Ministry of Energy and Meteorology
Lesotho Highlands Development Authority (LHDA)
The Kingdom of Lesotho

DATA COLLECTION SURVEY ON SMALL-HYDROPOWER DEVELOPMENT PROJECT IN THE KINGDOM OF LESOTHO

FINAL REPORT

MARCH 2020

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

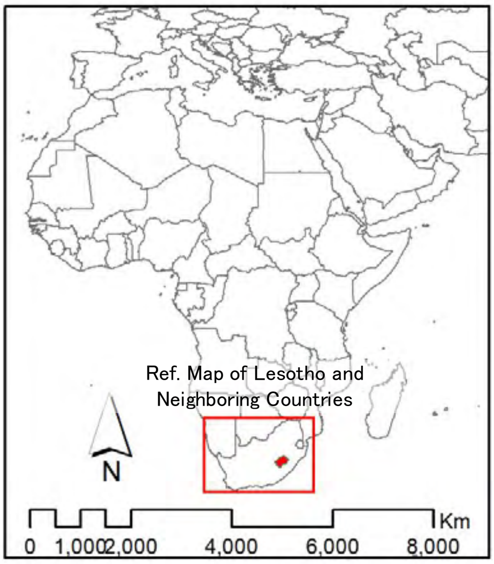
YACHIYO ENGINEERING CO., LTD.

IL
JR
20-018

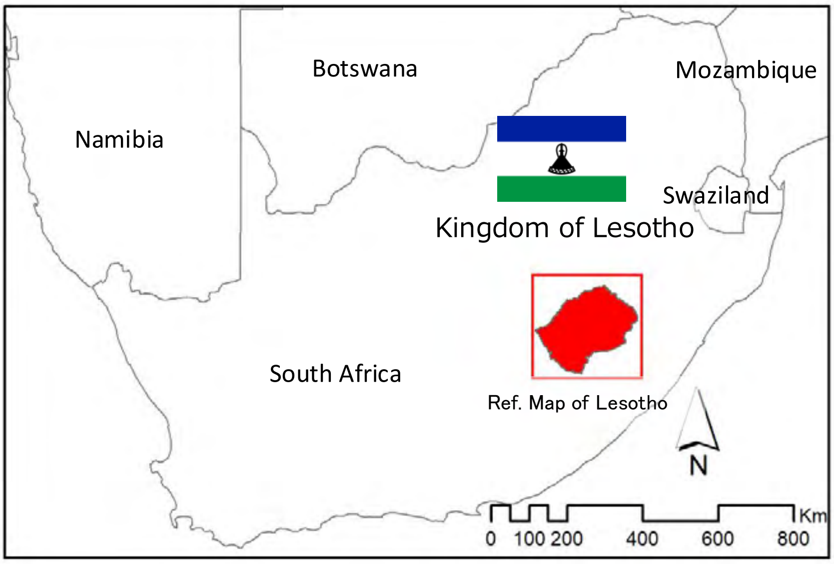
Contents

Appendix

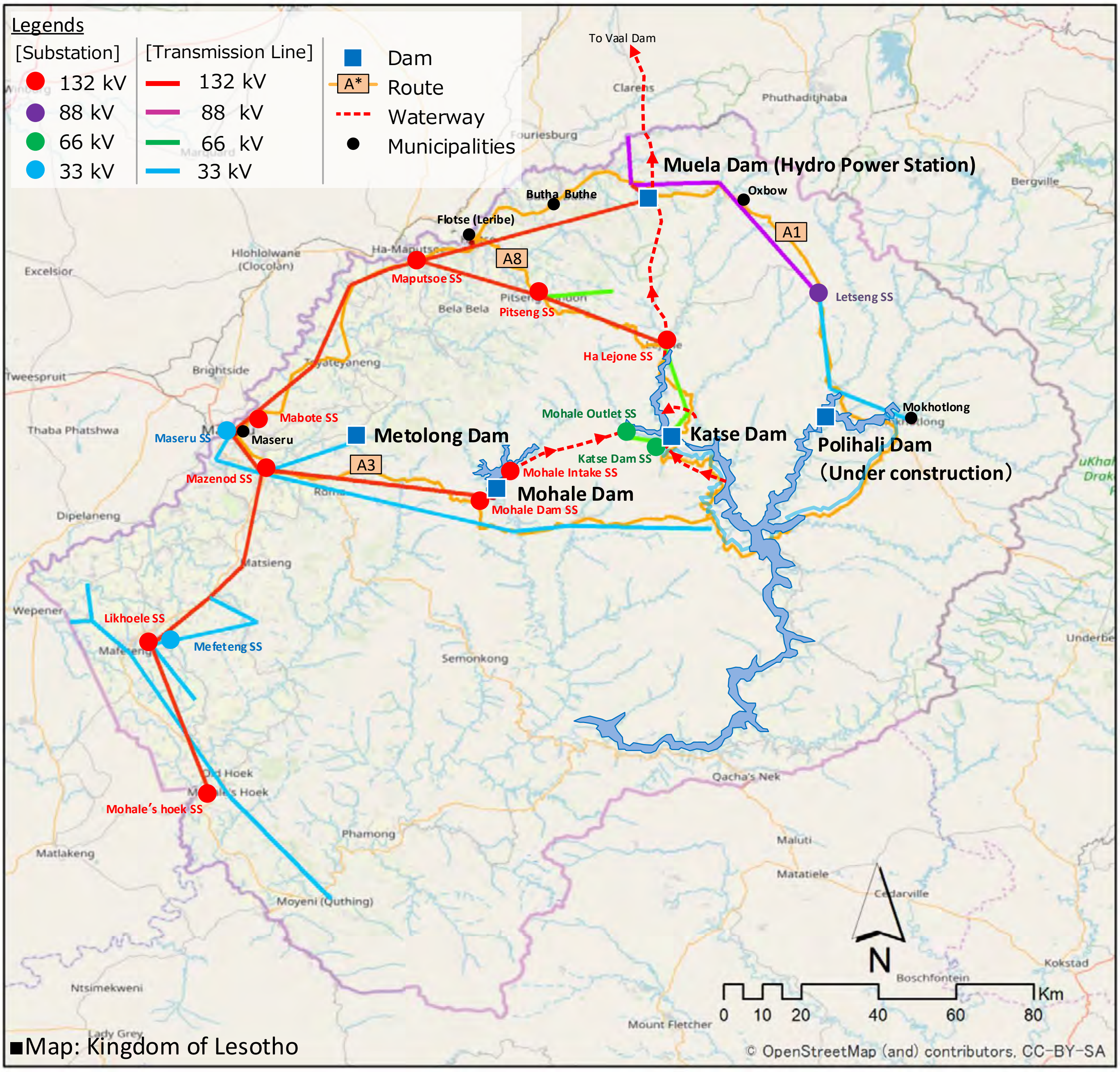
1. Member List of the Study Team
2. Study schedule
3. List of Parties
4. List of the Acquired Reference Materials and Data
5. Technical Memorandum
6. Lesotho Population data
7. Rainfall in each dam basin
8. Power system analysis data
9. IFR Presentation to Management
10. Water Level and Flow of Discharge
11. Project candidate site map



■ Map of Africa

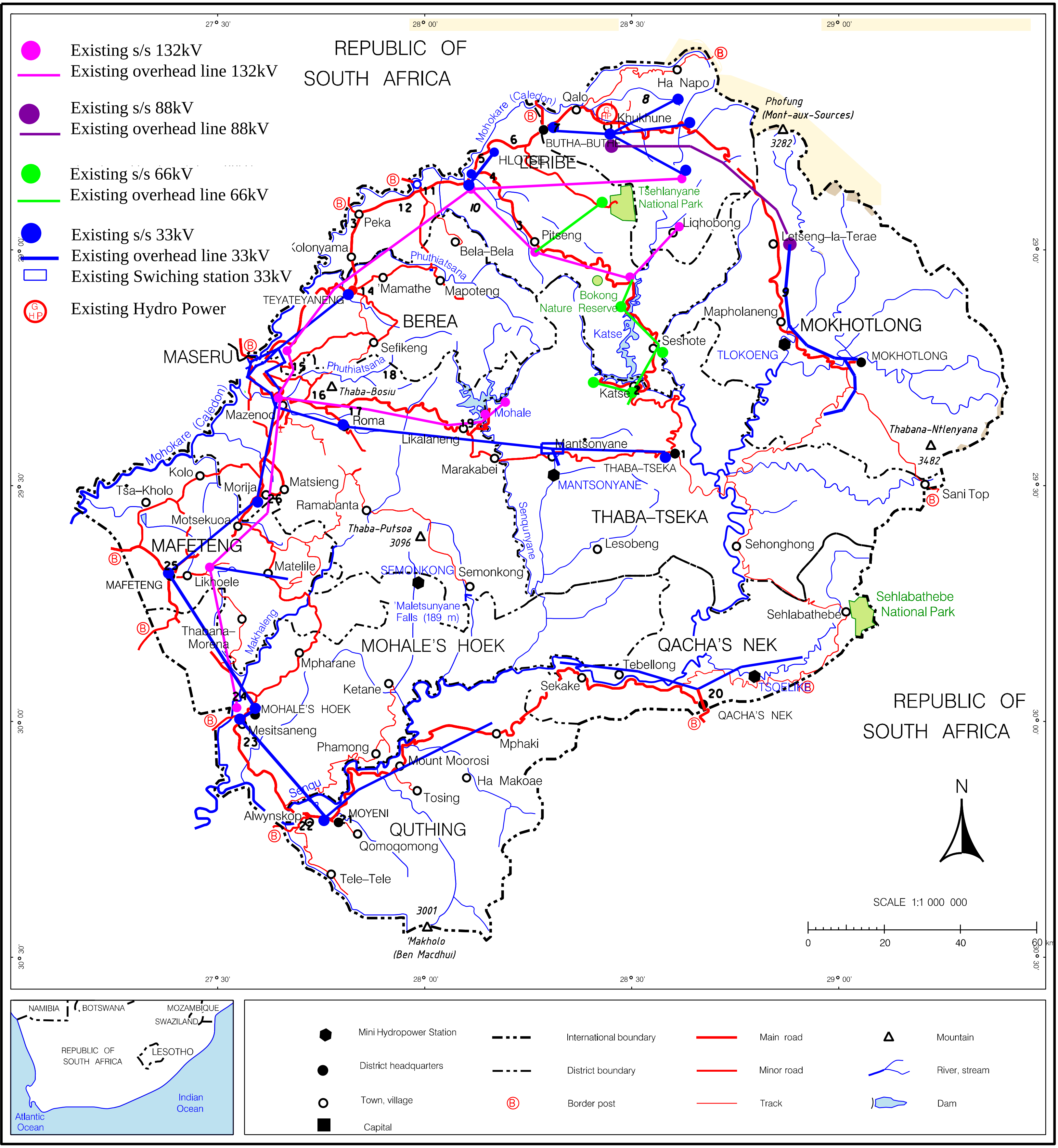


■ Map of Lesotho and Neighboring Countries



Location Map

LESOTHO



Prepared from Lesotho Map 1:750 000 (1977) by the Department of Lands, Surveys & Physical Planning (LSPP), P.O. Box 876, Maseru 100

Existing Network of Lesotho

Photos of the current situations in the survey areas (1/2)

Metolong dam

Gravity concrete dam for water supply managed by WASCO completed in 2016 under the Metolong Dam Water Supply Program (MDWSP)

(Nov. 27th, 2019)

Metolong dam discharge

Penstock for power generation branches from the downstream pipe of the two sets of discharge connection pipes. According to WASCO staff, the maximum discharge is 0.3 m^3/s.

(Nov. 27th, 2019)

Metolong dam discharge valve room

The discharge valve body and connecting pipe occupy most of the space, therefore no space to install new power generation equipment are given. (Nov. 27th, 2019)

Mohale dam

Rockfill dam completed in 2004 by LHWP Phase1B, managed by LHDA.

(Nov. 28th, 2019)

Mohale dam discharge

Compensation water discharge is made on three types of valves: φ200 mm, φ500 mm, φ1,400 mm.

(Nov. 28th, 2019)

Power generation facility compartment in the Mohale dam discharge valve room

One set of penstock end and turbine inlet valve is installed. Space for power generation facilities and overhead cranes for installation are available but their space are not enough.

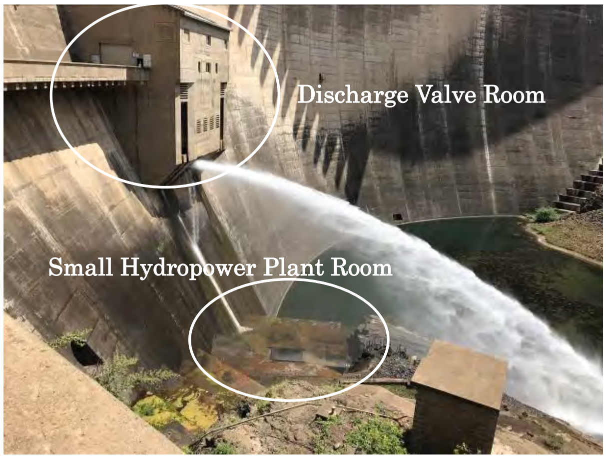
(Nov. 28th, 2019)

Photos of the current situations in the survey areas (2/2)

Katse dam

Arch type concrete dam are completed in 1996 by LHWP Phase1A, being managed by LHDA.

(Dec. 2nd, 2019)



Katse dam discharge

The small hydro power plant room is constructed below the discharge valve room. Vehicles cannot directly access the site without special facility. (Dec. 3rd, 2019)

Katse dam small hydro power plant room

The existing small hydro power plant (1 set) has been shut down due to flood damage. The space for the extension machine, the end of the penstock, and the water discharge pipe for connecting the draft tube are available. (Dec. 3rd, 2019)

Polihali Dam Construction Site

Completion is planned around 2026 by LHWP Phase II. Currently, detailed design and the construction of access roads to the site are underway.

(Dec. 4th, 2019)

Muela hydroelectric power plant turbine room

Underground hydroelectric power station with a total power 72 MW. The reservoirs of Katse, Mohale, and Matsoku dams are accessed by a water tunnel. The equipment kept very good condition despite 20 years from completion.

(Nov. 30th, 2019)

Discussion with power sectors on 26th November 2019

At the start of the site survey, the relevant organizations in the power sector (MEM, LHWC, LHDA, LEC, COW, LEWA) gathered to discuss the Inception Report and the study outline.

(Nov. 26th, 2019)

List of Figures & Tables

Abbreviations

AETS	Application Européenne de Technologies et de Services
AFD	Agence françise de développement
AGOA	African Growth and Opportunity Act
AfDB	African Development Bank
AU	African Union
CB	Circuit Breaker
CBO	Community-based Organization
CFRD	Concrete Facing Rock Fill Dam
COMESA	Common Market for Eastern and Southern Africa
COW	Commission of Water
DCS	Digital Control System
DOD	Department and Operation Division
DOE	Department of Energy
E/N	Exchange of Notes
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EIU	Economist Intelligence Unit
EMP	Electrification Master Plan
EWR	Environmental Water Requirements
F/S	Feasibility Study
GDP	Gross Domestic Product
GNI	Gross National Income
GRDP	Gross Regional Domestic Product
GSU	Generator Step Up Transformer
IPP	Independent Power Producer
JICA	Japan International Cooperation Agency
LEA	Lesotho Electricity Authority
LEC	Lesotho Electricity Company

LEWA	Lesotho Electricity and Water Authority
LHDA	Lesotho Highland Development Authority
LHWC	Lesotho Highland Water Commission
LHWP	The Lesotho Highlands Water Project
M/D	minute of discussion
MEM	Ministry of Energy and Meteorology
MOW	Ministry of Water
NCC	National Control Center
NGO	Nongovernmental Organization
ODA	Official Development Assistance
OPGW	Optical Fiber Composite Overhead Ground Wire
PLC	Power Line Carrier
PPA	Power Purchase Agreement
RC	Reinforced Concrete
RCC	Regional Control Center
REU	Rural Electrification Unit
RTU	Remote Terminal Unit
SACU	Southern African Customs Union
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SE4ALL	Sustainable Energy for All
TCTA	The Trans-Caledon Tunnel Authority
USAID	United States Agency for International Development
VAT	Value-added tax
WASCO	The Water and Sewerage Company
WB	World Bank

CHAPTER 1 INTRODUCTION

Chapter 1　Introduction

1-1　Background and the Purpose of the Survey

(1)　Background of the Survey

The Lesotho Highlands Water Project (LHWP) is a binational project between Lesotho (the Kingdom of Lesotho referred to as Lesotho) and South Africa (the Republic of South Africa referred to as South Africa). The project consists of a group of dams centered on the Katse Dam located in the center of Lesotho, and water is collected from the river to the Katse Dam through long-distance headrace tunnels. The project was launched in 1986 as a joint project between Lesotho and South Africa, where water was supplied via an underground tunnel to Vaal Dam in South Africa, 120 km away from the Katse Dam, and the Muela power plant located close to the Muela Dam, which generates electricity and supplies electricity to Lesotho. The government of Lesotho has made use of renewable energy resources in the country in response to the increase in power demand, has drafted a basic plan for self-sufficiency in power (Lesotho Energy Policy 2015-2025), and has sought widespread support from the international community. Under this background, Lesotho is examining the possibility of technical assistance through Japan's grant aid. Lesotho is expected to develop electric power by environmentally friendly hydroelectric power generation, and the data collection and confirmation study of the power sector in Lesotho concerning the project implementation is conducted in this study.

(2)　Purpose of the Survey

The purpose of this project is to collect information on the construction of environmentally friendly hydropower plants. This is to confirm the progress or feasibility of the construction, and to sort out the issues related to the construction of hydropower plants for existing dams of candidate, e.g., Katse, Mohale, Metolong and Polihali Dam, then propose possible countermeasures.

1-2　Investigation Process

In this survey, in addition to domestic work, two on-site works were performed. In the first on-site work, covering the period from 26th November 2019 to 13th December 2019, interviews with related organizations, information gathering, site reconnaissance of each site, consultation with Lesotho side, and the report of the site survey results by the study team were implemented. For the second field work, covering the period from 28th January 2020 to 4th February 2020, the draft final report was explained and discussed, and the report was finalized in the domestic reorganization work after returning to Japan.

CHAPTER 2 OUTLINE OF LESOTHO

Chapter 2 Outline of Lesotho

2-1 Politics and Economic Situation

2-1-1 Politics Situation

Lesotho is a constitutional monarchy. The present constitution came into force in 1993, shortly after the return to multiparty democracy, and was amended in 2001 to introduce an element of proportional representation. The monarch is head of state, the succession being ratified by the College of Chiefs. The Prime Minister is head of government and appoints a cabinet. The legislature has two chambers: the National Assembly which is elected for a five-year term, with 80 seats elected on a first-past- the-post basis, and 40 by means of proportional representation; and the non-elected Senate with 33 members, comprising 11 nominated by the monarch on the advice of the Prime Minister and the 22 principal chiefs of Lesotho.

Nonalignment and neutrality are the basic policy of diplomacy of Lesotho. It has joined the African Union (AU), Southern African Customs Union (SACU) and Southern African Development Community (SADC) in addition to the British Commonwealth, but it left the Common Market for Eastern and Southern Africa (COMESA) in 1997. Lesotho is working to promote regional cooperation.

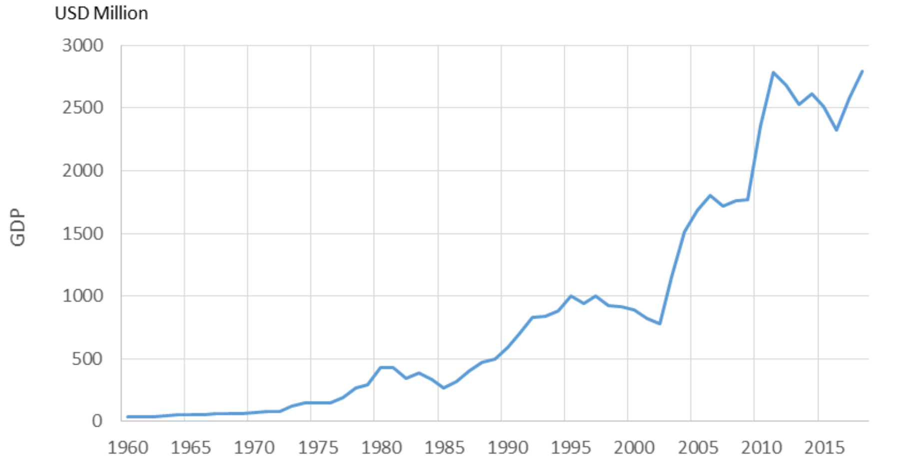
2-1-2 Economic Situation

Water is the most economically important resource in Lesotho, and hydropower is used for power generation. The annual GDP growth rate averaged 4 % in 2006-2016, but it fell to 2.5 % in 2016 due to the drought and the slowdown in the global economic growth. The main industries in Lesotho are manufacturing (reproduction of tires, textile industry, diamond mining, shoes, electric light, candles, ceramics, explosives, furniture, and fertilizer)[1], agriculture (maize, wheat, sorghum) and construction. In the manufacturing industry, clothing and shoes for South Africa and the US (accounting for about 70% of its exports) are the main products. Lesotho's trade balance has been in the red for three consecutive years from 2016 to 2018 and is expected to be in the trade deficit for the next three years[2].

Since the 2000s GDP is growing and LHWP is leading the economy, including the construction industry. Figure 2-1.1 shows the transition of GDP in Lesotho. The project was started in 1986 after the Lesotho-South African government signed an agreement on the joint construction and export of water resources to South Africa. As of December 2019, the detailed design of the Polihali Dam is ongoing as Phase II.

Lesotho, together with South Africa, Botswana, Namibia and Swaziland, has formed SACU. These countries are the major trading partners of Lesotho (more than 95 % of the total imports are trade with SACU (2013: Economist Intelligence Unit: EIU)), and subsidies from SACU account for about 50 % of Lesotho's financial revenue (2013: Lesotho Annual Financial Report).

[1] www.nationsencyclopedia.com/Africa/Lesotho-INDUSTRY.
[2] Economic Outlook 2019-2021, Central Bank of Lesotho

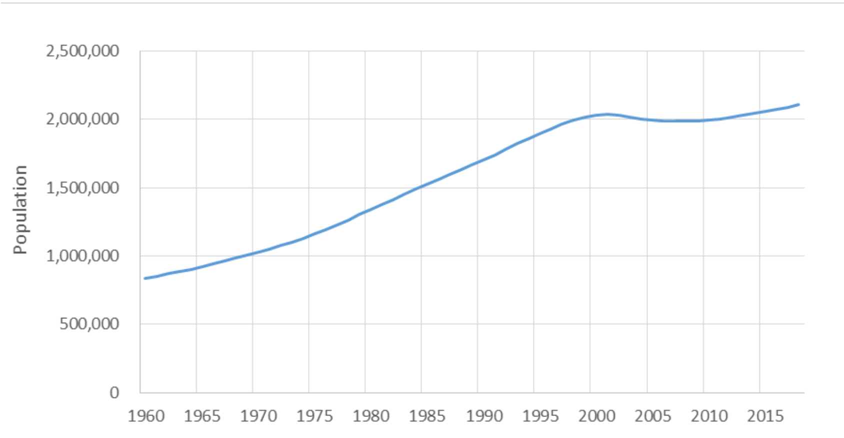


Source：World Bank

Figure 2-1.1 Trends of GDP in Lesotho

2-2 Social Situation

Lesotho is a country with a population of about 2.1 million as per census of Lesotho in 2016, the trend of the total population of Lesotho is shown in Figure 2-2.1. The population is concentrated in the plains and hills near the eastern border with a population of about 1.3 million. The population around the mountainous area, which is the target site of this project, is small, and those people are mainly living in agriculture and nomadism with a population of about 0.8 million. The official language is English, but some rural people do not speak English. Most of the people are Christians, and Sunday is a Sabbath and most shops and offices are closed. Population statistics data is shown in appendix-6.



Source: World Bank

Figure 2-2.1 Trends of Population in Lesotho

2-3 Geography and Climate

Lesotho is a country located in southern Africa (approximately 29° 30' south latitude 28° 30' east longitude) with a land area of 30,000 km^2. It is the only independent country in the world with an altitude of 1,000 m or higher. Almost all of the mountainous area is composed of outcropped rocks, and there is almost no topsoil, so no large trees can be seen, but weeds or shrubs can be seen on the mountain surface on collapsed rock masses. It is to some extent that large trees can be seen in some places. For this reason, it is thought that the rainwater holding ratio of the mountain is low, and in the dry season, the location where the stream flows is very limited. The highest point is Mt. Thabana Ntlenyana, which reaches an altitude of 3,482 m above sea level, thus the climate of Lesotho is cooler year-round than other regions at the same latitude. The capital Maseru and lowlands often reach 30 °C in summer and -7 °C in winter.

85 % of the annual rainfall occurs during the rainy season from October to April, with occasional floods. Winter is usually dry, but there is snowfall at the summit. Fluctuations in annual precipitation have led to periodic droughts in the dry season. Rainfall data in the last 10 years and Location map of rain gauges are shown in Appendix-7 of LHDP. According to the rainfall data since 1991, the annual rainfall in the Mohale, Katse, and Polihali basins is about 700-900 mm, and the annual rainfall in the Muela basin, located north of Katse, is about 1,400 mm. However, comparing the rainfall data for 1991-2009 and 2010-2019, the Mohale basin has decreased by about 200 mm per year in the last 10 years, the Katse basin has kept almost the same amount, the Polihali basin has decreased by about 100 mm per year. In the Muela basin, there is a tendency to decrease by about 150 mm per year. In particular, the decrease in rainfall in the Mohale basin is remarkable, and considering the amount of water in the Mohale Dam reservoir, the amount of water will drop by about 8.5 m per year.

(Calculation)

Annual rainfall: 200 mm (0.20 m)
Mohale Dam basin area: 938,000,000 m^2
Mohale Dam Reservoir area: 22,100,000 m^2
Mohale Dam Reservoir equivalent water level: 0.20 x 938,000,000 / 22,100,000 ≒ 8.5 m

In addition, the water of the Mohale Dam is sent to the Katse Dam, and since the amount of rainwater in the Katse basin is almost the same, the Katse Dam water level will drop about 5.3 m per year because of the decrease in the rainfall in the Mohale basin.

(Calculation)

Katse Dam reservoir area: 35,800,000 m^2
Katse Dam reservoir equivalent water level: 0.20 x 938,000,000 × 35,800,000 ≒ 5.3 m

In recent years, the water level of the dam has been declining due to the decrease in rainfall. In 2019, both the Mohale Dam and Katse Dam recorded the lowest water level ever since the dam was constructed. The monthly rainfall data shows that the rainfall from August to November is decreasing at most of the observatories, and the other months are the same as normal, and the dry season tends to be prolonged.

The basic data of the political economy, social situation, geography and climate in Lesotho is shown in Table 2-3.1.

Table 2-3.1 Basic Data in Lesotho

Land area		30,000 km^2
Population		2,100,000（2018, WB）
Capital		Maseru
Ethnic Groups		Sotho
Language		English (Common Language), Sesotho (Common Language)
Religion		Christianity (for the most part)
Currency		Loti (plural: Maloti) , (The LSL is pegged on par with the ZAR)
Major Industries		Manufacturing, Agriculture (maize, wheat, sorghum), Construction
Gross National Income (GNI)		3.13 Billion USD (2018, WB)
GNI per capita		1,380 USD (2018, WB)
Economic Growth Rate		1.5 % (2018, WB)
Price Increase Rate		6.0 % (2018, WB)
Unemployment Rate		23.5 % (2018, WB)
Trade Value（2018：EIU）	Export	1,221.1 Million USD
	Import	1,931.5 Million USD
Major Trading Items	Export	Clothing, diamond
	Import	Industrial products, food and livestock, machinery products
Major Trading Partners（2018：EIU）	Export	USA (32.6 %), Belgium (31.5 %), South Africa (23.9 %), UAE (4.0 %)
	Import	South Africa (87.5 %), China (4.3 %), India (2.1 %), Japan (0.7 %)

Source: Ministry of Foreign Affaires

2-4 Environment

The Environmental Law was enacted in 2008, and the Ministry of Tourism, Environment and Culture issued the "Environmental Impact Assessment Guidelines (2016)" (hereinafter referred to as EIA) based on the law.

The purpose of the EIA is primarily to promote the participation and compliance of project developers in Lesotho's environmental impact assessment projects, including those in Lesotho's National Environmental Policy 1998, Environmental Law 2008, and EIA Regulations. It is intended to integrate environmental issues and economic development from the early stages of project development, as described as follows;

- Incorporate environmental considerations into the development plans and thereby promote sustainable living.
- Ensure that the environmental and socio-economic costs and benefits of the economic development projects are properly considered.
- Ensure that undue negative impacts are avoided or mitigated early in the planning process.
- Ensure that potential benefits are identified and enhanced.
- Conduct environmental and socio-economic studies of the project in parallel with the engineering and economic feasibility analysis.
- Ensure that decision makers are provided with information on environmental costs and benefits to complement information on technical and economic feasibility at the decision making points in the project development.
- Ensure that all affected groups (local communities, government authorities, developers, NGOs, CBOs, etc.) participate in the process.
- To set up systems to perform mitigation, monitoring, auditing, and enforcement.
- Promote cooperation between departments.

In addition, the target group of the EIA is formed as follows.

- A project developer, general or private sector
- Department of the Environment (organization within the Ministry of Tourism, Environment and Culture)
- General society
- Consultant, others
- NGOs, CBOs and other civil society organizations

In Lesotho, consultants have established some minimum requirements for conducting an Environmental Impact Statement (EIS), and the staff of Department of the Environment recommends using a local consultant company that meets these requirements. It is necessary to obtain a license for environmental impact assessment. Relevant environmental issues include changes in the land use, impacts on the water bodies, air, soil, socio-economic and cultural impacts. For EIA related to energy business, it is basically necessary to submit a Project Brief. The guideline is EIA only, but the guideline does not describe the specific standards for the water volume (including the maintenance flow rate). The amount of water requires the permission of the Ministry of Water (MOW).

The current environmental issues at this project site include:

- Water shortage
- Climate change
- Reduction of dam water storage
- Blockage of headrace tunnel due to sedimentation of dam

Whereas, there is no problem at present such as environmental release.

When an EIA license is required, there are the following application steps.

Step 1: Conceptual discussion (discussion with relevant ministries or Department of the Environment)
Step 2: Choose an expert (expert approved by Department of the Environment).
Step 3: Prepare the project outline (including environmental impact).
Step 4: Submit a project summary.
Step 5: Review by the project outline by Department of the Environment.
Step 6: Prepare the survey scope and standards for the environmental impact studies.
Step 7: Approval of EIA consultant by Department of the Environment.
Step 8: Prepare the Environmental Impact Study.
Step 9: Submit an environmental impact assessment report.
Step10: Review of environmental impact assessment report by Department of the Environment.
Step11: Hearing.
Step12: Issuance EIA license by Department of the Environment.
Step13: Appeal Options

However, according to the Lesotho Highlands Development Authority (LHDA), for the development of small hydropower station on the existing dams, new EIA will not be required as all the relevant dams already have standing EIA approved. In this study, the EIA report at the time of construction was obtained (*cf.* Attachment-4, Source: LHDA), and the description on the environmental flow discharge was confirmed. At the time of the preparatory survey for this project, it is necessary to confirm the EIA report with the counterpart organization after the project planning to confirm the necessity of reacquiring the EIA.

2-5 Tax exemption and Procedure

After checking the tax exemption procedure with the Ministry of Finance, tax exemption is basically possible. There is no change from the latest cooperation practice of Japan. The specific procedure flow is as follows.

- It is necessary for the Ministry of Energy responsible for each project to budget the customs duties in advance. Normally referred a budget is provided by Lesotho Government through Department of Energy and is referred to as “counterpart funding” for meeting any customs and excise duties for the project.

- It is necessary to consult the Cabinet beforehand regarding the budget.

For this reason, when this plan is realized, it is difficult to confirm in advance to be deliberated at the Cabinet meeting, and it may take time regarding the implementation of implement the project. If this plan is realized, it is necessary to pay attention to the risk as to whether the project will be completed within the E/N (Exchange Notes) deadline.

2-6 Japan’s aid trends

Table 2-6.1 shows the projects that have been implemented with Japan's grant aid.

Table 2-6.1 Grant Aid Results (Energy and Electricity)

Implementation year	Name of Project	Project Cost (Unit: Million Yen)	Project Contents
2011~2012	The Project for Introduction of Clean Energy by Solar Electricity Generation System in Lesotho	300	1) Complete solar power generation system (solar panels (total 280 kW) (Battery panel mounting stand, power conditioner, measurement and monitoring device, weather observation device, display, etc.) 2) Consulting Services / Soft Component Content: Grid connection type (SHS type), basic knowledge about solar power generation system and maintenance inspection, emergency response Training on operation and maintenance

Source: HP of Ministry of Foreign Affairs

CHAPTER 3 CURRENT STATUS OF THE POLICY AND THE PLAN FOR THE ENERGY AND POWER SECTOR

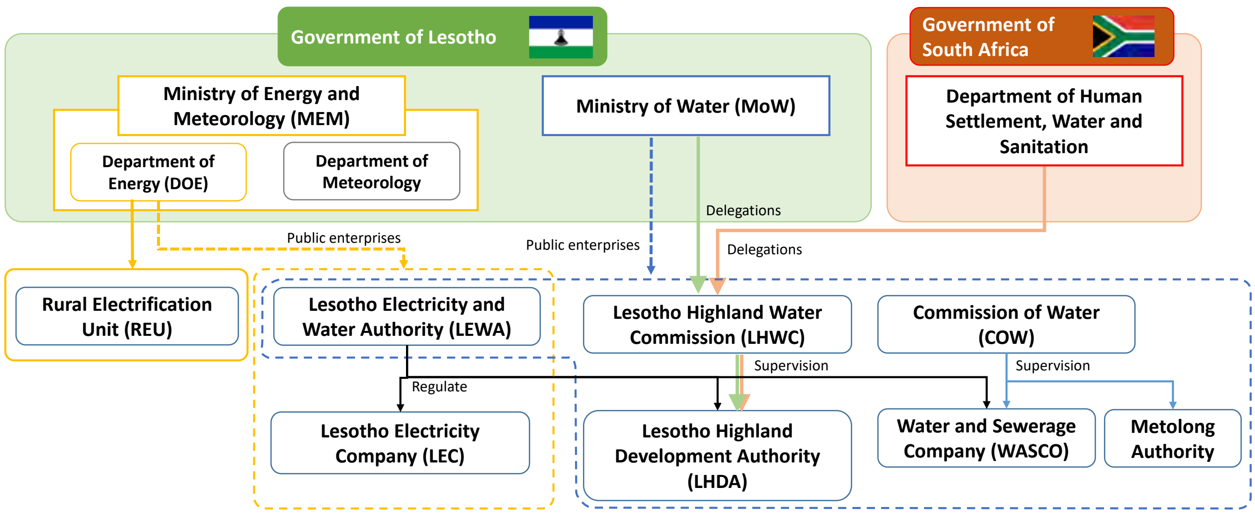
Chapter 3 Current Status of the Policy and the Plan for the Energy and Power Sector

3-1 Current Status of the Energy and Power Sector

As for the power supply of Lesotho, the 72 MW Muela hydropower plant is almost the only power source. Lesotho relies heavily on imports of electricity from Mozambique, Southern African and SAPP to meet its electricity demand. The domestic power demand continues to exceed 72 MW, which is the generation capacity of the Muela hydropower plant, so the amount of imported electricity is over 60 % of the power consumption of Lesotho. Lesotho has recorded a household connection rate of 38.5 % (World Bank in 2017). Under these circumstances, to achieve the goal of Sustainable Energy for All (SE4ALL) as the UN initiative, FORMULATION OF THE LESOTHO ELECTRIFICATION MASTER PLAN (EMP) was formulated. Lesotho encouraging the private sector and local governments to enter the power business to improve power generation capacity and low electrification rate. However, since 2008 independent power producers (IPPs) have been requesting interconnection with transmission and distribution network and market opening for renewable energy generation development.

3-1-1 Power Sector Related Organizations

The main organizations related to the power sector are as follows: Ministry of Energy and Meteorology (MEM), Department of Energy (DOE), Lesotho Electricity and Water Authority (LEWA), Lesotho Electricity Company (LEC), the Lesotho Highlands Development Authority (LHDA), and the Rural Electrification Unit (REU). The relationship between each organization is shown in Figure 3-1.1.



Source: JICA Study Team

Figure 3-1.1 Structure of Power Sector Organizations in Lesotho

(1) Lesotho Electricity and Water Authority (LEWA)

LEWA of the predecessor of Lesotho Electrical Projects Agency (Lesotho Electricity Authority: LEA) is an electric utility regulatory body, which was established by the electric Projects Agency Act in 2002.

LEA was re-named LEWA that was integrated with the water business in 2013 and officially started regulating both the electricity and the urban water and sewerage services sector as LEWA. In 2006, LEA issued a combined business license of power transmission, distribution and sales to LEC, and a power generation business license to LEC and LHDA. One of the responsibilities of LEWA is to collect, publish, and disseminate information on the performance standards by licensees and information on the power sector in Lesotho for the power industry, consumers and future investors.

(2) Lesotho Electricity Company (LEC)

LEC was established in 1969 in terms of the Lesotho Electricity Act of 1969. The LEC is authorized to manage power generation, transmission, distribution and power supply businesses. LEC generates its power through the small Hydropower generation system, etc., which is very small, 0.1 %[1] of the total maximum power demand in Lesotho. The bulk of the power supply is generated by LHDA and imported from South Africa (Eskom) and Mozambique (EDM).

The transmission and distribution business is basically handled by LEC. It relies on power from Muela Hydropower Station and imports, and LEC supplies power to the distribution network through three receiving substations: Mabote, Peka, and Hendriks Drift.

(3) Lesotho Highland Water Commission (LHWC)

The Lesotho Highlands Water Commission (formerly the Joint Permanent Technical Commission) was established by the Treaty of 1986 signed between Lesotho and South Africa on the implementation of LHWP. The LHWC is composed of two delegations, one from each Party to the Treaty (Lesotho and South Africa). The LHWC monitors the activities of the LHDA and Trans-Caledon Tunnel Authority (TCTA) against milestones and performance indicators agreed with the relevant boards, and oversees the activities of the LHDA and the TCTA. The LHWC as a body reports to the two Governments, through their Designated Authorities: Ministry of Water in Lesotho and Department of Human Settlement, Water and Sanitation in South Africa.

(4) Lesotho Highlands Development Authority (LHDA)

The LHDA is the executing agency of the LHWP within Lesotho. The Muela hydropower plant which is the only large-scale power source in Lesotho is owned by Lesotho Government and operates by LHDA. The power plant was built in the 1990s as part of the LHWP, and all of the generated electricity is sold to LEC under the power sale agreement. The Katse Dam, Mohale Dam and Polihali Dam are within the scope of LHWP, and when the generation facilities under this study are installed, LHDA will be the executing agency of the project and will carry out maintenance after the start of operation.

(5) Rural Electrification Unit (REU)

REU was established in 2003 under the Department of Energy and is responsible for the electrification

[1] The Ratio of 2.18 MW of LEC small hydro power plants to maximum power demand of 167 MW (Source: LEC Annual Report 2016/2017)

projects outside the LEC grid supply area. Electrification for the off-grid area is carried out with subsidies from the Government.

(6) Water and Sewerage Company (WASCO)

Water and Sewerage Company (WASCO) is a parastatal enterprise that was duly established under the Water and Sewerage Company Limited Act, 2010 enacted by the Parliament of Lesotho, and operates and manages the water and sewage systems in Lesotho. Metolong Dam is managed by WASCO, where the small hydropower station is considered under this programme.

3-1-2 Current Status of the Power Demand and Supply

(1) Current Status of the Power Demand

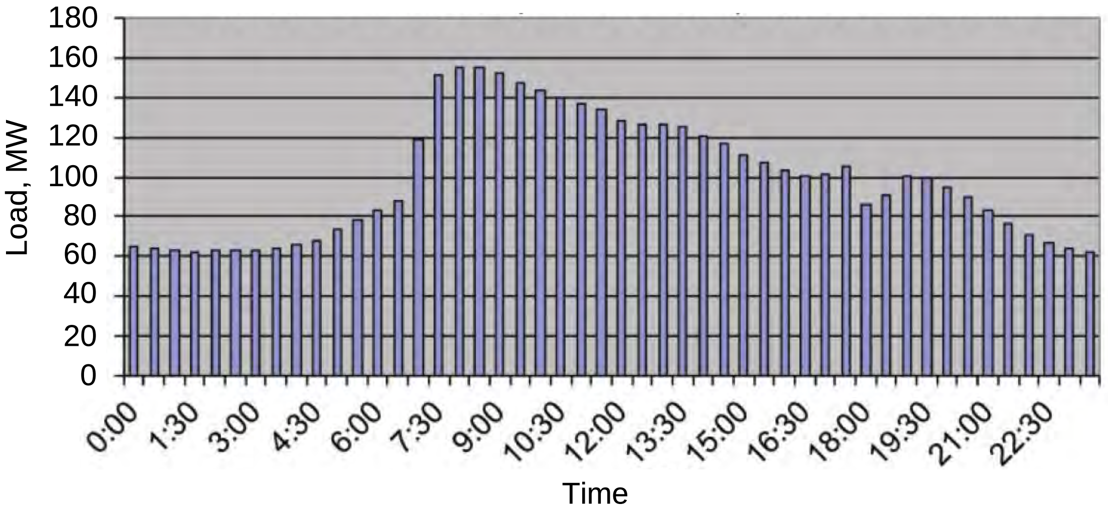
The electrification rate in Lesotho has improved rapidly in recent years and the power demand has increased drastically. Table 3-1.1 shows the trends in LEC's customers and the power demand. In the last six years from 2010/11 to 2016/17, 113,912 customers have been interconnected to the new grid. The average number of new customers per year was increasing rapidly, from 5,105 in 2006, compared with 15,608 in 2017. By customer category, pre-paid domestic customers account for the majority of the number of customers, but industrial customers accounted for the majority of the power consumption.

Table 3-1.1 Trends in LEC's Customers and Power Demand

	1986	1996	2006	2011	2016/17
Number of Special Domestic Consumers	5,278	8,462	16	5	5
General Purpose Special	2,028	2,972	38	30	24
Commercial	67	90	153	203	240
Industrial	39	86	160	150	218
LHDA		18	9	10	11
Pre-paid Domestic		2,000	43,747	97,859	207,584
Pre-paid General Purpose			5,061	7,263	11,217
Total Number of Consumers	**7,412**	**13,628**	**49,184**	**105,520**	**219,299**
Average annual increase in connections	551	1,105	5,105	16,205	15,608
Hereof pre-paid domestic consumption (MWh)			104,619	193,210	239,613
Pre-paid General Purpose (MWh)			62,217	89,728	87,642
LHDA (MWh)		41,786	7,877	6,098	7,488
Industrial (MWh)	14,936	63,588	153,118	217,964	256,247
Commercial (MWh)	32,207	75,700	78,800	104,887	135,834
Total Consumption (MWh)	**111,393**	**302,800**	**414,402**	**614,868**	**731,873**

Source: LEC Annual Report

Figure 3-1.2 shows the transition of the load on October 1, 2016. The peak load recorded at around 9:00 am is more than 150 MW, which is more than twice as much as the load recorded at night.



Source: LEC Annual Report 2016-2017

Figure 3-1.2 Day of Peak Load (1st Oct 2016)

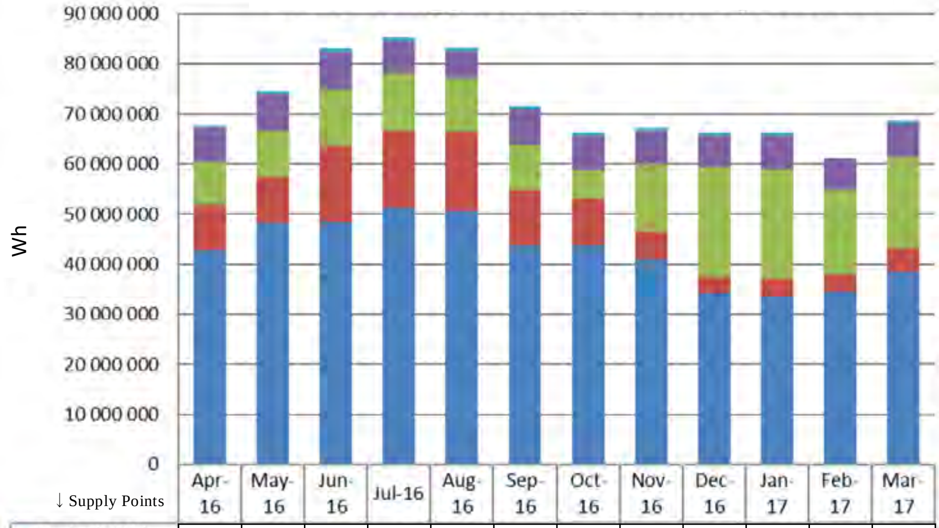
(2) Current Status of the Power Supply

The power source owned by LEC is a small amount. LEC purchases most of the power from the suppliers. The power purchase status of LEC is shown in Table 3-1.2, and the monthly power purchase is shown in Figure 3-1.3. As shown in Table 3-1.3, LEC purchases 535 GWh (59 % of the amount of power) from LHDA. The purchase price from LHDA is set low, so the purchase cost from EDM and ESKOM accounts for 86 % of the total. Furthermore, as shown in Figure 3-1.2, the maximum power demand in Lesotho has been increasing year by year, but the power generation capacity has not changed. That makes the shortage of power more serious.

Table 3-1.2 LEC Power Purchase Status

Supplier	2016/2017		2015/2016	
	kWh	Amount (Maloti)	kWh	Amount (Maloti)
LHDA	534,874,713	57,288,125	520,805,448	60,126,436
ESKOM MSU	181,436,340	152,823,788	114,105,793	111,626,071
ESKOM Clarens	78,703,117	58,536,728	81,199,101	55,327,946
ESKOM Qacha Suek	8,220,617	9,934,443	7,220,578	8,532,090
EDM	105,176,000	139,926,736	72,102,000	106,417,311
Total	**908,410,787**	**418,503,820**	**795,432,920**	**342,029,854**

Source: LEC Annual Report 2016-2017



↓ Supply Points	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17
Qacha (KWh)	501	686	771	773	752	692	670	670	604	637	1516	562
Clarens (KWh)	6,716	7,186	7,444	6,226	5,232	6,935	6,849	6,624	6,181	6,596	6,073	6,595
Msu Bulk (KWh)	8,647	9,360	11,135	11,587	10,851	9,268	5,721	13,666	22,015	21,897	17,015	18,264
EDM (KWh)	9,055	9,021	15,225	15,500	15,680	10,965	9,255	5,410	3,230	3,720	3,360	4,805
Muela (KWh)	42,803	48,344	48,484	51,239	50,763	43,717	43,883	40,970	34,252	33,453	34,574	38,444

Source: LEC Annual Report 2016-2017

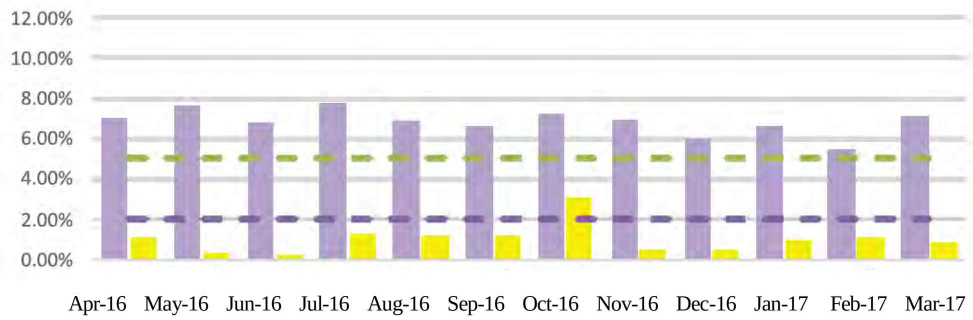
Figure 3-1.3 LEC Monthly Power Purchases

Table 3-1.3 Lesotho Maximum Demand Profile

Year	Maximum Demand (MW)	Installed Capacity (MW)	Imported Capacity (MW)	Capacity Deficit (%)
2012/13	147	74.7	72.9	49
2013/14	143	74.7	68.3	48
2014/15	149	74.7	74.3	50
2015/16	153	74.7	78.3	51
2016/17	162	74.7	87.1	54
2017/18	167	74.7	92.2	55

Source: LEWA Annual Report 2017-2018

In terms of power supply quality, LEC has some problems. As shown in Figure 3-1.4, voltage fluctuations exceed 5 % of the target value. Furthermore, the number of power outages is as frequent as 415 times per year as shown in Table 3-1.4.



	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17
max. dHV(%)	6.90%	7.51%	6.74%	7.58%	6.81%	6.49%	7.12%	6.83%	5.90%	6.52%	5.40%	6.98%
max. df(%)	0.97%	0.25%	0.11%	1.19%	1.12%	1.09%	3.03%	0.30%	0.33%	0.90%	0.94%	0.80%
Target dHV(%)	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Target df(%)	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%

Source: LEC Annual Report 2016-2017

Figure 3-1.4 Voltage and Frequency Deviation

Table 3-1.4 Number of Power Outages

Month	Total Number of Outages	Number of Outages (Within 4 hours)	Number of Outages (Within 24 hours)	Number of Outages (beyond 24 hours)
Apr-2016	25	20	5	0
May-2016	27	23	4	0
June-2016	20	14	6	0
July-2016	48	34	14	0
Aug-2016	30	21	9	0
Sep-2016	33	29	4	0
Oct-2016	28	25	3	0
Nov-2016	53	50	3	0
Dec-2016	9	9	0	0
Jan- 2017	59	56	3	0
Feb-2017	53	48	5	0
Mar-2017	30	26	4	0
Annual Total	**415**	**355**	**60**	**0**

Source: LEC Annual Report 2016-2017

The transition of power transmission loss is shown in Figure 3-1.5. Transmission loss has remained at 9-17 %. The Annual Report states that LEC has improved transmission loss due to measures taken against theft and the analysis of power demand by region. However, it has been almost the same over the past two years.

Source: LEC Annual Report 2016-2017

Figure 3-1.5 Trend of Losses

(3) Existing Power Facilities

1) Applicable industry Standards

Industrial standards applicable to the Hydropower facilities in Lesotho are as follows.

a) There is no industrial standard specific to Lesotho.

b) The world standard IEC is applied to the main turbines and generators.

c) Not only international standards such as IEC and ISO, but also European standards such as DIN and BS are applied to electrical / mechanical devices and parts other than the main engine. These standards are general standards for overseas hydropower plants.

2) Power System

The figure at the beginning of this report shows the existing network of Lesotho. The trunk power system in Lesotho is a 132 kV system, which is connected to the ESKOM power grid in Free State of South Africa. LEC has four voltage classes for transmission: 132 kV, 88 kV, 66 kV, and 33 kV. The power generated in Muela HPP, which is the largest hydropower station in the country, is transmitted to the major cities through the 132 kV trunk power system. The power transmission between regions utilize both 66 kV and 33 kV voltage classes. Data required for system analysis when the hydropower plant of this project is extended to the existing power system was obtained from LEC as shown in Appendix-8 (Power system analysis data).

3) Generation Facilities

Other than the Muela hydropower plant, which is operated by LHDA, there are small hydropower plants (Mantsonyane: 2,000 kW, Semonkong: 180 kW), which are operated by LEC. But in the dry season there is insufficient river water and the operation is stopped, and the alternative operation is performed by diesel generators. List of existing generation facilities is shown in Table 3-1.5 and the location of them are shown in Figure of the beginning of this report.

Table 3-1.5 List of existing generation facilities

Generation facilities	Generation Capacity	Operational status	O&M Organization
Muela	72MW	Operate	LHDA
Mantsonyane	2MW	Operate (In dry season, alternative operation by diesel generators.)	LEC
Semonkong	0.18MW	Operate (In dry season, alternative operation by diesel generators.)	LEC
Others（Diesel or PV）	Approximately 0.5MW	-	LEC, DOE etc.

Source: JICA Study Team based on LEC Annual Report 2016-2017

4) Substation Facilities

Table 3-1.6 shows a list of existing substations and transformers in Lesotho. There is a total of 47 substations with 132 kV, 88 kV, 66 kV, and 33 kV substations on the primary side, and 9 substations of them are 132kV substations on the primary side. Most of them have a 1-line configuration, and in the event of an accident or overhead line construction, a long-term blackout is inevitable.

Table 3-1.6 List of Existing Substations and Transformers

Substation	Transformer Voltage (kV) , Capacity (MVA)	Manufacturing Year	Impedance (HV-MV)	Configuration	Cooling Method
Pioneer	Transformer 33/11 kV, 10 MVA	1987	7.48	YNyn0	ONAN
	Transformer 33/11 kV, 10 MVA	1980	9.88	YNyn0	ONAN
Thetsane	Transformer 33/11 kV, 20 MVA	2002	7.71	YNd1	ONAN
	Transformer 33/11 kV, 20 MVA	2001	7.80	YNd1	ONAN
Tikoe	Transformer 33/11 kV, 10 MVA	2002	7.42	YNd1	ONAN
	Transformer 33/11 kV, 10 MVA	2002	7.42	YNd1	ONAN
Mazenod Transmission	Transformer 132/33 kV, 40 MVA	1992	12.00	YNd1	ONAF
	Transformer 132/33 kV, 40 MVA	1990	12.00	YNd1	ONAF
LEC Headquarters	Transformer 11/0,4 kV, 0.05 MVA	1988	4.00	Dyn11	ONAN
	Transformer 33/11 kV, 10 MVA	1979	9.80	YNyn0	ONAN
	Transformer 33/11 kV, 10 MVA	1979	9.90	YNyn0	ONAN
St Agnes	Transformer 33/11 kV, 5 MVA	1981	7.67	YNd1	ONAN
Maputsoe Transmission	Transformer 132/33 kV, 20 MVA	1990	10.00	YNd1	ONAF
	Transformer 33/11 kV, 10 MVA	1990	9.70	YNyn0	ONAN
	Transformer 33/11 kV, 10 MVA	1988	9.70	YNyn0	ONAN
Botshabelo	Transformer 33/11 kV, 10 MVA	1983	8.13	YNyn0	ONAN
	Transformer 33/11 kV, 10 MVA	2001	7.32	YNyn0	ONAN
Khukhune	Transformer 88/33 kV, 20 MVA	1990	9.83	YNd1	ONAN
Ngoajane	Transformer 33/11 kV, 5 MVA	1990	7.54	YNyn0	ONAN
Hololo	Transformer 33/11 kV, 5 MVA	1991	7.69	YNyn0	ONAN
Botha - Buthe	Transformer 33/11 kV, 5 MVA	1990	7.68	YNyn0	ONAN
	Transformer 33/11 kV, 5 MVA	1990	7.68	YNyn0	ONAN
Pitseng	Transformer 132/66 kV, 10 MVA	1991	21.50	YNyn0d1	ONAN
	Transformer 132/66 kV, 10 MVA	1991	21.2	YNyn0d1	ONAN
Lejone	Transformer 132/66 kV, 25 MVA	1991	19.70	YNyn0d1	ONAN
	Transformer 132/66 kV, 25 MVA	1991	19.80	YNyn0d1	ONAN
Katse Intake	Transformer 66/11 kV, 5 MVA	1991	9.22	YNyn0	ONAN
	Transformer 66/11 kV, 5 MVA	1992	9.13	YNyn0	ONAN
Matsoku Diversion	Transformer 66/11 kV, 5 MVA	1997	9.34	YNyn0	ONAN
Katse Dam	Transformer 66/11 kV, 15 MVA	1991	9.54	YNyn0	ONAN
Mafeteng	Transformer 33/11 kV, 5 MVA	1998	7.91	YNyn0	ONAN
	Transformer 33/11 kV, 5 MVA	1995	7.90	YNyn0	ONAN
Letseng	Transformer 88/33 kV, 20 MVA	1990	10.00	YNd1	ONAN
	Transformer 88/33 kV, 10 MVA	2008	10.30	YNd1	ONAN
Hlotse	Transformer 66/11 kV, 5 MVA	1991	9.26	YNyn0	ONAN
	Transformer 66/11 kV, 5 MVA	1991	9.26	YNyn0	ONAN
Muela	Transformer 33/11 kV, 5 MVA	1991	7.84	YNyn0	ONAN
	Transformer 33/11 kV, 5 MVA	1990	7.97	YNyn0	ONAN

Substation	Transformer Voltage (kV) , Capacity (MVA)	Manufacturing Year	Impedance (HV-MV)	Configuration	Cooling Method
Mohale Outlet	Transformer 66/11 kV, 15 MVA	1991	9.60	YNyn0	ONAN
Thaba - Tseka	Transformer 33/11 kV, 2 MVA	1995	6.10	YNyd0	ONAN
Quthing	Transformer 33/11 kV, 5 MVA	1998	7.95	YNyn0	ONAN
	Transformer 11/0.4 kV, 0.1 MVA	1998	Unknown	-	ONAN
Mohale's Hoek1	Transformer 33/11 kV, 10 MVA	2006	7.79	YNd1	ONAN
	Transformer 33/11 kV, 10 MVA	2006	7.69	YNd1	ONAN
Litsoeneng	Transformer 132/33 kV, 20 MVA	2006	12.00	YNd1	ONAN
	Transformer 132/33 kV, 20 MVA	2006	12.20	YNd1	ONAN
	Transformer 33/0.4 kV, 0.05 MVA	1995	Unknown	Dyn11	ONAN
Roma	Transformer 33/11 kV, 5 MVA	2007	8.11	YNd1	ONAN
	Transformer 33/11 kV, 5 MVA	2007	8.07	YNd1	ONAN
Morija	Transformer 33/11 kV, 2 MVA	1972	5.86	Yd11	ONAN
Mohale Dam	Transformer 132/11 kV, 10 MVA	1997	9.00	YNyn0	ONAN
	Transformer 132/11 kV, 10 MVA	1997	8.95	YNyn0	ONAN
	Transformer 11/0.4 kV, 0.01 MVA	1997	4.45	Dyn11	ONAN
Mohale Intake	Transformer 132/11 kV, 10 MVA	1997	8.06	YNyn0	ONAN
LEC - Border	Transformer 33/11 kV, 10 MVA	1988	7.21	YNyn0	ONAN
	Transformer 33/11 kV, 10 MVA	1988	7.44	YNyn0	ONAN
Mabote Transmission	Transformer 132/33 kV, 40 MVA	2003	11.20	YNd1	ONAF
	Transformer 132/33 kV, 40 MVA	1990	12.00	YNd1	ONAF
	Transformer 33/11 kV, 10 MVA	1990	9.28	YNyn0	ONAN
Highway	Transformer 33/11 kV, 10 MVA	1987	7.54	YNyn0	ONAN
	Transformer 33/11 kV, 10 MVA	2000	8.72	YNyn0	ONAN
Qacha's Nek	Transformer 33/11 kV, 1 MVA	2004	5.45	YNd11	ONAN

Source: LEC

5) Transmission Line

Table 3-1.7 shows the existing 132kV, 88kV, 66kV, and 33kV transmission lines in Lesotho. The total length of the transmission line is 903 km for the 132 kV transmission line, 126 km for the 88 kV transmission line, 32 km for the 66 kV transmission line, and 765 km for the 33 kV transmission line.

Table 3-1.7 List of Transmission Line

Line	Conductor	length(km)	Nominal Current (kA)
Botshabelo - Highway	PANTHER 33 KV LINE	5	0.420
Botshabelo - Mazenod Tx	PANTHER 33 KV LINE	10	0.420
Eskom Infeed - Mabote 1	BEAR132KV	5	0.529
Eskom Infeed - Mabote 2	BEAR132KV	5	0.529
Highway - Pioneer	PANTHER 33 KV LINE	8	0.420
KatseDam - MohaleOutlet	BEAR 88KV	11	0.520
KatseIntake - Matsoku	BEAR 88KV	14	0.520
Khukhune – Botha Bothe	HYENA 33 KV LINE	18	0.268
Khukhune – Hololo	HYENA 33 KV LINE	6	0.268
Khukhune - Mahlasela	88KV DOG	40	0.268
Khukhune - Ngoajane 33kv	HYENA 33 KV LINE	9	0.268
LEC Border - Pioneer	PANTHER 33 KV LINE	5	0.420
LEC HQ - LEC Border 1	PANTHER 33 KV LINE	1	0.420

Line	Conductor	length(km)	Nominal Current (kA)
LEC HQ - LEC Border 2	PANTHER 33 KV LINE	1	0.420
Lejone - Liqhobong	132KV WOLF	25	0.480
Letloepe - Mpiti	11KV HARE	10	0.268
Letseng - Tlokoeng	HYENA 33 KV LINE	30	0.268
Litsoeneng - Mohale's Hoek	AAAC SUPER A130	10	0.370
Litsoeneng - Maphohloane	HYENA 33 KV LINE	10	0.268
Litsoeneng - Mohale'sHoek	AAAC SUPER A130	10	0.370
Litsoeneng - Quthing	AAAC SUPER A130	39	0.370
Molimo Nthuse - Mantsonyane 33kv	AAAC SUPER A130	116	0.370
Mabote - Highway	PANTHER 33 KV LINE	7	0.420
Mabote - LEC Border 2	PANTHER 33 KV LINE	12	0.420
Mabote - Mazenod Tx	BEAR 132KV	19	0.529
Mabote - ST Agnes	PANTHER 33 KV LINE	25	0.420
Mabote - Tsosane	PANTHER 33 KV LINE	5	0.420
Mabote - Maseru Central	PANTHER 33 KV LINE	8	0.420
Mabote - Mazenod 2	BEAR 132KV	19	0.660
Mafeteng - Maphohloane	HYENA 33 KV LINE	50	0.360
Mahlasela - Letseng	DOG 88KV	46	0.360
Mantsonyane from gen to town	HARE 33 KV LINE （PHATE）	1	0.360
Mantsonyane from gen to town	HYENA 33 KV LINE	5	0.360
Mantsonyane to Thaba Tseka	AAAC SUPER A130	39	0.370
Maputsoe - Hlotse	WOLF 33 KV	1	0.370
Maphohloane - Mohale's Hoek	AAAC SUPER A130	10	0.370
Maphohloane - Mohale'sHoek	AAAC SUPER A130	10	0.370
Maputsoe - Mabote 1	BEAR 132KV	61	0.529
Maputsoe - Mabote 2	BEAR 132KV	61	0.529
Maputsoe - Pitseng	WOLF 132KV	32	0.480
Maseru Central - LEC Border	PANTHER 33 KV LINE	4	0.420
Matsoku - KatseDam	BEAR 88KV	14	0.520
Mazenod Dx - Tikoe	PANTHER 33 KV LINE	13	0.420
Mazenod DX-Morija	HYENA 33 KV LINE	30	0.360
Mazenod Tx - Mazenod Dx	185MM CABLE 33KV 3X1C	0.2	1.200
Mazenod Tx - Mohale Dam	BEAR 132KV	60	0.529
Mazenod Tx - Ramarothole	BEAR 132KV	55	0.529
Mazenod Tx - Roma	HYENA 33 KV LINE	20	0.268
Mazenod Tx - Tikoe	PANTHER 33 KV LINE	13	0.420
Mazenod - Metolong	HYENA 33 KV LINE	25	0.268
Mazenod - Morija	HYENA 33 KV LINE	30	0.268
Mazenod TX - Semonkong	PANTHER 33 KV LINE	90	0.420
Mazenod TX - Semonkong	PANTHER 33 KV LINE	90	0.420
Morija - Mafeteng	HYENA 33 KV LINE	30	0.268
Morija - Mafeteng	HYENA 33 KV LINE	30	0.268
Mpiti - Rankakala	RABBIT 33 KV LINE	25	0.185
Muela Hydro - Maputsoe 1	BEAR 132KV	62	0.660
Muela Hydro - Maputsoe 2	BEAR 132KV	62	0.660
Muela to Khukhune 33kv	HYENA 33 KV LINE	9	0.268
Pitseng - Ha Lejone	WOLF 132KV	51	0.480

Line	Conductor	length(km)	Nominal Current (kA)
Pitseng - Hlotse Adit	BEAR 66KV	32	0.520
Quthing-Mphaki	HYENA 33 KV LINE	44	0.268
Ramarothole - Litsoeneng	WOLF 132KV	47	0.480
Ramarothole - 132kV solar	WOLF 132KV	30	0.480
Ramarothole - Mafeteng 1	AAAC SUPER A130	10	0.370
Ramarothole - Mafeteng 2	AAAC SUPER A130	10	0.370
Ramarothole - Mafeteng2	AAAC SUPER A130	10	0.370
Ramarothole - Matelile	AAAC SUPER A130	25	0.370
Ramarothole - Thabana Morena	AAAC SUPER A130	30	0.370
Ramrothole - Mafeteng1	AAAC SUPER A130	10	0.370
Roma - Molimo Nthuse	HARE 33 KV LINE	30	0.268
Sekake - Mpiti	RABBIT 33 KV LINE	30	0.240
Thetsane - Pioneer 1	PANTHER 33 KV LINE	4	0.420
Thetsane - Pioneer 2	PANTHER 33 KV LINE	4	0.420
Tikoe - Thetsane 1	PANTHER 33 KV LINE	4	0.420
Tikoe - Thetsane 2	PANTHER 33 KV LINE	4	0.420
Tlokoeng - Mokhotlong	HYENA 33 KV LINE	25	0.268
Tsosane - Botshabelo	PANTHER 33 KV LINE	5	0.420
Lejone - KatseIntake	BEAR 88KV	1	0.520

Source: LEC

6) Transmission line protection and control centers

a) Transmission line protection

Table 3-1.8 shows a list of typical transmission line protection systems informed from LEC. The main body of the relay is mainly made by European manufacturers.

