Philippines
Department of Energy

Feasbility Study on WAWA River Mini-hydro Power Project in the Province of Agusan Del Sur, The Republic of the Pilippines （PPP Infrastructure Project）

Final Report

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Japan International Cooperation Agency（JICA）

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List of Abbreviations

Abbreviation	Official Name / Term
ADB	Asian Development Bank
ANECO	Agusan del Norte Erectric cooperative,Inc.
APPROVED CADTs	Certificate of Ancestral Domain Titles
ASEAN	Association of South East Asian Nations
ASELCO	Agusan del Sur Erectric Cooperative,Inc.
BOI	The Board of Investment
BOT	Build-Operate-Transfer Law
BPO	Business Process Outsourcing
BPAP	Business Processing Association of the Philippines
BSP	Bangko Sentral ng Pilipinas
CADT	Certificate Of Ancestral Domain Title
CBFM	Community Based Forest Management
CENRO	Community Environment and Natural Resource Office
CPI	Consumer Price Index
DBP	Development Bank of the Philippines
DENR	Department of Environmental and Natural Resources
DNA	Designated National Authority
DOE	Department of Energy
DPWH	Department of Public Works and Highways
ECA	Environmentally Critical Areas
ECC	Environmental Compliance Certificates
ECP	Environmentally Critical Projects
EDP	Environmental Development Project
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
EIRR	Economic Internal Rate of Retern
EPIRA	Electric Power. Industry Restructuring ACT
EMB	Environmental Management Bureau
ERC	Energy Regulatory Commision
FPIC	Free, Prior and Informed Concent
FIT	Feed-in Tariff
FIRR	Financial Internal Rate of Retern
FS	Feasibility Study
GDP	Gross Domestic Product
GIS	Geographic Information System

GOCC	Government Owned and Controlled Corporation
IEE	Initial Environmental Examination
IPP	Independent Power Producer
IPRA	Indigenous People's Rights Act
JBIC	Japan Bank for International Cooperation
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
KBA	Key Biodiversity Area
MinDa	Mindanao Development Authority
MOA	Memorandum of Agreement
MW	Megawatt
NAMRIA	National Mapping and Resources Information Authority
NCIP	National Commission on Indegenous Peoples
NEA	National Electrification Administration
NEDA	National Economic and Development Authority
NGCP	National Grid Power Corporation
NIPAS	National Integrated Protected Area System
NPC	National Power Corporation
NPV	Net Present Value
NREB	National Renewable Energy Board
NSCB	National Statistical Coordination Board
NSO	National Statistics Office
NWRB	National Water resources Board
OECD	Organization for Economic Cooperation and Development
PAGASA	The Philippine Atmospheric, Geophysical and Astronomical Services Administration
PAPs	Project Affected Peoples
PEISS	Philippine Environmental Impact Statement System
PENRO	Provincial Environment and Natural Resource Office
Phivolcs	the Philippine Institute of Volcanology and Seismology
PHP	Philippine Peso
PINAI	Philippines Investment Alliance for Infrastructure
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PSE	Philippine Stock Exchange
SCF	Standard Conversion Factor
SIOPAO	System Information of Provincial Agriculture Office
SPC	Special Purpose Company
TRANSCO	National Transmission Corporation

UNCTAD	United Nation Conference on Trade and Development
WB	World Bank
WFRs	Watershed Forest Reserves

Executive Summary

Chapter 1 Current Status & Challenges of the Electricity Sector in the Philippines and Project Necessity

1-1. Socioeconomic conditions in the Philippines

In recent years, the Philippines has enjoyed some of the most stable macroeconomic growth in all of Southeast Asia, thanks to sound fiscal policy, robust foreign currency reserves, and other proactive measures which have led to positive values across the board for all of the usual economic indicators. The estimated population of the country exceeded 100 million people in July 2014, and it is expected to reach 123 million people by 2028, thereby overtaking Japan and continuing to grow until 2091. The average age is young at just 23 years old, meaning that the country is likely to enjoy a long population dividend period that will help create a strong foundation for continued economic growth.

1-2. Socioeconomic conditions of the target location for the project

The Greater Manila Area is considered the center of the country's economy and government, and with 12.53 million people, makes up approximately 13% of its population and also accounts for 36.3% of its GDP. Meanwhile, the Caraga Region on the island of Mindanao has a population of nearly 2.55 million people, and only accounts for approximately 5% of the country's population and just 1.2% of its GDP. This discrepancy between regions is illustrated by the gap in GDP per capita, with a value of PHP 196,000 per person in the Greater Manila Area, but only PHP 33,000 in the Caraga Region, a figure that is just 1/6th the value. Additionally, the national average is PHP 69,000, indicating how much the region designated as the location for this project significantly lags behind the country as a whole. However, when looking at the GDP growth rate, the Caraga Region grew at 7.8%, outpacing the national average and establishing it as an area with a high potential for continued growth and development in the future.

1-3. Japanese corporations in the Philippines

Since the 1990s, numerous Japanese corporations have been doing business in the Philippines, with more than 1,000 companies in 2010. That number continues to grow thanks to the stable government and robust economic growth.

1-4. Energy situation in the Philippines

Electricity consumption is growing each year in the Philippines due to its economic growth, with demand especially strong on the island of Mindanao. Estimated demand is projected to grow by an average of 4.6% per year for the country as a whole for the period from 2014 to 2030, with Luzon at 4.1%, Visayas at 5.7%, and Mindanao the highest at 6.1%. Additionally, the electricity grid for Mindanao is separate from the national grid that covers Luzon and Visayas, meaning that the electricity needs of the island must be generated on the island itself. However, there is currently a severe lack of supply, leading to regular power outages during the times of day that electricity is needed the most.

1-5. Overview of the electricity sector

As a result of the Electric Power Industry Reform Act of 2001, reforms were enacted to help liberalize the electricity sector in the Philippines. By the end of 2012, approximately 91% of the power plants previously owned by the National Power Corporation (NPC) were privatized, with the NPC also selling the rights to buy and sell power through the use of Power Purchase Agreements (PPA) with Independent Power Producers (IPP). However, the privatization of power plants in Mindanao has lagged behind other areas of the country, and as of January 2015, approximately 65% of the total generating capacity of the island was still under the control of the NPC. This lack of privatization has led to growing discontent amongst local stakeholders upset with the sector's monopoly on the island and the resulting increases in electricity rates. Going forward, it will be necessary to focus on not only large, centralized power plants, but small and medium-sized projects as well. Therefore, the Mindanao Development Authority's "Mindanao Peace and Development Program" places a priority on the development of small hydro plants over that of larger scale ones.

1-6. Energy policies & related trends

For more than 30 years, the Philippines has pursued policies and legislation designed to eliminate its dependence on foreign oil through the development of domestic energy sources. Among them, renewable energy sources are positioned as a stable, reliable, and economical source of energy, with various presidential decrees and tax incentives devoted to the development of geothermal, small hydro, tidal, solar, and wind power. In December 2008, the Renewable Energy Act (RA9513) was passed, establishing a Feed-in Tariff (FIT) scheme along with various other favorable measures, helping to further invigorate the private sector in regards to the development of renewable energy sources.

1-7. Current state of PPP-led infrastructure projects in the Philippines

From early on, the government of the Philippines focused its attention on the development of Public-Private Partnerships (PPP), approving Asia's first Build-Operate-Transfer (BOT) law in 1990. In order to select project proponents with a high level of transparency, an emphasis is placed on government-requested projects over ones suggested by private entities. However, while there are multiple large-scale government-led infrastructure projects for the Luzon area, Mindanao has yet to directly benefit from the system, thereby forcing the island to rely on privately-led energy projects over government-requested PPPs to help alleviate the island's power shortages.

1-8. Project positioning for the target location (electricity supply and demand, current development situation, etc.)

Currently, there are no power plants in the province of Agusan del Sur, meaning it is forced to rely on electricity generated in other provinces and often faces power shortages as a result. The DOE has announced its goal of generating 1,702MW in Mindanao by 2030, with 1,264MW, or approximately 75% of the total, scheduled to come from hydroelectric power, so it is safe to say there will be strong demand for hydroelectric power in the region going forward.

1-10. Project necessity & importance

If this project is able to build the first power plant in Agusan del Sur, it will provide a stable source of locally-generated electricity for the province. This will help support efforts to lure foreign companies to the region, while providing employment opportunities through the construction, operation, and management of the plant that can stimulate the area’s economic development. Furthermore, power distribution companies in the neighboring provinces will benefit from the interconnected power grid, allowing the economic growth to spread to other provinces beyond Agusan del Sur.

Chapter 2 Topographical Surveys

2-1. Pre-existing topographic maps

The National Mapping and Resources Information Authority (NAMRIA) of the Philippines maintains 50,000:1 scale topographical maps of the entire nation and makes these maps available in either printed or electronic formats. The province of Agusan del Sur, the planned location for this project, is covered by these maps, and the schematic designs in previous surveys[1] have been based on these documents.

No other topographical maps of equivalent or superior detail of the area in question of have ever been created.

2-2. New topographic maps

For this survey, the creation of new topographical maps will be conducted using the following techniques.

[Basic topographical maps]

The first step was to purchase the world’s highest quality digital 3D images of the entire earth, taken by the Japan Aerospace Exploration Agency’s (JAXA) Advanced Land Observing Satellite (ALOS), “Daichi.” Using these images, we were able to create planimetric maps at a 5,000:1 scale, with contour lines at 5 meter intervals.

[Topographical maps for schematic design]

In order to ascertain the optimum positioning for the weir, the powerhouse and the water conduit at site number 1, determined to be the leading candidate site by previous surveys, we used traditional measuring techniques to conduct plane surveys, and added this information to the basic topographical maps to create 1,000:1 scale planimetric maps for schematic design.

Before the plane surveys, we set up six survey markers, and coordinated them with the Philippines national survey markers using GPS measurements. These became new survey markers, labeled GPS-1

[1] “Infrastructure Systems Export Strategy 2012 (yen-based loans, encouragement of private sector infrastructure projects) Wawa River Small Hydro Plant Study in Agusan del Sur, Philippines”, February 2013.

to GPS-6.

The results of the GPS survey coordinating the seven extant national survey markers and the six new survey markers were outlined accordingly.

The data for the new survey markers (GPS-1 to GPS-6) was used as the basis for plane surveys conducted using traditional methods. The measurements thereby obtained were used to create a 1,000:1 scale schematic design plan for site 1.

Chapter 3 Geological Surveys

3-1. Power Plant Site No.1

The planned location for the intake weir features a foundation primarily made up of CM-type bedrock consisting of andesitic tuff and andesite. This bedrock features low water permeability, eliminating the need for waterstop grouting. However, there are scattered concentrations of type D bedrock along a fault-crushing belt, meaning it is likely soft and highly water permeable, so it may be necessary to reinforce the area with concrete or take other such preventative measures. There are also scattered rocks approximately 2m in diameter along the cliffs of the right bank near the intake weir, so it is recommended that they be removed when excavating the foundation.

Along the planned route for the water conduit, the slope of the bank is steep on the upstream side, but much gentler downstream, meaning measures will need to be taken to deal with the steep slopes upstream after the excavation is finished. We plan to install a settling pond downstream from the intake weir, so it may be necessary during the detailed planning stages to conduct an additional boring survey to determine the nature of the underlying bedrock in that area.

In regards to the structural foundations for the head tank and powerhouse, the head tank location features a combination of talus accumulation and type D limestone deposits, while the pressure lines feature type D limestone deposits and mudstone, and the powerhouse is located in an area made of type D mudstone. However, since it is possible there may be cavities spanning several dozen centimeters within the limestone, it may be necessary to reinforce the area with concrete or undertake other similar measures once construction begins. The cut running from the head tank to the powerhouse features a standard maximum grade of 1:0.5 for mudstone, and 1:0.8 for weathered limestone and talus accumulation deposits. Since mudstone can easily erode due to repeated wet-dry cycles following the excavation, it will be important to consider appropriate countermeasures for the excavation process.

3-2. Power Plant Site No.2 & No.3

The intake weir location for both sites is located on a slope, with the CL to CH type bedrock deposits of the riverbed and its shallow depth making for an ideal foundation. Since the bedrock downstream is on an irregular incline, foundation treatments will be needed to combat the resulting water stoppages and other effects. Additionally, a portion of the cliffs above Site No.2 features an overhang, meaning measures will need to be taken to prevent its collapse when excavating the foundation.

The geology for the location of the headrace tunnel primarily consists of CL to CH type bedrock, meaning there should be no problems if NATM construction techniques are used. However, the distribution of fault-crushing belts and slopes at both ends of the tunnel mean that seismic prospecting, boring surveys, and other tests will need to be conducted as part of a geological survey.

The planned locations of the head tank and the powerhouse are believed to feature CL to CM type andesitic tuff breccia, making for a good structural foundation. It will be necessary during the detailed planning stages to perform additional boring surveys to ascertain the geological nature of the unconsolidated deposits and other features of the proposed locations for the structures.

Chapter 4 Hydrometeorological Survey

4-1. Collection of hydrometeorological data

4-1-1. Rainfall data

The nearest meteorological observation stations to the proposed sites for this project are in Butuan City and in Kitcharao in the north of the province of Agusan del Norte. These weather stations are managed by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), and daily observation data is collected from each site.

For this project, we obtained rainfall data from the closest rainfall measuring station in Butuan City, covering the 34 years from 1981 to 2014 and used it to calculate the design flood discharge for the intake point and power plant locations.

4-1-2. Streamflow data

There are no previously existing streamflow gauging stations in or near the proposed project area. The nearest existing streamflow gauging station is the Bayugan Gauging Station downstream from the proposed project location on the Wawa River.

For this survey, we have acquired the observed data for the available 20 year period of 1981 to 2001. The nine years from this sample which have no incomplete data points. There were a total of nine years from this sample which have no incomplete data points.

In addition to this, we have also acquired water level data from the Bayugan Gauging Station for the year from September 2014 to August 2015, which has not yet been converted to flow rates. The survey team has performed flow measurements at Bayugan Gauging Station to obtain this data, and has produced an H-Q curve (which plots the relationship between water level and river flow). This curve is in turn used to perform flow rate conversions and later to analyze the flow duration data.

Chapter 5 Examination of the Power Generation Plan

5-1. Formulation of the power generation plan

The power generation plan for this project took the existing plan formulated in 2012 and utilized the 5,000:1 scale topographical map generated from satellite imaging data, as well as the 1,000:1 scale topographical map based on actual surveys, to select more promising layouts for the power generation facilities. A comparative analysis focusing on the economic viability, terrain and geographical factors, and other important criteria was then carried out on the various candidate locations, with the best options eventually selected. Next, the streamflow analysis created for this study was used to find areas generating the most discharge, upon which the chosen layouts were subjected to a comparison of the unit construction costs per kWh.

As a result of these various studies, the Wawa No.1 plant and No.2 were chosen as the target locations for the project, with a maximum discharge of $10m^3/s$ and $7.6m^3/s$, respectively.

5-2. Basic design for the power plant facility

In regards to the layout and scale of the power plants, a basic design was decided upon for the main structures and generating equipment, thereby determining the type, layout, and scale of the necessary components.

The results of the power generation plan are detailed in Table 5-1 below.

5-3. Power transmission plan

Once completed, the amount of electricity generated by the two power plants will exceed 10MW, so after comparing the amount of electricity to be transmitted with the maximum allowable current of the power lines, it was decided to use 69kV power lines connected by T-junction power dividers.

Given that the administrative divisions of the location site and consumption site will differ, we have created a proposal placing the connection point on the 69kV lines running from Butuan to Bayugan owned by NGCP (Fig. 5-3), as well as a proposal placing it on the 69kV lines owned by ANECO running from Butuan to Santiago (Fig. 5-4).

Additionally, with the proposal to connect to the 69kV Butuan-Santiago lines, the Taguibo power plant lies along the electricity transmission route to be constructed, meaning that its integration could lead to reduced construction costs (Fig. 5-5).

Table 5-1: Wawa Small Hydro Plant Specifications List

Plant Location		Wawa No.1	Wawa No.2
River Name	-	Wawa River	Wawa River, Manangon River
Drainage Basin (Intake weir)	km^2	98.2	Wawa River : 35.2 Manangon River : 43.5
Generating Method	-	Run-of-the-river	Run-of-the-river
Headwater Level	EL. m	267.0	Wawa River : 440.0 Manangon River : 438.0
Tailwater Level	EL. m	231.0	273.0
Gross Head	m	36.0	167.0
Head Loss	m	5.5	11.5
Net Head	m	30.50	155.5
Maximum Discharge	m^3/s	10.00	7.60 (Wawa River intake weir: 3.40) (Manangon River intake weir: 4.20)
Maximum Output	kW	2,580	10,200
Annual Energy Output	kWh	6,763,704	30,823,608

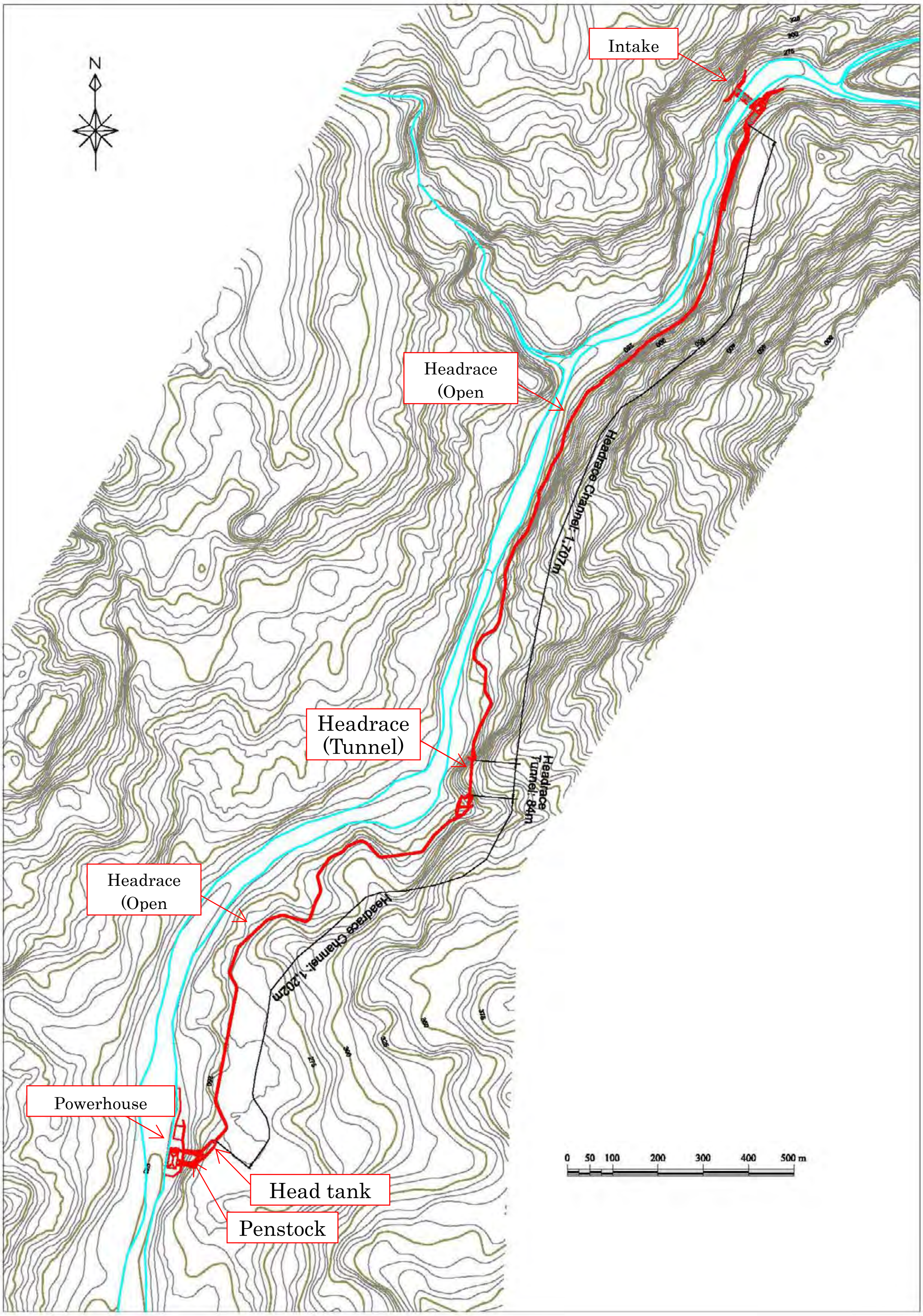


Fig. 5-1: Overall map of Wawa No. 1 plant

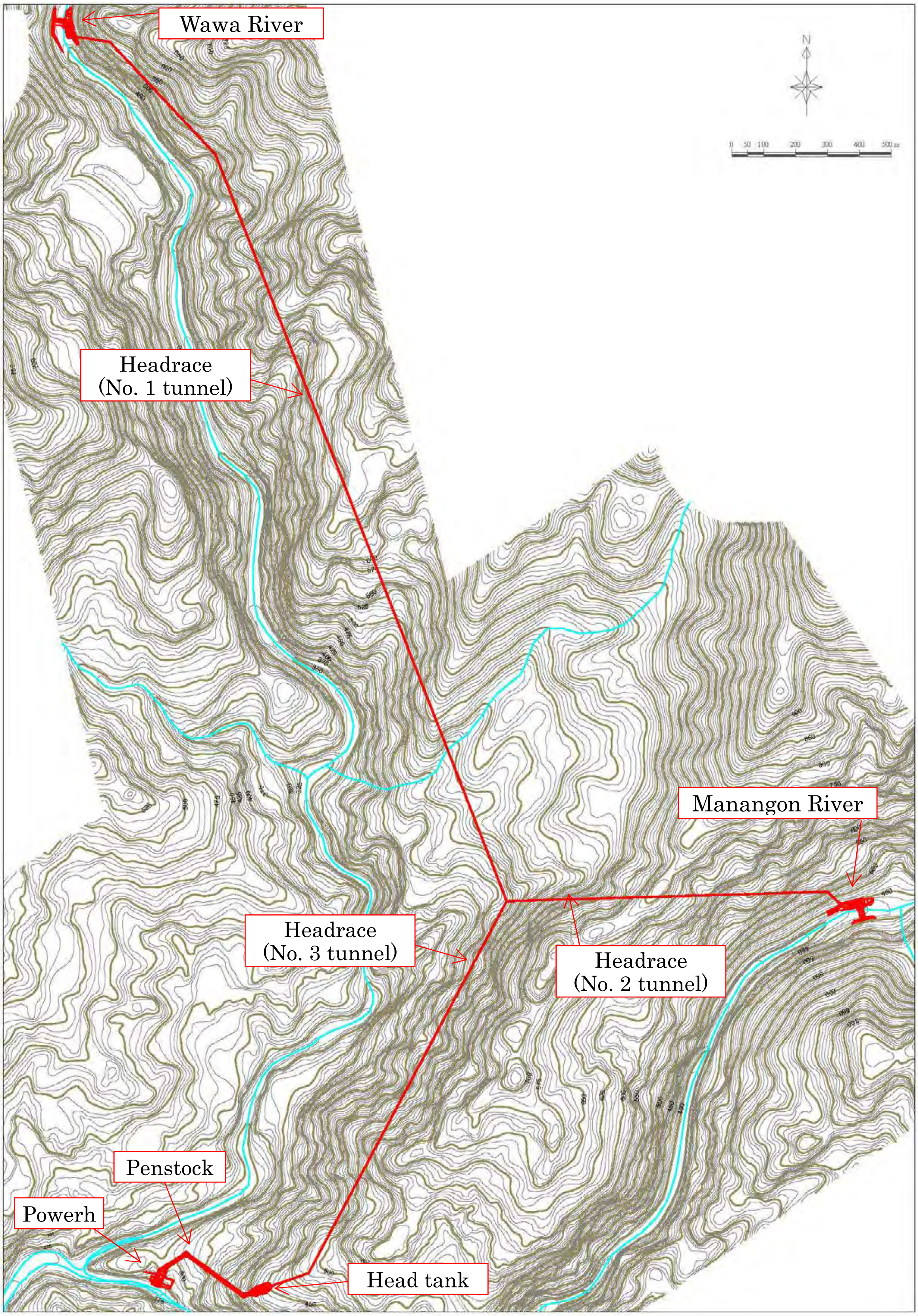


Fig. 5-2 Overall Plan of Wawa No. 2 Powerhouse

Chapter 6 Environmental & Social Considerations

6-1. Environmental & social considerations

While the planned project site is fundamentally surrounded by the hilly forest regions of Mindanao, it also lies within or adjacent to the Mt. Hilong-hilong Area, identified as a Key Biodiversity Area (KBA) for the protection of a wide range of animal and plant species, within the Eastern Mindanao Biodiversity Corridor. While the area around the planned site is not currently designated as a protected area by the Philippines government, the municipality of Sibagat has applied to have the Wawa River basin, including the planned project area, designated as the "Wawa River Basin Protected Landscape." Approval for this proposal is expected to be received during 2016.

Additionally, although there are no collective attachments such as ruins or cultural heritage sites, the planned location for the project has been issued a Certificate of Ancestral Domain Title (CADT) from the National Commission on Indigenous Peoples (NCIP), guaranteeing the rights of the indigenous people in the area. When implementing the project, the SPC leading the business will likely need to secure consensus on all of its activities (especially construction) as per the Free, Prior and Informed Content (FPIC) regulations designated by the Indigenous Peoples' Rights Act (IPRA).

To implement this project, we anticipate it will be necessary to apply for approval for each of its individual components. The Wawa River No.1 and Wawa River No.2 sites will generate 2.58MW and 10.2MW, respectively, meaning that according to the Environmental Impact Assessment System utilized by the Philippines, they are not subject to the EPC, and since the planned locations for both projects do not lie in a protected area, they are not subject to the ECA either. However, since a portion of the water conduit route for both the Wawa River No.1 and Wawa River No.2 sites will require the use of a tunnel, they do fall under Category B, meaning that in order to carry out the project, each component will require an environmental compliance certificate and an EIS report will need to be submitted.

Over the course of this survey, we reviewed numerous substitute proposals, including the option of doing nothing, as well as various forms that the water conduit could take, all with an eye towards minimizing the possible environmental and cultural impacts as much as possible. Based on these results, we examined the social and environmental factors that would be unavoidable by proceeding with this project and used them to create a scoping proposal. Out of the environmental items, those that were evaluated as a B- or C were studied, estimated, and evaluated in even more detail. The results of these studies are detailed in this report.

In regards to noise, it is estimated that the project will generate noise roughly on the same level as a light industrial park, and especially during the construction period, the construction vehicles are also likely to cause additional noise. Air quality is also a concern, especially during the construction phase, so it will be important to devise ways to minimize any negative impact from the project since there are residential areas located near the access roads.

Based on the results of the environmental study, any items which scored a B- or a C will require an Environmental Management Plan (EMP) and an Environmental Monitoring Plan (EMoP), meaning that this project will need to implement the proper monitoring systems and studies if it is to proceed.

These preliminary investigations were led by the main governing bodies of the project, and while following JICA's guidelines for environmental and social considerations, conferences were held with the villages that would be affected by the project as well as other local stakeholders. They included the first scoping proposal phase (July 31, 2014), and the second draft report phase (December 2-3, 2015). The results of these conferences with the various stakeholders are included within this report.

6-2. Land acquisition & displacement of the local population

Carrying out this project will require a total area of approximately 3.7ha for Wawa No.1, and approximately 1.7ha for Wawa No.2 in order to build the hydropower facilities (powerhouse, water conduit, etc.). Over the course of this study, various alternative plans and linear conduit types were studied in order to minimize the need for additional land acquisitions and displacement of the local population. Additionally, while some land acquisition and dislocation of the local population will be necessary for the power plant facility, access roads, and power transmission lines, the locations of the access roads and power transmission lines are not finalized during these preliminary stages, so it is believed that additional land may need to be acquired as the project progresses.

Chapter 7 Project Cash Flow Analysis & Acquisition of Funding

7-1. Investigation of business scheme for securing capital from financial institutions

After conducting interviews with a variety of financial institutions with regard to the investment environment for renewable energy projects within the Philippines, we learned that each interviewed company is actively pursuing investment and lending opportunities within the field. However, it was also made clear that there are two main issues that could prove problematic when it comes to financing: first, when using feed-in tariffs (FITs), a PPA based on the FIT will not be obtained until after the project is complete; and second, as there are already numerous small-scale renewable energy projects in the sector, it is possible that some institutions may be averse to lending to such projects.

7-2. Cash flow analysis

In order to perform an analysis of the project's financial and investment effects, a financial model was created to evaluate the project on a cash flow basis when balancing expenses (business expenses for the initial investment and maintenance costs after operations begin) with the profit obtained by selling the electricity generated from the plants.

The primary economic and financial indicators for Wawa No. 1 and Wawa No. 2 are summarized in the table below.

Economic and financial indicators

	FIRR	**NPV**	**EIRR**

Wawa No. 1	0.07%	79,137 thousand pesos	4.3%
Wawa No. 2	6.65%	577,194 thousand pesos	12.7%

Source: Created by the study team

Based on these numbers, we can see that Wawa No. 1 cannot be declared an attractive enough project for any investor to determine it to be profitable and to invest in its future. On the other hand, while Wawa No. 2 has an FIRR that is slightly below the hurdle rate (discount rate; 10% of capital cost), its NPV value is high, meaning that the project should easily qualify for financing. Judging from its EIRR, the project's socioeconomic value can also be easily appreciated. Furthermore, Wawa No. 2's Debt Service Coverage Ratio (DSCR), a common index used to show a project's ability to repay debt, returns an average value of 1.33 with a low value of 1.29, indicating a level that should not be problematic in terms of its viability as an investment.

However, in light of Wawa No. 2's current FIRR and NPV values, it will be imperative to eliminate any uncertainties regarding the project, and make use of JICA loans or similar facilities to improve profitability, in order to secure financing that provides long-term capital at low and stable interest rates. In addition to this, there also exists the possibility of the use of aid programs such as the JCM program to provide funding assistance for additional surveys or initial investment costs, leading to the expectation of a reasonable increase in the project's profitability.

In order to improve the viability of the implementation of this project, in addition to undertaking activities to procure funding, it is vital that every effort is made to reduce the amount of funding required by any such means available.

7-3. Sensitivity analysis

In regard to the implementation of this project, an FIRR sensitivity analysis was performed on the three factors that have the largest effect on investment efficiency in order to verify the stability of cash flow: project costs, loan interest rates and purchase price.

Since the purpose of a financial analysis is to measure the effects of a stress test on a base case, it remained difficult to demonstrate reasonable viability for the Wawa No. 1 project, but as the FIRR for the Wawa No. 2 project does not deviate greatly from the base case, this analysis revealed no reason that it should not be considered a valid investment.

7-4. Analysis of methods for acquiring capital

As this project is an infrastructure project capable of generating stable, long-term cash flow, by its very nature it is not a good fit for short-term or variable interest rate financing. From a business operator's perspective, therefore, such financing will be difficult to consider.

At the current moment, it must be said that only the Wawa No. 2 project has demonstrated its feasibility as a business based on the economic and financial analyses undertaken. For the Wawa No. 2 project only, the possibility of using senior loans from local financial institutions within the Philippines must not be ruled out, but in terms of eliminating uncertainties regarding the project, the conditions of the various facilities and financing systems provided by entities such as JICA are projected to be more favorable.

Additionally, when restricting the scope of our analysis to the Wawa No. 2 project, there are no areas of particular concern in terms of project scale or profitability that should prove a hindrance to the realization of the project, and thus hamper the securing of funding through equity or mezzanine financing.

Chapter 8 Risk Analysis for project implementation

The potential risks that this project may face are outlined in the table below.

Main Risk Category	Inspection Points (Sample)
Sponsor risk (sponsor assessment)	Investor composition (existence of core sponsors, role-sharing between investors, conflict of interests, etc.)
	Performance (financial, technical) of core sponsors
	Performance (financial, technical) of other sponsors
Construction risk/technical risk (EPC contractor assessment)	Technical ability of the EPC contractors
	Financial position of the EPC contractors
	Business plan details (applicable technology, project costs, construction schedule, etc.)
	EPC contract details (main contract terms: Fixed Lump Sum, Turn Key, Date Certain, etc.)
	Sponsor support details (if applicable)
Operator risk (operator assessment)	Technical ability of the operating body
	Financial position of the operating body
	O&M contract details (incentives, mechanisms, etc.)
	Possibility of alternative operating bodies (existence, ability, etc.)
	Sponsor support details (if applicable)
Offtaker risk	Performance of offtaker/lessee
	Sponsor support details (if applicable)
	(If no long-term contract) Demand, competitiveness, and competition plan for the energy generated, rate structure/pricing power for the energy generated, sponsor support details (if applicable)
Raw material/fuel procurement risk	Performance of raw material/fuel suppliers (including procurement conditions for raw material/fuel)
	Raw material/fuel supply contract details (contract period, quantity, contract amount, etc.)
	Sponsor support details (if applicable)
Other risks	Socio-environmental risk (including land acquisition)
	Related infrastructure and utility risk
	Interest rate and foreign exchange rate risk
	Price fluctuation risk
	Natural disaster/force majeure risk
	Political risk (war, civil war, riots, terrorism, laws/permits & licenses, expropriation, requisition/nationalization, contract non-fulfilment, etc.)

Analysis of these differing risk categories yielded the following results.

Sponsor risk

The project aims to create an SPC to carry out the business, with partners including Chodai Co., Ltd., Kiso-Jiban Consultants Co., Ltd., Equi-Parco Construction Company (the largest general contractor on the island of Mindanao), as well as Twinpeak Hydro Resources and Hydro Resources Management and Consultancy Inc. Since the preceding project, Asiga mini hydro power project has been progressing with almost same project structure as this project, it is believed that partner risk for this project is extremely low.

Construction risk

The investors in this project, including Chodai Co., Ltd., Kiso-Jiban Consultants, and Hydro Resources Management and Consultancy Inc., have a long history of technical consulting, and will carry out a detailed examination of the business costs for the project, while the construction management will be handled by Equi-Parco Construction, the primary investor in the project, with extensive experience in managing the construction of infrastructure projects. For the generator equipment, Japanese water turbines and generators manufacturers will be called upon to participate in the bidding process, and an analysis of the technical expertise each company can provide and the costs involved in using each company will be carried out, ensuring that there will be very little risk associated with the financial condition and track record of contracted companies. Finally, the EPC attempts to reduce risk to delineate the clear responsibilities of each party with regard to additional costs such as liquidated damages, as well as the methods for dealing with such costs in the contract.

