,476.7**	0.0	0.0	0.0	0.0	3,614.1	0.0	3,614.1	0.0	677.6	677.6	376.5	1,021.2	**5,689.4**	44,166.1
	3rd.	11	0.0	44,590.0	**44,590.0**	0.0	0.0	0.0	0.0	9,063.5	0.0	9,063.5	0.0	345.1	345.1	1,962.4	2,143.5	**13,514.5**	58,104.5
Aug.	1st.	10	0.0	39,351.7	**39,351.7**	0.0	0.0	0.0	0.0	13,905.9	0.0	13,905.9	1,694.1	0.0	1,694.1	4,400.0	3,251.8	**23,251.8**	62,603.4
	2nd.	10	0.0	19,740.0	**19,740.0**	0.0	0.0	0.0	0.0	15,854.1	0.0	15,854.1	3,865.1	0.0	3,865.1	5,797.6	3,710.6	**29,227.5**	48,967.5
	3rd.	11	0.0	20,766.7	**20,766.7**	0.0	0.0	0.0	0.0	16,602.4	0.0	16,602.4	6,067.5	0.0	6,067.5	7,030.6	3,887.1	**33,587.5**	54,354.1
Sep.	1st.	10	0.0	11,760.0	**11,760.0**	0.0	0.0	0.0	0.0	8,894.1	0.0	8,894.1	2,089.4	0.0	2,089.4	4,282.4	2,051.8	**17,317.6**	29,077.6
	2nd.	10	0.0	8,481.7	**8,481.7**	0.0	0.0	0.0	0.0	4,065.9	0.0	4,065.9	916.1	0.0	916.1	3,327.1	1,294.1	**9,603.1**	18,084.8
	3rd.	10	0.0	11,608.3	**11,608.3**	0.0	0.0	0.0	0.0	2,202.4	0.0	2,202.4	3,231.4	0.0	3,231.4	4,616.5	1,776.5	**11,826.7**	23,435.0
Oct.	1st.	10	0.0	16,940.0	**16,940.0**	6,889.4	0.0	6,889.4	0.0	0.0	3,289.4	3,289.4	7,002.4	0.0	7,002.4	6,621.2	2,717.6	**26,520.0**	43,460.0
	2nd.	10	0.0	20,055.0	**20,055.0**	16,188.2	0.0	16,188.2	0.0	0.0	8,611.8	8,611.8	9,487.1	0.0	9,487.1	7,736.5	3,258.8	**45,282.4**	65,337.4
	3rd.	11	0.0	15,516.7	**15,516.7**	15,416.5	0.0	15,416.5	0.0	0.0	5,280.0	5,280.0	7,611.0	0.0	7,611.0	5,868.2	2,327.1	**36,502.7**	52,019.4
Nov.	1st.	10	0.0	4,013.3	**4,013.3**	3,350.6	0.0	3,350.6	0.0	0.0	0.0	0.0	1,694.1	0.0	1,694.1	1,308.2	174.1	**6,527.1**	10,540.4
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	0.0	373.3	**373.3**	696.5	0.0	696.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.1	0.0	**743.5**	1,116.9
Dec.	1st.	10	0.0	4,456.7	**4,456.7**	8,978.8	0.0	8,978.8	0.0	0.0	2,894.1	2,894.1	1,223.5	0.0	1,223.5	2,098.8	644.7	**15,840.0**	20,296.7
	2nd.	10	0.0	5,133.3	**5,133.3**	12,254.1	0.0	12,254.1	0.0	0.0	5,294.1	5,294.1	1,192.2	0.0	1,192.2	2,889.4	1,209.4	**22,839.2**	27,972.5
	3rd.	11	0.0	3,628.3	**3,628.3**	11,576.5	0.0	11,576.5	0.0	0.0	6,677.6	6,677.6	244.7	0.0	244.7	2,329.4	1,520.0	**22,348.2**	25,976.6
Annual IWR (m^3/yr.)			*185,523.3*	*277,375.0*	***462,898.3***	*81,148.2*	*21,308.2*	*102,456.5*	*23,830.6*	*77,604.7*	*44,103.5*	*145,538.8*	*46,318.4*	*11,695.7*	*58,014.1*	*87,115.3*	*44,480.0*	***437,604.7***	*900,503.0*
Max IWR (m^3/dec.)			*41,043.3*	*44,590.0*	***44,590.0***	*16,188.2*	*6,249.4*	*16,188.2*	*8,131.8*	*16,602.4*	*8,611.8*	*16,602.4*	*9,487.1*	*2,955.3*	*9,487.1*	*7,736.5*	*3,887.1*	***45,282.4***	*65,337.4*

Notes

*1) Gross Irrigation Water Requirement (m^3/dec) = Net Irrigation Water Requirement (m^3/dec) / Irrigation Efficiency (%) * Wet Area Coefficient (%)

*2) Irrigation Efficiency : Rice 100 %
: Upland Cropping 85 % (= 95% (Conveyance Efficiency, "Lined Canal" FAO) * 90% (Field Application Efficiency, "Drip Irrigation" FAO)

*3) Wet Area Coefficient : Rice 100 % (= "Surface Irrigation", JICA)
: Upland Cropping 40 % (= "Micro Irrigation", JICA)

Legend of Table

Crop Combination		
Crop	Crop	Total
Crop Acreage (ha)		
(Crop Acreage (%))		

Table 2.2.2.15(2) Gross Irrigation Water Requirement (per Cropping Pattern)

Case-2 : Wet Area Coefficient = 50%

Gross Irrigation Water Requirement (per Cropping Pattern)

(Unit: m³/dec)

Month	Decade	Days	Rice Paddy			Upland Cropping													Grand Total
						Maize + Beans			Vegetable 1				Vegetable 2			Vegetable 3	Coffee	Total	
			Rice A	Rice B	Total	Maize	Beans	Sub-total	Eggplant	Carrot	Cabbage	Sub-total	Tomato	Beans	Sub-total	Tomato Tree			
			35.0 ha (12 %)			120.0 ha (40 %)			60.0 ha (20 %)				40.0 ha (13 %)			30.0 ha (10 %)	15.0 ha (5 %)	265.0 ha (88 %)	300.0 ha (100 %)
Jan.	1st.	10	0.0	501.7	**501.7**	5,576.5	0.0	5,576.5	0.0	0.0	7,076.5	7,076.5	0.0	0.0	0.0	1,541.2	1,479.4	**15,673.5**	16,175.2
	2nd.	10	13,848.3	0.0	**13,848.3**	1,670.6	0.0	1,670.6	0.0	0.0	5,982.4	5,982.4	0.0	0.0	0.0	805.9	1,479.4	**9,938.2**	23,786.6
	3rd.	11	38,768.3	0.0	**38,768.3**	0.0	0.0	0.0	0.0	0.0	2,011.8	2,011.8	0.0	0.0	0.0	964.7	1,605.9	**4,582.4**	43,350.7
Feb.	1st.	10	41,043.3	0.0	**41,043.3**	0.0	0.0	0.0	794.1	0.0	0.0	794.1	0.0	0.0	0.0	705.9	1,129.4	**2,629.4**	43,672.7
	2nd.	10	29,038.3	0.0	**29,038.3**	0.0	0.0	0.0	1,200.0	0.0	0.0	1,200.0	0.0	0.0	0.0	1,276.5	1,041.2	**3,517.6**	32,556.0
	3rd.	8	5,040.0	0.0	**5,040.0**	0.0	0.0	0.0	758.8	0.0	0.0	758.8	0.0	0.0	0.0	1,358.8	688.2	**2,805.9**	7,845.9
Mar.	1st.	10	10,861.7	0.0	**10,861.7**	0.0	2,188.2	2,188.2	6,776.5	0.0	0.0	6,776.5	0.0	0.0	0.0	4,770.6	2,029.4	**15,764.7**	26,626.4
	2nd.	10	12,588.3	0.0	**12,588.3**	0.0	7,811.8	7,811.8	10,164.7	0.0	0.0	10,164.7	0.0	0.0	0.0	6,270.6	2,444.1	**26,691.2**	39,279.5
	3rd.	11	9,695.0	0.0	**9,695.0**	0.0	5,741.2	5,741.2	8,294.1	0.0	0.0	8,294.1	0.0	0.0	0.0	5,082.4	1,588.2	**20,705.9**	30,400.9
Apr.	1st.	10	2,205.0	0.0	**2,205.0**	0.0	1,152.9	1,152.9	952.9	0.0	0.0	952.9	0.0	0.0	0.0	1,182.4	0.0	**3,288.2**	5,493.2
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
May	1st.	10	151.7	0.0	**151.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	151.7
	2nd.	10	315.0	0.0	**315.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	315.0
	3rd.	11	3,441.7	0.0	**3,441.7**	0.0	4,235.3	4,235.3	847.1	0.0	0.0	847.1	0.0	1,592.2	1,592.2	1,464.7	5.9	**8,145.1**	11,586.8
Jun.	1st.	10	4,013.3	0.0	**4,013.3**	0.0	3,623.5	3,623.5	0.0	0.0	0.0	0.0	0.0	2,541.2	2,541.2	1,941.2	338.2	**8,444.1**	12,457.5
	2nd.	10	5,145.0	0.0	**5,145.0**	0.0	1,882.4	1,882.4	0.0	352.9	0.0	352.9	0.0	3,694.1	3,694.1	2,558.8	850.0	**9,338.2**	14,483.2
	3rd.	10	4,923.3	23.3	**4,946.7**	0.0	0.0	0.0	0.0	1,394.1	0.0	1,394.1	0.0	3,419.6	3,419.6	2,088.2	1,076.5	**7,978.4**	12,925.1
Jul.	1st.	10	2,951.7	13,451.7	**16,403.3**	0.0	0.0	0.0	0.0	2,505.9	0.0	2,505.9	0.0	2,094.1	2,094.1	1,017.6	1,108.8	**6,726.5**	23,129.8
	2nd.	10	1,493.3	36,983.3	**38,476.7**	0.0	0.0	0.0	0.0	4,517.6	0.0	4,517.6	0.0	847.1	847.1	470.6	1,276.5	**7,111.8**	45,588.4
	3rd.	11	0.0	44,590.0	**44,590.0**	0.0	0.0	0.0	0.0	11,329.4	0.0	11,329.4	0.0	431.4	431.4	2,452.9	2,679.4	**16,893.1**	61,483.1
Aug.	1st.	10	0.0	39,351.7	**39,351.7**	0.0	0.0	0.0	0.0	17,382.4	0.0	17,382.4	2,117.6	0.0	2,117.6	5,500.0	4,064.7	**29,064.7**	68,416.4
	2nd.	10	0.0	19,740.0	**19,740.0**	0.0	0.0	0.0	0.0	19,817.6	0.0	19,817.6	4,831.4	0.0	4,831.4	7,247.1	4,638.2	**36,534.3**	56,274.3
	3rd.	11	0.0	20,766.7	**20,766.7**	0.0	0.0	0.0	0.0	20,752.9	0.0	20,752.9	7,584.3	0.0	7,584.3	8,788.2	4,858.8	**41,984.3**	62,751.0
Sep.	1st.	10	0.0	11,760.0	**11,760.0**	0.0	0.0	0.0	0.0	11,117.6	0.0	11,117.6	2,611.8	0.0	2,611.8	5,352.9	2,564.7	**21,647.1**	33,407.1
	2nd.	10	0.0	8,481.7	**8,481.7**	0.0	0.0	0.0	0.0	5,082.4	0.0	5,082.4	1,145.1	0.0	1,145.1	4,158.8	1,617.6	**12,003.9**	20,485.6
	3rd.	10	0.0	11,608.3	**11,608.3**	0.0	0.0	0.0	0.0	2,752.9	0.0	2,752.9	4,039.2	0.0	4,039.2	5,770.6	2,220.6	**14,783.3**	26,391.7
Oct.	1st.	10	0.0	16,940.0	**16,940.0**	8,611.8	0.0	8,611.8	0.0	0.0	4,111.8	4,111.8	8,752.9	0.0	8,752.9	8,276.5	3,397.1	**33,150.0**	50,090.0
	2nd.	10	0.0	20,055.0	**20,055.0**	20,235.3	0.0	20,235.3	0.0	0.0	10,764.7	10,764.7	11,858.8	0.0	11,858.8	9,670.6	4,073.5	**56,602.9**	76,657.9
	3rd.	11	0.0	15,516.7	**15,516.7**	19,270.6	0.0	19,270.6	0.0	0.0	6,600.0	6,600.0	9,513.7	0.0	9,513.7	7,335.3	2,908.8	**45,628.4**	61,145.1
Nov.	1st.	10	0.0	4,013.3	**4,013.3**	4,188.2	0.0	4,188.2	0.0	0.0	0.0	0.0	2,117.6	0.0	2,117.6	1,635.3	217.6	**8,158.8**	12,172.2
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	0.0	373.3	**373.3**	870.6	0.0	870.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.8	0.0	**929.4**	1,302.7
Dec.	1st.	10	0.0	4,456.7	**4,456.7**	11,223.5	0.0	11,223.5	0.0	0.0	3,617.6	3,617.6	1,529.4	0.0	1,529.4	2,623.5	805.9	**19,800.0**	24,256.7
	2nd.	10	0.0	5,133.3	**5,133.3**	15,317.6	0.0	15,317.6	0.0	0.0	6,617.6	6,617.6	1,490.2	0.0	1,490.2	3,611.8	1,511.8	**28,549.0**	33,682.4
	3rd.	11	0.0	3,628.3	**3,628.3**	14,470.6	0.0	14,470.6	0.0	0.0	8,347.1	8,347.1	305.9	0.0	305.9	2,911.8	1,900.0	**27,935.3**	31,563.6
Annual IWR (m³/yr.)			*185,523.3*	*277,375.0*	***462,898.3***	*101,435.3*	*26,635.3*	*128,070.6*	*29,788.2*	*97,005.9*	*55,129.4*	*181,923.5*	*57,898.0*	*14,619.6*	*72,517.6*	*108,894.1*	*55,600.0*	***547,005.9***	*1,009,904.2*
Max IWR (m³/dec.)			*41,043.3*	*44,590.0*	***44,590.0***	*20,235.3*	*7,811.8*	*20,235.3*	*10,164.7*	*20,752.9*	*10,764.7*	*20,752.9*	*11,858.8*	*3,694.1*	*11,858.8*	*9,670.6*	*4,858.8*	***56,602.9***	*76,657.9*

Notes

*1) Gross Irrigation Water Requirement (m³/dec) = Net Irrigation Water Requirement (m³/dec) / Irrigation Efficiency (%) * Wet Area Coefficient (%)

*2) Irrigation Efficiency	: Rice	100 %	
	: Upland Cropping	85 %	(= 95% (Conveyance Efficiency, "Lined Canal" FAO) * 90% (Field Application Efficiency, "Drip Irrigation" FAO)
*3) Wet Area Coefficient	: Rice	100 %	(= "Surface Irrigation", JICA)
	: Upland Cropping	50 %	(= "Micro Irrigation", JICA)

Legend of Table

Crop Combination		
Crop	Crop	Total
Crop Acreage (ha)		
(Crop Acreage (%))		

Table 2.2.2.15(3) Gross Irrigation Water Requirement (per Cropping Pattern)

Case-3：Wet Area Coefficient = 60%

Gross Irrigation Water Requirement (per Cropping Pattern)

(Unit: m³/dec)