Table 3-1.8 List of transmission line protection systems

	132kV power grid	88/66kV power grid	33kV T/L power grid	11kV T/L power grid
Main Protection	Distance	Distance	Differential	Overcurrent/ Power Fuse
Backup Protection	Directional Earth Fault	Overcurrent	Overcurrent	-

Source: LEC

b) Control Center

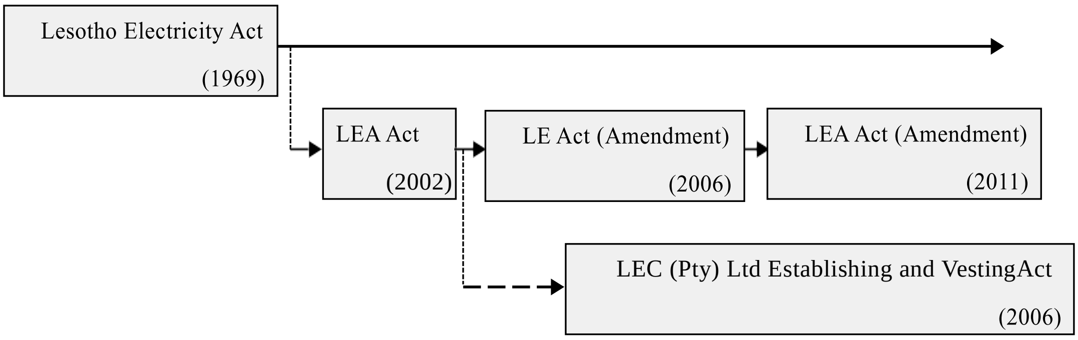
Each power station and substation are monitored from the control centers in Lesotho, i.e., NCC: National Control Center / RCC: Regional Control Center, and are managed by LEC. Communication devices (RTU: Remote Terminal Units) are placed in power stations and substations and transmit the data of Current and Power through communication medium from a Terminal Unit (PLC: Power Line Carrier) and ground wire (OPGW: Optical Fiber Composite Overhead Ground Wire). This step enables remote monitoring of the open / close status of the circuit breakers. Control of each power station and substation is conducted by telephone lines from NCC / RCC at each station. Facilities connected to the LEC power grid, owned by other companies such as IPPs and hydropower plants, and are also monitored by NCC / RCC.

3-1-3 Laws and Regulation in the Power Sector

(1) Laws Related in the Power Sector

The Laws of the Government of Lesotho obliges the Government to formulate an electric power policy to LEWA (Lesotho Electricity and Water Authority), which was established under the Lesotho Electricity Corporation Act of 2002.

The power-related laws and regulations in Lesotho are shown in Figure 3-1.6. Under the Electricity Law, the LEC is authorized to conduct power generation, transmission and distribution power supply.



Source: Information Collection Survey on Power Pools in Southern Africa, 2017

Figure 3-1.6 System of the Laws Related to the Power Sector in Lesotho

(2) Power Purchase Agreement

LEWA does not have official legislation for power sales contracts in Lesotho. The IPPs have individually signed PPA (Power Purchase Agreement) contracts and the content has not been made public. Therefore, a policy to promote power sales contracts is needed. In particular, in the development of electrification plan for suburban micro-grids, legislation is urgently needed. The following is an example of the necessary legal development.

- Electrification target / profit
- Regulation and certification system for developers of micro-grids
- Guidelines for electrification, impact on the residential environment, etc.
- Quality guidelines, quality check system

LEC purchases electricity from LHDA under a LEWA regulation, which sets a price for selling electricity. It is a contract with a fluctuating rate that takes into account economic conditions. In 2016, it was 0.11 Maloti (approximately 0.89 yen[2]) per kWh

(3) Tariff

LEC's electricity tariff is reviewed annually by LEWA. Consumers are categorized into household, street lighting, public, low and high pressure commercial, and low and high pressure industrial

[2] Calculated by 1$=¥110.09 (Nov. 2019) and 1$=13.5 Maloti (Nov. 2019)

applications. The tariff structure comprises two types: capacity fee and electricity fee. Table 3-1.9 shows the electricity rates of LEC for 2018-2019.

Table 3-1.9 Tariff in Lesotho

APPROVED LEC ENERGY CHARGES 2018/19 (Effective from 01 August, 2018) Unit: Maloti

Energy Charges							
Customer Category	Industrial HV	Industrial LV	Commercial HV	Commercial LV	General Purpose	Domestic	Street Lighting
Approved Energy Charges Including *Customer and Electrification Levies (Maloti/kWh)	0.2559	0.2767	0.2559	0.2767	1.6608	1.4782	0.8325
Maximum Demand Charges							
Customer Category	Industrial HV	Industrial LV	Commercial HV	Commercial LV	-	-	-
Approved Maximum Demand Charges (Maloti / kVA)	272.7953	318.6317	272.7953	318.6317	-	-	-

*Customer Levy= 0.0360 Maloti/ kWh; Electrification Levy for both Industrial HV/LV and Commercial HV/LV= 0.02Maloti / kWh; Electrification Levy for General Purpose, Domestic and Street Lighting= 0.035 Maloti / kWh

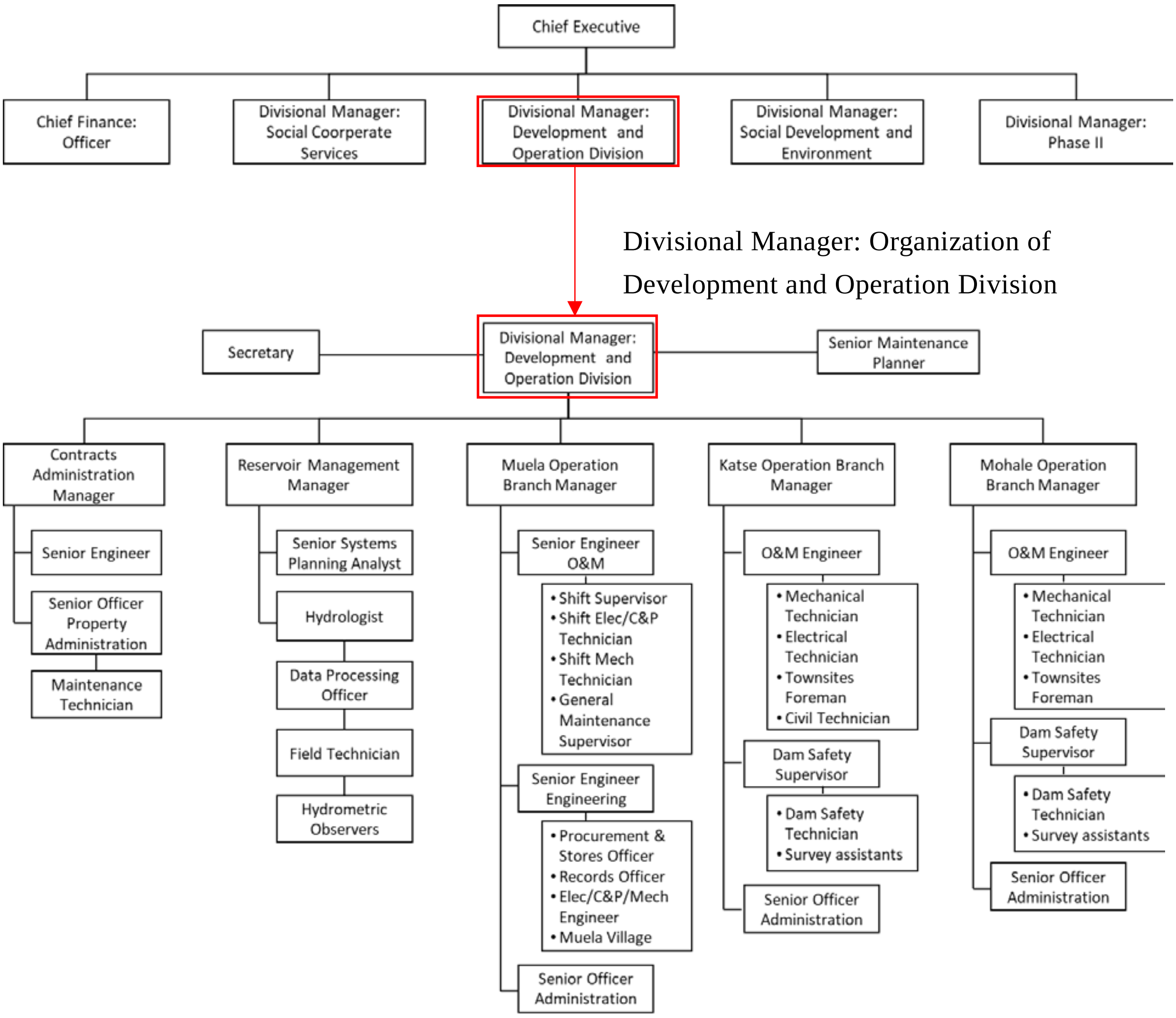
Source: LEWA

3-1-4 Operation and Maintenance

Figure 3-1.7 shows the organization of LHDA, which is expected to be the executing agency when this project is implemented. Figure 3-1.8 shows the organization of LEC, which conduct the operation and maintenance for transmission and distribution facilities. DOD (Department and Operation Division) of LHDA is responsible for the maintenance. Just below the DOD are the Katse branch and the Mohale branch, both of which have maintenance engineers. LHDA has a total of 293 employees, and DOD has 158 employees. The Katse branch has 42 staffs and the Mohale branch has 38 staffs. When the hydropower equipment is installed in this project, it is expected that engineers at each branch will mainly carry out the maintenance. On the other hand, LHDA partially outsources the operation such as security on the premises, and it is expected that local residents will be hired through companies in Lesotho for indirect operations for the target small hydropower facilities.

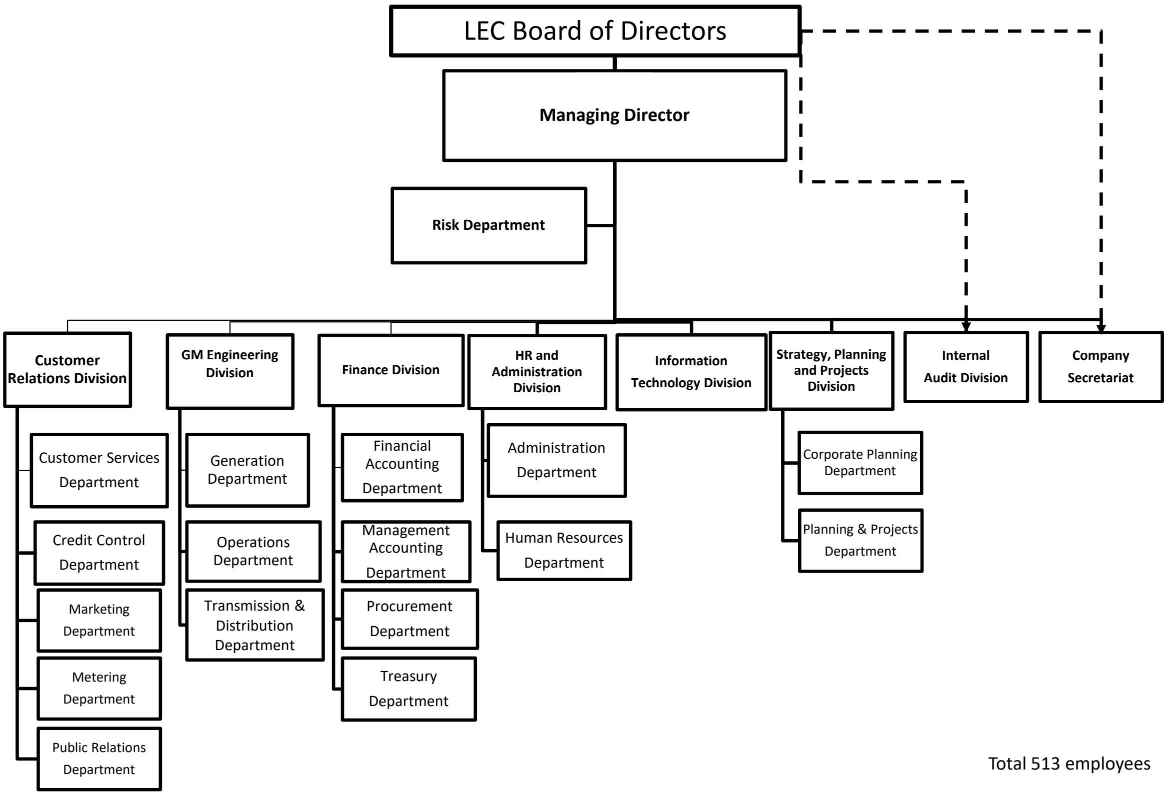
An inspection of the Muela Hydropower Plant, the largest hydropower plant in Lesotho, showed that despite the 20 years that have passed since the completion of the power plant, there was no oil stain around the hydraulic equipment and no accumulation of dust on the top of the equipment. It was in a very good condition. In accordance with the LHDA regulations, maintenance at the hydropower plant is to be carried out every year for two weeks with a main engine shutdown, and every ten years for two months with a main engine shutdown. Necessary repairs and replacement of worn parts are performed during these inspection periods. The main equipment is made by European companies that have a local factory in South Africa, so they can smoothly procure replacement parts and provide necessary technical support. The cost of equipment maintenance and periodic inspections is budgeted as an annual Government budget in Lesotho. Through the inspections and interviews with the hydropower station staff, a consistent level of operation and maintenance is established.

Regarding the power transmission and transformation, LEC monitors the 132 kV, 88 kV, 66 kV, 33 kV and 11 kV systems in Lesotho through the NCC and RCC on a 24-hour basis.



Source: LHDA

Figure 3-1.7 Organization chart of LHDA



Source: LEC

Figure 3-1.8 Organization chart of LEC

3-1-5 Financial Status

Table 3-1.10 shows the profit and loss statement of LHDA, which will be the executing agency of the project when the new power plant for this study is constructed. The operating profit was significantly negative from 2013 to 2015, and in 2017 it also lost 46.6 million Maloti (approximately 379 million yen). LHDA is a business administration that is funded by the Governments of South Africa and the Government of Lesotho. The revenue from selling electricity to LEC does not go to LHDA, but is Lesotho Government revenue.

Table 3-1.11 shows the balance sheet of LHDA. The equity ratio in 2017 was -4 %, indicating that the company is in debt. Facilities and equipment account for 98 % of assets. Under the agreement of the South African Government and the Government of Lesotho in 2002, the cost of the hydropower facilities will be borne by the Government of Lesotho and the cost of the water transfers will be borne by the Government of South Africa.

As shown in Table 3-1.12, the South African Government invests 90 % of the capital of LHDA.

Table 3-1.10 Profit and Loss statement of LHDA

Unit: 1000 Maloti

	2017	2016	2015	2014	2013
Revenue	465,966	595,114	-	-	-
Other Income	81,413	28,988	24,765	19,522	19,233
Total Income	**547,379**	**624,102**	**24,765**	**19,522**	**19,233**
Foreign Losses	(15,381)	(16,647)	(5,983)	(257)	(2,906)
Construction and Contractor Costs	-	-	-	(54,399)	(20,534)
Depreciation	(353,109)	(349,550)	(350,408)	(349,917)	(308,267)
Resettlement and Compensation Costs	(42,046)	(46,412)	(18,581)	(20,210)	(27,830)
Salaries and Wages	(117,032)	(104,252)	(93,610)	(75,138)	(63,180)
Other Administrative and Operating Expenditure	(66,417)	(48,697)	(149,353)	(39,707)	(81,429)
Operating Profit/ (Loss)	**(46,606)**	**58,544**	**(593,170)**	**(520,106)**	**(484,913)**
Finance Income	7,523	9,711	8,538	6,736	7,044
Finance Cost	(7,457)	(9,338)	(11,165)	(12,573)	(14,530)
Profit/ (Loss) for the year	**(46,540)**	**58,917**	**(595,797)**	**(525,943)**	**(492,399)**

Source: LHDA Annual Report

Table 3-1.11 Balance Sheet of LHDA

Unit: 1000 Maloti

	2017	2016	2015	2014	2013
ASSETS					
Non-Current Asset	**9,535,503**	**9,667,918**	**9,847,884**	**10,091,862**	**10,357,048**
Completed Works and Capital Work in Progress	9,528,740	9,660,803	9,840,417	10,080,205	10,343,452
Investment Property	6,763	7,115	7,467	11,657	13,596
Current Assets	**179,798**	**296,090**	**243,366**	**208,480**	**175,151**
Contract Advance Payments	4,495	8,548	-	3,578	4
Trade and Other Receivables and Prepayments	79,457	28,456	32,131	40,659	19,652
Cash and Cash Equivalents	95,846	259,086	211,235	164,243	155,495
Total Assets	**9,715,301**	**9,964,008**	**10,091,250**	**10,300,342**	**10,532,199**
FUNDS AND LIABILITIES					
Funds and Reserves	**(433,831)**	**(387,291)**	**(446,048)**	**9,656,669**	**9,905,691**
Capital Funds	(433,831)	(387,291)	(446,048)	10,168,703	10,329,839
Accumulated Loss- Hydropower	-	-	-	(512,034)	(424,148)
Non-Current Liabilities	**9,995,117**	**10,153,930**	**10,383,688**	**495,219**	**495,733**
Loans and Borrowings	30,531	70,562	100,586	139,791	163,933
Provisions	384,652	382,107	401,156	355,428	331,800
Accruals for Compensation	51,191	40,458	41,529	-	-
Deferred Income	9,528,743	9,660,803	9,840,417	-	-
Current Liabilities	**154,015**	**197,369**	**153,600**	**148,454**	**130,775**
Contract Payables and Accruals	47,999	40,968	27,247	21,817	10,040
Contract Retentions	3,472	2,365	1,035	2,578	2,158
Bank Overdraft	4,959	1,435	377	862	17,686
Provisions	31,452	79,198	65,508	18,443	241
Trade and Other Payables and Accruals	28,342	36,709	26,129	72,680	67,264
Current Portion of Loans and Borrowings	37,791	36,694	33,304	32,074	33,386
Total Funds and Liabilities	**9,715,301**	**9,964,008**	**10,091,240**	**10,300,342**	**10,532,199**

Source: LHDA Annual Report

Table 3-1.12 Capital Funds per Government of Lesotho and South Africa

Unit: 1000 Maloti

	Government of Lesotho	Government of South Africa
Capital Fund of LHDA in 2017	1,002,770	8,876,181

Source: LHDA

3-2 Review and the Main Issues of the Lesotho Energy Policy 2015-2025

In Lesotho, the national planning documents (Vision 2020 and National Strategic Development Plan (2012/13-2016/17) are expected to secure the renewable energy sources and make the energy use more efficient. It is expected that the market will be revitalized by the development of large power sources and the entry of electric power businesses such as private IPPs to utilize renewable energy such as solar power. For this reason, the country has prepared an energy policy (Lesotho Energy Policy 2015-2025) in response to the National Strategic Development Plan. In Lesotho, it is important to improve access to energy to improve people's lives, and is working on the following specific issues.

- Participation in the energy business of the local private sector and the third sector.
- Biomass fuels such as wood are required to effectively utilize a scarce resource for harvesting and permanent drought.
- Maintenance of power equipment network dilapidated for power transmission and distribution.
- Undeveloped conditions for private sector participation in the energy field, power costs are high, and the market does not grow.
- Efficient use of study and implementation of energy.
- Decrease dependence on imported power and fossil fuels. Financing to support energy infrastructure.

The vision for improving access to energy states that electricity is universally accessible in a sustainable and affordable manner with minimal environmental impact. In addition, the following four goals are set.

- Contribution to the improvement of living.
- Contribution to the promotion of investment and economic growth.
- Guarantee of supply.
- Contribution to environmental protection.

To achieve these goals, the Government has issued the following 15 policy statements.

Table 3-2.1 15 policy statements of Lesotho Government

Policy Statement	Abstract
1. Institutional and Regulatory Framework for the Energy Sector	Government will introduce appropriate institutional and regulatory framework for the management and development of the energy sector.
2. Information Management and Outreach	Government will ensure that sufficient information and data on all energy resources become available and are regularly updated.
3. Bioenergy resources.	Government will ensure sustainable supply of bioenergy resources.
4. Renewable Energies	Government will improve access to renewable energy services and technologies.
5. Energy Efficiency in Electricity	Government will promote energy efficient practices and equipment in all sectors of the economy.
6. Power Generation	Government will ensure the security of electricity supply in the country.
7. Power Transmission	Government will develop and sustain a reliable and efficient transmission network in order to avoid interruptions in the power supply.
8. Power Distribution	Government will increase access to electricity for all socio-economic sectors to meet electrification targets within the framework of reliability, affordability and efficiency.
9. Power Supply and Trading	Government will ensure transparent and competitive electricity market operations where participating players have equal opportunities.
10. Electricity Connections	Government desires to ensure more connections and utilization of electricity by end-users.
11. Importation and Storage of Petroleum Products	Government will take measures to ensure security of supply of petroleum products.
12. Distribution of Petroleum Products (Retailing and Transportation)	Government will ensure petroleum products are available and equitably distributed across the country.
13. End Users of Petroleum Products	Government will ensure wider access to petroleum products and related services accessible to the end-users.
14. Investment Framework and Financing	Government will create an enabling environment that will attract investment and financing at all levels of the energy sector value chain.
15. Energy Pricing	Government will ensure that energy prices allow cost-recovery and that price setting is transparent.

Source: Lesotho Energy Policy 2015-2025

Policy Statement 6 shows the public sector's participation in renewable energies such as large-scale hydropower, small hydro, wind and solar, while Policy Statement 7 shows the policy to provide a reliable and efficient power supply by establishing a maintenance management system and the expansion and rehabilitation of the facilities.

3-3 Fulfillment Status of the Development Plan based on the Lesotho Energy Policy 2015-2025

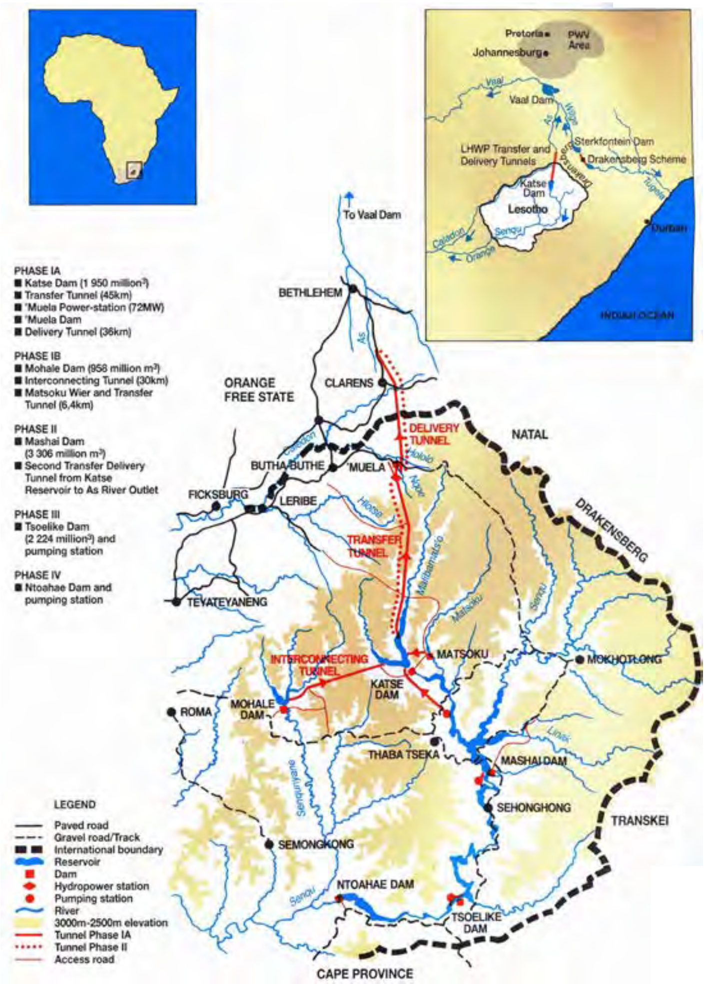
As for the development plan of the power sector based on the Lesotho Energy Policy 2015-2025, the Government of Lesotho has formulated the EMP in 2018 and has a long-term plan to 2037 with the support of the EU. There are plans to promote electrification from both on-grid and off-grid sides.

Regarding on-grid, an extension project of transmission and distribution substations has been underway since 2015 with the support of AfDB. There is also a plan to install a 20 MW photovoltaic power generation (IPP) at the 132 kV Mafetang substation, and F/S is being implemented. Regarding off-grid, Lesotho is actively promoting a micro grid plan using solar power, and has implemented projects with WB, UNDP, AfDB and USAID. SE4ALL (Suburban Microgrid Project by Solar Power) by UNDP is in the implementation stage.

3-4 Review and the Main Issues of LHWP and the LHDA Development Plan

3-4-1 Lesotho Highland Water Project (LHWP)

LHWP is a water transfer (to South Africa) and hydropower (for Lesotho own use) project, developed in a partnership between the Governments of Lesotho and South Africa. It consists of large dams and tunnels throughout Lesotho, supplying water to the Vaal Dam in South Africa. The outline of LHWP is shown in Figure 3-4.1. The project consists of Phase I to Phase IV. The Katse dam was constructed at Phase IA as a central storage for present and future Phase, and the Mohale dam was constructed at part of Phase IB. In Phase II, although the Polihali Dam is planned to be constructed, as of December 2019, the original plan has been delayed and F/S is being implemented, and 16.7 % of the project is now completed.



Source: Lesotho Government Official Website

Figure 3-4.1 Outline of LHWP

The Lesotho Government has deferred the Kobong pumped storage power plant, 1,200 MW to beyond 2030. Screening survey of LHDA in Oxbow (80 MW- preferred) hydropower plant has been developed. Table 3-4.1 lists the priority of candidate power stations and the development sites in "Sub-Task 4.6 Pre-feasibility Screening Study of other viable hydropower Option in Lesotho (Outside the LHWP)". LHDA is conducting a screening study of the Oxbow (80 MW) hydroelectric power station.

Table 3-4.1 Results of Screening study outside LHWP

Rank	Project
1	Oxbow
2	Senqu C, storage 65m dam
3	Senqu C, large storage 80m dam
4	Senqu D, large storage 65m dam
5	Senqu D, 35m dam
6	Senqu C
7	Senqu B
8	Senqunyane

Source: Sub-Task 4.6 Pre-feasibility Screening Study of Other Viable Hydropower Options in Lesotho (Outside the LHWP), LHDA

Regarding hydropower generation, screening studies on construction are being carried out by LHDA under LHWP, using the several rivers available. Since the river flow in the dry season is limited in some rivers in Lesotho, it is important to secure water sources. Hence the hydropower projects are made on the basis of the construction of large dams. In addition, since each hydropower station is located far from the demand area, it is necessary to construct the transmission line and the headrace (tunnel 9 construction) in economical locations. The list of existing and planned hydropower plants is shown in Table 3-4.2 to Table 3-4.4.

Table 3-4.2 Existing and Planned Hydropower Plants

[red box] : Existing

Project	River	Capacity/Specification	Cost	Remarks	Comments
1. Muela Hydropower Project (Phase-1)	Malibamatšo / Senqu(orange)	Capacity=72MW	M483.0 mil Sept 1989	Plant was commissioned in 1998 and has been under commercial operations since.	Taking into account the existing situation in the region (ecological, energetic and other) this project is considered to be positive
2. Muela Hydropower Project (Phase-1)	Malibamatšo/ Senqu (orange)	Capacity =110MW Output=516GWh/annum Ave net head=170m		Plant is an expansion (phase) of the 'Muela Hydropower generating station, the detailed feasibility of which will be considered holistically with LHWP phase 2 feasibility studies.	The expansion of the Muela Hydropower has to be made with Polihale project after full feasibility study, as it is envisioned in the second phase of the LHWP.
3. Oxbow Hydroelectric Project	Malibamatšo	Capacity=80MW Output= 516GWh/ annum		Feasibility studies completed in 1989 by Monenco Consultants Ltd of Canada under funding from CIDA. Project suspended due to LHWP Phase 1 certainty.	Despite of lack of information the project needs to be restudied. As the project was finished in 1989, the feasibility study has to be reassessed and it has to be defined whether it envisions current demands or not.
4. Jordan Multipurpose Project	Senqunyane	Capacity=36MW Output=200 GWh/annum	M396.0 mil Jan.1984	Original pre-feasibility done by HYDROPLAN Consultants under west German Aid Program. Project also envisaged as a water supply scheme to the lowland. Project suspended due to LHWP Phase 1.	
5. Quthing small Hydropower Project	Quthing	Capacity=15MW		Identification and pre-feasibility studies funded by the Austrian Government in 1984. SADCC Energy Ministers approved im1989 as SADCC project 3.3.5 Attracted very little interest in favor of big plants.	As the project was finished in 1984, the feasibility study has to be reassessed and it has to be defined whether it envisions current demands or not. It can be reviewed as the last stage of Quthing cascade.

Source: LEC

Table 3-4.3 Existing and Planned Small Hydropower Plants　　[red box] : Existing

Project	River	Capacity/ Specification	Cost (USD million)	Remarks	Comments
1. Tlokoeng	Khubelu	670 KW	0.321	Commissioned in early 1990	Despite the fact that the station is in operation, the negative part of this project is lack of generation balance and duration of operation.
2. Motete	Motete	524 KW	0.408	Feasibility Study was conducted in early 1980s by SOGREAH Consulting of France	As the project was finished in 1980s, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
3. Qacha's Nek	Tsoelike	482 KW	0.526	Ditto to the above.	Ditto to the above.
4. Mokhotlong	Bafali	242 KW	0.400	Ditto to the above.	Ditto to the above.
5. Mokhotlong	Sehonghong	205KW	0.480	Ditto to the above.	Ditto to the above.
6. Semonkong 1	Maletsunyane	180 KW	0.320	Phase-1 180 KW Plant commissioned in November 1988. Phase-2 not started although provisions are in place to expand the station to 400KW	Ditto to the above.
7. Lesobeng	Lesobeng	110 KW	0.496	Feasibility Study was conducted in early 1980s by SOGREAH Consulting of France.	Ditto to the above.
8. Sehonghong	Sehonghong	700KW	1.640	Ditto to the above.	Ditto to the above.
9. Sehlabathebe	Tsoelike (Leqooa)	100/245 KW	0.760	Ditto to the above.	Ditto to the above. .
10. Mokhotlong 1A	Mokhotlong	800 KW	0.281		
11. Mokhotlong 2A	Mokhotlong	700 KW	0.265		
12. Mokhotlong B	Mokhotlong	1500 KW	0.288		
13. Semonkong	Maletsonyane	340 KW	0.088	Feasibility Study done by NORPLAN, funded by Norway.	As the study was conducted in 1984, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
14. 'Mantšonyane	Mantšonyane	2000 KW	0.098	Under Operation.	Ditto to the above.
15. Sehlabathebe	Tsoelike (Leqooa & Tsoelikana)	150 KW	0.680		
16. St. Teresa	Masnat	200 KW	0.380		
17. Lethena	Quthing	2000 KW	0.244		
18. Mosetlelo	Quthing	2500 KW	0.344		
19. Likhabaneng	Likhebaneng	4500 KW	0.400		
20. Pitseng	Tsainyane	70 KW	0.384	Pre-feasibility studies were conducted by Taiwan Power Company in the mid-1980s.	As the study was conducted in 1980s, the feasibility will have to be reassessed, to define exact technical parameters and its ability to comply with current requirements.
21. Ha Ntsi	Liphiring	30 KW	0.904	Ditto to the above.	Ditto to the above.
22. Mokhothlong	Mokhotlong	795 KW	0.235		

Source: LEC

Table 3-4.4 Planned Pumped Storage Plants

Project	River	Capacity/ Specifications	Cost	Remarks	Comments
1. Monontša Pump/ Storage	Pitseng River (tributary of the Caledon River)	Capacity=1 000MW Net Static Head=620m		Memorandum of Understanding on the Project was signed between LHDA and Eskom in April 2004. Pre-feasibility studies shortly to commence.	The project is acceptable, but for the next stage of the project development diversion length has to be reassessed together with the reservoir location.
2. Three other pumped storage project	On 4 different Location.	≥1 000MW each option at net head of ≥500 m		The first pumped storage project Monontša was the most preferred site of the three identified in comparison of a number of factors. The 3rd option to consider is the feasibility of up to 1,500 MW peaking plant at LHWP Phase2 |Mashai Dam.	Despite of the lack of information on LHWP phases 2, 3, 4, and 5, we still can conclude that during the reservoir operation the water level changes down to minimum operation level will cause the increase of waterway length, which will have negative influence on Pumped Storage Plant.

Source: LEC

3-4-2 Development Plan Formulated by LHDA

(1) Sub-Task 4.3 Analysis of Viable Small or Medium Hydropower Options

The Sub-Task 4.3 Analysis of Viable Small or Medium Hydropower Options is an LHDA report showing the design plan of the small hydropower facilities of Katse Dam, Mohale Dam, and Polihali Dam, which are the subjects of this study. The report was prepared by a consortium of EDF (French Electric Power Company) and GIBB (Consultant in South Africa). The report does not provide any data of water discharge for environment and utilization. In this study, referring to the report as prior information, the adequacy of the above three sites was examined.

(2) Sub-Task 4.4 Review of the Existing and Planned Expansion of the Lesotho Transmission and Distribution Network

The Sub-Task 4.6 Review the Existing and Planned Expansion of the Lesotho Transmission and Distribution Network shows the plans to connect the planned hydropower system, including the Mohole Dam, Katse Dam and Polihali Dam to the grid. As for the Mohole Dam and Katse Dam, the capacity of the existing transformers is sufficient, and the generated power can be connected to the bus of the existing 11 kV substation via the step-up transformer. It also shows that the planned Polihali Dam can be connected to the transmission and substation facilities without problems.

(3) Sub-Task 4.6 Pre-feasibility Screening Study of Other Viable Hydropower Option in Lesotho (Outside the LHWP)

Implementation has made own screening survey for the proposed site of the hydropower, other than the above-mentioned as LHWP.

3-5 Power Demand Forecast and Power Supply Plan

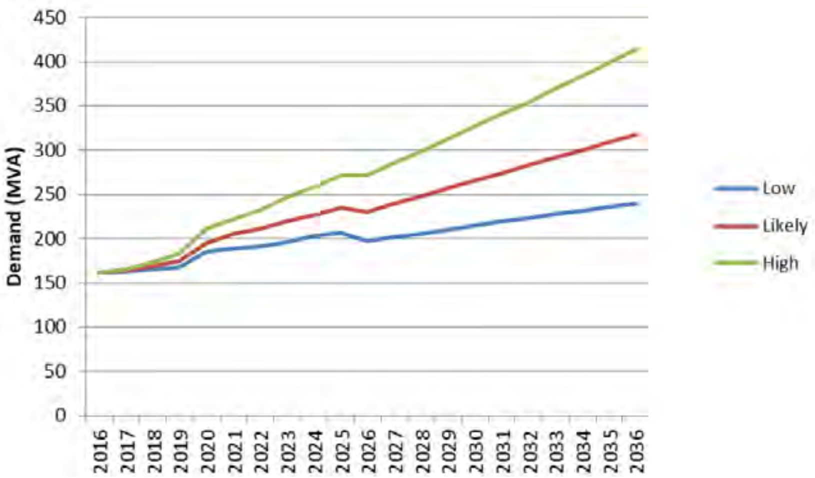
3-5-1 Outline of the Power Demand Forecast and the Power Supply Plan

(1) Power Demand forecast

In EMP, the Demand Forecast Report shows the demand forecast that is the basis of the development plan. This demand forecast adopts a model that forecasts power demand by category (household, Government, agriculture, industry, school, etc.) and accumulates them.

Figure 3-5.1 shows the power demand forecast up to 2036 for the base case (most likely), the high case, and the low case. In the base case, power demand will be about 320 MVA in 2036, and it is forecast to increase to about double in 20 years. The construction of the Kobong pumped-storage power plant from 2020 to 2025 is expected to generate a load of 20 MVA, which is expected to increase power demand during this period[3].

[3] Demand forecast as of March 2018. As of the survey November 2019, the construction of the Kobong pumped-storage power plant was postponed after 2030.



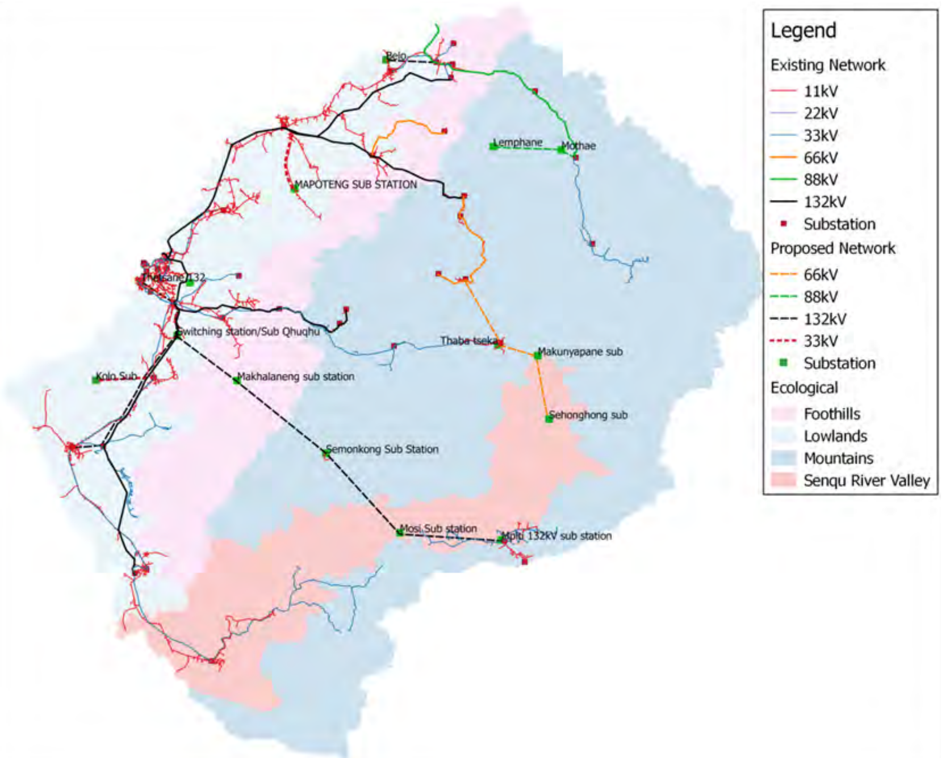
Source: FORMULATION OF THE LESOTHO ELECTRIFICATION MASTER PLAN, Demand Forecast Report

Figure 3-5.1 Forecast of power demand in Lesotho

(2) Power Supply Plan

1) Transmission and Distribution

The EMP shows the long-term transmission network development plan from 2017 to 2036 as shown in Figure 3-5.2 and Table 3-5.1. The main objective is to expand the power system and to increase equipment to meet the increasing demand in the future.



Future Power Grid (in 2036)

Source: FORMULATION OF THE LESOTHO ELECTRIFICATION MASTER PLAN, Grid Development Plan Report

Figure 3-5.2 Future Power System Network

Table 3-5.1 Transmission and Distribution facilities Development Plan

Type of Infrastructure	From	To	Description	Voltage	Year	Length (km)
Line	Maputsoe	Mapoteng	General reinforcement to meet existing demand growth	33 kV	2020	30
Line	Thaba Tseka	Mokhotlong	Reinforcement of Thaba Tseka & Mokhotlong supply	33 kV	2020	75
Line	Morija	Kolo	To address existing demand growth & for new mining	33 kV	2019	25
Line	Botshabelo	Ha Makhoathi	General reinforcement to meet existing demand growth	33 kV	2020	15
Line	Hlotse	Buth-Buthe	General reinforcement to meet existing demand growth	33 kV	2020	30
Line	Katse	ThabaTseka	Reinforcement of Thaba Tseka supply	66 kV	2022	50
Line	Mohale's Hoek	Mphaki	To reinforce existing grid	132 kV	2021	150
Line	Muela	Khukhune	For reinforcement of South Africa connection and connecting of Letseng & Mokhotlong to 132 kV grid	132 kV	2018	8
Line	Khukhune	Ha Belo	To serve proposed new factories (LNDC)	132 kV	2020	30
Line	Liqhobong	Lemphane	To supply Lemphane mine	132 kV	2021	25
Line	Letseng	Mothae	To supply Mothae mine	33 kV	2019	25
Line	Mazenod	Qacha's Nek	General reinforcement to meet existing demand growth	132 kV	2021	230
Line	Mazenod	Thetsane	To achieve a 132 kV grid "ring" connecting all regions of Lesotho	132 kV	2021	25
Line	Mt Moorosi	Mosi	To achieve a 132 kV grid "ring" connecting all regions of Lesotho	132 kV	2021	70
Line	Lejone	Polihali	To achieve a 132 kV grid "ring" connecting all regions of Lesotho	132 kV	2021	80
Line	Polihali	Mokhotlong	Related to new hydro/dam expected	132 kV	2020	30
Line	Letseng	Mokhotlong	To achieve a 132 kV grid "ring" connecting all regions of Lesotho	132 kV	2024	60
Line	Khukhune	Letseng	To achieve a 132 kV grid "ring" connecting all regions of Lesotho	132 kV	2024	75
Line	Letseng	Liqhobong	To achieve a 132 kV grid "ring" connecting all regions of Lesotho	132 kV	2024	50
Substation	-	-	Substations at Ha Mofoka, Ramabanta, Semonkong, Ha Mosi, Ha Mpiti	-	2021	-
Substation	-	-	Electrification of Ha Ramabanta, Semonkong, Ha Mosi, Ha Mpiti	-	2021	-
Customer compensation	-	-	Secure Line Route (compensation for 50 households)	-	2021	-
Substation	-	-	Maseru South Substation	33/11 kV	2019	-
Substation	-	-	Mapoteng Substation	33/11 kV	2020	-
Substation	-	-	Mokhotlong Substation	33/11 kV	2020	-
Substation	-	-	Kolo 33/11 kV substation	33/11 kV	2019	-
Substation	-	-	Ha Makhoathi 33/11 kV Substation	33/11 kV	2020	-
Substation	-	-	Thaba Tseka Substation	66/11 kV	-	-
Substation	-	-	Thetsane Substation	132/33 kV	-	-
Substation	-	-	Ha Mofoka Switching Station	132 kV	-	-
Substation	-	-	Upgrading of Khukhune to 132 kV - for reinforcement of interconnection	132 kV	-	-

Type of Infrastructure	From	To	Description	Voltage	Year	Length (km)
			with South Africa			
Substation	-	-	Ha Ramabanta Substation	132/33/11 kV	-	-
Substation	-	-	Semonkong Substation	132/33/11 kV	-	-
Substation	-	-	Ha Mosi Substation	132/33/11 kV	-	-
Substation	-	-	Ha Mpiti B Substation	132/33/11 kV	-	-
Substation	-	-	Ha Belo Substation - for reinforcement of interconnection with South Africa	132/33/11 kV	-	-
Substation	-	-	Lemphane Substation	132/33/11 kV	-	-
Substation	-	-	Mothae Substation	33/11 kV	-	-
Other upgrades	-	-	New switchroom SW12 switching station to address load growths at Limkokwin, Lerotholi Polytechnic up to Mashoeshoe 2	-	2018	-
Other upgrades	-	-	New switchgear at SW12 to address load growths at Limkokwin, Lerotholi Polytechnic up to Mashoeshoe 2	-	2018	-
Other upgrades	-	-	New Switching Station at Ha Foso to address loads in the northern part of Maseru	-	2018	-
Other upgrades	-	-	Replacement of mini-sub & 3-way RMU that limit capacity at Palace of Justice, Hills View, Husteds, CTC, Alliance, Sefika HS & Cenez Rd	-	2018	-

Source: FORMULATION OF THE LESOTHO ELECTRIFICATION MASTER PLAN, Grid Development Plan Report

2) Power System Analysis

EMP allocates power demand to each substation based on the power demand forecast described above, conducts power flow analysis every five years for 20 years up to 2036, and plans equipment that requires new construction and repair.

LEC owns the system analysis software DIg SILENT, and the system analysis engineer has the ability to perform analysis.

(3) Transmission and distribution network, substation construction and off-grid with solar

For transmission and distributions, EMP has developed a long-term grid development plan for 2017-2036 by LEC. The main issues are listed below.

- The total budget in Lesotho Maloti, 2.4 Billion Maloti (= 120 Million Maloti / year × 20 years, approximately 19,560 Million yen) is planned, but the budget and development period have not been officially approved by the Lesotho Government.
- As a prioritization of the transmission network development plan, ideally a distribution plan network at the village level is desired, but key data such as the number of households in each village has not been prepared and remains of uncertainty.
- Since the power characteristics of urban and rural areas are different, a power supply plan suited to the region is required. In urban areas, where the load is high, measures such as multiplexing of

transmission lines should be taken into account in designing the power network. On the other hand, rural areas often require long-distance transmission lines and low voltages and low loads, and require consideration to reduce costs without sacrificing the quality.

Lesotho has a new energy development plan as the following issues;

- EMP allocates approximately 30 million Maloti (approximately 220 million yen) per year for small-scale power plants to realize off-grid electrification plans, but the Government of Lesotho has not officially approved the budget and the development period.
- Undeveloped conditions for private participation have been a barrier to entry for IPP promotion.
- The price of imported power is less than USD 0.1 / kWh in 2017 and the cost of power generation may exceed the import price if a new power source is developed.

(4) International Grid Connection

Lesotho is a member of the SAPP, which consists of representatives of electric power companies in Southern Africa. The organization was established to provide reliable and economical power supply to the member countries. It comprises 12 countries in Southern Africa (South Africa, Lesotho, etc.) and plans to build a transmission system and the system operations are being implemented in cooperation.

Regarding the SAPP member domestic supply-demand balance as of 2015, the total generating capacity in SAPP is 61,859 MW, the available capacity at the transmitting end is 46,910 MW, the peak demand is 48,216 MW, and the required supply capacity including reserve capacity is 55,157 MW. In short, the supply capacity of 8,247 MW is insufficient. 7,921 MW is insufficient as a supply capacity even when calculated only in the SAPP member countries that are connected to the grid. South Africa accounts for under 80 % of both power generation capacity and peak demand within SAPP. Lesotho provides power with two 132 kV, 230 MW lines from South Africa, and receives the power from South Africa during the time of power shortage.

In 2008, a severe power shortage in South Africa and a lack of imported power from South Africa forced LECs to undergo major rolling blackouts, exposing the risk of a power shortage in their own country.

CHAPTER 4 DONOR SUPPORT

Chapter 4 Donor support

Table 4-1.1 outlines the assistance provided by donors in the power sector, as confirmed by the officials of the Government of Lesotho after domestic and field surveys. The assistance provided by each donor is mainly aimed at the local optimal electrification, i.e., planning and construction of solar power generations and suburban micro-grid facilities, where is no connection into the LEC power grid. In Lesotho, there is presumed to be about 1 million nomads living in a wide range of mountainous areas, and the power supply to the residents living in those regions are distributed PV power supplies. Small Hydropower generation on this survey plan is essentially power grid connections in LEC to supply the electricity through the distribution network to the residents.

Table 4-1.1 Overview of the donor support

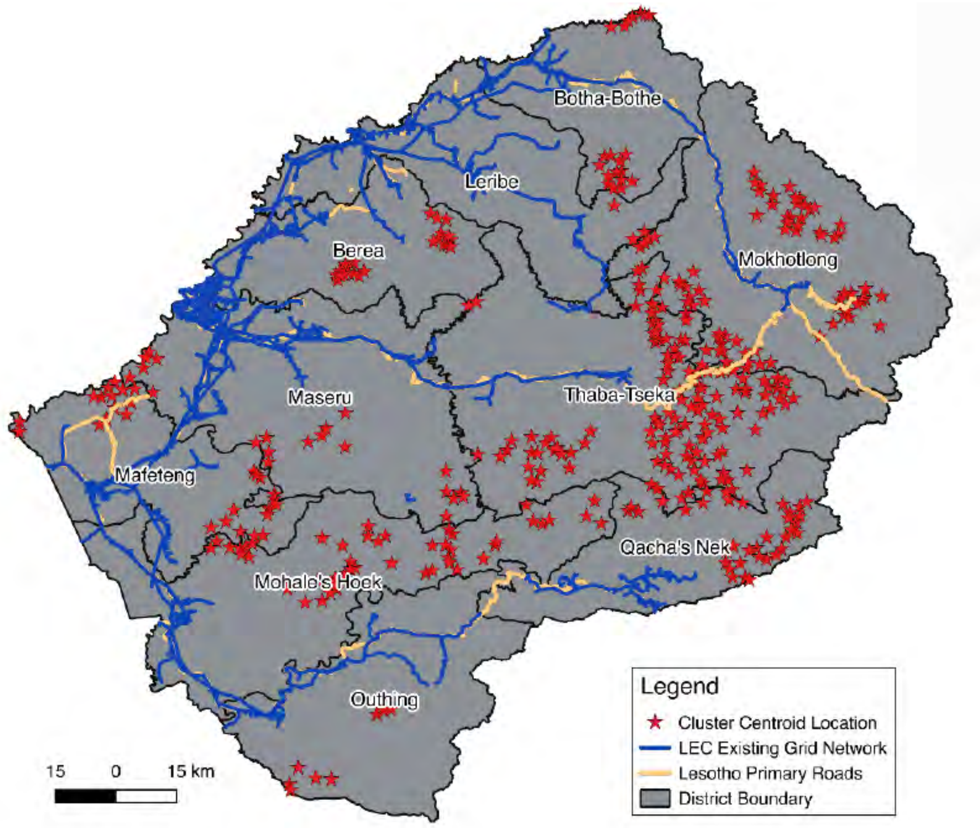
Implementation year	Name of Executing agency	Name of the Project	Project cost	Types of cooperation projects	Project contents
Ongoing	Delegation of the European Union to Lesotho (EU)	FORMULATION OF THE LESOTHO ELECTRIFICATION MASTER PLAN	-	Gratis	Master Plan
2015~Ongoing	African Development Bank (AfDB)	The Urban Electricity Distribution and Transmission Expansion Project	-	Loan	Power transmission & distribution Project
2016~Ongoing	United Nations Development Program (UNDP)	Development of Cornerstone Public Policies and Institutional Capacities to accelerate Sustainable Energy for All (SE4ALL) P/J	US$ 22,767,837	Gratis	Suburban micro-grid with solar power generation project.
2016~Ongoing	United States Agency for International Development (USAID)	Feasibility study on a portion of the One Power – Neo 1 Solar PV 20 MW.	-	Loan	Suburban micro-grid with solar power generation project.
2016~Ongoing	United States Agency for International Development (USAID)	Feasibility study on LHWP Phase2(Muela)	-	Gratis	Hydropower plant plan
2018~Ongoing	African Development Bank (AfDB)	Renewable Energy Grid Integration Study	-	Gratis	Survey of Photovoltaic (PV)
2021~2022	World Bank (WB)	Lesotho Renewable Energy & Energy Access Project (P166936)	-	Loan	Suburban micro-grid with solar power generation project.

Source: JICA survey team

4-1 World Bank (WB) support for Lesotho

WB is planning to proceed with the micro-grid Project from 2021 to 2022. PPAs are decided by LEWA. A detailed electrification report has been made by LHDA. The LHDA plan is surveyed by the French Government (a separate organization from EDF) as a consultant and approved by the Lesotho Government.

WB mainly focuses on loan projects. One of the loan projects of WB, Lesotho Renewable Energy and Energy Access Project (P166936), is currently still pending. The location of the micro-grid project is shown by the red star marks in Figure 4-1-1, which is away from the existing LEC power grid.



Source: WB Report

Figure 4-1-1 Micro-grids located away from the LEC power grid

Since Lesotho represent a much smaller credit facility for the WB, collaboration with JICA and other donors through a joint financing project is the preferred strategy for expanding the scope of involvement of the WB to Lesotho.

4-2 African Development Bank (AfDB)

The South African office of the AfDB has a jurisdiction of 13 countries over the Southern African Region. The South African office also supports the power sector in Lesotho. AfDB consultants are stationed in Lesotho. Although a plan of AfDB for small photovoltaic (PV) power generation is considered, the combination with a small hydropower plant is also considered as a concept. Since Southern African power pool does not have enough power, it is also useful for SAPP to reduce the power export to Lesotho country.

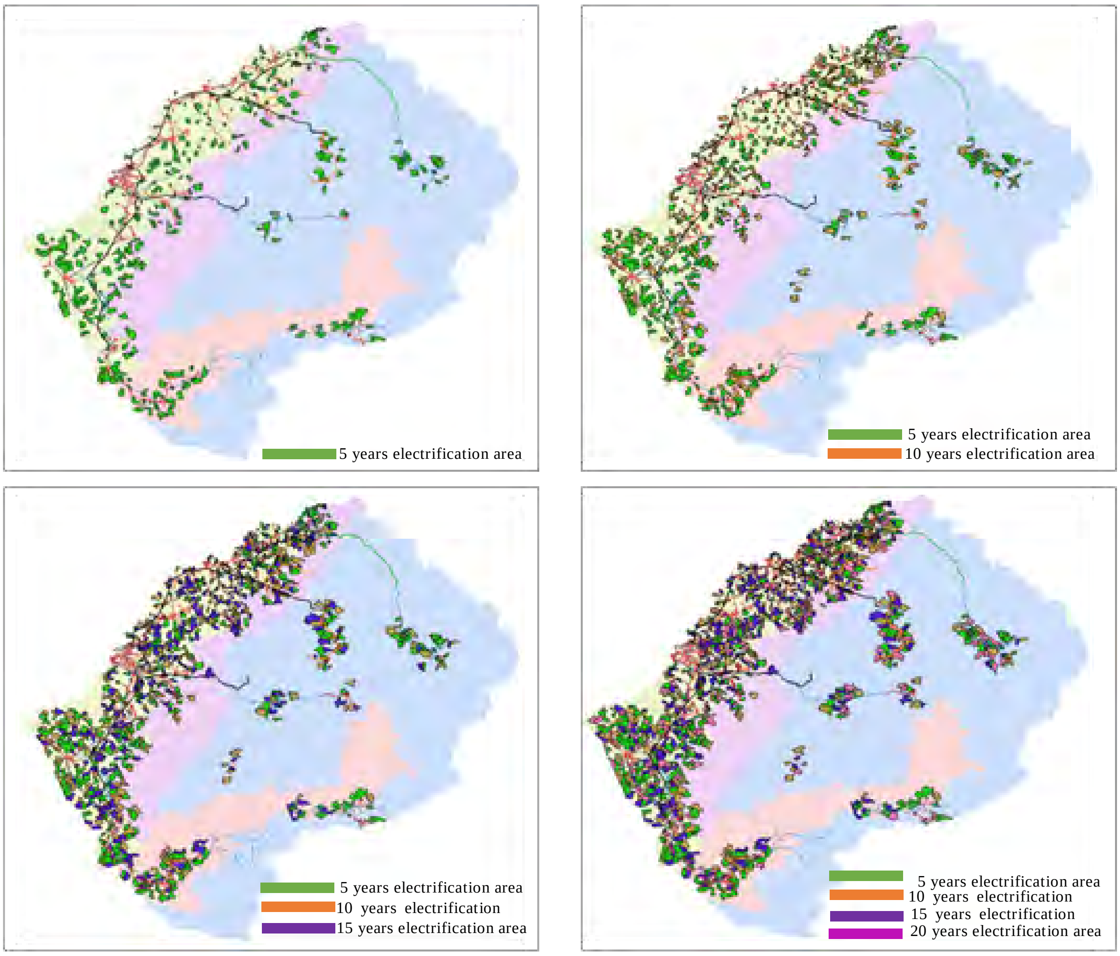
In the future, AfDB is supporting the Project with a focus on improving the transmission and distribution systems, suburban renewable energy electrification, and IPP development.

4-3 United Nations Development Programme (UNDP)

UNDP has been implementing 10 solar PV as pilot projects since 2016 in the Central and South district of Lesotho through the Development of Cornerstone Public Policies and the Institutional Capacities to accelerate Sustainable Energy for All (SE4ALL) Project. Figure 4-3-1 shows an example of a mobile phone charging station in the Micro-grid. Despite its detailed design stage, the process has been delayed from the original schedule. The project charter has been formally approved by the Lesotho Government. The SE4ALL project has been promoted by UNDP; (1) Promoting future IPP investment by improving the Government regulations, (2) Developing population data residing outside of towns or villages, and the number of households living in nomadic areas in mountainous regions, (3) In the Outreach Program, maintenance of Micro-grid (solar PV) educational books. Figure 4-3-2 shows a 20-year system expansion plan. UNDP recognizes that solar electricity costs are higher than other electricity sources. The donor is the Global Environmental Facility, UN, which also considers and evaluates the living environment.

Source: SE4ALL

Figure 4-3-1 Example of a mobile phone charging station in the Micro-grid



Source: SE4ALL

Figure 4-3-2 System expansion 20-year plan (5, 10, 15, 20 years)

4-4 United States Agency for the International Development (USAID)

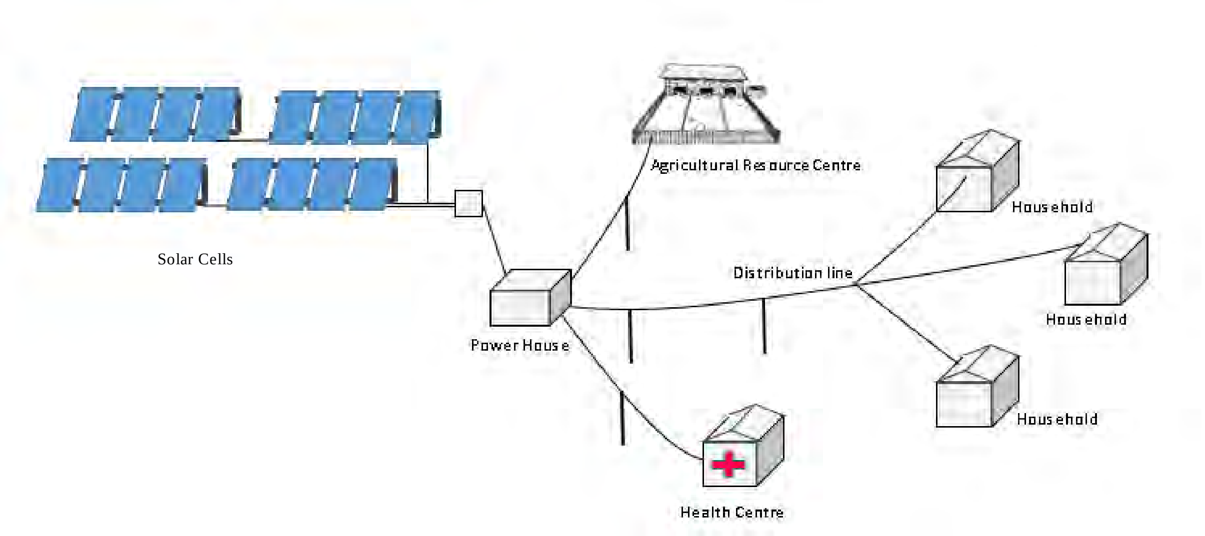
The USAID head office in Southern Africa is located in Pretoria, and mainly implements the support for the cooperation of technical assistances as well as official management and policy planning to LEC.

The 20 MW solar system of Mafeteng 132 kV Substation, Feasibility study on a portion of the One Power - Neo 1 Solar PV 20 MW (IPP), was bid in 2017, but is still at the contract negotiation stage. Construction is scheduled to start in 2021. USAID in South Africa is responsible for USAID's power development in Lesotho. According to CDM Smith that was a consultant of LHWP Phase 2 (Polihali), there is a project office in LHWP phase 2 in Maseru, but the renewable energy business in Lesotho is managed by the office of CDM Smith in Pretoria, South Africa. A feasibility study of “One Power - Neo 1 Solar PV 20 MW of power projects” is one of their involvement.

Some micro-grids comprising solar power systems are expected to incorporate small Hydropower generation of less than 3 MW, but there are no plans for developments of small Hydropower generation.

4-5 Delegation of the European Union to Lesotho (EU)

As an example of the final version of the EMP (off-grid /on-grid) plan by EU in 2018, Figure 4-5-2 shows a system configuration of solar PV and Figure 4-5-2 shows an example of solar PV for each household. The report is already approved by the Lesotho Government and some project are tendering stage.



Source: EU off-grid plan

Figure 4-5-1 System configuration of solar PV

Source: EU off-grid plan

Figure 4-5-2 Household Solar PV sample

CHAPTER 5 SPECIFICATION OF THE CANDIDATE PROJECTS

Chapter 5 Specification of the Candidate Projects

5-1 Relationship between the power supply and demand plan in this survey

The only major power source in Lesotho is the Muela hydropower plant (72 MW). According to the LEWA Annual Report 2017-2018, the power demand in 2017/18 was 167 MW, and the power generation capacity was less than half (49-55 %) of the power demand. For this reason, imports from SAPP [1] (valued at about 1.5 billion yen from South Africa and about 900 million yen from Mozambique: LEC 2017 Annual Report) have made up for the shortage of electricity (Details 3-1-2 (2)). In order to resolve the power shortage, the LHDA, which manages the dams, has developed a power development plan (Sub-Task4.3-Analysis of Viable Small or Medium Hydropower Options within the Existing LHWP System) and is promoting the plan. Lesotho is considering technical assistance through the Japanese grant aid. Since the distribution lines are extended at each of the dams, the small hydropower plants using discharge water are able to be integrated with the transmission network in Lesotho.

The transmission network in Lesotho consists of a 132 kV transmission line that is connected to the Muela hydropower station, which constitutes the backbone of the power system. Transmission and distribution lines are located along arterial roads in the country, and substations, which are located in each village, distribute electricity to the residents through distribution lines. In addition, the transmission line is also connected to the SAPP transmission network so that it can be interchanged in case of power shortage. According to the World Bank data [2], the current electrification rate is about 38 % (World Bank 2017) and it tends to increase year by year. Half of the inhabitants live near the border around Maseru, while the other half live in remote mountainous areas. For this reason, the transmission line network is built radially toward each dam, centering on the demand area in the border region. As mentioned above, in response to the power situation that is increasing year by year, Lesotho has prepared an EMP with the support of the EU and is planning to expand the transmission and distribution network. USAID and UNDP are also implementing rural electrification projects. In addition, LHDA is conducting F/S for the construction of large hydropower plants in the Northern region with the support of the French Ministry of Electricity. In this way, donors have provided assistance to the power sector, but the support for the construction of small hydropower plants has not been provided. It seems that there is no duplication for this project.

5-2 Short list of the candidate projects

The small hydropower plant of this project effectively uses the discharge water for environment including water utilization called EWR (Environmental Water Requirements, here in after discharge water), which has not been used as an energy source before. Based on the situation of the target sites and the data on the discharge, the estimated amount of generated power was calculated. The estimated

1 LEC 2017 Annual Report

2 https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?end=2017&locations=LS&start=2000

output at each target sites is shown in Table 5-2.1.

Table 5-2.1 Status and expected output of each target sites

Site	Status	Expected output	Feasibility and issues
Katse	2 units of 500 kW turbine / generator can be installed.	Up to about 1MW	Uses oil-less motors such as inlet valves to save space and achieve automatic operation. It needs construction of a 200 m loading path.
Mohale	The power plant building and water outlet are completed.	Up to about 1MW	The building needs remodeling work to install a draft tube. It needs confirmed building structure and bar arrangement survey.
Metolong*	There is no space for power plant construction in the discharge valve room.	Up to about 0.1MW	It needs the penstock extension and to secure the power plant site and building on the riverbed. Cost effectiveness is a problem.
Polihali	Bid for dam construction is scheduled by 2020.	Flow rate is unknown. It is assumed to be similar to Mohale.	Construction of a small hydropower plant on the dam body. There are many uncertainties as the completion of the dam is scheduled for 2023.

Note: * Metolong Dam is under the Commission of Water.
Source: JICA Study Team

5-3 Feasibility for the Grant Aid Projects

(1) Current status and future policy regarding discharge

Basically, discharge water at each dam is based on the policy of releasing about 10 % of the dam inflow calculated by the consultants in other countries. Regarding this point, Lesotho's “Environmental Impact Assessment Guidelines” do not have any discharge regulations, and the Department of the Environment does not consider it to be a problem unless there is a complaint from the residents of the water area. LHDA has a management department for hydrological data. The department stipulates its own calculation method for inflow into each dam and discharge water. The calculation method is shown in Appendix-9 (IFR Presentation to management, source: LHDA).