Operator risk

With one of the primary investors also participating in the everyday operation of the plants, risks concerning the O&M contract are not anticipated.

Offtaker risk

On the assumption of the potential use of the FIT system, this project is currently investigated and, due to its reliability and stability, the NGCP is being considered as a possible offtaker for the energy produced. It will be vital to carefully monitor the progress of other FIT applicant candidates and keep track of the current status of each, their completion schedules and the timing of any FIT approvals.

In the instance that a bilateral contract is signed, ASELCO has indicated a willingness to purchase the electricity generated under the same terms as the FIT system. Should this come to pass, it will be necessary to carefully examine the contract terms, with particular attention paid to price and contract period.

Raw material/fuel procurement risk (including water rights)

For this project, an analysis of long-term flow rate data through this preliminary study, together with the monitoring of the existence of other infrastructure projects along the upper river basin, will be undertaken to guard against any such risks, and raw material and procurement risks are considered low.

Other risks

Pertinent factors related to the below risk categories must also be considered as the project develops.

(1) Socio-environmental risk
(2) Land acquisition risk
(3) Related infrastructure and utility risk
(4) Capital acquisition, interest rate and foreign exchange risk
(5) Price fluctuation risk
(6) Force majeure/natural disaster risk
(7) Licensing risk

Some possible risks regarding the invalidation of permits and licenses for the project are listed below.

・Invalidation of the renewable energy service contract

・Invalidation of environmental permits

・Invalidation of water usage rights permits

8-1. Overview of contracts necessary for project implementation

- Renewable energy service contract
- Basic contract and investment contract between partner companies
- Offtaker contract (FIT or bilateral contract)
- EPC contract
- O&M-related contract, etc.

Chapter 9 Project Impacts and Impact Verification

Both the island of Mindanao in general and the Caraga region in the northeast of the island in particular suffer from a serious electricity supply deficiency. Peak demand for the island of Mindanao is around 1,580 MW (2013 data), but a maximum supply deficit of 600 MW is experienced at six o'clock in the evenings, the peak hour for the switching on of lights.

Power peak demand for the Caraga region, where the planned project site is located, is 146 MW, of which the networks of the power distribution utilities ANECO and ASELCO, to which this project may provide power, face demands of 57 MW and 27 MW respectively, meaning that between them these network areas represent just under 60% of the region's demand.

The Wawa No. 1 plant is projected to have an output capacity of 2.6 MW (yearly generated energy of 6,764 MWh) and Wawa No. 2 an output capacity of 10.2 MW (yearly generated energy of 30,824 MWh). These figures equate to 15% of the peak demand on the ANECO and ASELCO networks of 84 MW, representing a significant boost to the electricity supply capacity of the area.

From an economic perspective, the following direct and indirect effects can be expected:

・The employment of construction and other workers (direct effects related to construction)

・The supply of construction materials and everyday supplies (indirect effects related to construction)

・The employment of power plant operators; economic contributions to the local indigenous peoples (direct effects following the commission of the plants for electricity generation)

・The supply of maintenance materials and everyday supplies; contribution to the future peace and prosperity of Mindanao through the realization of a model private corporation-led regional development project and the provision of a stable electricity supply to the area (indirect effects following the commission of the plants for electricity generation)

Furthermore, in terms of environmental effect, the project can be expected to provide a 19,432 metric ton yearly reduction in CO_2 emissions.

Chapter 10 Summary

After growing at a yearly rate of 5% to 7% in the period leading up to the 2008 global financial crisis, then undergoing a period of stagnation (yet still maintaining positive yearly growth) due to its effects, the Philippine economy rebounded to record growth of 7.3% in 2010, underlining its stable progress.

Peak demand for the island of Mindanao is 1,572 MW (2013 data), but a maximum supply deficit of 600 MW is experienced at six o'clock in the evenings, the peak hour for the switching on of lights.

The Caraga region, in the northeast of the island, suffers from the lack of a single significant electricity-generating facility, leading to chronic power shortages.

Peak demand for the Caraga region, where the planned project site is located, is 146 MW, of which the networks of the power distribution utilities ANECO and ASELCO, to which this project may provide power, face demand of 57 MW and 27 MW respectively, meaning that between them these network areas represent almost 60% of the region's demand.

The Wawa No. 1 plant is projected to have an output capacity of 2.6 MW (yearly generated energy of 6,764 MWh) and Wawa No. 2 an output capacity of 10.2 MW (yearly generated energy of 30,824 MWh). These figures equate to 15% of the peak demand on the ANECO and ASELCO networks of 84 MW, representing a significant boost to the electricity supply capacity of the area.

The basic details of Wawa No. 1 are as follows.

Water intake weir location:	Downstream from the confluence of the Wawa and Manangon Rivers
Headrace route:	Open conduit on the Wawa River left bank
Maximum usable flow:	10.0 m^3/s
Head:	32.6 m
Maximum power output:	2,580 KW
Yearly generated energy:	6,764 MWh
Capacity factor:	30.0%

The basic details of Wawa No. 2 are as follow.

Water intake weir location:	Two intake weirs; one on each of the Wawa and Manangon Rivers
Headrace route:	Tunnel-style, linking the two intake locations
Maximum usable flow:	7.60 m^3/s
Head:	155.5 m
Maximum power output:	10,200 KW
Yearly generated energy:	30,824 MWh

Capacity factor: 34.4%

From an environmental and social standpoint, no factors that should prove an impediment to the implementation of the project have been identified.

The financial evaluation of the project found that while Wawa No. 1 cannot be declared an attractive enough enterprise for any investor to determine it to be profitable and to invest in its future, Wawa No. 2 has a high NPV value and should easily qualify for financing. Even for Wawa No. 2, however, it will be imperative to secure funding in the form of long-term capital at low and stable interest rates. Reductions in direct expenditure through the lowering of EPC costs and the securing of aid or other subsidies will further improve the viability of the implementation of the project. Potential methods for the lowering of EPC costs could be through the use of local technical expertise, a re-evaluation of projected rates, a shortening of the construction period through a streamlining of the schedule, and other cost-saving efforts.

In terms of the implementation schedule of the project, the planned construction periods are four years for Wawa No. 1 and five years for Wawa No. 2.

Japanese companies have competitive advantages in tunnel excavation technology, construction schedule management and civil engineering construction technology, all of which will provide direct benefits to this project. Additionally, electricity generation machinery produced by Japanese corporations enjoys a competitive advantage over rival technology in terms of delivery reliability, product quality and the supply of maintenance parts. The benefits of the involvement of Japanese companies can be appreciated in these areas as well.

This project is a necessary one in the context of the electricity supply situation of the region, and the effect of its inception would be significant. While taking into account the various risks made clear through this feasibility study, it is our intention to make every effort to further improve the profitability of the enterprise through the investigation of practical and realistic cost reduction strategies identified via detailed studies of the situation on the ground and via the formulation of comprehensive plans for each aspect of the project.

Chapter 1 Overview of the current status of the electric power sector in the Philippines, issues facing the sector, and project necessity

1-1. The socio-economic situation in the Philippines

1-1-1. Economic overview

After achieving independence in 1946 and going through a period of recovery under the guidance of the United States, the economy of the Philippines made steady progress on the road to becoming a developed nation as a result of the aggressive development policies pursued by President Marcos, who came to power in 1965, eventually achieving a GDP per capita that was second only to Japan in Asia. From around 1972, however, Marcos's rule became increasingly dictatorial and after his removal from power, political unrest led to a period of economic stagnation. Overtaken in terms of per capita GDP by South Korea and Taiwan in the 1970s, by Malaysia and Thailand in the following decade, by China in the late 1990s, and Indonesia in the early 2000s, the nation found itself left behind economically by the rapid growth of its neighbors. However, while the Asian financial crisis of 1997 led to a dramatic devaluation of the peso, the Philippines did not have a "bubble economy," and was able to recover much more swiftly than countries such as Thailand, which suffered a total fiscal catastrophe, and Indonesia and South Korea, which faced the threat of political collapse. The Philippines also avoided the necessity of a bailout from the IMF. As the political and social situation improved in the following years, the economy also stabilized, so much so that it even achieved 1.1% growth in 2009, immediately following the global financial crisis of 2007-2008.

The custom of traveling overseas to find work, originally encouraged as the "export of excess labor" under Marcos, has now become a key pillar supporting the economy of the Philippines. Over 10% of all citizens of the Philippines are now "overseas Filipino workers," and remittances from these workers are setting new records every year: over USD 20 bn in 2011, a 6.3% increase to USD 21.4 bn in 2012, and a further 7.5% increase to USD 23 bn in 2013. Remittances from overseas-based workers provide a solid foundation for private consumption, which in turn makes up 70% of the GDP of the Philippines. It also counteracts the country's trade deficit, contributing heavily to the positive account balance achieved for the last 11 consecutive years.

Table 1-1: Trends in principal economic indicators

	Units	2009	2010	2011	2012	2013
GDP	$ m	168,485	199,591	224,143	250,240	272,067
GDP growth rate	%	1.1	7.6	3.7	6.8	7.2
GDP per capita	$	1,851	2,155	2,379	2,612	2,790
Inflation rate	%	4.2	3.8	4.7	3.2	2.9
Unemployment rate (urban)	%	7.5	7.4	7.0	7.0	7.1
Foreign exchange reserves	$ m	38,783	55,363	67,290	73,478	75,689
Exchange rate (average peso/USD)		46.36	43.89	43.928	41.19	44.41
External debt	$ m	54,856	60,048	60,442	60,337	58,506
External debt/GDP	%	32.6	30.1	27.0	24.1	21.5

Source: Created by the study team, based on data from the IMF World Economic Outlook Database of October 2014 and the Japan External Trade Organization (JETRO)

Since the inauguration of Benigno Aquino III as president in June 2010 (term to continue until June 2016), economic growth of 3.7% in 2011, 6.8% in 2012, and 7.2% in 2013 has been realized, meaning that the country’s economy is performing at a level that outstrips the other Association of South East Asian Nations (ASEAN) countries. Inflation spiked at a yearly rate of 9.3% in 2008 as a result of increases in worldwide crude oil and food prices, placing a significant burden on the populace, but since then inflation rates have fallen to within the 3 to 5% range established as the objective of the national government: 4.7% in 2011, 3.2% in 2012 and 2.9% in 2013. All of the principal economic indicators suggest that the country is in a positive economic state (Table 1-1); prudent fiscal management and abundant foreign currency reserves have ensured that the Philippines has become one of the most stable nations in Southeast Asia at the macro-economic level.

The key issues facing the Aquino government are the eradication of corruption, job creation, reducing the income gap, fiscal consolidation, and development of infrastructure. The plans put in place to achieve these aims have been highly evaluated by international financial institutions, with the Big Three credit rating agencies (Moody’s, Standard and Poor’s, and Fitch Group) all raising their credit ratings of Philippine government bonds to investment grade or higher. The fact that moderate inflation rates, a diminishing reliance on overseas debt, improvements in public finances and sound fiscal policies from the central bank are all functioning to promote growth is the reason given for these raised credit ratings. Other major factors in the continued strong growth of the Philippine economy are robust domestic demand and the continued maintenance of a positive account balance thanks to the ever-growing remittances sent back to the country from workers based overseas.

The stock market is also maintaining healthy levels, with the Philippine Stock Exchange Composite Index (PSEi) recording its highest ever benchmark of 7,392 points on May 15, 2013. Compared to the low levels recorded in 2010, the index has ballooned to over three times its earlier level in the past five years (Fig. 1-1).

Fig. 1-1: Philippine Stock Exchange Composite Index (PSEi) levels over the past five years
Source: SBI Securities Co., Ltd.

1-1-2. Industrial structure

A breakdown of the industrial structure of the Philippines reveals that the service industry is the largest industry in the country, accounting for 57% of GDP, followed by mining, construction and manufacturing at 32%, and agriculture, forestry, and fisheries at 11%. While this heavy reliance on the service industry has been unchanged for many years, the proportion of the nation's GDP it comprises has increased year upon year, while the proportions comprised by the mining, construction and manufacturing industries and agriculture, forestry and fisheries industries have gradually declined. The Philippines has abundant human resources among its youth, who have all grown up receiving relatively high levels of education and learning English as an official language. As a result, call centers for English-speaking customers and the business process outsourcing (BPO) industry are exhibiting high levels of growth, to the extent that these have become key pillars supporting the economy, along with the remittances sent back by workers based overseas. According to the Business Process Association of the Philippines (BPAP), estimated revenue for all BPO businesses was USD 11 bn in 2011, before increasing by 22% to USD 13.4 bn in 2012, and then by a further 15.6% to USD 15.5 bn in 2013. Employees of such businesses were estimated at 640,000 in 2011, before showing a 21.8% increase to 780,000 in 2012, and another 15.4% increase to 900,000 in 2013. In an administrative policy speech of July 2012, President Aquino demonstrated his recognition of the key role that the BPO industry can play in future economic growth, stating that it "can be expected to grow to be a 25 billion dollar industry, employing 1.3 million, by 2016."

A breakdown of growth rates by industry for the year 2013 reveals that in terms of major categories, the service industry unsurprisingly showed increasing dominance, leading the way with a rate of 10.7%, followed by mining, construction and manufacturing at 8.9% and agriculture, forestry, and fisheries at 3.7%. When divided into more specific categories, the fastest-growing industries were the finance industry, which experienced significant fluctuations in the stock market, at 15.9%, followed by the construction industry at 14.2% and housing and real estate at 12.4%. At the other end of the scale, mining experienced negative growth for the second consecutive year (Table 1-2).

Table 1-2: GDP distribution trends by industry (unit: billion pesos)

Industry type	2009 (growth from previous year)		2010 (growth from previous year)		2011 (growth from previous year)		2012 (growth from previous year)		2013 (growth from previous year)	
Agriculture, forestry and fisheries	1,050	2.7%	1,109	5.6%	1,235	11.4%	1,251	1.3%	1,297	3.7%
Mining, construction and manufacturing	2,545	0.3%	2,932	15.2%	3,042	3.7%	3,300	8.5%	3,594	8.9%
Mining	106	11.5%	129	21.0%	143	11.1%	121	-15.1%	115	-4.9%
Manufacturing	1,706	-3.1%	1,931	13.1%	2,048	6.1%	2,171	6.0%	2,355	8.5%
Construction	460	9.8%	551	19.7%	521	-5.5%	633	21.5%	723	14.2%
Electricity, gas, water	272	3.5%	322	18.3%	330	2.7%	375	13.4%	400	6.9%
Service industry	4,431	6.5%	4,962	12.0%	5,429	9.4%	6,017	10.8%	6,658	10.7%
Transport, storage, logistics	561	2.2%	586	4.5%	627	7.0%	685	9.2%	730	6.5%
Commercial	1,360	3.3%	1,564	15.0%	1,696	8.4%	1,871	10.3%	2,052	9.7%
Finance	545	8.9%	622	14.3%	684	9.9%	764	11.6%	885	15.9%
Housing and real estate	884	8.3%	979	10.7%	1,105	12.9%	1,221	10.5%	1,373	12.4%
Public services, defense	324	13.2%	372	15.0%	404	8.6%	458	13.2%	491	7.4%
Other private services	758	9.5%	839	10.6%	913	8.8%	1,019	11.7%	1,126	10.5%
TOTAL	8,026	4.0%	9,003	12.2%	9,706	7.8%	10,567	8.9%	11,548	9.3%

Source: Created by the study team based on data from the Japan External Trade Organization (JETRO)

1-1-3. Trade

Trade in the Philippines has expanded rapidly in recent times, with exports now six times the value they were in 1990, and imports five times their 1990 value. Other than 1999 and 2000, the Philippines has consistently recorded a trade deficit, with imports outpacing exports by USD 12 bn in 2011, the highest trade deficit value since 1990 (Table 1-3).

Trade of intermediate goods, whereby semifinished products, often electronics, are imported and assembled before being exported as finished products, is the key pillar of Philippine trade. Raw materials and semifinished products make up approximately 40% of the total value of imports into the country, while completed electronic goods account for almost half of the nation’s total export value (as of 2011).

In terms of the Philippines’ primary trading partners, as of 2013 exports with the highest total value were made to, in order, Japan, the United States, China, Hong Kong, and Singapore, while imports came from, in order of total imported value, China, the United States, Japan, Taiwan, and South Korea. For a long time, Japan was the Philippines’ number one trading partner when combining both imports and exports, but while exports to Japan have risen in recent years, imports from Japan have remained constant or even fallen slightly. China, on the other hand, has become a far more important trade partner, with trade levels rising rapidly; exports now total 2.7 times the value and imports 2.1 times the value that they were in 2009.

Table 1-3: Trade balance (unit: million USD)

	2010		2011		2012		2013		2014	
Total Exports	51,541		48,316		52,072		53,928		61,932	
Total Imports	54,932		60,495		62,128		61,832		64,530	
Trade balance	-11,096		-13,866		-12,745		-10,648		-12,753	
Foreign currency reserves	62,373		75,302		83,831		83,187		79,541	
Main Trading Partner	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports
Japan	6,208	5,363	7,841	6,744	8,886	6,516	9,881	6,470	12,048	5,224
The United State	6,789	5,113	7,559	5,887	7,102	6,536	7,417	7,124	8,324	7,020
China	2,934	3,807	5,724	4,628	6,237	6,085	6,169	6,680	7,025	8,072
Singapore	2,477	3,724	7,319	5,187	4,279	4,899	4,867	4,405	4,142	4,236
Korean	1,828	3,005	2,243	3,833	2,237	4,420	2,882	4,526	3,400	4,822
Taiwan	1,325	3,014	1,752	3,676	1,993	4,209	1,943	4,855	1,983	4,883
Hong Kong	3,213	1,457	4,336	1,470	3,701	1,510	4,776	1,466	4,541	1,298

Source: Created by the study team based on data from the Philippine National Statistics Office (NSO) and the Japan External Trade Organization (JETRO)

1-1-4. National finances

Having operated at a fiscal deficit for many years, the national debt at the time of the previous President Arroyo's inauguration in 2001 was such a significant burden on the national coffers that one third of all government revenue was being spent on paying off interest alone. Following her reelection in 2004, President Arroyo declared the country to be in a state of financial crisis, and passed a number of measures designed to rebuild the economy: raising the value-added tax (VAT) from 10% to 12%, raising taxes on alcohol and cigarettes, and the introduction of tax incentive laws. Spending cuts were also implemented, and after a period of sacrifice, the budget deficit began to be gradually reduced, finally resulting in the dramatic improvement symbolized by a yearly budget surplus of PHP 1.3 bn in 2008. Increased government spending in 2009 in response to the global financial crisis meant that a fiscal deficit of in excess of PHP 200 bn was recorded for two consecutive years (Fig. 1-2). However, policies to attain fiscal stability were maintained through into the Aquino regime, whose primary pledges were to stamp out corruption and illegality. By 2013, the fiscal deficit had been significantly reduced to just PHP 15.4 bn. However, while the structures put in place for fiscal stability and the results they have achieved have been widely praised, there have also been voices of criticism, particularly pertaining to the negative effects of these policies on the domestic economy, such as the stagnation of public works projects.

With the reduction in the fiscal deficit, the national debt as a proportion of GDP has also fallen year by year, from 66% in 2004 to 39% in 2013 (Fig. 1-3). Further, the privatization of the National Power Corporation (NPC) as part of the Electric Power Industry Reform Act (EPIRA) of 2001 has also contributed to a reduction of the national debt. Power plants owned by the NPC were sold to private companies under the stipulations of the EPIRA, and the power purchasing and selling rights of the NPC, formerly guaranteed under Power Purchase Agreements (PPA) with Independent Power Producers (IPP), were also sold to private firms.

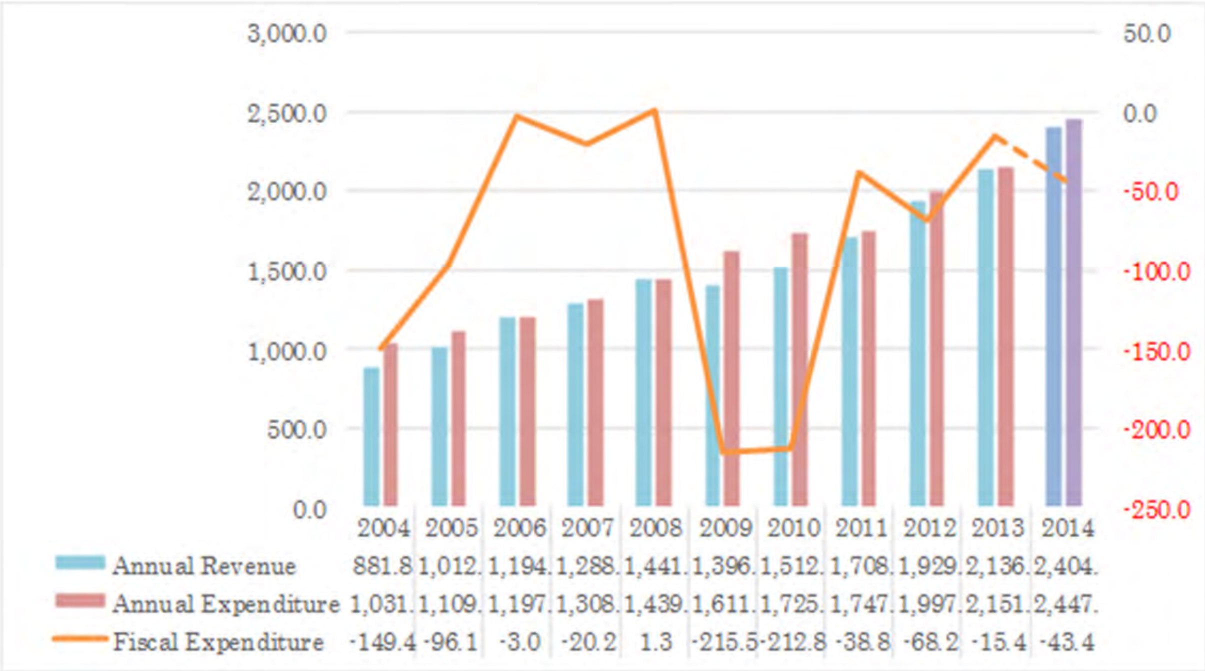


Fig. 1-2: Philippine government fiscal balance (unit: billion pesos)

Source: Created by the study team based on data from the IMF World Economic Outlook Database

*Figures are final up until 2013; figures for 2014 are the IMF's estimates as of October 2014

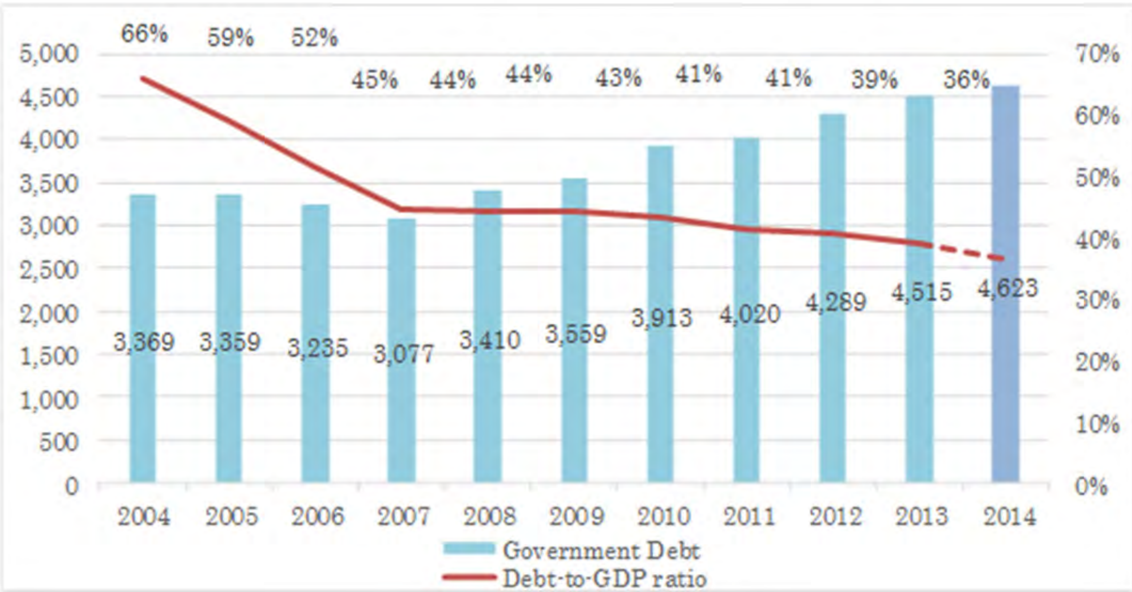


Fig. 1-3: Philippine government total national debt and as a proportion of GDP (unit: billion pesos)

Source: Created by the study team based on data from the IMF World Economic Outlook Database

*Figures are final up until 2013; figures for 2014 are the IMF's estimates as of October 2014

1-1-5. Foreign direct investment

The Philippine government approved PHP 274 bn of direct inward investment from foreign countries in the year 2013, a figure which was almost unchanged from the record-breaking numbers of 2012. Over the long term, the peso has also strengthened against the dollar (Fig. 1-4). After converting to dollars based on the yearly average exchange rate (pesos/dollars), the central bank of the Philippines, the Bangko Sentral ng Pilipinas (BSP), released a figure of USD 6.45 bn in approved foreign direct investment for 2013.

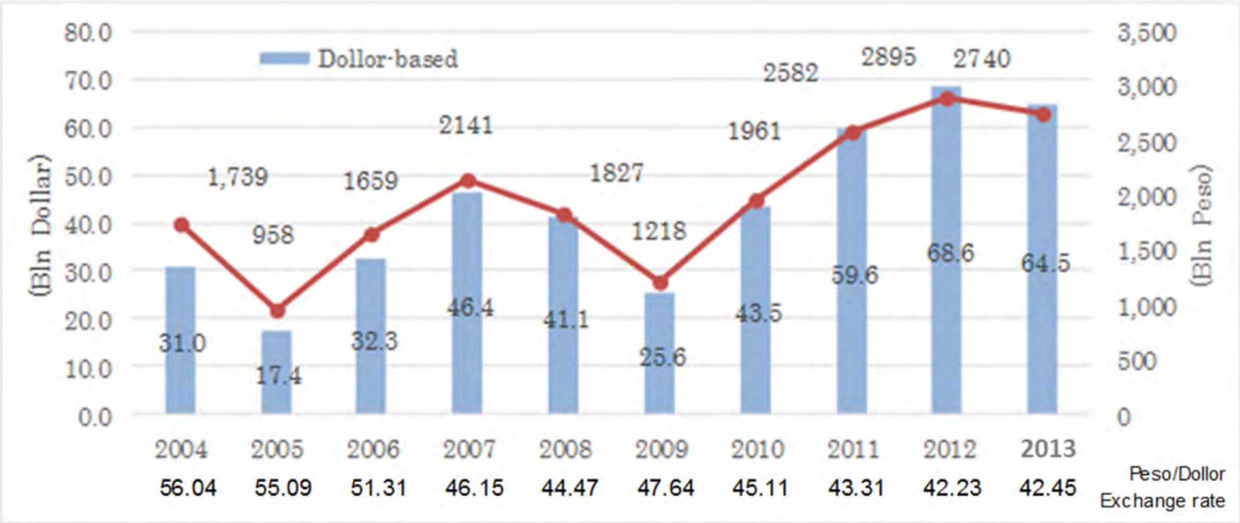


Fig. 1-4: Total value of approved foreign direct investment to the Philippines

Source: Created by the study team based on data from the National Statistical Coordination Board (NSCB) and the Central Bank of the Philippines (BSP)

*Peso-based data has been converted to dollar-based data using the yearly average exchange rate of the BSP

As can be seen in Fig. 1-4, foreign direct investment to the Philippines has been expanding consistently since a downturn in 2009 following the global financial crisis, but as shown in Fig. 1-5, foreign investment levels remain low in comparison to the country's Southeast Asian neighbors. The most noticeable expansion in recent years has been shown by Indonesia, whose figures for foreign direct investment in 2013 were 9.7 times the equivalent figures from ten years prior. Another key statistic is that the cumulative total of all foreign direct investment to the Philippines in the last ten years is USD 21.5 bn. Comparatively, Indonesia has received USD 106.8 bn, Thailand USD 84.6 bn, Malaysia USD 75.6 bn, and Vietnam USD 62.9 bn; these figures are 5.0, 3.9, 3.5, and 2.9 times the numbers of the Philippines respectively. According to the analyses of the Asian Development Bank and the World Bank, the reasons for the comparative lack of foreign direct investment in the Philippines include a poorly developed highway network, expensive power costs, unclear business regulations, complex tax refund schemes, convoluted investment enticement schemes, and unreasonable legal restrictions.

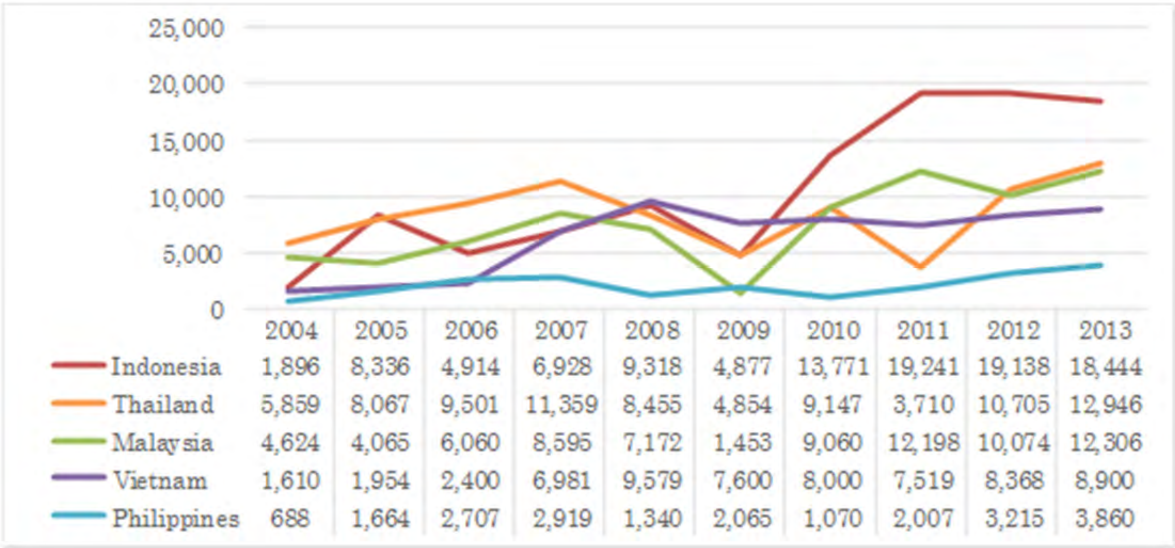


Fig. 1-5: Actual foreign direct investment values for major ASEAN nations (unit: million dollars)
Source: Created by the study team based on data from the United Nations Conference on Trade and Development (UNCTAD)

Broken down by country, Japan is the largest investor in the Philippines, with its PHP 320.2 bn invested making up 28.2% of the total of PHP 1.137 tn of approved foreign direct investments over the past five years. The Netherlands are the next largest investors at PHP 196.5 bn (17.3%), followed by the United States at PHP 191.7 bn (16.9%).

Table 1-4: Approved foreign direct investment in the Philippines from its three major investment partner nations (unit: billion pesos)

	2009	2010	2011	2012	2013	Five-year cumulative total	Proportion (%)
Japan	70.7	58.4	77.3	69.0	44.8	320.2	28.2%
The Netherlands	2.1	36.8	28.4	104.3	24.9	196.5	17.3%
The United State	12.9	13.1	70.4	40.0	55.3	191.7	16.9%
Total (including others)	121.9	196.0	256.0	289.1	274.0	1,137.0	

Source: Created by the study team based on data from the National Statistical Coordination Board (NSCB) and the Japan External Trade Organization (JETRO)

When divided by industry, we see that the industries benefiting from foreign direct investment have changed significantly over the past several years (Fig. 1-6). The manufacturing industry, which received 83.1% of all foreign direct investment in 2010, has seen its share diminish, while the real estate industry (in 2011) and the shipping and transportation industry (in 2012-2013) have surged significantly. Further, with the energy industry attracting more interest recently, direct foreign investment in the electricity and gas industries has also increased dramatically. Overall, this paints a picture of the diversification of investment targets, from the previous manufacturing-dominated state of affairs.

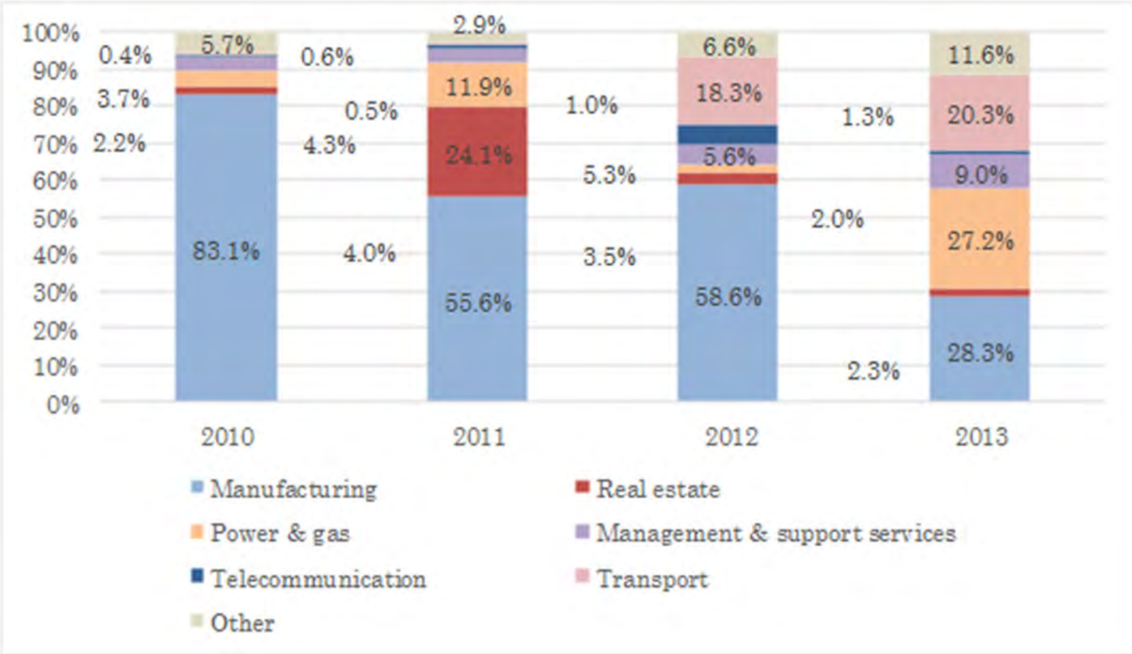


Fig. 1-6: Approved foreign direct investment by industry

Source: Created by the study team based on data from the National Statistical Coordination Board (NSCB)

1-1-6. Population

As of the 2010 census, the population of the Philippines stood at 92.34 million, but a survey conducted by the National Statistical Coordination Board in 2013 estimated the population at 98.20 million and an estimate by the Philippine government's population committee placed it at over 100 million in July of 2014. This ranks the Philippines in 12th place, just behind Mexico, among the world's most populous nations, and second among ASEAN nations behind Indonesia with 250 million. Further, calculations by the United Nations suggest that the population of the Philippines will reach 123 million in 2028, overtaking Japan, and will continue to grow until the year 2091.