Month	Decade	Days	Rice Paddy			Upland Cropping													Grand Total
						Maize + Beans			Vegetable 1				Vegetable 2			Vegetable 3	Coffee	Total	
			Rice A	Rice B	Total	Maize	Beans	Sub-total	Eggplant	Carrot	Cabbage	Sub-total	Tomato	Beans	Sub-total	Tomato Tree			
			35.0 ha (12 %)			120.0 ha (40 %)			60.0 ha (20 %)				40.0 ha (13 %)			30.0 ha (10 %)	15.0 ha (5 %)	265.0 ha (88 %)	300.0 ha (100 %)
Jan.	1st.	10	0.0	501.7	**501.7**	6,691.8	0.0	6,691.8	0.0	0.0	8,491.8	8,491.8	0.0	0.0	0.0	1,849.4	1,775.3	**18,808.2**	19,309.9
	2nd.	10	13,848.3	0.0	**13,848.3**	2,004.7	0.0	2,004.7	0.0	0.0	7,178.8	7,178.8	0.0	0.0	0.0	967.1	1,775.3	**11,925.9**	25,774.2
	3rd.	11	38,768.3	0.0	**38,768.3**	0.0	0.0	0.0	0.0	0.0	2,414.1	2,414.1	0.0	0.0	0.0	1,157.6	1,927.1	**5,498.8**	44,267.2
Feb.	1st.	10	41,043.3	0.0	**41,043.3**	0.0	0.0	0.0	952.9	0.0	0.0	952.9	0.0	0.0	0.0	847.1	1,355.3	**3,155.3**	44,198.6
	2nd.	10	29,038.3	0.0	**29,038.3**	0.0	0.0	0.0	1,440.0	0.0	0.0	1,440.0	0.0	0.0	0.0	1,531.8	1,249.4	**4,221.2**	33,259.5
	3rd.	8	5,040.0	0.0	**5,040.0**	0.0	0.0	0.0	910.6	0.0	0.0	910.6	0.0	0.0	0.0	1,630.6	825.9	**3,367.1**	8,407.1
Mar.	1st.	10	10,861.7	0.0	**10,861.7**	0.0	2,625.9	2,625.9	8,131.8	0.0	0.0	8,131.8	0.0	0.0	0.0	5,724.7	2,435.3	**18,917.6**	29,779.3
	2nd.	10	12,588.3	0.0	**12,588.3**	0.0	9,374.1	9,374.1	12,197.6	0.0	0.0	12,197.6	0.0	0.0	0.0	7,524.7	2,932.9	**32,029.4**	44,617.7
	3rd.	11	9,695.0	0.0	**9,695.0**	0.0	6,889.4	6,889.4	9,952.9	0.0	0.0	9,952.9	0.0	0.0	0.0	6,098.8	1,905.9	**24,847.1**	34,542.1
Apr.	1st.	10	2,205.0	0.0	**2,205.0**	0.0	1,383.5	1,383.5	1,143.5	0.0	0.0	1,143.5	0.0	0.0	0.0	1,418.8	0.0	**3,945.9**	6,150.9
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
May	1st.	10	151.7	0.0	**151.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	151.7
	2nd.	10	315.0	0.0	**315.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	315.0
	3rd.	11	3,441.7	0.0	**3,441.7**	0.0	5,082.4	5,082.4	1,016.5	0.0	0.0	1,016.5	0.0	1,910.6	1,910.6	1,757.6	7.1	**9,774.1**	13,215.8
Jun.	1st.	10	4,013.3	0.0	**4,013.3**	0.0	4,348.2	4,348.2	0.0	0.0	0.0	0.0	0.0	3,049.4	3,049.4	2,329.4	405.9	**10,132.9**	14,146.3
	2nd.	10	5,145.0	0.0	**5,145.0**	0.0	2,258.8	2,258.8	0.0	423.5	0.0	423.5	0.0	4,432.9	4,432.9	3,070.6	1,020.0	**11,205.9**	16,350.9
	3rd.	10	4,923.3	23.3	**4,946.7**	0.0	0.0	0.0	0.0	1,672.9	0.0	1,672.9	0.0	4,103.5	4,103.5	2,505.9	1,291.8	**9,574.1**	14,520.8
Jul.	1st.	10	2,951.7	13,451.7	**16,403.3**	0.0	0.0	0.0	0.0	3,007.1	0.0	3,007.1	0.0	2,512.9	2,512.9	1,221.2	1,330.6	**8,071.8**	24,475.1
	2nd.	10	1,493.3	36,983.3	**38,476.7**	0.0	0.0	0.0	0.0	5,421.2	0.0	5,421.2	0.0	1,016.5	1,016.5	564.7	1,531.8	**8,534.1**	47,010.8
	3rd.	11	0.0	44,590.0	**44,590.0**	0.0	0.0	0.0	0.0	13,595.3	0.0	13,595.3	0.0	517.6	517.6	2,943.5	3,215.3	**20,271.8**	64,861.8
Aug.	1st.	10	0.0	39,351.7	**39,351.7**	0.0	0.0	0.0	0.0	20,858.8	0.0	20,858.8	2,541.2	0.0	2,541.2	6,600.0	4,877.6	**34,877.6**	74,229.3
	2nd.	10	0.0	19,740.0	**19,740.0**	0.0	0.0	0.0	0.0	23,781.2	0.0	23,781.2	5,797.6	0.0	5,797.6	8,696.5	5,565.9	**43,841.2**	63,581.2
	3rd.	11	0.0	20,766.7	**20,766.7**	0.0	0.0	0.0	0.0	24,903.5	0.0	24,903.5	9,101.2	0.0	9,101.2	10,545.9	5,830.6	**50,381.2**	71,147.8
Sep.	1st.	10	0.0	11,760.0	**11,760.0**	0.0	0.0	0.0	0.0	13,341.2	0.0	13,341.2	3,134.1	0.0	3,134.1	6,423.5	3,077.6	**25,976.5**	37,736.5
	2nd.	10	0.0	8,481.7	**8,481.7**	0.0	0.0	0.0	0.0	6,098.8	0.0	6,098.8	1,374.1	0.0	1,374.1	4,990.6	1,941.2	**14,404.7**	22,886.4
	3rd.	10	0.0	11,608.3	**11,608.3**	0.0	0.0	0.0	0.0	3,303.5	0.0	3,303.5	4,847.1	0.0	4,847.1	6,924.7	2,664.7	**17,740.0**	29,348.3
Oct.	1st.	10	0.0	16,940.0	**16,940.0**	10,334.1	0.0	10,334.1	0.0	0.0	4,934.1	4,934.1	10,503.5	0.0	10,503.5	9,931.8	4,076.5	**39,780.0**	56,720.0
	2nd.	10	0.0	20,055.0	**20,055.0**	24,282.4	0.0	24,282.4	0.0	0.0	12,917.6	12,917.6	14,230.6	0.0	14,230.6	11,604.7	4,888.2	**67,923.5**	87,978.5
	3rd.	11	0.0	15,516.7	**15,516.7**	23,124.7	0.0	23,124.7	0.0	0.0	7,920.0	7,920.0	11,416.5	0.0	11,416.5	8,802.4	3,490.6	**54,754.1**	70,270.8
Nov.	1st.	10	0.0	4,013.3	**4,013.3**	5,025.9	0.0	5,025.9	0.0	0.0	0.0	0.0	2,541.2	0.0	2,541.2	1,962.4	261.2	**9,790.6**	13,803.9
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	0.0	373.3	**373.3**	1,044.7	0.0	1,044.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.6	0.0	**1,115.3**	1,488.6
Dec.	1st.	10	0.0	4,456.7	**4,456.7**	13,468.2	0.0	13,468.2	0.0	0.0	4,341.2	4,341.2	1,835.3	0.0	1,835.3	3,148.2	967.1	**23,760.0**	28,216.7
	2nd.	10	0.0	5,133.3	**5,133.3**	18,381.2	0.0	18,381.2	0.0	0.0	7,941.2	7,941.2	1,788.2	0.0	1,788.2	4,334.1	1,814.1	**34,258.8**	39,392.2
	3rd.	11	0.0	3,628.3	**3,628.3**	17,364.7	0.0	17,364.7	0.0	0.0	10,016.5	10,016.5	367.1	0.0	367.1	3,494.1	2,280.0	**33,522.4**	37,150.7
Annual IWR (m³/yr.)			*185,523.3*	*277,375.0*	***462,898.3***	*121,722.4*	*31,962.4*	*153,684.7*	*35,745.9*	*116,407.1*	*66,155.3*	*218,308.2*	*69,477.6*	*17,543.5*	*87,021.2*	*130,672.9*	*66,720.0*	***656,407.1***	*1,119,305.4*
Max IWR (m³/dec.)			*41,043.3*	*44,590.0*	***44,590.0***	*24,282.4*	*9,374.1*	*24,282.4*	*12,197.6*	*24,903.5*	*12,917.6*	*24,903.5*	*14,230.6*	*4,432.9*	*14,230.6*	*11,604.7*	*5,830.6*	***67,923.5***	*87,978.5*

Notes

*1) Gross Irrigation Water Requirement (m³/dec) = Net Irrigation Water Requirement (m³/dec) / Irrigation Efficiency (%) * Wet Area Coefficient (%)

*2) Irrigation Efficiency	: Rice	100 %	
	: Upland Cropping	85 %	(= 95% (Conveyance Efficiency, "Lined Canal" FAO) * 90% (Field Application Efficiency, "Drip Irrigation" FAO)
*3) Wet Area Coefficient	: Rice	100 %	(= "Surface Irrigation", JICA)
	: Upland Cropping	**60 %**	(= "Micro Irrigation", JICA)

Legend of Table

Crop Combination		
Crop	Crop	Total
Crop Acreage (ha)		
(Crop Acreage (%))		

Table 2.2.2.15(4) Gross Irrigation Water Requirement (per Cropping Pattern)

Case-4：Wet Area Coefficient = 70%

Gross Irrigation Water Requirement (per Cropping Pattern)

(Unit: m³/dec)

Month	Decade	Days	Rice Paddy			Upland Cropping													Grand Total
						Maize + Beans			Vegetable 1				Vegetable 2			Vegetable 3	Coffee	Total	
			Rice A	Rice B	Total	Maize	Beans	Sub-total	Eggplant	Carrot	Cabbage	Sub-total	Tomato	Beans	Sub-total	Tomato Tree			
			35.0 ha (12 %)			120.0 ha (40 %)			60.0 ha (20 %)				40.0 ha (13 %)			30.0 ha (10 %)	15.0 ha (5 %)	265.0 ha (88 %)	300.0 ha (100 %)
Jan.	1st.	10	0.0	501.7	**501.7**	7,807.1	0.0	7,807.1	0.0	0.0	9,907.1	9,907.1	0.0	0.0	0.0	2,157.6	2,071.2	**21,942.9**	22,444.6
	2nd.	10	13,848.3	0.0	**13,848.3**	2,338.8	0.0	2,338.8	0.0	0.0	8,375.3	8,375.3	0.0	0.0	0.0	1,128.2	2,071.2	**13,913.5**	27,761.9
	3rd.	11	38,768.3	0.0	**38,768.3**	0.0	0.0	0.0	0.0	0.0	2,816.5	2,816.5	0.0	0.0	0.0	1,350.6	2,248.2	**6,415.3**	45,183.6
Feb.	1st.	10	41,043.3	0.0	**41,043.3**	0.0	0.0	0.0	1,111.8	0.0	0.0	1,111.8	0.0	0.0	0.0	988.2	1,581.2	**3,681.2**	44,724.5
	2nd.	10	29,038.3	0.0	**29,038.3**	0.0	0.0	0.0	1,680.0	0.0	0.0	1,680.0	0.0	0.0	0.0	1,787.1	1,457.6	**4,924.7**	33,963.0
	3rd.	8	5,040.0	0.0	**5,040.0**	0.0	0.0	0.0	1,062.4	0.0	0.0	1,062.4	0.0	0.0	0.0	1,902.4	963.5	**3,928.2**	8,968.2
Mar.	1st.	10	10,861.7	0.0	**10,861.7**	0.0	3,063.5	3,063.5	9,487.1	0.0	0.0	9,487.1	0.0	0.0	0.0	6,678.8	2,841.2	**22,070.6**	32,932.3
	2nd.	10	12,588.3	0.0	**12,588.3**	0.0	10,936.5	10,936.5	14,230.6	0.0	0.0	14,230.6	0.0	0.0	0.0	8,778.8	3,421.8	**37,367.6**	49,956.0
	3rd.	11	9,695.0	0.0	**9,695.0**	0.0	8,037.6	8,037.6	11,611.8	0.0	0.0	11,611.8	0.0	0.0	0.0	7,115.3	2,223.5	**28,988.2**	38,683.2
Apr.	1st.	10	2,205.0	0.0	**2,205.0**	0.0	1,614.1	1,614.1	1,334.1	0.0	0.0	1,334.1	0.0	0.0	0.0	1,655.3	0.0	**4,603.5**	6,808.5
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
May	1st.	10	151.7	0.0	**151.7**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	151.7
	2nd.	10	315.0	0.0	**315.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	315.0
	3rd.	11	3,441.7	0.0	**3,441.7**	0.0	5,929.4	5,929.4	1,185.9	0.0	0.0	1,185.9	0.0	2,229.0	2,229.0	2,050.6	8.2	**11,403.1**	14,844.8
Jun.	1st.	10	4,013.3	0.0	**4,013.3**	0.0	5,072.9	5,072.9	0.0	0.0	0.0	0.0	0.0	3,557.6	3,557.6	2,717.6	473.5	**11,821.8**	15,835.1
	2nd.	10	5,145.0	0.0	**5,145.0**	0.0	2,635.3	2,635.3	0.0	494.1	0.0	494.1	0.0	5,171.8	5,171.8	3,582.4	1,190.0	**13,073.5**	18,218.5
	3rd.	10	4,923.3	23.3	**4,946.7**	0.0	0.0	0.0	0.0	1,951.8	0.0	1,951.8	0.0	4,787.5	4,787.5	2,923.5	1,507.1	**11,169.8**	16,116.5
Jul.	1st.	10	2,951.7	13,451.7	**16,403.3**	0.0	0.0	0.0	0.0	3,508.2	0.0	3,508.2	0.0	2,931.8	2,931.8	1,424.7	1,552.4	**9,417.1**	25,820.4
	2nd.	10	1,493.3	36,983.3	**38,476.7**	0.0	0.0	0.0	0.0	6,324.7	0.0	6,324.7	0.0	1,185.9	1,185.9	658.8	1,787.1	**9,956.5**	48,433.1
	3rd.	11	0.0	44,590.0	**44,590.0**	0.0	0.0	0.0	0.0	15,861.2	0.0	15,861.2	0.0	603.9	603.9	3,434.1	3,751.2	**23,650.4**	68,240.4
Aug.	1st.	10	0.0	39,351.7	**39,351.7**	0.0	0.0	0.0	0.0	24,335.3	0.0	24,335.3	2,964.7	0.0	2,964.7	7,700.0	5,690.6	**40,690.6**	80,042.3
	2nd.	10	0.0	19,740.0	**19,740.0**	0.0	0.0	0.0	0.0	27,744.7	0.0	27,744.7	6,763.9	0.0	6,763.9	10,145.9	6,493.5	**51,148.0**	70,888.0
	3rd.	11	0.0	20,766.7	**20,766.7**	0.0	0.0	0.0	0.0	29,054.1	0.0	29,054.1	10,618.0	0.0	10,618.0	12,303.5	6,802.4	**58,778.0**	79,544.7
Sep.	1st.	10	0.0	11,760.0	**11,760.0**	0.0	0.0	0.0	0.0	15,564.7	0.0	15,564.7	3,656.5	0.0	3,656.5	7,494.1	3,590.6	**30,305.9**	42,065.9
	2nd.	10	0.0	8,481.7	**8,481.7**	0.0	0.0	0.0	0.0	7,115.3	0.0	7,115.3	1,603.1	0.0	1,603.1	5,822.4	2,264.7	**16,805.5**	25,287.2
	3rd.	10	0.0	11,608.3	**11,608.3**	0.0	0.0	0.0	0.0	3,854.1	0.0	3,854.1	5,654.9	0.0	5,654.9	8,078.8	3,108.8	**20,696.7**	32,305.0
Oct.	1st.	10	0.0	16,940.0	**16,940.0**	12,056.5	0.0	12,056.5	0.0	0.0	5,756.5	5,756.5	12,254.1	0.0	12,254.1	11,587.1	4,755.9	**46,410.0**	63,350.0
	2nd.	10	0.0	20,055.0	**20,055.0**	28,329.4	0.0	28,329.4	0.0	0.0	15,070.6	15,070.6	16,602.4	0.0	16,602.4	13,538.8	5,702.9	**79,244.1**	99,299.1
	3rd.	11	0.0	15,516.7	**15,516.7**	26,978.8	0.0	26,978.8	0.0	0.0	9,240.0	9,240.0	13,319.2	0.0	13,319.2	10,269.4	4,072.4	**63,879.8**	79,396.5
Nov.	1st.	10	0.0	4,013.3	**4,013.3**	5,863.5	0.0	5,863.5	0.0	0.0	0.0	0.0	2,964.7	0.0	2,964.7	2,289.4	304.7	**11,422.4**	15,435.7
	2nd.	10	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**	0.0
	3rd.	10	0.0	373.3	**373.3**	1,218.8	0.0	1,218.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.4	0.0	**1,301.2**	1,674.5
Dec.	1st.	10	0.0	4,456.7	**4,456.7**	15,712.9	0.0	15,712.9	0.0	0.0	5,064.7	5,064.7	2,141.2	0.0	2,141.2	3,672.9	1,128.2	**27,720.0**	32,176.7
	2nd.	10	0.0	5,133.3	**5,133.3**	21,444.7	0.0	21,444.7	0.0	0.0	9,264.7	9,264.7	2,086.3	0.0	2,086.3	5,056.5	2,116.5	**39,968.6**	45,102.0
	3rd.	11	0.0	3,628.3	**3,628.3**	20,258.8	0.0	20,258.8	0.0	0.0	11,685.9	11,685.9	428.2	0.0	428.2	4,076.5	2,660.0	**39,109.4**	42,737.7
Annual IWR (m³/yr.)			*185,523.3*	*277,375.0*	***462,898.3***	*142,009.4*	*37,289.4*	*179,298.8*	*41,703.5*	*135,808.2*	*77,181.2*	*254,692.9*	*81,057.3*	*20,467.5*	*101,524.7*	*152,451.8*	*77,840.0*	***765,808.2***	*1,228,706.6*
Max IWR (m³/dec.)			*41,043.3*	*44,590.0*	***44,590.0***	*28,329.4*	*10,936.5*	*28,329.4*	*14,230.6*	*29,054.1*	*15,070.6*	*29,054.1*	*16,602.4*	*5,171.8*	*16,602.4*	*13,538.8*	*6,802.4*	***79,244.1***	*99,299.1*