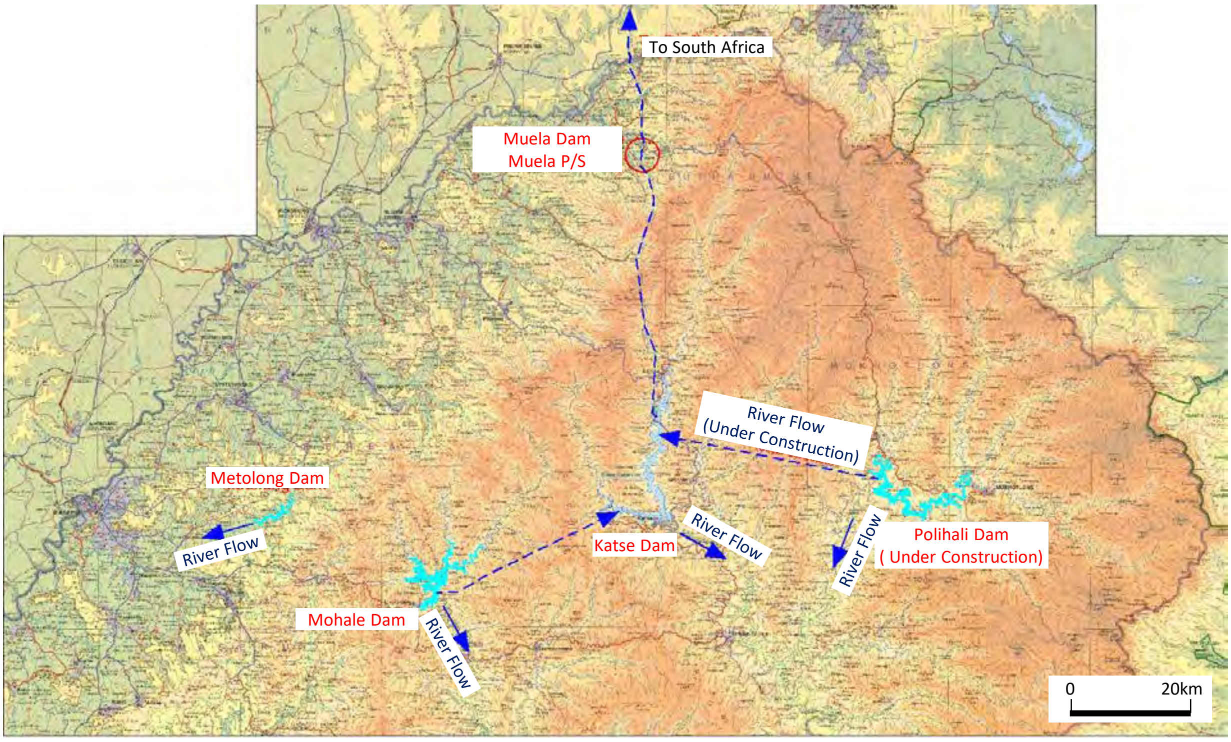
In addition, the main purpose of water usage in Mohale Dam and Katse Dam is to transfer water to South Africa for export, and the main purpose of water usage in Metolong Dam is for consumption in Lesotho. Table 5-3.1 shows the data obtained from LHWC. According to this table, when the Mohale Dam and the Katse Dam were connected by a tunnel (since 2005), the water supply to South Africa has increased. It can be seen that the water supply will be further increased after the completion of the dam (after 2019 in the table). However, the minimum quantities of water shown in the table are not guaranteed ones but provisional ones. According to the explanation by LHDA, the first priority of usage of water stored in each dam is for the compensation discharge. And they consider the water usage for electricity is important. Thus, the quantity of water exported to South Africa is determined considering comprehensive view point. On the other hand, adjustment of quantity of water delivered to South Africa is conducted solely by the output control of Muela hydropower plant (including the change of operating units), which is located at near end of LHDA dam-tunnel system.

Table 5-3.1 Minimum quantities of water supplied to South Africa for the calculation of royalties

Year	Volume (million m^3)	Year	Volume (million m^3)
1995	57	2021	927
1996	123	2022	941
1997	190	2023	954
1998	258	2024	968
1999	327	2025	982
2000	398	2026	996
2001	470	2027	1,010
2002	543	2028	1,024
2003	618	2029	1,037
2004	695	2030	1,051
2005	772	2031	1,065
2006	780	2032	1,079
2007	780	2033	1,093
2008	780	2034	1,107
2009	780	2035	1,120
2010	780	2036	1,134
2011	780	2037	1,148
2012	780	2038	1,162
2013	780	2039	1,176
2014	780	2040	1,190
2015	780	2041	1,203
2016	780	2042	1,217
2017	780	2043	1,231
2018	780	2044	1,245
2019	899	-	-
2020	913	-	-

Source: LHDA

Originally, the water at the Katse, Mohale and Polihali dams flows to the Southern side of Lesotho as the Senqu River, but the water supply to South Africa has been changed to the Northern basin via the Muela power plant.



Source: JICA Study Team

Figure 5-3.1 Water flow of each dam

Based on the information collected in this study, it is considered difficult to increase the discharge water for small hydropower, because the increasing the discharge water will lead to a decrease in the amount of water transport to South Africa, and water export revenue in Lesotho will decrease. It is reasonable to think that the current amount of discharge water is the maximum flow rate that can be used for power generation. Since the Polihali Dam is currently under construction, the operation of the discharge water will be determined in the future and will not be described here.

The optimal amount of water used in hydropower generation is determined from the relationship between the amount of generated power and the construction cost, but it is often around the amount of ninety-five-day discharge (Q95: the amount of water that does not decrease below this flow on 95 days of the year) (See Appendix-10). Therefore, the optimum amount of water usage is about 1.0 m^3/sec at Mohale and Katse, and 0.3 m^3/sec at Metolong. However, the Metolong site has a large variation depending on the year. It is conceivable to set the maximum flow rate at 0.31 m^3/sec as the design flow although the facility utilization rate is low. The power generation output is estimated as follows, assuming the power generation head[3] and power generation efficiency at each point.

[Katse Site]

Water usage $Q = 1.0\ m^3$ / sec, Net head $H = 150$ m, Synthesis efficiency $\eta = 0.8$

Power generation output $P = 9.8 \times 1.0 \times 150 \times 0.8 = 1{,}176 \fallingdotseq 1{,}100$ kW

[Mohale Site]

[3] When the water level of the dam changes, the net head of the turbine also changes. The entire range of the net head is referred to as “power generation head”.

Water usage Q = 1.0 m^3 / sec, Net head H = 130 m, Synthesis efficiency η = 0.8

Power generation output P = 9.8 × 1.0 × 130 × 0.8 = 1,019.2 ≒ 1,000 kW

[Metolong Site]

Water usage Q = 0.31 m^3 / sec, Net head H = 50 m, Synthesis efficiency η = 0.8

Power generation output P = 9.8 × 0.31 × 50 × 0.8 = 121.52 ≒ 120 kW

According to the Department of the Environment, small hydropower projects such as this project are subject to the environmental impact assessment. So, the discharge volume submitted by Lesotho will be calculated taking into account the environmental impact assessment guidelines. It is necessary to verify the adequacy of discharge water and determine the amount of water usage.

(2) Future Project framework

Table 5-3.2 shows the project framework in each target sites.

Table 5-3.2 Project framework in each target sites

Priority	Site	Main equipment configuration incidental work (including supervision and execution supervision)	Reason of prioritization
1.	Katse	500kW turbine / generator x 2 Main transformer and circuit breaker for system integration Equipment loading road 200 m	The power, generated by the hydropower plant is determined by the amount of water flowing into the turbine and the head. Since the water is sent from the Mohale Dam to the Katse Dam, the output of the Katse Dam, whose water level is relatively high, is secured. In addition, there is winter snowfall around the Katse Dam, and power outages may be prolonged due to transmission line failures.
2.	Mohale	1,000kW turbine / generator x 1 Main transformer, circuit breaker for system integration Renovation of hydropower building	There is a possibility of improvement due to the planned construction of the Polihali Dam, but the water level will drop due to water supply to the Katse Dam, which may affect the power output.
2.	Metolong	100kW turbine / generator x 1 Extension of the existing drainage pipes, construction of a hydroelectric power station building on the riverbed, and other constructions such as access roads and renovation of existing substation	It is about the office power supply; not applicable
4.	Polihali	Flow rate is unknown. It is assumed to be similar to Mohale.	Dam will be completed after 2023; not applicable

Source: JICA Study Team

(3) Validity of the project

As described in 3-4-1 “Lesotho Highland Water Project (LHWP)”, the power generation capacity in Lesotho is less than half of the power demand, and the power shortage is serious. Under the circumstances, the Government of Lesotho regards power development as a national priority and has set forth a policy in the Lesotho Energy Policy 2015-2025. This project, which effectively utilizes the discharge water that has been simply discharged into rivers as renewable energy, is consistent with this policy.

The transmission line from the small hydro power plant is extended to the Maseru city from the Katse dam. In the event of the transmission line faults, it is possible to supply the power from the small hydro power plant of this project to the fault section of the transmission line. As long as the Katse Dam substation does not become a fault point electricity can be supplied to surrounding villages distributed from the Katse Dam substation. When the hydropower plants (Katse and Mohale) of this study are realized, a total of approximately 2 MW of power can be supplied. The amount of power that can be generated is approximately 14.4 million kWh (approximately valued at 160 million yen for 1 kWh = 10 cents). Assumed beneficial effects are as follows.

- Improving the trade balance: The electricity imports can be reduced.
- Improving the energy security: Improving the domestic power ratio
- Climate change mitigation: CO_2 emissions reduced by 13,723 ton/year for approximately 14.4 million kWh of generated power. (It is calculated that assuming that the operation of small hydropower plants will reduce imported power from South Africa.)
- Improving the power supply reliability: The power supply of the hydropower station can be backed up during the LEC power outage to secure the power supply in the area around the dam. It is possible to support the operation of the dam smoothly and to promote the economy around the dam.
- Reduction of power generation costs through long-term operation: If the generated power is sold with a long life equipment, the initial investment can be recovered within 20 years.

5-4 The current state of the target site and plan

5-4-1 Katse Dam

(1) Location

The Katse dam is located on the Malibamatso River in the Thaba-Tseka district, 219 km Northeast of Maseru. The conditions of A1 and A25 roads to the site are good, so there is no problem with access to the site. It takes about 200 minutes by car from Maseru. (*cf.* Figure 5-4.1)

Source: JICA Study Team

Figure 5-4.1 Location of the Katse Dam

(2) Water usage and power generation specifications

It would be sure to use the official compensation discharge data prepared by LHDA for planning power generation at Katse, because the discharge from the dam has been controlled and conducted rigorously based on their rules. The power generation output is approximately 1MW, assuming the optimal water consumption calculated from discharge water (for utilization and environment) rate of LHDA from 2009 to 2018, and the power generation head and power generation efficiency. (For details, see 5-3 (1))

For planning turbine specification, the head variation (maximum head ~ minimum head) resulted from natural variation of Katse dam water level is considerably large and the dam water level has a declining trend in recent years. Thus, the selection of turbine design head and the determination of head range for restricting turbine operation should be examined carefully in future design stage.

(3) Existing power generation facilities

According to the prior information, one (1) set of a small hydropower generation facility was already installed inside the power generation facility building. However, although it had been operating in the past, it has not been operated since 2010 due to the flooding of the power plant building. According to the information from LHDA, the flooding events of this building have occurred twice in the past. This flooding accident did not mean that there was a structural problem in the main building section.

Two reasons of the water immersion accident were explained by LHDA staff as follows.

1) A part of large amount of falling spilled water from a crest spillway of the dam in flood condition infiltrated from the opening around the discharge valve room located above the powerhouse and fell along inspection galleries to the powerhouse. (*cf*. Figure 5-4.2)

2) In addition, a worker forgot to close a drainage valve at a drain pit of the powerhouse in flood condition. The valve was to be closed originally by rule in flood condition.

Source: LHDA Web site

Figure 5-4.2 Water flow from Katse Dam spillway (at flood)

Though the splashing water from the dam crest during flood periods is unavoidable, countermeasures to preventing water immersion such as the installation of water-tight doors at some places in the inspection galleries should be applied. LHDA staff recognized this matter sufficiently and they are to plan appropriate countermeasures. Regarding the rating plates, the specifications of the existing generating main machines are as follows.

1) Turbine

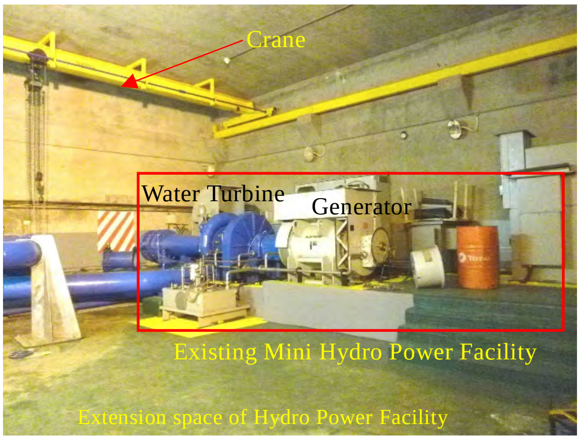
Type:	Horizontal Francis turbine
Rated output P:	500 kW
Rated discharge Q:	0.5 m^3/s
Normal head H_n:	123 m
Speed n:	1,500 rpm
Manufacturer:	GEC Alstom – Neyrpic Minihydro (France)
Supply year:	1998

2) Generator

Type:	Horizontal 3-phase synchronous generator
Rated capacity:	625 KVA
Rated effective output:	500 kW (power factor; 0.8)
Rated voltage V:	3,300 V

Speed n:	1,500 rpm (50 Hz, 4-pole)
Applied standard:	IEC 34
Product weight:	4,730 kg
Manufacturer:	Alstom (France)

- In the building, the end portion of the penstock and the discharge pipe for the draft tube for the expansion turbine, in addition to the ones for the existing unit, were installed previously.
- Near the ceiling of the building, a crane having a rated lifting capacity of 5 ton has been installed (*cf*. Figure 5-4.3).
- The size of the equipment entrance on the ceiling on the right bank side of the building is approximately 2 x 3 m (*cf*. Figure 5-4.4).



Source: JICA Study Team

Figure 5-4.3 Existing generating facility

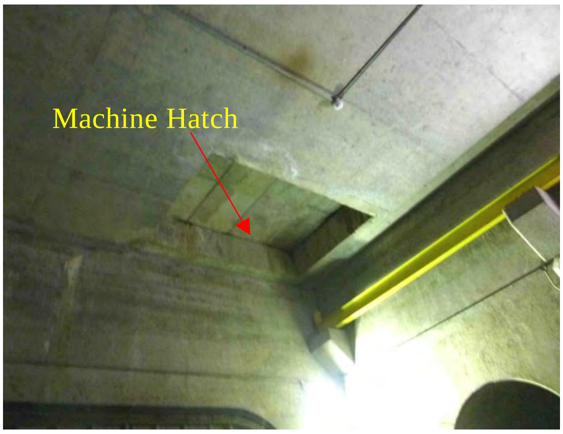


Figure 5-4.4 Service entrance opening in the room

(4) Space in the existing equipment room

According to the report prepared in 2018, Sub Task 4.3-Analysis of Viable Small or Medium Hydroelectric Power Options within the Existing LHWP System, arrangement drawing was shown under the future plan of 2-unit installation. One set of the unit has been installed, and it would be considered that there is the space for installing an additional one set of the unit having the same specifications. But, it might be considerably cramped for the two-unit arrangement (*cf.* Figure 5-4.3). The existing turbine has the conventional pressure-oil system for operating guide vanes to control turbine output and the open-close operation of a turbine inlet valve. Thus, additional installation space is needed for installation of the pressure-oil equipment. From the viewpoint of total installation space and simplification of maintenance, it would be appropriate to apply the motorized control method, instead of the pressure-oil control method, to newly installed generating units. The motorized control method is very popular for the current Japanese small hydropower plants.

As the result of the survey on the current condition of Katse dam facility, the study team confirmed that the final capacity of the new small hydropower equipment should be determined after the sufficient examination on the possible capacity using the flow rate available for generation, the outer dimensions and weights of the major equipment, and the relation between those data and carrying-in/installation method, in order to examine the final specifications of the new generating facility.

(5) Issues related to the generator room

1) Access to the powerhouse

At present, since a vehicle cannot directly access the generator room, a facility for carrying in equipment is necessary.

The following three plans are considered as viable methods and the problems are also described.

Table 5-4.1 Loading method proposed to the power plant building

Item	Name	Method	Evaluation
1.	Use of the downstream passage of the dam	Although the width of the passage is 4.4m, when hanging equipment by a crane, there is not enough space and difficult to install a support, outrigger to stabilize the crane. In addition, the passage is supported by a beam overhanging from the dam, and when a heavy object passes through the passage supported by the beam, it is necessary to confirm the load that can pass or recalculate the structural strength.	Reinforcement of passage is necessary and implementation is difficult. △
2.	Crane and Incline installation method	This is a method, where the equipment is lowered to a dam footing under the current access road by a crane, and transported to the power plant by an incline. Although realistic, the incline cannot be permanently installed due to the possibility of flooding during floods. (See the figure below). 	Although it is feasible, it is likely to damage if the water level rises. △
3.	Installation of access road	The plan is to construct a new access road from the vicinity of the secondary dam located downstream to the power plant. However, the road may be submerged in the event of a flood, and will be installed by cutting rock. Because it is a road on a bedrock, it can be used even if it is submerged in a flood. However it is necessary to take measures such as pavement surfaces and guardrails against the water from the spillway. (See the figure below.) Also, in planning the access road, it is necessary to take care not to affect the cave leading from the secondary dam to the lower part of the dam.	Although it costs money, it can be used for maintenance even after completion. ○
			

Source：JICA Study Team

Considering the above, item 2. Method by crane and incline installation and item 3. The installation of access roads is considered to be influential, and it is necessary to consider in detail the available heavy equipment etc.

2) Leakage on the powerhouse

There are some cracks in the wall of the powerhouse, but this is not a problem. However, water leakage can be seen from the opening for carrying in equipment on the ceiling. At the time of the survey, there is no doubt that water from the discharge valve at the top of the powerhouse has leaked, but it seems that the entire powerhouse will be submerged during a flood. It is necessary to repair the watertight material of the opening cover and the concrete crack at the corner of the opening. In addition, since water may leak in the future, it is desirable to install a water receiving pit directly under the ceiling opening and a submerged pump that automatically operates when a specified water level is detected.

3) Issues related to flooding of the power plant building

As described in 5-4-1 (3), the flooding of the power plant building occurred twice due to followings;

- (i) The scattered water invades from the opening near the upper discharge valve room.
- (ii) The water flows down the audit corridor and flows into the lower generator room. (*cf.* Figure 5-4.5)
- (iii) The staff forgot to close the drain valve of the drain pit in the power generation facility building to be closed.

Of these factors, (i) and (ii) are structural factors, and (iii) is a human factor, and their countermeasures are currently under the responsibility of LHDA.

As a countermeasure for (i) and (ii), if there is a problem after checking the water tightness of the opening, it is considered effective to renovate the door and watertight rubber or to install the waterproof door to secure the water tightness. For (iii), it is considered effective to automate the opening and closing of the drain valve and to install a check valve at the outlet. At the same time, it is considered desirable to install a drainage pump in case of emergency.

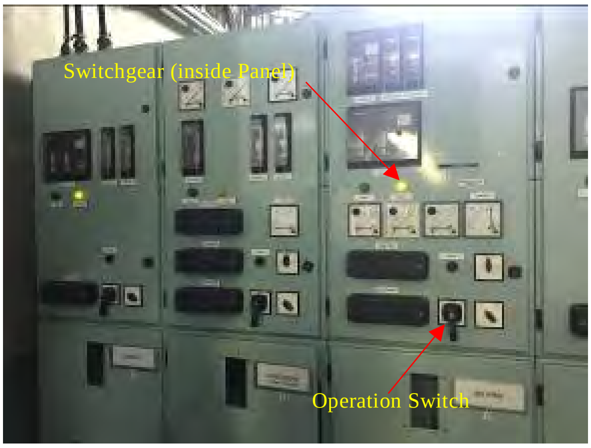
Source: JICA Study Team

Figure 5-4.5 Dam Auditorium Location

(6) Connection to the LEC (Lesotho Electricity Company) 11kV power grid

1) Existing Equipment

The existing power system of Katse Dam has just been receiving electricity from LEC 11 kV power grid through Katse Dam 66 kV/11 kV Substation. Three backup generators have been installed and those are connected to the 11 kV busbar at the LHDA premises. The rated voltage of existing mini hydro generator is 3.3 kV, and goes to 11 kV by GSU (Generator Step Up transformer) (630 kVA). Then it is connected to the above 11 kV bus bar. As a GSU has been installed in the upper floor of the power house, there is a space for a new GSU next to the existing GSU. The existing GSU was damaged and It will be necessary to replace the GSU. A switchgear room is planned on the same floor of the GSU. But, the space is not enough for the installation of a new switchgear. Consideration for a location of a new Switchgear is needed. (*cf.* Figure 5-4.6 and Figure 5-4.7)



Source: JICA Study Team

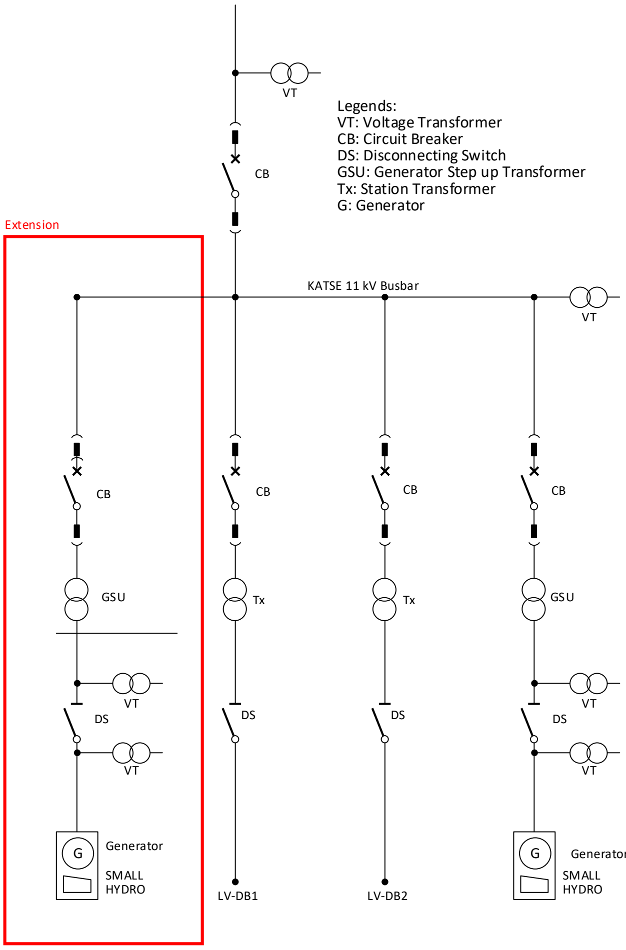
Figure 5-4.6 Katse Trans yard

Figure 5-4.7 Existing Katse switchgear

2) Extension of the new equipment

The newly installed generator will be connected in parallel as per Figure 5-4.8. The newly proposed power system is to consist of a Turbine, a Generator, an Exciter Transformer, a 3.3 kV GMCB (Generator Main Circuit Breaker), a GSU rated 3.3/11 kV, a 11 kV Metal Clad Switchgear with busbar, and secondary equipment with Tariff, e.g., Turbine, a Generator, and Transformer control & protection.

The specification of the existing busbar is not available yet as it is necessary to check the specification (capacity, etc.,) and to consider the needs for in-situ replacement of the existing equipment.



Source: JICA Study Team

Figure 5-4.8 Extension of the new 11kV generator bay

3) Supervision of the hydropower station

The control method of the existing small hydropower generation equipment is performed at the local end. Therefore, SCADA and local DCS are not installed and the condition of the existing generator is not supervised by NCC in LEC. According to LHDA, the existing transformer has deteriorated due to the overload from such a condition, and a function to remotely monitor abnormalities is required when designing of this project.

(7) Background in which power generation facilities have not been installed to date

For the Katse and Mohale dams, building space for small hydropower plants has been planned from the beginning. Although procurement of equipment was necessary to realize the plan, there is an implementation difficulty due to the budget constraints. The Katse Dam had a 500 kW small hydroelectric power plant that could be connected to the grid, but in 2010 the operation was stopped due to flooding. Diesel generators, with low initial costs but rising fuel costs, are installed as a substitute, and they must be started up when the power supply for the city becomes insufficient.

(8) Inland Transportation in Lesotho

When the Katse dam is installed away from Maseru city, inland transportation of heavy electrical materials and transformers that cannot be disassembled and are likely to be the heaviest cargoes will be critical points. At the detail planning stage, it is essential to investigate the transportation route from Durban Port in South Africa. Especially the hills in the Lesotho country will be the constraints, in terms of not only the weight but also the length, width, and height as well as the width of the bridges and wires.

This study did not confirm the transportation regulations of Lesotho. According to the regulations of South Africa, the specification of cargo containers is L12.5 m x W2.6 m x H4.3 m (or less), and it is necessary to obtain a permission for transportation. The port of South Africa is usually Durban Port, but Richards Bay Port may be selected for heavy goods due to the ease of transportation.

5-4-2 Mohale Dam

(1) Location

The Mohale dam is located on Senqunyane River in Maseru district, 105 km east of Maseru city. The condition of the paved road to the site is good, so there is no problem with access to the site. It takes about 120 minutes by car from Maseru. (*cf.* Figure 5-4.9)

Source: JICA Study Team

Figure 5-4.9 Mohale dam location

(2) Relation between the maximum discharge and the predicted power output

The power generation output is approximately 1.0 MW, assuming the optimal water consumption calculated from discharge water (for utilization and environment) rate of LHDA from 2009 to 2018, and the power generation head, and power generation efficiency. (See 5-3 (1).)

Same as Katse dam condition, for planning turbine specification, the head variation (maximum head ~ minimum head) resulted from natural variation of Mohale dam water level is considerably large and the dam water level has a declining trend in recent years. Thus, the selection of turbine design head and the determination of head range for restricting turbine operation should be examined carefully in future design stage.

(3) Space in the existing discharge valve room

The Mohale dam has an existing building for discharge valves at the downstream side. A compartment or room for a future small hydropower facility is provided in the building. In the compartment, one set of the end portion of penstock and an inlet valve for a turbine were installed previously for future power generation. The major part of the compartment is one open space, making it available for the installation of a generating facility, especially for a set of turbine and a generator. In addition, an overhead 5-ton crane for the equipment was installed previously.

Source: JICA Study Team

Figure 5-4.10 Compartment for generating equipment

Figure 5-4.11 Overhead Crane

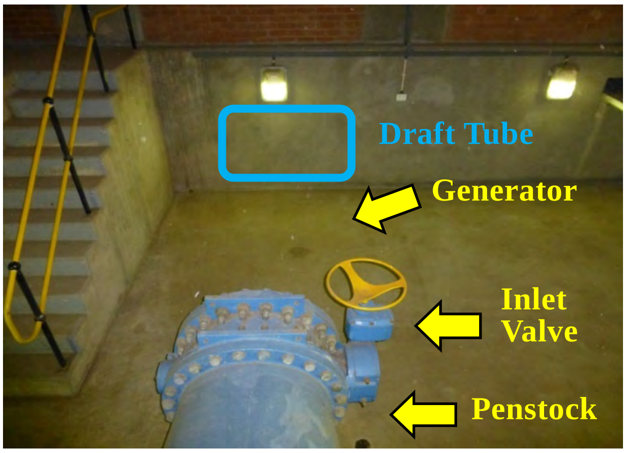
On the other hand, the open space of the compartment would not be wide enough for generating equipment, and the lifting capacity of the crane might be one of the restrictions (*cf.* Figure 5-4.10 and Figure 5-4.11). Thus, the rated capacity of generating equipment will be determined under the conditions of the space and the maximum weight of the major components.

Under the premise that reconstruction of the existing powerhouse including the change of building structure and the enlargement of building main dimensions, etc. is not carried out, the plant rating capacity might be reduced from the capacity noted above item (2) on the viewpoint of sizes of generating equipment. On the other hand, the reconstruction of powerhouse might be needed to install the equipment having the capacity corresponding to the full available discharge. Thus, careful examination on this point is needed in future design stage.

In addition, for each plan the power water from a turbine is to be discharged to the outside of the building through a draft tube, one of the turbine components. For such a purpose, the new work of reconstruction at the downstream wall of the building is needed for the installation of the draft tube. Additionally, a discharge basin, a concrete structure is to be reconstructed at the place adjacent to the building for enhancing the function of the draft tube.

(4) Issues associated with the new generator room

The space in the generator room is narrow and the draft tube must be installed diagonally. Therefore, it is necessary to demolish the wall that has already been constructed, but since the upper part is a brick wall, the strength of the wall must be confirmed before demolishing the wall. It will be done manually (*cf.* Figure 5-4.12 and Figure 5-4.13)



Source: JICA Study Team

Figure 5-4.12 Space in the generator room in Mohale

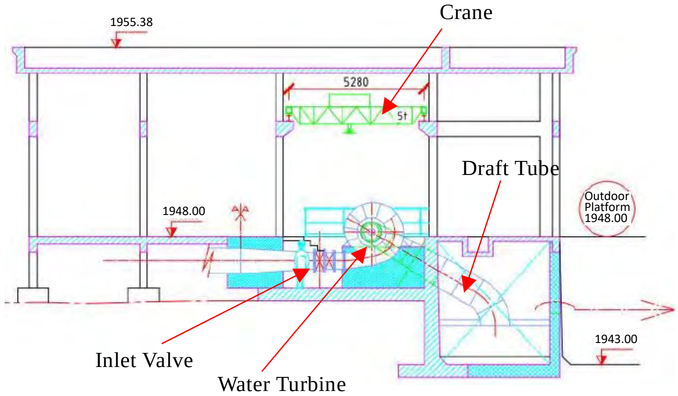


Figure 5-4.13 Sectional plan in the generator room

Although the tailrace is installed, it is necessary to install a wall that matches the draft tube as a tailrace to secure the discharge level.

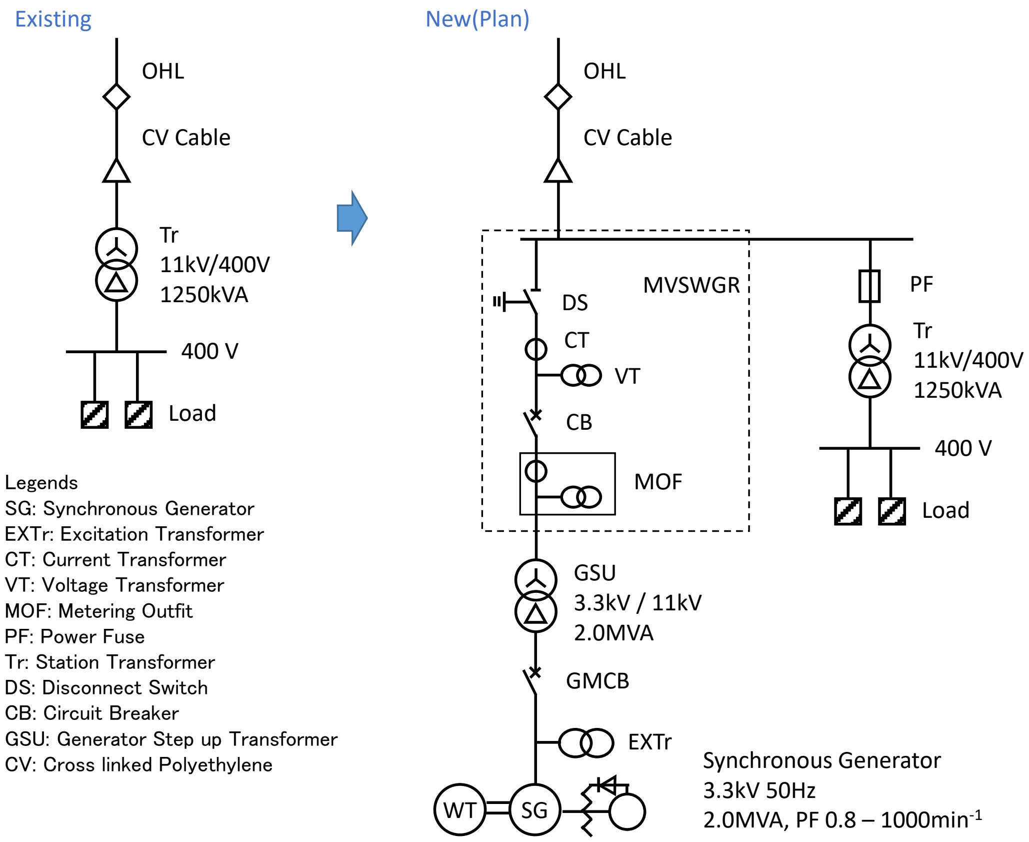
The equipment access road will use the road installed on the downstream side of the dam, but it will need to bend around the sharp curve, so the trailer cannot be used and vehicles with a length of about 10 m seems to be the limitation.

(5) Feasible solution for the commission to the LEC (Lesotho Electricity Company) 11kV power grid

The existing power system has just been receiving electricity from the LEC 11 kV power grid through the Station Transformer rated 1.25 MVA, 11 kV/400 kV and the 11kV Distribution board for loading of the Valve control.

The newly proposed power system comprises a Turbine, a Generator rated 1.0 MW, a 11 kV GMCB (Generator Main Circuit Breaker) with auto Synchronization, a GSU (Generator Step Up transformer) rated 3.3/11 kV, a 11 kV Metal Clad Switchgear with Busbar, and secondary equipment with Tariff, e.g., Turbine, Generator and Transformer control & protection. These provisions are made on the basis of electricity being moved upstream towards the LEC power grid.

The existing and the newly proposed key line diagrams are shown in Figure 5-4.14 for the conceptual understanding and evaluation purposes.



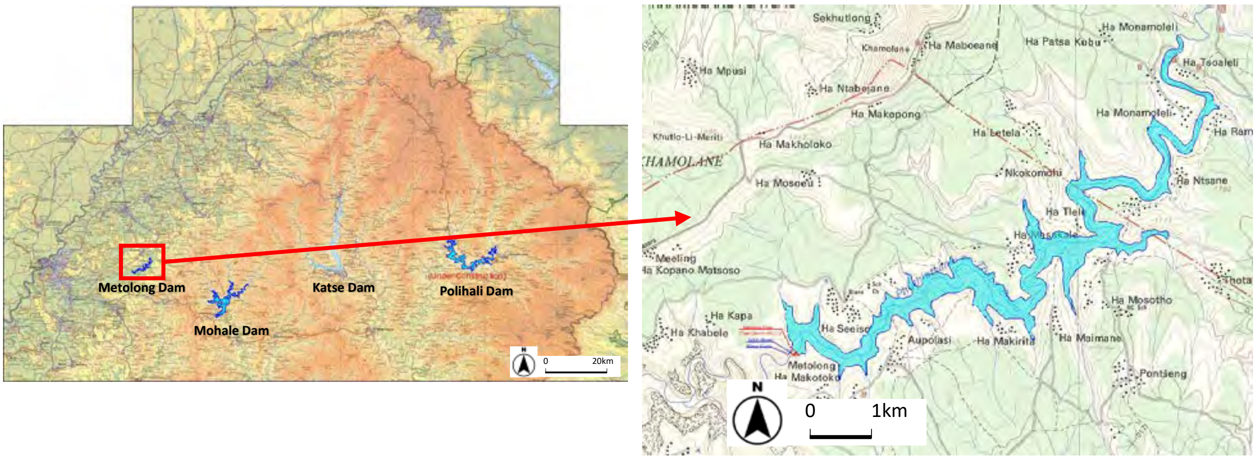
Source: JICA Study Team

Figure 5-4.14 Proposed key line diagram

5-4-3 Metolong Dam

(1) Location

The Metolong dam is located on the south Phuthiatsana River in Maseru district, 37 km east of Maseru city. The condition of the paved road to the site is good, so there is no problem with access to the site. It takes about 40 minutes by car from Maseru. (*cf.* Figure 5-4.15)



Source: JICA Study Team

Figure 5-4.15 Metolong Dam Location

(2) Relation between the maximum discharge and the predicted power output

The power generation output estimated from the discharge water from 2016 to 2018 and the estimated power generation, assuming the power generation head and power generation efficiency, is about 120 kW (see 5-3 (1)). The above is the output at the maximum discharge rate. Considering annual operation, the average discharge rate in the past three years is 20 liter / sec (0.02 m^3/sec), so the power generation scale is about 10 kW. Therefore, it is determined that the scale is too small to connect to the power system.Space in the existing discharge valve room

(3) Space in the existing discharge valve room

In the existing discharge valve room, two (2) sets of discharge valve bodies and connecting penstocks occupy a large central part of the room. Thus, it would be impossible to have enough space for new power generating equipment (such as turbine, generator, penstock for a turbine, control panels, etc.), as a result of this survey. Photos taken in the discharge valve room and a floor plan of the room are shown in Figure 5-4.16 and Figure 5-4.17.

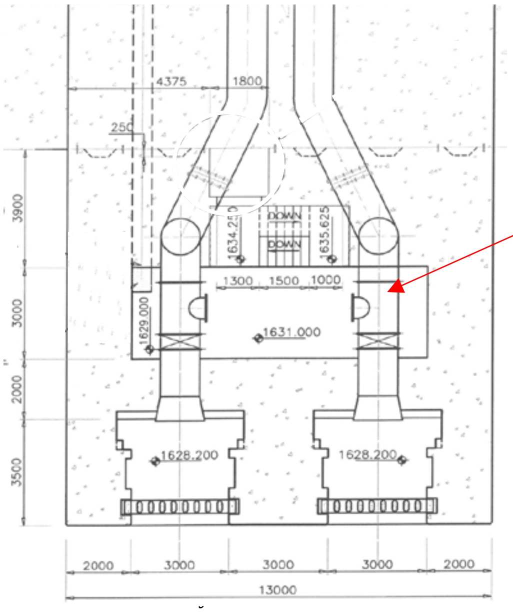


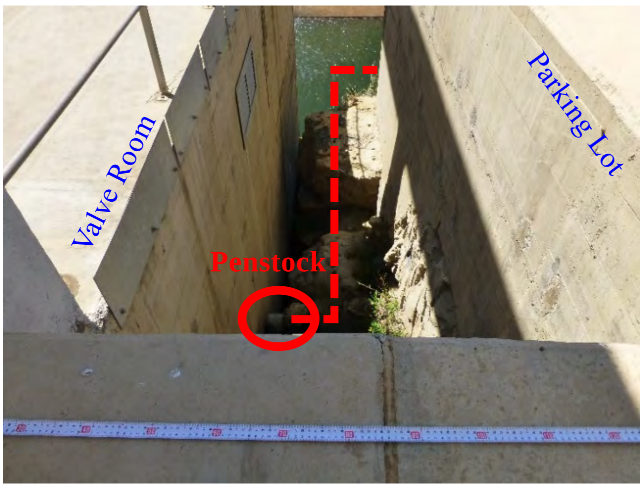
Figure 5-4.16 Floor plan of existing valve room

Figure 5-4.17 Valve room

The estimated plan dimensions of the room necessary for the installation of power generating equipment having the capacity calculated in above item 4.3.2 are 3 m×5 m for the entire installation, operation, maintenance and inspection.

(4) Problems associated with the new generator room

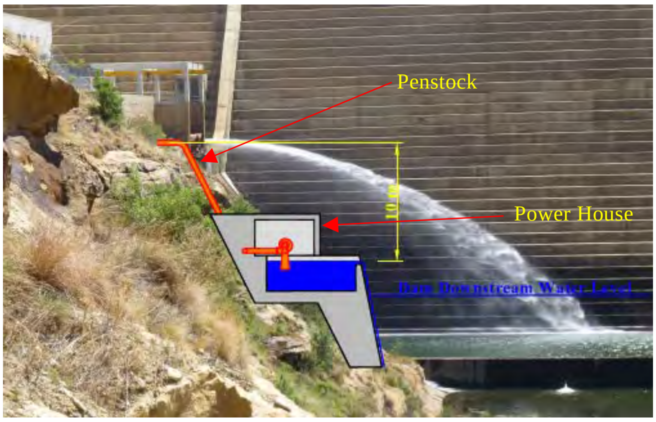
With the two sets of discharge connection pipes, the pipe for power generation (penstock) is branched from the downstream pipe and the branched pipe ends at a position 0.3 - 0.4 m downstream from the discharge valve chamber. The pipe connection from the end of the penstock should originally use a curved pipe, however the space between the downstream wall of the discharge valve chamber and the wall of the parking lot is 1.65 m and 90 ° elbow will be used. Consequently, the power generation head loss increases, whereas the power generation output decreases. (*cf.* Figure 5-4.18)



Source: JICA Study Team

Figure 5-4.18 Overview of the new generator room

The generator room will be installed downstream of the dam downstream revetment. (*cf.*Figure 5-4.19) Although the foundation surface is bedrock, the slope is steep, and it is necessary to install a foundation of the generator room and a tailrace with concrete from near the riverbed, thereby presenting a major issue for civil work. However, as the water level in the tailrace can be estimated to be about 10 m lower than the current valve position, the effective head becomes higher and the power output is expected to increase by about 20 % from the value calculated in section 4.3.2.



Source: JICA Study Team

Figure 5-4.19 Sectional plan of the generator room

(5) Infeasibility of the commission to the LEC 33 kV power grid.

Due to the small power generation output less than 100 kW, we presume not to reach the LEC 33 kV power grid through the existing WASCO 11 kV Switch yard. The power train from the Turbine/Generator to the LEC 33 kV power grid is to comprise the following items;

1) Generator to the GSU (Generator Step Up Transformer) , a secondary voltage 11 kV : 11 kV XLPE Power Cable Connection
2) GSU to 11 kV MVSWGR (Middle Voltage Switchgear): 11 kV XLPE Power Cable Connection
3) 11 kV MVSWGR to the existing WASCO 11 kV Switch yard: 11 kV ACSR (Aluminum Conductor Steal Reinforced) Connection via OHL (Over Head Line) with new gantry structure
4) Modification of the existing WASCO 11 kV Switch yard to incorporate 1) ~ 3).

5-4-4 Polihali Dam

(1) Location

The Polihari dam is located on the Senqu River in Mokhotlong district, 278 km northeast of Maseru is scheduled to be completed in 2023. The condition of the A1 road to Mapholaneng is good, but the access road from Mapholaneng to the site about 16 km is not paved as of December 2019. It takes about 300 minutes by car from Maseru to the site. (*cf.* Figure 5-4.20)

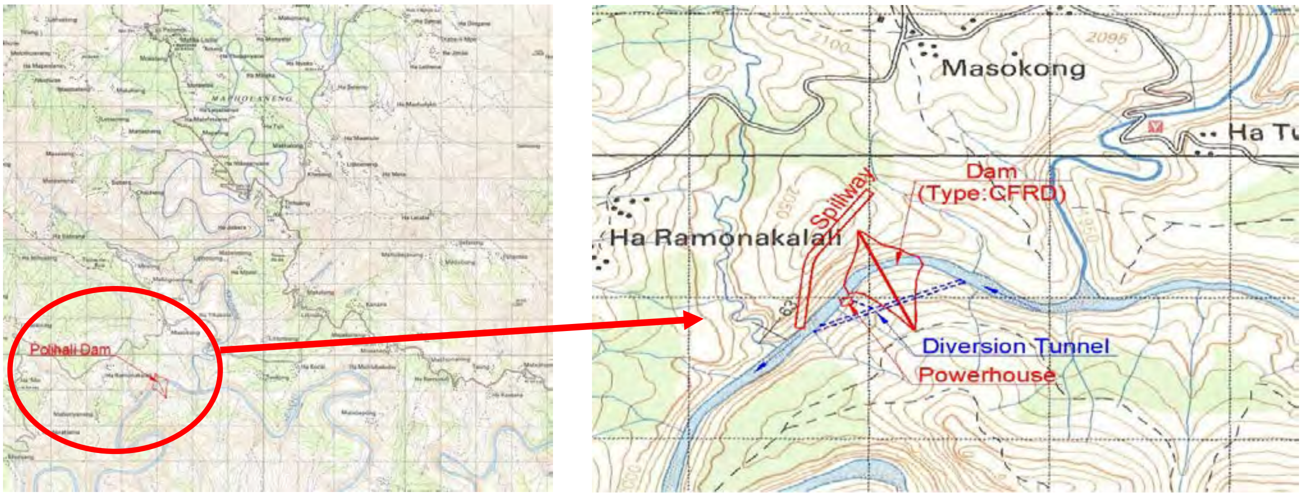
Source: JICA Study Team

Figure 5-4.20 Location of the Polihali Dam

(2) Polihali Dam future plan

The results of local confirmation of the Polihali dam project are as follows; (*cf.* Figure 5-4.21)

i) Polihali dam is planned as CFRD (Concrete facing rock fill dam).
ii) Dam has almost the same shape as the Mohale dam.
iii) A spillway route is planned on the right bank of the dam.
iv) A powerhouse is planned at the dam downstream of the right bank.



Source: JICA Study Team

Figure 5-4.21 Location and preliminary plan of the Polihali Dam

(3) Scheme of small hydropower facility

When the study team visited the Polihali site on 17th December 2019, the construction was at the stage of the temporary works such as access roads, not at the stage of the dam portion as informed previously.

According to the information from a project officer of LHDA at the site, the dam has the same design concept as one of the Mohale dams and a small hydropower plant is to be installed annexed to the dam on the downstream side.

Though the data and drawings of the Polihali dam concerning the discharge related to discharge water and the targeted small hydropower plant have not been delivered to the team by LHDA at present, those data and drawings are expected to be provided. After that, the technical study by the team is to be carried out.

On the other hand, in the report “Sub Task 4.3-Analysis of Viable Small or Medium Hydroelectric Power Options within the Existing LHWP System” issued in 2018, a plan view drawing of the small hydropower plant building, proposed in a FS report issued in 2008 for LHWP project, was shown.

In the report (Sub Task 4.3), the expected specifications of the generating facility were proposed using the result of the technical examination on the discharge water available for power generation as follows.

Turbine type;	Horizontal Francis turbine
Number of unit;	1 unit
Generator capacity;	3.0 MVA
Design turbine discharge;	1.8 m^3/s
Maximum design gross head;	153 m (not net head)

At the same time, the problem indicated below was pointed out in the report (Sub Task 4.3). The building plan dimensions proposed in the FS report for LHWP are considerably small, and some portions of the generating equipment, which is examined in above item 5), are to interfere with the building structure. Thus, an alteration of the original building design that is needed for enlarging the dimensions of the generating facility compartment in the building is described clearly in the report. According to the explanation, a design alteration is possible at present because the construction of the generating facility is in the planning stage.

If a design alternation of the building is not conducted, the capacity/dimensions of the generating equipment should be reduced for installing in the small building compartment of the original design. In this case, the discharge water available for power generation is “not” to be utilized effectively.

For the installation of a small hydropower facility in the future by a donor, JICA, or another donor, an enlargement of compartment dimensions for a generating facility in the building should be examined to realize the appropriate hydropower generation.

5-4-5 Muela Dam

The Muela Hydropower Plant is not the target site of this project, but a field survey was conducted to confirm the status of the information collection and maintenance of the existing facilities.

(1) Overview of the Power Plant

- The Muela HPP is located in the Botha-Bothe district, 153 km northeast of Maseru. The condition of the A1 road to the site is good, so there is no problem with access to the site. It takes about 150 minutes by car.
- Three (3) sets of turbines and generators were installed in the hydropower plant and the total generating output is 72 MW. The commissioning year of the plant was 1997.
- The generating equipment was installed below ground, so-called “underground hydropower plant” and the plant is accessible through a tunnel. On the other hand, the management and control rooms are in a building on the ground.
- Water stored in the Katse dam reservoir is supplied to the plant through a water tunnel system, and the water after generation is transferred and exported to the Republic of South Africa via the Muela dam.
- When the study team visited on November 30th, the plant was out of service because of the periodical inspection and maintenance of the water tunnel system that are conducted every 10 years as of 30th November 2019

(2) Existing generating equipment

1) Turbine

Type;	Vertical Francis turbine
Rated output;	25.2 MW
Speed;	750 rpm
Runaway speed;	1,380 rpm
Maximum head;	287.0 m
Rated head;	237.0 m
Minimum head;	196.0 m
Turbine setting elevation;	1,746.0 m a.s.l
Manufacturer;	Kvaerner (Norway)

2) Generator

Type;	Vertical synchronous generator
Rated output;	32,000 kVA
Power factor;	0.85
Voltage;	11,000 V

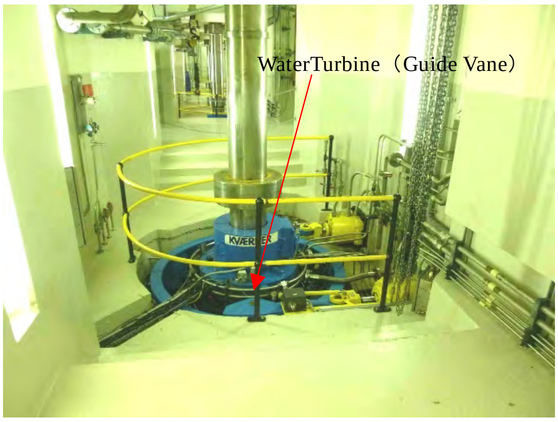
Speed;	750 rpm
Frequency;	50Hz
Manufacturer;	ABB (Switzerland)

(3) Operation and Maintenance

The plant is owned by LHDA, and LHDA has the responsibility for the operation and maintenance of the plant.

The operation and maintenance personnel of the plant was trained in the United Kingdom.

In spite of the fact that the generating equipment has been operated for approximately 20 years, the equipment was in very clean condition and no oil-spot around pressure-oil equipment and no dust accumulation on various equipment units were found. That means that a higher level of maintenance work has been conducted by the personnel. (*cf*. Figure 5-4.22 and Figure 5-4.23)



Source: JICA Study Team

Figure 5-4.22 Turbine Room

Figure 5-4.23 Turbine pressure-oil equipment

Though overhaul inspection and maintenance work has not been carried out at present, replacement of the wearing parts of the turbine such as guide vane bearing bushes, etc. is scheduled to be implemented next year. That means the overhaul work is to be carried out.

Heat-exchangers of the air-cooler system of the generator were replaced by new ones several years ago. In accordance with the LHDA regulations, the maintenance and management of the power generation facilities at the Muela Power Station are to be carried out every year for two weeks with the main engine stopped, and every ten years for two months with the suspension of the main engine. The JICA study team had confirmed that Necessary repairs and replacement of worn parts were performed during these inspection periods.

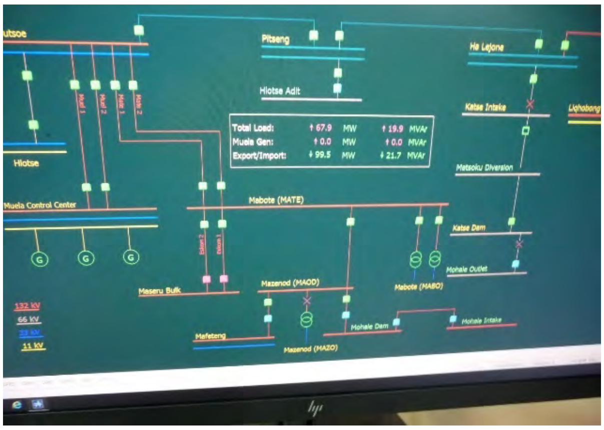
The main equipment is manufactured by European companies, but the company has a local factory in South Africa, so the procurement of replacement parts and the necessary technical support are carried out smoothly.

The technical staff required for the maintenance and management of the equipment is allocated according to the organization chart for each office at the dam. The cost of equipment maintenance and periodic inspections is budgeted annually by the Lesotho Government.

(4) Relation between the DCS (Digital Control System) in the Muela Hydropower Station and the NCC / RCC in Lesotho

NCC and RCC, which are located in Maseru, belong to LEC. RCC is a subset of NCC and their equipment are Spider, ABB made. The old NCC / RCC equipment, Mosaic board, is not currently used. (*cf.* Figure 5-4.24)

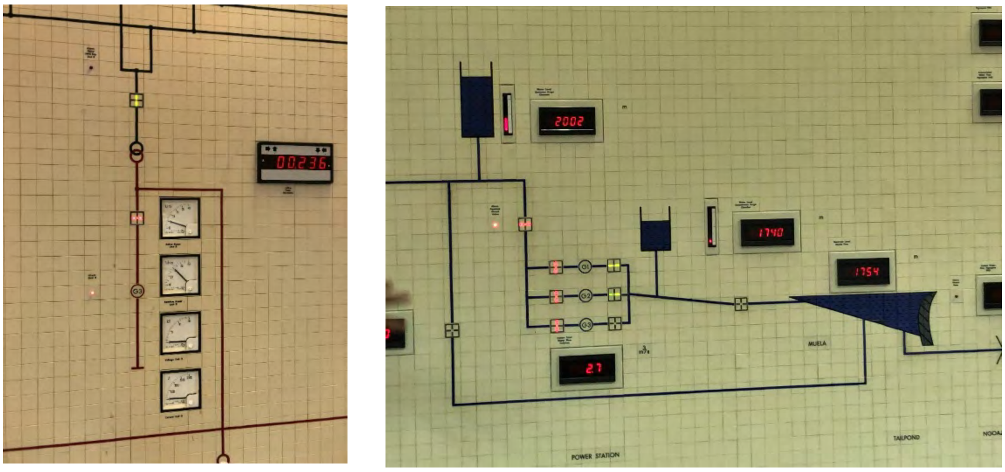
NCC / RCC is used to simulate 132 kV, 66 kV, 33 kV, and 11 kV systems in the Muela Hydropower stations for the monitoring purpose. NCC can monitor and control the same system as RCC. If maintenance or any other control is required, contact an employee in the Muela Hydropower stations via conventional telephone calls.



Source: JICA Study Team

Figure 5-4.24 Display of NCC

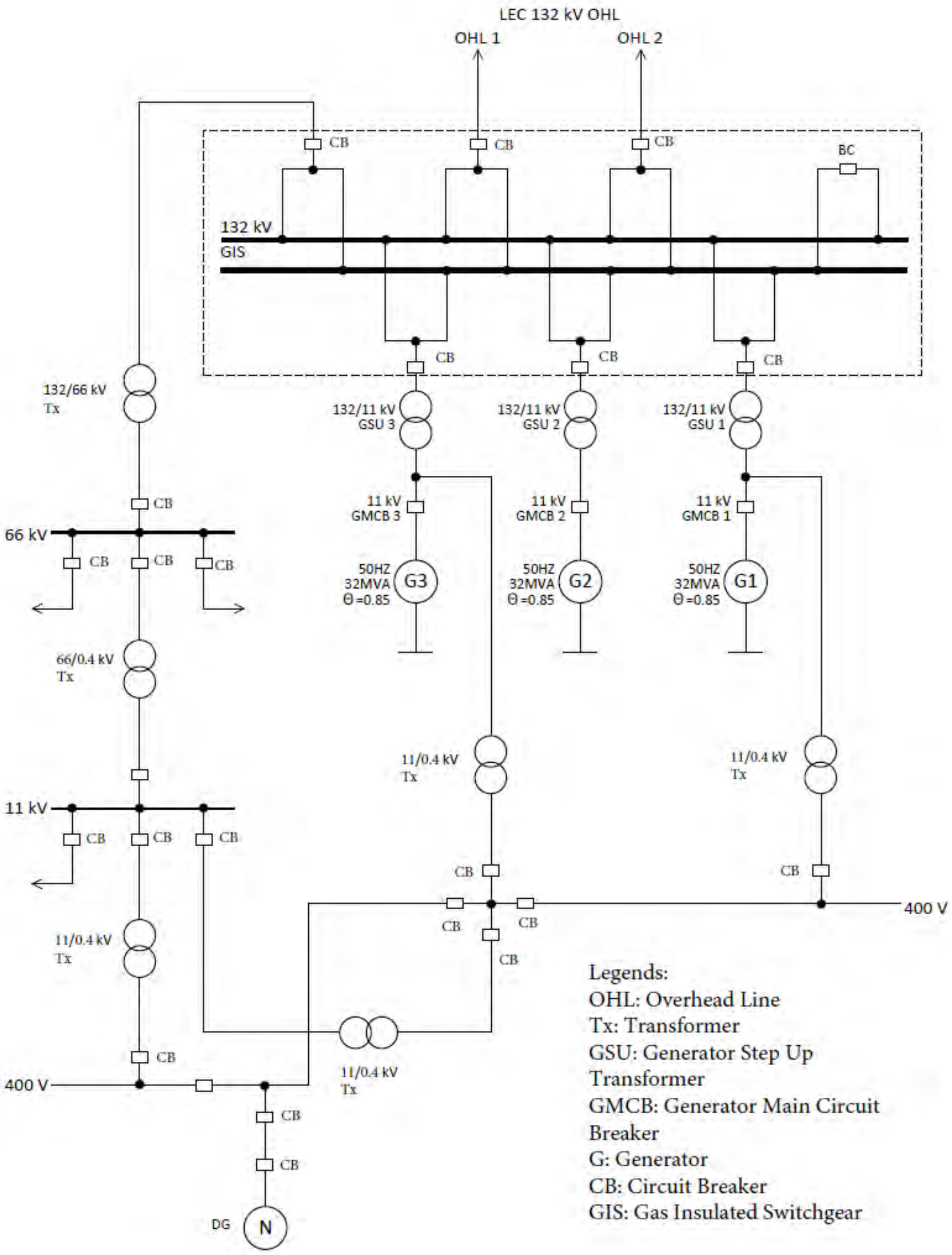
DCS, which is owned by LHDA, in Muela, monitors hydropower stations onto the mosaic boar for both the electrical key line and the water flow state for the health condition as shown in the photographs below. The circuit breakers and valves are to be controlled through a single line diagram and a piping and instrumentation diagram in DCS. (*cf.* Figure 5-4.25). Whenever monitoring and control of another newly installed small hydropower plants, DCS (panel) in the small hydropower plants, NCC can supervise the status of DCS.



Source: JICA Study Team

Figure 5-4.25 Mosaic board in the Muela Hydroelectric Power Station

There is some room to incorporate a new DCS in small hydropower plants into the existing DCS in Muela, with required modification in the key line diagram that is shown below. (*cf*. Figure 5-4.26)



Source: LHDA

Figure 5-4.26 Key Line Diagram in Muela Hydroelectric Power Station

CHAPTER 6 RECOMMENDATIONS

Chapter 6 Recommendations

In this study, the JICA Study Team visited the four candidate sites for hydroelectric power plants and conducted a survey on the status of the sector, the amount of discharge, the installation space for turbines and generators, the organization of operation and maintenance, and the grid connection. The dams in Lesotho are managed by LHDA and WASCO. Even if new small hydroelectric power plant is realized, it is assumed that LHDA and WASCO will operate and maintain the hydroelectric power plant. The LHDA organization has about 300 employees and has the experience in managing the Muela hydroelectric power plant, so there is no problem in implementing the project. The items to be considered as a preliminary survey in this survey are as follows.

(1) Discharge rate

As for the amount of water used for power generation, only records calculated from the water level of the dam as shown in 5-3 have been confirmed. Although there is no data on the amount of water used for power generation the same flow rate has been calculated based on the LHDA report and gate opening, etc., and it is considered no problem in preparing an outline plan using the figures. However, it is necessary to reconfirm the relationship between the water level of the dam and the discharge rate as data for designing the turbine, and to measure the actual discharge rate.

(2) Surveying and flow measurement

As for the Mohale Dam small hydro power plant, only a power house has been constructed. However, it is necessary to provide a new drain tube opening, a draft tube on the wall of the building. It has been a long time since the completion of the existing power plant building, then it was found that the structural drawing of the building are unavailable. Therefore, in planning, confirmation of the arrangement of the reinforcing bars on the wall are mandatory during the preparatory survey.

(3) Surveying and Measurement

At the following points, it is necessary to conduct terrain survey and flow measurement for facility design.

- Topographical survey of Katse dam equipment road (about 50 m x 300 m) and canal (about 20 m x 350 m).
- When planning a hydroelectric power plant at Metolong Dam, a partial survey of the riverbed (about 50 m x 50 m) is required to select a site for the power plant facility.
- Measurement of water flow for Katse and Mohale power generation. Specific measurement method of discharge water should be calculated from dam water level, valve opening, secondary dam water level, etc. under the guidance of a JICA survey engineer.

(4) Environmental and social considerations

According to the Ministry of the Environment, there are no environmental issues in the area around the dam. According to the Lesotho Environmental Guidelines, all construction projects need to obtain an EIA. On the other hand, according to LHDA, the EIA was acquired at the beginning of the dam construction, and no provision of new EIA is made. During the preparatory survey, confirmation of EIA is necessary toward Ministry of Environment.

(5) Preparatory survey for cooperation

1) Necessary assignment

i) Chief Consultant, ii) Designing Turbine System, iii) Designing Generator System, iv) Civil Engineering, v) Substation Equipment, vi) Power Flow Analysis, vii) Road Planning viii) Social and Environmental Considerations ix) Facility Planning, x) Cost Estimation and Construction Planning, xi) Cost Estimation and Procurement Planning

2) Local Outsourcing

Local outsourcing of (3) Surveying and flow measurement.

3) Other considerations

The following points need to be noted in addition to the items to be considered when conducting the preparatory survey for cooperation.

- A Cabinet approval is required to secure the necessary budget for the tax exemption (Counterpart Funding), and it is assumed that the time required for the cabinet approval and will be a risk to the project delay. Under circumstances, it is necessary to promote the project smoothly through discussions with relevant Ministries and Agencies through M/D during the preparatory survey.
- In addition, rehabilitation works related to the existing facilities will occur when installing the equipment, so it is necessary to discuss scope of work. Lesotho has experienced Japan's ODA project “The Project for Introduction of Clean Energy by Solar Electricity Generation System in Lesotho”. The counterparts of this study was the Ministry of Finance of Lesotho through Japan's grant aid scheme.
- It is assumed that there will be no major problems with other permits and licenses. However it is necessary to obtain confirmation from the respective organizations, such as building permits and domestic transport, after the components are confirmed.