While average life expectancy is relatively low at 68.55 years, placing it 123rd in the world, the birth rate is 3.08, and the population distribution forms an almost perfect pyramid, with the population increasing continuously with younger demographics (Fig. 1-7). With the average age of a citizen just 23, the Philippines is much younger on the whole than its neighbors such as Vietnam, and with a high productive age population, it is well placed to continue to receive the so-called "demographic bonus" said to be most conducive to economic growth.

Almost half of this population (49%) resides in cities, and a still high ratio (23%) lives below the poverty line on less than $2.50 a day ("State of World Population," 2011). While the working population has exceeded 40 million, unemployment is currently hovering around the 7% mark. While unemployment has been gradually declining in recent years as a result of consistent economic growth, the proportion of inadequately employed workers (desiring a change in jobs or additional work) remains high, at just under 20%. The creation of employment opportunities remains a key issue facing the nation as a whole.

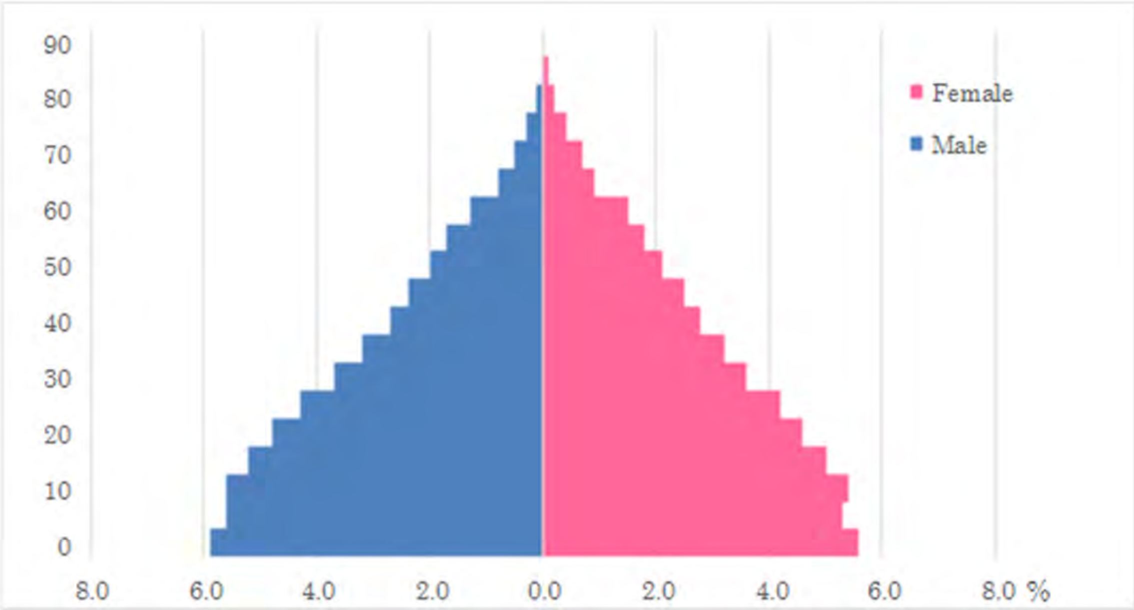


Fig. 1-7: Population pyramid of the Philippines (estimated 2015 values)
Source: Created by the study team based on data from the "United Nations World Population Prospects: the 2012 Revision"

1-2. The socio-economic status of the planned project area

1-2-1. Population and economic overview

The 300,000 square kilometers covered by the land of the Philippines are divided into three main island groups: Luzon, containing the capital, Manila; the Visayas, with its main city of Cebu; and Mindanao, with Davao City at its center. Administratively, the nation is divided into 17 regions, which are further subdivided into 80 provinces (the equivalent of Japanese prefectures). Below this, and making up each province, are cities and municipalities, and these are further divided into the smallest administrative unit, barangays. The Wawa River, the projected site of this project, runs through Sibagat City in the province of Agusan del Sur, located in the Caraga region in the northeast of the island of Mindanao, in the Mindanao island group (Fig. 1-8).

The greater Manila area is the political and economic hub of the country, with a population of 12.53 million (13% of the country's population), a GDP contribution ratio of 36.3% and GDP growth of 9.1% (Table 1-5). The Mindanao island group, on the other hand, despite being home to roughly 20% of the total population of the Philippines, contributes just 14.3% of its GDP. The Caraga region has a population of 2.55 million (2.5% of the total), yet it contributes just 1.2% of the nation's GDP. This regional disparity is also evident in per capita GDP, which stands at 196,000 pesos in the greater Manila area, but only 41,000 in Mindanao as a whole, and 33,000 in Caraga, rates which are only one fifth and one sixth of those in Manila. The national per capita GDP is 69,000 pesos, which indicates to what extent the economy of the area in which this project is planned is lagging behind the rest of the country. In terms of GDP growth rates, however, the Caraga region exceeds the national average with a level of 7.8%. This is a particularly high growth rate within the Mindanao island group, suggesting that development and economic progress can be expected for this region.

The population of the province of Agusan del Sur as a whole is 656,000 (as of the 2010 census), with Sibagat City making up 30,000 of this number (2010 census).

Fig. 1-8: Location of survey site (overview)

Source: Created by the study team

Table 1-5: Comparison of population and GDP by area

2013	Population (thousands)	Pop. Ratio	DGP (million Pesos)	Contribution Rate	GDP Per Person	GDP Growth Rate
The Philippines	98,197	100%	6,765,459	100%	68,897	7.2%
Luzon	55,916	57%	4,946,316	73.1%	88,460	7.6%
Metro Manila	12,539	13%	2,455,306	36.3%	195,806	9.1%
Visayas	18,909	19%	850,371	12.6%	44,972	6.0%
Mindanao	23,372	24%	968,771	14.3%	41,450	6.3%
Caraga Region	2,551	2.5%	83,550	1.2%	32,752	7.8%

Source: Created by the study team based on data from the National Statistical Coordination Board (NSCB)

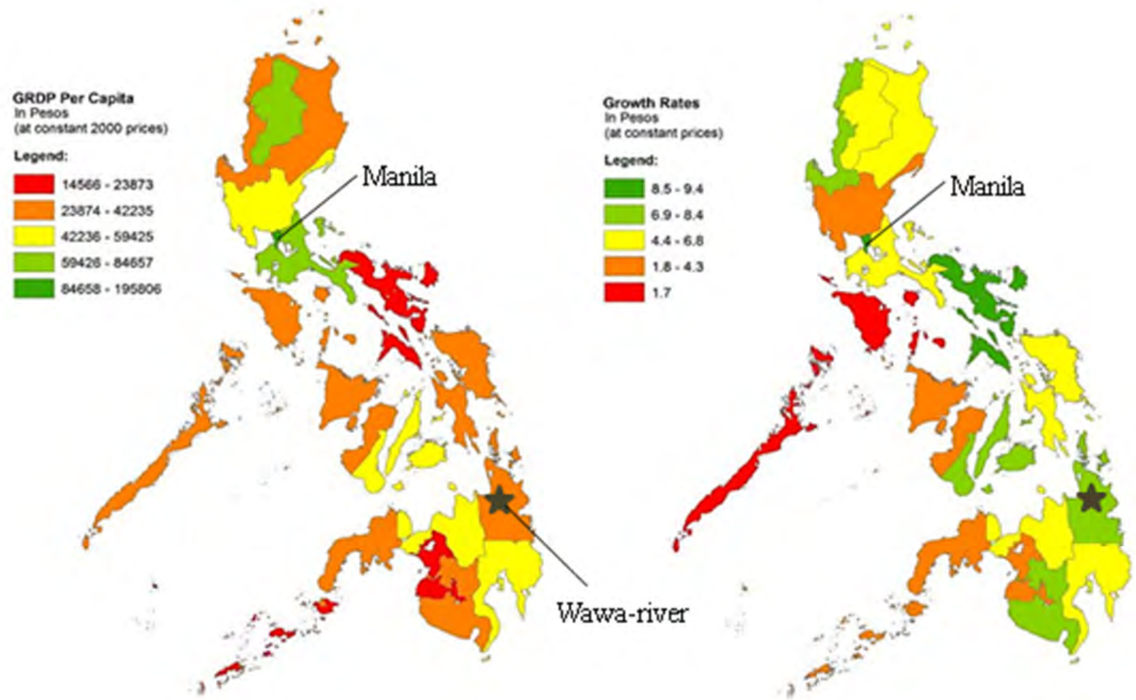


Fig. 1-9: Comparison of per capita GDP (in pesos) and GDP growth (percentage) by area

Source: National Statistical Coordination Board (NSCB) materials of 2013

1-2-2. Industry

The primary industries of the province of Agusan del Sur are agriculture, mining and forestry, while its primary agricultural products are rice, corn, bananas and oil palms (Table 1-6).

Table 1-6: Agricultural production in Agusan del Sur (unit: metric tons)

Crop type	Production			
	2005	2006	2007	2008
Rice	222,720	202,018	236,321	260,568
Corn	56,439	70,079	76,810	76,207
Bananas	19,298	25,087	28,418	32,702
Rubber	8,228	10,931	11,378	15,406
Root vegetables	9,312	4,397	4,630	7,859
Vegetables (leaves, roots, fruit)	1,366	945	530	4,427
Durians	861	504	500	1,984
Citrus fruit	2,284	1,064	717	1,753
Rambutans	564	111	183	1,151
Coffee	4,625	1,670	975	826
Beans	108	161	109	289
Mangoes	90	147	105	244
Lanzones	221	49	204	148
Cacao	24	184	36	53
Mangosteens	2	2	8	4

Source: Created by the study team based on data from the Agusan del Sur Provincial Agriculture Office

1-2-3. Infrastructure development

As the province of Agusan del Sur is landlocked, cargo is primarily shipped over land. The Philippine-Japan Friendship Highway (AH26 from Surigao to Davao) runs through the center of the province, while the nearest airport to the provincial government headquarters is Bancasi Airport in Butuan City, roughly 80 kilometers, or an hour’s drive, away. The neighboring province of Agusan del Norte has the port of Nasipit, from which regular ferry services run to and from Manila and Cebu.

1-2-4. Geography and climate

With an area of approximately 9,000 square kilometers, Agusan del Sur is the largest province on the island of Mindanao, and the fourth largest in the entire Philippines. The municipality of Sibagat lies in the very north of the province, in the greater Bayugan area, and has an area of 500 square kilometers. 75.9% of the province is covered in forestland, divided into 48.7% for plantations and 27.2% for protected forests. Over 90% of the municipality of Sibagat is covered in forestland, over 30% of which is protected. Their major resources are plantations, while their mineral production of gold and gravel is also thriving.

Topographically, mountain ranges run through both the east and west of the province, forming a large valley in the center. The Agusan River, the longest in Mindanao, runs through this valley, and lakes and wetlands can be found in the south.

In terms of climate, Agusan del Sur has no dry season at all, while rain is particularly prevalent from October to January. Of the four major climate types in the Philippines, divided by rainfall distribution, this area falls into "Type 2," with no dry season, a clear rainy season from December to February, and lowest rainfall recorded from March to May. Annual precipitation is 3,470 mm, one and a half times the national average of 2,081 mm, indicating that rainfall is plentiful (Fig. 1-10). In terms of soil types, while strongly acidic soil can be found in places, it is fundamentally clay-based and rich in nutrients, ideal for the cultivation of crops.

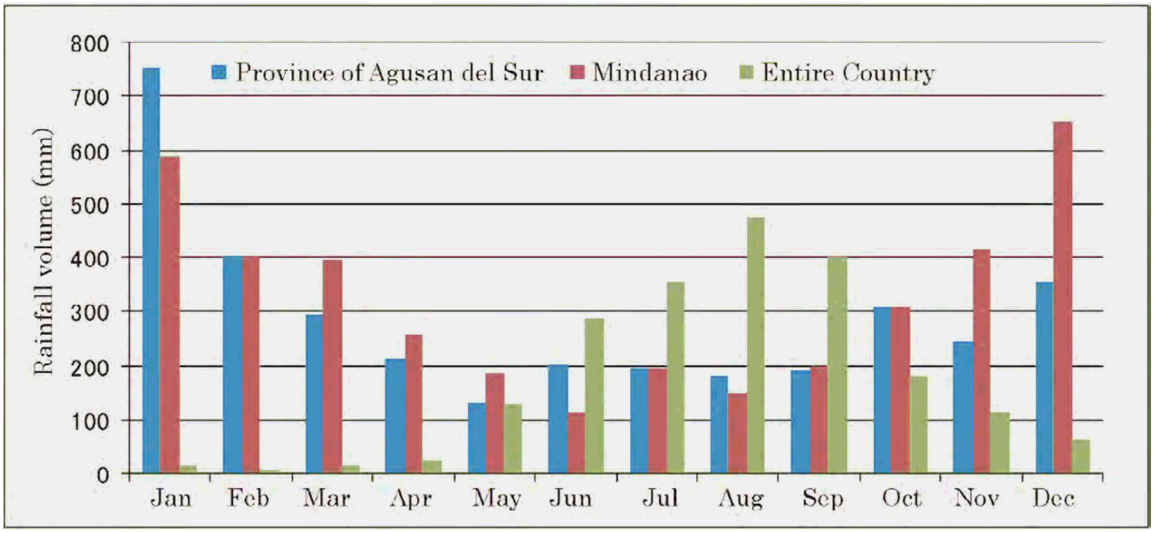


Fig. 1-10: Rainfall by month

Source: Created by the study team based on data from the System Information of Provincial Agriculture Office (SIOPAO)

1-2-5. Barangays

There are a total of 318 barangays in the province of Agusan del Sur, 24 of which make up the municipality of Sibagat. Of these, the three barangays of Padiay, Perez and Kolambugan lie on the Wawa River. Each of these barangays is home to around 380 households and 1000 people.

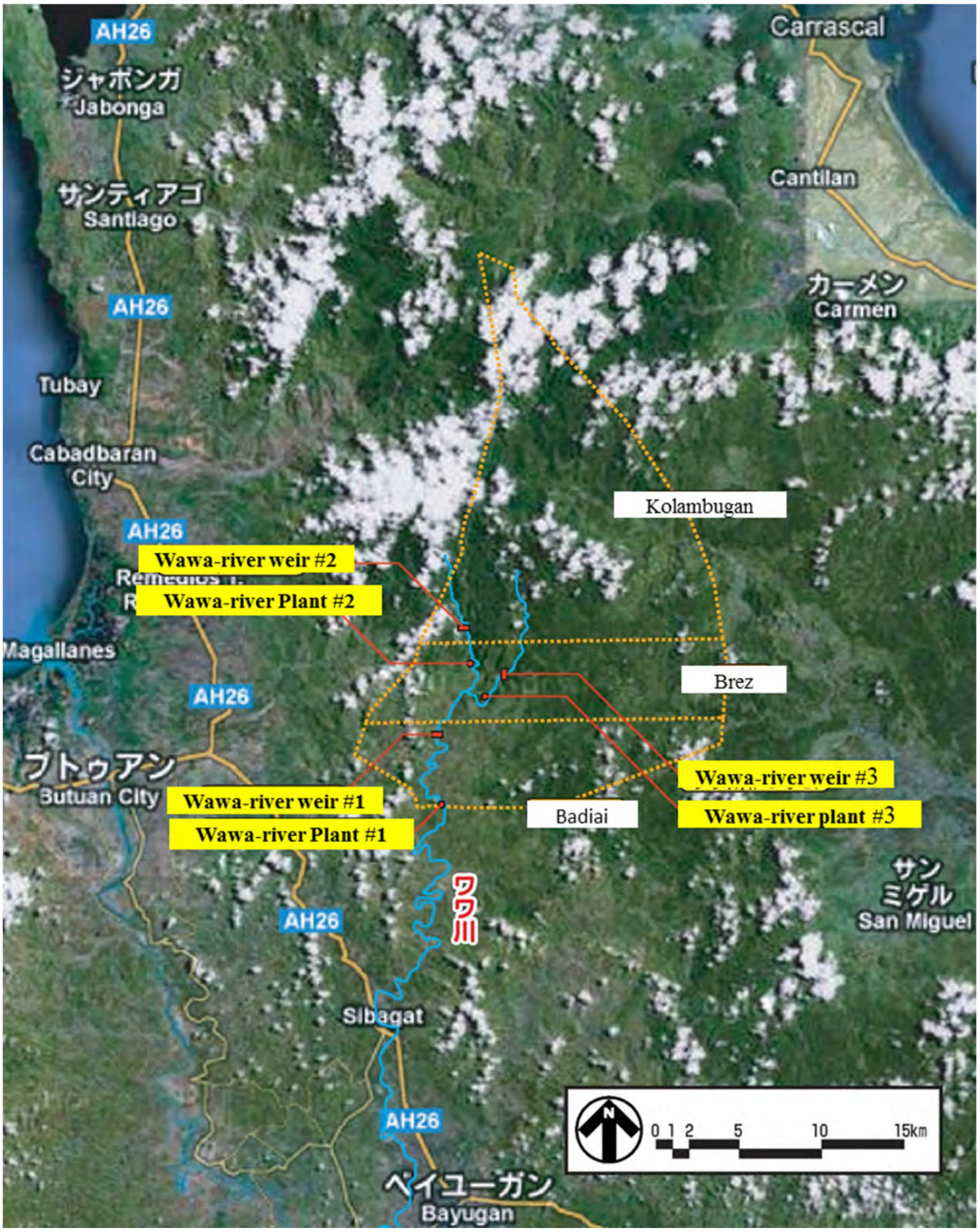


Fig. 1-11: Location of survey site (detailed)

Source: Created by the study team based on data from the Global Administrative Areas' publicly released Geographic Information System (GIS)

1-3. Japanese corporations in the Philippines

Many Japanese corporations have ventured into the Philippines since the 1990s, with their number exceeding 1,000 in 2010, and reaching 1,171 as of October 2011 (Table 1-7). With increasing political stability and economic growth, the Philippines has shown signs of continuing to attract more Japanese companies.

Broken down by area, the Luzon island group is home to 1,003 Japanese companies, or 86% of the total number. Of these, 577 corporations are based in greater Manila, making up almost half of the country's total (Table 1-8). Divided into industrial sectors, almost half of the Japanese firms in Luzon are secondary industry businesses, while another half are tertiary industry, leaving just 1.1% of Japanese companies in the area focusing on primary industry (Table 1-9).

Table 1-7: Japanese corporations in the Philippines by form of enterprise (October 2011)

Form of enterprise	Philippines	Luzon area	Visayas area	Mindanao area
Japanese corporations	101	96	5	0
Branch offices	39	38	1	0
Liaison offices, temporary agencies	62	58	4	0
Japanese companies incorporated locally	1,070	907	145	18
Wholly-owned subsidiaries	604	502	93	9
Joint ventures	283	246	29	8
Companies established locally by Japanese citizens	183	159	23	1
TOTAL	1,171	1,003	150	18

Source: Japan Bank for International Cooperation, based on survey data from the Embassy of Japan in the Philippines

Table 1-8: Japanese corporations in the Philippines by area (October 2011)

Area	Province	Number of Japanese corporations	Ratio (%)
Luzon area	Greater Manila	577	46.9%
	Laguna	199	16.2%
	Cavite	150	12.2%
	Batangas	53	4.3%
	Zambales	31	2.5%
	Pampanga	22	1.8%
	Other	29	2.4%
	Subtotal	1,061	86.3%
Visayas area	Cebu	149	12.1%
	Aklan	1	0.1%
	Leyte	1	0.1%
	Subtotal	151	12.3%
Mindanao area	Davao del Sur	11	0.9%
	Misamis Oriental	3	0.2%
	Surigao del Norte	2	0.2%
	South Cotabato	1	0.1%
	Agusan del Norte	1	0.1%
	Subtotal	18	1.5%
TOTAL		1,230	100.0%

Source: Japan Bank for International Cooperation, based on survey data from the Embassy of Japan in the Philippines

*Note: Some corporations have offices in multiple provinces, so the total does not match that from Table 1-7.

Table 1-9: Japanese corporations in Luzon by industry (October 2011)

Industrial sector	Industry	Number of Japanese corporations	Ratio (%)
Primary sector	Agriculture	11	1.1%
	Forestry	0	0%
	Fisheries	0	0%
	Subtotal	11	1.1%
Secondary sector	Mining	2	0.2%
	Construction	66	6.6%
	Manufacturing	411	41.0%
	Subtotal	479	47.8%
Tertiary sector	Electricity, gas, heating, waterworks	7	0.7%
	Telecommunications	45	4.5%
	Transportation	60	6.0%
	Wholesale and retail	119	11.9%
	Finance and insurance	21	2.1%
	Real estate	9	0.9%
	Catering and accommodation	30	3.0%
	Medical and welfare	8	1.6%
	Education and learning support	16	1.6%
	Composite services	30	3.0%
	Other services	138	13.8%
	Public service	1	0.1%
	Subtotal	484	49.1%
Other		29	2.9%
TOTAL		1003	100%

Source: Japan Bank for International Cooperation, based on survey data from the Embassy of Japan in the Philippines

1-4. The energy situation in the Philippines

1-4-1. Overview

A brief glance at the changes in the key facts pertaining to energy in the Philippines since 1980 reveals that the population of the country has doubled in 30 years, while the electric power generated has quadrupled in the same time frame (Table 1-10). In 1980, oil was relied upon for 70% of all power generation, but with no domestic oil resources, all oil needed to be imported from overseas, leading to moves being made to find alternative energy sources. With the aim of increasing energy self-sufficiency, construction was begun on a nuclear power plant on the Bataan peninsula in Luzon, but the administration of Corazón Aquino (the mother of current President Benigno Aquino) never commissioned the plant to produce electricity, citing concerns over safety and economic viability. No other nuclear power plants have been built in the country since. New fuel sources were then explored; coal-fired thermal power generation was introduced in the late 1990s, and gas-fired thermal power generation in the 2000s, following the development of the Malampaya underwater gas field. Coal remains the primary energy source, producing 37% of all electricity, followed by natural gas with 30%, renewable energy with 29% (including hydropower at 14%), while oil has fallen significantly to just 5%. As of 2011, energy self-sufficiency stood at 59.1%, meaning the Philippines remains an energy-importing nation.

Table 1-10: Energy production in the Philippines

	1980	1990	2000	2005	2010	2011
Population (unit: millions)	48.32	61.50	76.79	85.26	92.60	94.20
Energy production (unit: ktoe)	1,549	2,264	3,895	4,865	5,826	5,949
Ratios by energy source						
Oil	68%	47%	20%	11%	10%	5%
Coal	1%	7%	37%	27%	34%	37%
Natural Gas	0%	0%	0%	30%	29%	30%
Nuclear	0%	0%	0%	0%	0%	0%
Renewable energy	32%	45%	43%	33%	27%	29%
Hydropower	20%	23%	15%	15%	12%	14%

Source: Created by the study team based on data from the IMF World Economic Outlook Database and the “IEA Energy Balances of Non-OECD Countries, 2013 Edition”

1-4-2. Energy supply and demand in the Philippines

Energy consumption in the Philippines is increasing year-on-year in response to economic growth, with an average yearly increase in consumption over the ten-year period from 2004 to 2013 of 3.8%. Broken down by application, the average yearly consumption increases are 3.0% for domestic use, 5.1% for commercial use and 3.2% for industrial use (Fig. 1-12). Divided by area, Luzon has seen an average yearly consumption increase of 3.3%, the Visayas 5.6% and Mindanao 3.7% (Fig. 1-13).

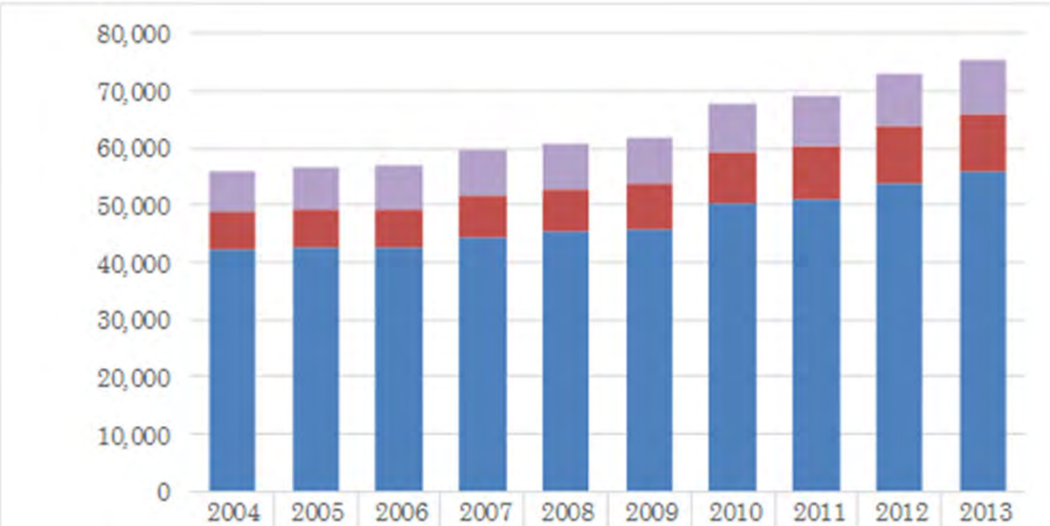
Supply is currently failing to keep pace with demand, with MERALCO, the Philippines’ number one electricity provider, primarily covering the greater Manila area, putting rolling blackouts in place. Increased energy production capacity and stability are key issues facing the entire nation.

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Other	1,358	1,177	1,274	1,641	1,394	1,523	1,595	1,446	1,667	1,971
Industrials	15,011	15,705	15,888	16,521	17,030	17,084	18,576	19,333	20,070	20,676
Commerce	11,785	12,245	12,679	13,470	14,136	14,756	16,260	16,623	17,777	18,303
House	15,920	16,031	15,830	16,375	16,644	17,503	18,833	18,693	19,694	20,613

Fig. 1-12: Electricity consumption over the past ten years by application (unit: Gwh)

Source: Created by the study team based on data from the Department of Energy's "2013 Philippine Power Statistics"

*Data values do not match those from Fig. 1-13 as self-consumed and lost energy quantities are not included



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Mindanao	7,087	7,242	7,413	7,890	7,971	8,235	8,402	8,702	9,126	9,346
Visayas	6,480	6,762	6,945	7,381	7,532	8,063	9,017	9,508	10,072	10,183
Luzon	42,389	42,562	42,424	44,339	45,316	45,635	50,322	50,964	53,723	55,735

Fig. 1-13: Electricity consumption over the past ten years by area (unit: Gwh)

Source: Created by the study team based on data from the Department of Energy's "2013 Philippine Power Statistics"

1-4-3. Electricity prices

Electricity prices in the Philippines are the highest among all neighboring Asian nations (Fig. 1-14). Its domestic and industrial rates of 0.29 USD/kWh and 0.19 USD/kWh are even 20% more expensive than the prices in Japan. While Japan's annual yearly income is roughly JPY 4.30 mn (according to the National Tax Agency's income survey), the equivalent figure in the Philippines is just JPY 480,000 (according to a survey of the International Labor Organization). When one considers that income in the Philippines is just one ninth of the level of Japan, the abnormity of its electricity prices can be appreciated.

A survey conducted by JETRO in January of 2014 revealed that MERALCO's electricity rates were 13 pesos/kWh for domestic use and 8.3 pesos/kWh for industrial use (Fig. 1-15). This means that the average yearly price increase has been 8.5% for domestic use and a remarkable 20.7% for industrial use, far outstripping the average yearly GDP growth of 5.3% and the average yearly inflation rate of 3.8% for the same period. Naturally, the rapid increases in the price of electricity are largely due to the chronic power shortages facing the country, making the stabilization of energy production an even more vital issue.

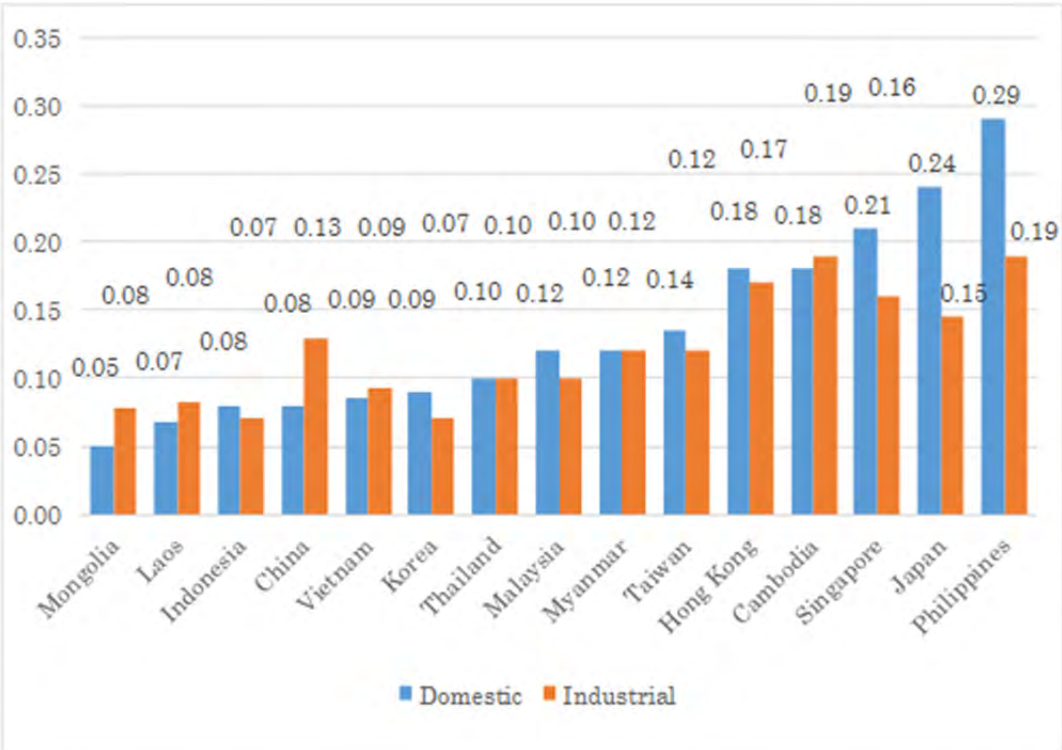


Fig. 1-14: Comparison of electricity prices in Asian countries (unit: USD/kWh)

Source: Created by the study team based on JETRO data of January 2014

*Note: When price differences by industry type, season or time of day exist, average figures have been used.

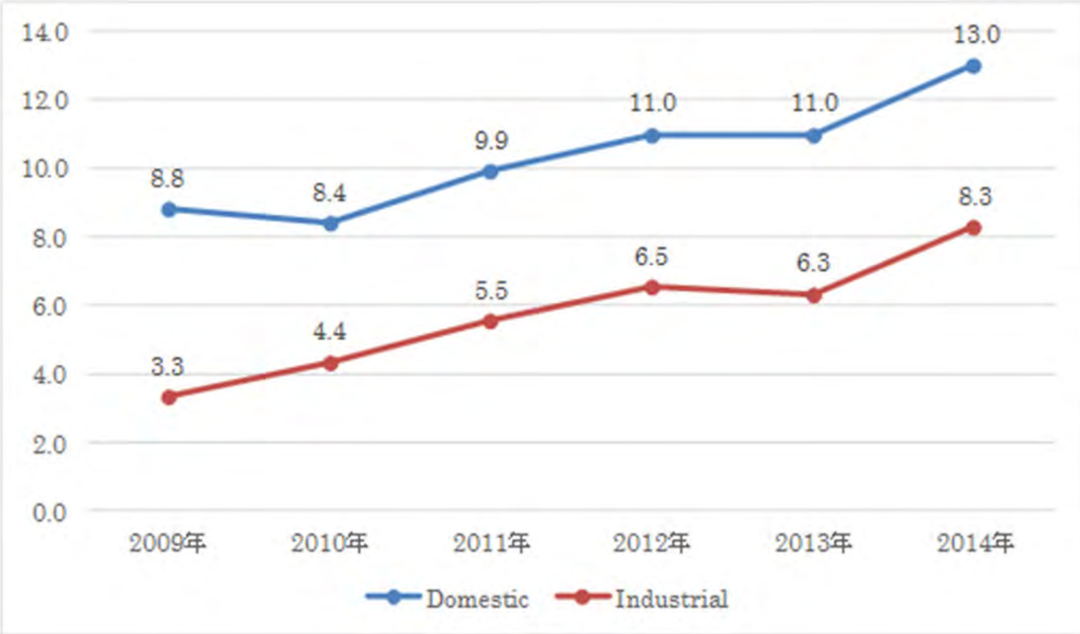


Fig. 1-15: MERALCO's electricity prices (unit: pesos/kWh)

Source: Created by the study team based on JETRO data

1-4-4. The energy situation in the planned project area

Peak electricity demand in the year 2013 was 11,305 MW (8,305 MW in Luzon, 1,572 MW in the Visayas, and 1,428 MW in Mindanao) (Fig. 1-16). These figures represented an increase of 5.1% over the previous year at the national level, with the growth rates by area coming in at 5.3%, 1.4% and 8.1% respectively. Already, the rapid growth of demand for electricity in Mindanao can be appreciated. Going forward, also, estimates for the period from 2014 to 2030 see an average increase in electricity demand of 4.6% for the nation as a whole, broken down into 4.1% for Luzon, 5.7% for the Visayas and the largest figure of 6.1% for Mindanao. Additionally, while the actions of the Moro Islamic Liberation Front (MILF), a militant separatist group based in the south of the island of Mindanao, have long hindered growth in the region, a peace accord was signed between MILF and the Philippine government on March 27, 2014. This peace agreement is expected to accelerate resource development and regional development, as well as increase electricity consumption in response to the increased stability of everyday lives in the region.