Notes

*1) Gross Irrigation Water Requirement (m³/dec) = Net Irrigation Water Requirement (m³/dec) / Irrigation Efficiency (%) * Wet Area Coefficient (%)

*2) Irrigation Efficiency : Rice 100 %

: Upland Cropping 85 % (= 95% (Conveyance Efficiency, "Lined Canal" FAO) * 90% (Field Application Efficiency, "Drip Irrigation" FAO)

*3) Wet Area Coefficient : Rice 100 % (= "Surface Irrigation", JICA)

: Upland Cropping 70 % (= "Micro Irrigation", JICA)

Legend of Table

Crop Combination		
Crop	Crop	Total
Crop Acreage (ha)		
(Crop Acreage (%))		

3) Simulation of water balance

Effective storage capacity or water utilization capacity of reservoir is calculated by water balance simulation based on inflow to reservoir and outflow from reservoir every ten days.

Following conditions are applied in this simulation such as rainfall, evaporation, seepage loss from reservoir and so on.

(1) Conditions of simulation

a) Inflow to reservoir

Inflow to reservoir is river discharge (1,111,000m^3 per year) in the reference year for design of 1974 estimated by tank model method.

b) Outflow from reservoir

Outflow from reservoir consists of irrigation water requirement for paddy including river maintenance water and upland cropping and seepage loss. Irrigation water requirement for paddy including river maintenance water is estimated around 250,000 m^3 per year by calculation mentioned above.

The result of comparative study on different value of wet area coefficient (Kw=40, 50, 60 and 70 %) is applied as irrigation water requirement for upland cropping. And, 0.05% of storage volume of reservoir is applied as seepage loss from reservoir.

(a) Rainfall and evaporation

Rainfall at the reservoir and evaporation from reservoir are considered for water balance simulation as well as inflow and outflow which mentioned in the above. Water surface area, which is used for calculation for evaporation is obtained from H-Q curve at full water surface.

Rainfall data observed at Gahororo meteorological station

Table 2.2.2.16 Inflow and Supply Water for Rice

Inflow & Supply Water for Rice Paddy

Month	Decade	days	Inflow (m^3) Decade	Inflow (m^3) Monthly	Inflow (m^3) Cumulative	Supply Water for Rice Paddy & river(m^3) Decade	Supply Water for Rice Paddy & river(m^3) Monthly	Supply Water for Rice Paddy & river(m^3) Cumulative
Jan.	1st.	10	29,632	90,339	90,339	5,134	15,914	15,914
	2nd.	10	29,108			5,134		
	3rd.	11	31,599			5,647		
Feb.	1st.	10	30,310	82,809	173,148	9,366	26,225	42,139
	2nd.	10	29,926			9,366		
	3rd.	8	22,573			7,493		
Mar.	1st.	10	27,705	82,301	255,449	7,802	24,186	66,325
	2nd.	10	26,572			7,802		
	3rd.	11	28,024			8,582		
Apr.	1st.	10	25,364	117,214	372,663	3,456	10,368	76,693
	2nd.	10	44,641			3,456		
	3rd.	10	47,209			3,456		
May	1st.	10	44,116	179,310	551,973	3,456	10,714	87,407
	2nd.	10	83,504			3,456		
	3rd.	11	51,690			3,802		
Jun.	1st.	10	37,420	99,443	651,416	3,456	10,368	97,775
	2nd.	10	31,299			3,456		
	3rd.	10	30,724			3,456		
Jul.	1st.	10	39,976	109,623	761,039	3,456	10,714	108,489
	2nd.	10	36,168			3,456		
	3rd.	11	33,479			3,802		
Aug.	1st.	10	28,219	78,995	840,034	16,931	52,487	160,976
	2nd.	10	25,232			16,931		
	3rd.	11	25,544			18,624		
Sep.	1st.	10	22,008	66,245	906,279	12,745	38,236	199,212
	2nd.	10	22,890			12,745		
	3rd.	10	21,347			12,745		
Oct.	1st.	10	20,859	63,443	969,722	9,662	29,951	229,163
	2nd.	10	20,472			9,662		
	3rd.	11	22,112			10,628		
Nov.	1st.	10	19,735	70,473	1,040,195	3,456	10,368	239,531
	2nd.	10	19,665			3,456		
	3rd.	10	31,073			3,456		
Dec.	1st.	10	25,304	70,941	1,111,136	3,456	10,714	250,245
	2nd.	10	23,802			3,456		
	3rd.	11	21,835			3,802		
Total			**1,111,136**	1,111,136	-	**250,245**	250,245	-

Note: The amount of supply water for rice paddy includes river maintenance discharge.

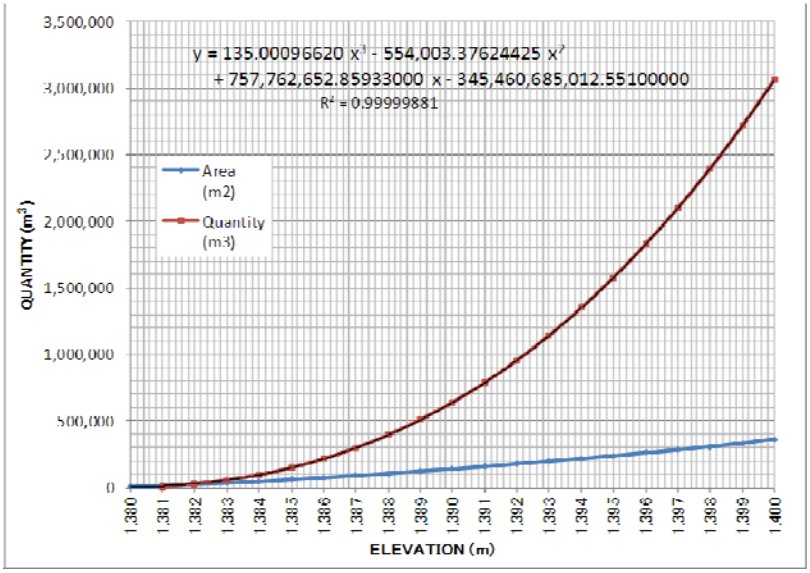


Figure 2.2.2.11 The Relation between Water Depth, Volume and Surface Area of Reservoir

in 1974 are applied as rainfall to reservoir.

Though evaporation from reservoir has not been observed in this command area, annual evaporation is reported approximately from 1,500 to 1,600mm in "Country Paper" by FAO. Therefore, reference evapotranspiration (ETo) which is calculated by CROPWAT-8.0 and its value is close to aforementioned one is applied.

Based on the conditions mentioned above, balance between rainfall and evaporation is calculated and summarized in following table.

Table 2.2.2.17 Balance between Rainfall and Evaporation on Reservoir

Water Surface Area: A = 17.6 ha (@ FWS.1,392.0m)

Month	Decade	days	Provable Rainfall		Reference Evapotranspiration	Evaporation	Evaporation from Water Surface		Remarks
			Rm (mm/month)	Rd (mm/decade)	ETo (mm/day)	Eo (mm/decade)	E = Eo - Rd (mm/decade)	Ev = E * A (m^3/decade)	
Jan.	1st.	10	76.8	24.8	4.47	44.7	19.9	3,507	
	2nd.	10		24.8		44.7	19.9	3,507	
	3rd.	11		27.3		49.2	21.9	3,863	
Feb.	1st.	10	84.4	30.1	4.58	45.8	15.7	2,756	
	2nd.	10		30.1		45.8	15.7	2,756	
	3rd.	8		24.1		36.6	12.5	2,197	
Mar.	1st.	10	42.8	13.8	4.26	42.6	28.8	5,068	
	2nd.	10		13.8		42.6	28.8	5,068	
	3rd.	11		15.2		46.9	31.7	5,581	
Apr.	1st.	10	173.3	57.8	3.77	37.7	-20.1	-3,532	
	2nd.	10		57.8		37.7	-20.1	-3,532	
	3rd.	10		57.8		37.7	-20.1	-3,532	
May	1st.	10	148.3	47.8	3.50	35.0	-12.8	-2,260	
	2nd.	10		47.8		35.0	-12.8	-2,260	
	3rd.	11		52.6		38.5	-14.1	-2,486	
Jun.	1st.	10	76.2	25.4	3.31	33.1	7.7	1,355	
	2nd.	10		25.4		33.1	7.7	1,355	
	3rd.	10		25.4		33.1	7.7	1,355	
Jul.	1st.	10	53.4	17.2	3.58	35.8	18.6	3,269	
	2nd.	10		17.2		35.8	18.6	3,269	
	3rd.	11		18.9		39.4	20.5	3,599	
Aug.	1st.	10	0.0	0.0	5.19	51.9	51.9	9,134	
	2nd.	10		0.0		51.9	51.9	9,134	
	3rd.	11		0.0		57.1	57.1	10,050	
Sep.	1st.	10	75.2	25.1	4.93	49.3	24.2	4,265	
	2nd.	10		25.1		49.3	24.2	4,265	
	3rd.	10		25.1		49.3	24.2	4,265	
Oct.	1st.	10	30.5	9.8	5.00	50.0	40.2	7,068	
	2nd.	10		9.8		50.0	40.2	7,068	
	3rd.	11		10.8		55.0	44.2	7,775	
Nov.	1st.	10	176.1	58.7	3.81	38.1	-20.6	-3,626	
	2nd.	10		58.7		38.1	-20.6	-3,626	
	3rd.	10		58.7		38.1	-20.6	-3,626	
Dec.	1st.	10	64.5	20.8	3.59	35.9	15.1	2,656	
	2nd.	10		20.8		35.9	15.1	2,656	
	3rd.	11		22.9		39.5	16.6	2,924	
Total / Average			1,001.5	1,001.5	4.17	1,520.2	519	91,285	

Notes

*1) Provable Rainfall : 1974, Gahororo Station, Rurenge Sector, Ngoma District

*2) Reference Evapotranspiration : Calculated from Climate Data (Temperature, Humidity, Wind Velocity, Sunshine Hours) by CROPWAT8

*3) Climate Data / Min. Temp. : 1974, Gahororo Station, Rurenge Sector, Ngoma District

Max. Temp. : 1974, Gahororo Station, Rurenge Sector, Ngoma District

Humidity : 1974, Kigali International Airport

Wind Velocity : 1974, Kigali International Airport

Sunshine : 1974, Kigali International Airport

(2) Results of simulation

The results of simulation are mentioned in following tables and the required effective storage capacity of reservoir is summarize in next table for each case.

Table 2.2.2.18 Effective Storage Capacity of Reservoir

Wet Area Coefficient Kw (%)	Effective Dam Storage Volume (m^3)		
	Maximum (1)	Minimum (2)	Balance /Required Storage Volume (3) = (1) - (2)
40	450,000	8,438	441,562
50	450,000	5,303	444,697
60	416,984	2,168	414,816
70	382,937	-966	383.903

As the results of simulation mentioned above, effective storage of reservoir is estimated approximately from 400,000 to 450,000m^3 according to wet area ratio. Consequently, design effective storage of reservoir in this study is determined 450,000m^3 for safety reason.

Design discharge of hillside cropping is fixed as follows based on annual maximum water requirement on wet area ratio of 70%, and water requirement per area are shown as follows together with water requirement for paddy field. Both values are calculated on the assumption that daily irrigation time is ten hours.