APPENDIX

Appendix-1 MEMBER LIST OF THE STUDY TEAM

Appendix-1 Member List of the Study Team

(1) THE FIRST SURVEY FOR DATA COLLECTION SURVEY ON SMALL-HYDRO POWER DEVELOPMENT PROJECT IN LESOTHO

Name	Company	Category
Kiyofusa TANAKA	Yachiyo Engineering Co., Ltd.	Team Leader / Hydropower planning
Fumio TAKEZAWA	Yachiyo Engineering Co., Ltd.	Hydropower civil engineering
Shoichi KUSHIMOTO	Yachiyo Engineering Co., Ltd.	Hydropower machinery
Masahiro YAMAGUCHI	Yachiyo Engineering Co., Ltd.	Electric machinery
Tatsuhiro URABE	Yachiyo Engineering Co., Ltd.	System planning

(2) THE SECOND SURVEY FOR DATA COLLECTION SURVEY ON SMALL-HYDRO POWER DEVELOPMENT PROJECT IN LESOTHO

Name	Company	Category
Kazunari Oshima	Japan International Cooperation Agency	JICA Senior Advisor
Kiyofusa TANAKA	Yachiyo Engineering Co., Ltd.	Team Leader / Hydropower planning
Shoichi KUSHIMOTO	Yachiyo Engineering Co., Ltd.	Hydropower machinery

Appendix-2 STUDY SCHEDULE

Appendix-2 Study schedule

(1) First Field Survey

No.	Date		Description					Accommodation
			Chief Consultant / Hydro Power Station Planning	Hydro Turbine	Civil Work	Distribution Network	Electrical Equipment	
name			Kiyofusa TANAKA	Shoichi KUSHIMOTO	Fumio TAKEZAWA	Tatsuhiro URABE	Masahiro YAMAGUCHI	
1	2019.11.24	SUN	**Trip[Haneda→Hongkong]**					
2	2019.11.25	MON	**Trip[Hongkong→Johannesburg]** ・9:30 AfDB ・11:30 Courtesy call to JICA South Africa Office ・16:00 USAID					Pretoria
3	2019.11.26	TUE	Trip[Johannesburg(09:40)→Maseru(10:35)SA8052] ・14:00 Explanation of inception report, site survey schedule and questionnaire to Ministry of Energy & Meteorogy Department of Energy, LEWA, LHDA, LEC, WASCO					Maseru (LANCERS INN HOTEL)
4	2019.11.27	WED	・AM/8:00 DOE Start→Site Survey for Metong Dam					Maseru
5	2019.11.28	THU	・8:00 DOE Start→10:00 Site Survey for Mohare Dam, 12:00 Meeting with LHDA 16:00 back to Maseru					Maseru
6	2019.11.29	FRI	・8:30 Technical Meeting with DOE ・9:30 Technical Meeting with LEC	・9:30 Technical Meeting with LEC	・Preparation Report,	・9:30 Technical Meeting with LEC		Maseru
7	2019.11.30	SAT	・8:00 Hotel Start→11:00 Site Survey for **Muela Dam (72MW Hydro Power Station),** 15:00 back to Maseru					Maseru
8	2019.12.1	SUN	Preparation Report					Maseru
9	2019.12.2	MON	・8:00 : Meeting with DOE to arrage the meeting with other donners and Ministries ・10:00 : Maseru Start→ 15:00 Site Survey for Katse Dam (Stay Katsue Visitor Center)				AM: Meeting with DOE PM: Meeting with WB	Katse/Maseru
10	2019.12.3	TUE	・9:00 : Site Survey for Katse Dam, Meeting with LHDA				PM: Meeting with Ministry of Finance for Tax exemption Meeting with USAID	Katse/Maseru
11	2019.12.4	WED	・8:00 : (Start Katsue Visitor Center) →move to Polihali Dam→13:00Site Survey for : Polihali Dam ・15:00 Polihali Dam→19:00 Maseru				AM: Meeting with CDM Smith (Contractor of LHWP) PM: Meeting with DOE	Maseru
12	2019.12.5	THU	・8:00 Meeting with DOE to report about site seeing and arrage meetings ・10:00 Meeting with Depart of Environment to hear about environmental reguration and information ・14:30 Meeting with MEM for hearing UNDP's SE4ALL P/J	・10:00 Meeting with Depart of Environment to hear about environmental reguration and information ・Preparation Report		・8:00 Meeting with DOE to report about site seeing and arrage meetings ・10:00 Meeting with Depart of Environment to hear about environmental reguration and information ・Preparation Report	・8:00 Meeting with MEM to report about site seeing and arrage meetings ・10:00 Meeting with Depart of Environment to hear about environmental reguration and information ・14:30 Meeting with DOE for hearing UNDP's SE4ALL P/J	Maseru
13	2019.12.6	FRI	・9:00 meeting with LHWC, LHDA to confirm the correlation of organizations and the answers for questionnaire ・Internal meeting ・Preparation Report					Maseru
14	2019.12.7	SAT	・Internal meeting, Preparation Report					Maseru
15	2019.12.8	SUN	Preparation Report					Maseru
16	2019.12.9	MON	・Preparation Report ・Meeting with LEC	・Preparation Report, Study of permissioins		・Preparation Report ・Meeting with LEC		Maseru
17	2019.12.10	TUE	・AM: Meeting with LHDA ・Preparation Report, Obtain Answer of Questione			・Preparation Report ・Meeting with LEC		Maseru
18	2019.12.11	WED	Preparation Report, Obtain Answer of Questioner/Ministry of Energy & Meteorogy Department of Energy, LHDA, LEC, WASCO					Maseru
19	2019.12.12	THU	・Wrap up survey, meeting with Ministry of Energy & Meteorogy Department of Energy, LHDA, LEC, WASCO, ・Prepare report,					Maseru
20	2019.12.13	FRI	**Trip [Maseru(8:10)→Johannesburg(9:05)] SA8053** 11:30 Reporting to JICA South Africa Office and Embassy of Japan					Pretoria
21	2019.12.14	SAT	**・Trip [Johannesburg→Hong kong]**					
22	2019.12.15	SUN	**・Trip [→Haneda]**					

(2) Second Field Survey

No.	Date		Description		
			JICA Senior Advisor	Chief Consultant / Hydro Power Station Planning	Shoichi KUSHIMOTO
name			Kazunari OSHIMA	Kiyofusa TANAKA	Hydro Turbine
1	2020.1.26	SUN	Trip [(16:10)Haneda→(20:20)Hongkong] CX0549		
2	2020.1.27	MON	Trip →(07:30)Johannesburg] CX0749 ・Meeting with JICA South Africa Office		
3	2020.1.28	TUE	Trip [(09:40)Johannesburg→(10:35)Maseru]SA8052 ・Discussion with the Project Design Report of Katse and Mohale Dam, DOE, LHDA, LEC, WASCO		
4	2020.1.29	WED	・(07:30~)Mohale Dam Site Servay		
5	2020.1.30	THU	・(07:30~)Katse Dam Site Servay		
6	2020.1.31	FRI	・(10:00~)Meeting with DOE	・(10:00~)Meeting with DOE, ・(11:30~)Meeting with LHDA Hydrological	
7	2020.2.1	SAT		・Internal meeting, Preparation Report	
8	2020.2.2	SUN		・Internal meeting, Preparation Report	
9	2020.2.3	MON		・Internal meeting ・(14:00~) Meeting with DOE and LHDA	
10	2020.2.4	TUE		Trip [(10:55)Maseru→(11:50)Johannesburg] SA8053 PM: Report to JICA South Africa Office, EOJ	
11	2020.2.5	WED		Trip [(13:10)Johannesburg→] QR1364	
12	2020.2.6	THU		Trip [→(17:45)Narita] QR806	

Appendix-3 LIST OF PARTIES CONCERNED IN THE RECIPIENT COUNTRY

Appendix-3 List of Parties Concerned in the Recipient Country

Ministry of Finace, Department of Debt

Mr. Khotho Moleleki	Director of Dept.
Ms.Makubatu Rakubutu	Seniro Dept. Officer
Mr. Thuso Seoane	Seniro Dept. Officer

Ministry of Energy and Meteorology (MEM), Department of Energy (DOE)

Mr. Mokhethi Jerry Seitlheko	Director of Energy
Ms. Mantsabeng Lifalakane	Economic Planner
Mr. Bokang Shakhane	SEO(RE)
Ms. Matseleng Sepiriti (Palesa)	Technical Officer
Ms. Liketso Makututsa	-
Ms. Keketso Jobo	Energy Planner
Ms. Itumeleng Ramone	REO(Renewable Energy Officer) for energy efficiency
Mr. Teboho Dlamini	-
Mr. Lengeta Mabea	Energy officer

Ministry of Tourism, Environment and Culture, Depart of Environment

Ms. Mammeli Makhate	Enviroment Officer

Lesotho Highland Water Commission (LHWC)

Mr. Mzamo Lephoma	Chief Delegate
Mr. Tumisang Mosotho	Delegate
Mr. Moroke Nteene	Technical Advisor
Mr. Molefi Mokhethi	Alternative Delegate
Mr. Lerato Makholela	Alternative Delegate

Lesotho Electricity and Water Authority (LEWA)

Mr. Bahlakoana Lepheane	-

Lesotho Electricity Company (LEC)

Mr. Lefa Motlalane	GM-Strategy, Planning
Mr. Leana Kente	-
Mr. Alex Nyamane	Protection Supervisor
Mr. Thabiso Phate	PPM
Mr. Ntsikoe Ntho	CAD
Mr. Retselisitsoe Pii	Planner
Mr. Lenato Mpobole	Planning Supervisor
Dr. Thakane Makume (Ms.)	Corporate Planning
Mr. Mohau Ntai	-
Mr. Lereko Lefela	SCADA Engineer
Mr. N. Sello	Regional Manager

Lesotho Highlands Development Authority (LHDA)

Mr. Thabo Hloele	CM Phase II
Mr. Tsibela Mochaba	DC-Hydropower
Mr. Seele Pyphofe,	-
Mr. Molula Khoilaleoata	O&M engineer
Mr. Tatuku Maseaiwe	Manager
Mr. Leula Ngosa	O&M engineer
Mr. N. Thinyane	Phase II - Engineer
Mr. Siting Matonangoane	Branch Mnager- Katse Operation Branch

Rural Electrification Unit (REU)

Mr. Phetho Sebatana	-

Commission of Water (COW)

Mr. Neo Makhalemele	Senior Engineer

Water and Sewerage Company (WASCO)

Mr. Mohlasoa Mosquite	Instrumentation technician
Mr.Selino	Plant Superviser

World bank

Mr. Bobojon Yatimov	Sr. Agricaltual Specialist
Mr. Frédéric Verdol	Senior Power Engineer

United Nations Development Programme (UNDP)

Mr. Mabohlokoa Tau	Project Manager

EU

Mr. Koena Marabe	Project Manager
Ms. Silvia Sala Giner	Programme Manager

US Embassy

Mr. Rodd, Joshua R	Political/Economic Affairs

CDM Smith

Mr. Jeffery Dickinson	Lead Renewable Energy Specialist

Embassy of Japan in South Africa

Soutaro Ozaki	Counsellor
Shunsuke Fujiwara	Economic Researcher

JICA South Africa Office

Tomohiro Seki	Chief Representative
Kensuke Oshima	Senior Representative
Takahiro Saeki	Representative
Tomoko Miyata	Project Formulation Advisor

Appendix-4 LIST OF THE ACQUIRED REFERENCE MATERIALS AND DATA

Appendix-4. List of the Acquired Reference Materials and Data

No.	Name	Form Book/data/Map/Photograph etc.	Original・Copy	Issue Authority	Issue Year
1	Sub Task4.3 Analysis of Viable Small or medium hydropower Operations Within the Existing LHWP System	Book	Copy	LHDA	Mar. 2018
2	Sub Task 4.4 Review the Existing and Planned Expansion of the Lesotho Transmission and Distribution Network	Book	Copy	LHDA	Mar. 2018
3	Sub Task 4.6 Prefeasibility Screening Study of Conventional Hydropower outside LHWP.	Book	Copy	LHDA	Mar. 2018
4	Oxbow Feasibility Study	Book/Data	Copy	LHDA	Aug. 2019
5	LESOTHO ENERGY POLICY 2015-2025	Book	Copy	MEM, DOM	2015
6	SERP INVESTMENT PLAN OF THE GOVERNMENT OF LESOTHO	Book	Copy	MEM	Nov. 2017
7	Mohale dam Architectural Plan Sheet	Data	Copy	LHDA	2009
8	Mohale Compensation Flow Outlet Drawing	Data	Copy	LHDA	2009
9	'Muela hydropower Eletromechanical specification	Data	Copy	LHDA	-
10	Organization Chart of LHDA	Book	Copy	LHDA	2019
11	Annual Report of LHDA	Book/Data	Copy	LHDA	2013-2018
12	Katse Dam Single Line Diagram	Book/Data	Copy	LHDA	1999
13	Katse Dam Minihydro Plant Drawings	Data	Copy	LHDA	1994
14	Katse Dam Minihydro Design Report	Data	Copy	LHDA	1989
15	Hydrometric Stations map	Data	Copy	LHDA	-

No.	Name	Form Book/data/Map/Photograph etc.	Original・Copy	Issue Authority	Issue Year
16	IFR Presentation to Management	Data	Copy	LHDA	2019
17	INSTREAM FLOW REQUIREMENTS OPERATIONS PROCEDURES	Data	Copy	LHDA	2015
18	Katse and Mohale Lake Levels + IFR previous 10years	Data	Copy	LHDA	2019
19	Rainfall data	Data	Copy	LHWP	2020
20	River inflow data	Data	Copy	LHDA	-
21	Metolong Dam Drawings	Book	Copy	MEM, DOM	Sep. 2010
22	Metolong Dam Single Line Diagram	Book	Copy	WASCO	-
23	GUIDELINES FOR ENVIRONMENTAL IMPACT ASSESSMENT	Data	Copy	Department of Environment	2016
24	ENVIRONMENT ACT 2008	Data	Copy	Department of Environment	2008
25	Preparing Project Brief	Data	Copy	Department of Environment	-
26	Implementation of National Biosafety Frameworks Project.	Book	Copy	Department of Environment	2015
27	Organization Chart of LEC	Data	Copy	LEC	2019
28	ENVIRONMENT AND SOCIAL MANAGEMENT FRAMEWORK	Data	Copy	LEC	Oct. 2019
29	RESETTLEMENT POLICY FRAMEWORK	Data	Copy	LEC	Nov. 2019
30	LESOTHO POWER GENERATION MASTER PLAN	Data	Copy	LEC (SSI)	2009

No.	Name	Form Book/data/Map/Photograph etc.	Original･Copy	Issue Authority	Issue Year
31	Lesotho existing network, 10year map	Data	Copy	LEC	2003
32	Billing Certificate from LHDA to LEC	Data	Copy	LEC	2003
33	Transmission Line data	Data	Copy	LEC	-
34	Transformer data	Data	Copy	LEC	-
35	TRANSMISSION SINGLE LINE DIAGRAM	Data	Copy	LEC	Mar. 2017
36	SINGLE LINE DIAGRAM of Katse dam S/S	Data	Copy	LEC	-
37	SINGLE LINE DIAGRAM of Mohale dam S/S	Data	Copy	LEC	-
38	SINGLE LINE DIAGRAM of Metolong S/S	Data	Copy	LEC	-
39	Transmission and Distribution Lines Data	Data	Copy	LEC	-
40	APPROVED LEC ENERGY CHARGES 2018/19 (Effective from 01 August 2018)	Data	Copy	LEC	2018
41	NATIONAL Grid PEAK Projection	Data	Copy	LEWA	2014
42	LESOTHO GRID CODE	Data	Copy	LEWA	2015
43	LEWA Annual Report	Data	Copy	LEWA	2019
44	LEC Annual Report	Data	Copy	LEWA	2016-2017
45	World Small Hydropower Development Report 2016	Data	Copy	UNIDO	2016

No.	Name	Form Book/data/Map/Photograph etc.	Original･Copy	Issue Authority	Issue Year
46	Development of Cornerstone Public Policies and Institutional Capacities toaccelerate Sustainable Energy for All (SE4All) Progress.	Book	Copy	United Nations Development Programme	2013
47	Final Report Development of Regulatory Framework/Guidelines for Operation of Clean Energy Centres	Book	Copy	United Nations Development Programme	Apr. 2019
48	Development of Cornerstone Public Policies and Institutional Capacities to accelerate Sustainable Energy for All (SE4All) Progress National Energy Survey Final Survey Report	Book	Copy	United Nations Development Programme	Apr. 2018
49	LESOTHO Sustainable Energy for All INVESTMENT PROSPECTUS	Book	Copy	United Nations Development Programme	2016
50	LESOTHO Sustainable Energy for All COUNTRY ACTION AGENDA	Book	Copy	United Nations Development Programme	2018
51	Prefeasibility Mohales Hoek_v9	Book	Copy	United Nations Development Programme	Oct. 2018
52	Prefeasibility Mokhotlong_v9	Book	Copy	United Nations Development Programme	Oct. 2018
53	Prefeasibility Qacha's Nek_v9	Book	Copy	United Nations Development Programme	Oct. 2018
54	Prefeasibility Quthing_v9	Book	Copy	United Nations Development Programme	Oct. 2018
55	Prefeasibility Thaba-Tseka_v9 (1)	Book	Copy	United Nations Development Programme	Oct. 2018

No.	Name	Form Book/data/Map/Photograph etc.	Original・Copy	Issue Authority	Issue Year
56	FORMULATION OF THE LESOTHO ELECTRICATION MASTER PLAN Socio-Economic Analysis (Final Report)	Book	Copy	The European Union	Apr. 2018
57	FORMULATION OF THE LESOTHO ELECTRICATION MASTER PLAN Off-Grid Master Plan Report	Book	Copy	The European Union	Jun. 2018
58	FORMULATION OF THE LESOTHO ELECTRICATION MASTER PLAN Grid Development Plan Report	Book	Copy	The European Union	Jun. 2018
59	FORMULATION OF THE LESOTHO ELECTRICATION MASTER PLAN Action& Investment Plan (Final Report)	Book	Copy	The European Union	Sep. 2018
60	Project Information Document/ Integrated Safeguards Data Sheet (PID/ISDS)	Data	Copy	World bank	Mar. 2019
61	INTERNATIONAL DEVELOPMENT ASSOCIATION PROJECT APPRAISAL DOCUMENT ON A PROPOSED CREDIT (DRAFT)	Data	Copy	World Bank	2019
62	Lesotho Map 1:250,000 (whole country)	Data	Copy	Lesotho Government	1994
63	Lesotho Map 1:50,000 (project site)	Data	Copy	Lesotho Government	1980
64	2016 PHC Report Volume IIIA Population Dynamics	Data	Copy	Lesotho Government	2016
65	LESOTHO HIGHLANDS WATER PROJECT DELIVERY TUNNEL AN ENVIRONMENTAL ASSESSMENT OF THE DELIVERY TUNNEL NO 1, PHASE 1A Highlands Delivery Tunnel Consultant 343 Surrey Avenue Ferndale RANDBURG2194Final	Data	Copy	TCTA	Sep. 1989

No.	Name	Form Book/data/Map/Photograph etc.	Original･Copy	Issue Authority	Issue Year
66	REPORT NO: 0150/1.0 LESOTHO HI.GHLANDS WATER PROJECT CONTRACT NO. LHDA 604 Development and Management of Nature Reserves in the LHWP Phase 1A Area BOKONG NATURE RESERVE VISITORS CENTRE ACCESS ROAD ENVIRONMENTAL IMPACT ASSESSMENT REPORT	Data	Copy	LHDA	Jun. 1998
67	LESOTHO HIGHLANDS DEVELOPMENT AUTHORITY ENVIRONMENT DIVISION IMPACT ASSESSMENT 1: ARABLE LAND IN PHASE IA AREAS OF LHWP (Second Edition)	Data	Copy	LHDA	Jul. 1992
68	Contract No. LHDA 615 –VO3 Biological Monitoring in the Lesotho Highlands Water Project Phase IA Area WETLANDS MONITORING REPORT, 2000 AfriDev Consultants (Pty) Ltd	Data	Copy	LHDA	Nov. 2000
69	KINGDOM OF LESOTHO LESOTHO HIGHLANDS DEVELOPMENT AUTHORITY LESOTHO HIGHLANDS WATER PROJECT Phase 1B ENVIRONMENTAL IMPACT ASSESSMENT	Data	Copy	LHDA	May 1997

Appendix-5 TECHNICAL MEMORANDUM

TECHNICAL MEMORANDUM

ON

RESULTS OF THE FIRST SURVEY

FOR

DATA COLLECTION SURVEY

ON

SMALL-HYDRO POWER DEVELOPMET PROJECT

IN

LESOTHO

BETWEEN

MINISTRY OF ENERGY AND METEOROLOGY (MEM),

AND

JICA STUDY TEAM

In Lesotho, December 12th, 2019

Mr. Kiyofusa TANAKA Chief Consultant JICA Study Team Yachiyo Engineering Co., Ltd.	Mr. M. Jerry Seitlheko Director of Energy Ministry of Energy and Meteorology (MEM) (for acknowledgement)

The Government of Lesotho required the Government of Japan to provide assistance concerning the installation of power stations on existing dams with the aim of boosting the country's hydroelectric capacity. In response, JICA dispatched a study team for gathering relevant information in accordance with Inception Report.

1. Main objectives of the Survey

This information gathering and confirmation survey will have the objective of organizing the progress and issues facing Lesotho's power policies and plans and the progress and issues of hydropower plans at multiple existing dams with a view to gathering basic information for examining the future direction of JICA's assistance based on grant aid and technical cooperation.

1.1 Scope of Work

The team explained that the scope of the Survey is as follows:

- Implementation Frame Work
- Requested Sites for the Project and their Priority
  Confirmation of existing equipment and examination of technical support.

1.2 Confirmation of the Project feasibility

The team explained that the expected output of the Survey is as follows:

- The basic policy, stipulated in item 2 Findings of the First Field Survey will be adopted for resolving issues in the power and the energy sector in order to established hydro power.
- For each hydro power station will be connect with National power network in Lesotho.
- All the hydro power station of this Project will be operated, maintenance and controlled by LHDA.

2. Findings of the First Site Survey

2.1 Information and Data collection

2.1.1 Implementation framework

As a result of confirming, the structure of power sector in Lesotho is shown as following Fig 2.1.1-1 Responsible Agency and Implementing Agency for the project will be Ministry of Energy and Meteorology (MEM) and Lesotho Highland Development Authority (LHDA), respectively.

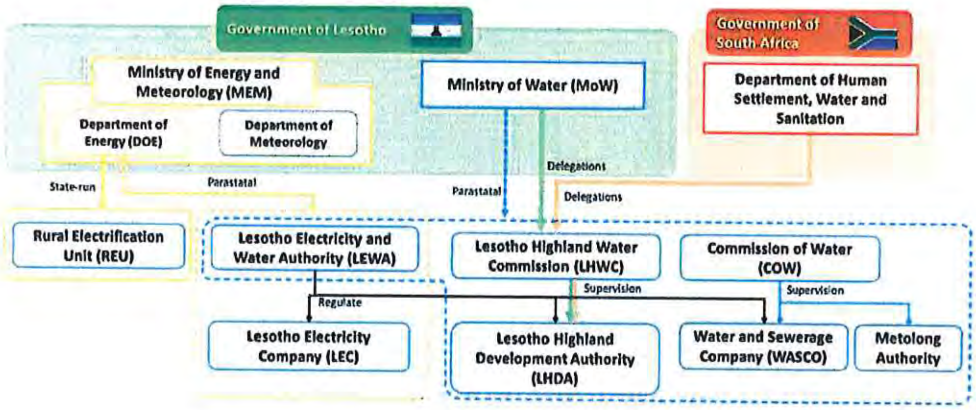


Fig 2.1.1-1 Structure of the Energy Sector of the Project

2.1.2 Requested sits for the Project and their Priority

1. Katse
2. Mohale
3. Metolong
4. Polihali

2.1.3 Result of Main survey

As a result of confirming Main Survey Contents, the following information in Table 1 ~ 4 were surveyed in Lesotho;

Table 1 Main Survey Contents concerning Hydropower Civil Engineering

Survey Items and Objective	Information to be confirmed
Past (at least 10 years) dam inflow, EWR, dam water level, operating regulations	Operating regulation is judged to none, due to lack of observation of existing inflow. The inflow & EWR value are tentatively decided by the previous consultant survey reporting in FS.

3 / 35

	Above Survey Report, Inflow, EWR and water level data are to receive on Tuesday 10th of Dec from LHDA.
Specification (drawings, document and specification) of existing equipment for EWR facility	Confirmed the existing of Metolong drawing. For Mohale, we have received the existing building. Their drawings, however, are excluded the rebar alignment, so structural calculations have not been made. Further no data of pipe diameter, etc. is available, head loss cannot be calculated.
Dams and related equipment (layout drawings and specification of the equipment)	It is important to note that penstock drawings from the water intake to the turbine are requested. To the designing for an equipment of turbine & generator needs to calculate penstock and waterway losses, then need to calculate Head Net.
Survey data concerning dam sedimentation conditions	Surface Water intake method is taken for Mohale & Katsue DAM, therefore no disturbance may be found for hydro power generation, however environmental problem of Mohale regarding climate change will be provided by Ministry of Environment.
Specification of hydro power generating equipment (layout drawings and specifications of the equipment)	We have received that Katsue Dam equipment layout.
Reasons for stoppage of existing equipment at Katse Dam	Backed with 2010 the equipment are soaked, useless and the stoppage. It is impossible to get a budget to retrofit for the existing equipment. Space for Future extension is planned from the future fund Mohale is made a provision of penstock and turbine inlet for future installation of generating equipment due to difficulty of future installation. Balance equipment are not made due to budget restriction.
Polihali Dam construction schedule and design drawings	Tender will be held in January 2020.Construction will start at the end of 2020.Takingover will be estimate in 2023.Collection of drawings are on made 10th Dec.
Metolong Dam turbine and generator room plan and design information	Well received

Table 2 Main Survey Contents concerning the Power System

Survey Items and Objective	Information to be confirmed
Power station connections and transmission lines	Existing drawing are confirmed by LEC, and well received.
Transmission network in Lesotho overall	Existing drawing are confirmed by LEC, and well received..
Current diagram and transmission capacity	Existing drawing are confirmed by LEC.

Table 3 Main Survey Contents related to Maintenance Structure and Budget

Survey Items and Objective	Information to be confirmed
Conditions regarding operation of communication	OPGW, PLC and Micro wave

routes between currently operating remote monitoring and control systems (SCADA) and small hydro power stations	communication media are confirmed and operation of communication are in healthy condition in NCC/RCC in LEC.
Organization chart, number of assigned employees, replacement parts procurement, periodic inspection items, response to troubles, etc.	Development and Operations Division
Project plans	Confirmed Master plan is official under Lesotho Govement.

Table 4 Survey of Scope of Works on the Lesotho Side and Main Contents concerning Permits and Licenses

Survey Items and Objective	Information to be confirmed
Inland transportation permit	To be advised by MEM later
National grid connection permit	LEWA
Construction permit	To be advised by MEM later
Metrological drawing	To be advised by MEM later
Environment (EIA)	Ministry of Tourism, Environment & Culture
Tax exemptions	Dept. of Debt in Ministry of Finance.

2.2 Site Survey

2.2.1 Metolong Dam

2.2.1.1 Location

Metolong dam is located on the south phuthiatsana River in Maseru district, 37 km east of Maseru city. The condition of paved road to the site is good, so there is no problem with access to the site. It takes about 40 minutes by car.

Fig. 2.2.1.1-1 Metolong Dam location

2.2.1.2 Relation between the maximum discharge and the predicted power output

1) According to the information from an officer at Metolong dam office, the maximum dam discharge is to be 300 liter/sec (0.3 m3/s).

2) If the maximum discharge is used for power generation, the power output would be predicted as follows;

Precondition:
Maximum generating discharge; Q = Maximum dam discharge = 0.3 m3/s
Maximum net head; H = 45 m (predicted)
Generating efficiency; η = 80% = 0.8 (predicted)

Maximum generating output; $P = 9.8 \times Q \times H \times \eta = 9.8 \times 0.3 \times 45 \times 0.8 =$ <u>106 kW</u>

3) The above output is for the maximum discharge, and the minimum dam discharge is 10 liter/sec (0.01 m3/s) in a year based on the information from the officer.

Thus, the expected power generating facility will have the averaged output of several <u>10kW</u> in a year, and it would be inappropriate for connecting to an adjacent power grid line.

2.2.1.3 Space in the existing discharge valve room

1) In the existing discharge valve room, two (2) sets of discharge valve bodies and connecting penstocks occupied large plain part of the room. Thus, it would be impossible to have enough space for new power generating equipment (such as turbine, generator, penstock for a turbine, control panels, etc.), as a result of this survey.

2) A photo taken in the discharge valve room and a floor plan of the room are attached.

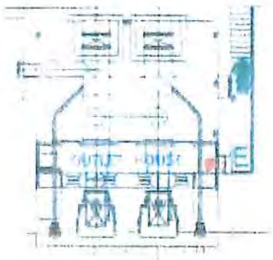


Fig. 2.2.1.3-1 Floor plan of existing valve room Fig. 2.2.1.3-2 valve room

3) The plan dimensions of the room necessary for the installation of power generating equipment having the capacity calculated in above item 2.2.1.2 is predicted roughly to be 3m×5m, considering totally the perspective of installation, operation, maintenance and inspection.

2.2.1.4 Problems associated with the new generator room

1) With the two sets of discharge connection pipes, the pipe for power generation (penstock) is branched from the downstream pipe and the branched pipe ends at a position 0.3 - 0.4 m downstream from the discharge valve chamber. The pipe connection from the end of the penstock should originally use a curved pipe, however the space between the downstream wall of the discharge valve chamber and the wall of the parking lot is 1.65m and 90 ° elbow will be used. Consequently, the power generation head loss increases, whereas the power generation output decreases.

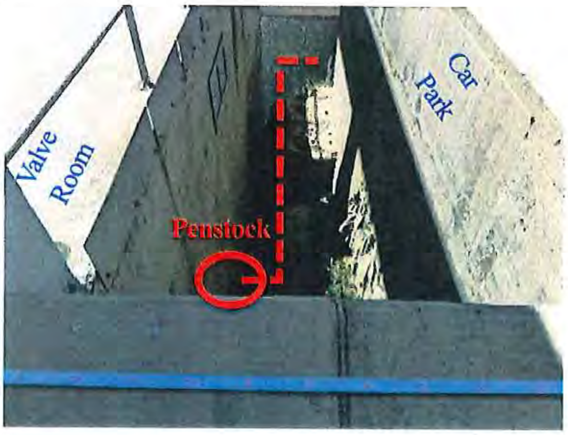


Fig 2.2.1.4-1 Overview of new generator room

2) The generator room will be installed downstream of the dam downstream revetment.

Although the foundation surface is bedrock, the slope is steep, and it is necessary to install the foundation of the generator room and the water discharge garden with concrete from near the riverbed, and civil work becomes a major issue. However, as the water level in the water discharge garden can be estimated to be about 10m lower than the current Valve position, the effective head becomes higher and the power output is expected to increase by about 20% from the value calculated in 2.2.1.2 -2).

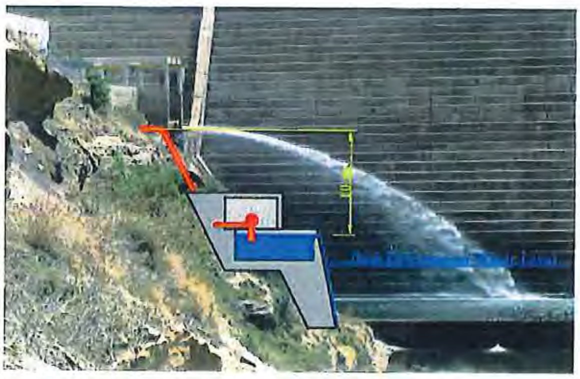


Fig. 2.2.1.4-2 Sectional plan of generator room

2.1.2.5. Infeasibility of commission to LEC 33kV power grid

Due to the small power generation output less than 100kW, we presume not to reach LEC 33kV power grid through WASCO existing 11kV Switch yard. Power train from Turbine/Generator to LEC 33kV power grid are to comprise of the followings;

1) Generator to GSU (Generator Step Up Transformer) , secondary voltage 11kV : 11kV XLPE Power Cable Connection
2) GSU to 11kV MVSWGR (Middle Voltage Switchgear): 11kV XLPE Power Cable Connection
3) 11kV MVSWGR to WASCO existing 11kV Switch yard: 11kV ACSR (Aluminum Conductor Steal Reinforced) Connection via OHL (Over Head Line) with new gantry structure
4) Modification of WASCO existing 11kV Switch yard to incorporate 2.1.2.5.-3).

2.2.2 Mohale Dam

2.2.2.1 Location

Mohale dam is located on Senqunyane River in Maseru district, 105 km east of Maseru city. The condition of paved road to the site is good, so there is no problem with access to the site. It takes about 120 minutes by car.

Fig. 2.2.2.1-1 Mohale dam location

2.2.2.2 Relation between the maximum discharge and the predicted power output

1) During the survey, the team confirmed that the maximum discharge available for hydropower generation was difficult to estimate since actual flow measurement might have not been carried out until now. But, it was confirmed mutually that the discharge data were to be submitted by LHDA at a later date, because those data were requested by the questionnaire of the study team.

2) According to the FS report prepared in 2018, Sub Task 4.3-Analysis of Viable Small or Medium Hydropower Options within the Existing LHWP System, the study result on the small hydropower facility for Mohale dam was described. (Noted below in item 3))

3) As the expected rated specifications for the new small hydropower facility,

- Maximum discharge ; 1.4 m^3/s
- Minimum discharge ; 0.4 m^3/s
- Maximum net head ; 130 m

・Minimum operating net head ; 106 m
・Turbine setting level ; 1,948 m a.s.l
・Turbine speed ; 1,000 rpm
・Turbine rated output ; 1.64 MW
・Generator rated output ; 2.0 MVA (power factor = 0.8)
・Generator output voltage ; 3.3 kV

4) The above rated output is under the condition at the maximum head and the maximum discharge, and the facility will produce output power of 500–1,000 kW during major period in a year.

Thus, if the output power of this level is obtained, it would be appropriate to connect the facility to adjacent power grid line.

5) After the study team obtain detailed data of dam discharge, the discharge available for power generation will be decided and the rated specifications of new hydropower facility to be installed at Mohale dam will be examined.

2.2.2.3. Space in the existing discharge valve room

1) Mohale dam has an existing building for discharge valves at the downstream side. A compartment or room for future small hydropower facility is provided in the building.

2) In the compartment, one set of the end portion of penstock and an inlet valve for a turbine was installed previously for future power generation. Major part of the compartment is one open space available for the installation of generating facility, especially for a set of turbine and generator. And an overhead crane for the equipment installation was installed previously.

Fig 2.2.2.3-1 Compartment for generating equipment

Fig.2.2.2.3-2 Overhead Crane

3) On the other hand, the open space of the compartment would not be wide enough for generating equipment, and the lifting capacity of the crane might be one of restrictions. Thus, the rated capacity of generating equipment will be determined under the conditions of the space and the maximum weight of major components. Accordingly, there is a possibility that the capacity of the facility will be smaller than the specification noted in item 2.2.2.-3).

4) The power water from a turbine is to be discharged to the outside of the building through a draft tube, one of turbine component. For such purpose, the new work of reconstruction at the downstream wall of the building is needed for the installation of the draft tube.

Additionally, a discharge basin, a concrete structure, for enhancing the function of the draft tube, is necessary to be reconstructed at the place adjacent to the building.

2.2.2.4. Issues associated with the new generator room

1) The space in the generator room is narrow, and the draft tube must be installed diagonally. Therefore, it is necessary to demolish the wall that has already been constructed, but since the upper part is a brick wall, strength of the wall shall be confirmed before demolishing the wall. It will be done manually.

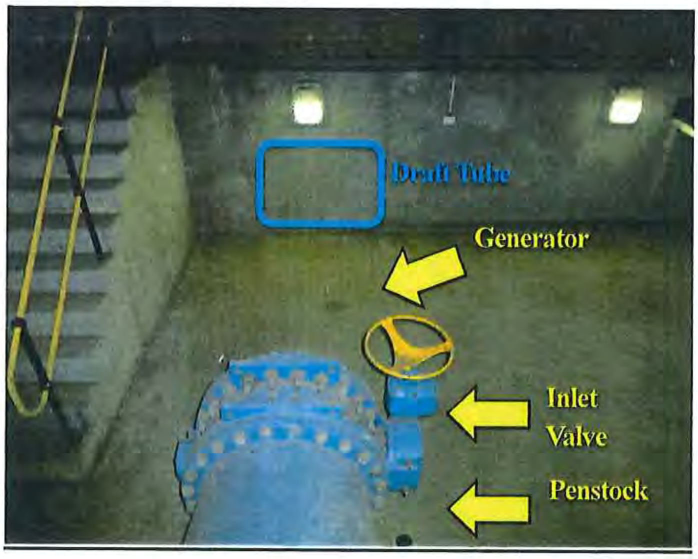


Fig. 2.2.2.4-1 Space in the generator room

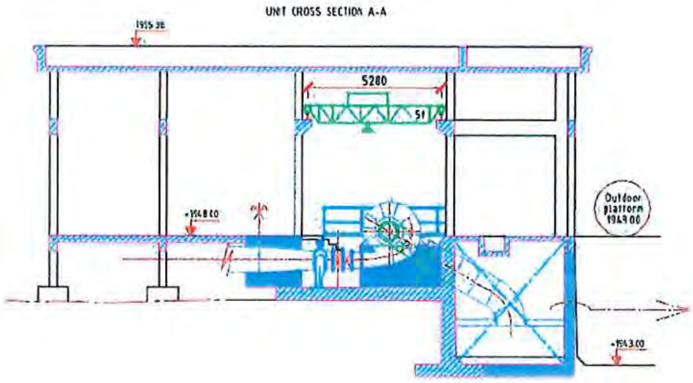


Fig. 2.2.2.4-2 Sectional plan in the generator room

2) Although the tailrace is installed, it is necessary to install a wall that matches the draft tube as a forebay to secure the discharge level.

3) Although the equipment access road will use the road installed on the downstream side of the dam, it will bend the hairpin curve, so the trailer cannot be used, and vehicles with a length of about 10 m seems to be limitation.

2.2.2.5. Feasible solution for commission to LEC (Lesotho Electricity Company) 11kV power grid

i. Existing power system has just been receiving electricity from LEC 11kV power grid through Station Transformer rated 1.25MVA, 11k/400V and 400V Distribution board for loading of Valve control

ii. Newly proposed power system comprises Turbine, Generator rated 2.0MW, 11kV GMCB (Generator Main Circuit Breaker) with auto Synchronization, GSU (Generator Step Up transformer) rated 3.3/11 kV, 11kV Metal Clad Switchgear with Busbar, and secondary equipment with Tariff, e.g., Turbine, Generator and Transformer control & protection. These provisions are made on the basis of electricity upstreaming toward LEC power grid.

i. the existing and ii. the newly proposed key line diagram are shown in below for conceptual understanding and evaluation purpose;

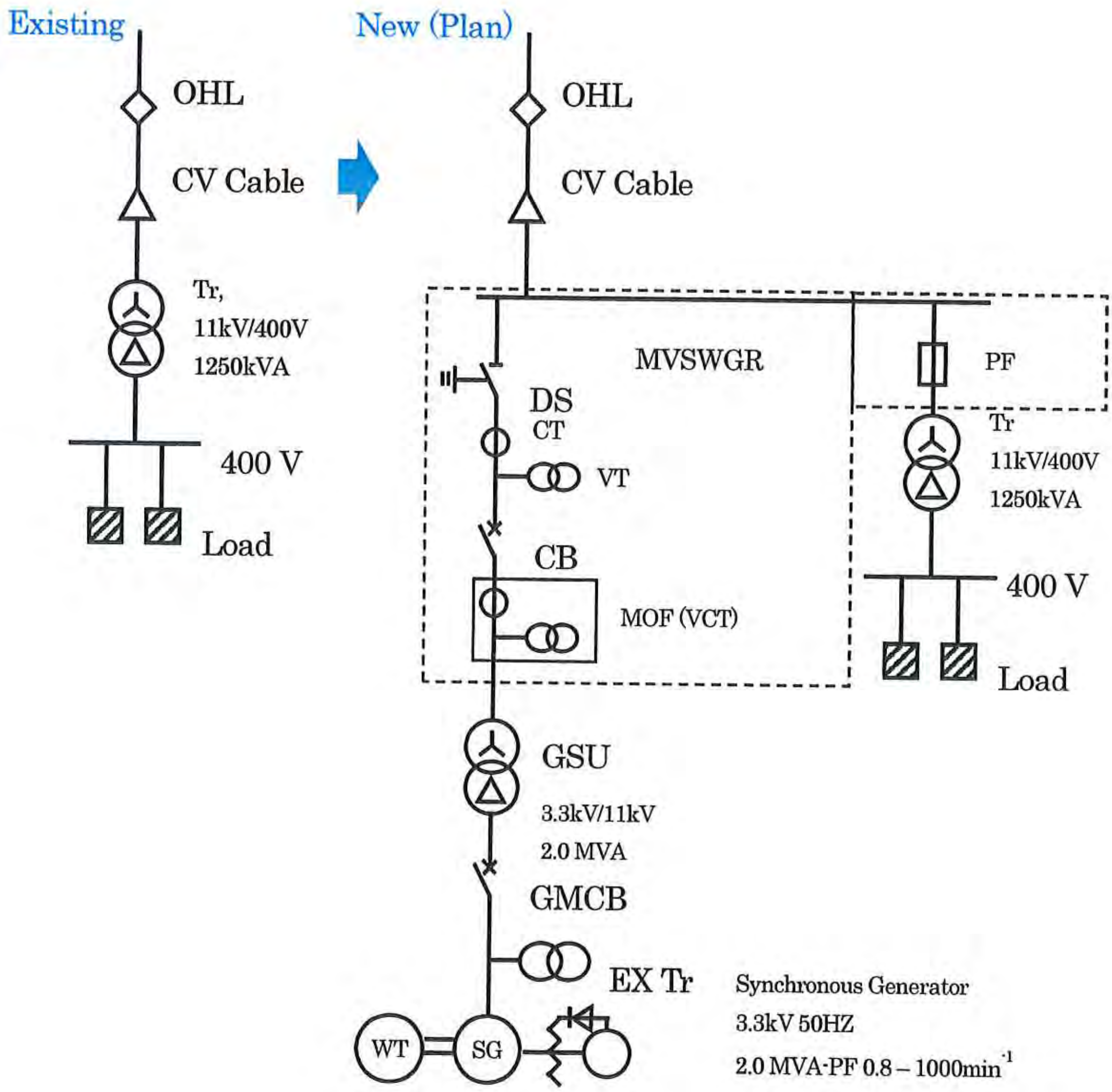


Fig. 2.2.2.5-1 Proposed key line diagram.

2.2.3 Muela Dam

Regarding Muela, survey for condition of existing Hydro Power Station to conform maintenance skill of the site.

2.2.3.1 Location

Muela HPP is located in Botha-Bothe district, 153 km northeast of Maseru. The condition of A1 road to the site is good, so there is no problem with access to the site. It takes about 150 minutes by car.

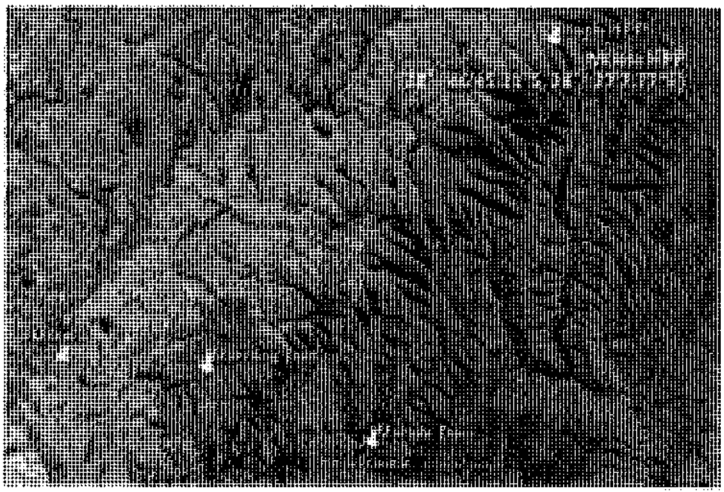


Fig 2.2.3.1-1 Muela Dam location

2.2.3.2 Outline of the power plant

1) Three(3) sets of turbine and generator were installed in the hydropower plant, and total generating output is 72 MW. The commissioning year of the plant was 1997.

2) The generating equipment was installed below ground, so-called "underground hydropower plant", and we can visit the plant through a tunnel. On the other hand, management and control rooms are in a building on the ground.

3) Water stored in Katse dam reservoir is supplied to the plant through a water tunnel system, and the water after generation is transferred and exported to The Republic of South Africa via Muela dam.

4) When the study team visited on November 30th, the plant was out of service because of the periodical inspection and maintenance of the water tunnel system every ten(10) years.

2.2.3.3 Existing generating equipment

The specifications of existing major generating equipment are as follows.

1) Turbine

Type; vertical Francis turbine
Rated output ; 25.2 MW
Speed; 750 rpm
Runaway speed; 1,380 rpm
Maximum head; 287.0 m
Rated head; 237.0 m
Minimum head; 196.0 m
Turbine setting elevation; 1,746.0 m a.s.l
Manufacturer; Kvaemer

2) Generator

Type; vertical synchronous generator
Rated output; 32,000 kVA
Power factor; 0.85
Voltage; 11,000 V
Speed; 750 rpm
Frequency; 50Hz
Manufacturer; ABB

2.2.3.4 Operation and Maintenance

1) The plant is owned by LHDA, and LHDA has the responsibility for operation and maintenance of the plant.

2) The operation and maintenance personnel of the plant was trained in United Kingdom.

3) In spite that the generating equipment has been operated for approximately 20 years, the equipment was in very clean condition, no oil-spot around pressure-oil equipment and no dust accumulation on various equipment were found. That means higher level of maintenance work by the personnel.

Fig. 2.2.3.4-1Turbine room

Fig. 2.2.3.4-2 Turbine pressure-oil equipment

4) Though overhaul inspection and maintenance work has not been carried out at present, replacement of wearing parts of turbine such as guide vane bearing bushes, etc. is scheduled to be implemented next year. That means the overhaul work is to be carried out. Heat-exchangers of air-cooler system of the generator were replaced to new ones several years ago.

2.2.3.5 Relation between DCS (Digital Control System) in the Muela Hydro Power Station and NCC (National Control Center) / RCC (Regional Control Center) in Lesotho

NCC and RCC belong to LEC. RCC is subset of NCC and their equipment are Spider, ABB made. The old NCC / RCC equipment, Mosaic board is not currently used.

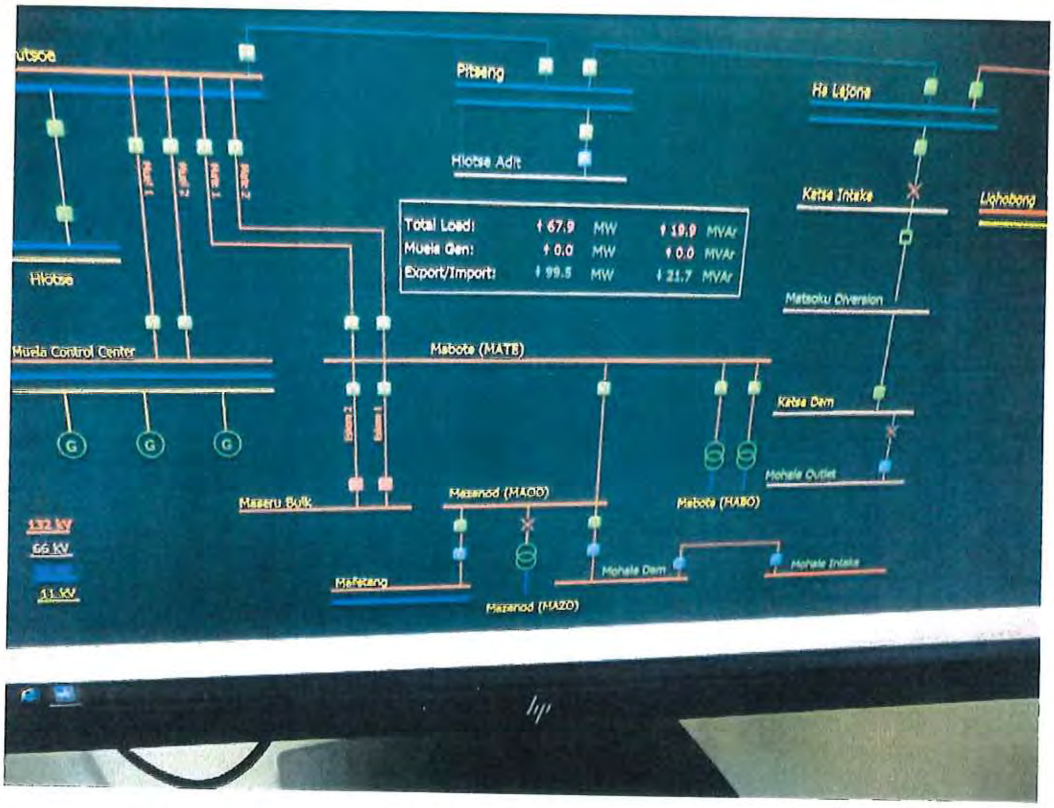
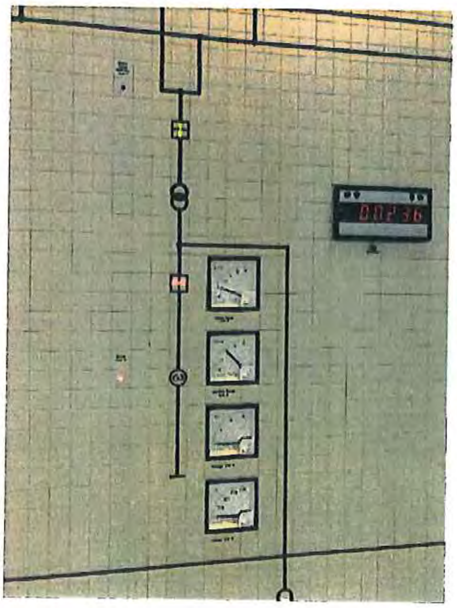


Fig. 2.2.3.5-1 HMI (Human Machine Interface) of NCC

NCC / RCC is used to simulate 132kV, 66kV, 33kV, and 11kV systems in the Muela Hydro power stations for monitoring purpose. NCC can monitor and control the same system as RCC. If maintenance or other control is required, contact employee in the Muela Hydro power stations via conventional telephone calls.

DCS, possessed by LHDA, in Muela Hydro Power stations has monitored onto Mosaic boar both electrical key line and water flow state in health condition, shown in the below pictures. Control of circuit breakers and valves are to be made through single line diagram and Piping and instrumentation diagram in DCS.



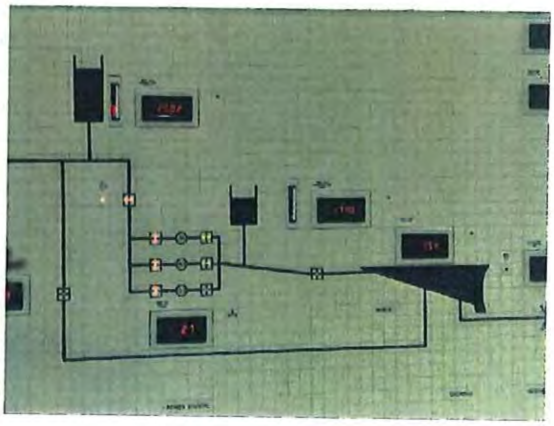


Fig. .2.3.5-3 Water flow state

Fig. 2.2.3.5-2 Extract of Electrical Key Line

Whenever monitoring and control of another newly installed small hydropower plants, DCS (panel) in the small hydropower plants. And NCC could supervise the status of DCS.

There is some room to incorporate new DCS in small hydropower plants into the existing DCS in Muela, with required modification shown in the below Key line diagram.

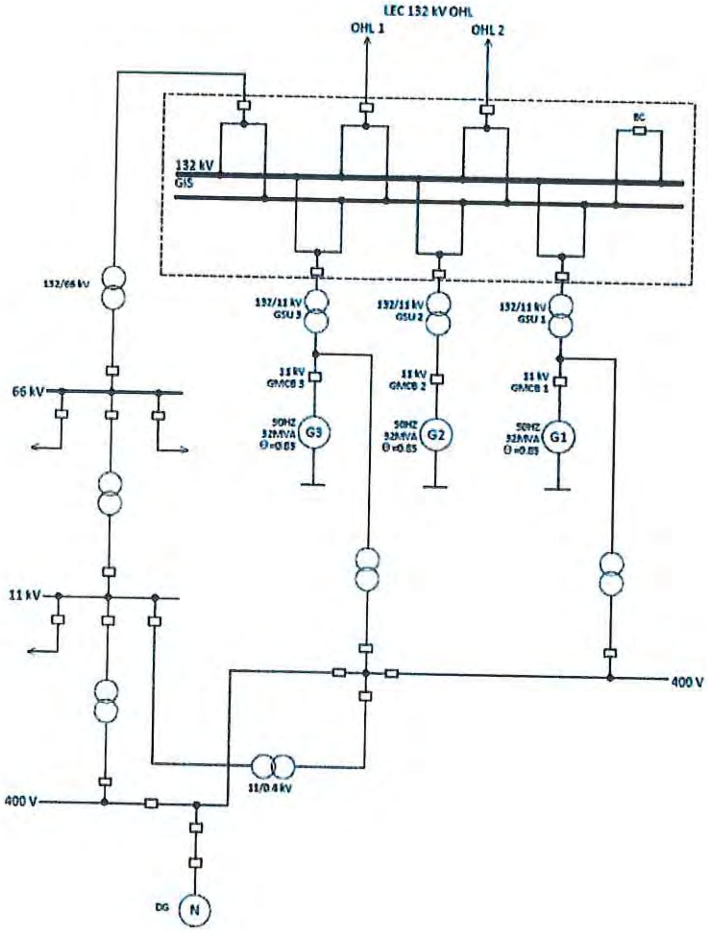


Fig. 2.2.3.5-4 Existing Electrical Key line in Muela

2.2.4 Katse Dam

2.2.4.1 Location

Katse dam is located on the Malibamatso River in Thaba-Tseka district, 219 km northeast of Maseru. The condition of A1 and A25 road to the site is good, so there is no problem with access to the site. It takes about 200 minutes by car.

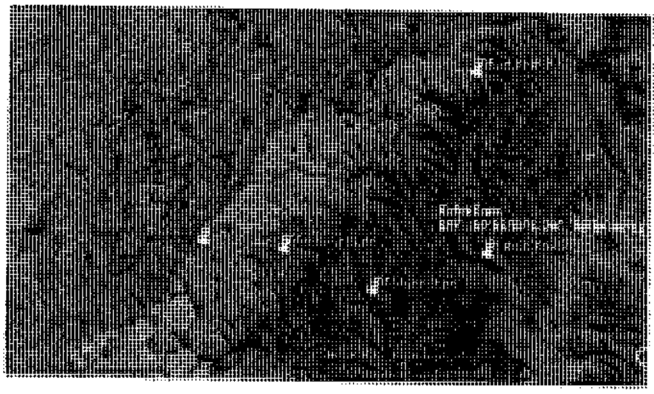


Fig. 2.2.4.1-1 Location of Katse Dam

2.4.2.2 Dam discharge data and generating specification

1) During the site survey at Katse dam, detail information on the discharge from the dam and the maximum discharge available for hydropower generation were not provided by LHDA site personnel.

2) But, the study team requested the detailed discharge data by the questionnaire, and it was confirmed that the data was to be provided for us at LHDA Maseru office at a later date.

3) After the team received the data, the discharge available for power generation will be determined and the study on items such as the rated output of generating equipment to be installed, etc., is to be carried out.

2.4.2.3 Current status of the existing generating facility

1) According to the previous information, one (1) set of small hydropower facility was installed in a hydropower facility building annexed to the dam.

On the other hand, the facility had been operated and it has been out of service since 20Dec because of the water immersion in the building. When the team visited the building, the facility was stopped and the exciter of the generator had been dismantled.

Fig. 2.2.4.3-1 Existing generating facility

Fig. 2.2.4.3-2 Service entrance opening in the room

2) According to the rating plates, the specifications of existing generating main machines are as follows.

a) Turbine

Type ; horizontal Francis turbine
Rated output P; 500 kW
Rated discharge Q; 0.5 m^3/s
Normal head Hn; 123 m
Speed n; 1,500 rpm
Manufacturer ; GEC Alsthom – Neyrpic Minihydro (France)
Supply year ; 1998

b) Generator

Type ; horizontal 3-phase synchronous generator
Rated capacity ; 625 KVA
Rated effective output ; 500 kW (power factor; 0.8))
Rated voltage V; 3,300 V
Speed n; 1,500 rpm (50 Hz, 4-pole)
Applied standard ; IEC 34
Product weight ; 4,730 kg
Manufacturer ; Alsthom

3) In the building, an end portion of penstock and a discharge pipe for a draft tube for the expansion turbine, in addition to ones for the existing unit, were installed previously.

4) Near the ceiling of the building, a crane having rated lifting capacity of five (5)-ton has been installed. The capacity of the existing crane will be one of major restrictions for examining the future new generating equipment.

5) Although a service entrance opening, on the side of the right bank, has been installed at the ceiling of the building, it seems considerably narrow for outer dimensions of major equipment.
It would become to be one of major restrictions for examining new generating equipment. On the other

hand, the building seems to be constructed under the condition of submergence during times of flooding.

Thus, a hatch for the service entrance opening should be a water-tight structure, and it would be necessary to confirm that the hatch keeps the water-tight performance in the future.

2.4.2.4 Space in the existing equipment room

1) According to the report prepared in 2018, Sub Task 4.3-Analysis of Viable Small or Medium Hydropower Options within the Existing LHWP System, a plane view drawing of equipment arrangement was shown under the future plan of two (2)-unit installation.
As noted in above item 4.4.3-1), one (1) set of unit has been installed, and it would be considered that there is the space for installing additional one (1) set of unit having same specifications.
But, it might be considerably cramped for two-unit arrangement.

2) The existing turbine has the conventional pressure-oil system for operating guide vanes to control turbine output and the open-close operation of a turbine inlet valve. Thus, additional installation space was needed for installation of the pressure-oil equipment.
From the view point of total installation space and simplification of maintenance, it would be appropriate to apply the motorized control method, instead of the pressure-oil control method, to newly installed generating units. The motorized control method is very popular for current Japanese small hydropower plants.

3) According to the report prepared in 2018, Sub Task 4.3-Analysis of Viable Small or Medium Hydropower Options within the Existing LHWP System, the turbine having specifications of output 1,640kW, speed 1,000 rpm, 2-unit plan was proposed for new hydropower equipment.
Regarding this proposal, outer dimensions and component weights of equipment will increase comparing with the existing, and sufficient future technical examination should be carried out concerning the relation with the crane capacity and dimensions of the service entrance opening

4) As the result of survey on the current condition of Katse dam facility, the study team confirmed that the final capacity of the new small hydropower equipment should be determined after sufficient examination on the possible capacity using the flow rate available for generation, the outer dimensions and weights of major equipment, the relation between those data and caring-in/installation method, to examine the final specifications of new generating facility.
At present, the plan of capacity 500 kW, two (2)-unit plan is considered to be feasible.

2.2.4.5 Issues related to the generator room
1) Access to the powerhouse
At present, since the vehicle cannot directly access the generator room, a facility for carrying in equipment is necessary.
The following three plans are considered as methods, and the problems are also described.

① Use of dam downstream passage

The passage width is 4.4m, but when hanging the equipment with a crane, the outriggers cannot be extended, so heavy objects cannot be lowered.

In addition, the passage is supported by beams protruding from the dam, and it is necessary to confirm or recalculate the load that can be passed when transporting heavy objects. (Requires bar arrangement)

② Method by installing crane and incline.

It is a method of unloading equipment to a dam footing under the current access road with a crane and transporting it to the power station by an incline. Although realistic, an incline can be submerged during a flood and cannot be permanently installed.

Fig. 2.2.4.5-1 Method by installing crane and incline.

③ Installation of access road

The plan is to establish a new access road from the vicinity of the counter dam installed downstream to the powerhouse

Since roads may be submerged during flooding, they cannot be installed on the embankment, so they will be installed by cutting out the bedrock, but they can be used after being submerged by flooding because the road is on the bedrock.

Fig. 2.2.4.5-2 Installation of access road.

Considering the above, it is considered that ② Method by installing crane and incline and ③ Installation of access road are promising. The implementation needs to be considered in detail, taking into account the heavy equipment that can be used.

2) Leakage on the powerhouse

There are some cracks on the wall of the powerhouse, but it is not a problem.

However, water leakage can be seen from the opening for carrying in equipment on the ceiling.

At the time of the survey, there is no doubt that water from the discharge valve at the top of the powerhouse has entered, but it seems that the entire powerhouse will be submerged during a flood. It is necessary to repair the watertight material of the opening cover and the concrete crack at the corner of the opening.

In addition, since water may leak in the future, it is desirable to install a water receiving pit directly under the ceiling opening and a submerged pump that automatically operates when the water level is detected.

2.2.4.6 Connection to LEC (Lesotho Electricity Company) 11kV power grid

1) Existing equipment

- Existing power system of Katse Dam has just been receiving electricity from LEC 11kV power grid through Katse Dam Substation, 66kV/11kV.
- Three backup Generators have installed and those are connected to the 11kV bus bar at the LHDA premises.
- The rated voltage of existing mini hydro generator is 3.3kV, and goes to 11kV by GSU (Generator Step Up transformer). Then it is connected to the above 11kV bus bar.
- GSU has installed upper floor than the power house, there is a space for new GSU next to the existing GSU.
- Switchgear room is planned same floor of GSU. But the space is not enough for new Switchgear installation. Consideration for location of the new Switchgear is needed.

Fig. 4.2.4.6-1 Existing Equipment

2) Extension of new equipment

- The Newly installed generator will be connected in parallel as following drawing.
- Newly proposed power system are to be consist of Turbine, Generator, Exciter Transformer, 3.3kV GMCB (Generator Main Circuit Breaker), GSU rated 3.3/11 kV, 11kV Metal Clad Switchgear with

Busbar, and secondary equipment with Tariff, e.g., Turbine, Generator and Transformer control & protection.

- The specification of the existing bus bar has not been available, hence it is necessary to check the specification (capacity, etc.,) and to consider the needs for in-situ replacement of existing equipment.

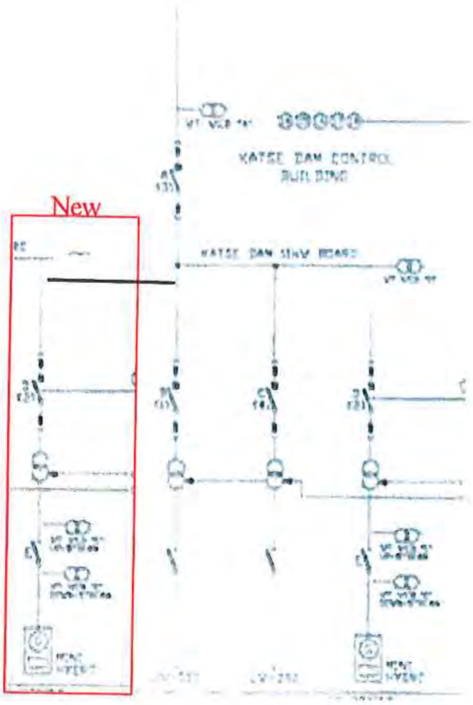


Fig. 4.2.4.6-2 Extension of new equipment

3) Supervision of hydro power station

- SCADA (local DCS) is not installed. The Condition of the existing generator is not supervised by NCC in LEC.
- According to a LHDA engineer, the existing transformer has been broken by overheating, which need to repair or replacement.

2.4.3 Polihali Dam (Under construction)

2.4.3.1 Location and current situation

Polihari dam is located on the Senqu River in Mokhotlong district, 278 km northeast of Maseru, targeted completion in 2023. The condition of A1 road to Mapholaneng is good, but the access road from Mapholaneng to the site about 16 km is not paved as of December 2019. It takes about 300 minutes by car from Maseru to the site.

2.4.3.2 Local condition toward Polihali Dam project

The results of local confirmation of the Polihali dam project are as follows

① Polihali dam is planned as CFRD (Concrete facing rock fill dam).
② Dam has almost the same shape as Mohale dam.
③ Spillway route is planned on the right bank of the dam.
④ Powerhouse is planned dam downstream of the right bank.

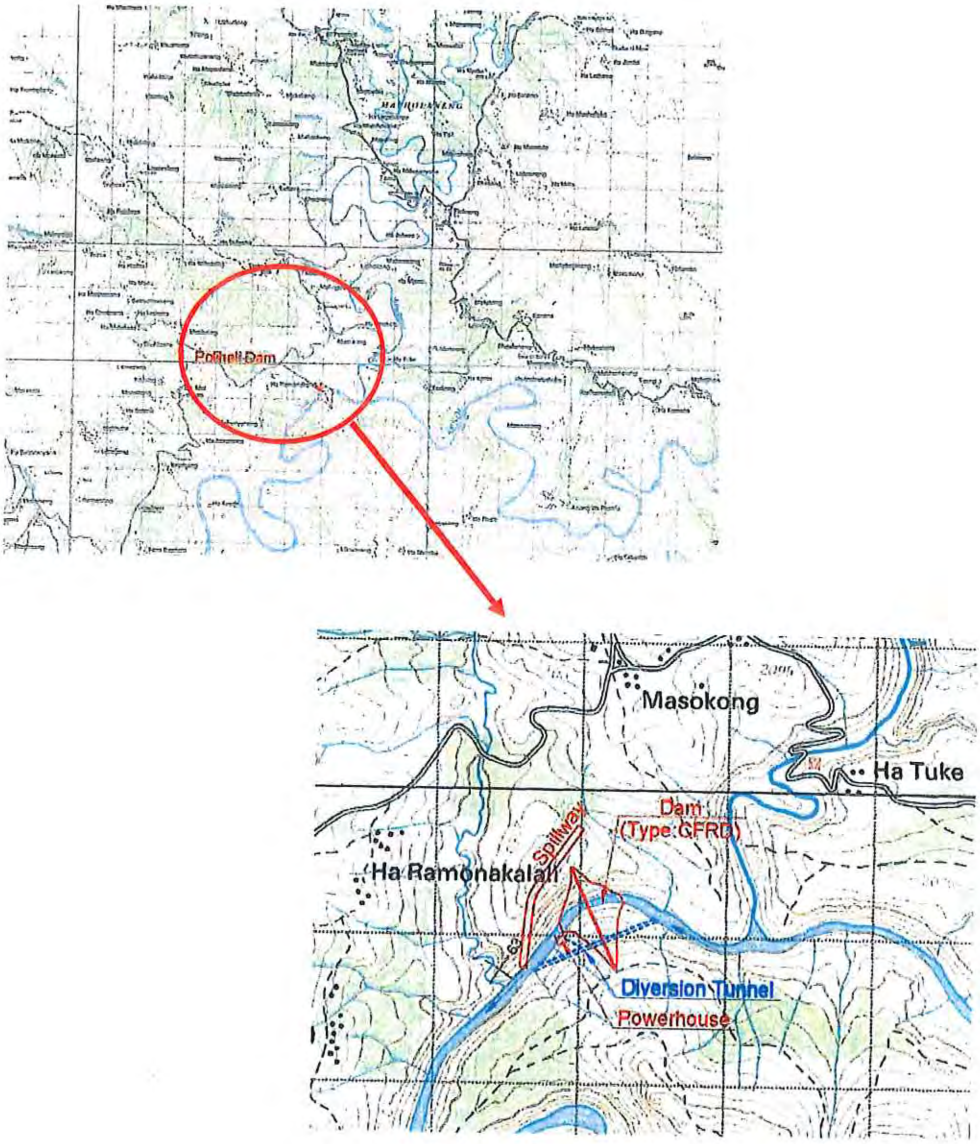


Fig.4.2.5.3-2 **Polihali dam project image**

2.4.3.3 Scheme of small hydropower facility

1) When the study team visited the Polihali site, the construction was at the stage of the temporary works such as access roads, not at the stage of the dam portion, same as the previous information.