As of October 2014, the total generating capacity of all facilities in Mindanao stands at 1,829 MW, but only 1,546 MW can be produced in practice. Divided by generating source, hydropower makes up almost half of the industry with 776 MW of generating capacity, followed by diesel's 462 MW, which makes up almost one third (Fig. 1-17). As hydropower is heavily relied upon, most of the facilities are found in the north of the island, where water resources are abundant. At the same time, however, almost half of the island's entire demand is centered on the southeastern province of Davao, meaning that energy generated in the north has to be transported south. The electricity supply network of Mindanao features a total of 5,145.64 cct-km (circuit kilometers) of primary and secondary power lines, making this the second largest network in the country, behind that covering north Luzon. Total substation capacity of the system is 3,317 MVA. An important factor to note is that the Mindanao power grid is entirely separate from the national grid covering Luzon and the Visayas, meaning that all supply demands for the island must be met by electricity generated on the island.

Looked at in terms of times of day, while electricity shortages are occasionally felt all day long, the most serious shortages are during the primary active hours of 9 a.m. to 10 p.m. Around 6 p.m., in particular, electricity supply shortages of up to 600 MW have been recorded on some days, leading to chronic blackouts. According to the results of a survey undertaken by the Mindanao Development Authority (MinDA), the economic effects of blackouts on the area led to losses of PHP 2.3 bn in the first quarter of 2014 alone. In response to this overwhelming electricity shortage, President Aquino declared an “energy crisis” at the Mindanao Energy Summit held on April 13, 2012, positioning this issue as one that must be urgently addressed.

In terms of the energy supply to Butuan City, a review of the 2014 annual report of the Agusan del Norte Electric Cooperative (ANECO), responsible for the construction and maintenance of the electricity supply network in the city, reveals that the area for supply was 2,730.24 km^2 covering 120,336 households, peak demand was 57,240 kW, and total electricity sold in the year was 271,003,754.13 kWh. Contractually, they have a production capacity of 57,950 kW, made up of 27,950 kW from the NPC and a further 30,000 from IPPs. However, there is barely any difference at all between this production capacity and the peak demand, with a gap of just 710 kW between the two. Electricity stoppages for the year totaled 38,636 (roughly 105 per day), affecting a total of 958,893 homes and businesses. All of this data pertaining to production capacity and electricity stoppages clearly indicates that the energy supply in the project area remains at a level that is far from sufficient.

Fig. 1-16: Electricity peak demand estimates by area (unit: MW)

Source: Created by the study team based on data from the “2013 Supply-Demand Outlook” of the Department of Energy (DOE)

*Figures are final for 2013; figures for 2014 and beyond are the DOE’s estimates

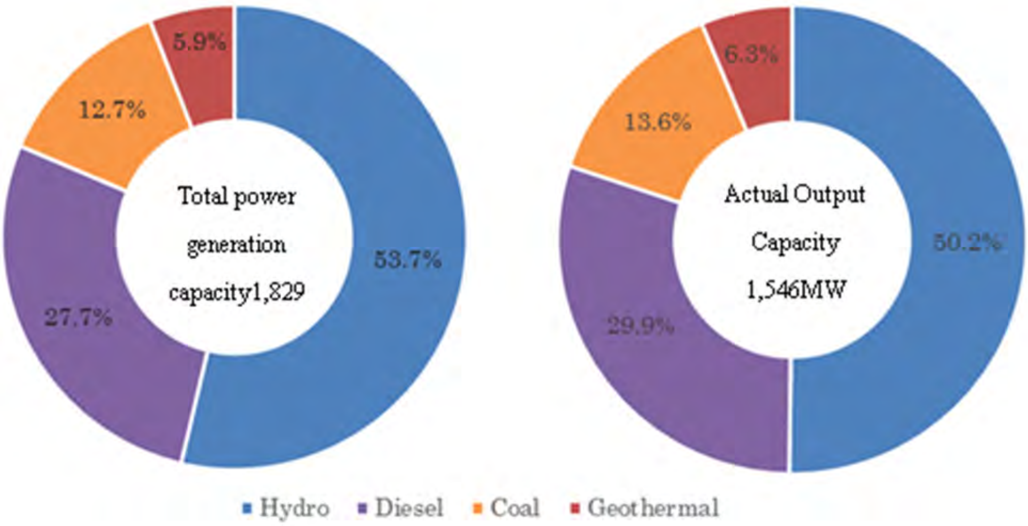


Fig. 1-17: Electricity generation sources in the Mindanao area

Source: Created by the study team based on a Department of Energy (DOE) report of October 2013

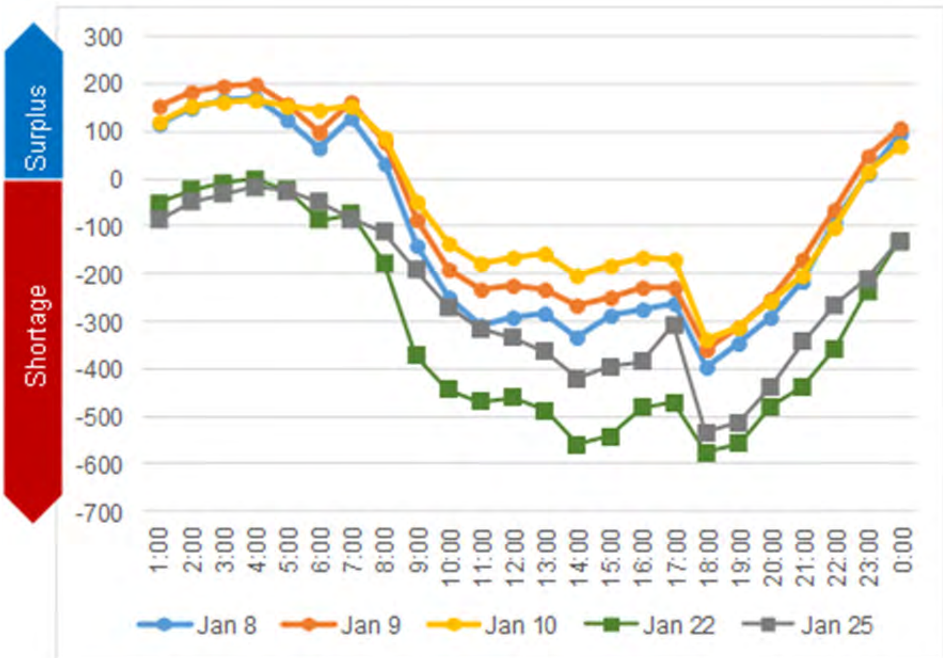


Fig. 1-18: Electricity supply-demand balance in the Mindanao area by time of day (unit: MW)

Source: Created by the study team based on data released in January 2015 by the National Grid Corporation of the Philippines (NGCP)

1-5. Electric power sector overview

1-5-1. Removal of restrictions on the electric power sector

Until recently, power generation and distribution in the Philippines was a monopoly of the National Power Corporation (NPC), but an overhaul of the sector with an eye to the creation of free competition was begun in 2001 with the passing of the Electric Power Industry Reform Act (EPIRA). The aims of the EPIRA were: a) the privatization of the power generation and distribution businesses of the NPC; b) the functionalization of market mechanisms through the establishment of a wholesale market; and c) the encouragement of healthy competition in both supply and demand through the opening of the retail market.

By the end of 2012, approximately 91% of NPC-owned power plants had been privatized, and the power purchasing and selling rights of the NPC, as stipulated in power purchasing agreements (PPA) between the NPC and independent power producers (IPP) had also been sold to private enterprise. The power transmission sector of the NPC was also separated from the company, and a new entity known as TRANSCO was created. In 2009, the rights to this business were handed over to the National Grid Corporation of the Philippines (NGCP), a private company. In terms of the wholesale market, wholesale electricity spot markets (WESM) were established in Luzon and the Visayas in 2006 and 2010 respectively. Finally, as regards retail sales, until recently consumers had no choice but to purchase their electricity from the distributor (power distribution company or power production union) who had won the franchise for the region in which they lived, and were unable to choose power production companies who could provide the service at a lower cost. With the liberalization of this market and the introduction of open access to it, consumers can now select their own electricity provider. This has, in turn, had the effect of encouraging increased fairness in electricity pricing. The opening of the electricity transmission and power grid businesses is planned to be conducted in three stages, gradually expanding the consumers for whom the service can be provided: the first stage is for consumers of 1 MW or more; the second is for consumers of 0.75 MW or more; while the third and final stage is for all remaining customers. The first of these stages was put in place in June of 2013, opening access to the marketplace to provide electricity for large consumers of at least 1 MW.

1-5-2. Issues facing the electric power sector

There are three main issues currently facing the electric power sector: a) private company-led expansion of supply capacity; b) the oligopolistic state of the power generation industry; and c) expensive electricity prices. We will now examine each of these in detail.

a) Private company-led expansion of supply capacity

With the opening of the electric power sector, the importance of the role of private firms in the establishment of stable and reliable power production cannot be underestimated. Power plant construction is a time-consuming process, meaning that development tends to be playing catch-up with demand, but in order to ease the very serious electricity shortages currently faced, it will be crucial to decide on investments in the short term that will be based on a firm analysis of uncertain medium-to-long term demand. Whether or not these private companies can make full use of market mechanisms and smoothly expand their production capacity without placing undue strain on the supply-demand balance will be scrutinized closely.

b) The oligopolistic state of the power generation industry

In the privatization of the electric power sector, through the selling of NPC-owned power plants and the rights to buy and sell electricity, major local financial groups such as San Miguel, Aboitiz, Lopez, MERALCO and Metro Group have played a significant role. When one considers that in the 1990s, overseas investment was relied on for the construction of any new power plants, the increased strength and aggressive involvement of local financial groups in infrastructure investment may be considered a major step forward. At the same time, however, the major players in the industry remain restricted to these few names, resulting in the power production and distribution industry becoming something of an oligopoly. However, upper limits on market shares are set for each separate electricity grid at the national level. As open access to the industry continues its expansion, and once the customer's right to choose has been properly reinforced, it is hoped that an environment can be maintained in which healthy competition is secure.

c) Expensive electricity prices

Unlike other ASEAN nations, there are no fuel subsidies in place in the Philippines, meaning that the prices paid by consumers for electricity are higher than in other countries. In order to lower electricity prices to an appropriate level, the securing of a sufficient supply and proper competition is vital, in that this would ensure that market mechanisms function properly. For this reason, too, continued expansion of market scale and improvements in efficiency brought about by privatization will be necessary in order to create a fair and even market.

1-5-3. Issues facing the electric power sector in the planned project area, and future development plans

Compared to the other areas, the privatization of the electric power sector in Mindanao has been slow, and power distribution in the area has predominantly been handled not by private companies but by non-profit power production unions. As of January 2015, approximately 65% of the power-generating infrastructure on the island remains under the management of the NPC. The primary reason for this state of affairs is that local stakeholders have opposed privatization on the grounds that it could lead to a monopoly on power supply in the area, and that this would, in turn, lead to an increase in power costs. Most significant of all such power-generating infrastructure is the Agus-Pulangui hydropower complex, which is made up of six distinct plants, and is owned by the NPC. With a total generating capacity of 776 MW (as of June 2015), it makes up roughly 40% of the power generating capacity of the island as a whole. The complex cannot be divided up and sold off without compromising its generating efficiency, but if it is privatized and sold to a single company, that company will wield excessive influence over power pricing in the entire Mindanao area. At the current time, the MinDA is in the process of establishing a government-owned and controlled corporation (GOCC) to which to transfer the ownership rights of the Agus-Pulangui hydropower complex. The possibility of operating and managing the complex through the use of a public-private partnership (PPP) is also currently being explored.

Moving forward, in order to smoothly expand the power-generating capacity of the area, rather than large-scale development, for which there are high barriers to entry and long lead times for construction, decentralized, small-to-medium-scale energy development will assume a role of greater importance. The "Mindanao Peace and Development Framework Plan 2011-2030," released by the MinDA, specifically states that the construction of small hydro plants will be given priority over large hydro plants in terms of incentivization. The plan outlined in this document calls for an increase in generating infrastructural capacity of 20% by 2020, of which half is to be achieved with renewable energy sources.

1-6. Political policies and trends related to the energy sector

1-6-1. Relevant organizations and fundamental policies

All political policies related to the energy field are overseen by the Department of Energy (DOE). The department's main tasks include the formulation, implementation and administration of all governmental plans in the energy field; the identification, extraction, development and application of energy resources; and the promotion of energy conservation. In terms of organizations related to renewable energy, the National Renewable Energy Board (NREB) is responsible for promoting entry for private corporations into the renewable energy field, while the Energy Regulatory Commission (ERC) approves feed-in tariff (FIT) rates, as well as overseeing the electric power market, setting power price regulations, and issuing business permits. In addition to these agencies, the National Electrification Administration (NEA), which falls under the purview of the DOE, promotes electrification programs in the regions, and provides assistance with financing and construction of regional power-generating infrastructure.

According to a report compiled in February 2014 by the Institute of Energy Economics, Japan, the most recently produced "Philippine Energy Plan 2012-2030" (PEP2012-2030, published in December 2012), laid out the following seven key energy policy objectives.

a) Maintenance of energy security
   - Expansion of renewable energy usage
   - Promotion of oil and coal exploration and mining
b) Improvements in energy access
c) Promotion of a low-carbon society
   - Ingraining of energy-conserving habits
   - Promotion of clean alternative fuels and technology
d) Improvements in the durability of the energy sector in the face of climatic variation
e) Creation of regional energy plans
f) Promotion of investment in the energy sector
g) Increased awareness of the need for change in the energy sector, and the ability to carry out such changes

1-6-2. Summary of renewable energy policies and related laws

Having experienced two oil crises in the past, the Philippine government has pursued policies and passed laws to reduce dependency on imported oil and develop domestic energy resources for over 30 years. Geothermal energy has the longest history in the Philippines of any such alternative energy source, with a presidential decree issued in 1972 (PD1442) to grant tax and accounting incentives to geothermal power plant operators. Currently, the geothermal energy-generating infrastructural capacity of the Philippines is second only to the United States.

Regarding small hydropower, the passing of the Mini-Hydroelectric Power Incentives Act in 1991 (RA7156) provided small hydropower producers with a variety of tax breaks under the condition that foreign investment was kept to below 40%. Similar incentives were put in place for ocean, solar and wind energy resources through an executive order of 1997 (EO462) and its later amendment in 2000 (EO232).

Upon entering the 21st century, energy generation and electrification were positioned as high-priority issues by the Arroyo administration, with the formulation of an energy independence and savings program designed to ensure that 60% of all consumed energy resources were produced domestically by the end of the president's term in 2010. In this program, also, renewable energy was positioned as highly desirable for its stability, economy and durability, and the fact that its costs are not swayed by the costs of primary energy resources such as oil and coal. With the ratification of the Renewable Energy Act of December 2008 (RA9513), the introduction of feed-in tariffs (FITs) and other incentives provided additional stimulus to the private corporation-led development of renewable energy.

(1) Renewable Energy Act of 2008 (RA9513)

This act established the National Renewable Energy Board (NREB) to deal with environmental and energy issues, and put a series of incentives in place to promote the development of renewable energy resources. Additionally, it set the government share on all renewable energy projects at 1% of total sales.

Table 1-11: Tax Conditions Relating to the Project

Item	Details
Income Tax Holiday	Exemption from corporate income tax for 7 years after the start of operations. If further investment is performed (expansion, increase in main machinery etc.) then further exemption of up to 7 years x 2 can be authorized (a maximum of 21 years).
Reduction of Corporate Income Tax	Reduction of corporate income tax to 10% from the 8th year of operations onward (usually 32%).
Exemption of Taxes Related to Importing Materials and the Sale, Transfer and Disposal of Asset Facilities	After receiving business authorization from DOE, exemption for 10 years on taxes relating to importing all asset materials related to the project. Also exempt from taxes relating to the sale, transfer or disposal of asset facilities.
Reduction of Real Estate Tax	Reduction of tax on land used for the placement of machinery to 1.5% or less of the acquisition cost or the book value.
Preferential Policy for Accounting	Being in the red for the first 3 years of operation is deducted from profits over the next 7 years. However, deduction from profits is not made as an initial adjustment, but only applies when the operation itself is in the red.
Acceleration of Depreciation	If no preferential treatment such as a reduction of corporate income tax was received prior to starting operation, special measures that accelerate depreciation can be used. (however, once these measures are used a reduction of corporate income tax cannot then be received)

Item	Details
Exemption from Value Added Tax	Exemption from Value Added Tax (VAT) on the sale of fuel and power.
Emission Rights	Exemption from taxes relating to purchase and sale of emission rights.
Preferential Treatment for Special Electrification Regions	Those establishing new business in target regions for electrification receive 50% of standard power charges paid in cash.
Tax Exemption Measures for Domestic Transactions	Exemption of VAT and import taxes on machinery and services on domestic business-related transactions.

Source: Created by the study team

(2) National Renewable Energy Program, 2011 (NREP)

Formulated by the DOE, the NREP supplemented the Renewable Energy Act as a road map for the development of renewable energy, stipulating that the generating capacity of renewable energy was to triple from 2010 to 2030, to reach a level of 15,304 MW (Table 1-12). This document also clarifies that hydropower made up 63% of all renewable energy generating capacity in 2010, and that it was projected to represent 55% of all targeted additions to this capacity from 2011 to 2030, thus underscoring the fact that hydropower resources will remain the most vital renewable energy resource available to the Philippines in the future. The specific objectives for the Mindanao area place the targeted increase in capacity by 2030 at 1,702 MW, of which 1,264 MW, or 75%, is to be provided by hydropower, indicating the particularly significant demand for hydropower development in comparison to other areas.

Hydropower itself is divided into three categories, depending on the generating capacity of the infrastructure: over 10 MW is considered large hydropower, 101 kW to 10 MW small hydropower, and less than 100 kW micro hydropower. NREP figures put the development potential of each of these three categories at 11,223 MW (18 sites), 1,847 MW (888 sites), and 27 MW respectively, for a total of 13,097 MW. As of 2010, the total hydropower generating capacity stands at 3,400 MW, meaning that only one fourth of the total potential water resources of the Philippines is being used at the present time. As reasons for this wasted potential, the high initial costs of large-scale hydropower development and the fact that it takes a long time to recoup costs certainly play a major role. Since the privatization of the industry in the Philippines, private corporations have been expected to lead the way in developing new power plants, but concerns over financing, together with environmental and social concerns, have undoubtedly proven obstacles to this happening. Small hydropower, on the other hand, has far fewer such concerns, and while its effect on the overall energy balance is relatively insignificant, its ability to provide locally produced and locally consumed energy for mountainous regions off the grid leads to great expectations for future development.

Table 1-12: Installation Targets for Renewable Energy (Units: MW)

	Installed Capacity as of 2010	Target Additional Capacity					Total Installed Capacity by 2030
		2015	2020	2025	2030	Total	
Philippines							
Hydro	3,400	341	3,161	1,892	0	5,394	8,794
Geothermal	1,966	220	1,100	95	80	1,495	3,461
Wind	33	1,048	855	442	0	2,345	2,378
Biomass	39	277	0	0	0	277	316
Solar	1	269	5	5	5	284	285
Tidal	0	0	36	35	0	71	71
Total	5,439	2,155	5,157	2,469	85	9,865	15,304
Mindanao							
Hydro	1,040	75	889	300	0	1,264	2,304
Geothermal	103	50	240	30	20	340	443
Wind	0	0	15	0	0	15	15
Biomass	0	37	0	0	0	37	37
Solar	1	7	5	5	5	22	23
Tidal	0	0	0	24	0	24	24
Total	1,144	169	1,149	359	25	1,702	2,846

Source: Created by the study team based on the DOE's "National Renewable Energy Plans and Programs"

(3) Power Development Plan 2009-2030 (PDP 2009-2030)

The DOE formulated the PDP 2009-2030 in 2008 as a long-term energy development plan. In it, they estimate that, not including new plants either planned or under construction or existing plants with plans for expansion of capacity, a further 16,550 MW of generating infrastructural capacity will be needed by the year 2030 (Table 1-13). By combining this data with Table 1-12, which was also based on these estimates, we can see that of the total additional generating capacity of 16,550 MW, 9,865 MW (or 59.6%) is expected to come from renewable energy sources, and 5,394 MW (32.6%) from hydropower alone. Once again, the vital importance of hydropower in particular and renewable energy in general in the future energy generation plans of the Philippines can be easily appreciated. The same statements apply to the Mindanao area.

Table 1-13: Necessary additional generating infrastructural capacity (unit: MW)

	2009	2010	2015	2020	2025	2030	Total
Luzon	0	0	1,500	2,700	3,400	4,300	11,900
Visayas	150	0	0	350	700	950	2,150
Mindanao	0	50	550	400	650	850	2,500

Source: Created by the study team based on data from the DOE's "Power Development Plan 2009-2030"

(4) Feed-in tariffs (FITs)

As a policy designed to encourage the adoption of renewable energy, the ERC introduced feed-in tariffs in July of 2010, with an entitlement period guaranteed at 20 years under the operation guidelines established by the ERC in the "Resolution Adopting the Feed-In Tariff Rules" (Resolution No. 16, Series of 2010). Regarding the tariff rates themselves, however, debate took much longer, and it was only on July 27, 2012, that the ERC adopted a resolution approving the FIT rates and equivalent degression rates for all RE technologies entitled to FITs except Ocean, whereby the rates were established as set out in Table 1-14 below. It was also decided that tariff rates would be revisited in three years' time, in 2015. The tariff rates for solar power and wind power were lowered in March and October of 2015 respectively, but in a hearing conducted with the DOE, it was decided that until it reached the target (initially set for December of 2017) of 200 MW of additional generating capacity, the tariff rates for small hydropower would be kept at the present level.

It should be noted that the EPIRA of 2001 is the first law in the Philippines to feature the term "renewable energy," which was used as an umbrella term covering solar power, wind power, hydropower, ocean power, biomass power and all other renewable energy sources for which political policies were put in place in the 1990s or later. The notable exception here is geothermal power, which received political support from a long time prior to this. As a result, geothermal power plants are not included in the feed-in tariffs, and have not been the beneficiary of any such fixed price purchase agreements.

Table 1-14: Feed-in tariff rates in the Philippines

Type	Primary Approved Price	Secondary Approved Price	Degression Rate	Installation Target
Solar	9.68 Peso/kWh	8.69 Peso/kWh March 2015	0.6% from 1 year from the effective start date of FIT	500MW 50MW until 2014
Wind	8.53 Peso/kWh	7.40 Peso/kWh October 2015	0.5% from 2 years from the effective start date of FIT	200MW
Biomass	6.63 Peso/kWh	6.63 Peso/kWh	0.5% from 2 years from the effective start date of FIT	250MW
Hydro	5.90 Peso/kWh	5.90 Peso/kWh	0.5% from 2 years from the effective start date of FIT	250MW

Source: Created by the study team

In terms of how projects were selected, details of the criteria were determined under the "Guidelines for the Selection Process of Renewable Energy Projects under Feed-in Tariff System and the Award of Certificate for Feed-in Tariff Eligibility" (DOE, June 2013). The most pertinent details of this document are as follows.

Section 3：Only those renewable energy developers with valid and subsisting renewable energy service contracts may apply for eligibility and inclusion of their project under the FIT system. A notarized proof and/or declaration that the project is not bound under any contract to supply its generated energy to any distribution utility or consumer must be submitted to the DOE, together with a business plan.

Section 4：The DOE shall complete its evaluation of the project's commerciality within thirty working days from receipt thereof.

Section 5：Projects that have complied with the requirements for conversion from Pre-Development Stage to Development Stage under FIT system shall be issued a Certificate of Confirmation of Commerciality.

Section 6：Once the electromechanical phase has begun and the construction phase is at least 80% complete, the DOE shall begin to make arrangements for power distribution, and then arrange for the issuance of a Certificate of Endorsement for FIT Eligibility once the electromechanical phase is completed.

Under the guidelines determined by the ERC, the total generating capacity eligible for FIT support for small hydropower is 250 MW. As of October 2015, there were a total of four businesses in operation with FIT contracts, producing a total of 26.60 MW. While this appears to leave 223.4 MW of production capacity available for FIT contracts, the reality is that FIT approval has already been granted to a large number of enterprises, whose plants would generate as much as 570 MW when operational (Table 1-15). However, despite receiving FIT approval, the vast majority of these projects are making poor practical progress. Of the 59 approved projects, only nine have firm construction plans in place. Businesses are required to submit quarterly progress reports to the DOE, and based on these reports the DOE is able to closely monitor the status of all approved ventures.

If we wish to consider the possibility of using the electricity-selling scheme established by the FIT framework, it will be necessary to confirm the latest FIT approval status with the DOE, and then file the necessary paperwork in line with the required regulations. Should FIT approval prove problematic as a result of the number of already approved projects, it may be possible to make use of a new incentive target pricing scheme currently being considered by the ERC instead. However, following a recent discussion with the DOE, it has been established that this new incentive price scheme will most likely not be able to provide prices to match those offered by the FIT system.

Table 1-15: Enterprises with FIT approval and their generating capacity

Type	Installation Target	No. of Approved Projects	Approved Capacity	No. of Installed Projects	Installed Capacity
Solar	500MW	17	638.12MW	7	131.90MW
Wind	200MW	5	313.00MW	6	393.90MW
Biomass	250MW	6	44.37MW	9	56.75MW
Hydro	250MW	59	576.49MW	4	26.60MW
Total	1200MW	87	1571.98MW	26	609.15MW

Source: Created by the study team based on the DOE's "FIT Monitoring Board Summary" of October 31, 2015

(5) Benefits to Host Communities Pursuant to ER1–94, As Amended

Pursuant to law ER1-94, in order to provide a benefit to the host community, this enterprise plans to provide a total of 0.01 pesos for every kWh of electricity sold, to be donated to three funds dedicated to the electrification of the host community, its development and livelihood, and protection of its environment.

1-6-3. Summary of laws pertaining to foreign investment

The major regulations pertaining to foreign investment in the Philippines are contained within the Omnibus Investments Code, the Foreign Investment Act and the Special Economic Zone Act. In this report, we will summarize the key elements of these laws which pertain to the planned project.

(1) The Omnibus Investments Code, Executive Order No. 226, 1987

This executive order was issued in 1987 in order to encourage investment in the Philippines through the establishment of tax and other incentives. This law lays out the requirements for an investment to avail of fiscal incentives, and what these incentives are. In order to be eligible to receive these incentives, an enterprise must register with the Board of Investments (BOI) and be granted approval. Registered enterprises receive incentives including an exemption from income taxes for a limited period, exemption from custom duties on the export of raw materials and other related transactions, and additional tax deductions for labor costs. The details of the incentives for registered enterprises which apply to this project are as follows.

- Exemption from income tax (also known as an Income Tax Holiday, or ITH)

  Newly registered companies are exempt from all corporate income tax for a period of six years for so-called “pioneer” enterprises, and four years for non-pioneer enterprises. The ITH can be extended under certain circumstances, but the total period of the ITH cannot exceed eight years. When expanding an enterprise, an ITH of three years proportionate to the scale of the expansion can be received, provided that the conditions set by the BOI are met.

- Additional tax deductions for labor costs

  For the first five years from registration, a registered enterprise shall be allowed an additional deduction from the taxable income of 50% of the wages corresponding to the increment in the number of direct labor if the project meets the prescribed ratio of capital equipment to number of workers set by the BOI.

- Unrestricted use of consigned equipment
- Employment of foreign nationals in supervisory, technical or advisory positions for the first five years from registration (extendable)
- Tax credit equivalent to the National Internal Revenue taxes and customs duties paid on the supplies, raw materials and semi-manufactured products used in the manufacture, processing or production of its export products and forming part thereof
- Access to bonded manufacturing/trading warehouse system
- Exemption from wharfage dues and any export tax, duty, impost and fee
- Simplification of customs procedures
- Executive Order No. 70 of March 29, 2012, reduced the rates of duty on certain goods, capital equipment, spare parts and accessories imported by BOI-registered enterprises to 0%. This executive order is valid for a period of five years.

(2) The Foreign Investments Act, Republic Act No. 7042, 1991

This act was ratified in 1991 as a replacement for the regulations pertaining to investments not eligible for incentives as originally specified in the omnibus. It clarifies the allowable foreign investment ratios for enterprises on the negative list. This act defines our planned enterprise as a domestic market enterprise, for which foreign investment is limited to a maximum of 40%, as it will fall into the following categories on the negative list:

17. Exploration, development and utilization of natural resources

22. Contracts for the supply of materials, goods and commodities to government-owned or

controlled corporation, company, agency or municipal corporation.[1]

(3) The Special Economic Zone Act of 1995

The Special Economic Zone Act of 1995 provides incentives for corporations beginning enterprises in certain selected areas of the country. Such zones will be administered by the Philippine Economic Zone Authority (PEZA), and include the Subic Bay, Clark, and Aurora freeport zones.

As can be seen from the above summaries, the enterprise that is the subject of this report will be eligible to receive a variety of incentives by registering with the BOI under the Omnibus Investments Code. Further, as the enterprise is likely to be classified under categories specified in the negative list with a maximum foreign investment ratio of 40%, the particular form that the operating business takes will need to be carefully considered. In terms of incentives, it is up to each enterprise to decide whether to register with the BOI or under the Renewable Energy Act. Incentives are available for each, so an examination of the relative advantages of each will be necessary. At the present moment in time, we will operate under the assumption that this enterprise will opt to receive the incentives provided under the Renewable Energy Act.

1-7. Current status of PPP-created infrastructure in the Philippines

1-7-1. Overview of political policies relating to PPPs in the Philippines

For many years, the lack of properly maintained infrastructure such as ports, roads and airports has, together with high electricity prices, proven a stumbling block to the encouragement of foreign investment. A survey conducted by JETRO among Japanese companies in the country found that 60% believed that “poor infrastructure (electrical, logistical, communication)” was a major impediment to investment. With little room in the national budget, the government has looked to private enterprise to help improve the infrastructure of the nation. From a very early stage, public-private partnerships (PPPs) have been seen by the government as vitally important, as evidenced by the passing of Asia’s first ever Build-Operate-Transfer (BOT) Law in 1990 (RA6957).

While the current Aquino administration is actively pursuing diplomatic policies that will encourage foreign investment, it has also positioned the development of infrastructure through PPPs as a key political policy, with construction projects underway to create highways, airport access roads, and light rail transit (LRT) networks. In September 2010, the BOT Center was reconfigured as the PPP Center, with its administrative control transferring from the Department of Public Works and Highways (DPWH) to the National Economic and Development Authority (NEDA). The fundamental process for a PPP project begins with approval from the NEDA Board, followed by prequalification examinations of the bidding enterprises, followed by the bidding itself, then the awarding of the project.

While the Aquino government is actively encouraging PPP businesses, its other main policy is the

[1] By the President of the Philippines, Executive Order No. 98, Promulgating the Ninth Regular Foreign Investment Negative List, October 29, 2012.

eradication of corruption, and to that end, it values transparency throughout the process. Large corporations, in particular, have been faced with repeated reconsiderations of the details of their projects, so that bids have been frequently delayed, leading to criticism that progress is slow. Furthermore, so that the operator of the enterprise can be selected with the highest possible level of transparency, solicited bids (in which the government initiates the project and requests corporations to make bids) have been prioritized over unsolicited bids (in which a corporation makes the initial approach). In the amended version of the BOT Law passed in July 2012, it was determined that no government aid would be made available to unsolicited projects. It should also be noted that government aid for PPP projects is generally provided at a fixed rate, after an examination of the feasibility of the project, and only in cases in which banks cannot provide funding. No assurances are generally provided against risks of supply or foreign exchange.

1-7-2. Current status of PPP-created infrastructure

The Aquino administration convened a forum in November 2010 regarding infrastructure, at which government policies concerning PPPs were explained, and the ten infrastructure projects the government would be requesting bids for in 2011 were announced. In practice, however, the only one of these projects for which bidding was carried out within the year was the Daang Hari – SLEX Link Road.

The figures provided by the PPP Center indicate that, as of January 9, 2015, there are 61 PPP projects underway (including latent projects), of which 14 are preparing for bids to be made, and eight have already awarded contracts (Table 1-16). Of these, the Ninoy Aquino International Airport (NAIA) Expressway construction project involves the construction of a 7.75 km long highway linking NAIA and the capital, as well as a 2.22 km access road linking the Metro Manila Skyway (between NAIA and South Metro Manila) and the Manila-Cavite Expressway (CAVITEX). This project promises to improve the infrastructural links between the airport and the capital, as well as between these areas and the province of Cavite, where industrial estates are concentrated, bringing significant merits for locally-based Japanese businesses, which have long desired improvements in logistics and distribution in the area.

However, infrastructure projects under the auspices of the PPP Center have tended to be large-scale and focused on the Luzon area, while the Mindanao area has yet to receive any direct benefits. The energy deficiency issues on the island have not been addressed by government-initiated PPPs at all, but instead rely on energy development from purely private corporations (Table 1-17).