Table 2.2.2.19 Unit Design Discharge of Hillside Crop and Paddy

	Hillside cropping（265ha）		Remarks
	(m^3/decade)	(m^3/sec/ha)	
Water Requirement	79,244	0.0008[(a)]	October, second decade(refer to Table2.2.2.21)

	Paddy Field（35ha）		Remarks
	(m^3/month)	(m^3/sec/ha)	
Water Requirement	79,859[(b)]	0.0020[(c)]	August(refer to Table2.2.2.21)
Supplemental Supply (included return flow)	52,487	0.0013[(d)]	Requested quantity in August (refer to Table2.2.2.6)

(a):79.244/10days/(10hours × 3600seconds)/265ha＝0.0008m^3/sec/ha

(b):Table2.2.2.21; Water requirement in August=39,352＋19,740＋20,767＝79,859m^3/month

(c):79,859/31days/（10hours×3600seconds）/35ha＝0.0020m^3/sec/ha

(d):52,487/31days/（10hours×3600seconds）/35ha＝0.0013m^3/sec/ha

Table 2.2.2.20(1) Water Balance Study
Case-1 : Wet Area Coefficient = 40%

Cropping Acreage

Crop		Area	
Rice Paddy		35 ha	12 %
Upland Cropping	Maize+Beans	120 ha	40 %
	Vegetable-1	60 ha	20 %
	Vegetable-2	40 ha	13 %
	Vegetable-3	30 ha	10 %
	Coffee	15 ha	5 %
	Sub-total	265 ha	88 %
Total		300 ha	100 %

Efficiencies

Description		Coefficient	Remarks
Irrigation Efficiency	Rice Paddy	100 %	
	Upland Cropping	85 %	= 95% (Conveyance: Lined Canal) * 90% (Field Application: Drip)
Wetting Area Coefficient	Rice Paddy	100 %	"Suface Irrigation"
	Upland Cropping	**40 %**	"Micro Irrigation"

Reservoir

Description	EL & Volume	Remarks
Full Water Surface	EL. 1,392.00 m	FWS (Water Surface Area: 17.6 ha)
Dead Water Surface	EL. 1,389.00 m	DWS (Water Surface Area: 12.1 ha)
Bottom of Reservoir	EL. 1,380.00 m	ELbttm
Active Storage Capacity	450,000 m3	between FWS and DWS (H=3.00m)
Dead Water Volume	510,000 m3	between DWS and ELbttm (H=9.0m)

Results of Water Balance Study

Month	Decade	days	Inflow (m^3) ①	Outflow (m^3) Rice Paddy: Supply Water ②	Upland Crop: Irrigation Water Requirement ③	Seepage Loss ④	Evaporation from W. Surface ⑤	Total ⑥=Σ②~⑤	Balance between In & Outflow (m^3) ⑦=①-⑥	Cumulative Storage Volume of Reservoir (m^3) ⑧	Remarks
										0	
Jan.	1st.	10	29,632	5,134	12,539	15	3,507	21,194	8,438	**8,438**	**Min.**
	2nd.	10	29,108	5,134	7,951	15	3,507	16,606	12,502	20,939	
	3rd.	11	31,599	5,647	3,666	16	3,863	13,192	18,407	39,347	
Feb.	1st.	10	30,310	9,366	2,104	15	2,756	14,241	16,069	55,416	
	2nd.	10	29,926	9,366	2,814	15	2,756	14,951	14,975	70,391	
	3rd.	8	22,573	7,493	2,245	11	2,197	11,946	10,627	81,018	
Mar.	1st.	10	27,705	7,802	12,612	14	5,068	25,496	2,209	83,228	
	2nd.	10	26,572	7,802	21,353	13	5,068	34,236	-7,664	75,564	
	3rd.	11	28,024	8,582	16,565	14	5,581	30,742	-2,718	72,846	
Apr.	1st.	10	25,364	3,456	2,631	13	-3,532	2,568	22,796	95,642	
	2nd.	10	44,641	3,456	0	22	-3,532	-54	44,695	140,337	
	3rd.	10	47,209	3,456	0	24	-3,532	-52	47,261	187,598	
May	1st.	10	44,116	3,456	0	22	-2,260	1,218	42,898	230,496	
	2nd.	10	83,504	3,456	0	42	-2,260	1,238	82,266	312,762	
	3rd.	11	51,690	3,802	6,516	26	-2,486	7,858	43,832	356,594	
Jun.	1st.	10	37,420	3,456	6,755	19	1,355	11,585	25,835	382,429	
	2nd.	10	31,299	3,456	7,471	16	1,355	12,298	19,001	401,430	
	3rd.	10	30,724	3,456	6,383	15	1,355	11,209	19,515	420,946	
Jul.	1st.	10	39,976	3,456	5,381	20	3,269	12,126	27,850	448,795	
	2nd.	10	36,168	3,456	5,689	18	3,269	12,433	23,735	450,000	
	3rd.	11	33,479	3,802	13,515	17	3,599	20,932	12,547	**450,000**	**Max**
Aug.	1st.	10	28,219	16,931	23,252	14	9,134	49,331	-21,112	428,888	
	2nd.	10	25,232	16,931	29,227	13	9,134	55,306	-30,074	398,814	
	3rd.	11	25,544	18,624	33,587	13	10,050	62,275	-36,731	362,083	
Sep.	1st.	10	22,008	12,745	17,318	11	4,265	34,339	-12,331	349,752	
	2nd.	10	22,890	12,745	9,603	11	4,265	26,624	-3,734	346,018	
	3rd.	10	21,347	12,745	11,827	11	4,265	28,848	-7,501	338,517	
Oct.	1st.	10	20,859	9,662	26,520	10	7,068	43,260	-22,401	316,116	
	2nd.	10	20,472	9,662	45,282	10	7,068	62,022	-41,550	274,566	
	3rd.	11	22,112	10,628	36,503	11	7,775	54,917	-32,805	241,762	
Nov.	1st.	10	19,735	3,456	6,527	10	-3,626	6,367	13,368	255,130	
	2nd.	10	19,665	3,456	0	10	-3,626	-160	19,825	274,955	
	3rd.	10	31,073	3,456	744	16	-3,626	590	30,483	305,438	
Dec.	1st.	10	25,304	3,456	15,840	13	2,656	21,965	3,339	308,777	
	2nd.	10	23,802	3,456	22,839	12	2,656	28,963	-5,161	303,616	
	3rd.	11	21,835	3,802	22,348	11	2,924	29,085	-7,250	296,366	
Total			**1,111,136**	250,245	437,605	558	91,285	**779,693**	331,443	-	-
									Max. - Min. =	**441,562**	

Notes

*1) Seepage loss from dam body of 0.05 % of storage volume is assumed.

*2) Evaporation from water surface is estimated based on balance of rainfall and evaporation from FAO Irrigation and Drainage Paper No.24. *(See Table "Evaporation from Water Surface of Reservoir, Ngoma 22" for reference.)*

*3) Water Supply for Rice Paddy including river maintenance water 250,245 m3/yr.

*4) Cumu. Storage Volume : Start at DWS.1,389.00m 0 m3 (Effective Dam Storage Volume)

Table 2.2.2.20(2) Water Balance Study
Case-2 : Wet Area Coefficient = 50%

Cropping Acreage

Crop		Area	
Rice Paddy		35 ha	12 %
Upland Cropping	Maize+Beans	120 ha	40 %
	Vegetable-1	60 ha	20 %
	Vegetable-2	40 ha	13 %
	Vegetable-3	30 ha	10 %
	Coffee	15 ha	5 %
	Sub-total	265 ha	88 %
Total		300 ha	100 %

Efficiencies

Description		Coefficient	Remarks
Irrigation Efficiency	Rice Paddy	100 %	
	Upland Cropping	85 %	= 95% (Conveyance: Lined Canal) * 90% (Field Application: Drip)
Wetting Area Coefficient	Rice Paddy	100 %	"Suface Irrigation"
	Upland Cropping	**50 %**	"Micro Irrigation"

Reservoir

Description	EL & Volume	Remarks
Full Water Surface	EL. 1,392.00 m	FWS (Water Surface Area: 17.6 ha)
Dead Water Surface	EL. 1,389.00 m	DWS (Water Surface Area: 12.1 ha)
Bottom of Reservoir	EL. 1,380.00 m	ELbttm
Active Storage Capacity	450,000 m3	between FWS and DWS (H=3.00m)
Dead Water Volume	510,000 m3	between DWS and ELbttm (H=9.0m)

Results of Water Balance Study

Month	Decade	days	Inflow (m^3) ①	Outflow (m^3) Rice Paddy Supply Water ②	Outflow (m^3) Upland Crop Irrigation Water Requirement ③	Outflow (m^3) Seepage Loss ④	Outflow (m^3) Evaporation from W. Surface ⑤	Outflow (m^3) Total ⑥=Σ②–⑤	Balance between In & Outflow (m^3) ⑦=①–⑥	Cumulative Storage Volume of Reservoir (m^3) ⑧	Remarks
										0	
Jan.	1st.	10	29,632	5,134	15,674	15	3,507	24,329	5,303	**5,303**	**Min.**
	2nd.	10	29,108	5,134	9,938	15	3,507	18,594	10,514	15,817	
	3rd.	11	31,599	5,647	4,582	16	3,863	14,108	17,491	33,308	
Feb.	1st.	10	30,310	9,366	2,629	15	2,756	14,766	15,544	48,851	
	2nd.	10	29,926	9,366	3,518	15	2,756	15,655	14,271	63,123	
	3rd.	8	22,573	7,493	2,806	11	2,197	12,507	10,066	73,189	
Mar.	1st.	10	27,705	7,802	15,765	14	5,068	28,649	-944	72,245	
	2nd.	10	26,572	7,802	26,691	13	5,068	39,574	-13,002	59,243	
	3rd.	11	28,024	8,582	20,706	14	5,581	34,883	-6,859	52,384	
Apr.	1st.	10	25,364	3,456	3,288	13	-3,532	3,225	22,139	74,523	
	2nd.	10	44,641	3,456	0	22	-3,532	-54	44,695	119,218	
	3rd.	10	47,209	3,456	0	24	-3,532	-52	47,261	166,479	
May	1st.	10	44,116	3,456	0	22	-2,260	1,218	42,898	209,377	
	2nd.	10	83,504	3,456	0	42	-2,260	1,238	82,266	291,643	
	3rd.	11	51,690	3,802	8,145	26	-2,486	9,487	42,203	333,846	
Jun.	1st.	10	37,420	3,456	8,444	19	1,355	13,274	24,146	357,992	
	2nd.	10	31,299	3,456	9,338	16	1,355	14,165	17,134	375,125	
	3rd.	10	30,724	3,456	7,978	15	1,355	12,804	17,920	393,045	
Jul.	1st.	10	39,976	3,456	6,726	20	3,269	13,472	26,504	419,549	
	2nd.	10	36,168	3,456	7,112	18	3,269	13,855	22,313	441,863	
	3rd.	11	33,479	3,802	16,893	17	3,599	24,311	9,168	**450,000**	**Max**
Aug.	1st.	10	28,219	16,931	29,065	14	9,134	55,144	-26,925	423,075	
	2nd.	10	25,232	16,931	36,534	13	9,134	62,613	-37,381	385,694	
	3rd.	11	25,544	18,624	41,984	13	10,050	70,672	-45,128	340,567	
Sep.	1st.	10	22,008	12,745	21,647	11	4,265	38,668	-16,660	323,906	
	2nd.	10	22,890	12,745	12,004	11	4,265	29,025	-6,135	317,771	
	3rd.	10	21,347	12,745	14,783	11	4,265	31,805	-10,458	307,313	
Oct.	1st.	10	20,859	9,662	33,150	10	7,068	49,890	-29,031	278,283	
	2nd.	10	20,472	9,662	56,603	10	7,068	73,343	-52,871	225,412	
	3rd.	11	22,112	10,628	45,628	11	7,775	64,042	-41,930	183,482	
Nov.	1st.	10	19,735	3,456	8,159	10	-3,626	7,999	11,736	195,218	
	2nd.	10	19,665	3,456	0	10	-3,626	-160	19,825	215,043	
	3rd.	10	31,073	3,456	929	16	-3,626	775	30,298	245,341	
Dec.	1st.	10	25,304	3,456	19,800	13	2,656	25,925	-621	244,720	
	2nd.	10	23,802	3,456	28,549	12	2,656	34,673	-10,871	233,848	
	3rd.	11	21,835	3,802	27,935	11	2,924	34,672	-12,837	221,011	
Total			**1,111,136**	250,245	547,006	558	91,285	**889,094**	222,042	-	-
									Max. - Min. =	**444,697**	

Notes

*1) Seepage loss from dam body of 0.05 % of storage volume is assumed.

*2) Evaporation from water surface is estimated based on balance of rainfall and evaporation from FAO Irrigation and Drainage Paper No.24. *(See Table "Evaporation from Water Surface of Reservoir, Ngoma 22" for reference.)*

*3) Water Supply for Rice Paddy including river maintenance water 250,245 m3/yr.

*4) Cumu. Storage Volume : Start at DWS.1,389.00m 0 m3 (Effective Dam Storage Volume)

Table 2.2.2.20(3) Water Balance Study
Case-3 : Wet Area Coefficient = 60%

Cropping Acreage

Crop		Area	
Rice Paddy		35 ha	12 %
Upland Cropping	Maize+Beans	120 ha	40 %
	Vegetable-1	60 ha	20 %
	Vegetable-2	40 ha	13 %
	Vegetable-3	30 ha	10 %
	Coffee	15 ha	5 %
	Sub-total	265 ha	88 %
Total		300 ha	100 %

Efficiencies

Description		Coefficient	Remarks
Irrigation Efficiency	Rice Paddy	100 %	
	Upland Cropping	85 %	= 95% (Conveyance: Lined Canal) * 90% (Field Application: Drip)
Wetting Area Coefficient	Rice Paddy	100 %	"Suface Irrigation"
	Upland Cropping	**60 %**	"Micro Irrigation"

Reservoir

Description	EL & Volume	Remarks
Full Water Surface	EL. 1,392.00 m	FWS (Water Surface Area: 17.6 ha)
Dead Water Surface	EL. 1,389.00 m	DWS (Water Surface Area: 12.1 ha)
Bottom of Reservoir	EL. 1,380.00 m	ELbttm
Active Storage Capacity	450,000 m3	between FWS and DWS (H=3.00m)
Dead Water Volume	510,000 m3	between DWS and ELbttm (H=9.0m)