2) According to the information from a project officer of LHDA at the site, the dam has the same design concept as one of Mohale dam and a small hydropower plant is to be installed annexed to the dam on the downstream side.

3) Though the data and drawings of Polihali dam concerning the discharge related to EWR and the targeted small hydropower plant have not been delivered to the team by LHDA at present, those data and drawings are expected to be provided.
After that, the technical study by the team is to be carried out.

4) On the other hand, in the report "Sub Task 4.3-Analysis of Viable Small or Medium Hydropower Options within the Existing LHWP System" issued in 2018, a plan view drawing of the small hydropower plant building, proposed in a FS report issued in 2008 for LHWP project, was shown.

5) In the report (Sub Task 4.3), the expected specifications of generating facility were proposed using the result of technical examination on the discharge available for power generation as follows.

Turbine type; horizontal Francis turbine
Number of unit; 1 unit
Generator capacity; 3.0 MVA
Design turbine discharge; 1.8 m^3/s
Maximum design gross head; 153 m (not net head)

6) On the other hand, below problem was pointed out in the report (Sub Task 4.3).
The building plan dimensions proposed in the FS report for LHWP are considerably small, and some portions of the generating equipment, examined in above item 5), are to interfere with the building structure.
Thus, the alteration of the original building design is needed for enlarging the dimensions of the generating facility compartment in the building is described clearly in the report. And, the design alteration is explained to be possible at present because the construction of the generating facility is in the planning stage.

7) If the design alternation of the building is not conducted, the capacity/dimensions of generating equipment should be reduced for installing in the small building compartment of the original design. In this case, the discharge available for power generation is "not" to be utilized effectively.

8) Implementing the installation of small hydropower facility in the future by a donor, JICA or another donor, the enlargement of compartment dimensions for generating facility in the building should be examined to realize the appropriate hydropower generation.

3. Confirmation of existing equipment and examination of technical support:

(for example) Support to preparation for maintenance schedule, check list and measurement point of the Project.

4. **Environmental** Impact Assessment (EIA)

Apart from the mission of this survey, following EIA agenda proposed by Ministry of Energy, should be made for next survey on JICA local re-commissioned, or EIA investigation is by the partner country:

1. The desirability, purpose, nature, location and scope of the project.
2. The activities or operations proposed to be undertaken and a preliminary design (including site, technology, processes and procedures involved, including construction and operation procedures and handling of waste).
3. Location map of the project site (1:50.000) and detailed map of site (1:4000).
4. The key planning, policy, legal and administrative requirements and guidelines — for example, in addition to the EIA license, what other permits will be required? Consultation with DOE can help to identify all these issues.
5. The area(s) of air, land, water and ecosystems that may be affected by the activity.
6. The conditions and the sensitivity of the land, air, water and ecosystems that may be affected.
7. Anything of cultural or historic value that may be affected
8. Anticipated impacts, including cumulative impacts, of the project/activity on the natural and human environment.
9. The materials (liquid, solid and gaseous) that the project shall use and discard or emit throughout its lifecycle. The possible products or by-products anticipated and their environmental consequences.
10. The number of people the project is likely to employ, in both the construction and operations phases. The financial and economic cost-benefit analysis and the social benefits to the local community and the nation in general should be included.
11. A description of all alternatives identified relating to the site, layout, route, process or design of the project. — the most feasible and practicable project alternatives.
12. Interested and affected parties/individuals identified and/or consulted. Description of the public consultation process undertaken in preparation of the project brief and a summary of comments received during the process (see public consultation below);
13. Environmental issues identified — this should include any other issues associated with the project/activity that have not been included in the above points. These may be issues identified

by communities, individuals or organisations during the consultation process, and will have various levels of significance. These issues should be shortly commented in the PB.

14. Key elements of an environmental management and mitigation plan.
15. Your recommendation as to whether further formal environmental impact study is required or not.
16. A draft notice for publication in national and local newspapers describing the project and disclosing where and when the Project Brief is available for public review.

The above regulations are of requisite by future project execution.

Attachment

Attachment-1: Current status and future policy regarding maintenance flow discharge

Attachment-2: Network Map

Attachment-3: Study itinerary

Attachment -1

Current status and future policy regarding maintenance flow discharge

Basically, the maintenance flow discharge at each dam is implemented based on the policy of discharging about 10% of the dam inflow calculated by some LEC consultant. In this regard, there is no clear regulations in the "Environmental Impact Assessment Guidelines" in Lesotho, and there is a current situation that the Ministry of the Environment is not a problem unless there are complaints from the water area community.

In addition, Mohale Dam and Katse Dam water will be sent to South Africa, and Metolong Dam water will be used as water, being used in Lesotho. Therefore, although it is for power generation, it is difficult to simply discharge more water to the downstream than the conventional discharge because it is directly linked to income in Lesotho. It must be be difficult to set the actual maintenance discharge rate. Since Polihali Dam is currently under preparation, water operation (maintenance discharge) will be decided in the future, hence we do not address herein. The maximum values of utilization water discharge and environmental water discharge in the past (Mohale Dam, Katse Dam 2009-2018, Metolong Dam 2016-2018) are as follows.

Mohale Dam : Qmax = 5.80 m³/sec

Katse Dam : Qmax = 1.53 m³/sec

(Actual power generation maximum discharge 1.00 m³/sec···1 generator)

Metolong Dam : Qmax = 0.33 m³/sec

In addition, the past maintenance flow discharge status of each dam is as follows;

(Note*: the average value on the same day of each year, arranged in order from the maximum flow rate to the minimum.)

Table 5.1 Flow duration table of maintenance flow discharge

(Unit: m³/sec)

Dam name	Maximum flow	Ninety-five-day discharge	Ordinary water discharge	Low water discharge	Droughty water discharge	Minimum flow	Usage data
	Q1	Q95	Q185	Q275	Q355	Q365	
Mohale Dam	2.038	1.111	0.942	0.859	0.777	0.679	2009 - 2018
Katse Dam	1.143	0.973	0.867	0.788	0.638	0.628	2009 - 2018
Metolong Dam	0.063	0.031	0.013	0.007	0.000	0.000	2016 - 2018

The optimal amount of water used in hydropower generation is calculated from the relationship between the amount of generated power and cost, but it is often around the amount of ninety-five-day discharge (Q95). Therefore, the amount of water used is about 1.0m3 / sec at Mohale and Katse points and 0.03m3 / sec at Metolong points. However, since the Metolong point varies widely depending on the year, it may be possible to set the maximum flow rate of the installed Valve as 0.31m3 / sec.

In addition, assuming the net head etc of each point, the power generation output is roughly calculated as follows.

【Mohale Site】

Maximum discharge Q=1.0 ㎥/sec, net head H=130m, Synthesis efficiency η=0.8

Power generation output P = 9.8×1.0×130×0.8 = 1,019.2 ≒ 1,000 kW

【Katse Site】

Maximum discharge Q=1.0 ㎥/sec, net head H=150m, Synthesis efficiency η=0.8

Power generation output P = 9.8×1.0×150×0.8 = 1,176 ≒ 1,100 kW

【Metolong Site】

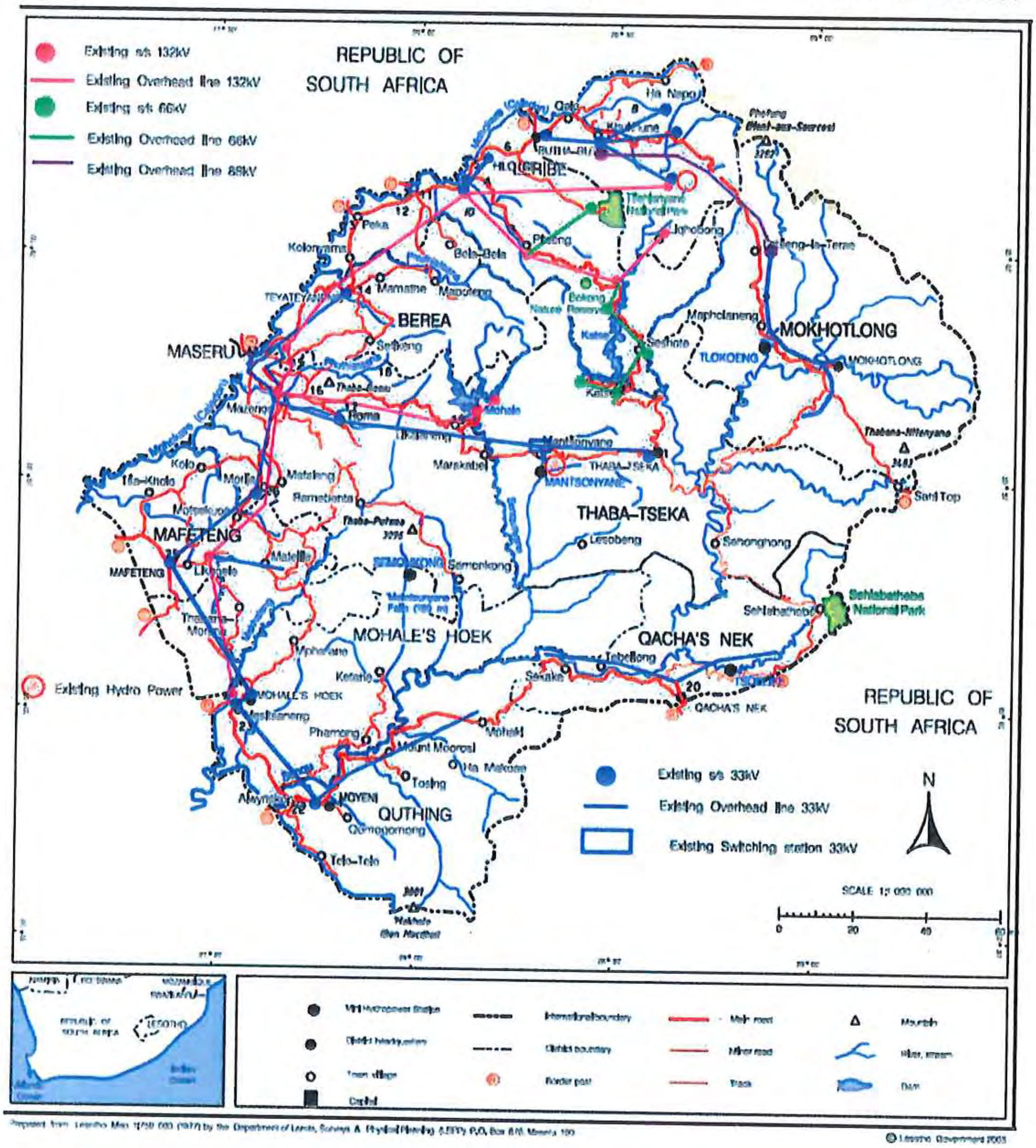
Maximum discharge Q=0.31 ㎥/sec, net head H=50m, Synthesis efficiency η=0.8

Power generation output P = 9.8×0.31×50×0.8 = 121.52 ≒ 120 kW

Through the meeting with the Ministry of the Environment, there is a comment that this project will be the subject of environmental impact assessment. From now on, it will be necessary to verify whether or not the maintenance flow discharge amount submitted by Lesotho is an accurate value and to determine the amount of water used, taking into account the environmental impact assessment guidelines.

Attachment-2

Edition 1 LESOTHO Scale 1:1 000 000



Attachment-3

Proposed Itinerary for First Field Survey

Data Collection Survey on Development of Hydro Power Station in Lesotho

2019.12.12

No.	Date		Description: Chief Consultant / Hydro Power Station Planning	Hydro Turbine	Civil Work	Distribution Network	Electrical Equipment	Accommodation
name			Kiyofusa TANAKA	Shoichi KUSHIMOTO	Fumio TAKEZAWA	Tatsuhiro URABE	Masahiro YAMAGUCHI	
1	2019.11.24	SUN	Trip[Haneda→Hongkong]					
2	2019.11.25	MON	Trip[Hongkong→Johannesburg] ・9:30 AfDB ・11:30 Courtesy call to JICA South Africa Office ・16:00 USAID					Pretoria
3	2019.11.26	TUE	Trip[Johannesburg(09:40)→Maseru(10:55)SA8053] ・14:00 Explanation of inception report, site survey schedule and questionnaire to Ministry of Energy & Meteorogy Department of Energy, LEWA, LHDA, LEC, WASCO					Maseru LANCERS INN HOTEL
4	2019.11.27	WED	・AM/8:00 MEM Start→Site Survey for Metong Dam					Maseru
5	2019.11.28	THU	・8:00 MEM Start→10:00 Site Survey for Mohare Dam. 12:00 Meeting with LHDA 16:00 back to Maseru					Maseru
6	2019.11.29	FRI	・8:30 Technical Meeting with MEM ・9:30 Technical Meeting with LEO	・9:30 Technical Meeting with LEC	・Preparation Report.	・9:30 Technical Meeting with LEC		Maseru
7	2019.11.30	SAT	・8:00 Hotel Start→11:00 Site Survey for Muela Dam (72MW Hydro Power Station), 15:00 back to Maseru					Maseru
8	2019.12.1	SUN	Preparation Report					Maseru
9	2019.12.2	MON	・8:00: Meeting with MEM to arrage the meeting with other donners and Ministries ・10:00: Maseru Start→ 15:00 Site Survey for Katse Dam (Stay Katsue Visitor Center)				AM. Meeting with MEM PM. Meeting with WB	Katse/Maseru
10	2019.12.3	TUE	・9:00: Site Survey for Katse Dam, Meeting with LHDA				PM. Meeting with Ministry of Finance for Tax exemption Meeting with USAID	Katse/Maseru
11	2019.12.4	WED	・8:00: (Start Katsue Visitor Center)→move to Polihali Dam→13:00Site Survey for Polihali Dam ・15:00 Polihali Dam→19:00 Maseru				AM. Meeting with CDM Smith (Contractor of LHWP) PM. Meeting with MEM	Maseru
12	2019.12.5	THU	・8:00 Meeting with MEM to report about site seeing and arrage meetings ・10:00 Meeting with Depart of Environment to hear about environmental reguration and information ・14:30 Meeting with MEM for hearing UNDP's SE4ALL P/J	・10:00 Meeting with Depart of Environment to hear about environmental reguration and information ・Preparation Report	・10:00 Meeting with Depart of Environment to hear about environmental reguration and information ・Preparation Report	・8:00 Meeting with MEM to report about site seeing and arrage meetings ・10:00 Meeting with Depart of Environment to hear about environmental reguration and information ・Preparation Report	・8:00 Meeting with MEM to report about site seeing and arrage meetings ・10:00 Meeting with Depart of Environment to hear about environmental reguration and information ・14:30 Meeting with MEM for hearing UNDP's SE4ALL P/J	Maseru
13	2019.12.6	FRI	・9:00 meeting with LHWC, LHDA to confirm the correlation of organizations and the answers for questionnaire ・Internal meeting ・Preparation Report					Maseru
14	2019.12.7	SAT	・Internal meeting, Preparation Report					Maseru
15	2019.12.8	SUN	Preparation Report					Maseru
16	2019.12.9	MON	Preparation Report, Obtain Answer of Questioner/MEM, LHDA, LEC, WASCO Meeting with LEC	Preparation Report, Obtain Answer of Questioner/Ministry of Energy & Meteorogy Department of Energy, LHDA, LEC, WASCO		Preparation Report, Obtain Answer of Questioner/Ministry of Energy & Meteorogy Department of Energy, LHDA, LEC, WASCO Meeting with LEC		Maseru
17	2019.12.10	TUE	・AM: Meeting with LHDA ・Preparation Report, Obtain Answer of Questioner/MEM, LHDA, LEC, WASCO			Preparation Report, Obtain Answer of Questioner/Ministry of Energy & Meteorogy Department of Energy, LHDA, LEC, WASCO Meeting with LEC		Maseru
18	2019.12.11	WED	Preparation Report, Obtain Answer of Questioner/Ministry of Energy & Meteorogy Department of Energy, LHDA, LEC, WASCO					Maseru
19	2019.12.12	THU	・Wrap up survey, meeting with Ministry of Energy & Meteorogy Department of Energy, LHDA, LEC, WASCO, Prepare report,					Maseru
20	2019.12.13	FRI	Trip[Maseru(9:10)→Johannesburg(9:60)]SA8059 13:50 Prepare report,					Pretoria
21	2019.12.14	SAT	・Trip:[Johannesburg→Hong kong]					
22	2019.12.15	SUN	・Trip:[→Haneda]					

Appendix-6 LESOTHO POPULATION DATA

Appendix-6 Lesotho Population data

Source: Census data in Lesotho in 2016

Lesotho Population by sex	
Male	982,133
Female	1,025,068
Total	2,007,201

Lesotho population by district and sex			
District	Male (%)	Female (%)	Total
Butha-Buthe	48.8	51.2	118,242
Leribe	48.8	51.2	337,521
Berea	49.0	51.0	262,616
Maseru	48.1	51.9	519,186
Mafeteng	50.0	50.0	178,222
Mohales Hoek	49.1	50.9	165,590
Quthing	49.2	50.8	115,469
Qachas Nek	49.0	51.0	74,566
Mokhotlong	49.7	50.3	100,442
Thaba-Tseka	49.9	50.1	135,347
Total	48.9	51.1	2,007,201

Lesotho households by district	
District	Total
Butha-Buthe	30,169
Leribe	90,313
Berea	69,999
Maseru	157,810
Mafeteng	46,563
Mohales Hoek	40,756
Quthing	26,345
Qachas Nek	17,584
Mokhotlong	24,362
Thaba-Tseka	33,556
Total	537,457

Lesotho population by zone and sex		
Ecological Zone	Percentage (%)	Total
Lowlands	62.0	1,244,465
Foothills	9.7	194,698
Mountain	19.6	393,411
Senqu River Valley	8.7	174,627
Total	100.0	2,007,201

Appendix-7 RAINFALL IN EACH DAM BASIN

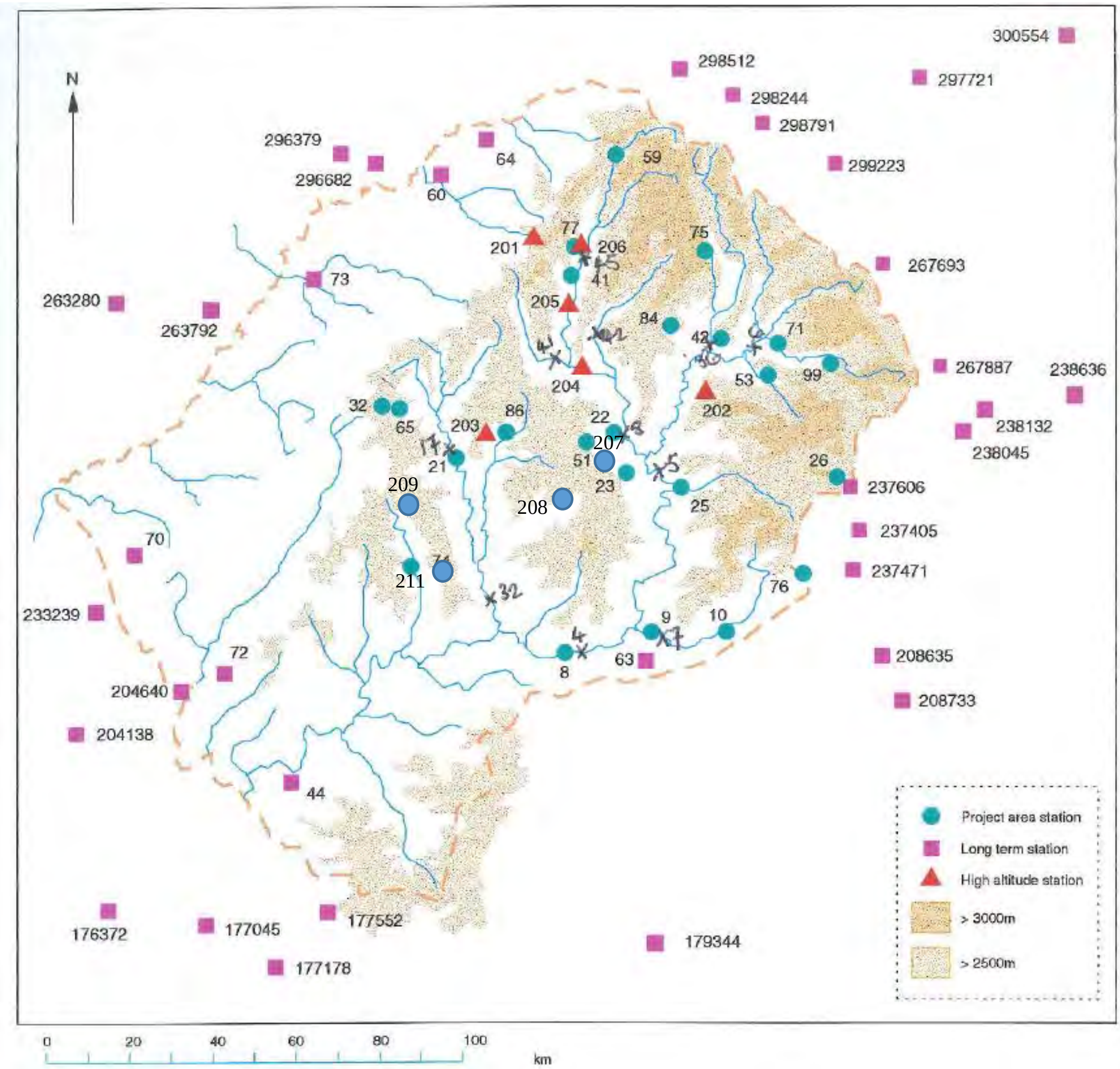
Appendix-7 Rainfall in each dam basin

(1) Annual rainfall in each dam basin

Annual rainfall in each basin

Rainfall Observation Station			Annual Rainfall		
Area	No	Station Name	1991-2009 Average	2010-2019 Average	Overall Average
Mohale Area	65	Thaba Putsoa	1,215.4	888.9	1,099.8
	203	Cheche	784.5	654.7	738.7
	209	Rapokolane	1,013.0	987.4	996.0
	211	Mohale Rainfall	—	733.8	733.8
	Average		1,004.3	816.2	892.1
Katse Area	205	Ha Poli	787.3	952.5	850.8
	206	Rampai 2	1,032.5	957.0	1,002.6
	207	Makopela	764.1	688.5	737.1
	208	Katse Village	723.6	674.9	702.0
	Average		826.9	818.2	823.1
Polihali Area	99	Malefiloane	697.0	525.5	634.1
	202	Libibing	698.5	615.9	669.3
	Average		697.8	570.7	651.7
Muela Area	201	KM 27	1,481.6	1,324.2	1,432.0
	Average		1,481.6	1,324.2	1,432.0

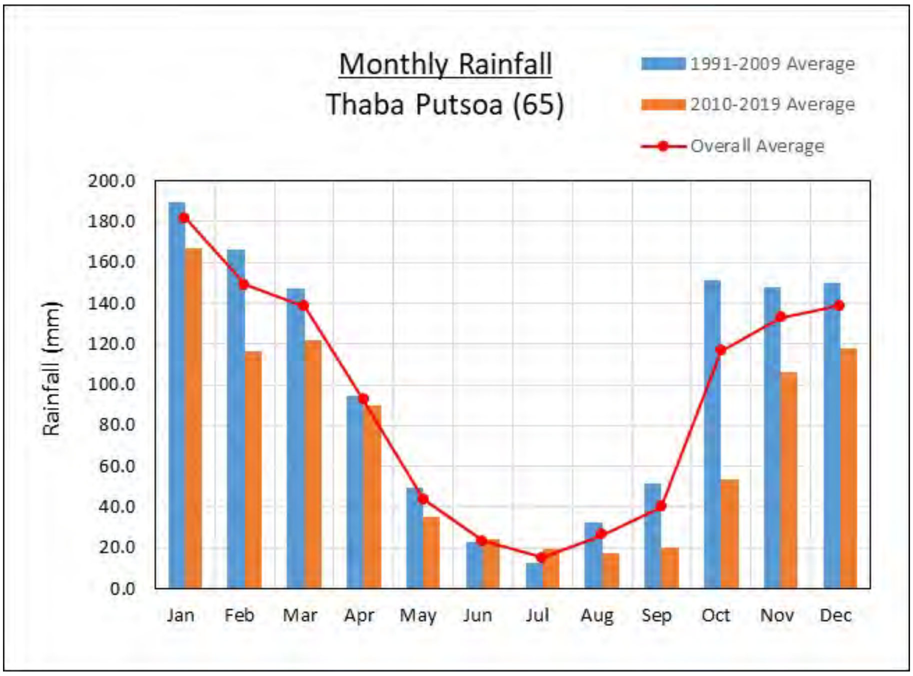
Locations of all raingauges considered



(2) Monthly Rainfall in Mohale area

1) Thaba Putsoa (Station No. 65)

Average Amount of Monthly Rainfall



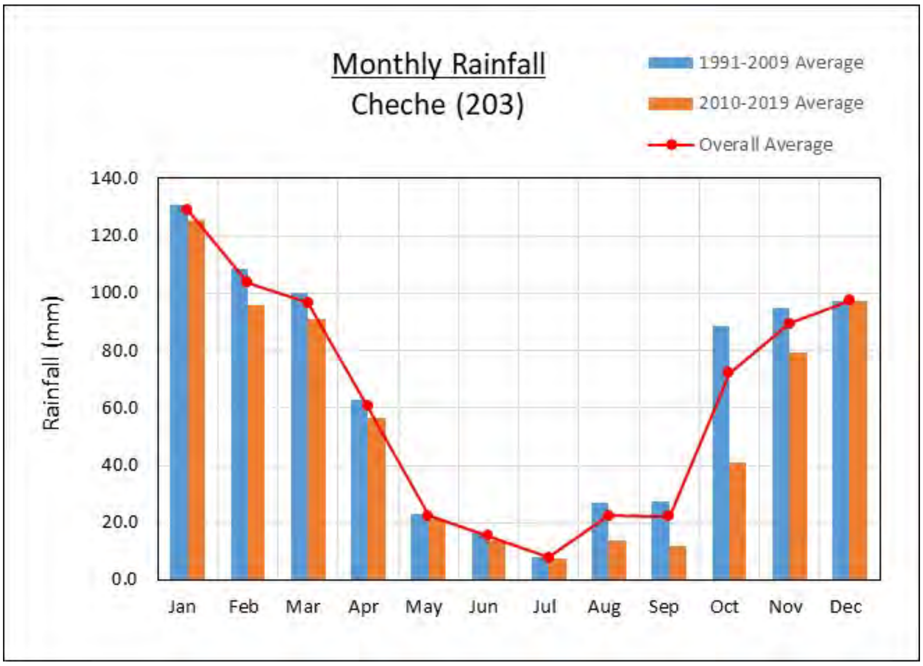
Monthly rainfall observation data

(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	275.0	199.5	162.7	14.1	1.0	–	5.8	–	81.3	258.6	87.4	112.6	–
1992	67.9	110.0	85.9	39.2	0.8	0.5	1.7	95.2	5.5	110.9	175.2	74.8	767.6
1993	149.6	205.0	140.5	147.5	–	9.9	0.0	22.7	1.5	219.7	178.3	129.6	–
1994	293.8	238.2	134.6	88.2	–	4.0	0.0	0.0	–	–	–	85.3	–
1995	152.0	44.4	119.0	40.3	43.6	7.2	6.7	6.4	37.8	188.1	137.4	–	–
1996	149.3	272.4	123.5	88.4	30.6	0.0	25.2	18.0	28.5	186.7	276.1	156.7	1,355.4
1997	188.6	122.7	224.7	130.4	136.0	26.7	90.2	12.6	23.7	60.0	100.1	–	–
1998	164.6	271.5	275.8	32.4	26.1	3.8	–	–	63.0	141.0	178.2	161.6	–
1999	175.2	167.6	107.3	27.1	–	–	7.4	10.5	14.8	111.7	58.5	242.4	–
2000	144.0	124.7	157.4	79.3	39.4	21.0	11.7	0.1	112.1	166.2	129.9	203.1	1,188.9
2001	85.3	121.7	85.3	236.9	58.0	20.4	19.1	107.9	23.2	187.7	147.9	247.0	1,340.4
2002	336.0	86.8	101.5	103.1	143.5	37.8	8.2	–	102.9	40.3	72.4	249.6	–
2003	187.4	136.6	163.1	89.9	10.8	0.0	0.0	30.2	137.3	70.3	175.2	84.9	1,085.7
2004	172.0	123.0	234.4	94.9	0.0	41.6	29.2	46.0	118.5	187.5	117.6	232.5	1,397.2
2005	312.3	206.5	191.2	177.4	28.0	2.8	0.0	40.0	51.5	163.5	207.5	55.9	1,436.6
2006	203.4	321.6	223.6	178.0	163.5	0.0	0.0	84.6	24.1	160.0	215.1	65.4	1,639.3
2007	156.6	28.6	66.6	98.6	0.0	–	–	7.3	78.5	184.9	118.0	179.0	–
2008	147.3	153.8	142.5	82.6	74.1	85.6	0.0	18.2	15.6	51.4	184.1	225.6	1,180.8
2009	238.9	219.9	63.4	46.3	34.8	107.1	9.2	14.9	8.2	239.1	101.7	41.8	1,125.3
2010	224.6	79.0	136.9	68.9	34.9	35.0	0.0	0.0	2.0	70.6	285.6	311.5	1,249.0
2011	441.2	90.8	100.6	136.5	153.2	40.6	32.4	3.2	0.0	38.0	60.5	126.0	1,223.0
2012	90.9	173.5	98.4	43.5	3.3	73.7	34.3	15.9	81.4	129.9	86.2	166.9	997.9
2013	164.3	20.2	99.5	89.4	6.6	1.3	0.0	10.5	3.7	72.2	118.2	98.0	683.9
2014	91.8	141.6	106.4	35.6	9.7	0.0	0.0	14.5	0.0	22.9	159.3	153.5	735.3
2015	91.8	61.3	159.8	57.5	13.5	76.3	42.4	7.5	26.6	46.9	25.7	18.0	627.3
2016	189.5	87.5	84.9	63.3	26.4	0.0	58.3	38.2	28.0	36.7	114.9	17.6	745.3
2017	141.3	224.6	76.5	97.3	19.1	13.0	0.0	0.0	32.4	94.4	99.3	108.8	906.7
2018	121.5	146.0	184.7	109.3	70.8	0.0	24.2	77.4	22.8	26.5	57.9	61.0	902.1
2019	111.8	143.8	169.8	194.3	12.5	0.0	3.2	5.3	2.1	0.0	56.5	–	–
Overall Average	181.7	149.1	138.6	92.8	43.9	23.4	15.2	26.4	40.3	116.6	133.0	138.8	1,099.8
1991-2009 Average	189.4	166.0	147.5	94.5	49.4	23.0	12.6	32.2	51.6	151.5	147.8	149.9	1,215.4
2010-2019 Average	166.9	116.8	121.8	89.6	35.0	24.0	19.5	17.3	19.9	53.8	106.4	117.9	888.9

2) Cheche (Station No. 203)

Average Amount of Monthly Rainfall



Monthly rainfall observation data

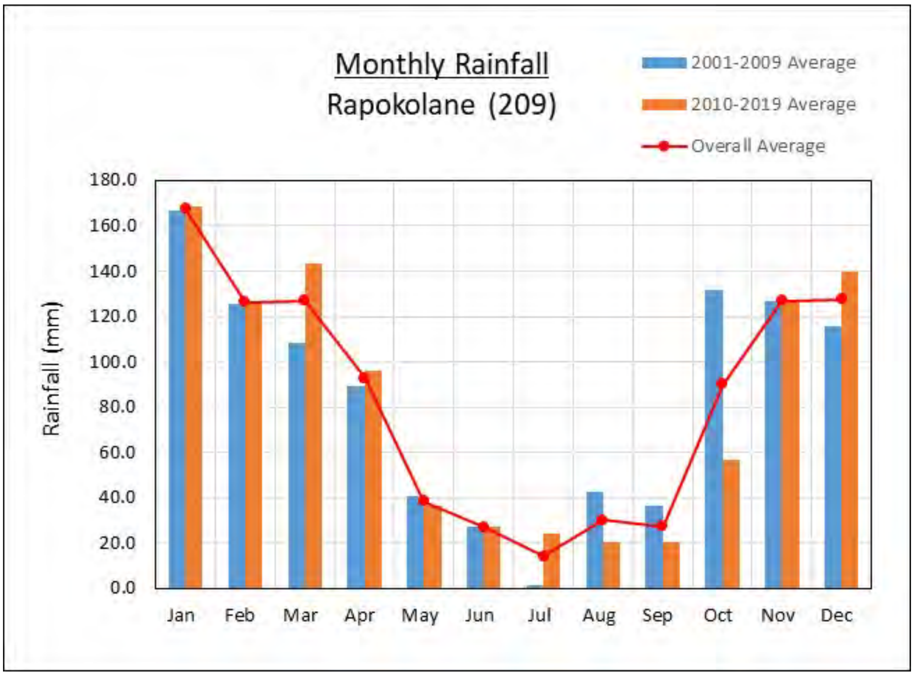
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	–	–	–	–	0.3	13.5	1.7	0.0	34.6	198.5	58.9	70.7	–
1992	22.4	47.4	22.8	15.0	1.2	–	0.0	70.9	28.8	78.3	110.8	19.6	–
1993	64.9	–	109.9	122.8	13.5	8.9	0.0	29.2	3.1	141.1	96.9	147.0	–
1994	162.5	92.2	111.1	58.7	0.0	6.1	9.9	0.0	0.0	20.8	43.3	60.1	564.7
1995	114.4	44.2	–	62.8	50.5	7.5	0.0	2.3	16.6	106.8	108.8	179.0	–
1996	173.6	143.6	108.8	87.2	–	17.5	23.8	26.3	4.5	140.3	133.3	95.4	–
1997	176.8	184.1	113.1	71.2	42.8	16.0	16.9	22.3	9.7	39.1	122.7	53.8	868.5
1998	138.4	127.6	156.2	5.2	17.7	0.0	30.2	2.9	45.5	107.3	119.0	122.2	872.2
1999	139.0	89.6	127.2	–	–	24.0	25.7	14.0	0.0	66.2	52.2	129.5	–
2000	111.3	105.2	120.0	97.7	18.0	6.0	2.5	0.0	72.1	87.7	81.7	158.0	860.2
2001	75.6	77.8	68.5	137.6	24.3	7.1	14.5	65.6	28.4	93.0	157.8	149.1	899.3
2002	129.7	38.3	94.4	48.3	84.8	28.0	16.0	118.3	66.8	65.3	126.1	111.8	927.8
2003	87.2	173.0	133.7	52.5	14.1	0.0	0.0	26.9	48.0	21.1	56.4	73.0	685.9
2004	167.7	115.7	104.5	30.6	0.0	16.1	8.1	32.9	64.3	47.2	92.5	102.3	781.9
2005	142.6	114.6	123.6	59.6	17.9	0.0	0.0	29.8	11.5	71.2	48.4	18.7	637.9
2006	243.7	201.6	135.2	62.1	47.1	1.2	0.0	53.6	34.1	134.6	108.8	60.1	1,082.1
2007	168.4	54.6	33.9	83.3	3.0	22.8	0.0	3.5	28.2	131.2	112.7	98.8	740.4
2008	139.6	84.9	112.2	45.5	37.4	49.5	0.0	8.0	23.0	23.4	128.8	138.9	791.2
2009	99.1	148.1	26.9	30.3	21.0	66.6	5.2	0.0	2.0	105.3	43.5	60.6	608.6
2010	132.5	82.4	61.5	127.3	23.0	32.5	0.0	0.0	4.0	100.0	141.0	187.0	891.2
2011	179.0	58.5	93.5	77.5	79.5	35.0	18.2	1.0	8.6	22.0	54.6	128.1	755.5
2012	78.6	102.4	63.5	37.0	3.5	50.0	23.5	21.0	43.5	42.0	75.0	166.0	706.0
2013	113.0	67.6	87.4	44.8	5.4	0.0	0.0	1.6	0.7	42.1	73.0	89.4	525.0
2014	130.9	141.4	134.9	30.7	0.0	0.0	0.0	30.3	9.8	43.2	167.1	88.1	776.4
2015	165.0	33.3	93.4	29.1	6.4	20.9	24.3	0.0	3.9	29.4	39.7	6.3	451.7
2016	115.0	73.7	61.2	53.8	39.2	0.2	6.8	35.1	21.7	65.8	117.1	53.1	642.7
2017	152.6	163.2	10.4	27.2	20.1	0.0	0.0	0.0	11.3	49.9	72.3	86.7	593.7
2018	131.8	127.4	182.1	26.9	26.2	0.0	0.0	50.3	16.1	17.9	5.8	70.3	654.8
2019	57.3	107.4	121.6	110.0	7.4	0.0	0.0	0.0	0.0	0.0	48.2	–	–
Overall Average	129.0	103.7	96.7	60.5	22.4	15.3	7.8	22.3	22.1	72.1	89.5	97.3	738.7
1991-2009 Average	130.9	108.4	100.1	63.0	23.2	16.2	8.1	26.7	27.4	88.3	94.9	97.3	784.5
2010-2019 Average	125.6	95.7	91.0	56.4	21.1	13.9	7.3	13.9	12.0	41.2	79.4	97.2	654.7

* Blue letters are estimates.

3) Rapokolane (Station No. 209)

Average Amount of Monthly Rainfall



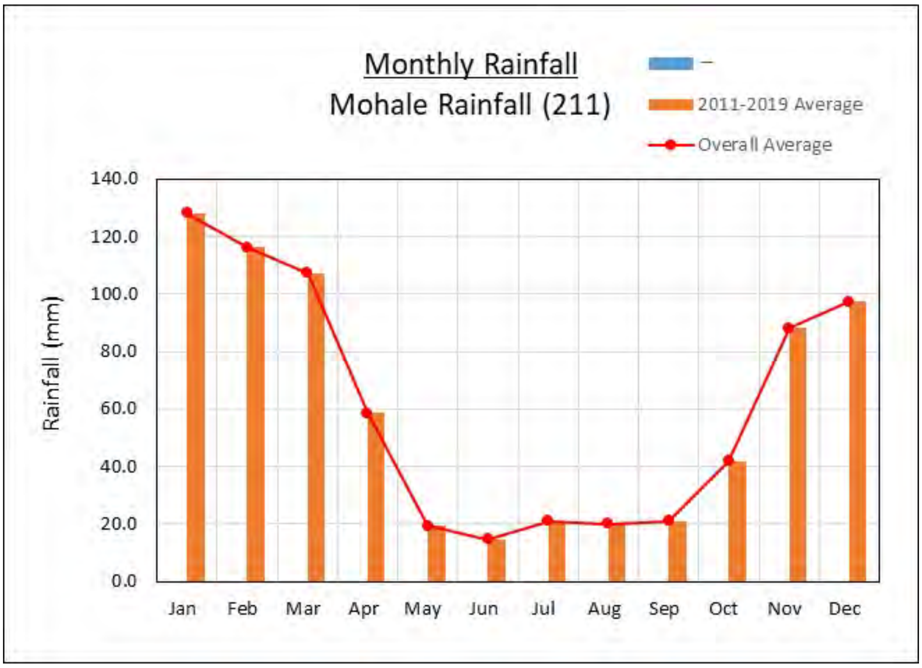
Monthly rainfall observation data

(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	–	–	–	–	–	–	–	–	–	–	–	–	–
1992	–	–	–	–	–	–	–	–	–	–	–	–	–
1993	–	–	–	–	–	–	–	–	–	–	–	–	–
1994	–	–	–	–	–	–	–	–	–	–	–	–	–
1995	–	–	–	–	–	–	–	–	–	–	–	–	–
1996	–	–	–	–	–	–	–	–	–	–	–	–	–
1997	–	–	–	–	–	–	–	–	–	–	–	–	–
1998	–	–	–	–	–	–	–	–	–	–	–	–	–
1999	–	–	–	–	–	–	–	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–	–	–	–	–	–
2001	0.0	63.0	56.0	220.0	21.0	4.0	5.0	0.0	32.5	215.0	206.8	113.0	936.3
2002	305.0	55.0	65.5	60.5	132.5	32.5	1.0	157.0	81.0	94.0	74.0	186.5	1,244.5
2003	67.5	97.0	147.2	58.5	9.5	0.0	0.0	44.0	83.8	65.0	60.0	21.9	654.4
2004	192.5	160.5	210.7	42.5	0.0	1.0	–	–	–	–	86.3	83.8	–
2005	192.2	128.8	123.8	115.2	31.0	0.5	0.0	36.7	26.0	100.2	139.9	46.0	940.3
2006	234.1	273.9	157.8	121.6	47.5	0.0	0.3	72.1	9.7	128.3	208.3	123.8	1,377.4
2007	110.6	35.1	65.0	84.7	4.7	45.8	0.3	4.2	38.9	194.6	101.9	150.1	835.9
2008	159.0	136.7	109.1	59.3	96.8	59.6	0.0	19.9	15.3	39.7	166.8	222.2	1,084.4
2009	237.9	182.1	38.6	39.6	21.2	102.5	6.2	9.4	5.5	216.0	98.1	96.4	1,053.5
2010	215.5	63.0	135.2	105.0	36.0	38.4	0.0	0.4	0.3	68.7	261.9	274.6	1,199.0
2011	428.0	43.3	98.7	105.4	125.9	42.1	23.0	0.0	0.0	39.4	45.6	153.8	1,105.2
2012	70.8	182.4	86.0	39.5	3.0	71.6	32.9	29.2	66.5	99.0	95.0	180.4	956.3
2013	168.3	39.4	130.3	56.4	11.8	0.3	0.4	13.5	4.1	68.8	130.8	82.6	706.7
2014	53.8	223.6	78.1	74.0	14.4	0.6	0.0	37.1	3.3	43.8	273.3	151.5	953.5
2015	142.8	39.9	160.0	61.2	8.9	84.7	41.8	14.3	38.0	63.6	64.2	26.7	746.1
2016	136.4	103.8	76.6	95.3	39.8	19.9	121.1	24.4	23.0	41.9	175.8	67.0	925.0
2017	208.5	213.6	64.7	30.8	24.9	13.4	0.0	0.0	40.1	102.0	82.6	218.4	999.0
2018	127.2	146.9	403.1	171.7	68.3	0.0	22.2	81.5	24.3	36.0	68.6	100.4	1,250.2
2019	135.2	214.3	203.2	223.9	32.6	0.0	1.1	2.3	2.0	4.0	72.9	–	–
Overall Average	167.6	126.4	126.8	92.9	38.4	27.2	14.2	30.3	27.5	90.0	127.0	127.7	996.0
2001-2009 Average	166.5	125.8	108.2	89.1	40.5	27.3	1.6	42.9	36.6	131.6	126.9	116.0	1,013.0
2010-2019 Average	168.7	127.0	143.6	96.3	36.6	27.1	24.3	20.3	20.2	56.7	127.1	139.5	987.4

4) Rapokolane (Station No. 209)

Average Amount of Monthly Rainfall



Monthly rainfall observation data

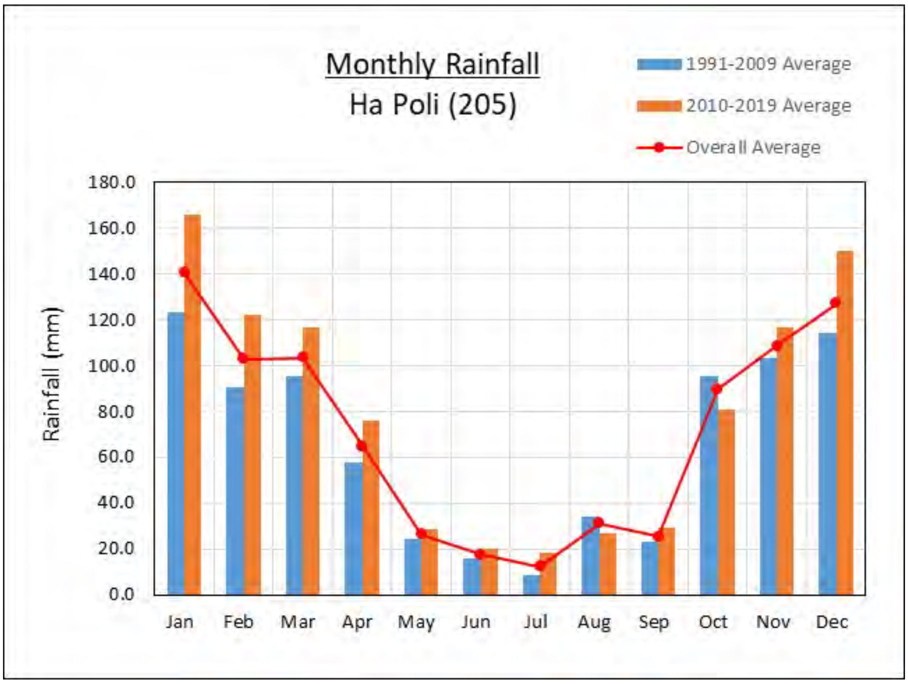
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	–	–	–	–	–	–	–	–	–	–	–	–	–
1992	–	–	–	–	–	–	–	–	–	–	–	–	–
1993	–	–	–	–	–	–	–	–	–	–	–	–	–
1994	–	–	–	–	–	–	–	–	–	–	–	–	–
1995	–	–	–	–	–	–	–	–	–	–	–	–	–
1996	–	–	–	–	–	–	–	–	–	–	–	–	–
1997	–	–	–	–	–	–	–	–	–	–	–	–	–
1998	–	–	–	–	–	–	–	–	–	–	–	–	–
1999	–	–	–	–	–	–	–	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–	–	–	–	–	–
2001	–	–	–	–	–	–	–	–	–	–	–	–	–
2002	–	–	–	–	–	–	–	–	–	–	–	–	–
2003	–	–	–	–	–	–	–	–	–	–	–	–	–
2004	–	–	–	–	–	–	–	–	–	–	–	–	–
2005	–	–	–	–	–	–	–	–	–	–	–	–	–
2006	–	–	–	–	–	–	–	–	–	–	–	–	–
2007	–	–	–	–	–	–	–	–	–	–	–	–	–
2008	–	–	–	–	–	–	–	–	–	–	–	–	–
2009	–	–	–	–	–	–	–	–	–	–	–	–	–
2010	–	–	–	–	–	–	–	–	–	–	–	–	–
2011	–	–	–	–	–	–	–	–	–	11.2	41.8	138.7	–
2012	48.5	173.4	115.1	41.4	7.9	71.8	21.9	22.8	62.8	70.3	86.0	192.5	914.4
2013	148.0	34.0	84.0	50.8	17.0	0.0	0.0	10.4	4.8	78.2	93.4	83.6	604.2
2014	209.0	195.1	94.2	35.9	3.7	1.1	0.0	39.9	4.9	52.2	216.6	106.2	958.8
2015	123.0	54.6	121.3	29.5	0.4	26.7	36.0	8.6	21.9	35.6	53.7	7.5	518.8
2016	170.7	73.5	70.1	80.1	39.7	12.7	97.2	18.0	18.2	50.4	115.6	58.2	804.4
2017	154.3	218.2	21.5	47.4	24.9	5.9	0.0	0.0	25.4	54.3	73.8	122.2	747.9
2018	89.2	52.8	266.2	41.1	42.9	0.0	13.6	58.5	27.9	23.9	44.7	70.6	731.4
2019	82.2	128.2	86.4	142.8	16.7	0.0	0.0	1.4	1.1	0.6	68.2	–	–
Overall Average	128.1	116.2	107.4	58.6	19.2	14.8	21.1	20.0	20.9	41.9	88.2	97.4	733.8
–	–	–	–	–	–	–	–	–	–	–	–	–	–
2011-2019 Average	128.1	116.2	107.4	58.6	19.2	14.8	21.1	20.0	20.9	41.9	88.2	97.4	733.8

(3) Monthly Rainfall in Katse area

1) Ha Poli (Station No. 205)

Average Amount of Monthly Rainfall



Monthly rainfall observation data

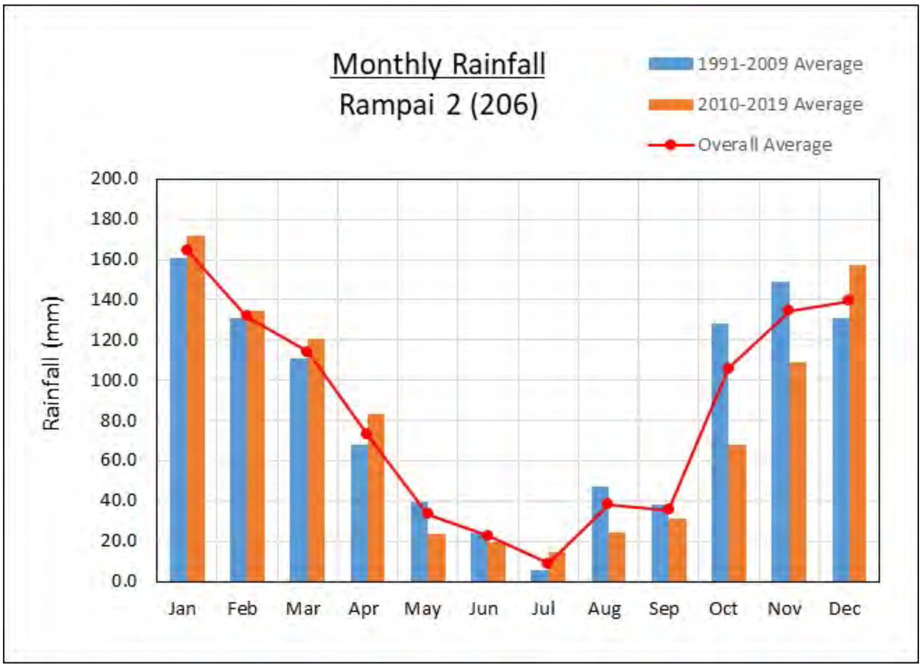
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	–	–	–	–	–	–	–	–	–	–	30.4	95.0	–
1992	94.1	57.7	61.8	52.2	–	–	0.0	71.7	9.1	118.1	88.0	81.1	–
1993	128.6	117.0	70.3	–	–	4.5	0.6	28.5	21.0	169.1	85.8	125.1	–
1994	111.6	114.3	121.7	87.4	3.9	3.1	9.3	6.5	0.0	27.0	53.2	68.7	606.7
1995	173.5	129.2	103.5	45.1	26.0	6.5	0.2	3.0	13.2	119.8	132.6	158.4	911.0
1996	72.6	93.0	94.0	23.5	57.1	0.0	52.4	39.0	11.4	126.4	160.5	168.5	–
1997	114.5	73.5	163.8	115.5	71.5	36.9	18.0	35.1	13.0	56.2	123.4	69.8	891.2
1998	166.1	148.8	146.9	17.5	12.4	0.0	21.3	–	–	–	–	–	–
1999	–	–	–	–	–	–	7.4	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–	–	–	–	–	–
2001	–	9.0	55.3	124.6	18.1	7.1	17.7	44.3	42.4	112.7	89.0	145.4	–
2002	149.6	12.5	63.2	44.9	36.9	15.9	4.6	85.2	60.6	38.5	53.0	145.9	710.8
2003	56.4	76.0	93.8	44.5	11.1	0.6	0.0	24.0	40.3	42.3	107.2	64.9	561.1
2004	91.8	92.7	133.3	26.7	0.6	19.1	3.5	22.8	43.2	52.7	68.9	130.7	686.0
2005	129.7	72.7	83.6	59.2	25.7	4.3	0.1	56.0	13.8	120.8	126.2	43.7	735.8
2006	141.6	174.3	81.1	48.8	17.1	1.8	2.0	68.7	7.3	112.1	194.7	157.5	1,007.0
2007	113.7	51.1	63.5	85.6	0.0	23.6	0.0	5.0	42.4	173.8	117.0	152.6	828.3
2008	119.4	60.6	147.1	56.0	22.9	40.9	1.6	8.7	17.9	23.6	153.3	136.4	788.4
2009	191.9	170.6	42.4	33.3	41.0	76.1	11.5	9.6	8.9	144.5	72.6	84.1	886.5
2010	224.1	113.2	68.2	92.7	9.5	37.6	0.0	0.0	0.0	89.4	212.3	218.1	1,065.1
2011	229.7	64.5	99.9	104.0	70.3	27.1	48.2	11.9	12.6	93.5	84.8	125.0	971.5
2012	89.7	84.0	47.6	33.5	2.0	67.8	19.7	29.2	75.5	82.8	70.7	151.6	754.1
2013	132.7	54.8	69.0	77.9	29.2	0.0	0.0	18.4	9.3	77.1	104.0	126.1	698.5
2014	110.4	188.3	98.2	24.9	1.2	0.0	0.0	49.6	16.3	92.9	208.4	123.9	914.1
2015	207.3	48.6	145.7	43.6	15.8	34.1	45.1	8.9	32.1	43.8	44.9	41.8	711.7
2016	159.4	130.6	96.5	77.5	44.8	16.7	55.7	54.5	86.8	129.5	169.8	204.2	1,226.0
2017	250.8	200.4	60.2	58.4	54.9	18.7	4.4	1.0	19.9	126.5	86.4	222.7	1,104.3
2018	136.6	131.3	336.2	67.5	38.5	0.0	12.0	89.7	25.8	74.2	85.0	138.1	1,134.9
2019	119.0	204.6	146.2	181.9	21.1	0.0	0.0	5.8	12.6	2.6	101.1	–	–
Overall Average	140.6	102.8	103.6	65.1	26.3	17.7	12.4	31.1	25.4	90.0	108.6	127.2	850.8
1991-2009 Average	123.7	90.8	95.3	57.7	24.6	16.0	8.8	33.9	23.0	95.8	103.5	114.2	787.3
2010-2019 Average	166.0	122.0	116.8	76.2	28.7	20.2	18.5	26.9	29.1	81.2	116.7	150.2	952.5

* Blue letters are estimates.

2) Rampai 2 (Station No. 206)

Average Amount of Monthly Rainfall



Monthly rainfall observation data

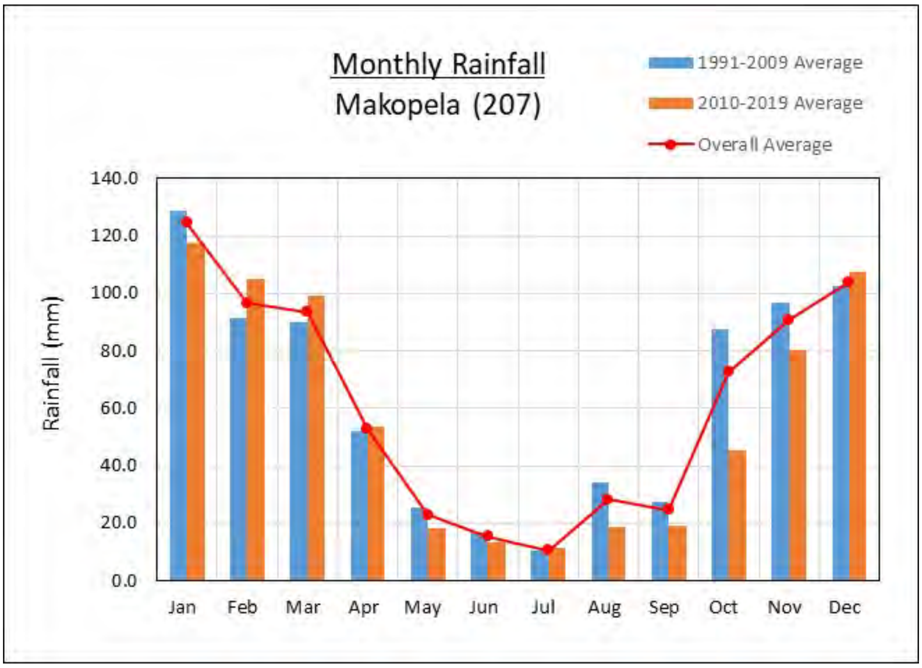
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	–	–	–	–	–	–	–	–	–	–	86.0	80.5	–
1992	44.5	71.0	63.0	42.0	2.5	0.2	0.2	88.5	4.5	125.0	174.1	75.9	691.4
1993	90.9	131.8	79.2	144.0	11.5	24.3	0.0	26.0	26.0	263.5	103.2	67.5	967.9
1994	214.5	–	55.5	59.0	2.2	0.5	0.0	–	–	27.5	103.6	–	–
1995	120.5	128.4	30.0	34.0	–	–	0.0	14.9	23.0	182.3	146.5	181.0	–
1996	160.3	152.5	103.9	67.0	66.0	0.0	4.3	37.0	–	93.9	216.6	182.8	–
1997	181.7	96.0	211.6	137.6	60.6	44.8	39.5	48.7	39.8	85.9	122.2	103.1	1,171.5
1998	174.9	156.6	172.5	17.0	–	–	–	–	–	–	186.0	131.5	–
1999	131.3	80.0	69.5	43.5	49.0	14.0	19.5	11.5	22.0	119.0	70.5	123.0	752.8
2000	87.5	199.5	126.0	68.5	44.5	21.5	10.0	0.0	108.0	128.0	164.5	138.7	1,096.7
2001	68.0	91.5	52.0	102.9	20.5	6.0	17.0	76.0	42.0	122.5	98.0	133.5	829.9
2002	174.0	71.0	88.8	67.2	69.8	36.5	4.0	152.0	74.5	105.0	67.5	155.0	1,065.3
2003	137.5	65.0	140.5	28.0	13.0	0.0	0.0	51.5	47.5	35.8	90.5	89.0	698.3
2004	155.7	122.5	138.7	18.0	1.0	35.0	0.0	24.5	82.5	88.0	109.6	140.3	915.8
2005	260.0	136.5	76.0	83.5	26.0	2.0	0.0	81.5	32.0	183.0	136.5	38.8	1,055.8
2006	222.0	208.5	74.5	65.5	45.0	0.0	0.0	118.0	8.0	122.5	314.5	154.0	1,332.5
2007	101.5	56.0	71.5	102.0	0.0	35.4	0.0	0.0	48.5	277.0	217.0	257.5	1,166.4
2008	374.3	154.5	227.0	114.5	147.5	29.2	0.0	11.9	12.0	45.5	278.0	294.5	1,688.9
2009	192.0	302.0	210.0	23.0	73.0	143.5	0.0	12.5	0.0	171.0	–	8.5	–
2010	259.6	154.0	159.5	116.0	21.5	30.0	0.0	0.0	0.0	139.0	126.5	275.5	1,281.6
2011	578.5	104.0	90.5	229.0	45.5	40.5	21.0	20.1	21.5	49.0	139.9	253.7	1,593.2
2012	73.0	196.0	73.5	21.7	2.3	68.5	18.4	21.2	50.4	65.2	45.7	104.7	740.6
2013	90.8	63.0	49.4	74.4	21.1	0.0	0.5	20.2	3.1	60.4	62.3	86.9	532.1
2014	82.6	141.8	70.0	41.5	1.7	0.0	0.0	42.0	12.6	64.6	214.5	194.3	865.6
2015	157.1	59.5	157.3	33.5	7.6	34.0	49.8	21.3	42.5	54.6	43.6	48.9	709.7
2016	104.0	172.4	100.2	78.4	51.4	12.9	37.0	53.4	61.5	85.3	147.7	147.1	1,051.3
2017	150.0	156.3	69.2	59.8	35.5	9.7	5.9	1.3	83.4	96.5	73.7	178.8	920.1
2018	124.5	163.4	313.1	41.2	25.8	0.0	11.7	52.3	31.8	55.8	111.7	125.0	1,056.3
2019	98.2	130.6	124.7	134.8	26.8	0.0	0.4	8.1	7.4	10.2	121.2	–	–
Overall Average	164.6	132.0	114.2	73.1	33.5	22.6	8.9	38.2	35.4	105.8	134.7	139.6	1,002.6
1991-2009 Average	160.6	130.8	110.6	67.6	39.5	24.6	5.6	47.2	38.0	128.0	149.2	130.8	1,032.5
2010-2019 Average	171.8	134.1	120.7	83.0	23.9	19.6	14.5	24.0	31.4	68.1	108.7	157.2	957.0

* Blue letters are estimates.

3) Makopela (Station No. 207)

Average Amount of Monthly Rainfall



Monthly rainfall observation data

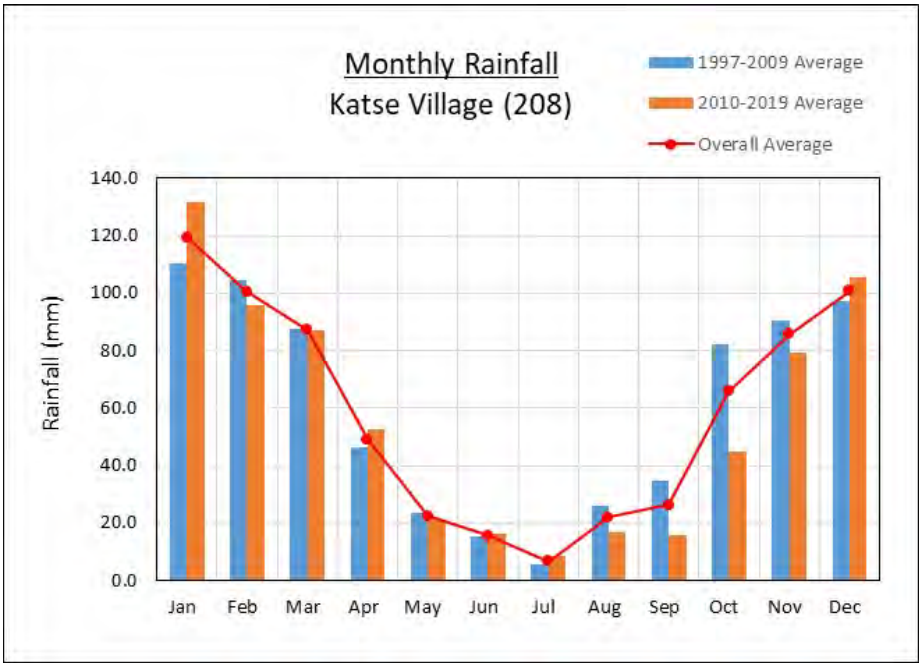
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	–	–	–	–	–	–	–	–	–	7.8	13.3	85.8	–
1992	31.8	45.5	47.9	19.0	–	–	–	–	–	–	–	–	–
1993	–	–	–	–	16.0	4.9	0.0	31.2	14.2	177.6	87.4	163.3	–
1994	127.0	110.3	93.0	98.0	1.1	4.1	10.0	7.6	0.0	35.1	19.3	74.5	580.0
1995	156.5	68.0	60.2	52.3	8.7	4.2	0.0	5.9	15.0	103.6	121.8	147.0	743.2
1996	167.7	127.2	77.4	43.9	32.5	1.5	62.2	46.3	13.0	186.9	173.2	95.5	1,027.3
1997	169.5	–	212.4	147.6	71.5	30.5	32.5	28.4	20.5	47.6	97.2	63.9	–
1998	123.2	145.7	145.6	26.2	12.8	0.0	23.2	0.7	23.6	84.1	186.7	67.9	839.7
1999	150.0	84.7	46.5	18.5	38.0	0.0	7.0	13.5	10.5	89.2	32.0	141.1	631.0
2000	93.3	85.9	93.0	44.8	39.0	16.0	8.5	0.0	75.8	106.0	124.0	120.8	807.1
2001	138.8	101.1	72.1	88.7	14.3	5.8	17.1	92.0	55.5	96.2	97.7	120.1	899.4
2002	183.7	30.8	69.1	63.4	75.3	31.5	11.0	129.4	53.6	49.6	31.2	111.8	840.4
2003	78.7	65.8	117.3	45.6	13.3	0.0	0.0	43.8	27.8	19.2	51.5	84.1	547.1
2004	107.1	104.4	108.5	27.3	0.7	22.0	3.8	38.7	74.2	41.4	100.5	115.2	743.8
2005	127.0	92.0	105.0	72.1	20.4	2.7	0.0	35.5	20.3	141.7	162.4	18.7	797.8
2006	194.6	154.8	98.8	44.8	20.0	1.8	0.3	75.9	11.2	105.1	121.5	130.8	959.6
2007	92.6	31.1	32.0	41.1	2.5	22.0	0.5	3.7	23.3	191.6	94.8	97.0	632.2
2008	89.7	63.9	102.8	38.2	33.7	62.0	0.0	4.2	27.2	22.2	128.5	150.9	723.3
2009	157.5	154.3	51.7	17.7	36.0	76.9	0.0	22.0	3.8	75.4	97.2	54.1	746.6
2010	212.1	96.3	90.5	66.2	10.2	0.0	0.0	0.0	–	59.0	189.2	206.3	–
2011	195.0	70.5	75.5	82.9	62.3	34.2	27.5	17.0	8.5	53.2	40.0	123.5	790.1
2012	131.4	140.7	66.2	34.3	2.4	60.3	12.5	33.9	68.0	67.2	49.4	87.1	753.4
2013	145.2	92.7	70.4	82.6	12.5	0.0	0.0	16.9	7.1	57.8	50.9	127.4	663.5
2014	95.0	92.0	120.4	31.8	0.0	0.0	0.0	21.9	4.2	36.4	173.7	116.3	691.7
2015	94.1	57.4	141.8	24.7	4.7	23.5	28.4	13.0	23.4	40.1	42.4	22.5	516.0
2016	83.8	117.2	70.9	55.2	27.6	4.9	34.5	29.2	40.3	45.1	85.5	97.0	691.2
2017	95.5	143.6	45.3	30.8	36.4	8.6	0.0	0.0	8.8	52.1	53.3	122.8	597.2
2018	98.7	75.8	218.2	30.5	14.6	0.0	10.4	54.2	6.0	42.0	81.5	63.0	694.9
2019	24.4	162.5	93.4	95.9	10.8	0.0	0.0	0.4	6.5	0.0	35.2	–	–
Overall Average	124.6	96.7	93.6	52.7	22.9	15.5	10.7	28.3	24.7	72.6	90.8	104.0	737.1
1991-2009 Average	128.7	91.6	90.2	52.3	25.6	16.8	10.4	34.0	27.6	87.8	96.7	102.4	764.1
2010-2019 Average	117.5	104.9	99.3	53.5	18.2	13.2	11.3	18.7	19.2	45.3	80.1	107.3	688.5

* Blue letters are estimates.