Table 1-16: PPP projects for which contracts have been awarded (unit: 100 million pesos)

Name of Project	Budget
Daang Hari-SLEX Link Road	20.1
School Infrastructure Project Phase I	162.8
NAIA Expressway (Phase II)	155.2
School Infrastructure Project Phase II	38.6
Modernization of the Philippine Orthopedic Center	56.9
Automatic Fare Collection System (AFCS)	17.2
Mactan-Cebu International Airport Passenger Terminal	175.2
LRT Line 1 Cavite Extension and O&M	649.0

Source: Created by the study team based on PPP Center data

Table 1-17: Private Sector Led Energy Development Projects in Mindanao

Type	Project Operator	Facility Capacity	Progress	Estimated Start of Operation
Coal	Sarangani Energy	200MW	Under Construction	Phase 1 (100MW): Nov 2015
				Phase 2 (100MW): Nov 2016
	Therma South	300MW	Commissioning	Unit 1 (150MW): Sep 2015
				Unit 2 (150MW): Feb 2016
	San Miguel Consolidated Power	300MW	Under Construction	Unit 1 (150MW): Mar 2016
			FS ongoing for Additional 900MW	Unit 2 (150MW): Jun 2016
	FDC Utilities	405MW	Under Construction	Unit 1 (135MW): Jun 2016
				Unit 2 (135MW): Sep 2016
				Unit 3 (135MW): Dec 2016
	Minergy Coal	165MW	Under Construction	Unit 1 (55MW): Jan 2017
				Unit 2 (55MW): Mar 2017
				Unit 3 (55MW): May 2017
	GN Power Kauswagan	540MW	EPC Contract Concluded	Mar-18
Oil	Supreme Power	11.9MW	Under Construction	Diesel 1.7MW x 7 Unit : Dec 2015
Hydro	Agusan Power	25MW	Under Construction	Mar-16
	Euro Hydro Power (Asia)	2.4MW	Under Construction	Jan-17
	Hedcor Bukidnon	68.8MW	Preparing for Construction	43.4 MW＋25.4 MW: Oct 2019
	First Gen Mindanao Hydropower	30MW	Construction Halted Due to Regional Security Issues	Jul-18
	Asiga Green Energy	8.0MW	Under Construction	Aug-19
Biomass	Philippine Trade Center	1.6MW	Operating For Private Use	Oct-15
	Green Earth Enersource	2.6MW	Under Construction	Dec-15
	Lamsan Power	10MW	Under Construction	Feb-16
Total	15 Projects	2,070.3MW	-	-

Source: Created by the study team based on DOE Committed Private Sector Initiated Power Projects as of Oct 15, 2015

1-7-3. Involvement of this project with the above PPP schemes

The enterprise that is the subject of this survey is not a PPP project of the type that would involve the PPP Center, but is instead projected to be developed based on the amended BOT Law. The amended BOT Law does not have fixed policies regarding the division of risk between government and private enterprise for demand risk, foreign exchange risk and construction risk, and in particular the extent and details of any government guarantees; these must be negotiated on a case-by-case basis. Furthermore, the Electric Power Industry Reform Act (EPIRA) specifies that new, independent electricity-generation enterprises will not receive any governmental guarantees. In light of this, it is clear that a comprehensive risk analysis will need to be undertaken.

1-8. The evaluation of this enterprise in the projected construction area in terms of electricity demand and power generation plans

1-8-1. Expectations for this enterprise in the province of Agusan del Sur

With no power plants at all within its borders, the province of Agusan del Sur is entirely dependent on supply from other provinces for its energy needs, exacerbating the energy deficiency issues it faces. For this reason, expectations from within the province for this enterprise are high, in that it would represent the construction of the first power plant in the province, thus making the consistent supply of electrical power possible, which should in turn revitalize industry in the area.

1-8-2. Effects of the enterprise on the surrounding area

While the increase in power-generating capacity provided by this enterprise will not be enough to fully solve the energy deficiencies of the entire island of Mindanao, it could provide a major boost to the electrical supply of the province of Agusan del Sur. The peak demand recorded by ASELCO in 2012 was 27 MW, a figure which is projected to increase to approximately 40 MW by the time this enterprise is projected to be partially complete, between 2016 and 2017. This project should ensure that this amount of power could be produced and consumed locally. The construction and operation of a power plant is one of the most fundamental needs that the area has, suffering as it does from a chronic energy shortage. In this respect, this enterprise projects to be a pillar that will support a wide variety of economic activity. A stable supply of electrical power will provide a vital boost to the region’s efforts to attract foreign enterprise, so that this project will not only provide employment opportunities in the construction, operation and management of the plant, but contribute to the economic development of the entire region.

Additionally, in accordance with law ER 1-94 (Benefits to Host Communities Pursuant to ER 1–94, As Amended), this enterprise will donate a proportion of all electricity sold (0.01 pesos per kWh) to provide aid to the economy of the indigenous population. This can be broken down into three funds: 0.005 pesos per kWh for the electrification of the host community; 0.0025 pesos per kWh to raise the lifestyle level of the indigenous peoples; and 0.0025 pesos per kWh for the protection of forests and other environmental conservation. Stable operation of the plant will allow these funds to be relied upon and used effectively for the long-term good of the region.

Finally, as the power distribution companies of the neighboring provinces are all connected to each other, the implementation of this project will not only allow for the stable production of electricity for Agusan del Sur, but will also indirectly provide benefits to the economy of the wider local area.

1-8-3. Governmental energy policies

Of the DOE's electric power development plans for the period from 2009 to 2030, the production capacity for projects to which a commitment has already been made is no greater than 101 MW, meaning that further development, including through the involvement of private enterprise, is essential.

Further, according to the DOE's National Renewable Energy Program (NREP, 2011-2030), hydropower is expected to make up 57% of the generating capacity of all renewable energy by the year 2030. While this number is slightly lower than the 2010 figure of 62.5%, it is still above half, with hydropower expected to fulfil 55% of the additional capacity target for the period from 2011 to 2030. These numbers make it clear that hydropower resources will continue to be the most important of all renewable energy sources for the Philippines in the future. The specific objectives for the Mindanao area place the targeted increase in capacity by 2030 at 1,702 MW, of which 1,264 MW, or approximately 75%, is to be provided by hydropower, indicating the particularly significant demand for hydropower development in comparison to other areas.

Under the Renewable Energy Act, several attractive economic incentives are offered to encourage enterprises developing a wide variety of renewable energy sources, including biomass, solar (heat), wind, hydro, geothermal, and ocean energy. These incentives include a seven year exemption on corporate income tax, a ten year exemption from duties on imported materials, lowered tax rates on land used for facility construction, and the ability to offset any losses in the first three years against profits in the next seven years.

Based on all of the above factors, it is our firm belief that this enterprise is entirely consistent with the electrical energy policies of the Philippines.

1-9. Interest and movement shown by domestic and foreign corporations and other donors towards the electric power sector, renewable energy, and small hydropower in particular

In this section of the report, any movements and interest shown by corporations towards the development of renewable energy (hydropower, geothermal, solar, biomass, tidal power) in Mindanao will be summarized, based on an analysis of DOE documents and interviews.

1-9-1. Hydropower-generating enterprises

Table 1-18 is a summary of all of the hydropower enterprises currently approved by the DOE, as of October 31, 2015. On the island of Mindanao, a total of 92 hydropower-generating sites from 42 domestic Philippine corporations, with a total generating capacity of 1,428 MW, are either in the planning or construction stages. The majority of these domestic companies are special-purpose companies (SPC) or power authorities established by major financial groups such as Ayala, Lopez and Aboitiz, or set up by conglomerates of local trading companies and developers.

Within the Caraga region (Region 13), where the projected site for this enterprise can be found, there are a number of projects in the works, including the Asiga River small hydro plant (8.0 MW), in which Chodai, the initiator of this survey, is an investor, and the Taguibo River small hydro plants #1 and #2 (totaling 23 MW), a project initiated by Chodai and now handed over to JBIC for investigation and survey. Elsewhere, the province of Agusan del Norte has plants in the planning stages with a capacity of 5.0 MW in Butuan City, 9.75 MW in Cabadbaran, and 25.0 MW and 30.0 MW in Jabonga; the province of Surigao del Sur has a 5.0 MW plant in Cantilan and a 25.0 MW plant in Madrid planned; while Sibagat in Agusan del Sur has the construction of a 13.0 MW power plant in the planning phase.

At the present time, no Japanese company other than Chodai appears to be involved in such enterprises in the region. Interest shown by other donors also appears to be restricted to JBIC's involvement (at a surveying level) with the Taguibo River small hydro plants.

This lack of involvement of Japanese corporations is thought to be a result of the fact that sufficient funding can be obtained from local financial groups or financial institutions, or that funding is still being considered for many of these projects. In terms of donors, although a peace agreement was reached in March of 2014, the area remains affected by the uncertainty of conflict, making any institution wary of financing ventures in Mindanao.

Table 1-18: Summary of hydropower enterprises in Mindanao approved by the DOE

ISLAND/ GRID	REGION	PROVINCE	CITY/ MUNICIPALITY	PROJECT NAME	COMPANY NAME	POTENTIAL CAPACITY (MW)
MINDANAO	IX	Zamboanga del Sur	Bayog	Bayog Hydroelectric Power Project	Global Sibagat Hydro Power Corp.	6.00
			Dumingag & Midsalip	Sindangan 4 Hydroelectric Power	Alsons Energy Development Corporation	8.00
			Zamboanga City	Pasonanca Hydroelectric Power	PhilCarbon Inc.	1.00
				Saaz Hydroelectric Power Project	Meadowland Developers, Inc.	1.00
		Zamboanga del Norte	Leon Postigo	Polandoc Hydroelectric Power Project	Euro Hydro Power (Asia) Holdings, Inc.	2.00
			Mutia	Dapitan River (Middle) Hydroelectric Power Project	Euro Hydro Power (Asia) Holdings, Inc.	7.20
		Zamboanga		Alimpaya	Everhydro Corporation	0.50
				Patalon Hydroelectric Power Project	Everhydro Corporation	0.50
				Tagpangi Hydroelectric Power Project	Everhydro Corporation	0.50
				Ayala Hydroelectric Power Project	Everhydro Corporation	1.00
		Bukidnon		Pulunai River Hydroelectric Power	Repower Energy Development Corporation	3.90
				Katipunan River Hydroelectric Power Project	Repower Energy Development Corporation	2.10
			Baungon	Tumalaong Hydroelectric Power	First Gen Mindanao Hydro Power Corp.	9.00
			Baungon and Libona	Bubunawan Hydroelectric Power Project	FGEN Bubunawan Hydro Corporation	23.00
			Dancagan	Kitaotao 1	Hedcor Bukidnon, Inc.	35.00
			Impasugong	Gakaon Hydroelectric Power Project	LGU of Impasugong	2.23
				Atugan 1 River Hydroelectric Power Project	Gerphil Renewable Energy, Inc.	2.40
			Impasugong and Sumilao	Tagoloan Hydroelectric Power	FGEN Tagoloan Hydro Corporation	39.00
			Kalilangan & Wao	Maladugao River (Lower Cascade) Hydroelectric Power	United Holdings Power Corporation	10.00
			Libona	Umalag 1 Hydroelectric Power	Meadowland Developers, Inc.	1.80
			Malaybalay	Sawaga Hydroelectric Power Project	Euro Hydro Power (Asia) Holdings, Inc.	1.20
					Repower Energy Development	2.00
				Middle Canayan Hydroelectric Power Project	Sta. Clara Power Corp.	3.00
			Malitbog	Malitbog Hydroelectric Power	Philnewriver Power Corp.	3.40
				Silo-o Hydroelectric Power Project	Philnewriver Power Corp.	4.5
			Manolo	Culaman Hydroelectric Power Project	Oriental Energy and Power Generation Corporation	10.00
			Manolo Fortich	Mangima Hydroelectric Power	Philnewriver Power Corp.	10.00

ISLAND/ GRID	REGION	PROVINCE	CITY/ MUNICIPALITY	PROJECT NAME	COMPANY NAME	POTENTIAL CAPACITY (MW)
			Maramag	Maramag Hydroelectric Power Project	First Bukidnon Electric Cooperative, Inc. transferred to Maramag Mini-Hydro Corporation	2.00
				Pulangui IV	Repower Energy Development	10.00
			Santiago	Manolo Fortich 1 Hydroelectric Power Project	Hedcor Bukidnon, Inc.	43.40
				Manolo Fortich 2 Hydroelectric Power Project	Hedcor Bukidnon, Inc.	25.40
			Valencia	Manupali Hydroelectric Power	Matic Hydropower Corporation	9.00
				Upper Manupali Hydroelectric Power Project	Bukidnon II Electric Cooperative, Inc.	2.00
			Wao	Maladugao River (Upper Cascade) Hydroelectric Power	UHPC Bukidnon Hydro Power I Corporation	5.50
		Cagayan de Oro	Claveria	Mat-i 1 Hydroelectric Power Project	Philnew Hydro Power Corp	4.85
		Misamis Occidental	Calamba	Langaran Hydroelectric Power	Misamis Occidental I Electric Cooperative,	3.64
			Clarin	Clarin Hydroelectric Power Project	Philnew Hydro Power Corp	6.20
		Misamis Oriental	Cagayan de Oro City	Limbatangon Hydroelectric Power Project	Turbines Resource & Development Corp.	9.00
				Mat-i 2 Hydroelectric Power Project	Philnewriver Power Corp.	1.60
				Mat-i 3 Hydroelectric Power Project	Philnewriver Power Corp.	3.25
				Umalag 2 Hydroelectric Power	Meadowland Developers, Inc.	2.50
			Jasaan	Lower Cabulig Hydroelectric Power Project	Mindanao Energy Systems, Inc.	10.00
			Odiongan, Gingoog City	Odiongan River A Mini-Hydroelectric Power Project	JE Hydropower Ventures, Inc.	0.25
		Lanao del Norte	Iligan City	Bayug Hydroelectric Power Project	Euro Hydro Power (Asia) Holdings, Inc.	1.00
				Lower Bayug Hydroelectric Power Project	Euro Hydro Power (Asia) Holdings, Inc.	4.00
				Upper Bayug Hydroelectric Power Project	Euro Hydro Power (Asia) Holdings, Inc.	3.30
				Bulanog-Batang Hydroelectric Power Project	Bukidnon Hydro Energy Corporation	150.00
				Agus VIII Modular Hydroelectric Power Project	Fu-Tai Philippines, Inc.	12.00
			Kolambogan	Titunod Hydroelectric Power Project	Euro Hydro Power (Asia) Holdings, Inc.	1.00

ISLAND/ GRID	REGION	PROVINCE	CITY/ MUNICIPALITY	PROJECT NAME	COMPANY NAME	POTENTIAL CAPACITY (MW)
	X	Lanao del Norte/Lanao del Sur	Pantar & Baloi/Saguiar an	Agus III	Maranao Energy Corp.	225.00
	XI	Davao del Sur	Digos City	Ruparan Hydroelectric Power	Davao de Sur Electric Cooperative, Inc.	5.00
			Malita	Malita Hydroelectric Power Project	LGU of Malita, Davao del Sur	2.50
		Compostela Valley	Maco	Upper Maco Hydroelectric Power Project	Sta. Clara Power Corp.	4.00
				Mt. Leonard Hydroelectric Power Project	Sta. Clara Power Corp.	2.00
				Tagum R Hydroelectric Power	Sta. Clara Power Corp.	4.00
				Hijo R. I Hydroelectric Power Project	Sta. Clara Power Corp.	3.00
				Hijo R. II Hydroelectric Power	Sta. Clara Power Corp.	3.00
			New Bataan	New Bataan Hydroelectric Power Project	Euro Hydro Power (Asia) Holdings, Inc.	2.40
		Davao Oriental	Baganga	Baganga River Hydroelectric Power Project	Global Sibagat Hydro Power Corp.	11.00
				Cateel River Hydroelectric Power Project	Global Sibagat Hydro Power Corp.	16.00
			Caraga	Osmena Hydroelectric Power	LGS Renewable Energies Corporation	2.00
			Lupon	Sumlog 2 Hydroelectric Power	Alsons Energy Development	15.00
				Sumlog 1 Hydroelectric Power	Alsons Energy Development	8.00
		Davao del Sur	Davao City	Davao Hydroelectric Power Project	San Lorenzo Ruiz Olympia Energy and Water, Inc.	140.00
	XII	North Cotabato	Alamada	Alamada Hydroelectric Power	Euro Hydro Power (Asia) Holdings, Inc.	1.00
			Magpet	Magpet 1 Hydroelectric Power	Universal Hydrotechnologies, Inc.	9.80
				Magpet 2 Hydroelectric Power	Universal Hydrotechnologies, Inc.	1.30
			Makilala	Makilala-1 Hydroelectric Power	Universal Hydrotechnologies, Inc.	2.00
	XII	Sultan Kudarat	Isulan	Kabulnan 2 Hydroelectric Power Project	Philnewriver Power Corp.	110.00
		Sarangani	Maasim	Siguil 1 Hydroelectric Power Project	Alsons Energy Development	8.70
				Siguil 2 Hydroelectric Power Project	Alsons Energy Development	3.20
				Siguil 3 Hydroelectric Power Project	Alsons Energy Development	4.80
		Saranggani	Maitum	Kalaong 3 Hydroelectric Power	Alsons Energy Development	4.00
				Kalaong 1 Hydroelectric Power	Alsons Energy Development	12.00

ISLAND/ GRID	REGION	PROVINCE	CITY/ MUNICIPALITY	PROJECT NAME	COMPANY NAME	POTENTIAL CAPACITY (MW)
				Kalaong 2 Hydroelectric Power	Alsons Energy Development	6.00
		South Cotabato	Lake Sebu	Lanon (Lam-alu) Hydroelectric Power Project	Euro Hydro Power (Asia) Holdings, Inc.	9.00
			Sebu	Takbo Hydroelectric Power Project	South Cotabato I Electric Cooperative,	15.00
	XIII	Agusan del Norte	Butuan City	Bugsukan Hydroelectric Power	Global Sibagat Hydro Power Corp.	5.00
			Cabadbaran	Cabadbaran Hydroelectric Power Project	First Gen Mindanao Hydro Power Corp.	9.75
			Jabonga	Lake Mainit Hydroelectric Power Project	Agusan Power Corporation	25.00
				Puyo Hydroelectric Power Project	FGEN Puyo Hydro Corporation	30.00
			Santiago	Asiga Hydroelectric Power Project	Asiga Green Energy Corporation	8.00
		Surigao del Sur	Cantilan	Lower Carac-an Hydroelectric Power Project	Meadowland Developers, Inc.	5.00
			Madrid	Carac-an Hydroelectric Power	Hydro Link Projects Corporation	25.00
		Agusan Del Sur	Sibagat	Wawa 1 Hydroelectric Power Project	Equi-Parco Construction Co.	7.70
				Wawa 2 Hydroelectric Power Project	Equi-Parco Construction Co.	7.00
				Wawa 3 Hydroelectric Power Project	Equi-Parco Construction Co.	5.60
				Wawa Hydroelectric Power Project	Global Sibagat Hydropower	13.00
		Lanao del Sur	Malabang & Tubaran	Maitling River Hydroelectric Power Project	AQA Global Power Inc.	50.00
				Baras River Hydroelectric Power Project	AQA Global Power Inc.	30.00
				Matadi River Hydroelectric Power Project	AQA Global Power Inc.	27.00
				Lake Dapao Hydroelectric Power Project	AQA Global Power Inc.	50.00
					Total	1427.87

Source: Created by the study team based on DOE web site

1-9-2. Geothermal power-generating enterprises

The Philippines' largest power company, the Energy Development Corporation (EDC), has plans to develop geothermal power plants in the provinces of Zamboanga del Sur (capacity of 40.0 MW), Misamis Occidental (30.0 MW), Misamis Oriental (20.0 MW) and Cotabato (20.0 MW). While their generating capacity is unknown, Aboitiz Power Renewables Inc. (APRI) is also planning the construction of two plants in the provinces of Davao del Sur and Cotabato. EDC is a subsidiary of the Lopez Group, while APRI is a subsidiary of the Aboitiz Group. No involvement from any other corporation or donor was identified. This is likely due to the fact that geothermal power generation is a highly-specialized area requiring the technical expertise that only firms like EDC and APRI possess, as well as to the fact that each of these two companies is backed by large investment groups providing plentiful funding, meaning that no outside financing is necessary.

1-9-3. Other renewable energy enterprises

The details for existing development plans for power plants using other renewable energy sources (solar, biomass, tidal power) are as follows.

For solar power, no fewer than 28 sites producing a total of at least 400 MW have been identified as being approved or in the process of receiving approval. Among these, three projects which have already been approved have been identified as particularly worthy of note: an operation run by PhilNewEnergy Inc., a joint venture between Mitsubishi Corporation and the Ayala Group, in Davao del Sur (with a generating capacity of 35.0 MW); Kirahon Solar Energy Corp.'s facility in Misamis Oriental (20.0 MW); and an enterprise under the auspices of the Marawi City administration in Lanao del Sur (35.0 MW).

Six domestic Philippine companies have had projects approved for biomass power generation, with a combined generating capacity of 76.0 MW.

A single tidal power venture has been identified in Surigao del Norte (6.0 MW), for which a feasibility study is currently being conducted.

None of the above enterprises feature any involvement from foreign corporations or donors. The most significant reason for this is that the corporations involved are still examining their financing options. For the donors, although a peace agreement was reached in March of 2014, the area remains affected by the uncertainty of conflict, making any institution wary of financing ventures in Mindanao.

1-9-4. Coal-fired thermal power enterprises

San Ramon Power, Inc. (SRPI), a subsidiary of Alsons Consolidated Resources (ACR), which is in turn under the umbrella of the Alcantara Group, is currently considering the construction of a 105 MW coal-fired thermal power plant in Zamboanga City, for which Japan's Toyota Tsusho Corporation is considering providing 25% of the financing.

MINERGY Coal Corporation, an electric power company established by Mindanao Energy Systems, Inc., a wholly-owned subsidiary of Cagayan Electric Power & Light Company, Inc., an electricity distribution company based in Mindanao, is in the process of building a coal-fired thermal power plant in Misamis Oriental province, planned for operation in 2017 with a generating capacity of 165 MW. The Japanese companies Mitsubishi Corporation and Toshiba Plant Systems & Services Corporation have received a contract of approximately JPY 30 bn to construct this plant.

Aside from this, plans are also in place for the construction of coal-fired thermal power plants in the area for the following companies and in the following locations: Aboitiz Power in Davao, with completion slated for 2017 to 2018 and a generating capacity of 300 MW to 645 MW; FDC Utilities Inc. in Misamis Oriental, to be completed in 2016 with a generating capacity of 405 MW; San Miguel Consolidated Power Corporation in Davao del Sur, for completion in 2016 and with 300 MW of generating capacity; and GNPower Kauwagan Ltd., Co. in Lanao del Norte with a projected generating capacity of 540 MW.

As can be seen, the power generation industry in Mindanao is dominated by domestic Philippine companies, while involvement of outside donors has been extremely limited. However, with the signing of a comprehensive peace accord in March of 2014, peace in Mindanao is becoming a more realistic proposition. As this happens, it is anticipated that investment in infrastructure and private investment in general will become more prevalent, and interest from foreign corporations and other donors is expected to grow rapidly.

1-10. The necessity and importance of this enterprise

As established above, the island of Mindanao is facing a critical power shortage, and the province of Agusan del Sur, where construction is planned for this project, has no power plants within its borders. In order to ease the current shortage and to provide solutions for the future, thermal, geothermal, solar, wind and tidal power all have a role to play, but from the perspectives of energy security and environmental impact, hydropower generation, making use of the area's latent water resources, appears to be the most appropriate solution of all.

The northeastern part of the island of Mindanao, where construction is planned, is the most suited area for hydropower in the entire nation, with its heavy rainfall and its particular geographical features of heavily sloping hills. Additionally, the project is necessary for the region both in order to alleviate its power shortage and to develop its economy. Finally, hydropower has a history of over a century in Japan, and over that time certain Japanese corporations have developed a high level of technical expertise which can be fully utilized in the execution of this enterprise.

At the current time, relatively few Japanese corporations have a presence on the island of Mindanao. Should this project prove successful and result in the stable supply of electrical power for the area, Mindanao may well receive more attention in the future as a potential target for Japanese business. The northeast of Mindanao once provided vast quantities of timber to support Japan's period of strong economic growth after the war, and its links with Japan remain robust. Aside from timber, it is rich in natural resources, particularly water, and its farming and mining industries are thriving.

However, issues concerning public safety in the region have tended to keep away corporations and investors, from both Japan and elsewhere. With a population of 20 million on the island of Mindanao alone, the region is rich in human resources. When combined with the fact that labor costs in the region are cheaper than in Luzon or the Visayas, it becomes clear that the area has tremendous potential as a target for Japanese companies, for example as a base for a Japanese food supply chain working in the food processing industry. If the peace process, supported also by the Japanese government, continues to progress well, Mindanao can become known for more than just its abundant natural resources. Hitherto largely untouched by foreign investment, it has the potential to become, like Myanmar, the true "last frontier in Asia."

1-11. Authorizations necessary for the implementation of a small hydropower-generating enterprise

The various authorizations needed in order to implement a small hydropower-generating enterprise, and the current status of each for this project, are displayed in the table below.

Table 1-19: Necessary authorizations for a small hydro plant and current status

Authorization	Administrating agency	Notes	Authorization status
Renewable energy service contract	Department of Energy (DOE)	Application made after receiving support from the barangays and the regional government authorities.	Contract acquired by Equi-Parco (registration of a special-purpose company is underway; once registration is complete, the contractual rights will be handed over to the SPC)
Environmental Compliance Certificates (ECC)	Department of Environmental and Natural Resources (DENR)	An Environmental Impact Statement (EIS) or Initial Environmental Examination (IEE) must be submitted to the Environmental Management Bureau (EMB) for its evaluation.	Submission not yet made
Water Right Permit	National Water Resources Board (NWRB)		Application not yet made
Free and Prior Informed Consent Certificate (FPIC)	Memorandum of Agreement (MOA) signed with the indigenous populace	A Field-Based Investigation (FBI) will be carried out by the National Commission on Indigenous Peoples (NCIP).	Currently in planning stages

Source: Created by the study team

Chapter 2 Topographical Survey

2-1. Pre-existing topographical maps

The National Mapping and Resources Information Authority (NAMRIA) of the Philippines maintains 1:50,000 scale topographical maps of the entire nation and makes these maps available in either printed or electronic formats. The province of Agusan del Sur, the planned location for this project, is covered by these maps, and the schematic designs in previous surveys[1] have been based on these documents.

No other topographical maps of equivalent or superior detail of the area in question of have ever been created.

Fig. 2-1 is a topographical map at a scale of 1:50,000 of the relevant area, published by NAMRIA.

[1] "Study on Economic Partnership Projects in Developing Countries in FY2012, Study on the Wawa River Mini-Hydro Power Project in the Province of Agusan Del Sur, The Republic of the Philippines Final Report" February, 2013

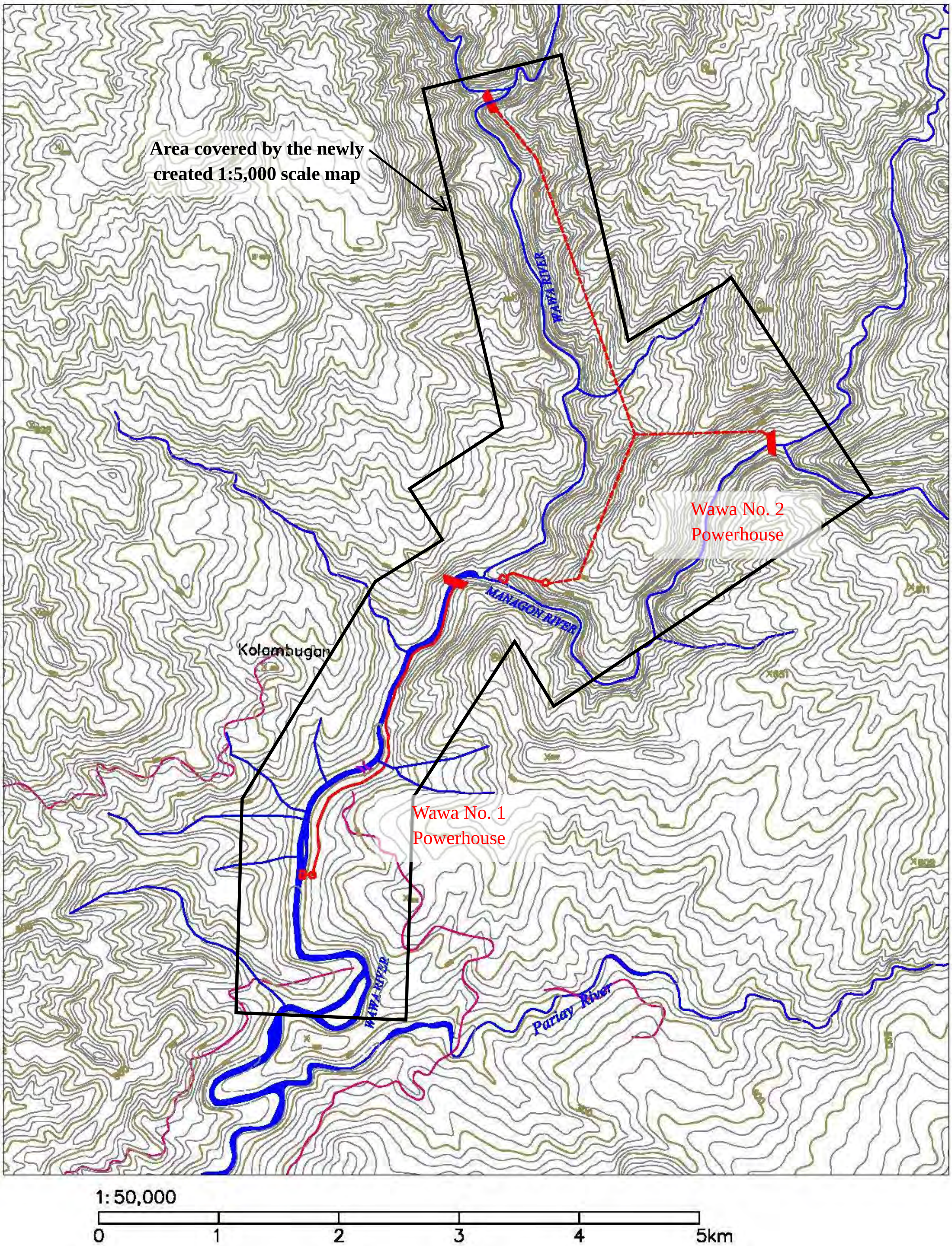


Fig. 2-1: Topographical map (1:50,000 scale) of the area surrounding the proposed sites

Source: NAMRIA

2-2. New topographical maps

For this survey, the creation of new topographical maps was conducted using the following techniques.

【Basic topographical maps】

The first step was to purchase the world’s highest quality digital 3D images of the entire earth, taken by the Japan Aerospace Exploration Agency’s (JAXA) Advanced Land Observing Satellite (ALOS), “Daichi.” Using these images, we were able to create planimetric maps at a 1:5,000 scale, with contour lines at 5 meter intervals. The figures on the following pages are these maps for sites 1 to 3.

【Topographical maps for schematic design】

In order to examine in detail the positioning for the weir, the powerhouse and the water conduit at site number 1, determined to be the leading candidate site by previous surveys, we used traditional measuring techniques to conduct plane surveys, and added this information to the basic topographical maps to create 1:1,000 scale planimetric maps for schematic design.

Prior to the planimetric survey, we set up six survey markers, and coordinated them with the Philippines national survey markers using GPS measurements. These became new survey markers, labeled GPS-1 to GPS-6.

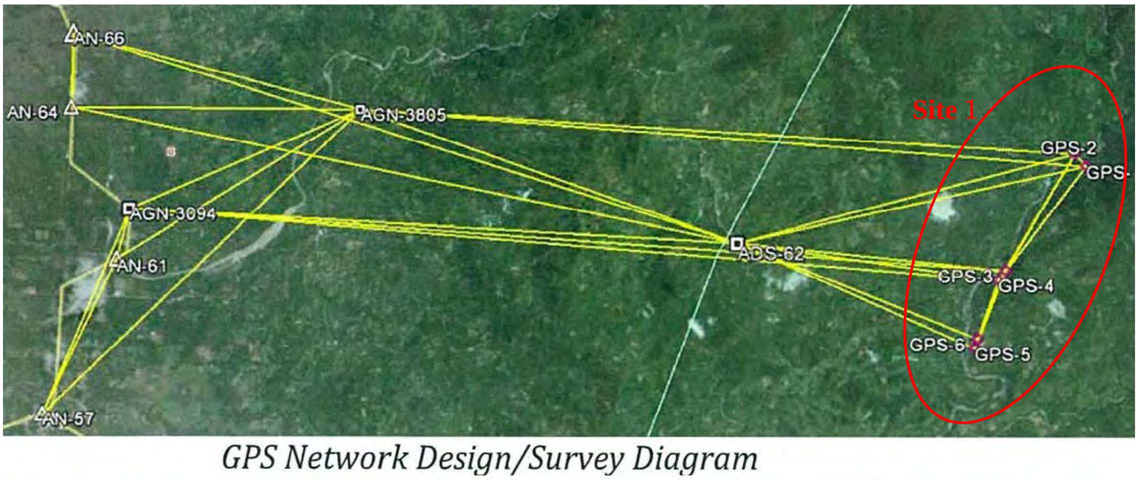


Fig. 2-2: Survey marker network

The results of the GPS survey coordinating the seven extant national survey markers and the six new survey markers are outlined in Table 2-1 below.

Table 2-1: Survey results for the Philippines national survey markers and the new survey markers

ID	Easting (Meter)	Northing (Meter)	Elevation EGM-08 (Meter)	Adjusted Elev. (MSL) (Meter)
ADS-62	796922.000	994344.775	549.911	550.2203
AGN-3094	787484.972	994789.851	18.861	19.1703
AGN-3805	791072.668	996351.619	61.851	62.1603
AN-57	786204.274	991630.104	14.448	14.7573
AN-61	787295.290	994018.240	23.827	24.1363
AN-64	786521.429	996360.113	11.577	11.8863
AN-66	786521.089	997520.549	9.332	9.6413
GPS-1	802317.640	995549.084	311.053	311.3623
GPS-2	802136.018	995734.712	345.401	345.7103
GPS-3	801075.813	993956.211	245.158	245.4673
GPS-4	800963.758	993810.205	269.926	270.2353
GPS-5	800603.174	992769.490	250.292	250.6013
GPS-6	800637.976	992920.125	263.952	264.2613

The data for the new survey markers (GPS-1 to GPS-6) was used as the basis for planimetric surveys conducted using traditional methods. The measurements thereby obtained were used to create a schematic design plan for site 1.