Results of Water Balance Study

Month	Decade	days	Inflow (m^3) ①	Outflow (m^3) Rice Paddy: Supply Water ②	Outflow (m^3) Upland Crop: Irrigation Water Requirement ③	Outflow (m^3) Seepage Loss ④	Outflow (m^3) Evaporation from W. Surface ⑤	Outflow (m^3) Total ⑥=Σ②–⑤	Balance between In & Outflow (m^3) ⑦=①–⑥	Cumulative Storage Volume of Reservoir (m^3) ⑧	Remarks
										0	
Jan.	1st.	10	29,632	5,134	18,808	15	3,507	27,464	2,168	**2,168**	**Min.**
	2nd.	10	29,108	5,134	11,926	15	3,507	20,581	8,527	10,695	
	3rd.	11	31,599	5,647	5,499	16	3,863	15,025	16,574	27,269	
Feb.	1st.	10	30,310	9,366	3,155	15	2,756	15,292	15,018	42,287	
	2nd.	10	29,926	9,366	4,221	15	2,756	16,358	13,568	55,854	
	3rd.	8	22,573	7,493	3,367	11	2,197	13,068	9,505	65,360	
Mar.	1st.	10	27,705	7,802	18,918	14	5,068	31,802	-4,097	61,263	
	2nd.	10	26,572	7,802	32,029	13	5,068	44,912	-18,340	42,923	
	3rd.	11	28,024	8,582	24,847	14	5,581	39,024	-11,000	31,922	
Apr.	1st.	10	25,364	3,456	3,946	13	-3,532	3,883	21,481	53,404	
	2nd.	10	44,641	3,456	0	22	-3,532	-54	44,695	98,099	
	3rd.	10	47,209	3,456	0	24	-3,532	-52	47,261	145,360	
May	1st.	10	44,116	3,456	0	22	-2,260	1,218	42,898	188,257	
	2nd.	10	83,504	3,456	0	42	-2,260	1,238	82,266	270,523	
	3rd.	11	51,690	3,802	9,774	26	-2,486	11,116	40,574	311,097	
Jun.	1st.	10	37,420	3,456	10,133	19	1,355	14,963	22,457	333,554	
	2nd.	10	31,299	3,456	11,206	16	1,355	16,033	15,266	348,821	
	3rd.	10	30,724	3,456	9,574	15	1,355	14,400	16,324	365,144	
Jul.	1st.	10	39,976	3,456	8,072	20	3,269	14,817	25,159	390,304	
	2nd.	10	36,168	3,456	8,534	18	3,269	15,277	20,891	411,194	
	3rd.	11	33,479	3,802	20,272	17	3,599	27,690	5,789	**416,984**	**Max.**
Aug.	1st.	10	28,219	16,931	34,878	14	9,134	60,957	-32,738	384,246	
	2nd.	10	25,232	16,931	43,841	13	9,134	69,919	-44,687	339,558	
	3rd.	11	25,544	18,624	50,381	13	10,050	79,069	-53,525	286,034	
Sep.	1st.	10	22,008	12,745	25,976	11	4,265	42,998	-20,990	265,044	
	2nd.	10	22,890	12,745	14,405	11	4,265	31,426	-8,536	256,508	
	3rd.	10	21,347	12,745	17,740	11	4,265	34,761	-13,414	243,094	
Oct.	1st.	10	20,859	9,662	39,780	10	7,068	56,520	-35,661	207,433	
	2nd.	10	20,472	9,662	67,924	10	7,068	84,663	-64,191	143,242	
	3rd.	11	22,112	10,628	54,754	11	7,775	73,168	-51,056	92,186	
Nov.	1st.	10	19,735	3,456	9,791	10	-3,626	9,631	10,104	102,290	
	2nd.	10	19,665	3,456	0	10	-3,626	-160	19,825	122,115	
	3rd.	10	31,073	3,456	1,115	16	-3,626	961	30,112	152,227	
Dec.	1st.	10	25,304	3,456	23,760	13	2,656	29,885	-4,581	147,646	
	2nd.	10	23,802	3,456	34,259	12	2,656	40,383	-16,581	131,065	
	3rd.	11	21,835	3,802	33,522	11	2,924	40,259	-18,424	112,641	
Total			**1,111,136**	250,245	656,407	558	91,285	**998,495**	112,641	-	-
									Max. - Min. =	**414,816**	

Notes

*1) Seepage loss from dam body of 0.05 % of storage volume is assumed.

*2) Evaporation from water surface is estimated based on balance of rainfall and evaporation from FAO Irrigation and Drainage Paper No.24. *(See Table "Evaporation from Water Surface of Reservoir, Ngoma 22" for reference.)*

*3) Water Supply for Rice Paddy including river maintenance water 250,245 m3/yr.

*4) Cumu. Storage Volume : Start at DWS.1,389.00m 0 m3 (Effective Dam Storage Volume)

Table 2.2.2.20(4) Water Balance Study
Case-4 : Wet Area Coefficient = 70%

Cropping Acreage

Crop		Area	
Rice Paddy		35 ha	12 %
Upland Cropping	Maize+Beans	120 ha	40 %
	Vegetable-1	60 ha	20 %
	Vegetable-2	40 ha	13 %
	Vegetable-3	30 ha	10 %
	Coffee	15 ha	5 %
	Sub-total	265 ha	88 %
Total		300 ha	100 %

Efficiencies

Description		Coefficient	Remarks
Irrigation Efficiency	Rice Paddy	100 %	
	Upland Cropping	85 %	= 95% (Conveyance: Lined Canal) * 90% (Field Application: Drip)
Irrigation Area Coefficient	Rice Paddy	100 %	"Surface Irrigation"
	Upland Cropping	**70 %**	"Micro Irrigation"

Reservoir

Description	EL & Volume	Remarks
Full Water Surface	EL. 1,392.00 m	FWS (Water Surface Area: 17.6 ha)
Dead Water Surface	EL. 1,389.00 m	DWS (Water Surface Area: 12.1 ha)
Bottom of Reservoir	EL. 1,380.00 m	ELbttm
Active Storage Capacity	450,000 m3	between FWS and DWS (H=3.00m)
Dead Water Volume	510,000 m3	between DWS and ELbttm (H=9.0m)

Results of Water Balance Study

Month	Decade	days	Inflow (m^3) ①	Outflow (m^3) Rice Paddy: Supply Water ②	Outflow (m^3) Upland Crop: Irrigation Water Requirement ③	Outflow (m^3) Seepage Loss ④	Outflow (m^3) Evaporation from W. Surface ⑤	Outflow (m^3) Total ⑥=Σ②-⑤	Balance between In & Outflow (m^3) ⑦=①-⑥	**Cumulative Storage Volume of Reservoir (m^3) ⑧**	Remarks
Jan.	1st.	10	29,632	5,134	21,943	15	3,507	30,598	-966	-966	**Min.**
	2nd.	10	29,108	5,134	13,914	15	3,507	22,569	6,539	5,572	
	3rd.	11	31,599	5,647	6,415	16	3,863	15,941	15,658	21,230	
Feb.	1st.	10	30,310	9,366	3,681	15	2,756	15,818	14,492	35,722	
	2nd.	10	29,926	9,366	4,925	15	2,756	17,062	12,864	48,586	
	3rd.	8	22,573	7,493	3,928	11	2,197	13,629	8,944	57,530	
Mar.	1st.	10	27,705	7,802	22,071	14	5,068	34,955	-7,250	50,281	
	2nd.	10	26,572	7,802	37,368	13	5,068	50,251	-23,679	26,602	
	3rd.	11	28,024	8,582	28,988	14	5,581	43,165	-15,141	11,461	
Apr.	1st.	10	25,364	3,456	4,604	13	-3,532	4,541	20,823	32,284	
	2nd.	10	44,641	3,456	0	22	-3,532	-54	44,695	76,979	
	3rd.	10	47,209	3,456	0	24	-3,532	-52	47,261	124,240	
May	1st.	10	44,116	3,456	0	22	-2,260	1,218	42,898	167,138	
	2nd.	10	83,504	3,456	0	42	-2,260	1,238	82,266	249,404	
	3rd.	11	51,690	3,802	11,403	26	-2,486	12,745	38,945	288,349	
Jun.	1st.	10	37,420	3,456	11,822	19	1,355	16,652	20,768	309,117	
	2nd.	10	31,299	3,456	13,074	16	1,355	17,901	13,398	322,516	
	3rd.	10	30,724	3,456	11,170	15	1,355	15,996	14,728	337,244	
Jul.	1st.	10	39,976	3,456	9,417	20	3,269	16,162	23,814	361,058	
	2nd.	10	36,168	3,456	9,956	18	3,269	16,700	19,468	380,526	
	3rd.	11	33,479	3,802	23,650	17	3,599	31,068	2,411	**382,937**	**Max.**
Aug.	1st.	10	28,219	16,931	40,691	14	9,134	66,770	-38,551	344,386	
	2nd.	10	25,232	16,931	51,148	13	9,134	77,226	-51,994	292,392	
	3rd.	11	25,544	18,624	58,778	13	10,050	87,465	-61,921	230,470	
Sep.	1st.	10	22,008	12,745	30,306	11	4,265	47,327	-25,319	205,151	
	2nd.	10	22,890	12,745	16,805	11	4,265	33,827	-10,937	194,214	
	3rd.	10	21,347	12,745	20,697	11	4,265	37,718	-16,371	177,843	
Oct.	1st.	10	20,859	9,662	46,410	10	7,068	63,150	-42,291	135,553	
	2nd.	10	20,472	9,662	79,244	10	7,068	95,984	-75,512	60,041	
	3rd.	11	22,112	10,628	63,880	11	7,775	82,294	-60,182	-141	
Nov.	1st.	10	19,735	3,456	11,422	10	-3,626	11,262	8,473	8,332	
	2nd.	10	19,665	3,456	0	10	-3,626	-160	19,825	28,157	
	3rd.	10	31,073	3,456	1,301	16	-3,626	1,147	29,926	58,083	
Dec.	1st.	10	25,304	3,456	27,720	13	2,656	33,845	-8,541	49,542	
	2nd.	10	23,802	3,456	39,969	12	2,656	46,093	-22,291	27,251	
	3rd.	11	21,835	3,802	39,109	11	2,924	45,846	-24,011	3,240	
Total			1,111,136	250,245	765,808	558	91,285	1,107,896	3,240	-	-
									Max. - Min. =	**383,903**	

Notes

*1) Seepage loss from dam body of 0.05 % of storage volume is assumed.

*2) Evaporation from water surface is estimated based on balance of rainfall and evaporation from FAO Irrigation and Drainage Paper No.24. *(See Table "Evaporation from Water Surface of Reservoir, Ngoma 22" for reference.)*

*3) Water Supply for Rice Paddy including river maintenance water 250,245 m3/yr.

*4) Cumu. Storage Volume : Start at DWS.1,389.00m 0 m3 (Effective Dam Storage Volume)

Table 2.2.2.21 Design Discharge Volume

Cropping Acreage

Crop		Area	
Rice Paddy		35	12%
Upland Cropping	Maize+Beans	120	40%
	Vegetable-1	60	20%
	Vegetable-2	40	13%
	Vegetable-3	30	10%
	Coffee	15	5%
	Sub-total	265	88%
Total		300	100%

Operation Hours

Crop	Operation Hours	Remarks
Rice Paddy	24 hrs	
Upland Cropping	12 hrs	

Efficiencies

Description		Coefficient	Remarks
Irrigation Efficiency	Rice Paddy	100 %	-
	Upland Cropping	85 %	-
Wetting Area Coefficient	Rice Paddy	100 %	"Suface Irrigation"
	Upland Cropping	70 %	"Micro Irrigation"

Design Discharge

Month	Decade	Days	Rice Paddy GIWR (m^3/dec)	Rice Paddy Discharge Volume (m^3/sec)	Upland Cropping GIWR (m^3/dec)	Upland Cropping Discharge Volume (m^3/sec)	Grand Total GIWR (m^3/dec)	Grand Total Discharge Volume (m^3/sec)	Remarks
Jan.	1st.	10	502	0.0006	21,943	0.0508	22,445	0.0514	
	2nd.	10	13,848	0.0160	13,914	0.0322	27,762	0.0482	
	3rd.	11	38,768	0.0408	6,415	0.0135	45,184	0.0543	
Feb.	1st.	10	41,043	0.0475	3,681	0.0085	44,725	0.0560	
	2nd.	10	29,038	**0.0336**	4,925	0.0114	33,963	0.0450	
	3rd.	8	5,040	0.0073	3,928	0.0114	8,968	0.0187	
Mar.	1st.	10	10,862	0.0126	22,071	0.0511	32,932	0.0637	
	2nd.	10	12,588	0.0146	37,368	0.0865	49,956	0.1011	
	3rd.	11	9,695	0.0102	28,988	0.0610	38,683	0.0712	
Apr.	1st.	10	2,205	0.0026	4,604	0.0107	6,809	0.0132	
	2nd.	10	0	0.0000	0	0.0000	0	0.0000	
	3rd.	10	0	0.0000	0	0.0000	0	0.0000	
May	1st.	10	152	0.0002	0	0.0000	152	0.0002	
	2nd.	10	315	0.0004	0	0.0000	315	0.0004	
	3rd.	11	3,442	0.0036	11,403	0.0240	14,845	0.0276	
Jun.	1st.	10	4,013	0.0046	11,822	0.0274	15,835	0.0320	
	2nd.	10	5,145	0.0060	13,074	0.0303	18,219	0.0362	
	3rd.	10	4,947	0.0057	11,170	0.0259	16,116	0.0316	
Jul.	1st.	10	16,403	0.0190	9,417	0.0218	25,820	0.0408	
	2nd.	10	38,477	0.0445	9,956	0.0230	48,433	0.0676	
	3rd.	11	44,590	0.0469	23,650	0.0498	68,240	0.0967	
Aug.	1st.	10	39,352	0.0455	40,691	0.0942	80,042	0.1397	
	2nd.	10	19,740	0.0228	51,148	0.1184	70,888	0.1412	
	3rd.	11	20,767	0.0219	58,778	0.1237	79,545	0.1455	
Sep.	1st.	10	11,760	0.0136	30,306	0.0702	42,066	0.0838	
	2nd.	10	8,482	0.0098	16,805	0.0389	25,287	0.0487	
	3rd.	10	11,608	0.0134	20,697	0.0479	32,305	0.0613	
Oct.	1st.	10	16,940	0.0196	46,410	0.1074	63,350	0.1270	
	2nd.	10	20,055	0.0232	79,244	**0.1834**	99,299	**0.2066**	
	3rd.	11	15,517	0.0163	63,880	0.1344	79,396	0.1508	
Nov.	1st.	10	4,013	0.0046	11,422	0.0264	15,436	0.0311	
	2nd.	10	0	0.0000	0	0.0000	0	0.0000	
	3rd.	10	373	0.0004	1,301	0.0030	1,675	0.0034	
Dec.	1st.	10	4,457	0.0052	27,720	0.0642	32,177	0.0693	
	2nd.	10	5,133	0.0059	39,969	0.0925	45,102	0.0985	
	3rd.	11	3,628	0.0038	39,109	0.0823	42,738	0.0861	
Annual			*462,898.3*	-	*765,808.2*	-	*1,228,706.6*	-	-
Maximum			*44,590.0*	***0.0475***	*79,244.1*	***0.1834***	*99,299.1*	***0.2066***	-

Notes

*1) GIWR (m^3/dec) : Gross Irrigation Water Requirement

*2) Discharge Volume (m^3/sec) = GIWR (m^3/dec) / dec (days) / (3,600 (sec/hr) * Operation Hours (hrs))

2-2-2-1-4 Estimation of Ecological River Discharge

1) Expected river flow rate at the dam site in drought years

The figure below shows the river flow rate conditions of top ten drought years from 1960 to 1993 estimated by the Tank Model analysis and then followings shall be pointed out.

- The year which has no or scarce rainfall in the rainy season from April to May becomes the drought year.
- The river flow rate becomes least in October to December.
- The least river flow rate in a year, i.e. the base flow, is almost constant to be 0.02m^3/sec regardless of the drought intensity.

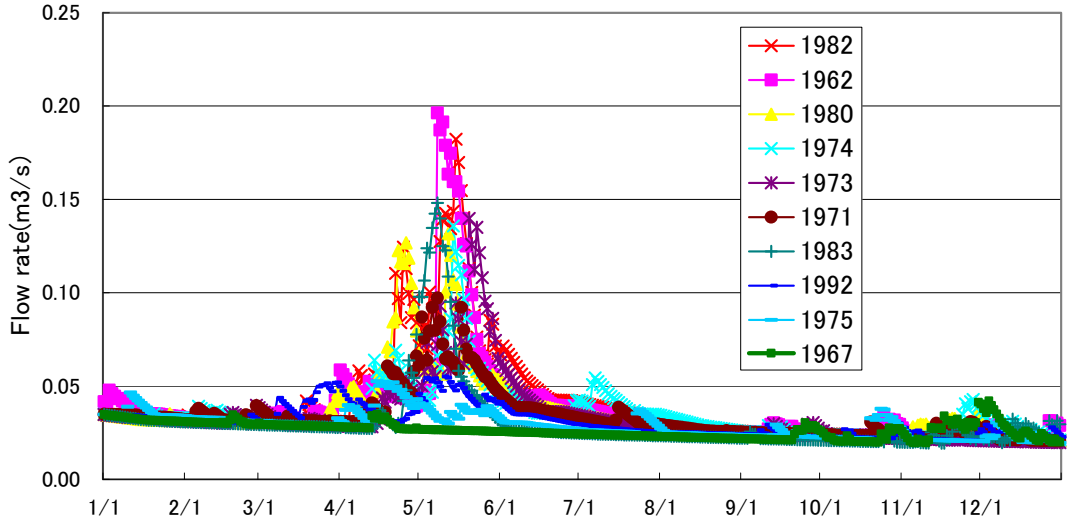


Figure 2.2.2.12 River Flow Rate in Drought Years

2) River flow rate conditions in Ngoma22 valley

According to the result of river flow rate observations carried out in 2012, the river flow rate in Ngoma22 valley differs from the dam site to the confluence at the exit of the valley as follows.