4) Katse Village (Station No. 208)

Average Amount of Monthly Rainfall



Monthly rainfall observation data

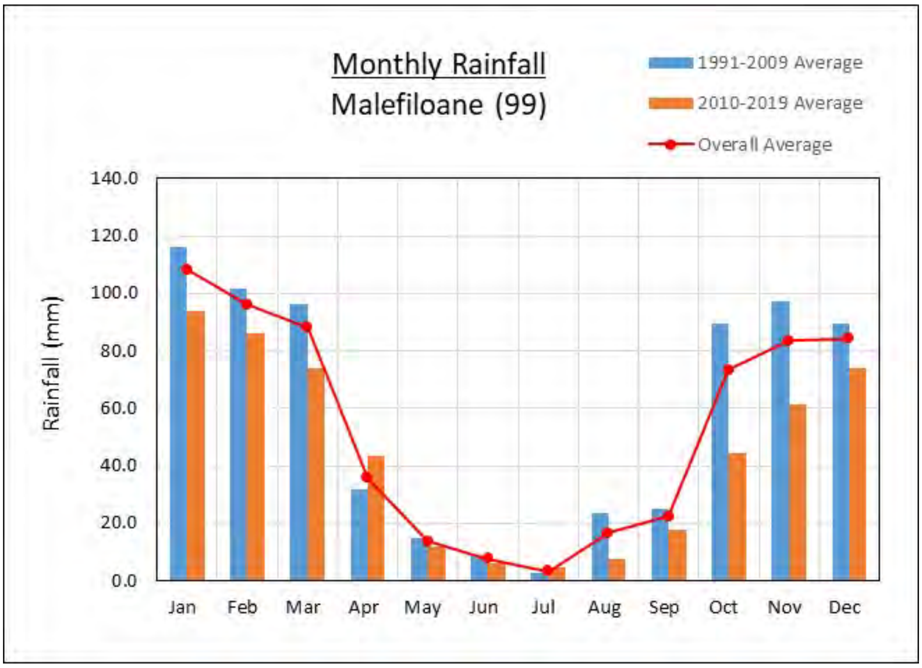
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	–	–	–	–	–	–	–	–	–	–	–	–	–
1992	–	–	–	–	–	–	–	–	–	–	–	–	–
1993	–	–	–	–	–	–	–	–	–	–	–	–	–
1994	–	–	–	–	–	–	–	–	–	–	–	–	–
1995	–	–	–	–	–	–	–	–	–	–	–	–	–
1996	–	–	–	–	–	–	–	–	–	–	–	–	–
1997	–	–	–	–	–	–	–	2.5	0.3	93.5	109.0	79.0	–
1998	124.0	–	156.0	17.5	15.5	1.4	29.0	5.0	19.0	102.0	217.0	72.0	–
1999	140.5	91.0	79.0	0.0	0.0	6.5	5.0	14.0	13.0	65.5	19.5	156.0	590.0
2000	106.0	139.0	104.0	38.0	52.0	24.0	3.0	0.0	57.2	84.5	108.0	126.0	841.7
2001	108.0	180.0	57.0	65.5	29.5	4.0	13.0	–	41.5	113.1	126.6	124.4	–
2002	137.7	30.8	60.6	51.7	67.4	26.2	9.3	120.1	55.0	53.5	46.4	115.2	773.9
2003	91.2	74.8	117.3	43.1	10.8	0.4	0.0	26.7	28.0	15.9	61.3	34.3	503.8
2004	79.0	88.3	115.0	22.1	0.3	14.0	3.5	31.7	87.4	52.5	52.9	106.6	653.3
2005	–	67.3	123.6	35.3	16.9	–	0.0	46.5	–	114.6	105.1	21.3	–
2006	174.4	160.8	101.8	51.7	16.0	0.0	0.0	56.5	18.0	106.1	72.0	132.0	889.3
2007	61.7	40.7	44.0	43.1	0.1	4.5	0.0	0.0	33.6	138.3	61.4	59.9	487.3
2008	74.3	52.0	84.9	35.8	26.2	38.7	0.0	6.0	14.5	17.0	177.0	159.0	685.4
2009	119.0	227.0	5.0	152.0	46.0	49.0	2.0	0.0	47.0	113.0	22.0	81.0	863.0
2010	166.0	74.0	20.0	27.0	6.0	43.0	0.0	0.0	0.0	77.1	174.0	250.0	837.1
2011	–	56.0	106.4	92.5	78.0	–	17.0	14.6	5.8	32.0	62.6	48.0	–
2012	116.5	121.6	31.1	29.7	3.0	64.8	19.6	16.2	58.4	33.7	38.2	99.5	632.3
2013	122.1	26.3	76.2	54.3	8.5	0.0	0.0	11.5	5.5	56.7	51.9	123.9	536.9
2014	195.8	196.0	66.7	29.5	0.4	0.9	0.0	36.1	3.9	50.6	170.0	88.7	838.6
2015	149.3	50.9	135.8	19.6	6.0	19.2	32.0	–	–	32.6	39.8	19.1	–
2016	–	–	31.6	102.1	–	–	–	20.3	21.3	47.1	87.7	122.4	–
2017	150.7	158.8	38.3	35.8	54.0	3.8	0.0	0.1	8.8	87.2	54.4	94.0	685.9
2018	94.5	100.3	244.3	32.7	20.4	0.0	9.2	49.9	32.1	28.4	81.6	104.1	797.5
2019	57.2	77.0	119.2	103.1	13.6	0.0	0.0	1.7	5.1	1.2	32.8	–	–
Overall Average	119.4	100.6	87.2	49.2	22.4	15.8	6.8	21.9	26.4	65.9	85.7	100.7	702.0
1997-2009 Average	110.5	104.7	87.4	46.3	23.4	15.3	5.4	25.8	34.5	82.3	90.6	97.4	723.6
2010-2019 Average	131.5	95.7	87.0	52.6	21.1	16.5	8.6	16.7	15.7	44.7	79.3	105.5	674.9

(4) Monthly Rainfall in Polihali area

1) Malefiloane (Station No. 99)

Average Amount of Monthly Rainfall



Monthly rainfall observation data

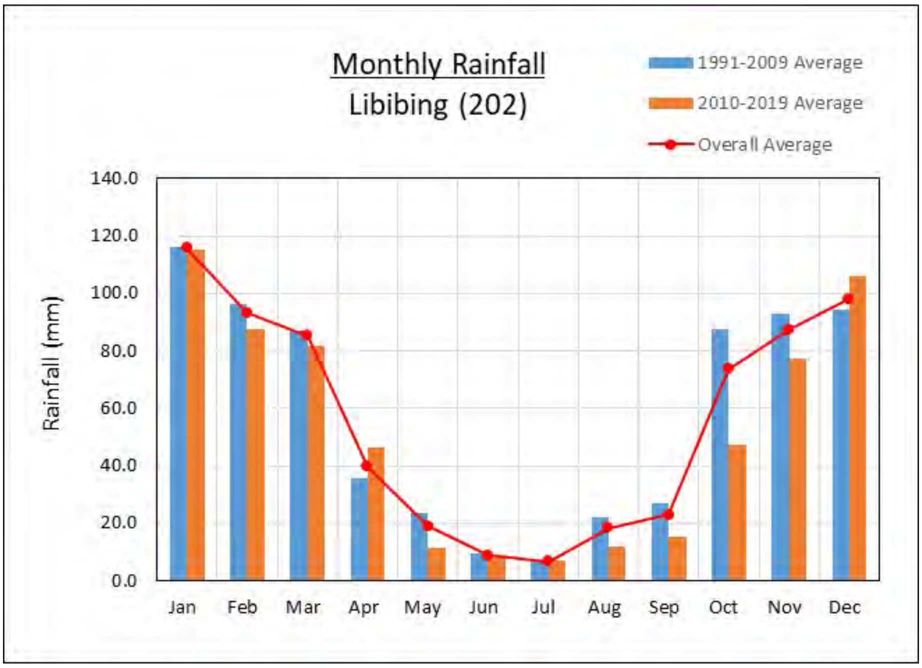
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	123.1	108.1	–	3.2	0.0	1.5	0.5	–	65.2	119.2	51.5	130.3	–
1992	96.5	59.5	79.1	40.0	0.0	0.0	0.0	32.3	12.3	68.7	104.2	32.8	525.4
1993	99.2	91.9	50.8	45.1	9.3	5.1	0.0	18.9	21.4	140.9	131.6	192.1	806.3
1994	139.6	86.6	145.7	74.2	0.0	0.0	0.0	–	4.5	72.0	–	45.2	–
1995	114.9	64.7	94.0	41.5	13.1	–	–	–	–	111.0	–	81.1	–
1996	–	121.7	100.9	53.5	113.0	0.0	–	–	95.0	–	82.3	–	–
1997	98.8	77.7	148.9	20.8	8.0	–	2.2	13.0	32.5	51.9	112.9	95.8	–
1998	121.1	156.8	125.5	19.0	9.6	0.0	–	–	1.5	102.3	106.5	64.6	–
1999	94.9	86.4	66.6	2.5	22.4	0.0	4.2	11.5	0.0	58.5	–	112.3	–
2000	161.6	100.8	133.5	41.9	10.2	0.0	1.5	0.0	40.5	74.4	91.9	86.5	742.8
2001	154.9	81.9	65.9	32.9	3.0	13.0	0.8	49.0	23.0	95.7	94.1	81.9	696.1
2002	155.2	32.5	103.8	39.9	55.7	22.5	18.0	83.0	41.2	75.7	48.7	101.1	777.3
2003	88.2	152.1	66.4	31.8	0.1	0.0	0.0	19.0	22.7	13.9	110.1	28.0	532.3
2004	92.2	127.5	79.8	21.2	2.4	7.0	9.0	1.9	38.5	83.9	121.0	184.7	769.1
2005	142.2	88.2	70.8	28.8	12.0	1.3	0.0	28.5	19.0	144.5	125.8	31.8	692.9
2006	171.6	145.5	147.3	47.4	17.0	0.0	0.0	39.8	7.5	137.4	186.7	99.7	999.9
2007	27.3	65.3	96.6	11.7	5.5	26.0	0.0	1.0	22.5	173.9	58.2	80.8	568.8
2008	112.3	149.0	84.9	34.8	0.0	32.5	1.5	8.2	0.0	4.5	69.6	119.8	617.1
2009	100.8	133.9	72.8	16.0	2.5	37.6	–	–	2.5	83.7	63.8	38.7	–
2010	176.2	76.8	73.2	49.0	2.0	18.0	0.0	0.0	0.0	74.8	177.3	9.6	656.9
2011	98.2	138.9	132.9	85.8	19.4	7.0	0.0	7.5	8.5	39.9	34.8	93.7	666.6
2012	108.7	82.0	80.9	17.8	1.0	17.3	3.0	11.4	69.7	82.1	39.6	121.9	635.4
2013	105.5	86.4	49.7	56.2	14.4	0.0	0.0	0.8	1.5	25.1	34.0	73.7	447.3
2014	91.5	83.4	53.0	16.5	1.1	0.3	0.0	21.8	5.7	79.7	79.6	82.1	514.7
2015	35.5	55.6	80.2	46.5	4.5	13.7	14.9	7.5	17.9	36.0	4.4	51.7	368.4
2016	79.4	98.2	57.7	41.3	20.4	1.1	25.1	18.3	19.7	37.6	73.3	82.6	554.7
2017	75.0	103.0	31.2	26.2	33.8	3.8	0.0	2.3	16.0	35.9	59.2	79.4	465.8
2018	91.9	54.2	121.5	26.3	15.8	0.0	5.1	2.8	26.0	30.7	61.7	73.1	509.1
2019	77.5	82.9	59.7	70.7	4.9	0.0	0.0	3.9	11.9	0.0	51.7	–	–
Overall Average	108.4	96.3	88.3	35.9	13.8	7.7	3.4	16.6	22.4	73.4	83.6	84.3	634.1
1991-2009 Average	116.4	101.6	96.3	31.9	14.9	8.6	2.5	23.5	25.0	89.6	97.4	89.3	697.0
2010-2019 Average	93.9	86.1	74.0	43.6	11.7	6.1	4.8	7.6	17.7	44.2	61.6	74.2	525.5

* Blue letters are estimates.

2) Libibing (Station No. 202)

Average Amount of Monthly Rainfall



Monthly rainfall observation data

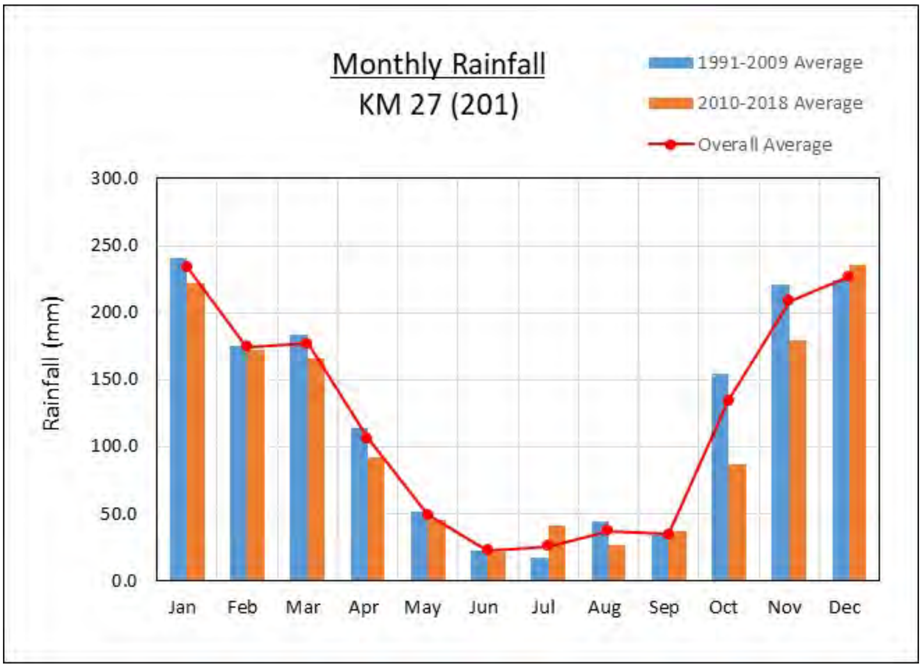
(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	–	–	–	–	–	0.0	0.0	0.0	60.4	108.0	33.6	75.0	–
1992	52.3	53.9	36.2	24.5	0.0	0.0	0.0	30.0	7.5	62.4	108.4	62.9	438.1
1993	68.4	76.5	106.1	52.5	21.0	3.5	0.0	16.0	13.0	141.5	126.5	130.7	755.7
1994	110.0	78.0	132.1	71.8	105.8	0.0	–	3.5	4.5	28.9	35.3	75.3	–
1995	141.2	54.3	57.7	25.5	14.4	1.5	8.0	0.0	15.0	118.3	100.5	121.8	658.2
1996	158.6	115.5	73.4	32.1	20.5	0.0	51.8	–	9.0	184.9	132.5	101.0	–
1997	119.4	66.9	126.2	66.5	36.0	34.5	19.5	25.0	24.2	60.4	81.8	80.9	741.3
1998	84.2	168.2	149.5	10.6	18.6	0.0	2.3	0.0	15.0	92.8	150.1	51.7	743.0
1999	91.7	84.8	52.6	44.2	34.3	2.8	2.0	14.5	8.2	56.3	59.0	126.0	576.4
2000	127.7	165.4	153.6	27.0	32.5	0.0	4.1	0.0	67.2	80.8	63.8	95.9	818.0
2001	177.1	81.6	53.0	45.1	5.8	6.5	6.5	59.6	39.2	93.0	103.0	84.3	754.7
2002	143.9	46.9	94.5	47.1	53.2	15.9	17.8	84.1	41.6	54.4	43.3	104.0	746.7
2003	83.6	83.7	72.6	22.5	10.5	0.0	0.0	17.5	25.5	16.4	96.9	44.9	474.1
2004	101.5	80.0	101.6	11.3	0.0	12.0	7.0	11.5	60.1	66.3	99.0	125.6	675.9
2005	162.7	91.2	97.8	37.8	17.6	0.4	0.0	28.7	23.5	99.4	132.8	32.1	724.0
2006	186.6	212.9	107.8	37.4	10.7	0.0	0.0	53.5	14.5	112.1	145.4	178.5	1,059.4
2007	71.8	42.0	26.1	32.4	1.0	22.6	0.0	21.9	42.0	188.8	94.0	93.8	636.4
2008	105.1	137.1	96.8	42.4	16.7	32.1	0.0	0.0	38.0	24.4	83.7	159.5	735.8
2009	106.7	91.9	31.2	14.5	23.0	45.5	0.0	29.5	4.0	74.4	73.8	48.4	542.9
2010	155.4	90.7	89.4	53.0	3.6	18.0	0.0	0.0	0.0	69.3	272.9	246.4	998.7
2011	191.7	113.3	91.0	91.4	39.9	15.2	18.5	10.5	12.4	31.5	53.3	116.1	784.8
2012	85.0	106.2	62.0	36.9	2.8	32.4	6.1	12.7	66.8	67.9	35.7	148.0	662.5
2013	137.5	60.8	82.8	72.2	9.6	0.0	0.0	5.9	3.7	63.6	58.4	173.6	668.1
2014	180.5	95.0	34.6	31.0	0.6	0.1	0.0	24.6	13.9	46.2	152.3	80.0	658.8
2015	99.0	52.7	132.2	26.6	4.0	16.1	21.6	11.6	17.8	44.8	24.1	29.9	480.4
2016	109.8	85.9	67.0	56.8	33.3	0.0	19.8	27.1	14.2	50.7	75.5	114.9	655.0
2017	113.8	168.8	56.2	32.8	4.2	0.3	0.0	2.5	5.8	68.5	54.9	37.5	545.3
2018	55.3	52.9	123.7	13.1	13.5	0.0	5.1	24.0	13.5	24.8	25.3	6.0	357.2
2019	24.6	51.3	78.3	52.1	3.0	0.0	0.0	0.6	3.0	6.1	23.0	–	–
Overall Average	115.9	93.2	85.2	39.7	19.1	8.9	6.8	18.4	22.9	73.7	87.5	98.0	669.3
1991-2009 Average	116.3	96.2	87.2	35.8	23.4	9.3	6.6	22.0	27.0	87.6	92.8	94.3	698.5
2010-2019 Average	115.3	87.8	81.7	46.6	11.5	8.2	7.1	12.0	15.1	47.3	77.5	105.8	615.9

(5) Monthly Rainfall in Muela area

1) KM 27 (Station No. 201)

Average Amount of Monthly Rainfall



Monthly rainfall observation data

(mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	–	–	–	–	–	–	–	–	–	261.3	95.2	217.1	–
1992	61.8	79.7	81.3	100.6	2.3	0.4	0.3	–	13.0	197.5	234.3	110.3	–
1993	120.3	194.9	100.0	204.4	32.3	31.6	0.0	35.7	13.4	303.1	240.0	184.5	1,460.2
1994	204.7	243.1	137.2	111.5	14.3	5.7	9.0	13.4	5.8	46.2	115.1	106.3	1,012.3
1995	248.3	105.5	187.8	58.9	46.2	11.5	0.0	5.5	17.1	206.1	243.8	310.4	1,441.1
1996	295.0	–	–	–	–	–	–	–	–	202.2	316.5	294.9	–
1997	266.7	110.4	416.4	181.2	92.2	37.5	27.1	40.6	53.7	105.6	194.9	138.3	1,664.6
1998	285.6	200.6	261.0	24.3	56.9	3.2	10.0	0.5	56.4	104.2	385.2	171.4	1,559.3
1999	220.0	93.1	122.0	79.2	66.2	5.5	–	11.0	2.3	115.9	73.5	488.5	–
2000	219.6	215.8	262.7	106.1	83.4	39.4	8.4	0.0	105.8	186.6	197.6	87.3	1,512.7
2001	124.9	159.0	203.1	298.7	61.0	7.1	20.1	110.5	28.8	211.0	314.8	373.6	1,912.6
2002	356.2	122.5	126.5	117.4	138.9	52.4	3.3	235.6	55.5	24.6	169.3	269.9	1,672.1
2003	196.5	194.7	175.3	83.4	15.0	0.2	0.0	41.2	41.5	72.1	141.6	218.1	1,179.6
2004	298.5	159.7	232.1	55.2	1.2	59.2	15.0	35.5	81.3	104.5	92.9	282.2	1,417.3
2005	417.5	143.7	217.1	101.1	50.9	0.9	2.9	44.7	0.0	284.3	272.3	79.2	1,614.6
2006	399.1	424.7	251.6	178.1	37.9	24.0	0.0	–	12.3	70.2	476.1	222.8	–
2007	114.7	84.4	59.5	85.8	28.5	13.1	56.3	6.5	67.7	186.2	220.8	252.5	1,176.0
2008	277.1	85.5	185.7	91.8	62.3	21.9	59.5	19.1	1.5	41.2	266.8	313.1	1,425.5
2009	223.5	366.0	95.8	64.4	86.0	75.9	70.4	59.3	16.7	209.4	139.9	128.9	1,536.2
2010	353.2	147.5	186.0	231.9	52.9	46.5	0.0	0.0	0.0	103.4	313.6	414.9	1,849.9
2011	420.3	134.6	249.5	167.1	90.6	8.8	23.4	66.5	16.5	77.9	88.2	263.3	1,606.7
2012	119.4	374.3	79.1	68.8	7.8	40.2	178.7	25.9	86.8	79.1	135.2	228.6	1,423.9
2013	148.3	150.0	63.5	48.4	25.5	6.9	0.0	15.4	11.3	109.0	116.6	290.5	985.4
2014	264.9	259.7	80.4	21.5	15.5	2.7	0.0	33.9	8.1	69.7	442.8	165.2	1,364.4
2015	155.4	36.4	152.0	47.3	15.9	54.5	44.2	52.6	9.6	0.0	46.5	69.4	683.8
2016	108.2	88.9	265.6	113.5	54.9	18.2	76.0	39.2	108.4	142.8	199.1	159.4	1,374.2
2017	298.3	224.8	63.1	67.7	53.2	0.0	21.1	2.6	36.0	115.1	96.6	288.5	1,267.0
2018	125.8	130.2	353.6	60.2	87.5	18.0	25.0	2.0	57.8	–	–	–	–
2019	–	–	–	–	–	–	–	–	–	–	–	–	–
Overall Average	234.2	174.2	177.2	106.5	49.2	22.5	26.0	37.4	34.9	134.4	208.5	227.0	1,432.0
1991-2009 Average	240.6	175.5	183.2	114.2	51.5	22.9	17.6	43.9	33.7	154.3	220.6	223.6	1,481.6
2010-2018 Average	221.5	171.8	165.9	91.8	44.9	21.8	40.9	26.5	37.2	87.1	179.8	235.0	1,324.2

Appendix-8 POWER SYSTEM ANALYSIS DATA

Appendix-8 Power system analysis data

Name	u, Magnitude Voltage (P.U)i	u, Magnitude Volatage(P.U)j	Loading %	Total Apparent Power Terminal i in MVA
Mabote-Maseru Central	1.04	1.02	74.92	18.72
Mabote - Highway	1.04	1.02	71.90	17.96
Mabote - LEC Border 2	1.04	1.01	62.36	15.58
Mabote - Tsosane	1.04	1.03	52.51	13.12
Highway - Pioneer	1.02	1.00	47.92	11.72
Mazenod Tx - Tikoe	1.03	1.00	42.52	10.54
Mazenod Dx - Tikoe	1.03	1.00	42.09	10.43
Maseru Central-LEC Border	1.02	1.01	37.33	9.10
Tsosane - Botshabelo	1.03	1.02	37.05	9.17
LEC HQ - LEC Border 1	1.01	1.01	32.12	7.76
Eskom Infeed - Mabote 1	1.05	1.05	31.46	39.87
Eskom Infeed - Mabote 2	1.05	1.05	31.46	39.87
Tikoe - Thetsane 1	1.00	1.00	30.02	7.24
Tikoe - Thetsane 2	1.00	1.00	30.02	7.24
LEC HQ - LEC Border 2	1.01	1.01	27.85	6.74
LEC Border - Pioneer	1.01	1.00	27.72	6.71
Muela Hydro - Maputsoe 1	1.04	1.04	23.68	37.22
Muela Hydro - Maputsoe 2	1.04	1.04	23.68	37.22
Maoutsoe - Hlotse	1.04	1.04	22.40	4.92
Mazenod Tx - Mazenod Dx	1.03	1.03	19.68	13.94
Mazenod Tx - Roma	1.03	1.02	19.60	4.16
Khukhune - Mahlasela	1.00	0.98	18.82	10.26
Botshabelo - Mazenod Tx	1.02	1.03	18.26	4.48
Mahlasela - Letseng	0.98	0.96	18.18	9.65
Muela to Khukhune 33kv	1.04	1.04	17.01	3.62
Khukhune - Bothabothe	1.03	1.04	16.03	3.38
Letloepe-Mpiti	1.04	1.03	15.36	1.10
Maputsoe - Mabote 1	1.04	1.05	14.69	23.14
Maputsoe - Mabote 2	1.04	1.05	14.69	23.14
Mabote - Mazenod Tx	1.05	1.04	13.83	21.86
Mabote-Mazenod 2	1.05	1.04	13.83	21.86
Mabote - ST Agnes	1.04	1.03	13.13	3.28
Thetsane - Pioneer 1	1.00	1.00	12.46	2.99
Thetsane - Pioneer 2	1.00	1.00	12.46	2.99
Botshabelo - Highway	1.02	1.02	12.36	3.03
Maputsoe - Pitseng	1.04	1.04	9.73	11.15
Pitseng - Ha Lejone	1.04	1.04	8.34	9.55
Mantsonyane from gen to town	1.00	1.00	8.01	1.65
Mazenod Tx - Ramarothole	1.04	1.04	7.58	11.95
Mantsonyane to Thaba Tseka	0.98	1.00	6.74	1.40
Letseng-Tlokoeng	0.98	0.97	6.61	1.33
Ramarothole - Litsoeneng	1.04	1.04	5.64	6.46
Lejone-Liqhobong	1.04	1.04	5.59	6.24
Roma-Molimo_Nthuse	1.02	1.01	5.24	1.10
Litsoeneng-Quthing	1.03	1.04	5.20	1.13
Litsoeneng-Quthing	1.04	1.03	5.20	1.14
Ramarothole-Mafeteng 1	1.04	1.04	5.13	1.13
Ramarothole-Mafeteng 2	1.04	1.04	5.13	1.13
Tlokoeng-Mokhotlong	0.97	0.97	5.03	1.00
M-Nthuse to Mantsonyane 33kv	1.01	1.00	5.01	1.08
Litsoeneng-Maphohloane	1.04	1.04	4.75	1.02
Litsoeneng - Mohale's Hoek	1.04	1.04	4.58	1.01
Litsoeneng-Mohale'sHoek	1.04	1.04	4.58	1.01
Litsoeneng-Maphohloane	1.04	1.04	3.80	0.81
Mphaki-Sekake	1.02	1.01	3.58	0.67
Mazenod-Metolong	1.03	1.03	3.41	0.72
Mpiti-Rankakala	1.00	0.99	3.03	0.41

Morija–Mafeteng	1.03	1.04	2.31	0.49
Maphohloane–Mohale's Hoek	1.04	1.04	2.25	0.49
Maphohloane–Mohale'sHoek	1.04	1.04	2.25	0.50
Mafeteng–Maphohloane	1.04	1.04	2.17	0.45
Mazenod Tx – Mohale Dam	1.04	1.05	2.08	3.28
Quthing–Mphaki	1.03	1.02	2.04	0.38
Mafeteng–Maphohloane	1.04	1.04	1.83	0.39
lejone–KatseIntake	1.04	1.04	1.57	0.97
KatseIntake–Matsoku	1.04	1.04	1.53	0.95
Mazenod DX–Morija	1.03	1.03	1.52	0.32
Mazenod–Morija	1.03	1.03	1.52	0.27
Matsoku–KatseDam	1.04	1.04	1.10	0.68
Matsoku–Polihali 66kV	1.04	1.04	0.97	0.60
Khukhune – Hololo	1.04	1.04	0.89	0.19
Pitseng – Hlotse Adit	1.04	1.04	0.33	0.20
Khukhune – Ngoajane 33kv	1.04	1.04	0.13	0.02
KatseDam–MohaleOutlet	1.04	1.04	0.01	0.01

Name	u, Magnitude HV-Side in p.u.	u, Magnitude LV-Side in p.u.
`Muela Trf1	1.04	1.02
`Muela Trf2	1.04	1.02
`Muela Trf3	1.04	1.02
BothaBothe TRF1	1.03	1.02
Botha-Bothe TRF2	1.03	1.02
Botha-Bothe TRF2 5MVA	0.00	0.00
Botsabelo Tr1	1.02	1.02
Botsabelo Tr2	1.02	1.02
Highway Tr1	1.02	1.03
Highway Tr2	1.02	1.03
Hloste Adit TRF 2	1.04	1.04
Hlotse Adit TRF1	1.04	1.04
Hlotse trf1 33/11	1.04	1.04
Hlotse trf2 33/11	1.04	1.04
Hololo TRF	1.04	1.04
Katse intake	1.04	1.04
KatseDam 66/11 trf	1.04	1.04
Khukhune1 trf 20MVA	1.00	1.00
Khukhune2 trf 20MVA	1.00	1.00
LEC Border Tr1	1.01	1.00
LEC Border Tr2	1.01	1.00
LEC HQ Tr1	1.01	1.03
LEC HQ Tr2	1.01	1.03
Letloepe TRF1	1.05	1.03
Letloepe TRF2	1.05	1.03
Letseng Trf1 20MVA	0.96	0.98
Letseng Trf2 20MVA	0.96	0.98
Liqhobong TRF 2	1.04	1.04
Liqhobong TRF1	1.04	1.04
Lits`oeneng Tr1 132/33	1.04	1.04
Lits`oeneng Tr2 132/33	1.04	1.04
Mabote Tr1 132/33	1.05	1.04
Mabote Tr2 132/33	1.05	1.04
Mabote Tr4 33/11	1.04	1.03
Mabote TRF 33/11	1.04	1.03
Mabote TRF5 132/33	1.05	1.04
Mafeteng Tr1	1.04	1.03
Mafeteng Tr2	1.04	1.03
Mahlasela TRF	0.98	0.98
Mantsonyane Gen	1.00	1.00
Maputsoe Tr1 132/33	1.04	1.04
Maputsoe Tr2 132/33	1.04	1.04
Maputsoe Tr3 33/11	1.04	1.03
Maputsoe Tr4 33/11	1.04	1.03
Maseru Central trf1	1.02	1.01
Maseru Central trf2 10MVA	1.02	1.01
Matsoku 66/11 trf	1.04	1.04
Mazenod Dx Tr	1.03	1.02
Mazenod Tx Tr2	1.04	1.03
Mazenod Tx Tr2	0.00	0.00
Mazenod Tx Tr3	1.04	1.03
Mohale Dam Tr1	1.03	1.03
Mohale Dam Tr1	1.05	1.05
MohaleOutlet 66/11 trf	1.04	1.04
Mohaleshoek TRF1 33/11	1.04	1.04
Mohaleshoek TRF2 33/11	1.04	1.04
Molimo Nthuse 33/11kv TRF	1.01	1.05

Morija TRF 33/11	1.03	1.03
Mpiti TRF2 33/11 TRF2	1.00	1.04
Mpiti TRF1 11/33	1.00	1.04
Muela TRF1 33/11	1.04	1.04
Muela TRF2 132/33	1.04	1.04
Muela TRF2 33/11	1.04	1.04
Ngoajane TRF	1.04	1.04
Pioneer Tr1	1.00	1.01
Pioneer Tr2	1.00	1.01
Quthing trf	1.03	1.16
Ramarothole Tr1	1.04	1.04
Roma Tr1	1.02	1.01
Roma Tr2	1.02	1.01
ST Agnes Tr1	1.03	1.02
St Agnes TR2	1.03	1.02
Thabateska TRF 33/11	0.98	0.98
Thetsane Tr1	1.00	0.99
Thetsane Tr2	1.00	0.99
Tikoe Tr1	0.00	0.00
Tikoe Tr2	1.00	0.99
Tsosane Tr1	1.03	1.03
Tsosane Tr2	1.03	1.03

Name	HV-Side in p.u.	LV-Side in p.u.	Loading %
`Muela Trf1	1.05	1.02	60.39
`Muela Trf2	1.05	1.02	63.48
`Muela Trf3	1.05	1.02	63.48
BothaBothe TRF1	1.03	1.03	37.78
Botha-Bothe TRF2	1.03	1.03	37.78
Botsabelo Tr1	1.02	1.02	60.40
Botsabelo Tr2	1.02	1.02	54.44
Highway Tr1	1.02	1.03	62.59
Highway Tr2	1.02	1.03	54.39
Hloste Adit TRF 2	1.04	1.04	1.71
Hlotse Adit TRF1	1.04	1.04	1.71
Hlotse trf1 33/11	1.04	1.04	6.05
Hlotse trf2 33/11	1.04	1.04	86.73
Hololo TRF	1.04	1.04	3.51
Katse intake	1.03	1.03	4.21
KatseDam 66/11 trf	1.03	1.02	5.57
Khukhune1 trf 20MVA	1.05	1.05	0.00
Khukhune2 trf 20MVA	1.05	1.05	0.00
LEC Border Tr1	1.00	0.99	21.84
LEC Border Tr2	1.00	0.99	21.84
LEC HQ Tr1	1.00	0.97	86.09
LEC HQ Tr2	1.00	0.97	86.09
Letloepe TRF1	1.05	1.03	53.01
Letloepe TRF2	1.05	1.03	53.01
Letseng Trf1 20MVA	0.98	0.98	36.83
Letseng Trf2 20MVA	0.98	0.98	36.83
Liqhobong TRF 2	1.03	1.03	13.94
Liqhobong TRF1	1.03	1.03	13.94
Lits`oeneng Tr1 132/33	1.04	1.04	14.67
Lits`oeneng Tr2 132/33	1.04	1.04	14.43
Mabote Tr1 132/33	1.05	1.05	36.01
Mabote Tr2 132/33	1.05	1.05	33.91
Mabote Tr4 33/11	1.05	1.05	64.11
Mabote TRF 33/11	1.05	1.05	59.11
Mabote TRF5 132/33	1.05	1.05	33.91
Mafeteng Tr1	1.03	1.03	46.63
Mafeteng Tr2	1.03	1.03	46.63
Mahlasela TRF	1.02	1.02	10.87
Mantsonyane Gen	1.00	1.00	0.33
Maputsoe Tr1 132/33	1.05	1.04	44.29
Maputsoe Tr2 132/33	1.05	1.04	40.05
Maputsoe Tr3 33/11	1.04	1.09	61.16
Maputsoe Tr4 33/11	1.04	1.09	61.16
Maseru Central trf1	1.01	1.01	42.13
Maseru Central trf2 10MVA	1.01	1.01	42.13
Matsoku 66/11 trf	1.03	1.03	0.29
Mazenod Dx Tr	1.03	1.02	59.90
Mazenod Tx Tr1			
Mazenod Tx Tr1	1.04	1.03	32.77
Mazenod Tx Tr2	0.00	0.00	0.00
Mazenod Tx Tr2	1.04	1.03	32.77
Mazenod Tx Tr3	1.04	1.03	32.77
Mohale Dam Tr1	1.05	1.05	0.01
Mohale Dam Tr1	1.03	1.03	8.04

Mohale Dam Tr2	1.05	1.05	0.01
Mohale Dam Tr2	1.03	1.03	8.04
MohaleOutlet 66/11 trf	1.03	1.03	0.00
Mohaleshoek TRF1 33/11	1.03	1.03	16.31
Mohaleshoek TRF2 33/11	1.03	1.03	16.31
Molimo Nthuse 33/11kv TRF	1.01	1.05	0.00
Morija TRF 33/11	1.03	1.03	62.70
Mpiti TRF2 33/11 TRF2	1.00	1.05	24.15
Mpiti TRF1 11/33	1.00	1.05	24.15
Muela TRF1 33/11	1.05	1.05	0.12
Muela TRF2 132/33	1.05	1.05	19.86
Muela TRF2 33/11	1.05	1.05	0.12
Ngoajane TRF	1.04	1.04	0.37
Pioneer Tr1	0.99	1.04	94.30
Pioneer Tr2	0.99	1.04	91.73
Quthing trf	1.03	1.16	33.28
Ramarothole Tr1	1.04	1.04	22.73
Roma Tr1	1.02	1.01	37.71
Roma Tr2	1.02	1.01	37.71
ST Agnes Tr1	1.03	1.02	33.97
St Agnes TR2	1.03	1.02	33.97
Thabateska TRF 33/11	0.98	0.98	57.64
Thetsane Tr1	0.99	0.98	55.13
Thetsane Tr2	0.99	0.98	55.13
Tikoe Tr1			
Tikoe Tr2	1.00	0.99	37.73
Tsosane Tr1	1.03	1.03	39.83
Tsosane Tr2	1.03	1.03	39.83
	HV-Side in p.u.	LV-Side in p.u.	%

Appendix-9　IFR PRESENTATION TO MANAGEMENT

IFR PRESENTATION TO MANAGEMENT

13th August 2019

Presenters: IFR Team

More than 30 years of successful collaboration

IFR PRESENTATION

- CONTENTS OF THE PRESENTATION
  - IFR Releases and Scheduling
    - Khojane Lepholisa
  - Automation of Daily IFR
    - Paul Lehloa
  - IFR Environmental Benefits
    - Puseletso Sebotsa

More than 30 years of successful collaboration

IFR Releases and Scheduling by Khojane Lepholisa

More than 30 years of successful collaboration

Legal Compliance: 1986 Treaty

- **Article 7 (9):** "…. shall at all times maintain rates of flow in the natural river channels immediately downstream of the Katse and Mohale dams of not less than five hundred and three hundred litres per second respectively…"

TABLE 5.2

LHWP RESERVOIR COMPENSATION FLOWS

Reservoir	Compensation Flow m^3/s
Katse	0.5
Mohale	0.3
Polihali	0.7
Taung	1.5
Mashai	1.5
Tsoelike	1.7
Ntoahae	2.0
Malatsi	0.6

More than 30 years of successful collaboration

Legal Compliance: 2003 Policy and Procedures

Associated control structure	From control structure		
	MAR (million m³/a)	Annual IFR release	Average Flow
		(as % inflow)	Cumecs (m³/second)
Katse Dam	554.8	12.1	2.1
Mohale Dam	339.0	10.3	1.1

More than 30 years of successful collaboration

Evolution of IFR Releases Scheduling

- 2004
  - Annual Schedule implemented on a monthly basis
  - Difficulty in accurately forecasting of hydrological classes
- 2006
  - Quarterly Schedule implemented on a monthly basis

	1st Quarter (Jan-Mar)		2nd Quarter (Apr-Jun)		3rd Quarter (Jul-Sep)		4th Quarter (Oct-Dec)	
	Max	Min	Max	Min	Max	Min	Max	Min
Plus 2	More than 284.0		More than 108.0		More than 81.0		More than 274.0	
Plus 1	284.0	268.0	108.0	81.0	81.0	46.0	274.0	208.0
Average	268.0	236.0	81.0	68.0	46.0	29.0	208.0	157.0
Minus 1	236.0	170.0	68.0	58.0	29.0	21.0	157.0	127.0
Minus 2	Less than 170.0		Less than 58.0		Less than 21.0		Less than 127.0	

  - Lack of Variability of flows
  - Floods releases inconsistent with natural events ("blue sky releases")
- 2016
  - Daily Schedule implemented with a one day lag (to mimic natural inflow variability)

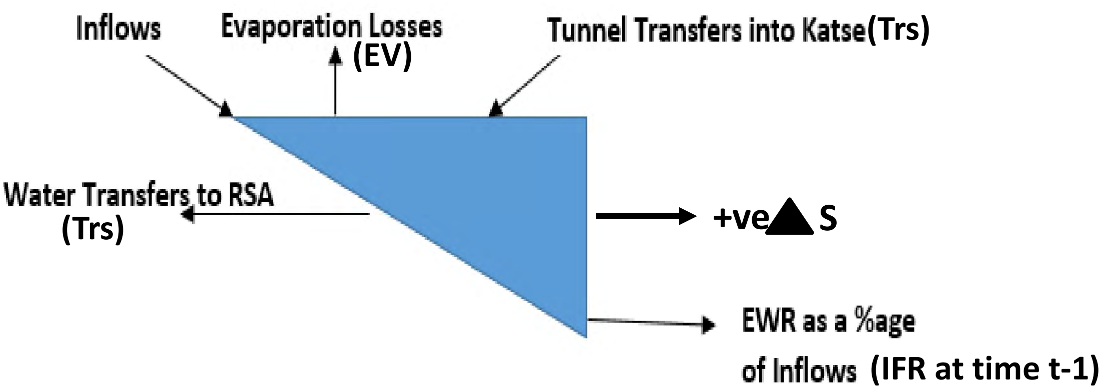
More than 30 years of successful collaboration

IFR Releases Compliance Criteria

- Release Categories
  - IFR released as %age of inflow subject to valve capacity
    - 12.1% at Katse
    - 10.3% at Mohale
- Compliance on Volume
  - 5% variance
- Compliance on Variability
  - Def: Accumulated absolute daily variances over monthly target
  - 15% variance

More than 30 years of successful collaboration

Calculation of Katse Inflows: Water Balance Approach



$$\text{Inflows} = \text{increased (S)} + IFR_{t-1} + \text{Trs (RSA)} + Ev - \text{Trs (Mohale)}$$

$$IFR_t = 12.1\% \times \text{Inflows}$$

NB: Inflow has to be determined by 8.00am of the operating day and IFR released at 9.00

Challenges in determining the correct inflow

- Dam level (Change in storage)
- IFR
- Mohale transfers
  - Problem: No measuring device and incorrect calculations during unusual events like floods
  - Solution: flow measuring device
- Evaporation
  - Problem: No direct measurement
  - Solution: Application of Phase II Ops Rule data
- Katse deliveries (Ngoajane)
  - Problem: No direct measurement and poor communication with Katse Ops
  - Solution: Direct transfer tunnel flow measurements

More than 30 years of successful collaboration

Operational Challenges

- Manual System (Spreadsheet)
  - Problem: Resistance to Change, Human Error and Communication breakdown between sites
- Operational Constraints

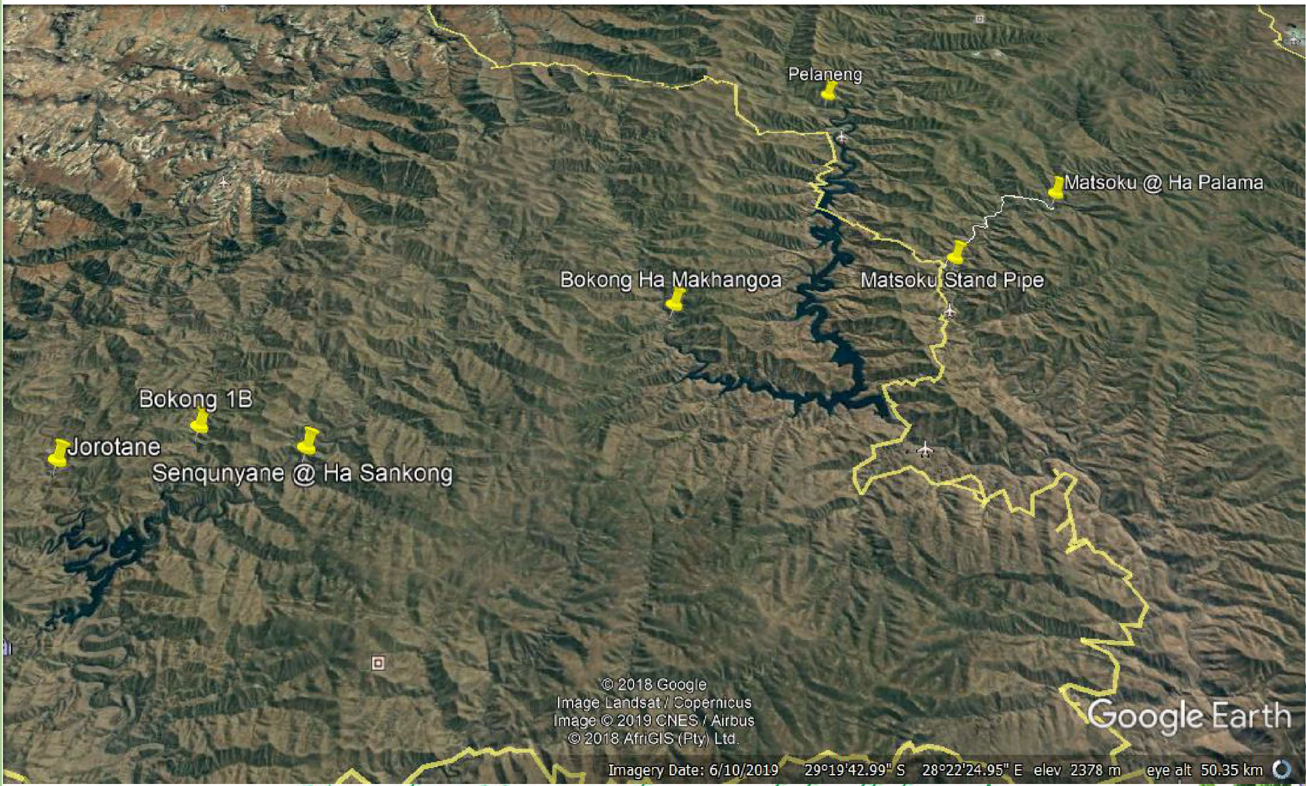
  Problem: Valve capacity limitations and Valve precision

Control structure and release mechanism	Minimum (m^3/s)	Maximum (m^3/s)
Katse Dam		
Compensation valve 2	0.2	1.5
Mini-hydro (1)		0.5
Low Level Outlet 1 (Radial Gate 1)	Approx 13	410
Low Level Outlet 2 (Radial Gate 2)	Approx 13	410

(masl)	0%	20%	30%	40%	50%	60%
2005	0.0	0.3	0.5	0.8	1.3	1.6
2010	0.0	0.5	0.9	1.2	1.6	2.0
2015	0.0	0.7	1.1	1.5	2.0	2.3

More than 30 years of successful collaboration

Calculation of Katse Inflows: Direct Measurement



More than 30 years of successful collaboration

Automation of Daily IFR by Paul Lehloa

More than 30 years of successful collaboration

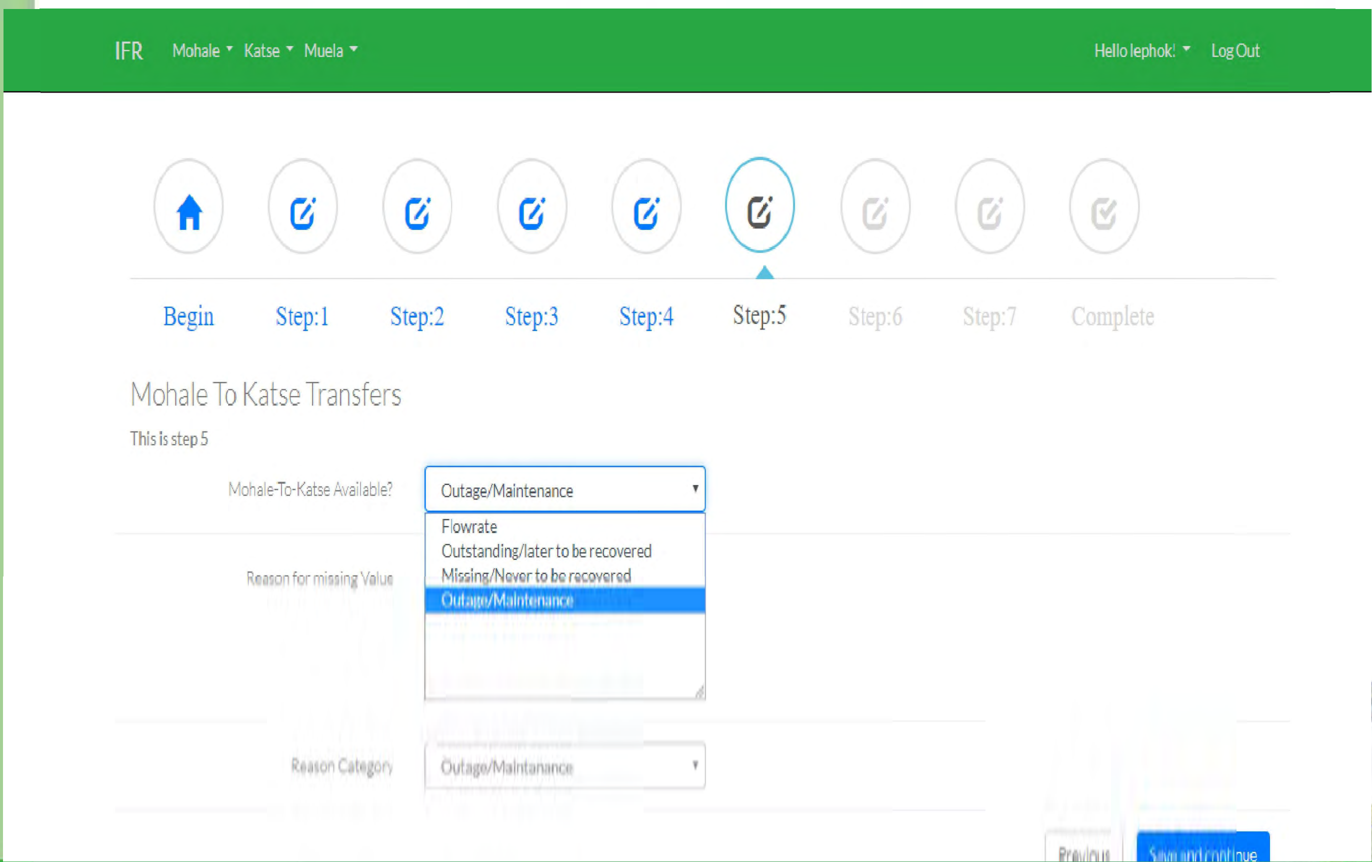
Solutions implemented to date

Problem	Solution
Incomplete data	Data Validation and Estimation
Multiple varying copies of the Spreadsheet model kept by different users	Centralised system
Lack of incident reports	Forced accountability by supervisors in case of variances for purposes of incident reporting and provision of notifications

NB: The system depends on network availability

More than 30 years of successful collaboration

Sample Screenshot



IFR Environment Benefits
by Puseletso Sebotsa

More than 30 years of successful collaboration

Environmental Benefits

- Biophysical monitoring disciplines
  - Main driver
    - Hydrology: Water level and flow variability
  - Other drivers :
    - Geomorphology: River structure – habitats
    - Water quality: insitu, chemical and biological
  - Responders in order of response time to changes in drivers
    - Macro invertebrates
    - Fish
    - Riparian vegetation

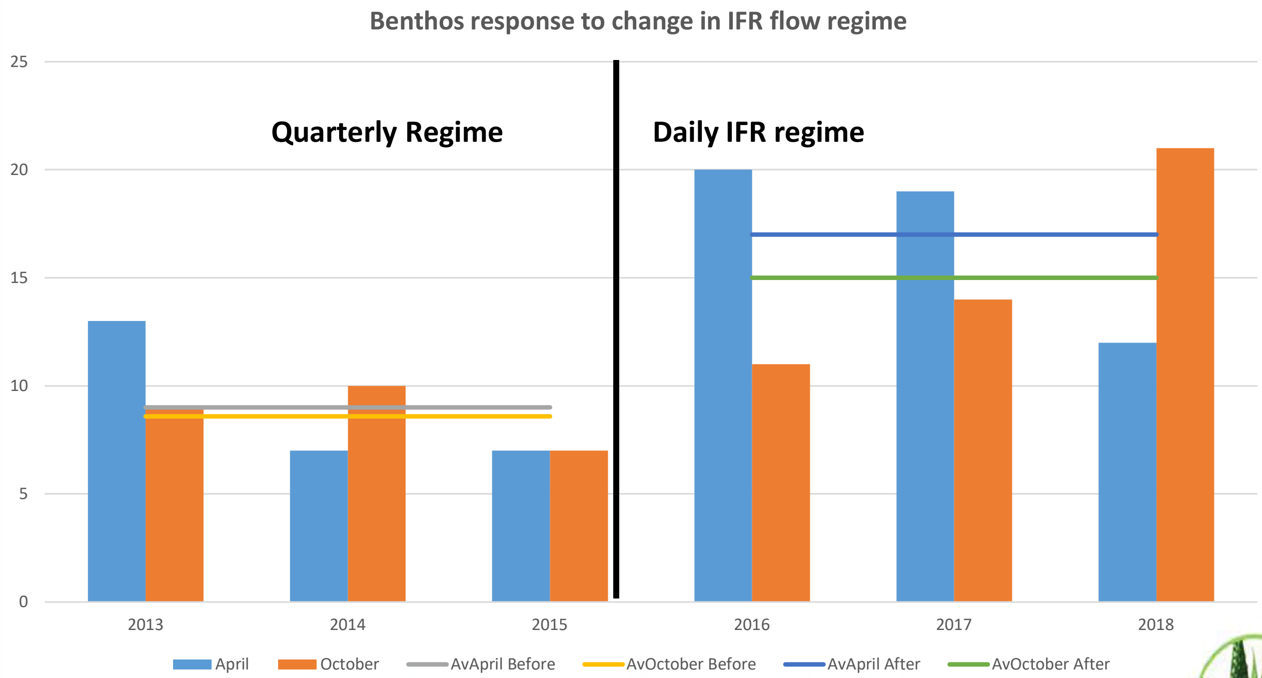
More than 30 years of successful collaboration

Macroinvertebrates

- Sedentary: they do not migrate as long as conditions are conducive
- Rapid indicators of river health
- Short life cycle
- They respond to change rapidly
- They recolonize rapidly if the conditions become conducive after pollution

More than 30 years of successful collaboration

Biophysical Benefits of Daily IFR Releases Regime



More than 30 years of successful collaboration

Thank You

More than 30 years of successful collaboration

Appendix-10 WATER LEVEL AND FLOW OF DISCHARGE

Appendix-10 Water Level and Flow of Discharge

(1) Mohale Dam

Chart of Discharge Flow Volume for Mohale Dam

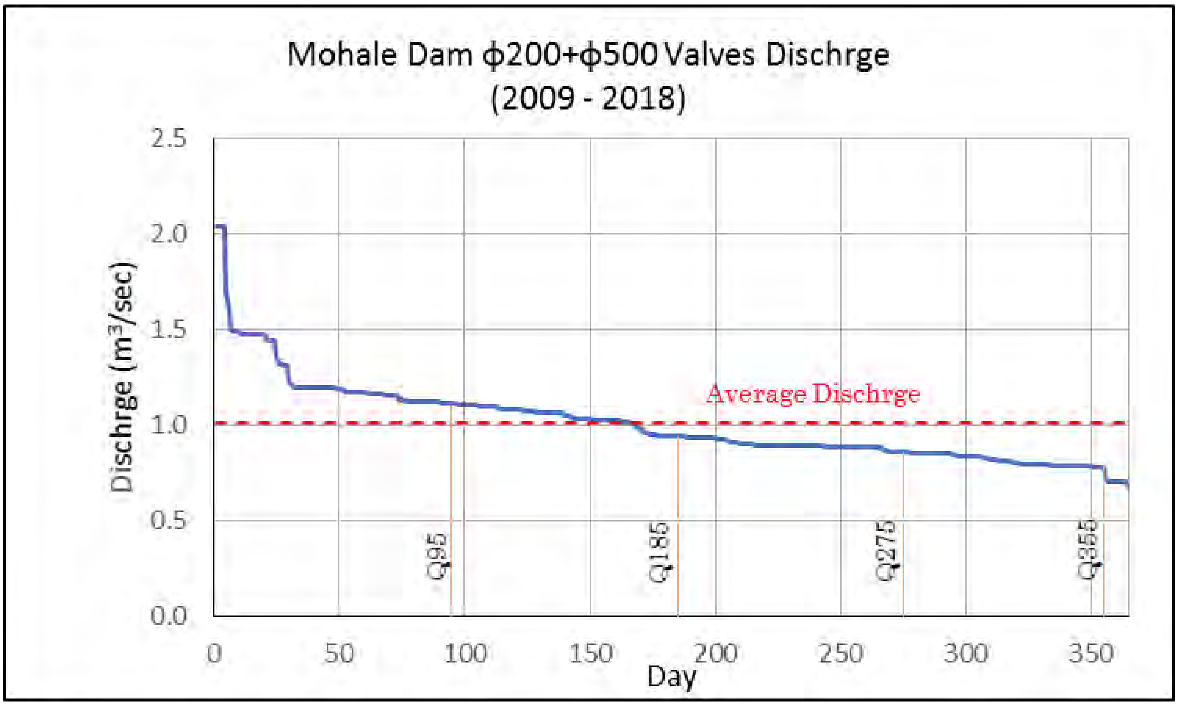
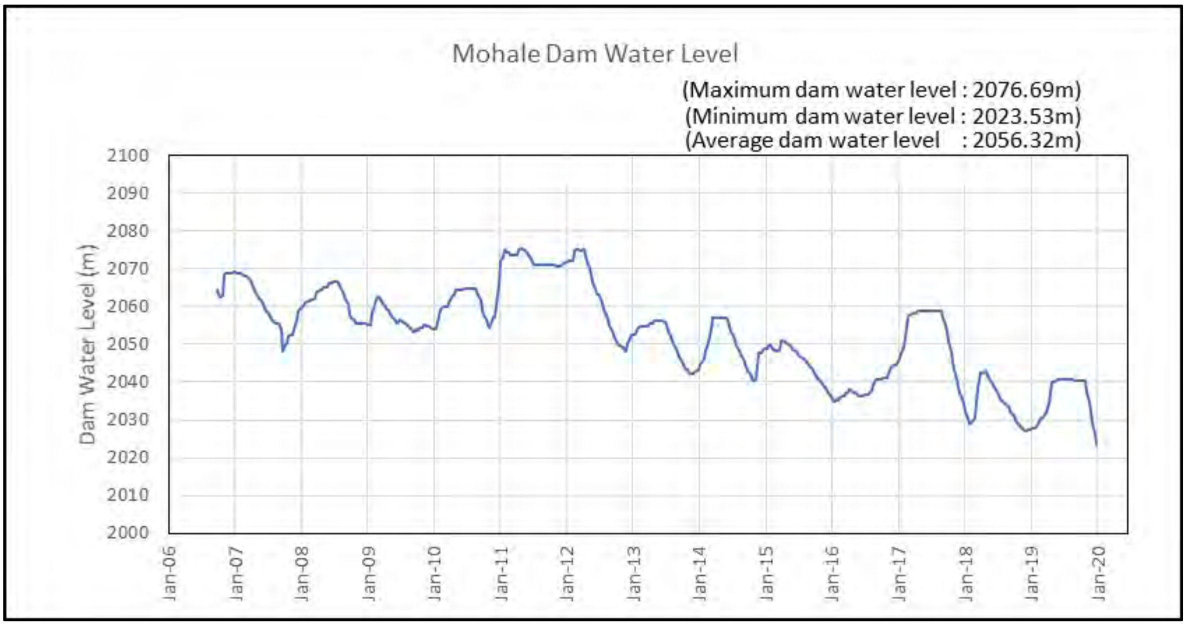


Chart of Water Level for Mohale Dam



Statistics of Discharge Flow Volume for Mohale Dam

Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)
1	2.038	56	1.167	111	1.096	166	1.011	221	0.895	276	0.859	331	0.793
2	2.038	57	1.167	112	1.096	167	1.006	222	0.895	277	0.858	332	0.793
3	2.038	58	1.167	113	1.096	168	1.006	223	0.894	278	0.854	333	0.793
4	2.038	59	1.167	114	1.084	169	0.984	224	0.894	279	0.854	334	0.789
5	1.694	60	1.167	115	1.084	170	0.984	225	0.894	280	0.854	335	0.789
6	1.601	61	1.167	116	1.084	171	0.965	226	0.894	281	0.854	336	0.789
7	1.496	62	1.166	117	1.084	172	0.957	227	0.894	282	0.854	337	0.789
8	1.494	63	1.166	118	1.084	173	0.956	228	0.894	283	0.854	338	0.789
9	1.494	64	1.166	119	1.084	174	0.950	229	0.894	284	0.854	339	0.789
10	1.494	65	1.166	120	1.078	175	0.950	230	0.894	285	0.852	340	0.789
11	1.477	66	1.166	121	1.078	176	0.950	231	0.894	286	0.852	341	0.789
12	1.477	67	1.166	122	1.078	177	0.944	232	0.894	287	0.852	342	0.789
13	1.477	68	1.155	123	1.078	178	0.942	233	0.894	288	0.852	343	0.789
14	1.477	69	1.153	124	1.075	179	0.942	234	0.894	289	0.852	344	0.789
15	1.477	70	1.153	125	1.073	180	0.942	235	0.894	290	0.852	345	0.789
16	1.477	71	1.153	126	1.069	181	0.942	236	0.894	291	0.852	346	0.784
17	1.477	72	1.150	127	1.069	182	0.942	237	0.894	292	0.850	347	0.784
18	1.477	73	1.150	128	1.069	183	0.942	238	0.893	293	0.850	348	0.784
19	1.477	74	1.129	129	1.067	184	0.942	239	0.893	294	0.850	349	0.784
20	1.477	75	1.129	130	1.067	185	0.942	240	0.893	295	0.839	350	0.784
21	1.458	76	1.129	131	1.067	186	0.942	241	0.893	296	0.839	351	0.779
22	1.443	77	1.122	132	1.067	187	0.942	242	0.893	297	0.837	352	0.779
23	1.441	78	1.122	133	1.067	188	0.942	243	0.893	298	0.837	353	0.779
24	1.441	79	1.122	134	1.067	189	0.934	244	0.887	299	0.837	354	0.779
25	1.347	80	1.122	135	1.067	190	0.930	245	0.887	300	0.837	355	0.777
26	1.319	81	1.122	136	1.067	191	0.930	246	0.887	301	0.837	356	0.720
27	1.318	82	1.122	137	1.067	192	0.930	247	0.887	302	0.834	357	0.700
28	1.308	83	1.120	138	1.067	193	0.930	248	0.887	303	0.834	358	0.700
29	1.308	84	1.120	139	1.067	194	0.930	249	0.887	304	0.834	359	0.700
30	1.225	85	1.120	140	1.047	195	0.930	250	0.887	305	0.834	360	0.700
31	1.210	86	1.120	141	1.047	196	0.930	251	0.885	306	0.834	361	0.700
32	1.194	87	1.120	142	1.047	197	0.930	252	0.885	307	0.830	362	0.700
33	1.194	88	1.120	143	1.036	198	0.930	253	0.885	308	0.829	363	0.700
34	1.194	89	1.120	144	1.035	199	0.930	254	0.885	309	0.829	364	0.700
35	1.194	90	1.120	145	1.035	200	0.930	255	0.885	310	0.819	365	0.679
36	1.194	91	1.117	146	1.035	201	0.925	256	0.885	311	0.816		
37	1.194	92	1.117	147	1.035	202	0.925	257	0.885	312	0.816		
38	1.193	93	1.117	148	1.035	203	0.925	258	0.885	313	0.812		
39	1.193	94	1.117	149	1.035	204	0.925	259	0.884	314	0.812		
40	1.193	95	1.111	150	1.035	205	0.917	260	0.884	315	0.812		
41	1.193	96	1.109	151	1.025	206	0.909	261	0.880	316	0.812		
42	1.192	97	1.107	152	1.025	207	0.909	262	0.880	317	0.812		
43	1.192	98	1.107	153	1.025	208	0.909	263	0.880	318	0.812		
44	1.192	99	1.101	154	1.025	209	0.909	264	0.880	319	0.803		
45	1.192	100	1.101	155	1.025	210	0.901	265	0.880	320	0.803		
46	1.192	101	1.101	156	1.025	211	0.901	266	0.880	321	0.803		
47	1.192	102	1.101	157	1.025	212	0.901	267	0.870	322	0.793		
48	1.192	103	1.101	158	1.025	213	0.901	268	0.869	323	0.793		
49	1.190	104	1.101	159	1.025	214	0.901	269	0.862	324	0.793		
50	1.190	105	1.101	160	1.025	215	0.901	270	0.860	325	0.793		
51	1.190	106	1.100	161	1.025	216	0.895	271	0.860	326	0.793		
52	1.167	107	1.100	162	1.025	217	0.895	272	0.860	327	0.793		
53	1.167	108	1.100	163	1.017	218	0.895	273	0.860	328	0.793		
54	1.167	109	1.100	164	1.011	219	0.895	274	0.859	329	0.793		
55	1.167	110	1.096	165	1.011	220	0.895	275	0.859	330	0.793		