Fig. 2-3: Topographic map (1:5,000 scale) of the project's target sites*

Source: Created by the survey team using JAXA satellite images

*The size of the 1:5,000 scale map has been reduced to fit A4-sized paper

Chapter 3 Geological Survey

3-1. Topography and Geology

The project site is located at hilly to mountainous areas, of which elevations are 200 to 500 meter above sea level, along downstream to upstream of Wawa River. Wawa River forms deep V-shaped valleys in mountainous areas. The difference of geographical features are related to the geology of the site. The hilly areas are composed of sedimentary rocks such as shale and limestone with small doline. On the other hand, steep mountainous areas are composed of andesite and andesitic pyroclastic rock.

Main stream of Wawa River generally flows toward south and south-southeast with some meandering. River branches flow into the main stream perpendicularly. Wawa River at the site also flows southward into Bayugan and joins Agusan River which flows northward into Butuan Bay. The configuration of the river system is related to geological structures such as active faults and thrust faults.

Based on geological map made by Mines and Geosciences Bureau in Philippines (1963), this area consists of the following geology:

Paleogene to Neogene Sedimentary Rocks such as calcareous sandstone, calcareous siltstone, tuff and tuffaceous sandstone occuring in downstream of Wawa River. Upper Miocene to Pliocene sandstone, mudstone, sandstone-mudstone alternated layers and coral limestone occur in the left bank of downstream of Wawa River-Managon River junction to middle stream of Manogon River. Miocene to Pliocene volcanic rocks such as andesite, basalt, pyroclastic rock (tuff and tuff breccia) and pyroclastic flow deposit occur in the upstream of Wawa River and Managon River.

Andesitic tuff breccia and pyroclastic breccia occur widely at the site. They consist of tuff mixed with andesitic volcanic breccia of which diameter are 5 centimeter to 5 meter. These andesitic pyroclastic rocks show strike of east-west direction and dip toward south. Hydrothermal alteration, calcite vanes, and impregnations of pyrite in the matrix are observed partially. The rocks are fresh, strong and slightly weathered; and classified as CL to CM Class Rocks based on the Rock Classification of the Rock Foundation as shown in Table 3-1. Quaternary unconsolidated sediments such as terrace deposit and talus sediment overlay these rocks.

Table 3-1: Rock Classification of the Rock Foundation and Characteristic

Table 1 Rock Classification by the CRIEPI*

Grade		Description
A		The rock mass is very fresh, and the rock forming minerals and grains undergo neither weathering nor alteration. Joints are extremely tight and Sound by hammer blow is clear.
B		The rock mass is solid. There is no opening joint and crack (even of 1mm). But rock forming minerals and grains undergo a little weathering and alteration in partly. Sound by hammer blow is clear.
C	**CH**	The rock mass is relatively solid. The rock forming minerals and grains undergo weathering except for quarts. the rock is contaminated by limonite, etc. The cohesion of Joint and cracks is slightly decreased and rock blocks are separated by firm hammer blow along joints. Clay materials remain on the separation surface. Sound by hammer blow is a little dim.
	CM	The rock mass is somewhat soft. The rock forming minerals and grains are somewhat softened by weathering, except for quarts. The cohesion of Joints and cracks is somewhat decreased and rock block are separated by ordinary hammer blow along the joints. Clay materials remain on the separation surface. Sound by hammer blow is somewhat dim.
	CL	The rock mass is soft. Weathering softens the rock forming minerals and grains. The cohesion of Joints and cracks is decreased and rock blocks are separated by soft hammer blow along the joints. Clay materials remain on the separation surface. Sound by hammer blow is dim.
D		The rock mass is remarkably soft. Weathering softens the rock forming minerals and grains. The cohesion of Joints and cracks is almost absent. The rock mass collapses by light hammer blow. Clay materials remain on the separation surface. Sound by hammer blow is remarkably.

**Central Research Institute of Electric Power Industry*

Source: Classification of the Rock Foundation for Dam based on CRIEPI (Tanaka, 1964)

3-2. Site Reconnaissance Results and Geological Investigation Plan

Site Reconnaissances were carried out around the site of each facility of Wawa #1 Mini-Hydro Power and Wawa #2 Mini-Hydro Power in order to understand geological conditions and geotechnical properties. These results are shown in following.

3-2-1. Wawa #1 Mini-Hydro Power

The whole layout of Wawa #1 Mini-Hydro Power is shown in Fig. 3-1.

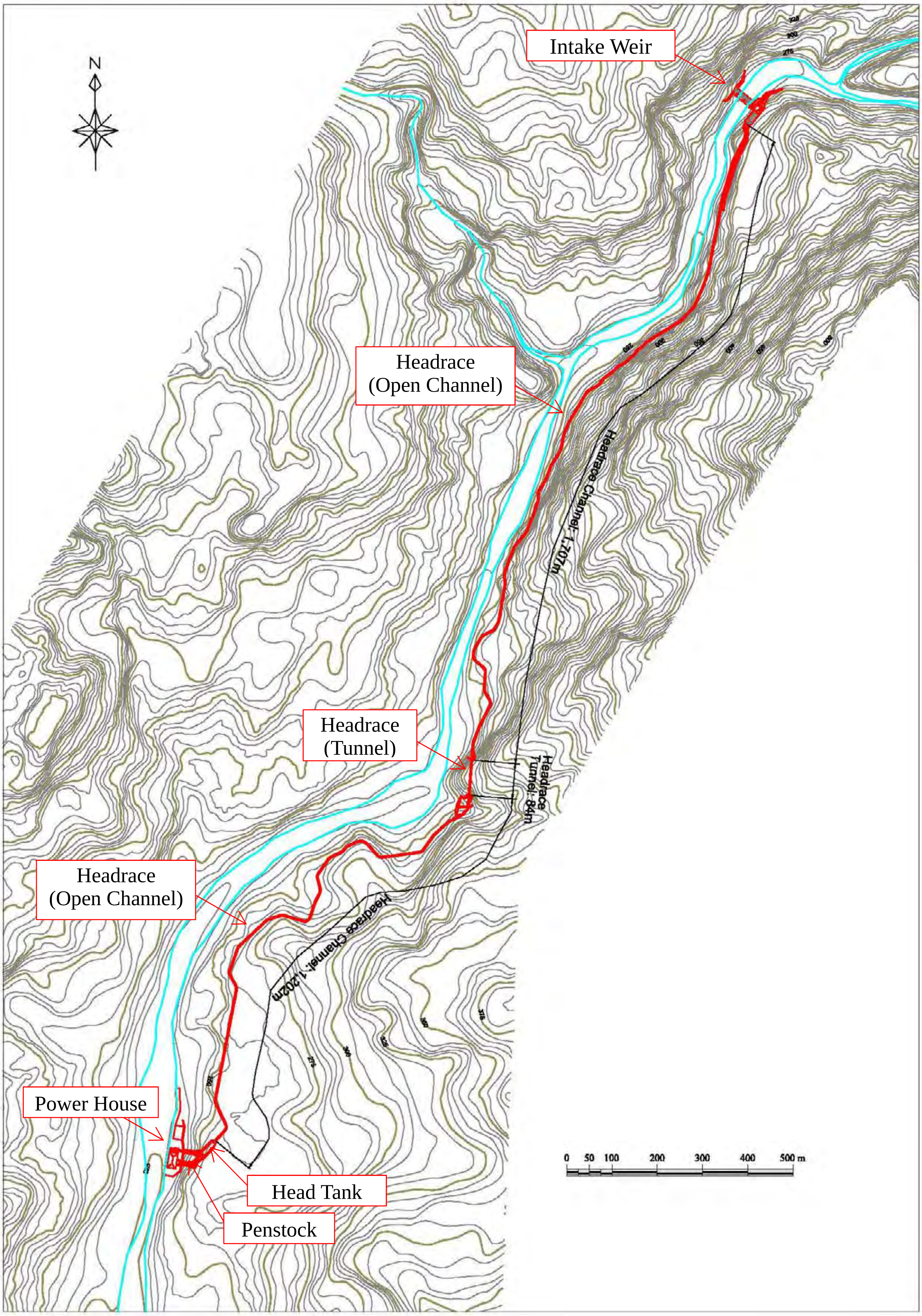


Fig. 3-1: The layout of Wawa No.1 Mini-Hydro Power

(1) Intake Weir

This intake weir is proposed 50 to 100 meters downstream from the junction of Wawa River and Managon River. At this location, Wawa River is about 10 meters wide and 9 meters deep at the narrowest point and about 50 meter wide in the downstream.

Photo 3-1: Panoramic View at the Location Proposed Intake Weir (View Toward Upstream)

The right bank is about 40 meter in height and very steep of which slope is 40 to 60 degree, and forms narrow ridge in the downstream of the junction of Wawa River and Managon River. The upper slope consists of limestone and the lower slope consists of andesitic tuff and lava. The rocks are hardly weathered and classified as CL to CM Class Rock at this location. Andesitic tuff is partially classified as D Class Rock.

Photo 3-2: Boundary of Limestone and Andesitic Tuff at the Right Bank of Location Proposed Intake Weir

Photo 3-3: Andesitic Tuff Classified as CL to CM Class Rock at the Right Bank of Location Proposed Intake Weir

Photo 3-4: Boundary of Limestone and Tuff at the Right Bank of Location Proposed Intake Weir

Photo 3-5: Limestone Classified as CM Class Rock at the Right Bank of Location Proposed Intake Weir

The left bank is 15 to 20 meter high very steep slope consisting of andesitic breccia and lava classified as CL to CM Class Rock. The riverbed is covered by gravels. A fault fracture zone, of which strike and dip are N60E, 55SE and width is 50 to 80 centimeter interbedding with brown clay partially, is observed in andesitic breccia.

Boring Investigation was carried out at this location in order to understand detailed geological conditions and hydraulic properties. The results are shown in Section 3-3.

Photo 3-6: Andesitic Breccia classified as CM Class Rock at the Left Bank of Location Proposed Intake Weir

Photo 3-7: Andesitic Breccia classified as CL Class Rock at the Left Bank of Location Proposed Intake Weir

Photo 3-8: Fault Fracture Zone observed at the Left Bank of Location Proposed Intake Weir (N60E, 55SE).

Photo 3-9: Junction of Wawa River and Managon River (View Toward Upstream)

(2) Headrace

Along the left bank of Wawa River proposed headrace is considered to consist of andesitic rocks in the upstream, and limestone and sandstone slate alternation at the both banks in the downstream. The slope of the left bank is very steep in the upstream and gentle in the downstream. There are two streams flowing into Wawa River at the left bank. Characteristic of the Karst such as limestone column and doline are also recognized in the gentle slope of the downstream of the left bank.

Photo 3-10: Outcrop of Limestone classified as CM Class Rock at Right Bank along Route of Proposed Headrace

Photo 3-11: Close up of Photo-18

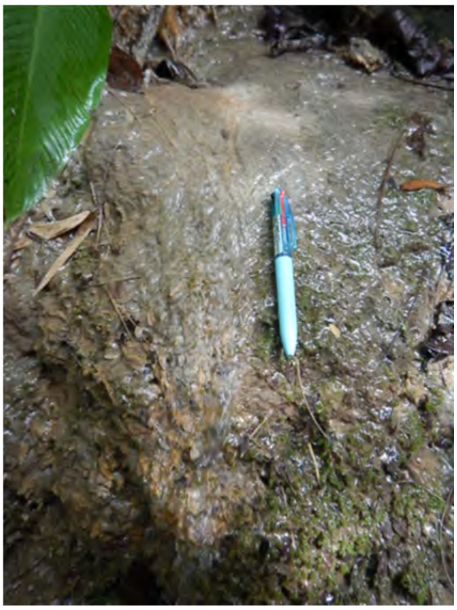


Photo 3-12: Outcrop of Dissolute Limestone classified as D Class Rock at Right Bank along Route of Proposed Headrace

It is necessary to cut slope due to steep slope and slope protection is required at upstream. However, it is easy to construct the headrace on gentle slope at left bank downstream.

Since desander is planned to be constructed at immediate downstream of the intake weir, additional geological investigation such as boring is required in order to understand geotechnical properties for detailed design.

(3) Head Tank and Power House

Power house is planned on terrace surface covered with terrace deposit. Head tank is planned on the slope behind of the power house or on the flat surface above the slope, which may consist of sandstone slate alternation and limestone.

Since the proposed power house is planned on the terrace which is 30 to 50 meters higher than riverbed level and covered with sandy gravel terrace deposits. And the location planned head tank may consist of limestone. Therefore, the boring investigations were carried out in the both locations in order to confirm foundation. These results are shown in Section 3-3.

3-2-2. Wawa #2Mini-Hydro Power

The whole layout of Wawa #2 Mini-Hydro Power is shown in Fig. 3-2.

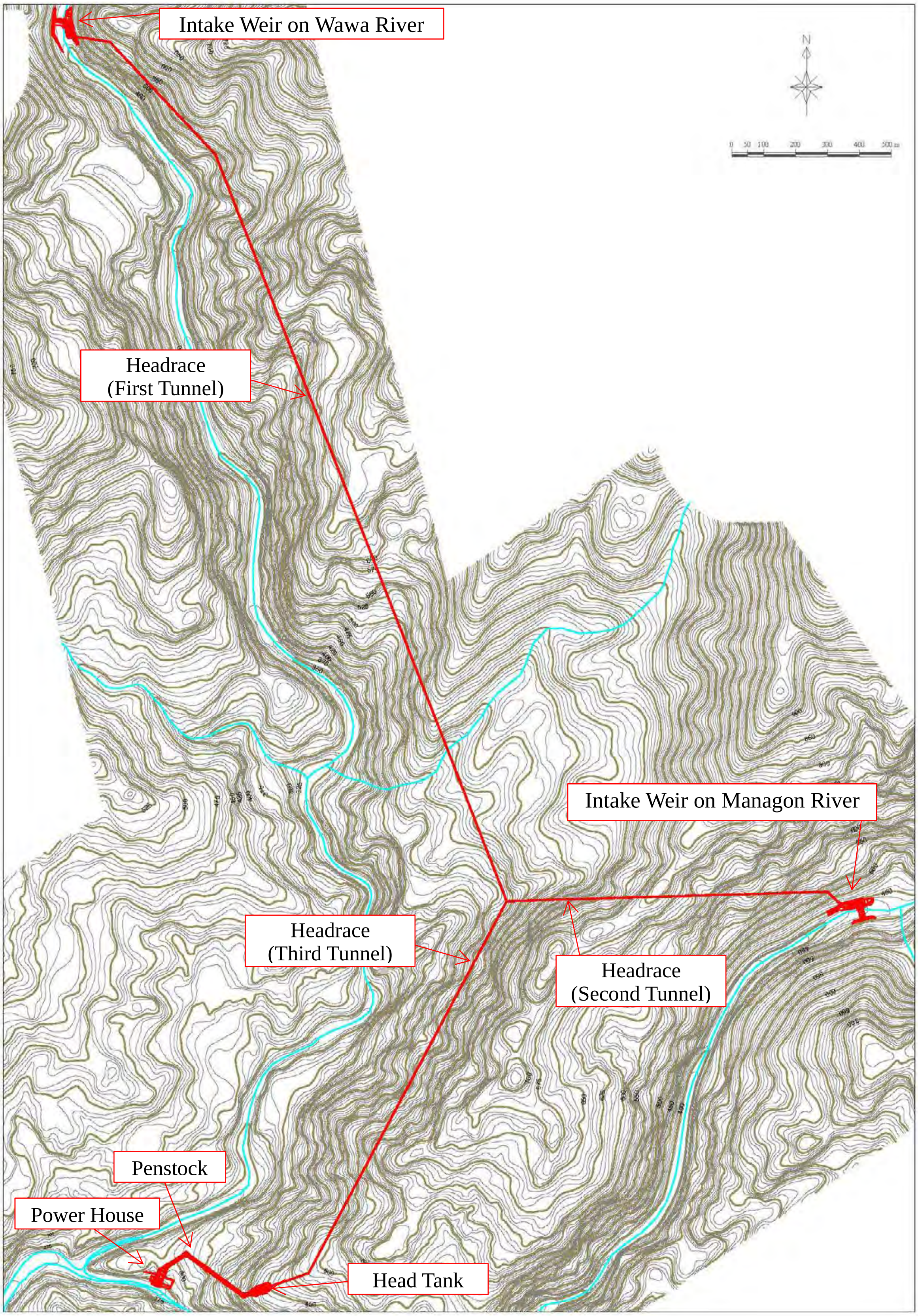


Fig. 3-2: The layout of Wawa No.2 Mini-Hydro Power

(1) Intake Weir

1) Wawa River

The slopes of both banks are very steep cliff of which high are 20 to 30 meters and gradient is 50 to 60 degrees. Width of Wawa River at this location is about 15 meters at the narrow point and about 30 meters in the downstream.

Andesitic tuff breccia and andesitic tuff classified as CL to CM Class Rock are exposed on the cliff surface. Bedding and flow structure of which strike is 50 to 60 degrees north-east direction and dip is 10-30 degrees southeastward (toward downstream) are recognized in the tuff. There are spring water from the middle and near top of the cliff. The geology of the riverbed is also andesitic tuff breccia classified as CL to CM Class Rock of which discontinuities such as bedding are dipping of 10 to 20 degrees toward downstream. The andesite classified as CM Class Rock and forming columnar joints is also observed in the riverbed.

Photo 3-13: Panoramic View at Location Proposed Intake Weir on Wawa River (View Toward Upstream)

Photo 3-14: Panoramic View at Location Proposed Intake Weir on Wawa River (View Toward Upstream)

Photo 3-15: Cliff observed Spring Water at the Right Bank of Location Proposed Intake Weir on Wawa River

Photo 3-16: Andesitic Tuff Breccia classified as CL Class Rock exposed at Surface of Cliff at the Right Bank of Location Proposed Intake Weir on Wawa River

Photo 3-17: Close up of the Photo-24. Discontinuities show Strike of 62 Degrees North-East Direction and Dip of 32 Degrees Southeastward

Photo 3-18: Andesitic Tuff with Bedding on the Riverbed.

Photo 3-19: Andesite with Columnar Joints classified as CM Class Rock on Riverbed.

Since the both banks consist of bedrock classified as CL to CM Class Rock and very steep slopes, and width of Wawa River is narrow in this location, it's conditions are favourable to construct the intake weir. Considerations for construction of intake weir are as follows;

- Bedrock is shallow at riverbed. However, bedding and flow structure of layers incline toward downstream with low angle. Therefore, it is necessary to take measures against sliding of the intake weir at flooding time such as foundation treatment including grouting water cutoff.
- Since spring water is observed from the cliffs of both ends of the intake weir, it is necessary to take measures for water cutoff in order to prevent water leak at flooding time.
- Since the upper cliff overhangs partially and the beddings of bedrock incline toward downstream, it is necessary to take measures for slope failures during slope excavation works.

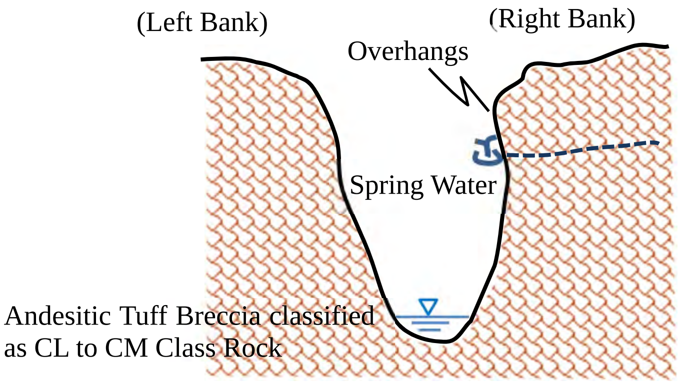


Fig. 3-3: Schematic Geological Profile at Location Proposed Intake Weir on Wawa River

2) Managon River

The slope of the left bank at proposed Intake Weir forms steep cliff, of which height is 30 to 40 meter and slope is 50 to 60 degrees, and “Managon Water Fall” of which height is about 20 meter. The slope of the right bank is rather gentle of which slope is 20 to 40 degree and high is 50 meter till knick line. Managon River in this location is about 15 meter wide at the narrowest point and 30 meters wide in the downstream.

Andesitic tuff breccia and andesite classified as CM to CH Class Rock are outcropped on the both banks and the riverbed. In this andesite, there are joints of which strike is 35 degree north-east direction and dip is 20 to 30 degree southeastward. This dipping direction is similar to downstream direction.

The slopes of both banks are steep and the width of Managon River is narrow. The depth of bedrock seems to be shallow because CM to CH Class Rocks are outcropped on the both banks and at the riverbed. Since the joints of bedrock incline toward downstream, it is necessary to take measures including for water cutoff when intake weir is constructed.

Photo 3-20: Panoramic View at Location Proposed Intake Weir on Managon River
(View Toward Downstream)

Photo 3-21: Managon Water Fall at Left Bank of Proposed Intake Weir Location

Photo 3-22: Outcrop of the Andesite classified as CH Class Rock at the Right Bank of Proposed Intake Weir Location

Photo 3-23: Outcrop of Andesite classified as CM Class Rock at Left Bank of Proposed Intake Weir Location

Photo 3-24: Panoramic View at Proposed Intake Weir Location (View Toward Downstream)

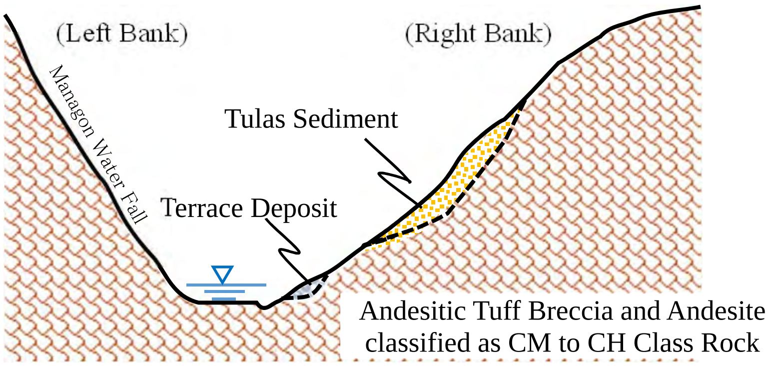


Fig. 3-4: Schematic Geological Profile at Proposed Intake Weir Location

(2) Headrace

1) First Tunnel

The right bank of Wawa River planned Headrace tunnel is continuous steep slope (40 to 60 degrees) and water falls with bedrock exposure. The route of Headrace tunnel consists of andesitic tuff, andesitic tuff breccia and andesite which are fresh and classified as CL to CM Class Rock. Limestone might partiality occur. There is boundary of andesite and andesitic tuff about 200 meters upstream from #2 Power House proposed location. This boundary show strike of 80 degrees north-west direction and dip of 28 degrees southwestward.

This route including desander is suitable as foundation. The tunnel is considered to be able to be constructed by NATM method because bedrock consists of fresh and hard andesitic tuff, andesitic tuff breccia, and andesite interbedded with limestone partially classified as CL to CM Class Rocks.

However, it is necessary to carry out additional investigations such as seismic survey and boring investigation after this preparatory survey in order to understand geotechnical properties of the slope at each tunnel entrance and distribution of fracture zone if the tunnel passes through east-west direction col.

Photo 3-25: Water Fall exposing Andesite classified as CM Class Rock at Right Bank along Route Proposed Headrace

Photo 3-26: Water Fall at Left Bank along Route Proposed Headrace


Photo 3-27: The Torrent exposing Andesite classified as CM Class Rock


Photo 3-28: Outcrop of Andesite classified as CM Class Rock


Photo 3-29: Water Fall at the Left Bank along Route Proposed Headrace


Photo 3-30: The Boundary of Andesite and Andesitic Tuff

2) Second and Third Tunnel

The route of headrace tunnel is proposed at the right bank along Managon River of which slope is generally about 20 degrees. However, it partiality passes through the torrent streams and steep slopes exposing the bedrock. The route consists of andesitic tuff breccia and andesite which are flesh and hard, and classified as CL to CH Class Rock.

The proposed route including desander is suitable as foundation. The tunnel is considered to be able to be constructed by NATM method because bedrocks consist of fresh and hard andesitic tuff breccia and andesite classified as CL to CH Class Rock. However, it is necessary to carry out additional investigations such as seismic survey and boring investigation after this preparatory survey in order to understand geotechnical properties of the slope at each tunnel entrance and distribution of fracture zones if the tunnel passes through the east-west direction col.

Photo 3-31: Water Fall and Andesite Outcrop classified as CM Class Rock at Left Bank along Proposed Headrace

Photo 3-32: Slope at Right Bank along Proposed Headrace

Photo 3-33: Outcrop of Andesite classified as CM Class Rock at Right Bank along Proposed Headrace

Photo 3-34: Situation of Torrent at Proposed Headrace

Photo 3-35: Outcrop of Andesite classified as CM Class Rock at Right Bank along Proposed Headrace

(3) Head Tank and Power house

The power house is proposed on the east-west direction ridge which is about 10m higher than riverbed level. This location consists of andesitic tuff breccia classified as CL to CM Class Rock which are covered thinly with terrace deposits. The head tank is proposed on top of slope behind the power house. The proposed site is considered to consist of andesitic tuff breccia classified as CL to CM Class Rock.

Photo 3-36: Panoramic View at Proposed Power House and Penstock Locations

Photo 3-37: Managon River under Proposed Power House Location
(View Toward Upstream)

Photo 3-38: River Pool formed in the Upstream of Photo 3-37

Photo 3-39: Outcrop of Andesitic Tuff Breccia classified as CM Class Rock at Right Bank of Proposed Power House Location

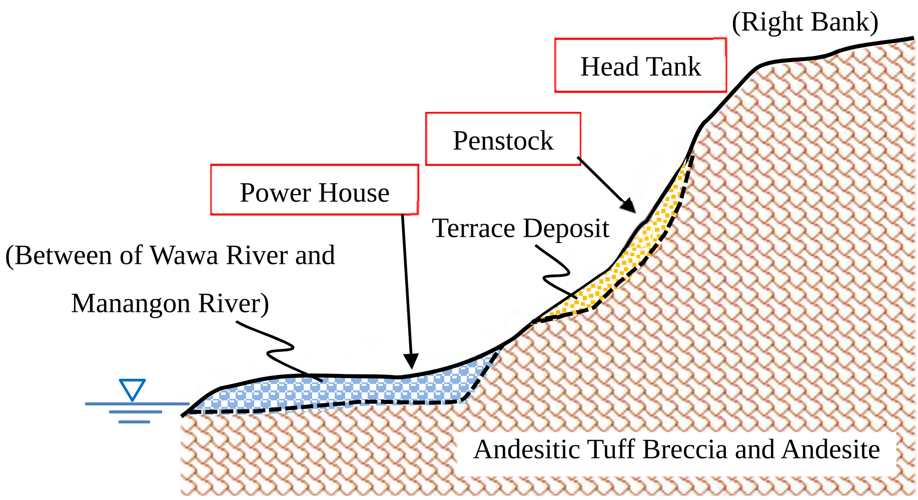


Fig. 3-5: Schematic Geological Profile at Proposed Head Tank, Penstock and Power House Locations (View Toward Downstream)

3-3. Boring Investigation

Boring Investigation was carried out at each facility of Wawa #1 in order to improve accuracy of this preparatory survey. The boring investigation were carried out at locations of intake weir, head tank and power house which were selected due to the results of layout studying of power generation facilities and site reconnaissance. In-situ tests such as standard penetration test and Lugeon test and unconfined compression test for core sample were also carried out in order to understand geological conditions, geotechnical properties of bedrock and hydraulic Properties.

3-3-1. Quantities and Locations of Investigation

The quantities of the investigation carried out are summarized in Table 3-2, ant boring investigation locations are shown in Fig. 3-6 to 3-8.

Table 3-2: Quantities of Proposed Investigation

	Boring No.	Location		Length (m)	Standard Penetration Test (Nos.)	Lugion Test (Nos.)	Unconfined Compression Test (Nos.)
#1	BH-1	Intake Weir	Right Bank	10.0	10	2	2
	BH-2		River Bed	15.0	15	2	2
	BH-3		River Bed	13.6	13	2	1
	BH-4		Left Bank	11.2	11	1	2
	BH-5	Head Tank		12.0	12	-	-
	BH-6	Power House		15.0	15	-	-

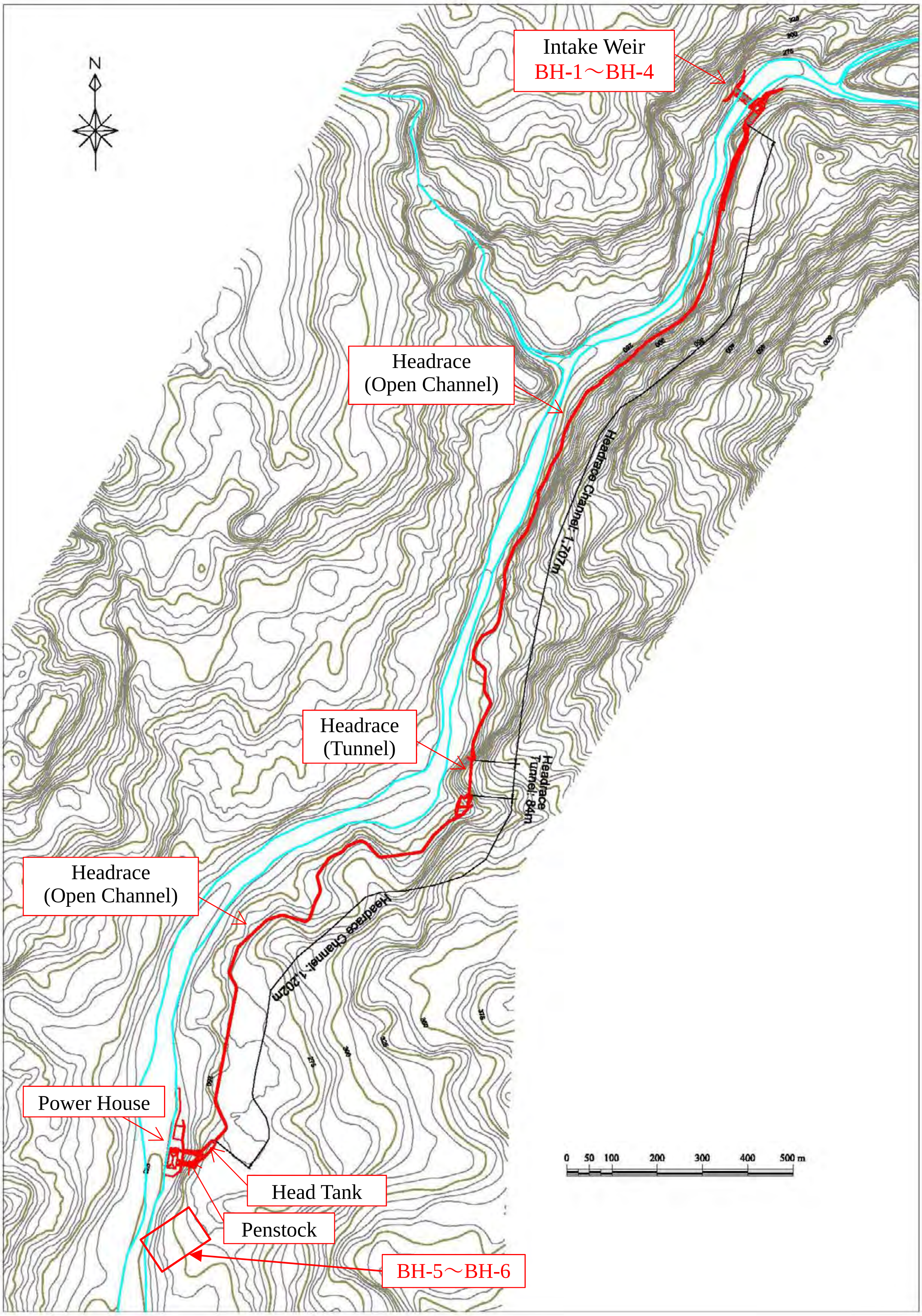


Fig. 3-6: Locations of Boring Investigation

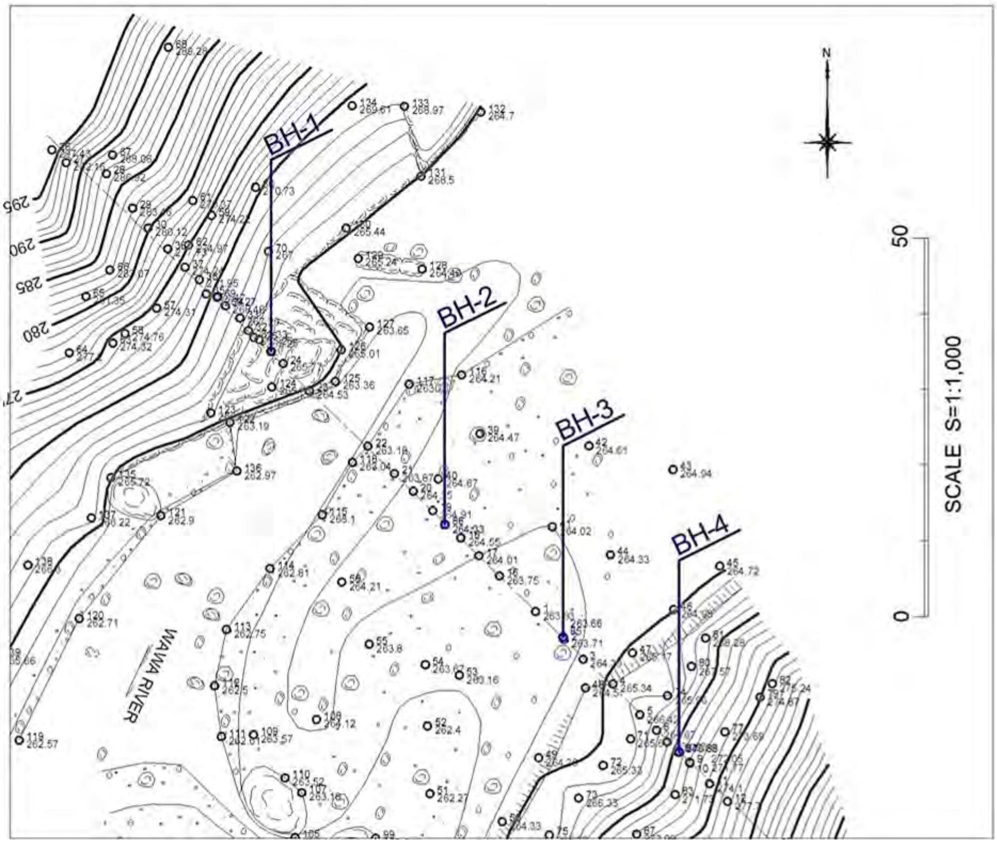


Fig. 3-7: Locations of Investigation on Proposed Intake Weir

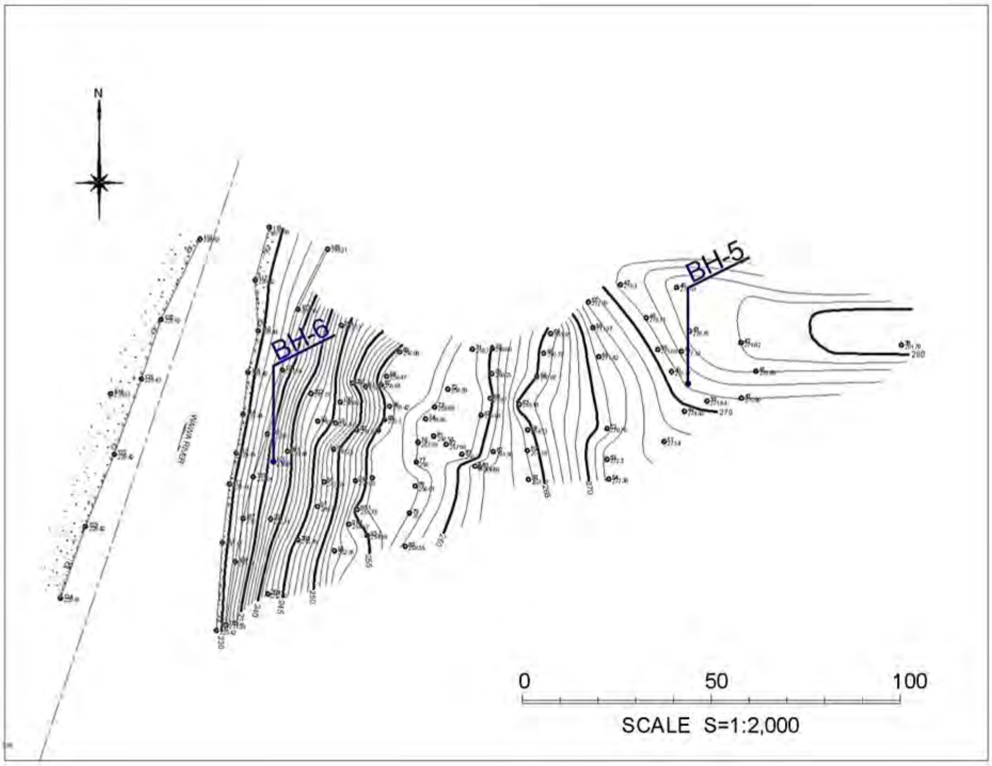


Fig. 3-8: Investigation Locations for Proposed Head Tank and Power House

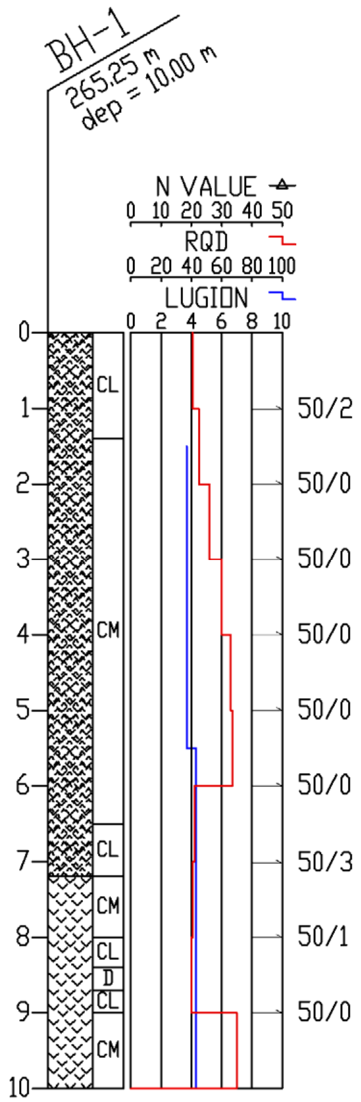
3-3-2. Boring Investigation Results

(1) Intake Weir

Boring investigations were carried out at BH-1 to BH-4 as shown in Fig. 3-7. Standard penetration test with 1 meter interval, Lugeon test and unconfined compression test for rock core were also carried out as shown in Table 3-2. The boring investigation results are shown in the columnar section below. The geological conditions, SPT N-values, Lugeon values and unconfined compression strength are shown as follows:

(a) BH-1

Length=10.00m, Elevation=265.25m



【Geological Condition】

・Depth 0.00m-1.40m: Andesitic Tuff classified as CL Class Rock

This section is charcoal grey bedrock with a little weathering and classified as CL Class Rock. There are cracks interbedding sandy silt at GL- 0.50 to 0.70 meter. The core is gravelly with clay at GL-1.00 to 1.10 meter. There is 3 centimeters wide crack interbedding clay at GL-1.30 to 1.40meter.

・Depth 1.40m-7.20m: Andesitic Tuff classified as CM Class Rock

This section is blueish-grey fresh and strong bedrock classified as CM Class Rock. There is crack dipping 70 degrees and interbedding brown sandy silt at GL- 2.60 to 2.80 meter. There is brown weathered crack dipping 70 degrees at GL-2.70 to 3.00 meter. There is horizontal crack interbedding sandy silt at GL-4.80 meter. There is brown weathered crack dipping 70 degrees at GL- 6.10 to 6.30 meter. The core is dark brown and rather weathered, and classified as CL Class Rock at GL- 6.50 to 7.20 meter.

・Depth 7.20m-10.00m: Andesite classified as CM Class Rock

This section is charcoal grey fresh strong bedrock classified as CM Class Rock. The core is gravelly by weathering at GL- 7.20 to 7.40 meter. The core is weathered and gravelly and is classified as D to CL Class Rock at GL-8.00 to 9.00 meter. The quartz is interbedded in crack dipping 30 degrees around GL-9.80 meter.

【Lugeon Value】

・Depth 1.50m-5.50m: 3.7Lu

・Depth 5.50m-10.00m: 4.3Lu

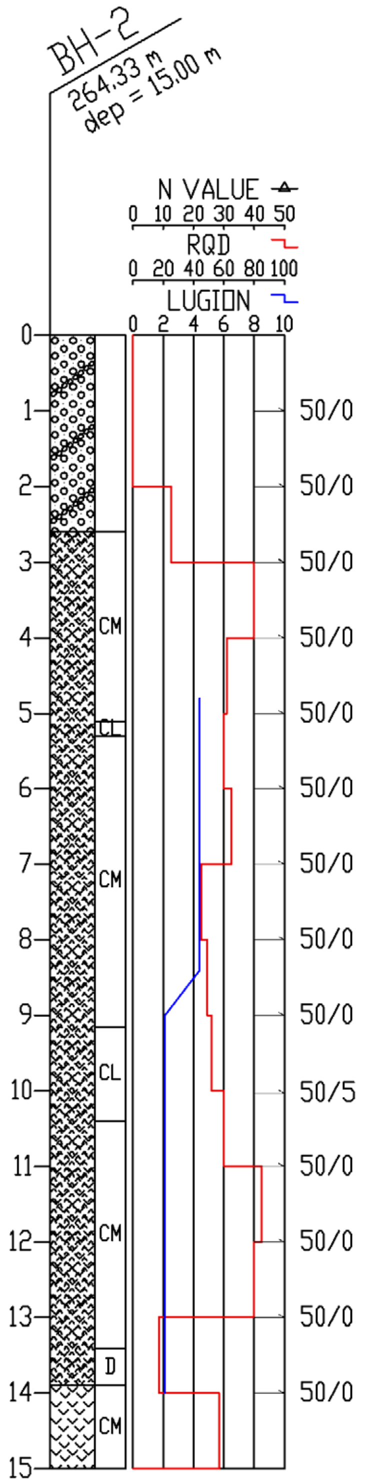
【Unconfined Compression Strength】

・Depth 4.80m-5.00m: 74,540 kN/m2

・Depth 9.20m-9.40m: 18,740 kN/m2

(b) BH-2

Length=15.00m, Elevation=264.33m



【Geological Condition】

・**Depth 0.00m-2.60m: Gravel on Riverbed**

This section is sandy gravel layer including andesitic boulders of which diameter is 30 to 60 centimeter.

SPT N-value: it is impossible to measure SPT N-value due to gravels and boulders.

・**Depth 2.60m-13.90m: Andesitic Tuff classified as CM Class Rock**

This section is blueish grey hard andesitic tuff classified as CM Class Rock.

There are conjugated cracks interbedding clay at GL-2.70 to 2.80 meter.

There is horizontal crack interbedding clay around GL-3.20 meter.

There is horizontal crack interbedding sandy silt at GL-3.50 to 3.70 meter.

There is horizontal crack interbedding clay at GL- 4.80 to 4.90 meter.

There are weathered gravelly cores classified as CL Class Rock at GL- 5.10 to 5.30 meter.

There is near vertical crack at GL- 7.10 to 7.30 meter.

The core is hydrothermal alterated, becomes weak and is classified as CL Class Rock at GL-9.20 to 10.40 meter.

The core is weathered, clayey and classified as D Class Rock at GL-13.40 to 13.90 meter.

・**Depth 13.90m-15.00m: Andesite classified as CM Class Rock**

This section is bluish grey strong core classified as CM Class Rock.

There is brown clayey crack around GL-14.20 meter.

There is 4 to 6 centimeter thick sandy and clayey portion at GL-14.80 to 14.90 meter.

【Lugeon Value】

・Depth 4.80m-8.40m: 4.4Lu (Conversion Value), The limit Water Pressure is 43MPa

・Depth 9.00m-14.00m: 2.1Lu

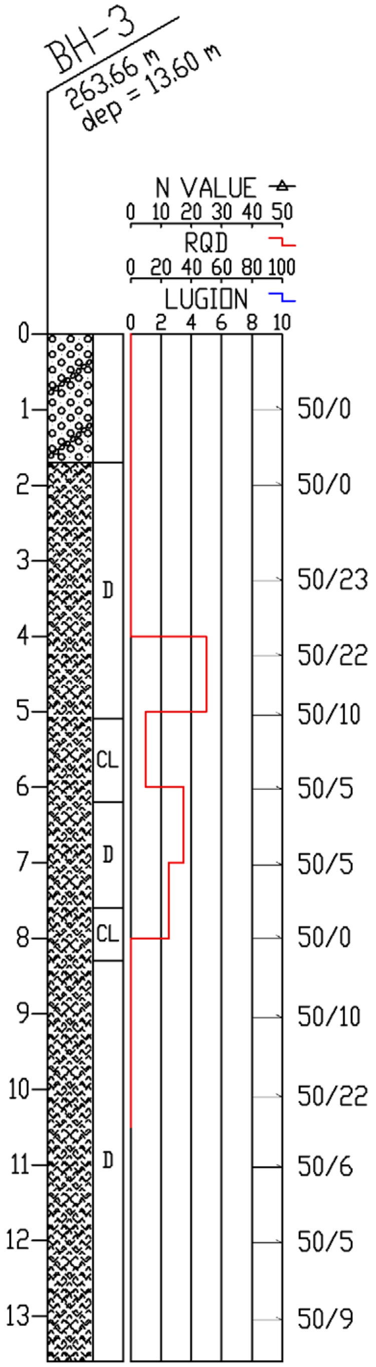
【Unconfined Compression Strength】

・Depth 2.80m-3.00m: 25,860 kN/m2

・Depth 5.00m-5.20m: 48,410 kN/m2

(c) BH-3

Length=13.60m, Elevation=263.66m



【Geological Condition】

・Depth 0.00m-1.70m: Gravel on Riverbed

This section is sandy gravel layer including andesitic boulders and rounded gravel of which diameters are 2 to 15 centimeter.

SPT N-value: It is impossible to measure SPT N-value due to boulders and gravels.

・Depth 1.70m-5.10m: Andesitic Tuff classified as D Class Rock

This section is weathered and consists of weak core classified as D Class Rock.

There is reddish brown weathered core at GL- 1.70 to 3.00 meter.

SPT N-value: 50/23 to 50/10

・Depth 5.10m-6.20m: Andesitic Tuff classified as CL Class Rock

The cores are 5 to 10 centimeter short columns at GL-5.40-5.70m.

The cores are gravelly at GL-6.00 to 6.10 meter.

・Depth 6.20m-7.60m: Andesitic Tuff classified as D Class Rock

The cores are weathered to become clayey soil at GL-6.30 to 6.60 meter.

The core can be crushed into gravelly or sandy by finger at GL-7.20 to 7.30 meter.

The cores are stronger and classified as CL Class Rock at GL-7.60 to 8.30 meter.

The cores are weathered to become clayey soil at GL-8.30 to 8.40 meter.

The cores are fine gravelly at GL-8.50 to 9.10 meter.

The cores are 1 to 50 millimeter brecciated at GL-9.10 to 9.50 meter.

The cores are weathered to become sandy to clayey at GL-10.00 to 10.30 meter.

The cores are stronger and classified as CL Class Rock at GL-10.70 to 11.00 meter.

The cores are weathered and can be crushed easily by finger at GL-11.00m and deeper.

The cores are fine gravelly and clayey at GL-12.80 to 13.00 meter.

The cores are fine gravelly at GL-13.40 to 13.50meter.

SPT N-value: 50/22-50/5

【Lugeon Value】

・Depth 5.00m-9.00m:

Since injection volume of water exceeds the pump capacity, it is impossible to measure Lugeon value. It should be more than 20 Lu.

・Depth 9.00m-13.60m:

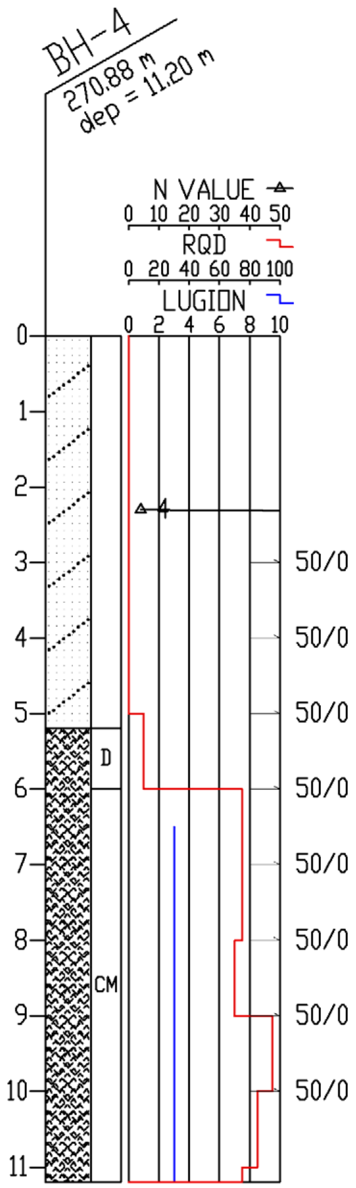
Since injection volume of water exceeds the pump capacity, it is impossible to measure Lugeon value. It should be more than 20 Lu.

【Unconfined Compression Strength】

・Depth 8.00m-8.20m: 88,310 kN/m2

(d) BH-4

Length=11.20m, Elevation=270.88m



【Geological Condition】

・**Depth 0.00m-5.20m: Colluvium soil**

This section consists of sandy soil including breccia of andesitic tuff of which diameters are 1 to 10 centimeter.

SPT N-value: N = 4 without hitting breccia.

・**Depth 5.20m-6.00m: Andesitic Tuff classified as D Class Rock**

The core are strong but classified as D Class Rock because the cracks are developed and the cores are short columnar and gravelly.

There 2cm thick clayey zone around GL-5.80 meter.

Parallel cracks are developed around GL-5.90 meter.

・**Depth 6.00m-11.20m: Andesitic Tuff classified as CM Class Rock**

This section is a little hydrothermal alterated strong rock classified as CM Class Rock. The zeolite veins are interbedded at GL-6.00 to 9.00 meter. The veins occur densely at GL-7.00 to 7.30 meter.

There is 1 cm clayey zone around GL-7.60 meter.

There is 1 cm clayey zone around GL-8.10 meter.

The core is dark bluish grey due to hydrothermal alternation at GL-8.20 meter and deeper.

【Lugeon Value】

・Depth 6.50m-11.2m: 3 Lu

【Unconfined Compression Strength】

・Depth 6.50m-6.80m: 47,890 kN/m2

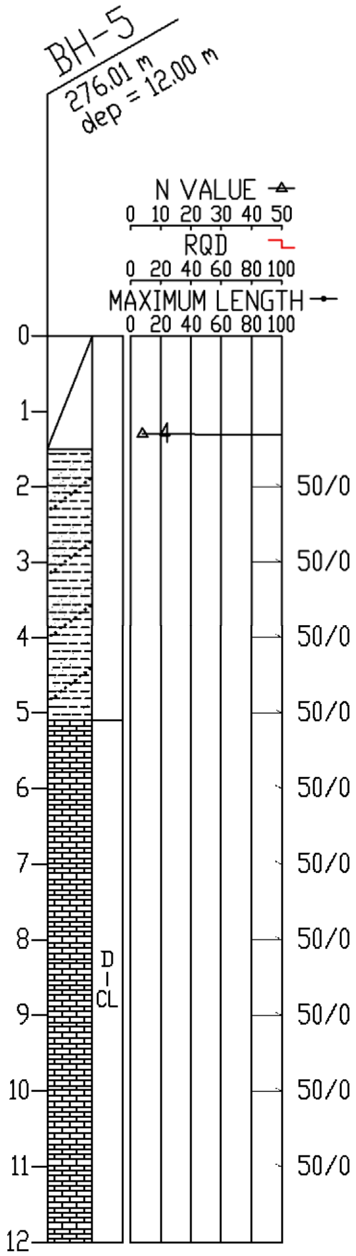
・Depth 9.80m-10.00m: 33,840 kN/m2

(2) Head tank and Power house

The boring investigations were carried out at of BH-5 and BH-6 shown in Fig. 3-8. Standard penetration test with 1 meter interval were also carried out as shown in Table 3-2. The summary results are shown in following in the columnar section below. The geological conditions, SPT N-value and unconfined compression strength are shown as follows:

(a) BH-5

Length=12.00m, Elevation=276.01m



【Geological Condition】

・**Depth 0.00m-1.50m: Surface Soil**

This section consists of brown sandy clay including plant roots.

SPT N-Value: N = 4

・**Depth 1.50m-5.10m: Sandy Clay with Gravel**

This section consists of sandy clay with flaky gravels of limestone.

The limestone gravels classified as CM Class Rock is interbedded at GL-2.30 to 3.20 meter.

It is rather dense at GL-4.30 to 4.70 meter.

SPT N-Value: It is impossible to measure SPT N-Value due to limestone gravels.

・**Depth 5.10m-12.00m: Limestone classified as D Class Rock**

This section consists of weathered gravelly limestone with sandy and fine gravelly soil.

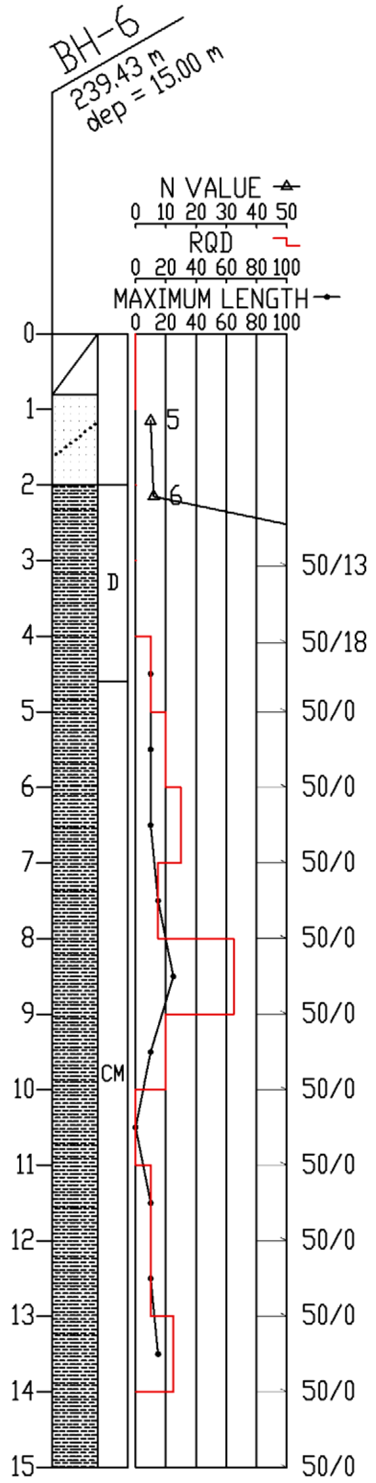
The cores are short columnar to flaky classified as D to CL Class Rock.

There may be cavity of which diameter is around 10 centimeter by dissolution due to acid rain.

SPT N-Value: It is impossible to measure SPT N-Value due to limestone gravels.

(b) BH-6

Length=15.00m, Elevation=239.43m



【Geological Condition】

・**Depth 0.00m-0.80m: Surface Soil**

This section consists of brown organic soil with limestone gravels.

・**Depth 0.80m-2.00m: Sandy soil with Gravels**

This section consists of brown sandy soil with limestone gravels.

SPT N-Value: N = 5

・**Depth 2.00m-4.60m: Mudstone classified as D Class Rock**

The section is weathered and classified as D Class Rock at GL-2.00 to 4.60 meter. The cores are gravelly and classified as CL Class Rock at GL-2.70 to 3.00 meter.

SPT N-Value: N = 6 to 50/18.

・**Depth 4.60m-15.00m: Mudstone classified as CM Class Rock**

This section is dark grey very strong rock classified as CM Class Rock and many closed cracks occur. Weathering and argillization occur along opened cracks.

The cores are flaky and weathered into sandy soil at the crack surface at GL-4.60 to 4.80 meter.

The surface of crack becomes gravelly around GL-5.30 meter.

There is fine gravelly core with width of 5 centimeter around GL-6.10 meter.

The cores are flaky at GL-7.10 to 7.20 meter.

The cores are weathered to D Class Rock at GL-7.40 to 7.60 meter.

The cores are gravelly and flakey at GL-11.30 to 11.50 meter.

The cores becomes clayey and can be pushed by finger at GL-11.70 to 11.80 meter.

The core is soften at GL-11.90 to 12.00 meter.

The cores are soften and classified as D Class Rock at GL-12.70 to 13.10 meter.

The cores become clayey along crack at GL-14.50 to 14.60 meter.

The cores become clayey along crack at GL-14.90 meter.

3-3-3. Discussion

(1) Intake Weir

Based on the boring investigations including Lugeon test and unconfined compression test, geological structure and geotechnical properties, permeability of bedrock, other bedrock parameters, and comments on design and construction are discussed as follows:

1) Geological Structure and Geotechnical Properties

Geological profile at the proposed Intake Weir is shown in Fig. 3-9.

The location consists of andesite and andesitic tuff. The riverbed is covered by gravels and the slopes of both banks are covered by talus sediments. Andesite and andesitic tuff are generally classified as CM Class Rock which are partially interbedded with D to CL Class Rock. The bedrock near surface is classified as D to CL Class Rock due to weathering. D to CL Class fault fracture zone is considered to occur at the riverbed near BH-3. The riverbed deposits consist of sandy gravels with boulders of which maximum diameter are 5 meter. Three to 5 meter talus sediments consist of sandy clay with gravel cover andesitic tuff.

In this project, the concrete dam of which high is lower than 10 meters is planned. Bedrock of andesite and andesitic tuff classified as CM Class Rock is suitable for Intake Weir foundation. It is necessary to remove unconsolidated deposits such as riverbed deposits and talus sediments. If the cutting depth is made shallow, it is conceivable that Intake Weir is constructed on the CL Class Rock or sandy clay with gravel as floating dam and the permeation from under Intake Weir are permitted. In this case, it is necessary that the creep length of Intake Weir is secured enough and the area of base is permitted for pressure bearing capacity of foundation.

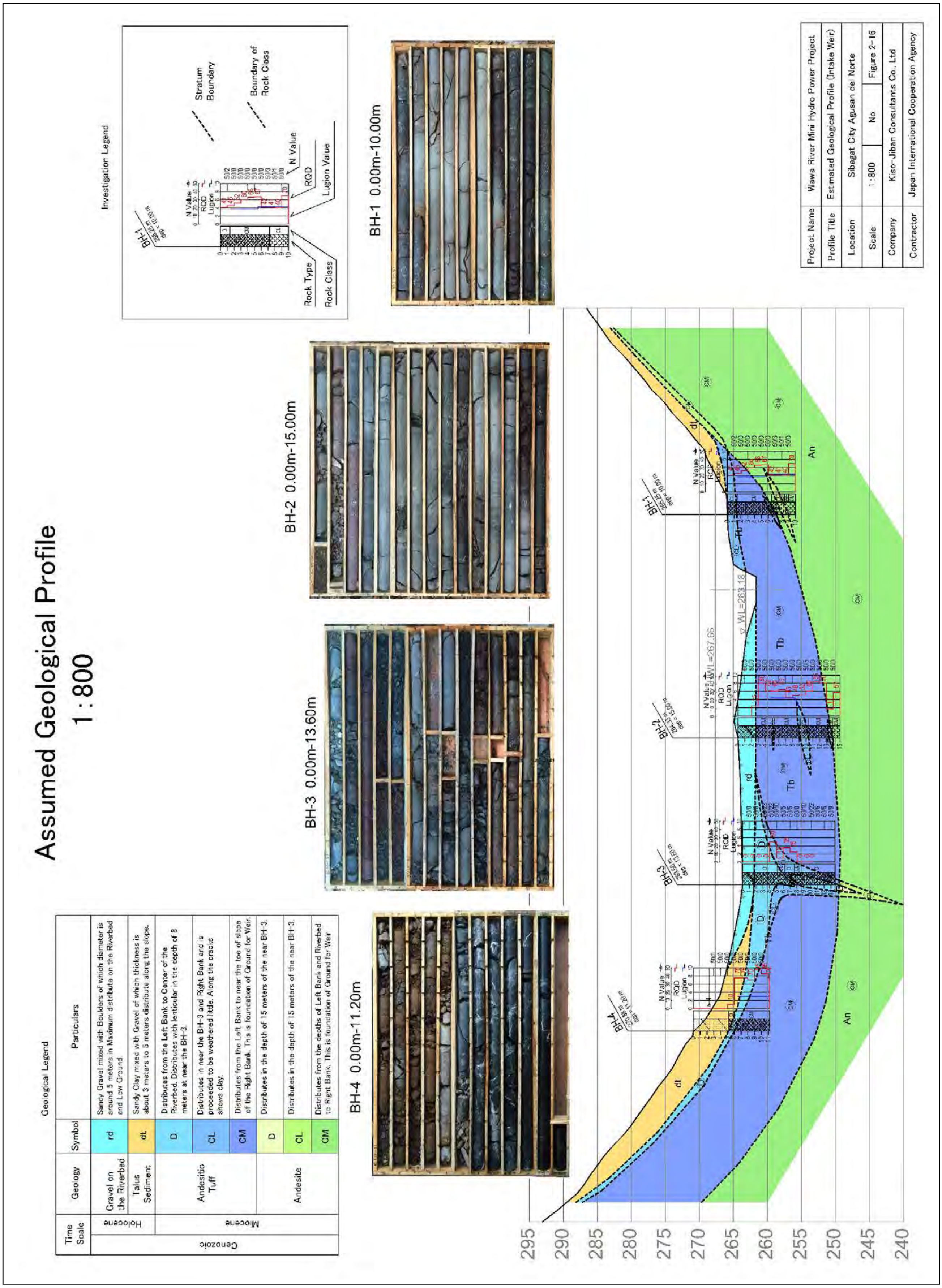


Fig. 3-9: Geological Profile at the Proposed Location of Intake Weir (View Toward Downstream)

2) Permeability of Bedrock

Permeability of bedrock classified as CM Class Rock is low (3 to 5 Lu). Target Lugeon value is set for grouting to prevent water leakage from dam foundation. In case of gravity dam of which height is higher than 15 meters, the general target Lugeon value are 2 Lu until the depth of one quarter dam height; 5 Lu until depth of one quarter to half of the dam height; and 10 Lu at deeper than half of the dam height. Since the dam height is less than 10m for this project, following target Lugeon values are proposed:

Target Lugeon Value	Depth
5 Lu	Till Half of Dam Height
10 Lu	Deeper than Half of Dam Height

Appling the above targets, it is not necessary to improve permeability of the bedrock. However, the permeability of D Class Rock at fault fracture zone is considered to be high. Thus, it is necessary to take measures discussed in (d) Design and Construction Consideration.

3) Bedrock Parameters

Based on unconfined compression test results, the cohesion of andesite and andesitic tuff is estimated as shown in Table 3-3. Cohesion and internal friction of dam foundation estimated based on the rock classification are also shown in Table 3-3.

Unconfined compression tests were carried out for the boring cores classified as CL to CM Class Rock obtained from BH-1 to BH-4. Obtained unconfined compression strength are 18,740 kN/m2 to 88,310 kN/m2.

Cohesion of rock can generally be estimated as one quarter to one sixth of unconfined compression strength. The Cohesions of CL to CM Class Rock are estimated as 3,000 kN/m2 to 14,000 kN/m2 by calculating as one sixth of unconfined compression strength.

On the other hand, cohesion and internal friction angle estimated based on the rock classification are 250 kN/m2 to 750 kN/m2 and 30 degrees to 40 degrees for CL Class Rock, 750 kN/m2 to 1,750 kN/m2 and 35 degree to 45 degree for CM Class Rock. Calculated cohesion based on unconfined compression strength are twice to ten times of those estimated based on rock classification.

These different can be because unconfined compression test was carried out for boring cores which are long columns of 10 to 20 cm in the length without the crack. That is why calculated cohesions are larger than those of bedrock mass with many discontinuities.

The cohesion and the internal friction angle used for design in this preparation survey are followed in the red frame of Table 3-3 referring from Foundation for Dam Ground.

Table 3-3: Bedrock Parameters

Boring No.	Length (m)	Rock Class	Result of Laboratory Test: Unconfined Compression Strength (MN/m2)	Result of Laboratory Test: Unconfined Compression Strength (kN/m2)	Calculated Value: Cohesion (kN/m2)	Foundation of Ground: Cohesion based on the Rock Class (kN/m2) Range	Foundation of Ground: Cohesion based on the Rock Class (kN/m2) Median	Foundation of Ground: Internal Friction Angle based on the Rock Class (°) Range	Foundation of Ground: Internal Friction Angle based on the Rock Class (°) Median
BH-1	4.8-5.0	CM	74.54	74,540	12,000	750～1,750	1,250	35～45	40
	9.2-9.4	CM	18.74	18,740	3,000	750～1,750	1,250	35～45	40
BH-2	2.8-3.0	CM	25.86	25,860	4,000	750～1,750	1,250	35～45	40
	5.0-5.2	CM	48.41	48,410	8,000	750～1,750	1,250	35～45	40
BH-3	8.0-8.2	CL	88.31	88,310	14,000	250～750	500	30～40	35
BH-4	6.5-6.8	CM	47.89	47,890	7,000	750～1,750	1,250	35～45	40
	9.8-10.0	CM	33.84	33,840	5,000	750～1,750	1,250	35～45	40

Source: Created by Study Team referring from Foundation of Ground

4) Comments on Design and Construction

Bedrock classified as D Class Rock at fault fracture zone is not suitable as the dam foundation. The permeability is considered to be high because water filling amount to the ground is more than pump capacity at the Lugeon tests. Thus, it is recommended to replace the D Class Rock to concrete.

The colluvium soil at the right bank includes andesitic boulders of which diameter are about 2 meter. It should be studied to break the boulders by free-fall or using static crush agent.

The level of Wawa River rise 2 to 3 meters than the normal level during flooding. It should be considered to take measures for flood such as multiple-stage diversion method or construction of temporary river channel during foundation excavation.

(2) Head Tank and Power House

Based on the boring investigations, geological structure and geotechnical properties, the bearing ground for each facility, and comments on design and construction are discussed as follows:

1) Geological Structure and Geotechnical Properties

Geological profile at the proposed head tank and power house made based on boring investigations is shown in Fig. 3-10.

The location consists of mudstone and limestone which are covered by riverbed deposits and talus sediments on the slope. Mudstone is generally classified as CM Class Rock except near the surface where it is classified as D Class Rock. The mudstone exposed on the surface is slaked by weathering. Limestone is generally classified as D Class Rock which is interbedded with CL Class Rock partially.