Table 2.2.2.22 River Flow Rate at the Dam Site and at the Confluence

Date	Flow rate (ℓ/sec)		
	①At the dam site	②Just before the confluence	②／①
02/02/2012	23	69.8	3
01/04/2012	23	71.3	3.1
08/04/2012	45	73.5	1.6
19/04/2012	26	68.3	2.6
25/04/2012	103	236	2.3
01/05/2012	104	218	2.1
20/05/2012	88	223	2.5

The table above shows that the river flow rate at the valley exit is about three times larger in the dry season and two times larger or more in the rainy season than the ones at the dam site. Followings shall be pointed out taking account of the catchment area of the dam site being 8.8km^2 and the one of the valley exit being 9.2km^2.

- Water resources originating from spring are richer in the downstream than that in the upstream.

- In the rainy season during which the ratio of direct runoff becomes increase, the river flow rate becomes directly proportional to the size of catchment area.

3) Ecological river discharge

The previous section has made it clear that the downstream area to the dam site has enough water resources of spring coming from the right and left hillsides. But the area just downstream to the dam site can not rely on such resources. In addition, the least amount of river discharge as the supplemental irrigation water supply that is sluiced according to Table 2.2.2.23 is only 1,000m^3 or so per month, which is too small amount to be 0.4ℓ/sec (1,000/30/86400=0.0004m^3/sec=0.4ℓ/sec).

Therefore, the concept of 'Ecological river discharge' shall be set up from the view point of environment preservation; here, the least river flow rate is to be 20ℓ/sec corresponding to the base flow rate and the ecological river discharge is to be 4ℓ/sec corresponding to a quarter of the base flow rate. The actual operation of discharge shall be carried out to cover the shortage volume to this amount of 4ℓ/sec so that the operation shall not be executed in case of the supplemental irrigation water supply being more than this amount. The total ecological river discharge is estimated to be 48,000m^3 per year as shown in the following table, where the calculation is done for the reference year for design of 1974.

Table 2.2.2.23 Calculation of Ecological River Discharge to the Reference Year for Design (1974)

Month	Irrigation water supply		②Ecological river discharge(ℓ/sec)	Discharge in operation	
	(m^3/Mon.)	① (ℓ/sec)		(②－①) (ℓ/sec)	(m^3/Mon.)
1	15,914.1	5.94	4.0	-1.9	
2	26,225.0	10.84	4.0	-6.8	
3	24,185.8	9.03	4.0	-5.0	
4	1,061.5	0.41	4.0	3.6	9306.5
5	1,077.5	0.40	4.0	3.6	9636.1
6	1,410.4	0.54	4.0	3.5	8957.6
7	1,621.6	0.61	4.0	3.4	9092.0
8	52,487.0	19.60	4.0	-15.6	
9	38,235.6	14.75	4.0	-10.8	
10	29,951.1	11.18	4.0	-7.2	
11	2,061.1	0.80	4.0	3.2	8306.9
12	8,419.6	3.14	4.0	0.9	2294.0
Total					47593.1

2-2-2-1-5 Utilization of Ground Water

1) Possibility of ground water as water resources for gravitational irrigation use

(1) Estimation based on field reconnaissance and specific discharges of the springs

Three valleys came to the surface as the water resources for gravitational irrigation use through the field reconnaissance carried out on 16th and 18th of March 2012, where springs existed at the point with high enough elevation and bore swamps and streams even at the end of dry season. These valleys are named 'Dry valley', 'Downstream right bank valley' and 'Downstream left bank valley' of which locations are shown on Figure 2.2.2.13. The potential of these valleys as the water resources for gravitational irrigation use is estimated as follows shown in Table 2.2.2.24.

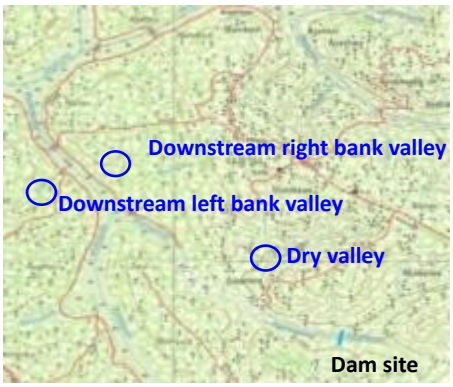


Figure 2.2.2.13 Location of the Valley with a Water Supply Potential

Table 2.2.2.24 Estimation of the Potential as the Water Resources for Gravitational Irrigation Use

Valley	Observation/Estimation	Evaluation
Dry valley (CA=1.7km^2)	At the midway point of the valley, there are one artificial ditch with approximate flow rate of 1ℓ/sec and other two small streams. When reckoning the base flow rate at the dam site to be 2,000m^3/day approximately based on the observed record (20ℓ/sec×86400sec≒2,000m^3/day), available quantity is estimated as follows. 2,000m^3/day×1.7km^2/8.8km^2=386m^3/day≒ 380m^3/day(=4.6ℓ/sec)	Considering the intake point to be located at the midway of the valley, about 50% of the estimated shall be counted. Evaluated quantity =2ℓ/sec
Downstream right bank valley (CA=0.5km^2)	At the midway point of the valley, there are swamps and a small stream. One spring exists in the back of the valley. Available quantity is estimated in the same manner as above. 2,000m^3/day×0.5km^2/8.8km^2=114m^3/day (=1.3ℓ/sec)	Based on the same view point as above, about 50% of the estimated shall be counted. Evaluated quantity =0.7ℓ/sec.
Downstream left bank valley (CA=0.8km^2)	A stream with the approximate flow rate of 2ℓ/sec exists at the midway of the valley. There is a spring with discharge quantity of 0.5ℓ/sec in the back of the valley. 2,000m^3/day×0.8km^2/8.8km^2=182m^3/day (=2.1ℓ/sec)	Based on the confirmed flow rate of the stream at the midway of the valley, the evaluation becomes as follows. Evaluated quantity =2ℓ/se

(2) In-site trial for studying utilization possibility of ground water

Location :Narrowed section on the upstream of Dry Valley

Date :11th - 15th of October, 2013

Trial :To measure the flow rate of the existing stream

- To construct an impervious wall in the ground and dam up the ground water
- To measure the gathered flow rate composed of the original stream and the damed-up ground water
- To compare the gathered flow rate with the original one and estimate the efficiency of the wall construction

Works :

i. The stream was diverted to the ditch excavated along the slope toe of the left side hill. The flow rate was measured at its exit as shown on the photo bellow.

Flow rate of the original stream Q_1=1.29ℓ/sec

ii. A trench, 5m long and 1.5m deep, was excavated across the stream by manpower. A layer composed of coarse sand ~ mixture of coarse sand and small gravel appeared under the river bed. It would be natural and common that an aquifer exists in the ground around the point where ground water appears on the ground surface. In other words, it would be said that the appearance of stream is brought from the overflow in an aquifer.

iii. A masonry wall was constructed in the trench and the concaves beside the wall were backfilled. The gathered flow rate was measured by pipes placed in the wall.


Gathered flow rate Q_2=1.37ℓ/sec



Estimation of the efficiency of the work;

The efficiency of the dam-up wall was not clear. Followings would be the causes of such result.

- Low flow velocity of the ground water
- Small scale of the aquifer
- Insufficiency of the dam-up (cut-off) wall due to the landscape, land owner's opinion not allowing the extension of the wall into her farm land, and the shortage of wall height not reaching the base layer

It would not be said that the trial resulted in success, but be said that the existence of available water of 1.3ℓ/sec originating from ground water was confirmed and that the possibility of utilizing the ground water of 2.0ℓ/sec or so was confirmed given the more sufficient cut-off wall was provided.

(3) Possibility of ground water as water resources for gravitational irrigation use

Speaking of Dry Valley, availability of reasonable amount of ground water was confirmed by the trial work though the trial site was located on the upstream of the valley. Therefore, it would be said that the valley where ground water appears to the ground surface and a stream is borne has the potential of supplying as much water for gravitational irrigation use as proportional with the catchment area of the intake point.

2.0ℓ/sec of water becomes 63,000m^3/year (2.0ℓ/sec× 86,400sec/day ×365days/year=63,000m^3/year), which makes it possible to irrigate farm lands more than 30ha approximately. The facilities needed for this irrigation would be canals laid on along the contour line and a small scale reservoir that can store the amount of 14 hours' discharge in case of the irrigation works being operated for 10 hours a day. Such a gravitational irrigation system would be economical so that it would be said the spring or the stream borne from spring existing on the midway of the valley has a high potential as a water resource for gravitational irrigation use.

2) Adequacy of implementation of ground water utilization

The river flowing down in the valley of Ngoma22 Project is small, of which width is less than 1m or so, but a considerable extent of paddy fields exists on the both sides along the river. At the foot of the hills along the valley, there are more than 10 springs that are used for domestic water and led into the paddy fields for irrigation use. In the previous section "2-2-2-1-2 Water Requirement for the Paddy Fields", the study has been done under the condition of the runoff including ground water flowing down into the valley from both downstream hillsides. Therefore, although "Dry valley" has a high potential of supplying water for gravitational irrigation use, diversion of this water for hillside

irrigation is not adequate because it functions already as a part of water sources for the paddy fields.

"Downstream right bank valley" and "Downstream left bank valley" have the same conditions. The main valleys have a river flowing down on its center and paddy fields. The springs existing in the branch valleys above function already as a part of water sources for these paddy fields so that it would not be adequate to utilize them for the hillside irrigation around there.

2-2-2-1-6 Examination of Irrigation Method

1) Dam height and irrigation method

Irrigation water conveyance method from reservoir to command area is divided into using natural heads type and using pumps type.

According to the results of water balance simulation aforementioned, dry year discharge with probability occurrence of 1/5 is about 1.11 million m^3, and then effective storage of reservoir in order to supply available water to paddy field and farmland on hillside is estimated 450,000m^3.

If the dam is lifted up 9.0m to secure dead water volume adding available water volume 0.45 million m^3, the dead water volume amounts to about 0.51 million m^3 and total storage capacity amounts to 0.960 million m^3. Since this volume is less than expected quantity of the river inflow rate corresponding to dry year discharge with probability occurrence of 1/5, it doesn't take a few years to be filled with water to the full water level.

Moreover, irrigation water can be supplied by natural gravity using lifted up head when constructing this dam. However, using pumps is required to distribute irrigation water to higher area of hillside since the command area by using gravity shall be limited in a certain area according to topographical conditions.

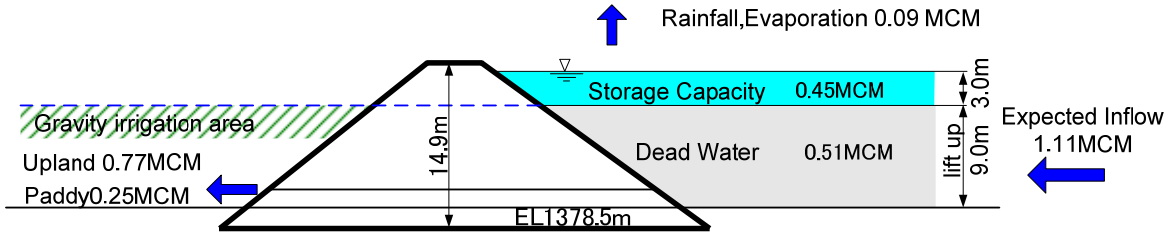


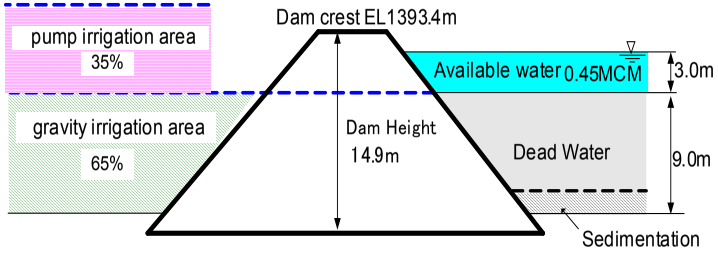
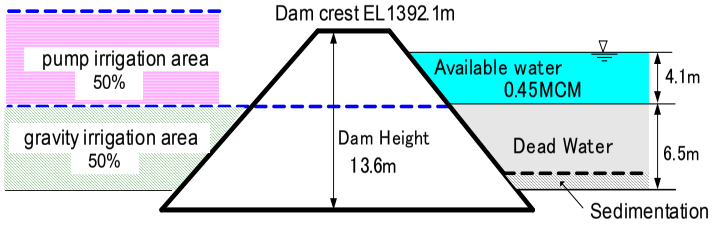
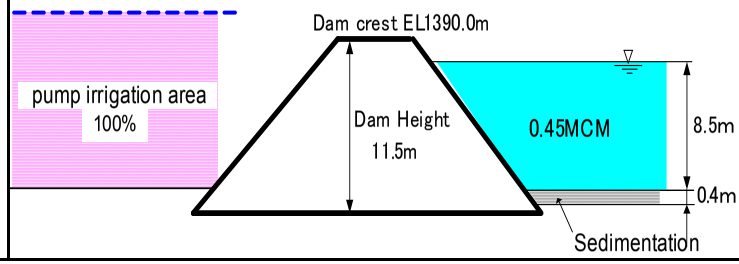
Figure 2.2.2.14 Water Balance Diagram

Then comparative study is conducted regarding the ratio of area irrigated by gravity or pumps, construction cost of dam and pump station as well as maintenance cost according to the dam height. Above mentioned 9m lifted up dam is the maximum scale while a dam with no dead water capacity is minimum size whose command area is irrigated by pumps only.

As the result of comparison, dam with 9m lifted up is found out as economical case since the total construction cost is greatly influenced by the construction cost of pump station based on required pump capacity rather than the construction cost of dam depending on the dam height. Furthermore, annual O&M cost is also cheapest in the case of largest dam because of the small ratio of pump operating cost. In addition, the number of affected people who have land around reservoir is almost same irrespective of a few meters change of full water level and this means the compensation by Rwandan government also has no difference.

For the reasons stated above, irrigation method with using gravity and pumps by lifting up the dam by 9m is adopted in this Project.

Table 2.2.2.25 Comparison of Dam Height and Cost

case	Diagram	Construction Cost Ratio (dam+pump)	Maintenance Cost Ratio (electricity and repairing)	Evaluation
A	MCM=Million Cubic Meters 	1.00	1.00	Though Construction cost of dam is highest in three cases, though total cost is lowest because the construction cost of pump facilities is small. O&M cost of pump is also the lowest because of low electrical charge necessary for operation. The number of affected people is maximum since the reservoir surface area is largest.
B		1.05	1.60	Both construction cost and maintenance cost are intermediate in three cases. The difference of water level with case A is about 1.3m and the number of affected people is almost same with case A.
C		1.15	2.80	Total cost is highest because construction cost of pump facilities is maximum. Since operation cost for pump is also maximum, this case is most uneconomical. The number of affected people is smallest.