Discharge Flow Volume for Mohale Dam

Date		φ200 + ϕ 500 Valves										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Jan	1	0.960	0.450	0.380	1.239	0.480	0.347	1.490	2.951	0.847	2.348	1.149
	2	0.960	0.450	0.380	1.239	0.480	0.347	1.490	2.951	0.847	2.348	1.149
	3	0.960	0.450	0.410	1.239	0.480	0.347	1.490	2.951	0.847	2.348	1.152
	4	0.960	0.450	0.410	1.239	0.480	0.347	1.490	2.951	0.847	2.348	1.152
	5	0.960	0.450	0.410	1.239	0.480	0.347	1.490	2.951	0.847	2.348	1.152
	6	0.960	0.450	0.410	0.400	0.480	0.347	1.490	2.951	0.847	2.348	1.068
	7	0.960	0.450	0.410	0.400	0.480	0.347	1.490	2.951	0.847	2.348	1.068
	8	0.960	0.450	0.410	0.400	0.480	0.347	1.490	2.951	0.847	2.348	1.068
	9	0.960	0.450	0.410	0.400	0.480	0.347	1.490	0.560	0.847	2.348	0.829
	10	0.960	0.450	0.410	0.400	0.480	0.347	1.490	0.280	1.419	2.348	0.858
	11	0.960	0.450	0.410	0.400	0.480	0.347	1.490	0.280	2.408	2.348	0.957
	12	0.960	0.450	0.410	0.400	0.480	0.347	1.490	0.280	2.084	2.348	0.925
	13	0.960	0.450	0.410	0.400	0.480	0.347	1.490	0.280	2.084	2.348	0.925
	14	0.960	0.450	0.410	0.400	0.480	0.347	1.490	0.280	2.084	2.348	0.925
	15	0.960	0.450	0.410	0.400	0.480	0.347	1.490	0.280	2.084	2.348	0.925
	16	0.960	0.450	0.410	0.400	0.480	3.347	1.490	0.280	2.084	2.348	1.225
	17	0.960	0.450	0.410	0.400	0.480	0.440	1.490	0.280	2.084	2.348	0.934
	18	0.960	0.450	0.410	0.400	0.480	0.440	1.490	0.280	0.532	2.348	0.779
	19	0.960	0.450	0.410	0.400	0.480	0.440	1.490	0.280	0.532	2.348	0.779
	20	0.960	0.450	0.410	0.400	0.480	0.440	1.490	0.280	0.532	2.348	0.779
	21	0.960	0.450	0.410	0.400	0.480	0.440	1.490	0.280	0.532	2.348	0.779
	22	0.960	0.450	5.700	0.400	0.480	0.440	1.490	0.280	0.532	2.348	1.308
	23	0.960	0.450	5.700	0.400	0.480	0.440	1.490	0.280	0.532	2.348	1.308
	24	0.960	0.450	5.800	0.400	0.480	0.440	1.490	0.280	0.532	2.348	1.318
	25	0.960	0.450	5.800	0.400	0.480	0.440	1.490	0.280	3.363	2.348	1.601
	26	0.960	0.450	5.800	0.400	0.480	0.440	1.490	0.280	1.763	2.348	1.441
	27	0.960	0.450	5.800	0.400	0.480	0.440	1.490	0.280	1.763	2.348	1.441
	28	0.960	0.450	5.800	0.400	0.480	0.440	1.490	0.280	2.295	2.348	1.494
	29	0.960	0.450	5.800	0.400	0.480	0.440	1.490	0.280	2.295	2.348	1.494
	30	0.980	0.450	5.800	0.400	0.480	0.440	1.490	0.280	1.763	2.348	1.443
	31	0.980	0.450	5.800	0.400	0.480	0.440	1.490	0.280	2.295	2.348	1.496
Feb	1	0.720	0.450	5.800	0.400	0.480	0.680	1.490	0.280	2.295	2.348	1.494
	2	0.720	0.450	5.800	0.944	0.480	0.680	1.490	0.280	0.000	2.348	1.319
	3	0.720	0.450	5.800	0.944	0.480	0.680	1.490	0.560	0.000	2.348	1.347
	4	0.720	0.900	5.800	0.944	0.480	0.680	4.600	0.468	0.000	2.348	1.694
	5	0.720	0.900	5.800	0.944	0.480	0.680	4.600	0.468	3.442	2.348	2.038
	6	0.720	0.900	5.800	0.944	0.480	0.680	4.600	0.468	3.442	2.348	2.038
	7	0.720	0.900	5.800	0.944	0.480	0.680	4.600	0.468	3.442	2.348	2.038
	8	0.720	0.900	5.800	0.944	0.480	0.680	4.600	0.468	3.442	2.348	2.038
	9	0.720	0.900	0.000	0.944	0.480	0.680	4.600	0.468	3.442	2.348	1.458
	10	0.720	0.900	0.717	0.944	0.480	0.680	0.960	0.468	3.442	2.348	1.166
	11	0.720	0.900	1.912	0.944	0.480	0.680	1.173	0.468	1.123	2.348	1.075
	12	0.720	0.900	3.265	0.944	0.480	0.680	1.173	0.468	1.123	2.348	1.210
	13	0.720	0.900	0.335	0.944	0.480	0.680	1.173	0.468	1.123	2.348	0.917
	14	0.720	0.900	0.720	0.944	0.480	0.680	1.173	0.468	1.123	2.348	0.956
	15	0.720	0.900	0.600	0.944	0.480	0.680	1.173	0.468	1.123	2.348	0.944
	16	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	0.655	2.348	0.837
	17	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	0.655	2.348	0.837
	18	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	0.655	2.348	0.837
	19	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	0.655	2.348	0.837
	20	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	0.655	2.348	0.837
	21	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	3.133	2.348	1.085
	22	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	3.133	2.348	1.085
	23	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	3.133	2.348	1.085
	24	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	3.133	2.348	1.085
	25	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	3.133	2.348	1.085
	26	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	3.133	2.348	1.085
	27	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	2.348	2.348	1.006
	28	0.720	0.900	0.000	0.944	0.480	0.680	1.173	0.468	2.348	2.348	1.006

Date		φ200 + ϕ 500 Valves										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Mar	1	0.720	0.900	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.047
	2	0.720	0.900	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.047
	3	0.720	0.900	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.047
	4	0.720	1.100	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.067
	5	0.720	1.100	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.067
	6	0.720	1.100	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.067
	7	0.720	1.100	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.067
	8	0.720	1.100	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.067
	9	0.720	1.100	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.067
	10	0.720	1.100	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.067
	11	0.720	1.100	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.067
	12	0.720	1.100	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.067
	13	0.720	1.100	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.067
	14	0.720	1.100	0.000	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.067
	15	0.720	1.100	4.100	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.477
	16	0.720	1.100	4.100	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.477
	17	0.720	1.100	4.100	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.477
	18	0.720	1.100	4.100	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.477
	19	0.720	1.100	4.100	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.477
	20	0.720	1.100	4.100	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.477
	21	0.720	1.100	4.100	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.477
	22	0.720	1.100	4.100	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.477
	23	0.720	1.100	4.100	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.477
	24	0.720	1.100	4.100	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.477
	25	0.720	1.100	1.250	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.192
	26	0.720	1.100	1.250	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.192
	27	0.720	1.100	1.250	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.192
	28	0.720	1.100	1.250	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.192
	29	0.720	1.100	1.250	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.192
	30	0.720	1.100	1.250	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.192
	31	0.720	1.100	1.250	0.944	0.480	1.086	1.173	0.468	2.348	2.348	1.192
Apr	1	0.720	0.900	1.250	0.944	0.480	0.925	0.700	0.155	2.348	2.348	1.077
	2	0.720	0.900	1.250	0.944	0.480	0.925	0.700	0.155	2.348	2.348	1.077
	3	0.720	0.900	1.250	0.944	0.480	0.925	0.700	0.155	2.348	2.348	1.077
	4	0.720	0.900	1.250	0.944	0.480	0.925	0.700	0.155	2.348	2.348	1.077
	5	0.720	0.900	1.250	0.944	0.480	0.925	0.700	0.934	2.348	2.348	1.155
	6	1.070	0.900	1.250	0.944	0.480	0.925	0.700	0.934	2.348	2.348	1.190
	7	1.070	0.900	1.250	0.944	0.480	0.925	0.700	0.934	2.348	2.348	1.190
	8	1.070	0.900	1.250	0.944	0.480	0.925	0.700	0.934	2.348	2.348	1.190
	9	1.070	0.900	1.280	0.944	0.480	0.925	0.700	0.934	2.348	2.348	1.193
	10	1.070	0.900	1.280	0.944	0.480	0.925	0.700	0.934	2.348	2.348	1.193
	11	1.070	0.900	1.280	0.944	0.480	0.925	0.700	0.934	2.348	2.348	1.193
	12	1.070	0.900	1.280	0.944	0.480	0.925	0.700	0.934	2.348	2.348	1.193
	13	1.070	0.900	1.280	0.944	0.480	0.925	0.700	0.658	2.348	2.348	1.165
	14	1.070	0.900	1.280	0.944	0.480	0.925	0.700	0.658	2.348	2.348	1.165
	15	1.070	0.900	1.280	0.944	0.480	0.925	0.700	0.658	2.348	2.348	1.165
	16	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.934	2.348	2.348	1.195
	17	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.155	2.348	2.348	1.117
	18	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.155	2.348	2.348	1.117
	19	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.155	2.348	2.348	1.117
	20	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.155	2.348	2.348	1.117
	21	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.934	2.348	2.348	1.195
	22	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.934	2.348	2.348	1.195
	23	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.934	2.348	2.348	1.195
	24	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.658	2.348	2.348	1.167
	25	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.658	2.348	2.348	1.167
	26	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.934	2.348	2.348	1.195
	27	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.934	2.348	2.348	1.195
	28	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.280	2.348	2.348	1.129
	29	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.280	2.348	2.348	1.129
	30	1.070	0.900	1.280	0.944	0.480	0.943	0.700	0.280	2.348	2.348	1.129

Date		φ200 + φ 500 Valves										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
May	1	1.070	1.200	1.280	0.944	0.480	1.021	0.118	0.280	2.348	2.348	1.109
	2	1.050	1.200	1.280	0.944	0.480	1.021	0.118	0.280	2.348	2.348	1.107
	3	1.050	1.200	1.280	0.944	0.480	1.021	0.118	0.280	2.348	2.348	1.107
	4	1.100	1.200	1.280	0.170	0.480	1.021	0.118	0.280	2.348	2.348	1.035
	5	1.100	1.200	1.280	0.170	0.480	1.021	0.118	0.280	2.348	2.348	1.035
	6	1.100	1.200	1.280	0.170	0.480	1.021	0.118	0.280	2.348	2.348	1.035
	7	1.100	1.200	1.280	0.170	0.480	1.021	0.118	0.280	2.348	2.348	1.035
	8	1.100	1.200	1.280	0.170	0.480	1.021	0.118	0.280	2.348	2.348	1.035
	9	1.100	1.200	1.280	0.170	0.480	1.021	0.118	0.658	2.348	2.348	1.072
	10	1.100	1.200	1.280	0.170	0.480	1.021	0.118	0.280	2.348	2.348	1.035
	11	1.100	1.200	1.280	0.170	0.480	1.021	0.118	0.280	2.348	2.348	1.035
	12	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.280	2.348	2.348	1.035
	13	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.934	2.348	2.348	1.101
	14	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.934	2.348	2.348	1.101
	15	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.934	2.348	2.348	1.101
	16	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.934	2.348	2.348	1.101
	17	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.934	2.348	2.348	1.101
	18	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.934	2.348	2.348	1.101
	19	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.934	2.348	2.348	1.101
	20	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	1.025
	21	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	1.025
	22	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	1.025
	23	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	1.025
	24	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	1.025
	25	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	1.025
	26	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	1.025
	27	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	1.025
	28	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	1.025
	29	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	1.025
	30	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	1.025
	31	1.100	1.200	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	1.025
Jun	1	1.100	0.600	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	0.965
	2	0.950	0.600	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	0.950
	3	0.950	0.600	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	0.950
	4	0.950	0.600	1.280	0.170	0.480	1.021	0.126	0.177	2.348	2.348	0.950
	5	0.950	0.600	1.280	0.170	0.480	0.609	0.126	0.177	2.348	2.348	0.909
	6	0.950	0.600	1.280	0.170	0.480	0.609	0.126	0.177	2.348	2.348	0.909
	7	0.950	0.600	1.280	0.170	0.480	0.609	0.126	0.177	2.348	2.348	0.909
	8	0.950	0.600	1.280	0.170	0.480	0.609	0.126	0.177	2.348	2.348	0.909
	9	0.950	0.600	1.280	0.170	0.480	0.609	0.040	0.177	2.348	2.348	0.900
	10	0.950	0.600	1.280	0.170	0.480	0.609	0.040	0.177	2.348	2.348	0.900
	11	0.950	0.600	1.280	0.170	0.480	0.609	0.040	0.177	2.348	2.348	0.900
	12	0.950	0.600	1.280	0.170	0.480	0.609	0.040	0.177	2.348	2.348	0.900
	13	0.950	0.600	1.280	0.170	0.480	0.609	0.040	0.177	2.348	2.348	0.900
	14	0.950	0.600	1.280	0.170	0.480	0.609	0.040	0.177	2.348	2.348	0.900
	15	0.950	0.600	1.280	0.000	0.480	0.609	0.040	0.177	2.348	2.348	0.883
	16	0.950	0.600	1.280	0.000	0.480	0.609	0.040	0.177	2.348	2.348	0.883
	17	0.950	0.600	1.280	0.000	0.480	0.609	0.057	0.177	2.348	2.348	0.885
	18	0.950	0.600	1.280	0.000	0.480	0.609	0.057	0.177	2.348	2.348	0.885
	19	0.950	0.600	1.280	0.000	0.480	0.609	0.057	0.177	2.348	2.348	0.885
	20	0.950	0.600	1.280	0.000	0.480	0.609	0.057	0.177	2.348	2.348	0.885
	21	0.950	0.600	1.280	0.000	0.480	0.609	0.057	0.177	2.348	2.348	0.885
	22	0.950	0.600	1.280	0.000	0.480	0.609	0.057	0.177	2.348	2.348	0.885
	23	0.950	0.600	1.280	0.000	0.480	0.609	0.057	0.177	2.348	2.348	0.885
	24	0.950	0.600	1.280	0.000	0.480	0.609	0.057	0.177	2.348	2.348	0.885
	25	0.950	0.600	1.280	0.000	0.480	0.609	0.068	0.177	2.348	2.348	0.886
	26	0.950	0.600	1.280	0.000	0.480	0.609	0.068	0.177	2.348	2.348	0.886
	27	0.950	0.600	1.280	0.000	0.480	0.609	0.068	0.177	2.348	2.348	0.886
	28	0.950	0.600	1.280	0.000	0.480	0.609	0.068	0.177	2.348	2.348	0.886
	29	0.950	0.600	1.280	0.000	0.480	0.609	0.068	0.177	2.348	2.348	0.886
	30	0.950	0.600	1.280	0.000	0.480	0.609	0.068	0.177	2.348	2.348	0.886

Date		φ200 + φ500 Valves										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Jul	1	0.950	0.600	1.280	0.000	0.846	0.000	0.068	0.177	2.348	2.348	0.862
	2	0.950	0.600	1.280	0.000	0.846	0.000	0.034	0.177	2.348	2.348	0.858
	3	0.950	0.600	1.280	0.000	0.846	0.000	0.034	0.177	2.348	2.348	0.858
	4	0.950	0.600	1.280	0.000	0.846	0.000	0.034	0.177	2.348	2.348	0.858
	5	0.950	0.600	1.280	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.859
	6	0.950	0.600	1.280	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.859
	7	0.950	0.600	1.280	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.859
	8	0.950	0.600	1.280	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.859
	9	0.950	0.600	0.800	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.811
	10	0.950	0.600	0.800	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.811
	11	0.950	0.600	0.800	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.811
	12	0.950	0.600	0.800	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.811
	13	0.950	0.600	0.800	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.811
	14	0.950	0.600	0.800	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.811
	15	0.950	0.370	0.800	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.788
	16	0.950	0.370	0.800	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.788
	17	0.950	0.370	0.800	0.000	0.855	0.000	0.034	0.177	2.348	2.348	0.788
	18	0.950	0.370	0.800	0.000	0.863	0.000	0.034	0.177	2.348	2.348	0.789
	19	0.950	0.370	0.800	0.000	0.863	0.000	0.034	0.177	2.348	2.348	0.789
	20	0.950	0.370	0.800	0.000	0.863	0.000	0.034	0.177	2.348	2.348	0.789
	21	0.950	0.370	0.800	0.000	0.863	0.000	0.034	0.177	2.348	2.348	0.789
	22	0.950	0.370	0.800	0.000	0.863	0.000	0.034	0.177	2.348	2.348	0.789
	23	0.950	0.370	0.800	0.000	0.863	0.000	0.034	0.177	2.348	2.348	0.789
	24	0.950	0.370	0.800	0.000	0.863	0.000	0.034	0.177	2.348	2.348	0.789
	25	0.950	0.370	0.800	0.000	0.863	0.000	0.034	0.177	2.348	2.348	0.789
	26	0.950	0.370	0.800	0.000	0.863	0.000	0.034	0.177	2.348	2.348	0.789
	27	0.950	0.370	0.800	0.000	0.863	0.000	0.034	0.819	2.348	2.348	0.853
	28	0.950	0.370	0.800	0.000	0.863	0.000	0.034	0.819	2.348	2.348	0.853
	29	0.950	0.370	0.800	0.000	0.871	0.000	0.034	0.819	2.348	2.348	0.854
	30	0.950	0.370	0.800	0.000	0.871	0.000	0.034	0.819	2.348	2.348	0.854
	31	0.950	0.370	0.800	0.000	0.871	0.000	0.034	0.819	2.348	2.348	0.854
Aug	1	0.950	0.370	0.800	0.000	0.871	0.000	0.034	0.819	2.348	2.348	0.854
	2	0.950	0.370	0.800	0.000	0.871	0.000	0.034	0.819	2.348	2.348	0.854
	3	0.950	0.700	0.800	0.000	0.871	0.000	0.034	0.819	2.348	2.348	0.887
	4	0.950	0.700	0.800	0.000	0.871	0.000	0.102	0.819	2.348	2.348	0.894
	5	0.950	0.700	0.800	0.000	0.871	0.000	0.102	0.819	2.348	2.348	0.894
	6	0.950	0.700	0.800	0.000	0.871	0.000	0.102	0.819	2.348	2.348	0.894
	7	0.950	0.700	0.800	0.000	0.871	0.000	0.102	0.819	2.348	2.348	0.894
	8	0.950	0.700	0.800	0.000	0.871	0.000	0.102	0.819	2.348	2.348	0.894
	9	0.950	0.700	0.800	0.000	0.871	0.000	0.102	0.819	2.348	2.348	0.894
	10	0.950	0.700	0.800	0.000	0.870	0.000	0.102	0.819	2.348	2.348	0.894
	11	0.950	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.895
	12	0.950	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.895
	13	0.950	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.895
	14	0.950	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.895
	15	0.950	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.895
	16	0.950	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.895
	17	0.950	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.895
	18	0.930	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.893
	19	0.930	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.893
	20	0.930	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.893
	21	0.930	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.893
	22	0.930	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.893
	23	0.930	0.700	0.800	0.000	0.879	0.000	0.102	0.819	2.348	2.348	0.893
	24	0.930	0.700	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.894
	25	0.930	0.700	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.894
	26	0.930	0.700	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.894
	27	0.930	0.700	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.894
	28	0.930	0.700	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.894
	29	0.930	0.700	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.894
	30	0.930	0.700	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.894
	31	0.930	0.700	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.894

Date		φ200 + φ 500 Valves										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Sep	1	0.930	0.560	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.880
	2	0.930	0.560	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.880
	3	0.930	0.560	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.880
	4	0.930	0.560	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.880
	5	0.930	0.560	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.880
	6	0.930	0.560	0.800	0.000	0.888	0.000	0.102	0.819	2.348	2.348	0.880
	7	0.930	0.560	0.800	0.000	0.779	0.000	0.102	0.819	2.348	2.348	0.869
	8	0.930	0.560	0.800	0.000	0.779	0.000	0.102	0.163	2.348	2.348	0.803
	9	0.930	0.560	0.800	0.000	0.779	0.000	0.102	0.163	2.348	2.348	0.803
	10	0.930	0.560	0.800	0.000	0.779	0.000	0.102	0.163	2.348	2.348	0.803
	11	0.930	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.793
	12	0.930	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.793
	13	0.930	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.793
	14	0.930	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.793
	15	0.930	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.793
	16	0.930	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.793
	17	0.930	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.793
	18	0.930	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.793
	19	0.930	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.793
	20	0.930	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.793
	21	0.930	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.793
	22	0.930	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.793
	23	0.000	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.700
	24	0.000	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.700
	25	0.000	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.700
	26	0.000	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.700
	27	0.000	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.700
	28	0.000	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.700
	29	0.000	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.700
	30	0.000	0.560	0.800	0.000	0.779	0.000	0.000	0.163	2.348	2.348	0.700
Oct	1	0.000	0.560	0.800	0.000	0.570	0.000	0.000	0.163	2.348	2.348	0.679
	2	0.000	0.560	0.800	0.410	0.570	0.000	0.000	0.163	2.348	2.348	0.720
	3	0.000	0.560	0.800	0.410	0.570	0.567	0.000	0.163	2.348	2.348	0.777
	4	0.000	0.560	0.800	0.480	0.570	0.567	0.000	0.163	2.348	2.348	0.784
	5	0.000	0.560	0.800	0.480	0.570	0.567	0.000	0.163	2.348	2.348	0.784
	6	0.000	0.560	0.800	0.480	0.570	0.567	0.000	0.163	2.348	2.348	0.784
	7	0.000	0.560	0.800	0.480	0.570	0.567	0.000	0.163	2.348	2.348	0.784
	8	0.000	0.560	0.800	0.480	0.570	0.567	0.000	0.163	2.348	2.348	0.784
	9	0.000	0.440	0.800	0.480	0.570	0.567	0.441	0.163	2.348	2.348	0.816
	10	0.000	0.440	0.800	0.480	0.570	0.567	0.441	0.163	2.348	2.348	0.816
	11	0.000	0.440	0.800	0.480	0.570	0.598	0.441	0.163	2.348	2.348	0.819
	12	0.000	0.440	0.800	0.480	0.570	0.598	0.540	0.163	2.348	2.348	0.829
	13	0.000	0.440	0.800	0.480	0.570	0.598	0.540	0.163	2.348	2.348	0.829
	14	0.000	0.440	0.800	0.480	0.570	0.598	0.589	0.163	2.348	2.348	0.834
	15	0.000	0.440	0.800	0.480	0.570	0.598	0.589	0.163	2.348	2.348	0.834
	16	0.000	0.440	0.800	0.480	0.570	0.598	0.589	0.163	2.348	2.348	0.834
	17	0.000	0.440	0.800	0.480	0.570	0.598	0.589	0.163	2.348	2.348	0.834
	18	0.000	0.440	0.800	0.480	0.570	0.598	0.589	0.163	2.348	2.348	0.834
	19	0.000	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.839
	20	0.000	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.839
	21	0.910	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.930
	22	0.910	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.930
	23	0.910	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.930
	24	0.910	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.930
	25	0.910	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.930
	26	0.910	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.930
	27	0.910	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.930
	28	0.910	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.930
	29	0.910	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.930
	30	0.910	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.930
	31	0.910	0.440	0.800	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.930

Date		φ200 + φ 500 Valves										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Nov	1	0.910	0.540	1.239	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.983
	2	0.910	0.540	1.239	0.480	0.570	0.598	0.638	0.163	2.348	2.348	0.983
	3	0.910	0.540	1.239	0.480	0.570	0.598	0.979	0.163	2.348	2.348	1.018
	4	0.910	0.540	1.239	0.480	0.570	1.202	1.166	0.163	2.348	2.348	1.097
	5	0.910	0.540	1.239	0.480	0.570	1.202	1.166	0.163	2.348	2.348	1.097
	6	0.910	0.540	1.239	0.480	0.570	1.202	1.166	0.163	2.348	2.348	1.097
	7	0.910	0.540	1.239	0.480	0.570	1.202	1.166	0.163	2.348	2.348	1.097
	8	0.910	0.540	1.239	0.480	0.570	1.202	1.166	0.861	2.348	2.348	1.166
	9	0.910	0.540	1.239	0.480	0.570	1.202	1.166	0.861	2.348	2.348	1.166
	10	0.450	0.540	1.239	0.480	0.570	1.202	1.166	0.861	2.348	2.348	1.120
	11	0.450	0.540	1.239	0.480	0.570	1.202	1.166	0.861	2.348	2.348	1.120
	12	0.450	0.540	1.239	0.480	0.570	1.202	1.166	0.861	2.348	2.348	1.120
	13	0.450	0.540	1.239	0.480	0.570	1.202	1.166	0.861	2.348	2.348	1.120
	14	0.450	0.540	1.239	0.480	0.570	1.202	1.166	0.861	2.348	2.348	1.120
	15	0.450	0.540	1.239	0.480	0.570	1.202	1.166	0.861	2.348	2.348	1.120
	16	0.450	0.540	1.239	0.480	0.570	1.202	1.166	0.861	2.348	2.348	1.120
	17	0.450	0.540	1.239	0.480	0.570	1.202	1.166	0.861	2.348	2.348	1.120
	18	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.861	2.348	2.348	1.167
	19	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.188	2.348	2.348	1.100
	20	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.188	2.348	2.348	1.100
	21	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.188	2.348	2.348	1.100
	22	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.188	2.348	2.348	1.100
	23	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.861	2.348	2.348	1.167
	24	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.861	2.348	2.348	1.167
	25	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.861	2.348	2.348	1.167
	26	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.861	2.348	2.348	1.167
	27	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.861	2.348	2.348	1.167
	28	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.861	2.348	2.348	1.167
	29	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.861	2.348	2.348	1.167
	30	0.450	0.540	1.239	0.480	1.035	1.202	1.166	0.297	2.348	2.348	1.111
Dec	1	0.450	0.360	1.239	0.480	1.035	0.380	1.166	0.297	2.348	2.348	1.010
	2	0.450	0.360	1.239	0.480	1.035	0.380	1.166	0.297	2.348	2.348	1.010
	3	0.450	0.360	1.239	0.480	1.035	0.380	1.166	0.297	2.348	2.348	1.010
	4	0.450	0.360	1.239	0.480	0.347	0.380	1.166	0.297	2.348	2.348	0.942
	5	0.450	0.360	1.239	0.480	0.347	0.380	1.166	0.297	2.348	2.348	0.942
	6	0.450	0.360	1.239	0.480	0.347	0.380	1.166	0.297	2.348	2.348	0.942
	7	0.450	0.360	1.239	0.480	0.347	0.380	1.166	0.297	2.348	2.348	0.942
	8	0.450	0.360	1.239	0.480	0.347	0.380	1.166	0.297	2.348	2.348	0.942
	9	0.450	0.360	1.239	0.480	0.347	0.380	1.166	0.297	2.348	2.348	0.942
	10	0.450	0.360	1.239	0.480	0.347	0.380	1.166	0.297	2.348	2.348	0.942
	11	0.450	0.360	1.239	0.480	0.347	0.380	1.166	0.297	2.348	2.348	0.942
	12	0.450	0.360	1.239	0.480	0.347	0.380	1.166	0.297	2.348	2.348	0.942
	13	0.450	0.360	1.239	0.480	0.347	0.380	1.166	0.297	2.348	2.348	0.942
	14	0.450	0.360	1.239	0.480	0.347	0.380	1.166	0.297	2.348	2.348	0.942
	15	0.450	0.360	1.239	0.480	0.347	0.380	0.455	0.297	2.348	2.348	0.870
	16	0.450	0.360	1.239	0.480	0.347	0.380	0.248	0.297	2.348	2.348	0.850
	17	0.450	0.360	1.239	0.480	0.347	0.380	0.248	0.297	2.348	2.348	0.850
	18	0.450	0.360	1.239	0.480	0.347	0.380	0.248	0.297	2.348	2.348	0.850
	19	0.450	0.380	1.239	0.480	0.347	0.380	0.248	0.297	2.348	2.348	0.852
	20	0.450	0.380	1.239	0.480	0.347	0.380	0.248	0.297	2.348	2.348	0.852
	21	0.450	0.380	1.239	0.480	0.347	0.380	0.248	0.297	2.348	2.348	0.852
	22	0.450	0.380	1.239	0.480	0.347	0.380	0.248	0.297	2.348	2.348	0.852
	23	0.450	0.380	1.239	0.480	0.347	0.380	0.248	0.297	2.348	2.348	0.852
	24	0.450	0.380	1.239	0.480	0.347	0.380	0.248	0.297	2.348	2.348	0.852
	25	0.450	0.380	1.239	0.480	0.347	0.380	0.248	0.297	2.348	2.348	0.852
	26	0.450	0.380	1.239	0.480	0.347	0.380	2.951	0.297	2.348	2.348	1.122
	27	0.450	0.380	1.239	0.480	0.347	0.380	2.951	0.297	2.348	2.348	1.122
	28	0.450	0.380	1.239	0.480	0.347	0.380	2.951	0.297	2.348	2.348	1.122
	29	0.450	0.380	1.239	0.480	0.347	0.380	2.951	0.297	2.348	2.348	1.122
	30	0.450	0.380	1.239	0.480	0.347	0.380	2.951	0.297	2.348	2.348	1.122
	31	0.450	0.380	1.239	0.480	0.347	0.380	2.951	0.297	2.348	2.348	1.122
Max		2009.000	2010.000	2011.000	2012.000	2013.000	2014.000	2015.000	2016.000	2017.000	2018.000	2.038
Min		0.000	0.360	0.000	0.000	0.347	0.000	0.000	0.155	0.000	2.348	0.679

(2) Katse Dam

Chart of Discharge Flow Volume for Katse Dam

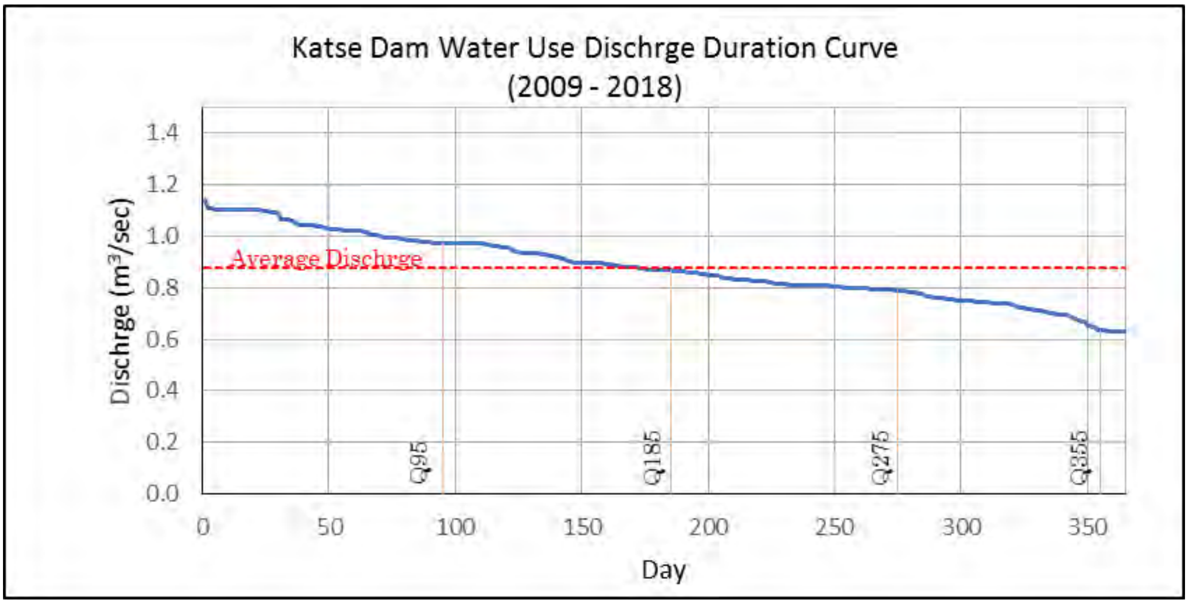
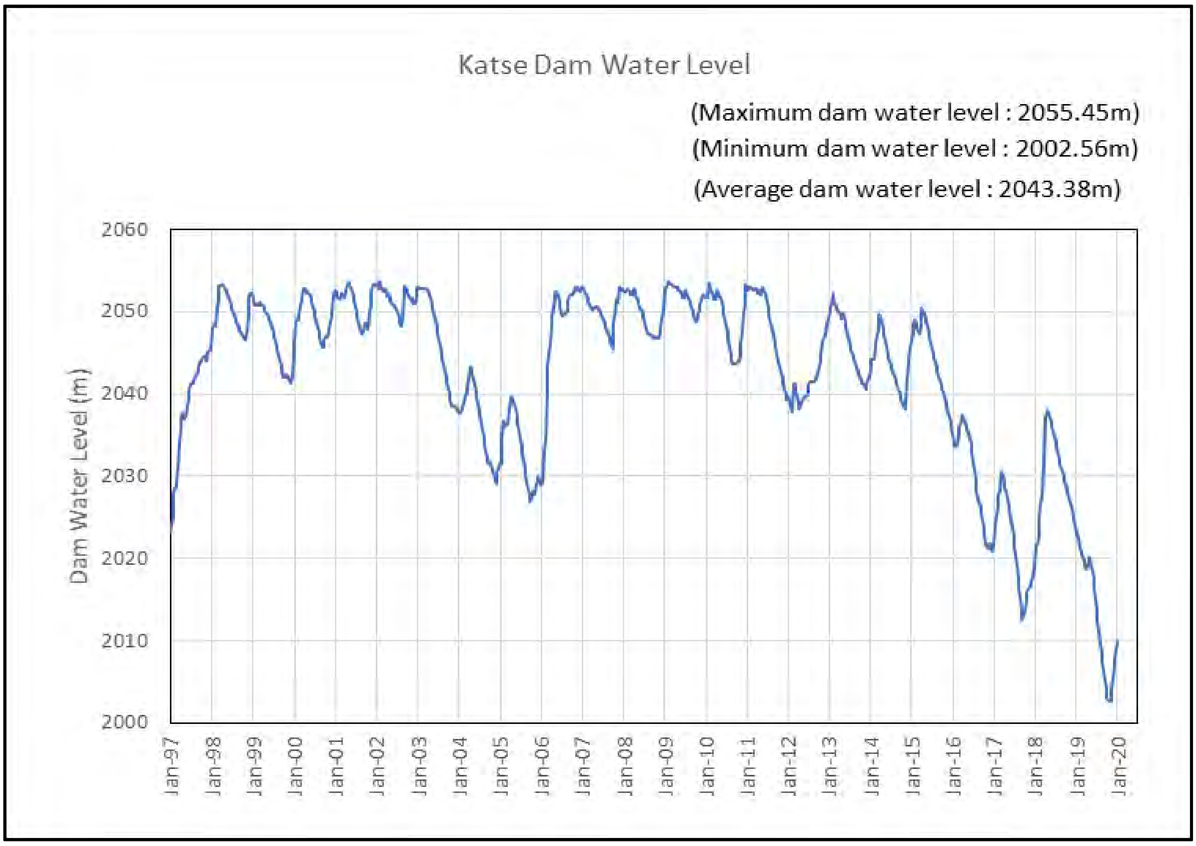


Chart of Water Level for Katse Dam



Statistics of Discharge Flow Volume for Katse Dam

Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)
1	1.143	56	1.022	111	0.970	166	0.882	221	0.824	276	0.788	331	0.714
2	1.110	57	1.021	112	0.969	167	0.882	222	0.824	277	0.787	332	0.710
3	1.110	58	1.020	113	0.969	168	0.881	223	0.824	278	0.787	333	0.708
4	1.107	59	1.020	114	0.969	169	0.881	224	0.823	279	0.785	334	0.708
5	1.103	60	1.020	115	0.960	170	0.880	225	0.819	280	0.784	335	0.701
6	1.103	61	1.020	116	0.960	171	0.879	226	0.816	281	0.782	336	0.700
7	1.103	62	1.020	117	0.960	172	0.879	227	0.816	282	0.780	337	0.699
8	1.103	63	1.019	118	0.958	173	0.876	228	0.815	283	0.777	338	0.695
9	1.103	64	1.014	119	0.958	174	0.875	229	0.814	284	0.776	339	0.694
10	1.103	65	1.014	120	0.958	175	0.875	230	0.813	285	0.776	340	0.693
11	1.103	66	1.008	121	0.958	176	0.872	231	0.813	286	0.766	341	0.693
12	1.103	67	1.007	122	0.949	177	0.872	232	0.812	287	0.765	342	0.693
13	1.103	68	1.005	123	0.948	178	0.868	233	0.812	288	0.765	343	0.689
14	1.103	69	1.003	124	0.941	179	0.868	234	0.810	289	0.763	344	0.684
15	1.102	70	1.001	125	0.939	180	0.868	235	0.809	290	0.762	345	0.681
16	1.102	71	1.000	126	0.937	181	0.867	236	0.809	291	0.762	346	0.674
17	1.102	72	0.996	127	0.936	182	0.867	237	0.809	292	0.762	347	0.671
18	1.101	73	0.994	128	0.936	183	0.867	238	0.809	293	0.758	348	0.666
19	1.101	74	0.993	129	0.935	184	0.867	239	0.809	294	0.757	349	0.666
20	1.101	75	0.993	130	0.935	185	0.867	240	0.809	295	0.756	350	0.650
21	1.101	76	0.993	131	0.934	186	0.865	241	0.808	296	0.755	351	0.650
22	1.101	77	0.992	132	0.932	187	0.865	242	0.808	297	0.754	352	0.647
23	1.101	78	0.991	133	0.932	188	0.865	243	0.808	298	0.752	353	0.646
24	1.100	79	0.990	134	0.929	189	0.865	244	0.808	299	0.751	354	0.638
25	1.098	80	0.987	135	0.928	190	0.862	245	0.808	300	0.749	355	0.638
26	1.098	81	0.985	136	0.928	191	0.862	246	0.808	301	0.748	356	0.637
27	1.094	82	0.982	137	0.926	192	0.861	247	0.807	302	0.747	357	0.633
28	1.094	83	0.982	138	0.925	193	0.859	248	0.807	303	0.747	358	0.630
29	1.093	84	0.982	139	0.924	194	0.858	249	0.805	304	0.747	359	0.630
30	1.092	85	0.982	140	0.917	195	0.858	250	0.805	305	0.747	360	0.629
31	1.064	86	0.979	141	0.917	196	0.858	251	0.803	306	0.746	361	0.629
32	1.064	87	0.979	142	0.913	197	0.855	252	0.802	307	0.745	362	0.629
33	1.064	88	0.979	143	0.912	198	0.854	253	0.802	308	0.745	363	0.629
34	1.064	89	0.979	144	0.909	199	0.851	254	0.800	309	0.745	364	0.628
35	1.060	90	0.979	145	0.902	200	0.850	255	0.797	310	0.743	365	0.628
36	1.058	91	0.975	146	0.901	201	0.850	256	0.797	311	0.742		
37	1.050	92	0.974	147	0.899	202	0.850	257	0.796	312	0.739		
38	1.044	93	0.974	148	0.899	203	0.849	258	0.796	313	0.737		
39	1.044	94	0.973	149	0.898	204	0.849	259	0.796	314	0.737		
40	1.044	95	0.973	150	0.896	205	0.840	260	0.796	315	0.737		
41	1.044	96	0.973	151	0.896	206	0.839	261	0.796	316	0.737		
42	1.044	97	0.973	152	0.895	207	0.839	262	0.796	317	0.737		
43	1.044	98	0.973	153	0.895	208	0.836	263	0.796	318	0.737		
44	1.043	99	0.973	154	0.895	209	0.835	264	0.795	319	0.737		
45	1.040	100	0.973	155	0.895	210	0.833	265	0.795	320	0.736		
46	1.040	101	0.973	156	0.895	211	0.833	266	0.795	321	0.732		
47	1.039	102	0.973	157	0.895	212	0.831	267	0.795	322	0.729		
48	1.034	103	0.973	158	0.894	213	0.831	268	0.794	323	0.724		
49	1.033	104	0.973	159	0.891	214	0.831	269	0.794	324	0.722		
50	1.027	105	0.972	160	0.891	215	0.831	270	0.793	325	0.722		
51	1.027	106	0.972	161	0.891	216	0.830	271	0.792	326	0.718		
52	1.027	107	0.970	162	0.889	217	0.828	272	0.791	327	0.718		
53	1.027	108	0.970	163	0.886	218	0.828	273	0.791	328	0.717		
54	1.027	109	0.970	164	0.885	219	0.824	274	0.790	329	0.714		
55	1.023	110	0.970	165	0.884	220	0.824	275	0.788	330	0.714		

Discharge Flow Volume for Katse Dam

Date		Valve Flow										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Jan	1	1.050	1.301	1.000	1.228	0.521	1.100	1.100	0.950	0.358	0.213	0.882
	2	1.050	1.301	1.000	1.228	0.521	1.100	1.100	0.950	0.213	0.213	0.868
	3	1.050	1.301	1.000	1.228	0.521	1.100	1.100	0.950	0.213	0.213	0.868
	4	1.050	1.301	1.000	1.228	0.521	1.100	1.100	0.950	0.213	0.213	0.868
	5	1.050	1.301	1.000	1.228	0.521	1.100	1.100	0.950	1.500	0.213	0.996
	6	1.050	1.301	1.000	1.228	0.519	1.100	1.100	0.950	0.213	0.213	0.867
	7	1.050	1.301	1.000	1.228	0.519	1.100	1.100	0.950	0.213	0.213	0.867
	8	1.050	1.301	1.000	1.228	0.519	1.100	1.100	0.950	0.353	0.213	0.881
	9	1.050	1.301	1.000	1.228	0.519	1.100	1.100	0.950	0.213	0.213	0.867
	10	1.050	1.301	1.000	1.228	0.519	1.100	1.100	0.950	0.213	0.213	0.867
	11	1.050	1.301	1.000	1.228	0.519	1.100	0.630	0.192	0.306	0.213	0.754
	12	1.052	1.301	1.000	1.228	0.518	1.100	0.630	0.192	0.213	0.213	0.745
	13	1.052	1.301	1.000	1.228	0.518	1.100	0.630	0.192	0.213	0.213	0.745
	14	1.052	1.301	1.000	1.228	0.518	1.100	0.630	0.292	0.213	0.213	0.755
	15	1.052	1.301	1.000	1.228	0.518	1.100	0.630	0.192	0.213	0.213	0.745
	16	1.052	1.301	1.000	1.228	1.104	1.100	0.630	0.192	0.213	0.213	0.803
	17	1.052	1.301	1.000	1.159	1.104	1.100	0.630	0.192	0.220	0.213	0.797
	18	1.052	1.301	1.000	1.159	1.101	0.900	0.630	0.192	0.213	0.213	0.776
	19	1.052	1.301	1.000	1.159	1.101	0.900	0.630	0.192	0.213	0.213	0.776
	20	1.052	1.301	1.000	1.159	1.101	0.900	0.630	0.380	0.213	0.213	0.795
	21	1.052	1.304	1.000	1.159	1.101	0.900	0.630	0.380	0.337	0.213	0.808
	22	1.052	1.304	1.000	0.386	1.101	0.900	0.630	0.380	0.213	0.213	0.718
	23	1.050	1.304	1.000	1.159	1.101	0.900	0.630	0.290	1.007	0.213	0.865
	24	1.050	1.307	1.000	0.435	1.101	0.900	0.630	0.290	0.213	0.213	0.714
	25	1.052	1.309	1.000	1.159	1.101	0.900	0.630	0.290	0.213	0.213	0.787
	26	1.052	1.309	1.000	0.676	1.101	0.900	0.630	0.379	0.213	0.213	0.747
	27	1.054	1.309	1.000	1.159	1.101	0.900	0.630	0.379	0.213	0.581	0.833
	28	1.057	1.309	1.000	1.159	1.101	0.900	0.630	0.379	0.213	0.213	0.796
	29	1.057	1.312	1.000	1.159	1.101	0.900	0.630	0.379	0.213	0.213	0.796
	30	1.054	1.312	1.000	1.159	1.101	0.900	0.630	0.379	0.213	0.213	0.796
	31	1.054	1.309	1.000	1.159	1.101	0.900	0.630	0.378	0.213	0.213	0.796
Feb	1	1.052	1.304	1.000	1.159	1.101	0.900	0.630	0.378	0.213	0.213	0.795
	2	1.052	1.307	1.000	1.159	1.101	0.900	0.630	0.378	0.213	0.213	0.795
	3	1.052	1.307	1.000	1.159	1.101	0.900	0.630	0.378	0.213	0.213	0.795
	4	1.052	1.307	1.000	1.159	1.098	0.900	0.630	0.378	1.500	0.213	0.924
	5	1.052	1.307	1.000	1.159	1.098	0.900	0.630	0.476	0.213	0.213	0.805
	6	1.052	1.307	1.000	1.159	1.098	0.900	0.630	0.476	0.213	0.213	0.805
	7	1.052	1.307	1.000	1.165	1.098	0.900	0.630	1.092	0.561	0.213	0.902
	8	1.054	1.307	1.000	1.165	1.098	0.900	0.630	0.376	0.213	0.213	0.796
	9	1.054	1.307	1.000	1.165	1.098	0.900	0.630	0.376	0.213	0.213	0.796
	10	1.054	1.307	1.000	1.168	1.098	0.900	0.630	0.376	0.213	0.213	0.796
	11	1.054	1.307	1.233	1.168	1.098	0.900	0.630	0.376	0.213	0.213	0.819
	12	1.054	1.307	1.233	1.168	1.098	0.900	0.630	0.286	0.213	0.213	0.810
	13	1.052	1.304	1.233	1.168	1.098	0.900	0.630	0.375	0.603	0.213	0.858
	14	1.052	1.304	1.233	1.168	1.098	0.900	0.630	0.473	0.213	0.213	0.828
	15	1.052	1.304	1.233	1.168	1.012	0.900	0.630	0.190	0.213	0.213	0.791
	16	1.052	1.304	1.233	0.389	1.009	0.900	0.630	0.347	0.213	0.213	0.729
	17	1.052	1.304	1.230	0.462	1.009	0.900	0.630	0.347	0.213	0.213	0.736
	18	1.052	1.304	1.230	1.168	1.009	0.900	0.630	0.472	0.213	1.500	0.948
	19	1.052	0.000	0.847	1.168	1.009	0.900	0.630	0.472	0.213	0.213	0.650
	20	1.052	1.304	0.847	1.168	1.009	0.900	0.630	0.472	0.213	0.324	0.792
	21	1.052	1.304	0.847	1.168	1.009	0.900	0.630	0.186	0.213	0.213	0.752
	22	1.052	1.304	0.847	1.168	1.009	0.900	0.630	0.472	0.213	1.500	0.909
	23	1.052	1.304	0.847	1.168	1.009	0.900	0.630	0.370	0.213	0.526	0.802
	24	1.052	0.460	0.847	1.168	1.009	0.900	0.630	0.190	0.213	0.526	0.700
	25	0.000	0.000	0.847	1.168	1.009	0.900	0.630	0.472	0.213	1.500	0.674
	26	1.052	1.025	0.847	1.168	1.009	0.900	0.630	0.370	1.500	1.500	1.000
	27	1.052	0.547	0.847	1.168	1.009	0.900	0.630	1.450	0.213	0.971	0.879
	28	1.052	0.000	0.847	1.168	1.009	0.900	0.630	1.450	0.213	0.550	0.782

Date		Valve Flow										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Mar	1	1.052	0.000	0.847	1.171	1.009	0.900	0.630	1.450	1.500	0.350	0.891
	2	1.052	0.000	0.847	1.171	1.007	0.900	0.630	1.440	0.213	0.213	0.747
	3	1.052	0.000	0.847	1.171	1.007	0.900	0.630	1.440	0.213	0.745	0.800
	4	1.052	0.000	0.847	1.171	1.007	0.900	0.630	1.440	0.213	0.322	0.758
	5	1.052	0.000	0.847	1.171	1.000	0.900	0.630	1.440	0.213	0.218	0.747
	6	1.052	0.000	0.845	1.171	1.000	0.900	0.630	1.110	0.213	0.218	0.714
	7	1.052	0.000	0.845	1.171	1.000	0.900	0.630	1.440	0.213	0.218	0.747
	8	1.052	0.000	0.845	1.171	1.000	0.900	0.630	1.080	0.213	0.884	0.777
	9	1.052	0.000	0.845	1.171	1.000	0.900	0.630	1.440	0.213	0.213	0.746
	10	1.052	0.000	0.845	1.171	1.000	0.900	0.630	0.921	0.213	0.213	0.694
	11	1.052	0.000	0.845	1.171	1.000	0.900	0.630	1.440	0.243	0.213	0.749
	12	1.052	0.000	0.843	1.171	1.000	0.900	0.630	1.297	0.213	0.213	0.732
	13	1.052	0.000	0.843	1.171	1.000	0.900	0.800	0.187	0.213	0.213	0.638
	14	1.052	0.000	0.843	1.171	1.000	0.900	0.800	0.997	0.263	0.213	0.724
	15	1.052	0.000	0.843	1.171	1.000	0.900	0.800	0.186	0.913	0.213	0.708
	16	1.052	0.000	0.843	1.083	1.000	0.900	0.800	0.370	0.213	0.213	0.647
	17	1.052	0.000	0.841	1.083	1.000	0.900	0.800	0.180	0.213	0.213	0.628
	18	1.052	0.000	0.841	1.083	1.000	0.900	0.800	0.180	0.213	0.213	0.628
	19	1.052	0.000	0.841	1.083	1.000	0.900	0.800	0.828	0.213	0.213	0.693
	20	1.052	0.000	0.841	1.083	1.000	0.900	0.800	0.185	0.213	0.213	0.629
	21	1.052	0.000	0.841	1.083	1.000	0.900	0.800	0.185	0.213	0.213	0.629
	22	1.052	0.000	0.841	1.083	1.000	0.900	0.800	1.074	0.213	0.213	0.718
	23	1.052	0.000	0.841	1.083	1.000	0.900	0.800	0.185	0.636	0.213	0.671
	24	1.052	0.000	0.841	1.083	1.000	0.900	0.800	0.740	0.213	0.213	0.684
	25	1.052	0.000	0.841	1.083	1.000	0.900	0.800	0.185	1.500	0.213	0.757
	26	1.052	0.000	0.841	1.083	1.000	0.900	0.800	0.185	0.213	0.213	0.629
	27	1.052	0.000	0.841	1.083	1.000	0.900	0.800	0.994	0.213	0.213	0.710
	28	1.052	0.000	0.841	1.083	1.000	0.900	0.800	1.495	0.469	0.213	0.785
	29	1.052	0.000	0.841	1.083	1.000	0.900	0.800	0.184	0.213	0.213	0.629
	30	1.052	0.000	0.841	1.083	1.000	0.900	0.800	1.068	0.213	0.213	0.717
	31	1.052	0.000	0.841	1.083	1.000	0.900	0.800	0.465	0.213	0.864	0.722
Apr	1	1.052	0.000	0.833	1.083	1.000	0.900	0.800	0.738	0.369	0.213	0.699
	2	1.052	0.000	0.833	1.083	1.000	0.900	0.800	0.281	0.213	0.213	0.638
	3	1.052	0.000	0.833	1.083	1.000	0.900	0.800	0.368	0.213	0.213	0.646
	4	1.052	0.000	0.833	1.083	1.000	0.900	0.800	0.281	0.213	0.496	0.666
	5	1.052	0.000	0.833	1.083	1.000	0.900	0.800	0.184	0.213	1.500	0.756
	6	1.052	0.000	0.833	1.083	1.000	0.900	0.800	0.184	0.213	0.746	0.681
	7	1.052	0.000	0.831	1.083	1.000	0.900	0.800	1.128	0.213	0.213	0.722
	8	1.052	0.000	0.831	1.083	1.000	0.900	0.800	0.462	0.213	1.305	0.765
	9	1.052	0.000	0.831	1.083	1.000	0.900	0.800	0.280	0.213	0.213	0.637
	10	1.052	0.000	0.831	1.083	1.000	0.900	0.800	0.985	0.213	0.213	0.708
	11	1.052	0.000	0.831	1.083	1.000	0.900	0.800	0.819	0.256	0.213	0.695
	12	1.052	0.000	0.828	1.083	1.000	0.900	0.800	0.239	0.213	0.213	0.633
	13	1.052	0.000	0.828	1.083	1.000	0.900	0.800	0.213	0.213	0.213	0.630
	14	1.050	0.000	0.828	1.083	1.000	0.900	0.800	0.213	0.213	0.213	0.630
	15	1.050	0.000	0.828	1.083	1.200	0.900	0.800	0.213	0.375	0.213	0.666
	16	1.050	0.000	0.828	1.083	1.200	0.900	0.800	0.213	0.213	0.213	0.650
	17	1.050	0.000	0.826	1.083	1.200	0.900	0.800	0.213	0.213	1.196	0.748
	18	1.050	0.000	0.826	1.083	1.200	0.900	1.100	0.213	1.500	0.257	0.813
	19	1.050	0.000	0.826	1.083	1.200	0.900	1.100	0.213	1.500	0.257	0.813
	20	1.050	0.000	0.826	1.083	1.200	0.900	1.100	0.672	1.500	0.257	0.859
	21	1.050	0.000	0.826	1.083	1.200	0.900	1.100	0.213	1.500	0.491	0.836
	22	1.050	0.000	0.826	1.083	1.200	0.900	1.100	0.213	1.500	0.213	0.808
	23	1.050	0.000	0.826	1.085	1.200	0.900	1.100	0.213	1.500	0.213	0.809
	24	1.050	0.000	0.826	1.085	1.200	0.900	1.100	0.213	1.500	0.213	0.809
	25	1.050	0.000	0.824	1.085	1.200	0.900	1.100	0.213	1.500	0.213	0.809
	26	1.050	0.000	0.824	1.085	1.200	0.900	1.100	0.213	1.500	0.428	0.830
	27	1.050	0.000	0.824	1.085	1.200	0.900	1.100	0.213	1.500	0.213	0.809
	28	1.050	0.000	0.824	1.088	1.200	0.900	1.100	0.213	1.500	1.117	0.899
	29	1.050	0.000	0.824	1.085	1.200	0.900	1.100	0.213	1.500	1.117	0.899
	30	1.050	0.000	0.824	1.085	1.200	0.900	1.100	0.213	0.787	0.234	0.739

Date		Valve Flow										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
May	1	1.050	0.000	0.822	1.085	1.200	0.900	1.100	0.213	0.787	0.678	0.784
	2	1.050	0.000	0.822	1.085	1.200	0.900	1.100	1.500	0.213	1.500	0.937
	3	1.050	0.000	0.822	1.088	1.200	0.900	1.100	1.500	1.014	0.213	0.889
	4	1.050	0.000	0.822	1.088	1.200	0.900	1.100	1.500	0.213	0.213	0.809
	5	1.050	0.000	0.822	1.088	1.200	0.900	1.100	1.500	0.213	0.213	0.809
	6	1.050	0.000	0.822	1.088	1.200	0.900	1.100	1.251	0.260	0.213	0.788
	7	1.050	0.000	0.820	1.088	1.200	0.900	1.100	1.392	0.844	0.213	0.861
	8	1.050	0.000	0.820	1.088	1.200	0.900	1.100	0.695	0.844	0.213	0.791
	9	1.050	0.000	0.820	1.088	1.200	0.900	1.100	0.686	0.844	0.213	0.790
	10	1.050	0.000	0.820	1.091	1.200	0.900	1.100	0.213	0.844	0.213	0.743
	11	1.050	0.000	0.820	1.179	1.200	0.900	1.100	0.213	0.337	0.213	0.701
	12	1.050	0.000	0.818	1.179	1.200	0.900	1.100	0.213	0.213	0.213	0.689
	13	1.048	0.000	0.818	1.179	1.200	1.530	1.200	0.213	0.394	0.213	0.780
	14	1.048	0.000	0.818	1.182	1.200	1.530	1.200	0.714	0.213	0.213	0.812
	15	1.048	0.000	0.818	1.182	1.200	1.530	1.200	0.213	0.213	0.213	0.762
	16	1.048	0.000	0.818	1.182	1.250	1.530	1.200	0.213	0.518	0.213	0.797
	17	1.048	0.000	0.816	1.182	1.250	1.530	1.200	0.213	0.213	0.213	0.766
	18	1.048	0.000	0.816	1.182	1.250	1.530	1.200	0.696	0.342	0.213	0.828
	19	1.048	0.000	0.816	1.182	1.250	1.530	1.200	1.500	0.213	1.082	0.982
	20	1.048	0.000	0.816	1.182	1.250	1.530	1.200	1.500	0.213	0.213	0.895
	21	1.048	0.000	0.816	1.185	1.250	1.530	1.200	1.500	0.213	0.213	0.895
	22	1.048	0.000	0.816	1.185	1.250	1.530	1.200	1.500	0.213	0.213	0.895
	23	1.048	0.000	0.814	1.185	1.250	1.530	1.200	1.500	0.213	0.213	0.895
	24	1.048	0.000	0.816	1.185	1.250	1.530	1.200	1.500	0.213	0.213	0.895
	25	1.048	0.000	0.816	1.185	1.250	1.530	1.200	1.500	0.574	0.213	0.932
	26	1.048	0.000	0.816	1.185	1.250	1.530	1.200	1.500	0.213	0.213	0.895
	27	1.048	0.000	0.816	1.188	1.250	1.530	1.200	1.500	0.213	0.213	0.896
	28	1.048	0.000	0.816	1.188	1.250	1.530	1.200	1.500	0.595	0.000	0.913
	29	1.048	0.000	0.814	1.188	1.250	1.530	1.200	1.500	1.399	0.000	0.993
	30	1.048	0.000	0.814	1.188	1.250	1.530	1.200	1.500	1.265	0.000	0.979
	31	1.048	0.000	0.814	1.188	1.250	1.530	1.200	1.500	1.500	0.000	1.003
Jun	1	1.045	0.000	0.814	1.188	1.250	1.530	1.200	1.500	1.383	0.000	0.991
	2	1.045	0.000	0.814	1.191	1.250	1.530	1.200	0.402	0.804	0.000	0.824
	3	1.045	0.000	0.814	1.191	1.250	1.530	1.200	0.664	0.851	0.000	0.854
	4	1.045	0.000	0.814	1.191	1.250	1.530	1.200	0.213	0.828	0.000	0.807
	5	1.045	0.000	0.814	1.191	1.250	1.530	1.200	1.500	0.273	0.000	0.880
	6	1.045	0.000	0.814	1.194	1.250	1.530	1.200	1.500	0.253	0.000	0.879
	7	1.045	0.000	0.814	1.194	1.250	1.530	1.200	1.500	0.213	0.000	0.875
	8	1.045	0.000	0.812	1.197	1.250	1.530	1.200	1.500	0.314	0.000	0.885
	9	1.045	0.000	0.812	1.197	1.250	1.530	1.200	1.500	0.213	0.000	0.875
	10	1.045	0.000	0.812	1.197	1.250	1.530	1.200	1.500	0.331	0.000	0.886
	11	1.045	0.000	0.812	1.197	1.250	1.530	1.200	1.500	0.407	0.000	0.894
	12	1.043	0.000	0.812	1.199	1.250	1.530	1.200	0.867	0.213	0.213	0.833
	13	1.043	0.000	0.812	1.199	1.250	1.530	1.200	0.213	0.428	1.500	0.917
	14	1.043	0.000	0.812	1.202	1.200	1.530	1.200	0.520	1.120	0.213	0.884
	15	1.045	0.000	0.812	1.202	1.200	1.530	1.200	1.500	1.218	0.213	0.992
	16	1.045	0.000	0.810	1.202	1.200	1.530	1.200	0.213	0.567	1.049	0.882
	17	1.045	0.000	0.810	1.202	1.200	1.530	1.200	0.213	0.233	0.213	0.765
	18	1.045	0.000	0.810	1.202	1.200	1.530	1.200	0.889	0.872	0.213	0.896
	19	1.045	0.000	0.810	1.202	1.200	1.530	1.200	0.231	0.898	0.530	0.865
	20	1.045	0.000	0.810	1.202	1.200	1.530	1.200	0.909	1.426	0.530	0.985
	21	1.048	0.000	0.810	1.202	1.200	1.530	1.200	0.213	1.500	1.374	1.008
	22	1.048	0.000	1.331	1.202	1.200	1.530	1.200	0.213	1.500	1.374	1.060
	23	1.048	0.000	1.247	1.202	1.200	1.530	1.200	1.126	1.500	1.374	1.143
	24	1.048	0.000	1.247	1.202	1.200	1.530	1.200	0.213	1.500	1.500	1.064
	25	1.048	0.000	1.243	1.202	1.200	1.530	1.200	0.213	1.500	1.500	1.064
	26	1.050	0.000	1.243	1.202	1.200	1.530	1.200	0.874	1.500	0.213	1.001
	27	1.050	0.000	1.243	1.202	1.200	1.530	1.200	1.500	1.500	0.213	1.064
	28	1.050	0.000	1.243	1.202	1.200	1.530	1.200	0.251	1.009	1.500	1.019
	29	1.050	0.000	1.243	1.202	1.200	1.530	1.200	1.500	0.987	0.584	1.050
	30	1.050	0.000	1.243	1.202	1.200	1.530	1.200	1.032	0.499	0.213	0.917