2) Intermittent irrigation

Irrigation interval is decided by the length of period during supplied water for irrigation is stored effectively within the root zone, used, absorbed and consumed by crops.

According to "Training manual" by FAO, irrigation intervals for the major crops are shown depending on soil type and climate condition (Reference evapotranspiration ETo).

Following table shows the interval days for the planned crops in this Project, design irrigation interval is assumed to be 6 days from the view point of soil and climate condition.

Table 2.2.2.26 Estimated Irrigation Schedules for the Major Field Crops during Peak Water Use Periods

	Shallow and/or sandy soil			loamy soil			clayey soil		
	Interval (days)			Interval (days)			Interval (days)		
Climate	A	B	C	A	B	C	A	B	C
Beans	6	4	3	8	6	4	10	7	5
Carrot	6	4	3	7	5	4	11	8	6
Coffee	9	6	5	13	9	7	16	11	8
Eggplant	6	4	3	8	6	4	10	7	5
Miaze	8	6	4	11	8	6	14	10	7
Tomato	6	4	3	8	6	4	10	7	5

Cimate A; ETo=4～5
Cimate B; ETo=6～7
Cimate C; ETo=8～9

Source：FAO Training manual No.4;Irrigation Water Management: Irrigation Scheduling

2-2-2-2 Land Husbandry Plan

2-2-2-2-1 Field Reconnaissance

Followings are the findings obtained through the field reconnaissance.

- The soil of ground surface in the catchment areas is composed of mainly clayey soil originating from highly weathered shale, where dikes of sandstone or shale-sandstone alternative layers appear in rare cases.
- Soils there are sorted into 5 types.
  i) Reddish brown soil (sandy clay, non-organic) borne as a result of laterization to the soil originating from highly weathered shale,
  ii) Dark brown soil (sandy clay, organic) borne as a result of cultivation to the reddish brown soil mentioned above,
  iii) Yellowish to yellowish grey soil which originated from highly weathered shale, not experienced laterization, looks like half-consolidated without cultivated experience, and is low organic with cultivated experience,
  iv) Yellowish grey transported soil which deposits around the mouth of large scale branch valleys and is composed of sand mainly as the result of clay portion flowing away with water, and
  v) Dark grey soil originating from highly weathered sandstone or sometimes from the mixture of go highly weathered sandstone and highly weathered shale with scattered gravels or rocks around there.
- Following areas need challenges for implementing the landscape shaping for land husbandry.

Area-A : This is the steep slope located upstream named Dry Valley, on which rocks measuring up to 30cm or more in diameter are scattered around. The soil layer is thin on the ground surface and the bed layer is so hard that the iron blade of the spade gets bended by hitting against the bed layer, which may contain ore of tin or tungsten.

Photo 2.2.2.3 Area-A

Area-B : This area is composed of a ridge at the mouth of the branch valley named Downstream Right Bank Valley; outcrops of sandstone appear everywhere on the slope so that the ridge itself probably is composed of a rock body of sandstone.

Photo 2.2.2.3 Area-B

Area-C : This is the area ranging from downstream slope next to the ridge mentioned above to the end of the plateau on the right bank; sandstone rocks measuring up to 30cm or more in diameter, i.e. the chips of un-weathered sandstone edges, are scattered everywhere due to the geological formation of sandstone-shale alternative strata with perpendicular beddings caused by folding. Most of the slopes are utilized as afforestation areas though some farmers cultivate there with efforts of digging out rocks from their farmlands.

Area-D : This area is composed of a upstream ridge located on the midway of the main valley and at the mouth of the branch valley eroded on the left plateau; outcrops of sandstone are scattered on the slope surface there. And adjacent to this ridge, upstream side, there is a landscape with a cliff caused by landslide falling, a steep to gentle slope of landslide deposit and ponds at its foot.

Photo 2.2.2.3 Area-C

Photo 2.2.2.3 Area-D

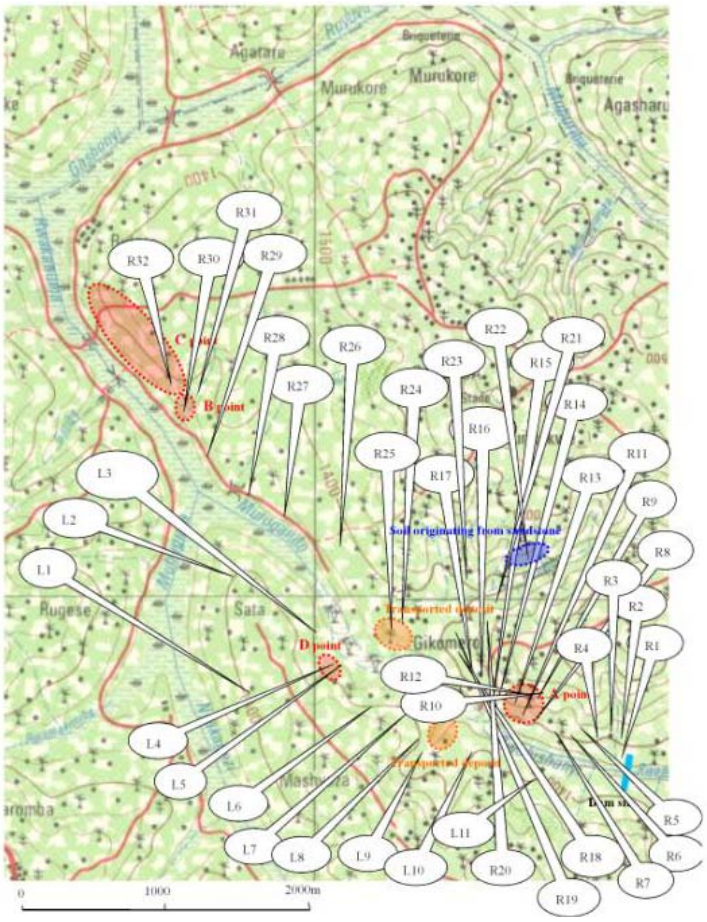


Figure 2.2.2.15 Location Map of Field Reconnaissance for Land Husbandry (Location of Soil Sampling)

Table 2.2.2.27(1) Results of Soil Sampling

Number	Thickness (cm)	Color	Soil type	Remarks	Photo
R-1	30～40	dark brown	cultivated soil, organic	originating from lateritic soil, sandy clay	
R-2	30～40	dark brown	top soil, organic	originating from lateritic soil, sandy clay	
R-3	50	yellowish brown～redish brown	top soil, organic	originating from lateritic soil, sandy clay	
R-4	20	dark brown	top soil, organic,	sandy clay, lateritic soil with gravels at the base	
R-5	25	yellowish brown	top soil, orgaic, dry	sandy clay, lateritic soil with shale gravels (φmax 50mm) at the base	
R-5				cut cliff at the front, lateritic soil accompanied by shale gravels	
R-6	25	light brown	top soil, organic, dry	accompanied by shale gravels	
R-6				cut cliff at the front composed of highly weathered shale	
R-7	70	yellowish～greyish brown	sandy clay originating from shale	small cliff, gravelly layer of quartz fragment at its foot	

Table 2.2.2.27(2) Results of Soil Sampling

Number	Thickness (cm)	Color, Location	Soil type	Remarks	Photo
R-8	60	yellowish brown 2°05' 26.8" S 30°30' 335.8"E	top soil, organic	small cliff, lateritic soil at its foot	
R-9	40	light brown	cultivated soil composed of top soil and lateritic soil mixture	small cliff, lateritic soil at its foot	
R-10	20	greyish brown	top soil cultivated little	steep slope, quartish and angular rocks (φ 30cm±) lying scattered on its surface	
				steep slope from R-10 to R-15	
R-11	40	yellowish dark brown 2°05' 25.9" S 30°30' 30.9" E	top soil, organic	gentle slope, but not cultivated	
R-12	0	light redish brown	lateritic soil	lateritic gravels at the depth of 50cm	
R-13	40	yellowish～greyish brown 2°05' 24.7" S 30°30' 27.8" E	sandy clay, organic	bedded by lateritic round gravels containing quartish gravels	
R-14	20	yellowish dark brown 2°05' 22.6" S 30°30' 25.2" E	sandy clay, organic	bedded by hard lateritic layer (mineral deposit of tin/wolfram?)	
R-15	20	yellowish dark brown 2°05' 20.9" S 30°30' 23.8" E	sandy clay, organic	bedded by hard lateritic layer (mineral deposit of tin/wolfram?)	

Table 2.2.2.27(3) Results of Soil Sampling

Number	Thickness (cm)	Color	Soil type	Remarks	Photo
R-16	60	dark brown 2°05' 18.4" S 30°30' 19.7" E	sandy clay, organic		
R-17	50	greyish dark brown 2°05' 17.7" S 30°30' 17.8" E	sandy clay, organic		
R-18	50	yellowish～greyish brown 2°05' 14.3" S 30°30' 15.0" E	sandy clay, organic	bedded by yellowish brown clay originating from shale	
R-19	25	dark greyish brown 2°05' 6.3" S 30°30' 8.9" E	sandy clay, organic	bedded by redish lateritic soil	
R-20	25	yellowish～greyish brown 2°05' 1.0" S 30°30' 15.4" E	sandy clay, organic	stif layer	
R-21	40	brown 2°04' 58.8" S 30°30' 16.4" E	sandy clay, organic	marshland soil	
R-22	20	dark grey 2°04' 57.1" S 30°30' 21.3" E	silty sand	slope with scattered sandstone rocks, light soil with a feature of volcanic ash	
R-23	40	dark grey 2°05' 01.7" S 30°30' 00.7" E	silty sand	bedded by lateritic soil	
R-24	5～10	brown 2°05' 06.1" S 30°29' 56.2" E	sady clay	organic a little	

Table 2.2.2.27(4) Results of Soil Sampling

Number	Thickness (cm)	Color	Soil type	Remarks	Photo
R-25	30	grey 2°05' 08.8" S 30°29' 56.7" E	sandy silt	sediment transported from the valley, bedded by yellowish soil originating from shale	
R-26	40	dark brown 2°05' 06.9" S 30°29' 52.6" E	sandy clay organic	originating from lateritic soil, extending wide on the genttle slope beyond Spring No.6	
					
R-27		dark brown ～yellowish brown		perpendicular cliff, 1m high, caused by excavation	
R-28		reddish brown ～yellowish brown, 300 m upstream from te river meeting point		Ditto	
R-29	30	dark brown 2°04' 30.8" S 30°29' 19.9" E	sandy clay organic	orginating from lateritic soil	
R-30	10～20	grey 2°04' 17.1" S 30°29' 11.9" E	clayey sand organic	with outcrops / rodks of sandstone	
R-31				slopes in the valley, covered by lateritic soil	
R-32	10～20	dark greyish brown 2°04' 15.8" S 30°29' 08.4" E	sandy clay organic	sandstone rocks lying scattered on the slope	

Table 2.2.2.27(5) Results of Soil Sampling

Number	Thickness (cm)	Color	Soil type	Remarks	Photo
L-1	30	dark greyish brown 2°04' 11.2" S 30°29' 19.0" E	cohesive sandy clay, organic	bedded by lateritic soil	
L-2	20	dark reddish brown 2°04' 47.4" S 30°29' 26.2" E	sandy clay organic	lateritic gravels are predominant	
L-3	30	greyish brown 2°04' 50.7" S 30°29' 32.4" E	sandy clay organic	bedde by yellowish stiff soil originating from shale	
L-4		2°05' 12.1" S 30°29' 43.3" E	outcrops of sandstone	at the mouth of fan-shaped erroded valley	
L-5	20	light brown 2°05'13.2" S 30°29' 45.7" E	sandy clay organic	steep slope composed of transported soil containing angular shale stones	
L-6	30	yellowish brown 2°05'13.2" S 30°29' 47.9" E	sandy silt cohesion low	originating from shale	
L-7	30	yellowish brown 2°05' 20.8" S 30°29' 59.7" E	sandy clay low organic cohesive	bedded by reddish brown lateritic soil	
L-8	5	dark yellowish brown 2°05' 26.2" S 30°30' 14.9" E	silty clay low organic	consolidated layer originating from shale	
L-9	50	dark brown 2°05' 28.3" S 30°30' 19.5" E	sandy clay low organic cohesive	organic portion; 5cm bedded by reddish lateritic soil	

Table 2.2.2.27(6) Results of Soil Sampling

Number	Thickness (cm)	Color	Soil type	Remarks	Photo
L-10	60	dark brown 2°05' 39.1" S 30°30' 32.4" E	sandy silt cohesion low	organic portion; 5cm bedded by reddish lateritic soil	
L-11	20	dark brown 2°05' 38.4" S 30°30' 50.5" E	sandy clay organic	bedded by yellowish soil ariginating from shale	

2-2-2-2-2 Soil Test

1) Location of soil sampling

Soil sampling and soil tests for selected samples are conducted. The results of test and evaluation are described as below.