Date		Valve Flow										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Jul	1	1.050	0.000	1.243	1.202	1.200	1.530	1.200	0.342	1.500	0.429	0.970
	2	1.050	0.000	1.240	1.205	1.200	1.530	1.200	1.500	1.500	0.678	1.110
	3	1.048	0.000	1.240	1.205	1.200	1.530	1.200	1.500	1.500	0.213	1.064
	4	1.048	0.000	1.240	1.208	1.200	1.530	1.200	1.500	1.500	0.671	1.110
	5	1.048	0.000	1.240	1.211	1.200	1.530	1.200	0.213	1.500	0.213	0.935
	6	1.048	0.000	1.240	1.211	1.200	1.530	1.200	1.500	1.500	0.641	1.107
	7	1.048	1.000	1.240	1.211	1.200	1.530	0.000	1.500	1.500	0.213	1.044
	8	1.048	1.000	1.240	1.211	1.200	1.530	0.000	1.500	1.500	0.213	1.044
	9	1.048	1.000	1.237	1.211	1.200	1.530	0.000	1.500	1.500	0.213	1.044
	10	1.048	1.000	1.237	1.213	1.200	1.530	0.000	1.500	1.500	0.213	1.044
	11	1.048	1.000	1.237	1.213	1.200	1.530	0.000	1.500	1.500	0.213	1.044
	12	1.048	1.000	1.237	1.213	1.200	1.530	0.000	1.500	1.500	0.213	1.044
	13	1.048	1.000	1.237	1.213	1.200	1.360	0.000	1.500	1.500	0.213	1.027
	14	1.048	1.000	1.237	1.213	1.200	1.360	0.000	1.500	1.500	0.213	1.027
	15	1.048	1.000	1.237	1.213	1.200	1.360	0.000	1.500	0.213	0.521	0.929
	16	1.048	1.000	1.234	1.213	1.200	1.360	0.000	1.500	0.213	1.500	1.027
	17	1.048	1.000	1.234	1.213	1.200	1.360	0.000	1.500	0.213	0.213	0.898
	18	1.048	1.000	1.234	1.213	1.200	1.360	0.000	1.500	0.213	0.646	0.941
	19	1.045	1.000	1.234	1.216	1.200	1.360	0.000	1.500	0.213	1.300	1.007
	20	1.045	1.000	1.234	1.216	1.200	1.360	0.000	1.500	0.213	1.500	1.027
	21	1.045	1.000	1.234	1.216	1.200	1.360	0.000	1.500	0.213	1.500	1.027
	22	1.045	1.000	1.165	1.216	1.200	1.360	0.000	1.500	0.213	1.500	1.020
	23	1.045	1.000	1.165	1.216	1.200	1.360	0.000	1.500	0.213	1.500	1.020
	24	1.045	1.000	1.162	1.219	1.200	1.360	0.000	1.500	0.213	0.659	0.936
	25	1.045	1.000	1.162	1.219	1.200	1.360	0.000	1.500	0.213	1.500	1.020
	26	1.045	1.000	1.162	1.219	1.200	1.360	0.000	1.500	0.213	1.500	1.020
	27	1.045	1.000	1.162	1.219	1.200	1.360	0.000	1.500	0.213	1.500	1.020
	28	1.045	1.000	1.162	1.219	1.200	1.360	0.000	1.500	0.213	1.233	0.993
	29	1.045	1.000	1.162	1.219	1.200	1.360	0.000	1.500	0.213	0.585	0.928
	30	1.045	1.000	1.162	1.219	1.200	1.360	0.000	1.500	0.213	0.550	0.925
	31	1.045	1.000	1.159	1.219	1.200	1.360	0.000	1.500	0.213	0.213	0.891
Aug	1	1.043	1.000	1.159	1.219	1.200	1.360	0.000	1.500	0.213	0.213	0.891
	2	1.043	1.000	1.159	1.219	1.200	1.360	1.000	1.500	0.213	0.000	0.969
	3	1.043	1.000	1.159	1.219	1.200	1.360	1.000	1.500	0.213	0.000	0.969
	4	1.043	1.000	1.159	1.222	1.200	1.360	1.000	1.500	0.213	0.000	0.970
	5	1.043	1.000	1.159	1.222	1.200	1.360	1.000	1.500	0.213	0.000	0.970
	6	1.043	1.000	1.159	1.222	1.200	1.360	1.000	1.500	0.213	0.000	0.970
	7	1.043	1.000	1.159	1.222	1.200	1.360	1.000	1.500	0.213	0.000	0.970
	8	1.043	1.000	1.159	1.222	1.200	1.360	1.000	1.500	0.731	0.000	1.021
	9	1.043	1.000	1.156	1.222	1.200	1.360	1.000	1.500	0.213	0.000	0.969
	10	1.043	1.000	1.156	1.222	1.200	1.360	1.000	1.500	1.462	0.000	1.094
	11	1.043	1.000	1.156	1.222	1.200	1.360	1.000	1.500	1.500	0.000	1.098
	12	1.043	1.000	1.156	1.222	1.200	1.360	1.000	1.500	1.500	0.000	1.098
	13	1.043	1.000	1.156	1.222	1.200	1.360	0.950	1.500	1.500	0.000	1.093
	14	1.043	1.000	1.159	1.224	1.200	1.360	0.950	0.992	1.500	0.000	1.043
	15	1.043	1.000	1.159	1.224	1.200	1.360	0.950	1.500	1.500	0.000	1.094
	16	1.040	1.000	1.159	1.224	1.200	1.360	0.950	0.967	1.500	0.000	1.040
	17	1.040	1.000	1.159	1.227	1.200	0.000	0.950	1.500	1.500	0.000	0.958
	18	1.040	1.000	1.159	1.227	1.200	0.000	0.950	1.500	1.500	0.000	0.958
	19	1.040	1.000	1.159	1.227	1.200	0.000	0.950	1.500	1.500	0.000	0.958
	20	1.040	1.000	1.312	1.224	1.200	0.000	0.950	1.500	1.500	0.000	0.973
	21	1.040	1.000	1.312	1.224	1.200	0.000	0.950	1.500	1.500	0.000	0.973
	22	1.040	1.000	1.312	1.224	1.200	0.000	0.950	1.500	1.500	0.000	0.973
	23	1.040	1.000	1.312	1.227	1.200	1.300	0.950	1.500	1.500	0.000	1.103
	24	1.040	1.000	1.312	1.227	1.200	1.300	0.950	1.500	1.500	0.000	1.103
	25	1.040	1.000	1.312	1.230	1.200	1.300	0.950	1.500	1.500	0.000	1.103
	26	1.040	1.000	1.308	1.230	1.200	1.300	0.950	1.500	1.500	0.000	1.103
	27	1.038	1.000	1.308	1.230	1.200	1.300	0.950	1.500	1.500	0.000	1.103
	28	1.038	1.000	1.308	1.230	1.200	1.300	0.950	1.500	1.500	0.000	1.103
	29	1.038	1.000	1.308	1.230	1.200	1.300	0.950	1.500	1.500	0.000	1.103
	30	1.038	1.000	1.308	1.230	1.200	1.300	0.950	1.500	1.500	0.000	1.103
	31	1.038	1.000	1.308	1.230	1.200	1.300	0.950	1.500	1.500	0.000	1.103

Date		Valve Flow										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Sep	1	1.038	1.000	1.308	1.230	1.200	1.300	0.950	1.500	1.500	0.000	1.103
	2	1.038	1.000	1.308	1.227	1.200	1.300	0.950	1.500	0.816	0.000	1.034
	3	1.038	1.000	1.308	1.227	1.200	1.300	0.950	1.500	1.500	0.000	1.102
	4	1.038	1.000	1.308	1.227	1.200	1.300	0.950	1.500	1.500	0.000	1.102
	5	1.038	1.000	1.305	1.224	1.200	1.300	0.950	1.500	1.500	0.000	1.102
	6	1.038	1.000	1.305	1.224	1.200	1.300	0.950	1.500	0.887	0.000	1.040
	7	1.038	1.000	1.305	1.224	1.200	1.300	0.950	1.500	0.213	0.000	0.973
	8	1.038	1.000	1.305	1.222	1.200	1.300	0.950	1.500	0.213	0.000	0.973
	9	1.036	1.000	1.305	1.222	1.200	1.300	0.950	1.500	0.213	0.000	0.973
	10	1.036	1.000	1.305	1.222	1.200	0.000	0.950	0.000	0.213	0.000	0.693
	11	1.036	1.000	1.305	1.222	0.000	1.300	0.950	1.500	0.000	0.000	0.831
	12	1.036	1.000	1.305	1.222	1.200	1.300	0.950	1.500	0.213	0.000	0.973
	13	1.036	1.000	1.305	1.222	1.200	1.300	0.950	1.500	0.213	0.000	0.973
	14	1.036	1.000	1.305	1.222	1.200	1.300	0.950	1.500	0.213	0.000	0.973
	15	1.036	1.000	1.305	1.222	1.200	1.300	0.950	1.500	0.213	0.000	0.973
	16	1.036	1.000	1.305	1.222	1.200	1.300	0.950	1.500	0.213	0.000	0.973
	17	1.036	1.000	1.302	1.222	1.200	1.300	0.950	0.791	0.213	0.000	0.901
	18	1.036	1.000	1.302	1.222	1.200	1.300	0.950	1.500	0.213	0.000	0.972
	19	1.033	1.000	1.302	1.222	1.200	1.300	0.950	1.500	1.500	0.000	1.101
	20	1.033	1.000	1.302	1.222	1.200	1.300	0.950	1.500	1.500	0.000	1.101
	21	1.033	1.000	1.302	1.222	1.200	1.300	0.950	1.500	1.500	0.000	1.101
	22	1.033	1.000	1.302	0.000	1.200	1.300	0.950	1.500	1.500	0.000	0.979
	23	1.033	1.000	1.302	1.222	1.200	1.300	0.950	1.500	1.500	0.000	1.101
	24	1.033	1.000	1.302	1.222	1.200	1.300	0.950	0.213	1.500	0.000	0.972
	25	1.033	1.000	1.302	1.222	1.200	1.300	0.950	1.500	1.500	0.000	1.101
	26	1.033	1.000	1.302	1.222	1.200	1.300	0.950	1.500	1.500	0.000	1.101
	27	1.033	1.000	1.299	1.222	1.200	1.300	0.950	1.500	1.500	0.000	1.100
	28	1.033	1.000	1.299	1.222	1.200	1.300	0.950	1.417	1.500	0.000	1.092
	29	1.033	1.000	1.299	1.219	1.200	1.300	0.950	0.718	1.500	0.000	1.022
	30	1.033	1.000	1.315	1.219	1.200	1.300	0.950	0.619	1.500	0.000	1.014
Oct	1	1.033	1.000	1.318	1.219	1.200	1.300	0.950	0.624	1.500	0.000	1.014
	2	1.033	1.000	1.321	1.219	1.200	1.300	0.950	0.213	1.500	0.000	0.974
	3	1.033	1.000	1.321	1.219	1.200	1.300	0.950	0.869	1.500	0.000	1.039
	4	1.031	1.000	1.321	1.219	1.200	1.300	0.950	0.233	1.500	0.000	0.975
	5	1.031	1.000	1.321	1.219	1.200	1.300	0.950	0.712	1.500	0.000	1.023
	6	1.031	1.000	1.321	1.219	1.200	1.300	0.950	0.300	1.500	0.000	0.982
	7	1.031	1.000	1.321	1.219	1.200	1.300	0.950	0.377	1.500	0.000	0.990
	8	1.031	1.000	1.321	1.219	1.200	1.300	0.950	0.353	1.500	0.000	0.987
	9	1.031	1.000	1.321	1.219	1.200	1.300	0.950	0.271	1.500	0.000	0.979
	10	1.033	1.000	1.321	1.219	1.200	1.300	0.950	0.418	1.500	0.000	0.994
	11	1.036	1.000	1.321	1.219	1.200	1.300	0.950	1.139	1.162	0.000	1.033
	12	1.036	1.000	1.321	1.219	1.200	1.300	0.950	0.213	1.500	0.000	0.974
	13	1.036	1.000	1.321	1.219	1.250	1.300	0.950	0.213	1.500	0.000	0.979
	14	1.036	1.000	1.321	1.216	1.250	1.300	0.950	0.213	0.830	0.000	0.912
	15	1.036	1.000	1.321	1.216	1.250	1.300	0.950	0.213	0.213	0.000	0.850
	16	1.036	1.000	1.321	1.216	1.250	1.300	0.950	0.213	0.213	0.000	0.850
	17	1.036	1.000	1.321	1.216	1.250	1.300	0.950	0.678	0.596	0.000	0.935
	18	1.036	1.000	1.321	1.216	1.250	1.300	0.950	0.213	1.500	0.000	0.979
	19	1.036	1.000	1.321	1.216	1.250	1.300	0.950	0.213	1.107	0.000	0.939
	20	1.036	1.000	1.321	1.216	1.250	1.300	0.950	0.719	1.032	0.000	0.982
	21	1.036	1.000	1.318	1.216	1.250	1.300	0.950	0.213	0.213	0.000	0.850
	22	1.036	1.000	1.318	1.216	1.250	1.300	0.950	0.213	1.039	0.000	0.932
	23	1.036	1.000	1.318	1.216	1.250	1.300	0.950	0.478	1.500	0.000	1.005
	24	1.036	1.000	1.318	1.036	1.250	1.300	0.950	1.314	0.376	0.000	0.958
	25	1.036	1.000	1.318	1.036	1.250	1.300	0.950	1.500	0.542	0.000	0.993
	26	1.038	1.000	1.318	1.036	1.250	1.300	0.950	1.500	1.191	0.000	1.058
	27	1.038	1.000	1.318	1.036	1.250	1.300	0.950	1.500	0.432	0.000	0.982
	28	1.038	1.000	1.315	1.036	1.250	1.300	0.950	1.500	0.213	0.000	0.960
	29	1.038	1.000	1.315	1.036	1.250	1.300	0.950	1.500	0.213	0.000	0.960
	30	1.038	1.000	1.315	1.036	1.250	1.300	0.950	1.391	0.213	0.000	0.949
	31	1.038	1.000	1.315	1.036	1.250	1.300	0.950	0.213	0.213	0.000	0.831

Date		Valve Flow										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Nov	1	1.038	1.000	1.315	1.036	1.250	1.300	0.950	1.500	0.213	0.000	0.960
	2	1.038	1.000	1.315	1.036	1.250	1.300	0.950	0.213	0.213	0.000	0.831
	3	1.040	1.000	1.315	1.033	1.250	1.300	0.950	0.213	0.213	0.000	0.831
	4	1.040	1.000	1.312	1.033	1.250	1.300	0.950	0.390	0.213	0.000	0.849
	5	1.040	1.000	1.392	1.033	1.250	1.300	0.950	0.213	0.213	0.000	0.839
	6	1.040	1.000	0.434	1.033	1.250	1.300	0.950	1.500	0.213	0.000	0.872
	7	1.040	1.000	1.388	1.033	1.250	1.300	0.950	0.213	0.213	0.000	0.839
	8	1.043	1.000	1.388	1.033	0.000	1.300	0.950	0.213	0.213	0.000	0.714
	9	1.043	1.000	1.388	1.036	0.000	1.300	0.950	1.299	0.213	0.000	0.823
	10	1.043	1.000	0.463	1.036	1.200	1.300	0.950	0.213	0.213	0.000	0.742
	11	1.043	1.000	0.000	1.036	1.200	1.200	0.950	0.293	0.213	0.000	0.693
	12	1.043	1.000	1.388	1.036	1.200	1.200	0.950	0.213	0.213	0.000	0.824
	13	1.043	1.000	1.388	1.036	1.200	1.200	0.950	0.519	0.213	0.000	0.855
	14	1.043	1.000	1.385	1.036	1.200	1.200	0.950	0.213	0.213	0.000	0.824
	15	1.043	1.000	1.385	1.036	1.200	1.200	0.950	0.213	0.213	0.000	0.824
	16	1.043	1.000	0.508	1.036	1.200	1.200	0.950	1.500	0.213	0.000	0.865
	17	1.043	1.000	1.222	0.937	1.200	1.200	0.950	0.213	1.500	0.000	0.926
	18	1.043	1.000	1.222	1.036	1.200	1.200	0.950	0.213	0.213	0.000	0.808
	19	1.045	1.000	1.222	1.036	1.200	1.200	0.950	0.537	0.213	0.000	0.840
	20	1.045	1.000	1.222	1.036	1.200	1.200	0.950	0.487	0.213	0.000	0.835
	21	1.045	1.000	1.222	1.036	1.200	1.200	0.950	0.296	0.213	0.000	0.816
	22	1.045	1.000	1.219	1.036	1.200	1.200	0.950	0.806	0.213	0.000	0.867
	23	1.045	1.000	1.219	1.036	1.200	1.200	0.950	1.416	0.213	0.000	0.928
	24	1.048	1.000	1.219	1.036	1.200	1.200	0.950	0.213	0.213	0.000	0.808
	25	1.048	1.000	1.219	1.033	1.200	1.200	0.950	0.858	0.213	0.000	0.872
	26	1.048	1.000	1.219	1.033	1.200	1.200	0.950	0.894	0.213	0.000	0.876
	27	1.048	1.000	1.219	1.033	1.200	1.200	0.950	0.625	0.213	0.000	0.849
	28	1.048	1.000	1.219	1.033	1.200	1.200	0.950	0.213	0.378	0.000	0.824
	29	1.048	1.000	1.219	1.033	1.200	1.200	0.950	0.718	0.213	0.000	0.858
	30	1.048	1.000	1.219	1.033	1.200	1.200	0.950	0.715	0.213	0.000	0.858
Dec	1	1.048	1.000	1.219	1.033	1.200	1.200	0.950	0.785	0.213	0.000	0.865
	2	1.048	1.000	1.219	1.033	1.200	1.200	0.950	0.213	0.645	0.000	0.851
	3	1.048	1.000	1.219	1.031	1.200	1.200	0.950	1.484	0.213	0.000	0.934
	4	1.048	1.000	1.219	1.031	1.200	1.200	0.950	0.758	0.213	0.000	0.862
	5	1.048	1.000	1.219	1.031	1.200	1.200	0.950	0.213	0.213	0.000	0.807
	6	1.048	1.000	1.222	1.031	1.200	1.200	0.950	0.757	0.213	0.000	0.862
	7	1.048	1.000	1.222	1.031	1.200	1.200	0.950	0.213	0.213	0.000	0.808
	8	1.048	1.000	1.222	1.031	1.200	1.200	0.950	1.500	0.213	0.000	0.936
	9	1.048	1.000	1.222	1.031	1.200	1.200	0.950	0.276	0.213	0.000	0.814
	10	1.048	1.000	1.222	1.031	1.200	1.200	0.950	0.213	0.213	0.000	0.808
	11	1.048	1.000	1.222	1.031	1.200	1.200	0.950	0.943	0.213	0.000	0.881
	12	1.048	1.000	1.222	1.028	1.100	1.100	0.950	0.213	0.213	0.000	0.787
	13	1.048	1.000	1.222	1.028	1.100	1.100	0.950	0.219	0.213	0.000	0.788
	14	1.048	1.000	1.225	1.028	1.100	1.100	0.950	0.359	0.213	0.000	0.802
	15	1.045	1.000	1.225	1.028	1.100	1.100	0.950	0.275	0.213	0.000	0.794
	16	1.045	1.000	1.225	1.028	1.100	1.100	0.950	0.275	0.213	0.000	0.794
	17	1.045	1.000	1.225	0.524	1.100	1.100	0.950	0.213	0.213	0.000	0.737
	18	1.045	1.000	1.225	0.524	1.100	1.100	0.950	0.213	0.213	0.000	0.737
	19	1.045	1.000	1.225	0.523	1.100	1.100	0.950	0.218	0.213	0.000	0.737
	20	1.045	1.000	1.225	0.523	1.100	1.100	0.950	0.213	0.213	0.000	0.737
	21	1.045	1.000	1.225	0.523	1.100	1.100	0.950	0.353	0.213	0.000	0.751
	22	1.045	1.000	1.225	0.523	1.100	1.100	0.950	0.213	0.213	0.000	0.737
	23	1.045	1.000	1.225	0.523	1.100	1.100	0.950	0.213	0.213	0.000	0.737
	24	1.045	1.000	1.225	0.523	1.100	1.100	0.950	1.006	0.213	0.000	0.816
	25	1.045	1.000	1.225	0.522	1.100	1.100	0.950	0.677	0.307	0.000	0.793
	26	1.045	1.000	1.225	0.522	1.100	1.100	0.950	0.213	0.968	0.000	0.812
	27	1.045	1.000	1.225	0.522	1.100	1.100	0.950	0.213	0.213	0.000	0.737
	28	1.045	1.000	1.225	0.522	1.100	1.100	0.950	0.991	0.213	0.000	0.815
	29	1.301	1.000	1.225	0.522	1.100	1.100	0.950	0.213	0.213	0.000	0.762
	30	1.301	1.000	1.225	0.522	1.100	1.100	0.950	0.213	0.213	0.000	0.762
	31	1.301	1.000	1.228	0.521	1.100	1.100	0.950	0.213	0.213	0.000	0.763
Max		1.301	1.312	1.392	1.230	1.250	1.530	1.200	1.500	1.500	1.500	1.143
Min		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.628

(3) Metolong Dam

Chart of Discharge Flow Volume for Metolong dam

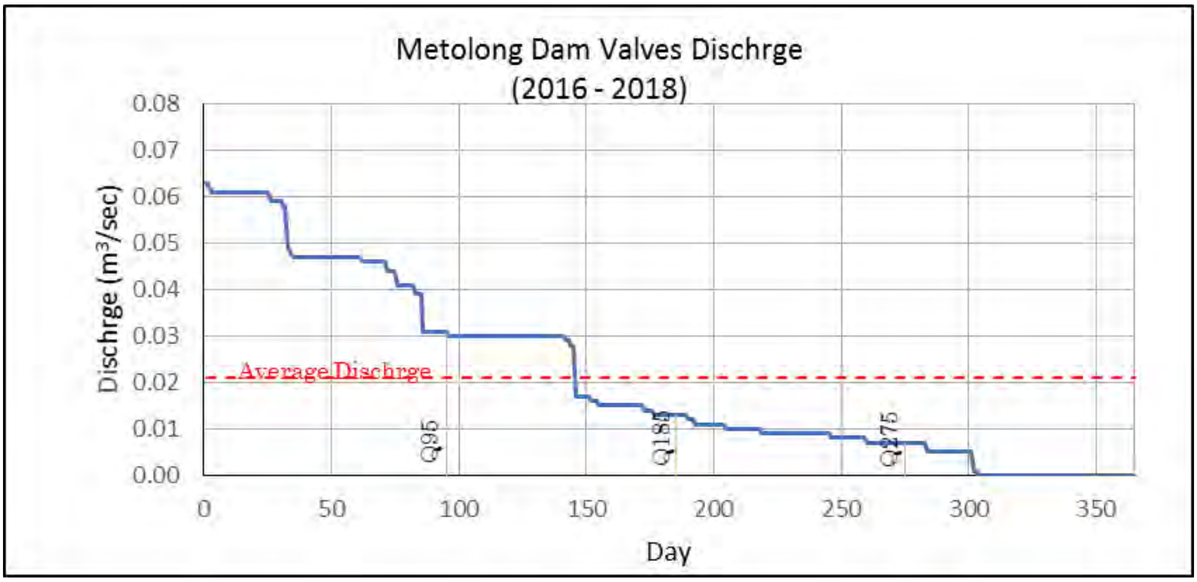
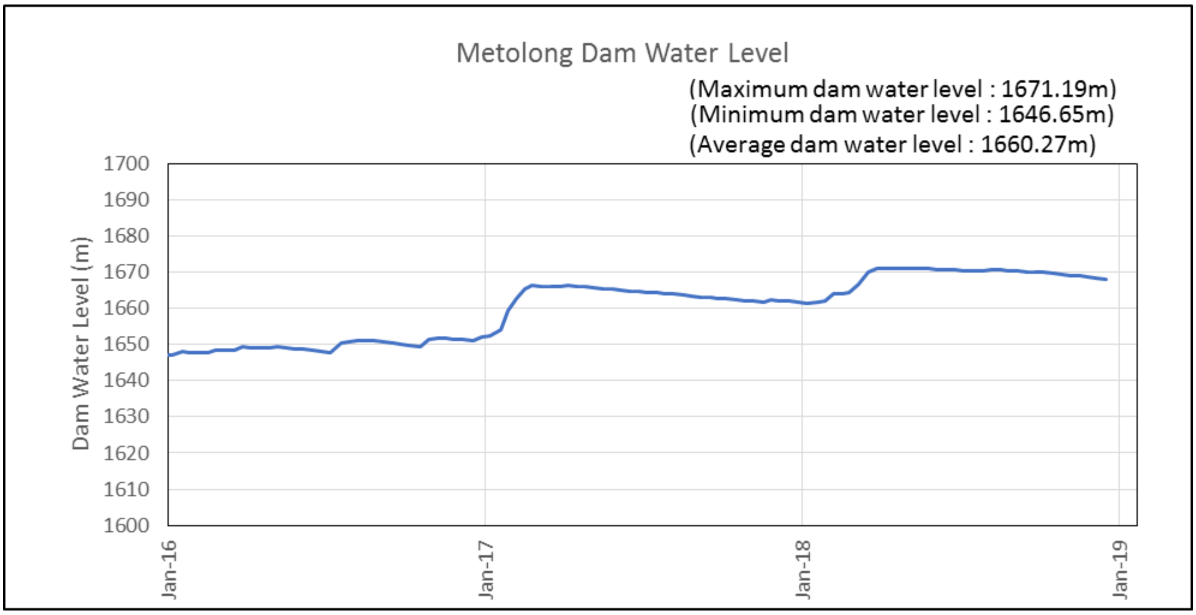


Chart of Water Level for Metolong Dam



Statistics of Discharge Flow Volume for Metolong Dam

Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)	Rank	Dischrge (m^3/sec)
1	0.063	56	0.047	111	0.030	166	0.015	221	0.009	276	0.007	331	0.000
2	0.062	57	0.047	112	0.030	167	0.015	222	0.009	277	0.007	332	0.000
3	0.061	58	0.047	113	0.030	168	0.015	223	0.009	278	0.007	333	0.000
4	0.061	59	0.047	114	0.030	169	0.015	224	0.009	279	0.007	334	0.000
5	0.061	60	0.047	115	0.030	170	0.015	225	0.009	280	0.007	335	0.000
6	0.061	61	0.047	116	0.030	171	0.015	226	0.009	281	0.007	336	0.000
7	0.061	62	0.046	117	0.030	172	0.015	227	0.009	282	0.007	337	0.000
8	0.061	63	0.046	118	0.030	173	0.014	228	0.009	283	0.007	338	0.000
9	0.061	64	0.046	119	0.030	174	0.014	229	0.009	284	0.005	339	0.000
10	0.061	65	0.046	120	0.030	175	0.014	230	0.009	285	0.005	340	0.000
11	0.061	66	0.046	121	0.030	176	0.014	231	0.009	286	0.005	341	0.000
12	0.061	67	0.046	122	0.030	177	0.013	232	0.009	287	0.005	342	0.000
13	0.061	68	0.046	123	0.030	178	0.013	233	0.009	288	0.005	343	0.000
14	0.061	69	0.046	124	0.030	179	0.013	234	0.009	289	0.005	344	0.000
15	0.061	70	0.046	125	0.030	180	0.013	235	0.009	290	0.005	345	0.000
16	0.061	71	0.046	126	0.030	181	0.013	236	0.009	291	0.005	346	0.000
17	0.061	72	0.044	127	0.030	182	0.013	237	0.009	292	0.005	347	0.000
18	0.061	73	0.044	128	0.030	183	0.013	238	0.009	293	0.005	348	0.000
19	0.061	74	0.044	129	0.030	184	0.013	239	0.009	294	0.005	349	0.000
20	0.061	75	0.044	130	0.030	185	0.013	240	0.009	295	0.005	350	0.000
21	0.061	76	0.041	131	0.030	186	0.013	241	0.009	296	0.005	351	0.000
22	0.061	77	0.041	132	0.030	187	0.013	242	0.009	297	0.005	352	0.000
23	0.061	78	0.041	133	0.030	188	0.013	243	0.009	298	0.005	353	0.000
24	0.061	79	0.041	134	0.030	189	0.013	244	0.009	299	0.005	354	0.000
25	0.061	80	0.041	135	0.030	190	0.012	245	0.009	300	0.005	355	0.000
26	0.059	81	0.041	136	0.030	191	0.012	246	0.008	301	0.005	356	0.000
27	0.059	82	0.041	137	0.030	192	0.012	247	0.008	302	0.001	357	0.000
28	0.059	83	0.039	138	0.030	193	0.011	248	0.008	303	0.001	358	0.000
29	0.059	84	0.039	139	0.030	194	0.011	249	0.008	304	0.000	359	0.000
30	0.059	85	0.039	140	0.030	195	0.011	250	0.008	305	0.000	360	0.000
31	0.058	86	0.031	141	0.030	196	0.011	251	0.008	306	0.000	361	0.000
32	0.058	87	0.031	142	0.029	197	0.011	252	0.008	307	0.000	362	0.000
33	0.049	88	0.031	143	0.029	198	0.011	253	0.008	308	0.000	363	0.000
34	0.048	89	0.031	144	0.028	199	0.011	254	0.008	309	0.000	364	0.000
35	0.047	90	0.031	145	0.028	200	0.011	255	0.008	310	0.000	365	0.000
36	0.047	91	0.031	146	0.017	201	0.011	256	0.008	311	0.000		
37	0.047	92	0.031	147	0.017	202	0.011	257	0.008	312	0.000		
38	0.047	93	0.031	148	0.017	203	0.011	258	0.008	313	0.000		
39	0.047	94	0.031	149	0.017	204	0.011	259	0.008	314	0.000		
40	0.047	95	0.031	150	0.017	205	0.010	260	0.007	315	0.000		
41	0.047	96	0.030	151	0.017	206	0.010	261	0.007	316	0.000		
42	0.047	97	0.030	152	0.016	207	0.010	262	0.007	317	0.000		
43	0.047	98	0.030	153	0.016	208	0.010	263	0.007	318	0.000		
44	0.047	99	0.030	154	0.016	209	0.010	264	0.007	319	0.000		
45	0.047	100	0.030	155	0.015	210	0.010	265	0.007	320	0.000		
46	0.047	101	0.030	156	0.015	211	0.010	266	0.007	321	0.000		
47	0.047	102	0.030	157	0.015	212	0.010	267	0.007	322	0.000		
48	0.047	103	0.030	158	0.015	213	0.010	268	0.007	323	0.000		
49	0.047	104	0.030	159	0.015	214	0.010	269	0.007	324	0.000		
50	0.047	105	0.030	160	0.015	215	0.010	270	0.007	325	0.000		
51	0.047	106	0.030	161	0.015	216	0.010	271	0.007	326	0.000		
52	0.047	107	0.030	162	0.015	217	0.010	272	0.007	327	0.000		
53	0.047	108	0.030	163	0.015	218	0.010	273	0.007	328	0.000		
54	0.047	109	0.030	164	0.015	219	0.009	274	0.007	329	0.000		
55	0.047	110	0.030	165	0.015	220	0.009	275	0.007	330	0.000		

Discharge Flow Volume for Metolong Dam

Date		Valve Flow										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Jan	1	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	2	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	3	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	4	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	5	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	6	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	7	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	8	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	9	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	10	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	11	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	12	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	13	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	14	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	15	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	16	—	—	—	—	—	—	—	0.000	0.011	0.288	0.030
	17	—	—	—	—	—	—	—	0.000	0.011	0.061	0.007
	18	—	—	—	—	—	—	—	0.000	0.011	0.061	0.007
	19	—	—	—	—	—	—	—	0.000	0.011	0.061	0.007
	20	—	—	—	—	—	—	—	0.000	0.011	0.061	0.007
	21	—	—	—	—	—	—	—	0.000	0.011	0.061	0.007
	22	—	—	—	—	—	—	—	0.000	0.011	0.061	0.007
	23	—	—	—	—	—	—	—	0.000	0.011	0.061	0.007
	24	—	—	—	—	—	—	—	0.000	0.011	0.061	0.007
	25	—	—	—	—	—	—	—	0.000	0.011	0.000	0.001
	26	—	—	—	—	—	—	—	0.000	0.011	0.000	0.001
	27	—	—	—	—	—	—	—	0.000	0.011	0.121	0.013
	28	—	—	—	—	—	—	—	0.000	0.011	0.121	0.013
	29	—	—	—	—	—	—	—	0.000	0.011	0.121	0.013
	30	—	—	—	—	—	—	—	0.000	0.011	0.121	0.013
	31	—	—	—	—	—	—	—	0.000	0.011	0.121	0.013
Feb	1	—	—	—	—	—	—	—	0.000	0.011	0.298	0.031
	2	—	—	—	—	—	—	—	0.000	0.011	0.298	0.031
	3	—	—	—	—	—	—	—	0.000	0.011	0.298	0.031
	4	—	—	—	—	—	—	—	0.000	0.011	0.298	0.031
	5	—	—	—	—	—	—	—	0.000	0.011	0.298	0.031
	6	—	—	—	—	—	—	—	0.000	0.011	0.298	0.031
	7	—	—	—	—	—	—	—	0.000	0.011	0.298	0.031
	8	—	—	—	—	—	—	—	0.000	0.011	0.298	0.031
	9	—	—	—	—	—	—	—	0.000	0.011	0.298	0.031
	10	—	—	—	—	—	—	—	0.000	0.280	0.298	0.058
	11	—	—	—	—	—	—	—	0.000	0.280	0.298	0.058
	12	—	—	—	—	—	—	—	0.000	0.320	0.298	0.062
	13	—	—	—	—	—	—	—	0.000	0.330	0.298	0.063
	14	—	—	—	—	—	—	—	0.000	0.011	0.298	0.031
	15	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	16	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	17	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	18	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	19	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	20	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	21	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	22	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	23	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	24	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	25	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	26	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	27	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061
	28	—	—	—	—	—	—	—	0.000	0.315	0.298	0.061

Date		Valve Flow										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Mar	1	―	―	―	―	―	―	―	0.000	0.315	0.298	0.061
	2	―	―	―	―	―	―	―	0.000	0.315	0.298	0.061
	3	―	―	―	―	―	―	―	0.000	0.315	0.298	0.061
	4	―	―	―	―	―	―	―	0.000	0.315	0.298	0.061
	5	―	―	―	―	―	―	―	0.000	0.315	0.298	0.061
	6	―	―	―	―	―	―	―	0.000	0.315	0.298	0.061
	7	―	―	―	―	―	―	―	0.000	0.315	0.298	0.061
	8	―	―	―	―	―	―	―	0.000	0.315	0.298	0.061
	9	―	―	―	―	―	―	―	0.000	0.000	0.298	0.030
	10	―	―	―	―	―	―	―	0.000	0.000	0.298	0.030
	11	―	―	―	―	―	―	―	0.000	0.000	0.298	0.030
	12	―	―	―	―	―	―	―	0.000	0.315	0.298	0.061
	13	―	―	―	―	―	―	―	0.000	0.295	0.298	0.059
	14	―	―	―	―	―	―	―	0.000	0.295	0.298	0.059
	15	―	―	―	―	―	―	―	0.000	0.000	0.298	0.030
	16	―	―	―	―	―	―	―	0.000	0.000	0.298	0.030
	17	―	―	―	―	―	―	―	0.000	0.295	0.298	0.059
	18	―	―	―	―	―	―	―	0.000	0.295	0.298	0.059
	19	―	―	―	―	―	―	―	0.000	0.295	0.298	0.059
	20	―	―	―	―	―	―	―	0.000	0.184	0.298	0.048
	21	―	―	―	―	―	―	―	0.000	0.160	0.298	0.046
	22	―	―	―	―	―	―	―	0.000	0.160	0.298	0.046
	23	―	―	―	―	―	―	―	0.000	0.160	0.298	0.046
	24	―	―	―	―	―	―	―	0.000	0.160	0.298	0.046
	25	―	―	―	―	―	―	―	0.000	0.160	0.298	0.046
	26	―	―	―	―	―	―	―	0.000	0.160	0.298	0.046
	27	―	―	―	―	―	―	―	0.000	0.160	0.298	0.046
	28	―	―	―	―	―	―	―	0.000	0.160	0.298	0.046
	29	―	―	―	―	―	―	―	0.000	0.160	0.298	0.046
	30	―	―	―	―	―	―	―	0.000	0.140	0.298	0.044
	31	―	―	―	―	―	―	―	0.000	0.140	0.298	0.044
Apr	1	―	―	―	―	―	―	―	0.000	0.140	0.298	0.044
	2	―	―	―	―	―	―	―	0.000	0.140	0.298	0.044
	3	―	―	―	―	―	―	―	0.000	0.111	0.298	0.041
	4	―	―	―	―	―	―	―	0.000	0.111	0.298	0.041
	5	―	―	―	―	―	―	―	0.000	0.111	0.298	0.041
	6	―	―	―	―	―	―	―	0.000	0.111	0.298	0.041
	7	―	―	―	―	―	―	―	0.000	0.111	0.298	0.041
	8	―	―	―	―	―	―	―	0.000	0.111	0.298	0.041
	9	―	―	―	―	―	―	―	0.000	0.111	0.298	0.041
	10	―	―	―	―	―	―	―	0.000	0.111	0.000	0.011
	11	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	12	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	13	―	―	―	―	―	―	―	0.000	0.128	0.000	0.013
	14	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	15	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	16	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	17	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	18	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	19	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	20	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	21	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	22	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	23	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	24	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	25	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	26	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	27	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	28	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	29	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000
	30	―	―	―	―	―	―	―	0.000	0.000	0.000	0.000

Date		Valve Flow										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
May	1	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	2	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	3	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	4	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	5	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	6	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	7	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	8	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	9	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	10	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	11	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	12	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	13	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	14	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	15	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	16	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	17	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	18	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	19	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	20	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	21	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	22	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	23	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	24	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	25	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	26	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	27	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	28	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	29	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	30	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	31	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
Jun	1	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	2	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	3	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	4	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	5	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	6	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	7	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	8	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	9	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	10	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	11	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	12	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	13	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	14	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	15	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	16	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	17	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030
	18	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	19	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	20	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	21	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	22	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	23	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	24	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	25	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	26	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	27	—	—	—	—	—	—	—	0.000	0.000	0.000	0.000
	28	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005
	29	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005
	30	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005

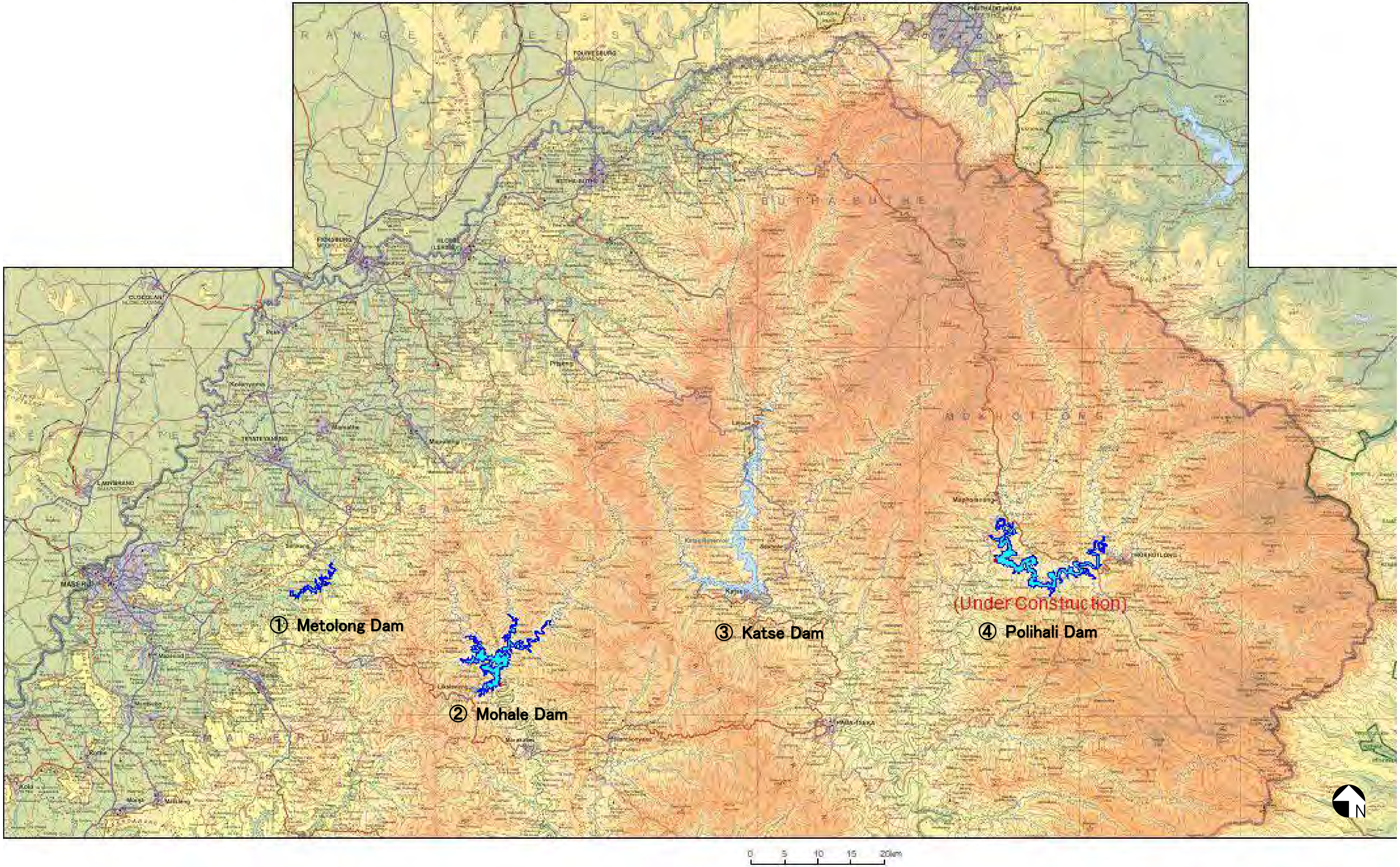
Date		Valve Flow										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Jul	1	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005
	2	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005
	3	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005
	4	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005
	5	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005
	6	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005
	7	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005
	8	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005
	9	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005
	10	—	—	—	—	—	—	—	0.000	0.000	0.052	0.005
	11	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	12	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	13	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	14	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	15	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	16	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	17	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	18	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	19	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	20	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	21	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	22	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	23	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	24	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	25	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	26	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	27	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	28	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	29	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	30	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	31	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
Aug	1	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	2	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	3	—	—	—	—	—	—	—	0.000	0.020	0.090	0.011
	4	—	—	—	—	—	—	—	0.000	0.020	0.090	0.011
	5	—	—	—	—	—	—	—	0.000	0.020	0.090	0.011
	6	—	—	—	—	—	—	—	0.000	0.020	0.090	0.011
	7	—	—	—	—	—	—	—	0.000	0.020	0.090	0.011
	8	—	—	—	—	—	—	—	0.000	0.020	0.090	0.011
	9	—	—	—	—	—	—	—	0.000	0.020	0.090	0.011
	10	—	—	—	—	—	—	—	0.000	0.020	0.090	0.011
	11	—	—	—	—	—	—	—	0.000	0.020	0.090	0.011
	12	—	—	—	—	—	—	—	0.000	0.020	0.090	0.011
	13	—	—	—	—	—	—	—	0.000	0.020	0.090	0.011
	14	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	15	—	—	—	—	—	—	—	0.000	0.000	0.090	0.009
	16	—	—	—	—	—	—	—	0.000	0.000	0.075	0.008
	17	—	—	—	—	—	—	—	0.000	0.000	0.075	0.008
	18	—	—	—	—	—	—	—	0.000	0.020	0.075	0.010
	19	—	—	—	—	—	—	—	0.000	0.020	0.075	0.010
	20	—	—	—	—	—	—	—	0.000	0.020	0.075	0.010
	21	—	—	—	—	—	—	—	0.000	0.020	0.075	0.010
	22	—	—	—	—	—	—	—	0.000	0.020	0.075	0.010
	23	—	—	—	—	—	—	—	0.000	0.020	0.075	0.010
	24	—	—	—	—	—	—	—	0.000	0.020	0.075	0.010
	25	—	—	—	—	—	—	—	0.000	0.020	0.075	0.010
	26	—	—	—	—	—	—	—	0.000	0.020	0.075	0.010
	27	—	—	—	—	—	—	—	0.000	0.020	0.075	0.010
	28	—	—	—	—	—	—	—	0.000	0.020	0.075	0.010
	29	—	—	—	—	—	—	—	0.000	0.020	0.075	0.010
	30	—	—	—	—	—	—	—	0.000	0.000	0.075	0.008
	31	—	—	—	—	—	—	—	0.000	0.000	0.300	0.030

Date		Valve Flow										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Sep	1	－	－	－	－	－	－	－	0.000	0.000	0.071	0.007
	2	－	－	－	－	－	－	－	0.000	0.000	0.071	0.007
	3	－	－	－	－	－	－	－	0.000	0.000	0.071	0.007
	4	－	－	－	－	－	－	－	0.000	0.000	0.051	0.005
	5	－	－	－	－	－	－	－	0.000	0.000	0.051	0.005
	6	－	－	－	－	－	－	－	0.000	0.000	0.051	0.005
	7	－	－	－	－	－	－	－	0.000	0.000	0.051	0.005
	8	－	－	－	－	－	－	－	0.000	0.000	0.051	0.005
	9	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	10	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	11	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	12	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	13	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	14	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	15	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	16	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	17	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	18	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	19	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	20	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	21	－	－	－	－	－	－	－	0.000	0.022	0.051	0.007
	22	－	－	－	－	－	－	－	0.006	0.022	0.051	0.008
	23	－	－	－	－	－	－	－	0.006	0.022	0.051	0.008
	24	－	－	－	－	－	－	－	0.061	0.022	0.051	0.013
	25	－	－	－	－	－	－	－	0.061	0.022	0.051	0.013
	26	－	－	－	－	－	－	－	0.061	0.022	0.051	0.013
	27	－	－	－	－	－	－	－	0.063	0.022	0.051	0.014
	28	－	－	－	－	－	－	－	0.052	0.022	0.051	0.013
	29	－	－	－	－	－	－	－	0.055	0.022	0.051	0.013
	30	－	－	－	－	－	－	－	0.052	0.022	0.051	0.013
Oct	1	－	－	－	－	－	－	－	0.054	0.022	0.051	0.013
	2	－	－	－	－	－	－	－	0.052	0.022	0.064	0.014
	3	－	－	－	－	－	－	－	0.052	0.022	0.064	0.014
	4	－	－	－	－	－	－	－	0.053	0.044	0.064	0.016
	5	－	－	－	－	－	－	－	0.062	0.044	0.064	0.017
	6	－	－	－	－	－	－	－	0.065	0.044	0.064	0.017
	7	－	－	－	－	－	－	－	0.066	0.044	0.064	0.017
	8	－	－	－	－	－	－	－	0.063	0.022	0.064	0.015
	9	－	－	－	－	－	－	－	0.067	0.022	0.064	0.015
	10	－	－	－	－	－	－	－	0.064	0.022	0.064	0.015
	11	－	－	－	－	－	－	－	0.060	0.022	0.064	0.015
	12	－	－	－	－	－	－	－	0.060	0.022	0.064	0.015
	13	－	－	－	－	－	－	－	0.064	0.022	0.064	0.015
	14	－	－	－	－	－	－	－	0.062	0.022	0.064	0.015
	15	－	－	－	－	－	－	－	0.059	0.022	0.000	0.008
	16	－	－	－	－	－	－	－	0.061	0.022	0.000	0.008
	17	－	－	－	－	－	－	－	0.063	0.022	0.000	0.009
	18	－	－	－	－	－	－	－	0.060	0.022	0.000	0.008
	19	－	－	－	－	－	－	－	0.062	0.022	0.000	0.008
	20	－	－	－	－	－	－	－	0.060	0.022	0.000	0.008
	21	－	－	－	－	－	－	－	0.060	0.022	0.000	0.008
	22	－	－	－	－	－	－	－	0.059	0.022	0.000	0.008
	23	－	－	－	－	－	－	－	0.063	0.022	0.000	0.009
	24	－	－	－	－	－	－	－	0.060	0.022	0.000	0.008
	25	－	－	－	－	－	－	－	0.060	0.022	0.000	0.008
	26	－	－	－	－	－	－	－	0.061	0.022	0.064	0.015
	27	－	－	－	－	－	－	－	0.058	0.022	0.064	0.014
	28	－	－	－	－	－	－	－	0.060	0.022	0.064	0.015
	29	－	－	－	－	－	－	－	0.059	0.022	0.064	0.015
	30	－	－	－	－	－	－	－	0.061	0.022	0.064	0.015
	31	－	－	－	－	－	－	－	0.059	0.022	0.064	0.015

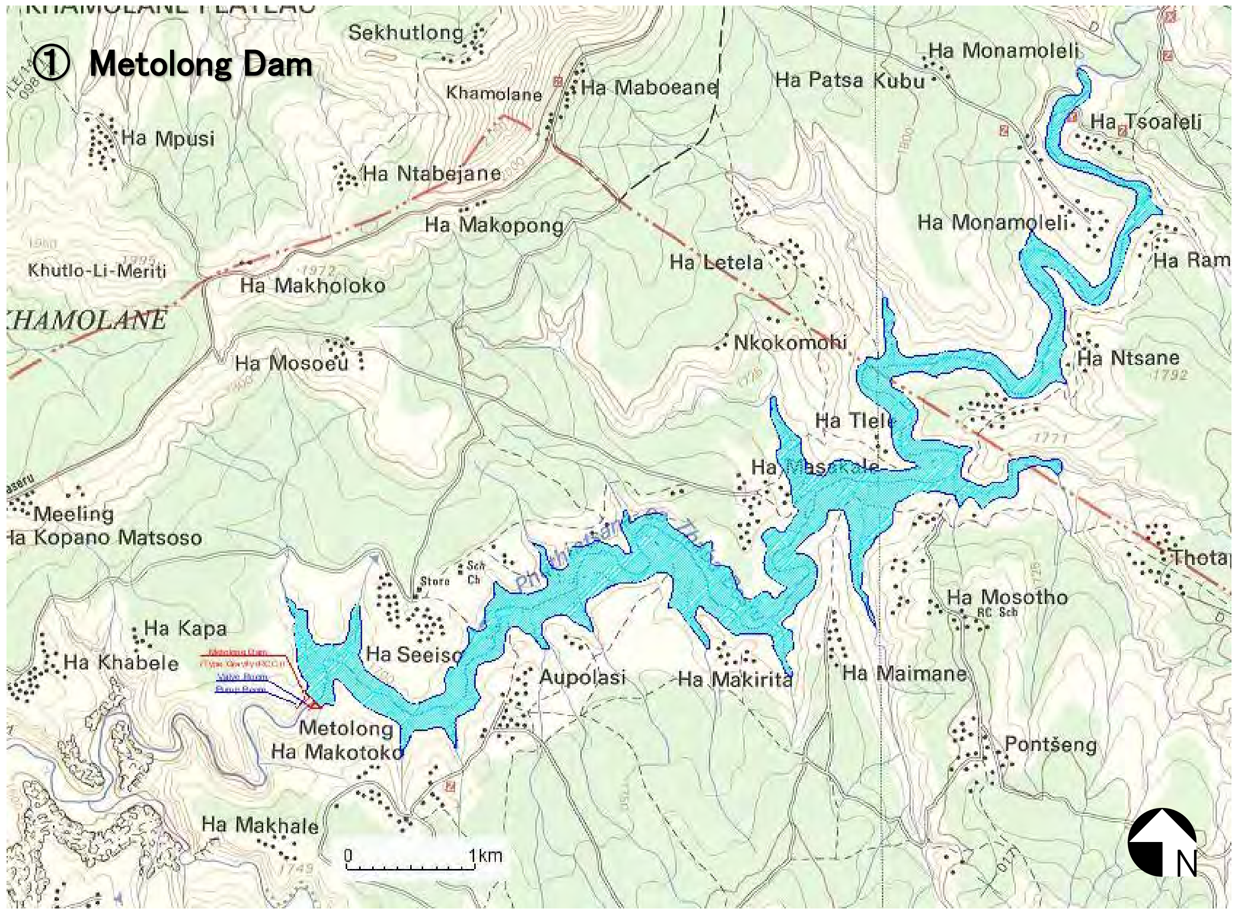
Date		Valve Flow										Average
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	
Nov	1	—	—	—	—	—	—	—	0.031	0.022	0.064	0.012
	2	—	—	—	—	—	—	—	0.030	0.022	0.064	0.012
	3	—	—	—	—	—	—	—	0.030	0.022	0.064	0.012
	4	—	—	—	—	—	—	—	0.010	0.022	0.064	0.010
	5	—	—	—	—	—	—	—	0.011	0.022	0.064	0.010
	6	—	—	—	—	—	—	—	0.010	0.022	0.120	0.015
	7	—	—	—	—	—	—	—	0.011	0.022	0.120	0.015
	8	—	—	—	—	—	—	—	0.010	0.022	0.120	0.015
	9	—	—	—	—	—	—	—	0.012	0.022	0.120	0.015
	10	—	—	—	—	—	—	—	0.015	0.022	0.120	0.016
	11	—	—	—	—	—	—	—	0.012	0.022	0.120	0.015
	12	—	—	—	—	—	—	—	0.016	0.022	0.120	0.016
	13	—	—	—	—	—	—	—	0.012	0.022	0.120	0.015
	14	—	—	—	—	—	—	—	0.014	0.040	0.120	0.017
	15	—	—	—	—	—	—	—	0.015	0.148	0.120	0.028
	16	—	—	—	—	—	—	—	0.016	0.148	0.120	0.028
	17	—	—	—	—	—	—	—	0.018	0.148	0.120	0.029
	18	—	—	—	—	—	—	—	0.018	0.148	0.120	0.029
	19	—	—	—	—	—	—	—	0.021	0.148	0.000	0.017
	20	—	—	—	—	—	—	—	0.020	0.148	0.000	0.017
	21	—	—	—	—	—	—	—	0.023	0.148	0.131	0.030
	22	—	—	—	—	—	—	—	0.019	0.148	0.131	0.030
	23	—	—	—	—	—	—	—	0.021	0.148	0.131	0.030
	24	—	—	—	—	—	—	—	0.022	0.148	0.131	0.030
	25	—	—	—	—	—	—	—	0.019	0.148	0.131	0.030
	26	—	—	—	—	—	—	—	0.020	0.148	0.131	0.030
	27	—	—	—	—	—	—	—	0.018	0.148	0.131	0.030
	28	—	—	—	—	—	—	—	0.019	0.148	0.131	0.030
	29	—	—	—	—	—	—	—	0.023	0.148	0.131	0.030
	30	—	—	—	—	—	—	—	0.010	0.246	0.131	0.039
Dec	1	—	—	—	—	—	—	—	0.010	0.246	0.131	0.039
	2	—	—	—	—	—	—	—	0.010	0.246	0.131	0.039
	3	—	—	—	—	—	—	—	0.010	0.246	0.208	0.046
	4	—	—	—	—	—	—	—	0.035	0.246	0.208	0.049
	5	—	—	—	—	—	—	—	0.015	0.246	0.208	0.047
	6	—	—	—	—	—	—	—	0.014	0.246	0.208	0.047
	7	—	—	—	—	—	—	—	0.014	0.246	0.208	0.047
	8	—	—	—	—	—	—	—	0.015	0.246	0.208	0.047
	9	—	—	—	—	—	—	—	0.014	0.246	0.208	0.047
	10	—	—	—	—	—	—	—	0.012	0.246	0.208	0.047
	11	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	12	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	13	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	14	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	15	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	16	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	17	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	18	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	19	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	20	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	21	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	22	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	23	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	24	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	25	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	26	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	27	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	28	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	29	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	30	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
	31	—	—	—	—	—	—	—	0.011	0.246	0.208	0.047
Max		—	—	—	—	—	—	—	0.067	0.330	0.300	0.063
Min		—	—	—	—	—	—	—	0.000	0.000	0.000	0.000

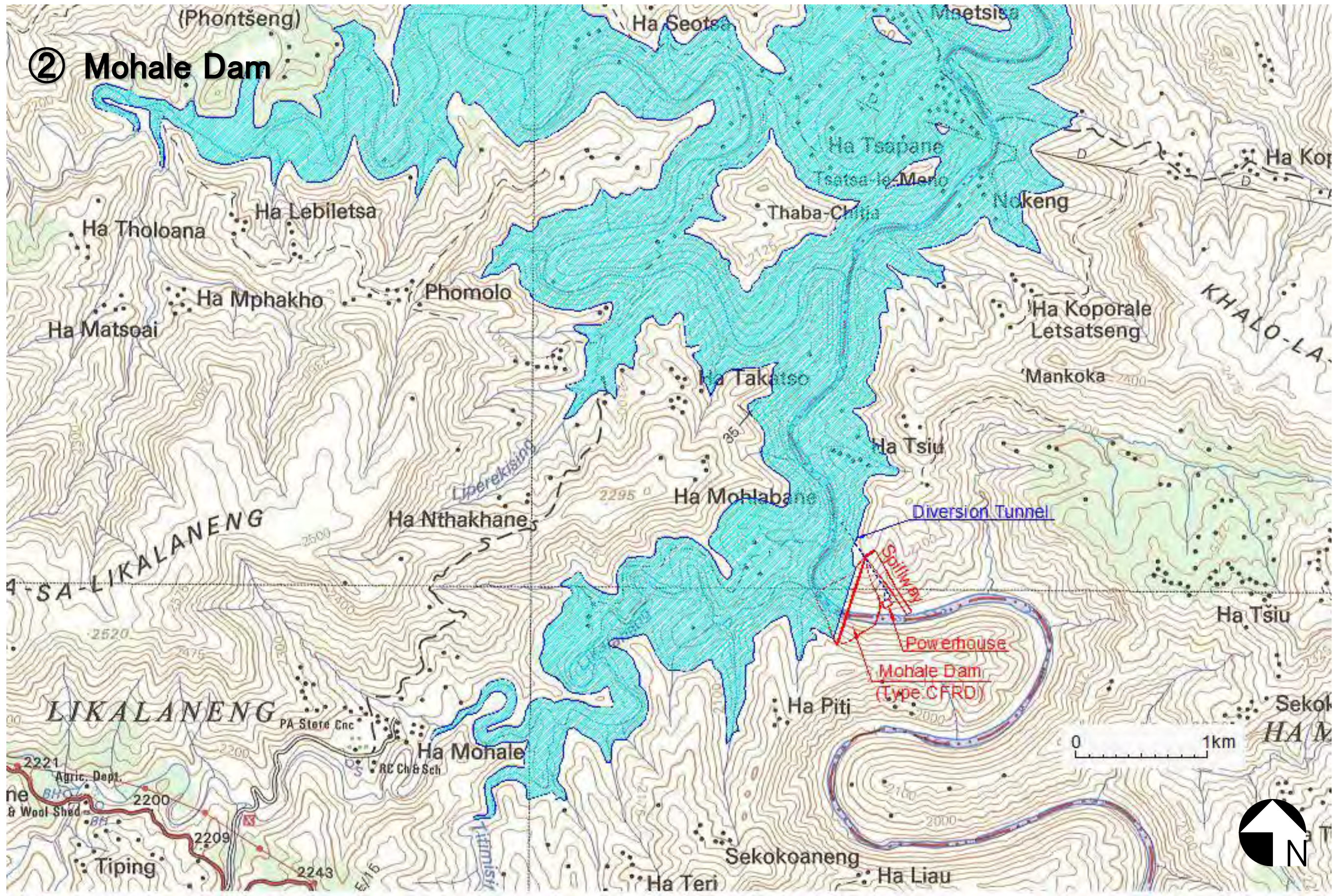
Appendix-11 PROJECT CANDIDATE SITE MAP

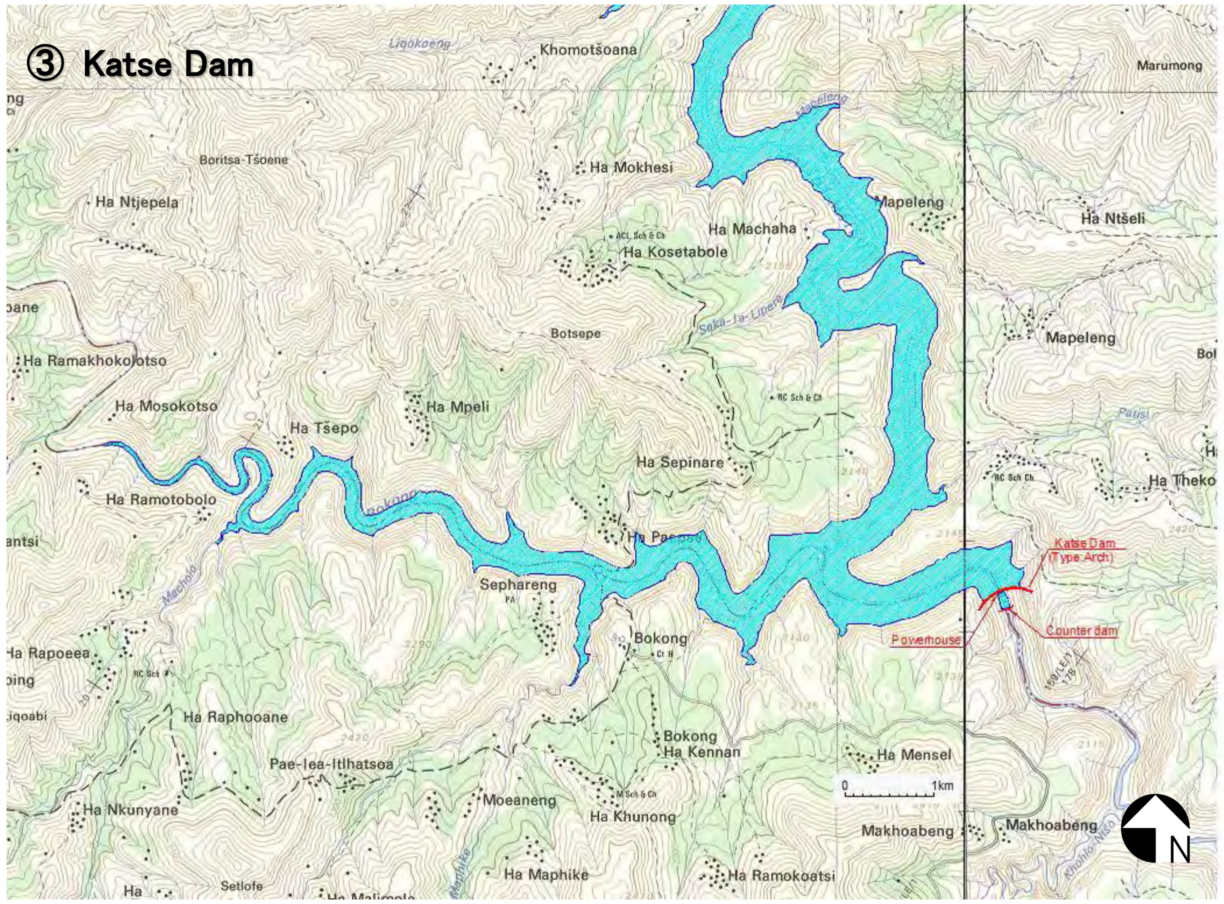
Appendix-11 Project Candidate Site Map

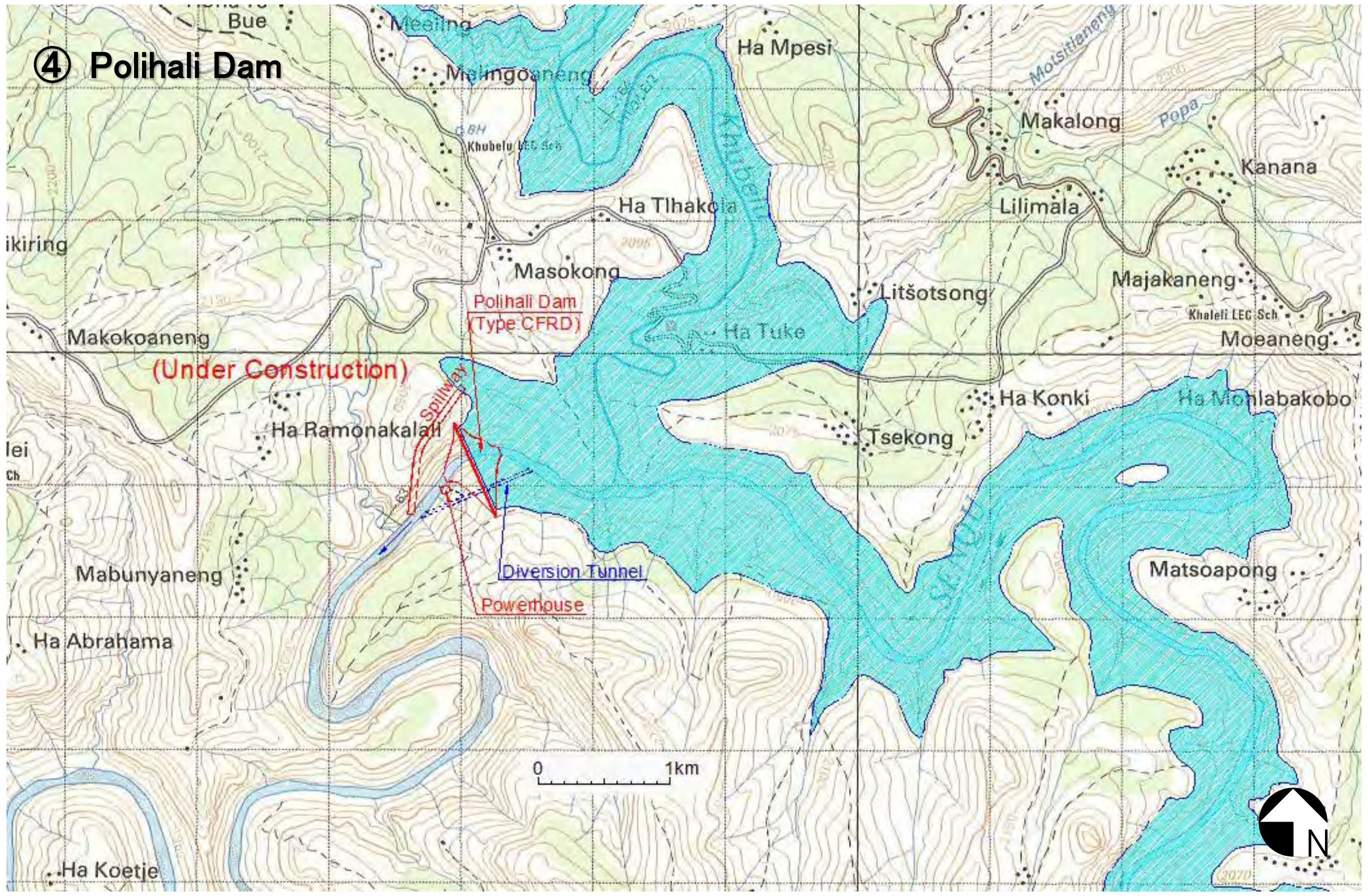


Project Candidate Site Map









Detail Maps of Project candidate site