Table 2.2.2.28 Location of the Sampling Sites for Soil Test and Proposed Soil Classification

Site	Topography	L.Use	Parent M.	Depth /color/ texture	Proposed SC(USDA)
R-1	Gentle slope	Plot	laterite	30 - 40cm/ DB/	Tropeptic Haplustox
R-7	Hill slope terrace	Plot	quarzite	70cm/ GB/ C	Ustic Humitropept
R-8	Hill slope	Plot	laterite	60cm/ YB/ C	Tropeptic Haplustox
R-9	Hill slope	Plot	laterite	40cm/ LB/ C	Tropeptic Haplustox
R-10	Steep slope	Plot-Bad	quarzite	20cm/ GB/ CL	Ustic Humitropept
R-12	Hill slope	Plot	laterite	0 - 50cm/ LRB/ C	Tropeptic Haplustox
R-17	Gentle slope	Plot	shale	0 - 50cm/ GDB/ C	Tropeptic Haplustox
R-21	Lowland	Plot	deposit	40cm/ B/ CL	Mollic troporthent
R-22	Steep slope riverside	Plot-Bad	Volcanic	20cm/ DG/ SCL	Humic Dystrandepts
R-23	Hill slope riverside	Plot	laterite	40cm/ DG/ S&C	Tropeptic Haplustox
R-25	Deposit	Plot	shale	30cm/ G/ Si,CL	Tropeptic Haplustox
R-30	Ridge slope	Badland	sandstone	10 - 20cm/ G/ CL	Lithic Tropopsament
L-1	Hill slope	Plot	laterite	30cm/ DGB/ C	Tropeptic Haplustox
L-5	Colluvial deposit	Badland	deposit	20cm/ LB/ SiCL	Distic Troporthent
L-6	Hill slope	Plot	shale	30cm/ YB/ SiCL	Tropeptic Haplustox
L-7	Hill slope	Plot	laterite	30cm/ YB/ C	Tropeptic Haplustox
L-8	Hill slope	Plot	shale	5cm/ DYB/ SiC	Tropeptic Haplustox
L-9	Hill slope	Plot	laterite	50cm/ GB/ CL	Oxic Humitropept
L-10	Hill slope	Plot	shale	60cm/ DB/ C	Tropeptic Haplustox
L-11	Hill slope	Plot	shale	20cm/ DB/ C	Tropeptic Haplustox

2) Results of soil test

Table 2.2.2.29 Result of Laboratorial Soil Test

Site	pH(H_2O)	Org. C	Total N	Avail. P	Ca	K	CEC	sand	silt	clay
Unit	-log H	w/w%	w/w%	ppm	Meq/100g	Meq/100g	Meq/100g	%	%	%
R-1	5.3	1.69	0.28	2.67	2.4	0.10	9.2	40.9	25.3	33.8
R-7	4.6	2.41	0.21	3.43	2.2	0.07	11.2	25.0	32.3	42.7
R-8	6.1	2.49	0.2	3.05	1.9	0.10	12.0	22.7	31.8	45.5
R-9	4.7	1.84	0.2	4.89	1.7	0.10	10.8	23.7	24.7	51.6
R-10	4.8	3.33	0.28	4.19	2.3	0.13	10.4	40.7	25.4	33.9
R-12	5.5	1.68	0.21	2.67	1.8	0.10	9.6	28.1	29.3	42.6
R-17	6.6	1.82	0.21	3.81	1.7	0.10	12.4	25.8	24.2	50.0
R-21	6.5	2.25	0.21	3.43	2.4	0.13	10.4	36.3	31.4	32.3
R-22	6.1	2.63	0.42	3.81	2.1	0.10	10.0	44.2	21.9	33.9
R-23	5.9	2.37	0.28	3.43	1.7	0.13	11.6	24.1	26.1	49.8
R-25	6.5	2.91	0.42	4.19	2.2	0.40	12.4	35.5	31.7	32.8
R-30	5.4	3.41	0.49	6.48	2.3	0.13	13.6	34.2	28.2	37.6
L-1	5.9	3.03	0.49	3.00	2	0.10	14.9	22.0	25.2	52.8
L-5	5.2	2.9	0.28	5.33	1.7	0.13	10.4	22.8	46.7	30.5
L-6	6.0	2.21	0.56	3.43	2.1	0.10	11.6	14.5	50.3	35.2
L-7	4.9	2.96	0.28	5.71	1.7	0.13	9.2	15.1	38.3	46.6
L-8	5.8	1.83	0.28	3.81	2.2	0.10	11.6	13.4	44.4	42.2
L-9	4.7	1.71	0.42	4.98	1.7	0.20	8.8	29.6	32.5	37.9
L-10	6.0	2.15	0.42	3.43	1.7	0.07	12.8	30.4	26.2	43.4
L-11	5.8	2.47	0.49	3.43	2.5	0.23	13.2	27.4	29.6	43.0

Table 2.2.2.30 Interpretation of the Result of Soil Test

Sample Site	pH in water	Organic Carbon	Total N	Available P	Ca	K	CEC	Base saturation ratio *	Soil texture
R-1	Low	VeryLo	Low	VeryLow	Low	Low	Low	54.3%	CL
R-7	Low	Low	Low	Low	Low	Low	Low	40.5%	C
R-8	Low	Low	Low	Low	VeryL	Low	Low	33.3%	C
R-9	Low	VeryLo	Low	Low	VeryL	Low	Low	33.3%	C
R-10	Low	Low	Low	Low	Low	Low	Low	46.7%	CL
R-12	Low	VeryLo	Low	VeryLow	VeryL	Low	Low	39.6%	C
R-17	Mediu	VeryLo	Low	Low	VeryL	Low	Low	29.0%	C
R-21	Low	Low	Low	Low	Low	Low	Low	48.7%	CL
R-22	Low	Low	Low	Low	Low	Low	Low	44.0%	SCL
R-23	Low	Low	Low	Low	VeryL	Low	Low	31.6%	C
R-25	Low	Low	Low	Low	Low	Mediu	Low	41.9%	CL
R-30	Low	Low	Low	Medium	Low	Low	Low	35.7%	CL
L-1	Low	Low	Low	Low	Low	Low	Low	28.2%	C
L-5	Low	Low	Low	Medium	VeryL	Low	Low	35.2%	SiCL
L-6	Low	Low	Low	Low	Low	Low	Low	37.9%	SiCL
L-7	Low	Low	Low	Medium	VeryL	Low	Low	39.8%	C
L-8	Low	VeryLo	Low	Low	Low	Low	Low	39.7%	SiC
L-9	Low	VeryLo	Low	Low	VeryL	Low	Low	43.2%	CL
L-10	Low	Low	Low	Low	VeryL	Low	Low	27.7%	C
L-11	Low	Low	Low	Low	Low	Low	Low	41.4%	C

Note: Abbreviation of the above three table: LB: light brown, DB: dark brown, GB; grayish brown, YB; yellowish brown, LRB; light reddish brown, GDB; grayish dark brown, DG; dark grey, B; brown, G; grey
RB: right bank, LB; left bank, HF; hill foot, IT; inside a valley of tributary, Mul.R; Mulganndo River, Rwa. R; Rwabishani River, Sata V.; Sata Village

3) Evaluation of soil test results

The results of soil test can be summarized as followed.

Table 2.2.2.31 Summary on the Result of Soil Test

Item	Result of tests and observation	Presumption of cause and mechanism	Influences to farming and countermeasures
pH(H_2O) Base saturation ratio	All test results indicate acidity as contrasted with neutrality (pH=7). Base saturation ratio of soil cations (base minerals) is low.	Leaching of base minerals by vertical infiltration of rainwater.	The analyzed range is still in an acceptable level for cropping. Further lowering remains depending on land use/ cultivation, often leading to deficiency of certain micro-nutrient elements because of lower water solubility in acidic media.
Organic Carbon	About 30% of the analyzed samples show very low level and the rest 70% also remains in low level, suggesting that low soil organic matter.	Faster decomposition rate of organic matter in the soil than supply rate from plant debris or organic fertilizers like manure. Slash-and-barn farming.	More than 5% is desirable. Hardness for cultivation, low water, mineral and other plant nutrient retention capacity due to weak formation of soil aggregates.
Total Nitrogen	All samples show very low level less than 0.5%.	Nitrogen content in soil tends to increase with organic matter content. The cause of low level is same as the reason of low organic carbon content. .	One of the most important plant/crop nutrients and it is desirable for arable soils to contain about 2%.
Available Phosphorus	The content is as low as 3-5ppm generally. Some samples show specifically as low content as 2ppm and some show as medium level as 5-7ppm.	Variation of the values might be caused by fertilization and influence of absorption by cultivated crops.	It is in an acceptable level for cropping. Supplemental fertilization is required for production of high quality grains and beans
Ca content	Content is as low as 1.7-2.5mg/100g.	Leaching of base minerals by vertical infiltration rainwater. Lack of decomposition of plant debris and livestock urines/droppings.	The content of more than 5mg/100g is desirable though present level is lowest. Low calcium content leads to low content of phosphorus.
K content	Content is as low as around 0.1-0.2mg/100g.	Leaching of base minerals by vertical infiltration rainwater. Lack of decomposition of plant debris and livestock urines/droppings.	Low level of potassium may affect yield of high potassium absorbing crops such as sweet potato, potato, groundnut and maize.
Cation exchange capacity(CEC)	Content is as a little low as around 9.0-13.0mg/100g.	Laterite originated soil.	It is in an acceptable level for cropping. More than 15.0mg/100g is desirable.
Soil texture	A half of samples have texture of Clay C, 30% of them have clay loam (CL) and the rest 20% belong to silty clay loam, sandy clay loam and silty clay.	Fine grained soil is reflected the soil texture produced by weathering of base rock on the Mesozoic and Proterozoic era.	Favorable soil structure for cultivation, though hardness of tillage in dry season may follow in the case of clay texture. Some measures for irrigation are necessary.

4) Issues and countermeasures on farming and soil management on these soils

(1) Issues and countermeasures for sustainable farming on these soils

As to soil pH, no particular measures have to be applied at the moment but if intensive farming is aimed on these soils, it can be recommended to rectify the soil reaction by spreading lime ($CaCO_3$) at the doze of 1ton/ha of lime to elevate pH by 0.1, until the soil pH is elevated to pH 6.5. If current pH is 5.2, 13ton of lime per hectare is needed.

As for measures for improving crop-nutrient retention of arable soils, various methods can be selected depending on resource availability: as direct measures soil dressing of arable top-soil with low utilized and under-utilized humus-rich wetland soils or swamp soils, etc. to enrich humus and available phosphate. Soil improvement by dressing is particularly effective in improving lateritic soils and soils of lateritic origin, because they have low CEC, in other words low nutrient retentive capacity. Active aluminum contained in lateritic red soils exerts detrimental effect on crop yields through the fixation of phosphoric acid and potassium converting them into non-available form to crop root system. Therefore, conducting soil improvement is recommended.

Further, as measures for soil-water retention, increasing doze of farm-yard manure or provision and application of compost coupled with micro-water harvesting by terracing works is effective. For enriching and improving soil fertility, introduction of agro-forestry into cropping parcels and grass-stripping along contour lines are in most cases useful. Compost preparation and application may be the cheapest way of improving humus deficit mineral soils since decomposition of organic matter (carbon) is rapid in such soils under tropical climate.

Natural vegetation available for the material of compost is not found around the Project site actually. Although people are prohibited to enter the marshland at present, papyrus which is native plant vegetated in marshland near the lake on downstream area may have a potential as the material of compost as one of possibilities.

As regards supply of nitrogen, introduction of agro-forestry is effective by nitrogen fixation of leguminous shrub tree species. Also, thriving leaves of leguminous agro-forestry species can be harvested to incorporate into compost. In the area where goats/ sheep herds graze it is the best way to employ not browsing species otherwise they are severely damaged by browsing before growing.

(2) Issues and countermeasures for controlling or minimizing soil erosion

Erosion caused by rainfall (annual rainfall is about 1,000mm) is not remarkable like Japan (annual rainfall is nearly 2,000mm). Outcrops are not found on valleys and gully-erosion on unpaved road is also unusual. However, cultivated soil of paddy field on valley composed of transported deposit, and malfunction occurs in some canals because of deposit. The result of analysis shows that cultivated soils on hillside have less organic content because the soil nutrition had been run off with surface flow of rain. Therefore, whole countermeasures against soil erosion as well as run-off of soil nutrition are necessary. Terracing works conducting as land husbandry project are regarded as suitable conservation measure.

(3) Relation between geological characteristics, soil and farming

Almost all the surface soil in this Project area is composed of sandy clay which is weathered from shale. Though it can be divided into two types whether it is produced by laterization or not, and it can be divided in two with high nutrition content through cultivation or low nutrition, conspicuous trend can not be seen due to lack of soil nutrition as a whole. The fact that laterization soil has particularly low content of organic carbon, available phosphorus and Ca ion should be noted. Soil improvement should be considered on farming planning since main soil in this Project area consists of laterite.

Table 2.2.2.32 Natural/ Indigenous Trees Useful for Land-husbandry and Agro-forestry

Family	Latin Name	English Name	Form	Usage and propagating methods

Family	Latin Name	English Name	Form	Usage and propagating methods
Rhamunaceae	*Ziziphus mauritiana*	Indian date	Bush tree	Tree belt, edible fruit, seedling plantation
Olacaceae	*Ximenia americana*	Citron of the sea	Bush tree	Shrub belt, edible fruit, seed &/or cutting
Rutaceae	*Casimiloa edulis*	Mexican apple	Low tree	Tree belt, edible fruit, seedling plantation
Rutaceae	*Citrus medica*	Common citron	Low tree	Tree belt, edible fruit, planted by cutting
Flacourtiaceae	*Dovyalis abyssinica*	Kei apple	2m - 6m	Live fence, edible fruit, seedling plantation
Leguminosae	*Tamarindus indica*	Tamarind	Low tree	Tree belt, edible fruit, seedling plantation
Leguminosae	*Erythrina brucei*	African coral tree	Low tree	Live fence, fuel-wood, planted by cutting
Boraginaceae	*Ehretia cymosa*	Puzzle bush	Bush tree	Shrub belt, furl-wood, seedling plantation
Papilionasae	*Gliricidia sepium*	Mexican lilac	Bush tree	Hedge-row, N. fixation, planted by cutting
Papilionasae	*Cajanus cajan*	Pigeon pea	Small bush	Hedge-row, N. fixation, direct sowing
Papilionasae	*Sesbania grandiflora*	Pea tree	3m - 10m	Edible pod, N. fixation, direct sowing
Mimosaceae	*Luecaena leucocephala*	Ipil-Ipil	Bush tree	Hedge-row, N. fixation, seed sowing
Moringaceae	*Molinga oleifera*	Horse radish tree	3m - 10m	Edible pod, fuel-wood, planted by cutting

Source: H project report V.8-2 and ICRAF: Tree species for agro-forestry

2-2-2-2-3 Design Policy of Terracing Works

Land husbandry is comprehensive slope land conservation project integrated with leveling of farm land by terracing works, soil amelioration by calcium hydroxide or compost, countermeasures for landslide by planting grasses or trees and drainage works for turbid water by constructing catch drain.

Subject area for land husbandry works can be divided into following four categories.

i) Water catchment area of reservoir

ii) Silt trap zone where grasses or trees shall be planted around the reservoir

iii) Command area catchment

iv) Command area

Secondary canals of PVC ϕ 50 and drainage canal (B=300mm) are planned to be constructed at 100m intervals each other along the direction of hillside slope. Terraces shall be constructed independent of these structures.

The structure of terracing works is shown below which is based upon design and construction control standard for land husbandry written by Dr. Azene.

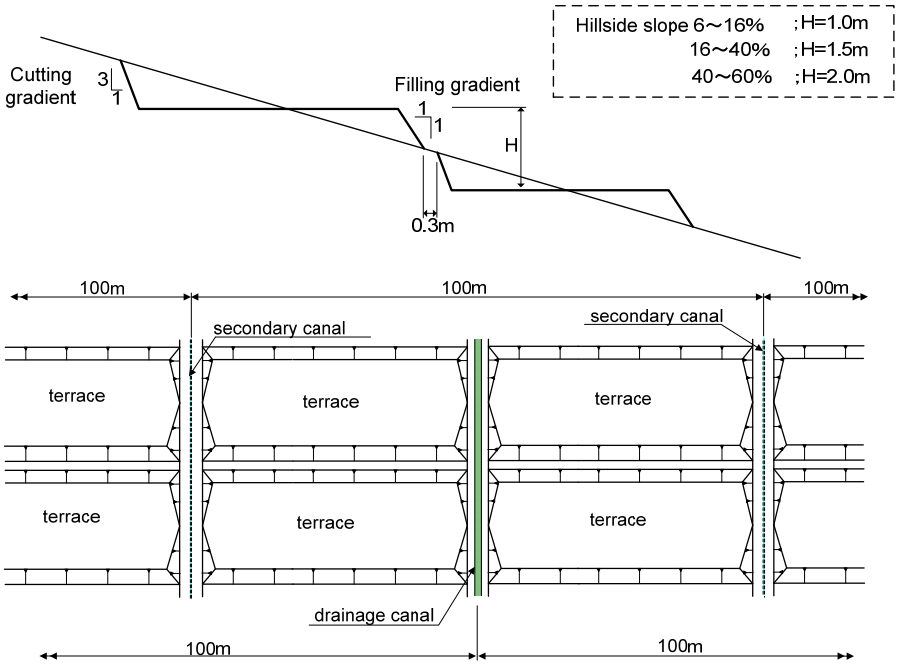


Figure 2.2.2.16 Basic Structure of Terracing Works