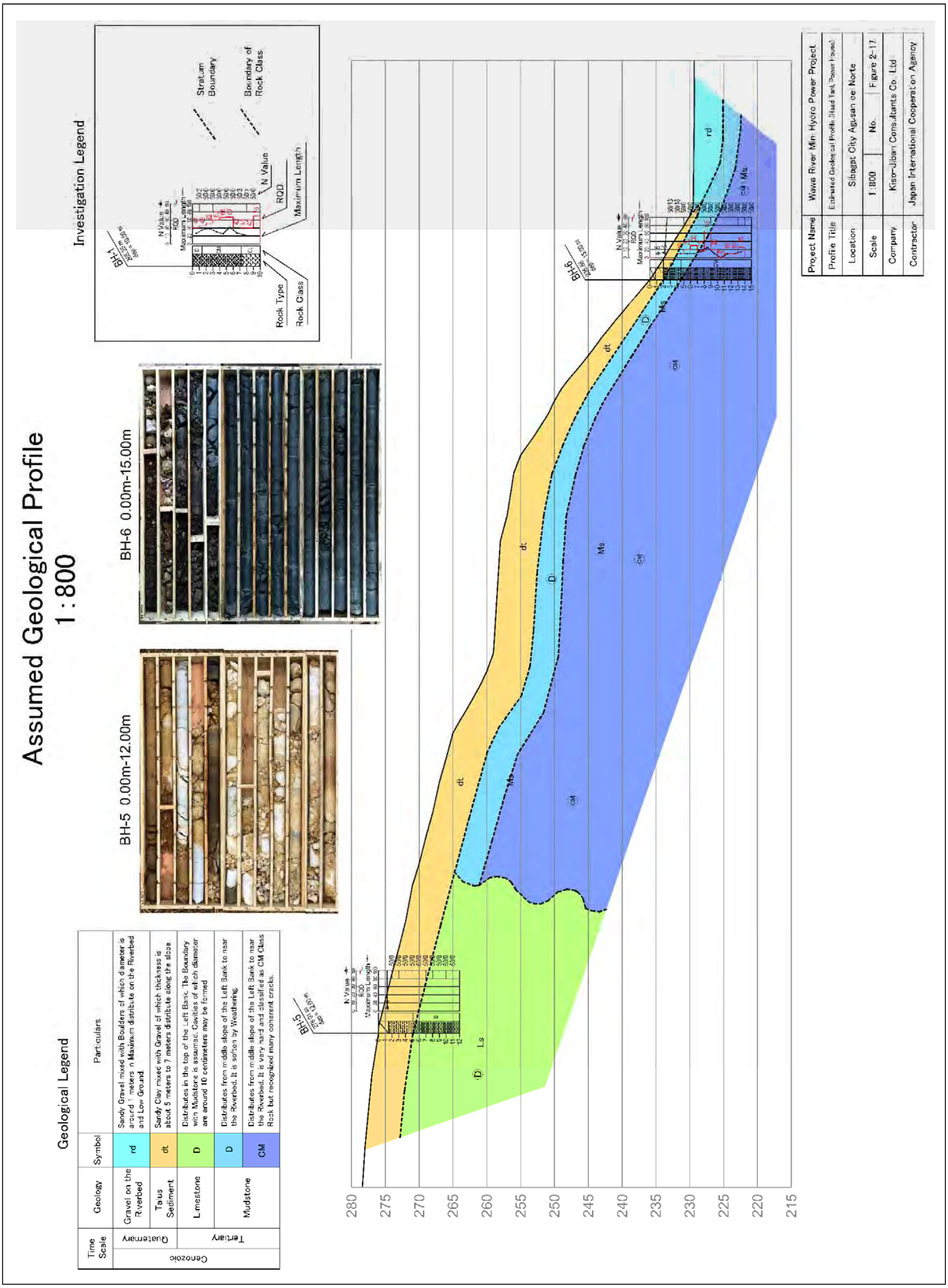


Fig. 3-10: Geological Profile at Proposed Location of Head Tank and Power House
(View Toward Downstream)

2) Bearing Ground for Each Facility

As the bearing ground for each Facility, talus sediments and limestone classified as D Class Rock are suitable for the head tank; limestone and mudstone classified as D Class Rock are suitable for the penstock; and mudstone classified as D Class Rock is suitable for the power house.

3) Comments on for Design and Construction

Limestone at foundation for head tank and Penstock may have cavities of which diameter is around 10 centimeter due to dissolution. Observation by specialists is required during construction and countermeasures such as concrete filling shall be studied.

The recommended cut slopes for head tank to power house are V:H = 1:0.5 for mudstone layer and V:H = 1: 0.8 for weathered Limestone and talus sediments.

Mudstone in this location is slaking prone which alters rock to sandy soil due to wetting and drying weathering when the rock is exposed. Countermeasures such as slope protection or concrete placing shall be carried out as soon as the excavation surface is exposed.

3-3-4. Challenges for Future

(1) Wawa #1 Mini-Hydro Power

The planned head tank, penstock and power house of #1 are moved to locations 120m upstream of the original planned locations after this geological investigation.

Based on our site reconnaissance, the newly planned locations consists of similar geology to the original planned locations except that limestone may occur until the power house location. Since cavity can be formed in limestone by rain etc, it is necessary to carry out boring investigation in order to understand conditions of limestone. Thus, it should be considered to carry out boring investigation at the newly proposed head tank and power house at detailed design stage.

(2) Wawa #2 Mini-Hydro Power

1) Intake Weir

Generally, boring investigation, standard penetration tests and Lugeon tests are carried out in order to understand geotechnical properties and permeability of ground at the proposed intake weir location. However, bedrock is expected to be shallow at proposed intake weir and desander based on our site reconnaissance. Therefore, it should be decided whether boring investigations will be carried out or not considering the cost effectiveness if the proposed intake weir location is not changed largely.

2) Headrace Tunnel Entrance

It will be considered to carry out horizontal and vertical boring investigation and standard penetration test at the both tunnels entrances selected by site reconnaissance and preliminary design. It will be also considered to carry out pore water pressure measurement in borehole if the aquifer is confirmed at the time of vertical boring investigation.

3) Headrace Tunnel Route

It should be considered to carry out seismic refraction survey along the route selected based on site reconnaissance and preliminary design in order to understand geotechnical properties such as the strength of the ground and fault fracture zones distribution.

4) Head Tank and Penstock

It should be considered to carry out boring investigation and standard penetration tests at the selected head tank and penstock locations based on site reconnaissance and preliminary design.

5) Power House

It should be considered to carry out boring investigation and standard penetration tests at the selected power house location based on site reconnaissance and preliminary design.

Table 3-4 shows summary of proposed quantities of geological investigations mentioned above.

Table 3-4: Quantities of Required Geological Investigation in Wawa No.2

Item	Boring Investigation		Standard Penetration Test (Nos.)	Lugion Test (Nos.)	Pore Water Pressure Measurement in Borehole (Nos.)	Seismic Refraction Survey (km)
	Location	Length (m)				
Intake Weir	Riverbed of #2	10.0	10	2	-	-
	Riverbed of #2	10.0	10	2	-	-
	Riverbed of #3	15.0	15	2	-	-
	Riverbed of #3	15.0	15	2	-	
Desander	Riverbed of #2	6.0	6	-	-	-
	Riverbed of #3	10.0	10	-	-	-
Head Race	Tunnel Entrance of #2 (horizontal)	15.0	-	-	-	6.0
	Tunnel Entrance of #2 (vertical)	20.0	20		1	
	Tunnel Entrance of #3 (horizontal)	15.0	-		-	
	Tunnel Entrance of #3 (vertical)	20.0	20		1	
	Tunnel Entrance (horizontal)	15.0	-		-	
	Tunnel Entrance (vertical)	20.0	20		1	
Head Tank	Proposed Location	10.0	10	-	-	-
Penstock	Proposed Location	10.0	10	-	-	-
Power House	Proposed Location	15.0	15	-	-	-
	Proposed Location	15.0	15			

Chapter 4　Hydrometeorological Survey

4-1　Collection of hydrometeorological data

4-1-1　Rainfall data

The nearest meteorological observation stations to the proposed sites for this project are in Butuan City and in Kitcharao in the north of the province of Agusan del Norte (Fig. 4-1). These weather stations are managed by the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), and daily observation data is collected from each site.

For this survey, we have used the daily rainfall data from the rainfall observation station in Butuan, nearest to the projected site, for the 34-year period from 1981 to 2014 as a resource to calculate the design flood discharge for both the water intake point and the powerhouse location. Table 4-1 and Fig. 4-2 show the monthly rainfall data for the area.

Fig. 4-1: Rainfall observation stations in the proposed project area

Source: Created by survey team based on Google Maps image

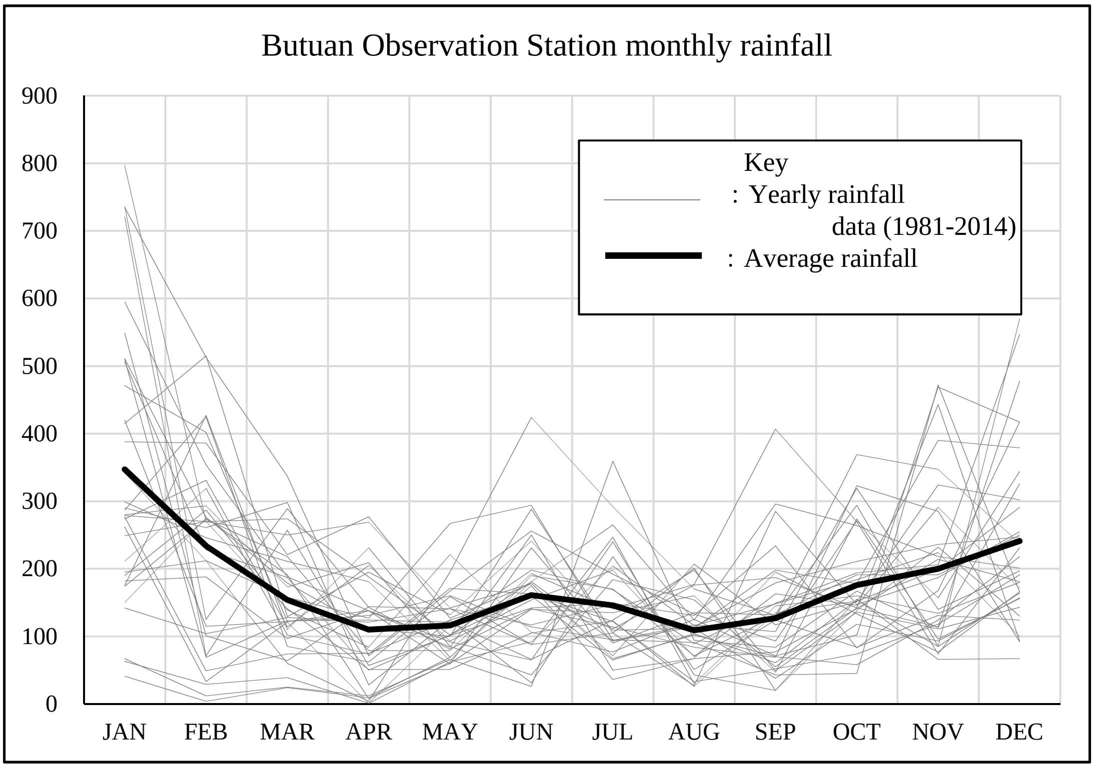


Fig. 4-2: Butuan Observation Station monthly rainfall graph

Source: Created by survey team based on PAGASA data

Table 4-1: Butuan Observation Station monthly rainfall data

Red figures indicate the highest rainfall for the year

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
1981	797	270	141	51	51	105	123	26	135	152	199	291	2,341
1982	506	228	187	50	102	160	65	104	61	154	85	164	1,866
1983	41	4	24	9	69	181	265	124	296	264	218	201	1,696
1984	287	425	85	62	159	88	105	27	285	147	187	255	2,112
1985	549	101	64	144	141	88	247	30	145	160	134	180	1,983
1986	736	125	289	143	81	141	114	84	69	323	285	92	2,482
1987	150	275	191	8	60	140	135	160	47	274	96	156	1,692
1988	142	104	128	121	141	117	147	112	198	178	390	379	2,157
1989	195	212	158	127	267	294	94	117	107	319	140	197	2,227
1990	277	49	74	75	124	163	111	176	187	142	443	93	1,914
1991	182	188	97	138	92	65	240	43	20	155	66	67	1,353
1992	67	12	25	12	66	26	359	94	84	167	113	326	1,351
1993	175	427	110	231	85	43	184	154	55	142	114	478	2,198
1994	249	270	250	269	142	178	67	102	70	58	124	218	1,997
1995	174	273	218	79	79	193	141	177	407	270	74	231	2,316
1996	595	354	188	138	59	231	90	135	132	191	191	250	2,554
1997	290	261	298	28	124	31	218	51	124	84	131	124	1,764
1998	63	29	39	1	62	92	204	116	148	184	224	100	1,262
1999	388	386	221	277	127	178	71	207	117	151	324	302	2,749
2000	299	246	211	181	64	190	170	71	130	369	347	238	2,516
2001	190	287	139	84	221	106	77	125	71	102	469	417	2,288
2002	280	293	173	209	69	175	36	67	195	133	77	166	1,873
2003	342	212	60	4	195	424	292	170	131	294	85	570	2,779
2004	211	319	102	74	171	163	122	33	52	74	118	191	1,630
2005	262	33	121	1	116	198	169	89	149	194	206	547	2,085
2006	415	515	129	195	132	241	109	112	38	118	93	157	2,254
2007	420	115	122	138	84	250	50	67	77	141	214	181	1,859
2008	279	270	274	188	102	181	93	114	179	211	236	247	2,374
2009	471	402	122	131	160	114	95	91	43	45	472	166	2,312
2010	510	69	123	124	121	66	124	198	49	136	111	143	1,774
2011	735	513	337	71	167	256	192	133	93	271	157	344	3,269
2012	274	331	114	205	93	154	198	70	163	146	291	171	2,210
2013	511	276	179	111	100	288	105	201	20	138	232	130	2,291
2014	721	71	257	57	101	142	149	131	234	83	168	417	2,531
Average	347	234	154	110	116	161	146	109	127	176	200	241	2,119

Source: Created by survey team based on PAGASA data

4-1-2 Streamflow data

There are no previously existing streamflow gauging stations in or near the proposed project area. The nearest existing streamflow gauging station is the Bayugan Gauging Station downstream from the proposed project location on the Wawa River (Fig. 4-3). As a fundamental resource for estimating the streamflow at the project location, the records of the Bayugan Gauging Station were acquired as part of this survey. Managed by the DPWH, Bayugan Gauging Station takes daily water level measurements, which are periodically converted to flow rates. Overall river flow data appears to be compiled once every few years based upon these periodically acquired flow rate results.

For this survey, we have acquired the observed data for the available 20 year period of 1981 to 2001. The nine years from this sample which have no incomplete data points are shown in Table 4-2 below.

In addition to this, we have also acquired water level data from the Bayugan Gauging Station for the year from September 2014 to August 2015, which has not yet been converted to flow rates. The survey team has performed flow measurements at Bayugan Gauging Station to obtain this data, and has produced an H-Q curve (which plots the relationship between water level and river flow). This curve is in turn used to perform flow rate conversions and later to analyze the flow duration data.

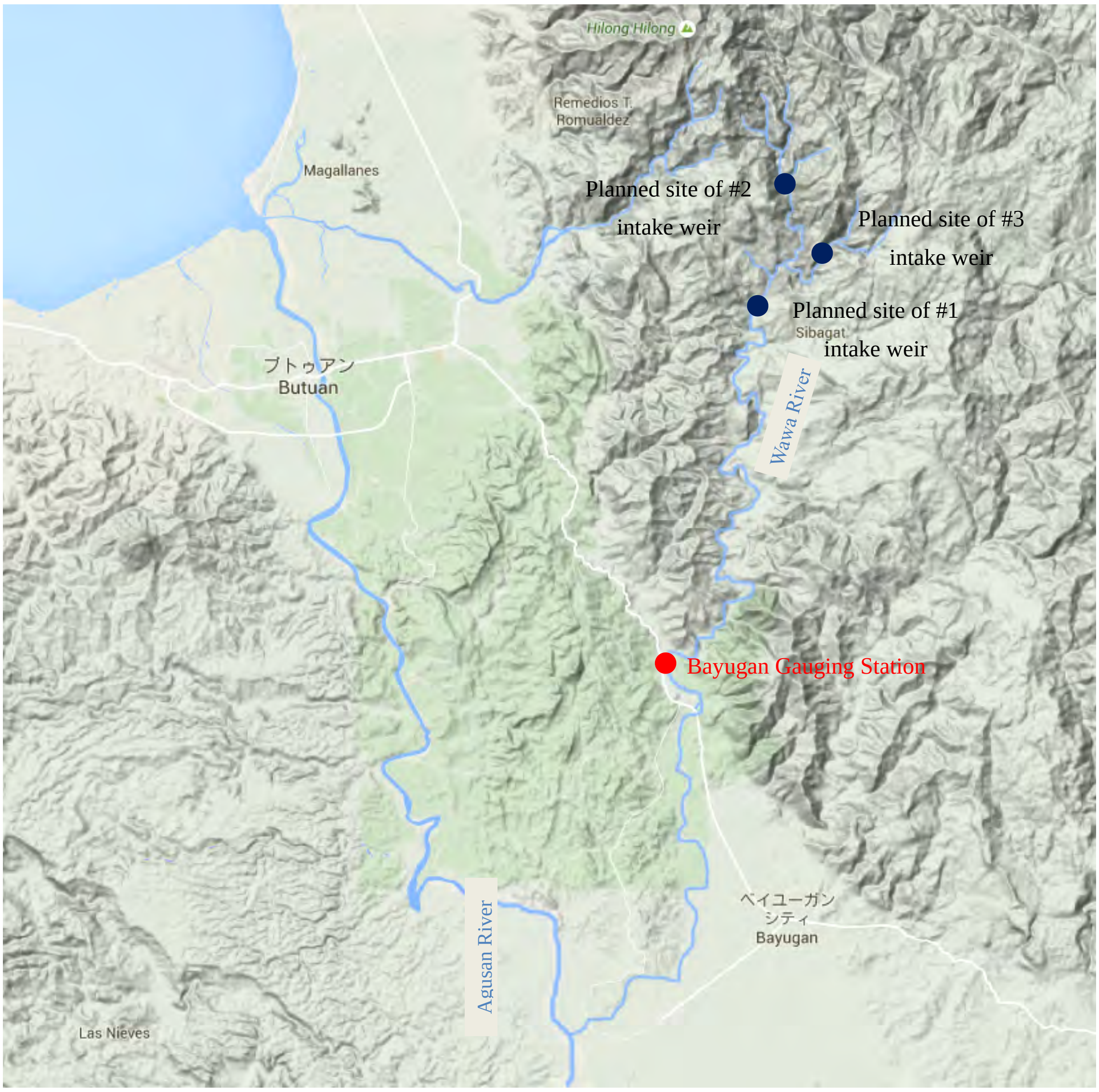


Fig. 4-3: Location of Bayugan Gauging Station

Source: Created by survey team based on Google Maps image

Table 4-2: River flow rates at Bayugan Gauging Station (unit: m^3/s)

Year	Maximum discharge	35-day discharge	High water discharge (95 days)	Ordinary water discharge (185 days)	Low water discharge (275 days)	Droughty water discharge (355 days)	Minimum discharge	Average discharge
1985	344.8	32.4	18.0	10.9	5.9	2.1	1.6	18.8
1986	655.8	122.0	27.2	12.0	5.3	3.0	2.0	41.0
1990	182.0	40.3	18.9	11.5	7.1	3.6	3.2	19.6
1991	216.0	61.5	21.7	12.6	7.1	2.8	1.8	23.5
1992	266.6	20.8	10.9	5.6	3.2	2.3	2.1	13.3
1994	182.0	60.0	24.4	10.4	3.9	1.8	1.6	21.5
1996	345.6	96.0	30.7	16.7	12.2	6.9	4.6	35.4
1999	414.2	181.0	89.2	20.7	7.8	4.3	3.7	58.1
2000	479.1	67.1	25.7	15.2	8.7	3.9	3.5	30.4
Total	3086.1	681.1	266.7	115.6	61.2	30.7	24.1	261.6
Average	342.9	75.7	29.6	12.8	6.8	3.4	2.7	29.1

Water catchment area: 409 km^2

Source: Created by survey team based on DPWH data

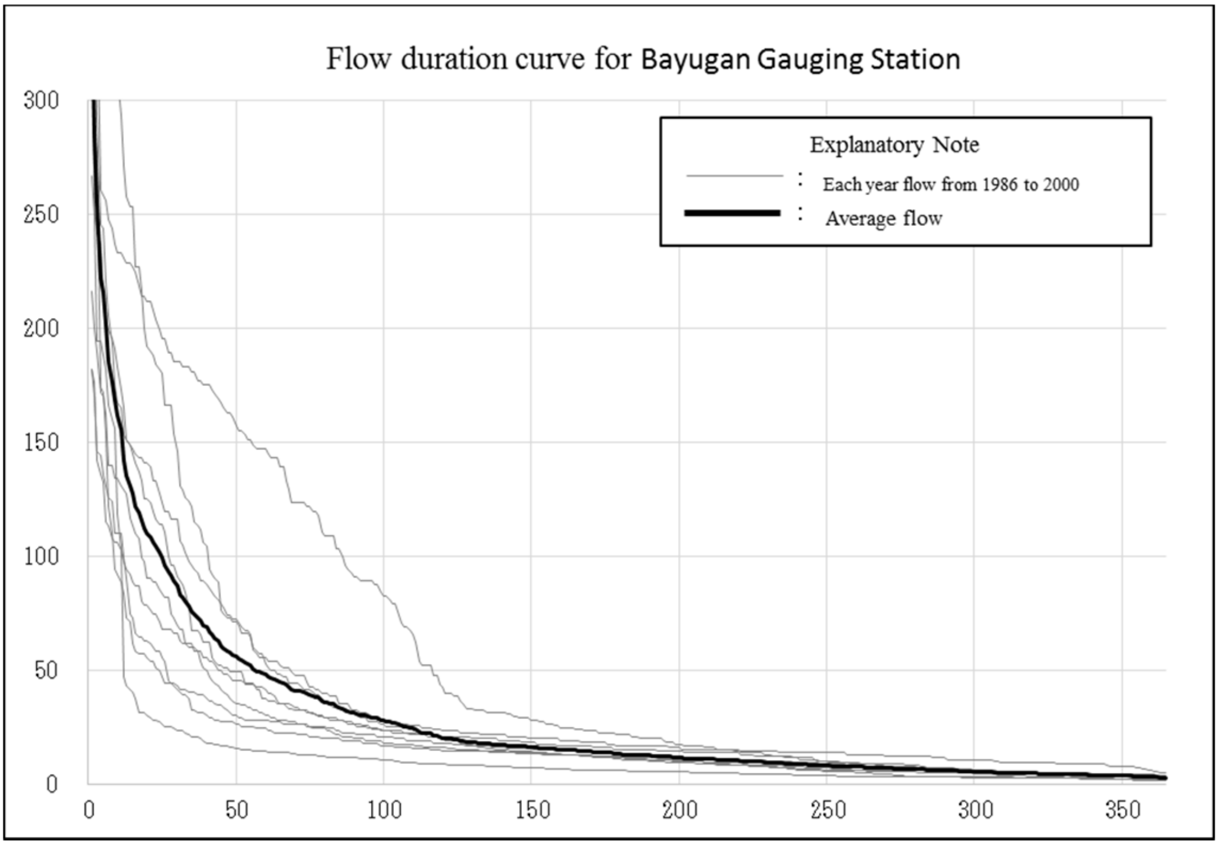


Fig. 4-4: Flow duration curve for Bayugan Gauging Station

4-2 Installation of a streamflow gauging station; measurement of water level and flow rate

4-2-1 Installation of a streamflow gauging station

As outlined in section 4-1 above, there are no streamflow gauging stations in the proposed construction area for this project. Therefore, in order to obtain data of the necessary accuracy for a feasibility study (FS), the survey team installed a streamflow gauging station near the planned site of the intake weir for Wawa No.1 Power Plant, and used this to measure the water level. The installation outline and measurement methods are detailed below.

(1) Selection of the streamflow gauging station installation site

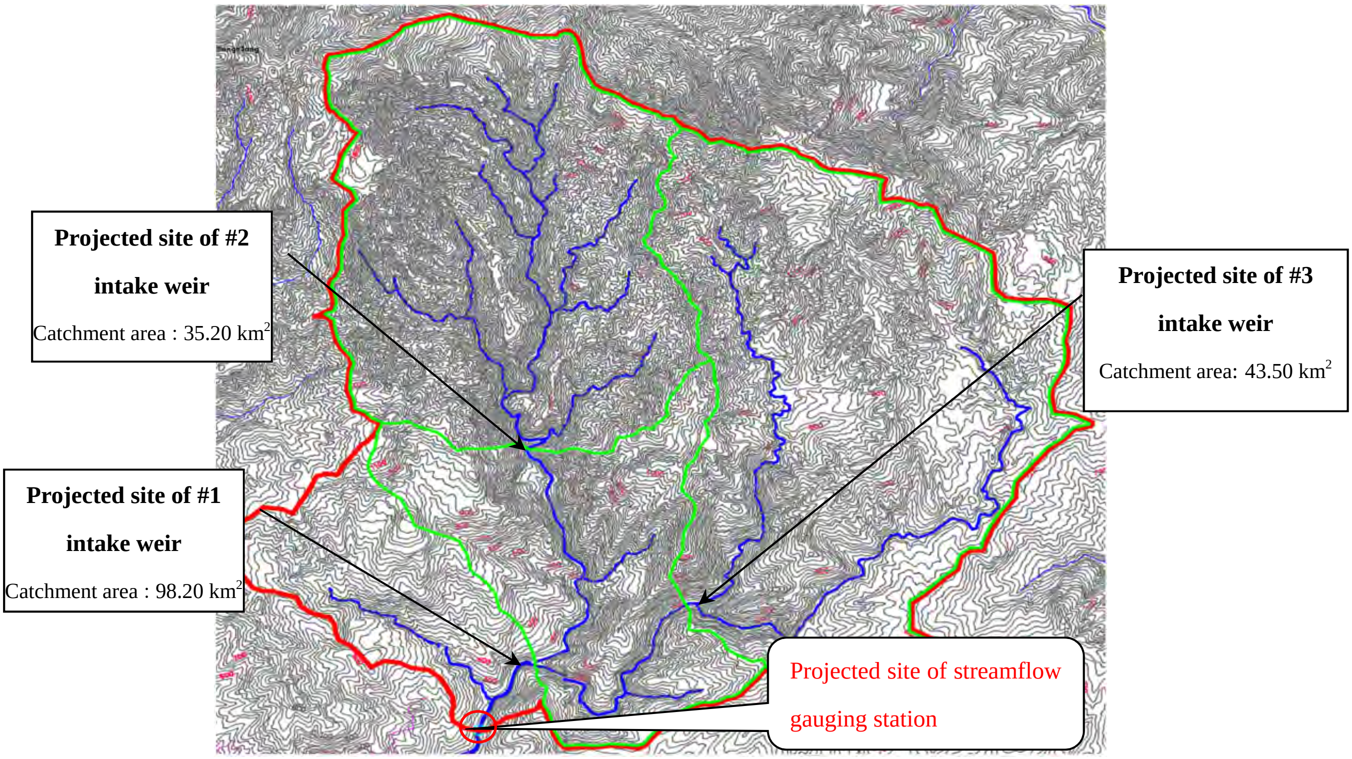
A wide range of factors were taken into account when selecting the site of the streamflow gauging station to ascertain the river regime pertaining to this project. They have been outlined below.

1) Selection of the streamflow gauging station installation area

The following conditions dictated the selection of the streamflow gauging station installation area. The area is indicated in Fig. 4-5 below.

- The area needed to be on the path to the projected powerhouse site, and needed to be reachable by roads sufficiently well-developed for the transportation of the necessary materials.
- The area needed to have a settlement nearby so that the personnel resources necessary for the installation and maintenance of the station could be secured relatively easily.
- The area needed to be downstream from the three water intake points planned for the project, and needed to be close to the furthest point downstream for the entire project area.

In order to obtain flow rate data for the planned locations, it was decided to use the installed streamflow gauging station to provide data for a catchment area ratio conversion calculation. This would, in turn, allow for the calculation of flow data for the electricity generation project site. The catchment area ratio (catchment area of the planned construction site / catchment area of the streamflow gauging station) used for this calculation was restricted to the range from 0.5 to 2.0, which indicates that the relevant sites are not markedly different.



Plan site name		Catchment area (km²)	Catchment area ratio (B, C, D / A)
A	Streamflow gauging station selection area	108.00	—
B	#1 intake weir (projected)	98.20	0.91
C	#2 intake weir (projected)	35.20	0.33
D	#3 intake weir (projected)	43.50	0.40

Fig. 4-5: Streamflow gauging station installation area

2) Selection of the precise streamflow gauging station installation site

After identifying the optimal area for installation, the precise site for the streamflow gauging station was selected after a field survey was carried out, searching for a site with the following parameters:

- The river flow is not too swift or too sluggish.
- Changes in the center line and in the riverbed are infrequent.
- There are no undercurrents, countercurrents or still pools.
- There are no noticeably inconsistent changes in water level caused by the confluence or diversion of tributaries.
- Influence of already existing man-made structures is minimal.

Other factors included the configuration of the riverbed (rock shapes, etc.) and whether the site had sufficient depth to handle changes in water level. Interviews with local residents were also used as a resource for determining the volatility of the riverbed and water levels.

Based on all of the above factors, two sites were selected as potential candidates. Their locations are indicated on the map below.

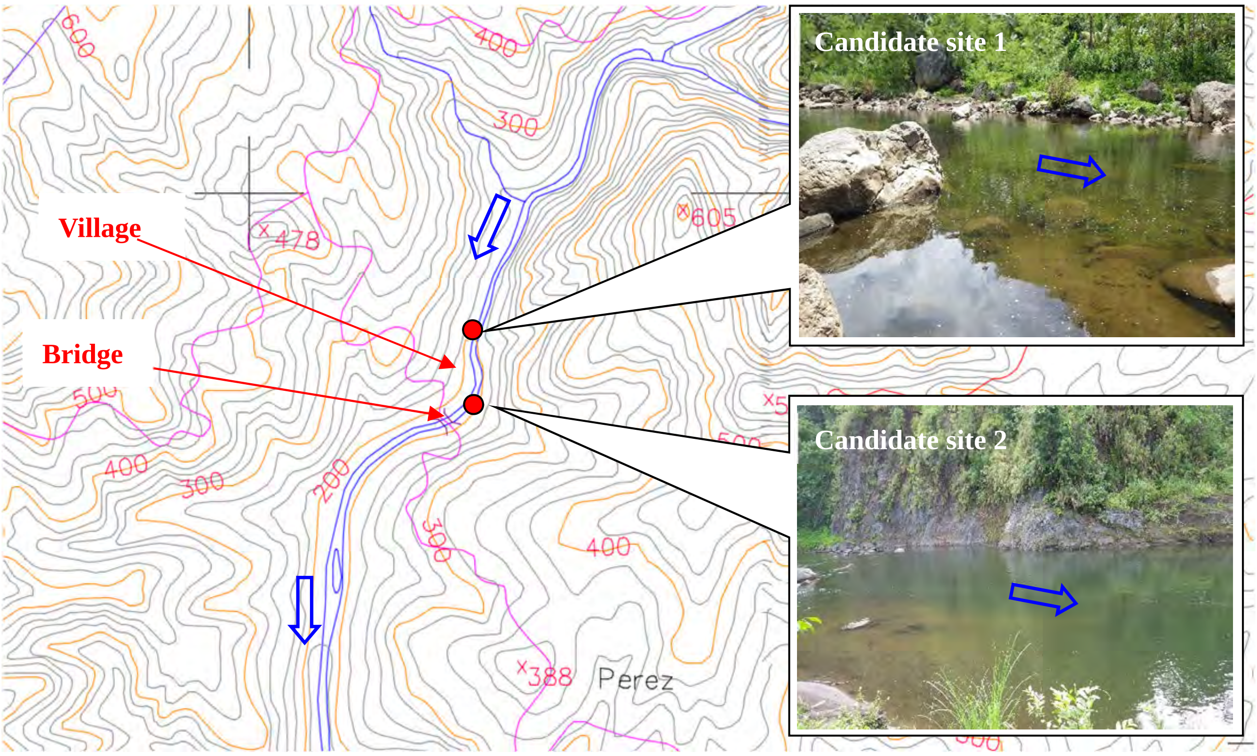


Fig. 4-6: Ground plan of candidate sites

From among these two candidate locations, candidate site 1 was selected for reasons of convenience in terms of construction, maintenance and management (measurement and data collection). The streamflow gauging station installed at this location will hereafter be referred to in this report as the "Wawa River Gauging Station."

(2) Streamflow gauging station installation diagram and water level gauge specifications

In order to obtain daily water level data, a water level sensor and a staff gauge were installed in the Wawa River Gauging Station. The water level sensor automatically records the water level at a fixed time each day and records this information in the data logger, which can store up to two years of water level data. The staff gauge is a back-up system, intended for a human monitor to read visually to obtain supplemental readings in case of malfunction with the water level sensor.

The below diagram indicates the design of the water level gauge.

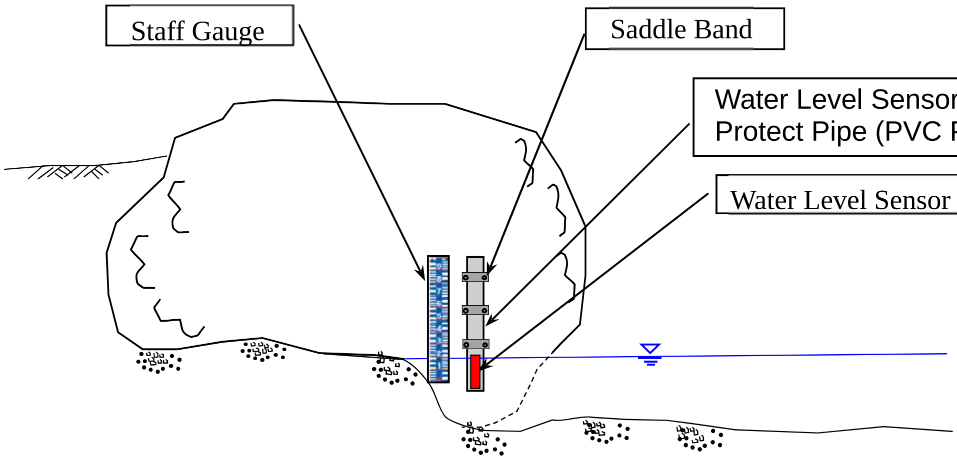


Fig. 4-7: Water level gauge diagram

Table 4-3: Specifications and performance of the water level sensor

Specifications / performance	Number
Model: U20-001-04 (Hobo U20 water level logger) Measurement scope: 0 to 4m Measurement accuracy: FS±0.075％ (±0.3cm) Resolution: 0.14cm Size: Outer diameter 24.6mm; length 150mm Material: Stainless steel Memory: 64KB (approx. 21,700 samples) Battery: 3.6V lithium battery (Battery life: 5 years)	2 （1 used for measuring atmospheric pressure）  Photograph of the sensor

(3) Streamflow gauging station installation

Installation of the Wawa River Gauging Station was carried out between August 25 and 29, 2014, while measurements commenced on August 29. Figures 4-8 to 4-10 are photographs of the installation process.

Fig. 4-8: Installation process (staff gauge)

Fig. 4-9: Installation process (water level gauge)

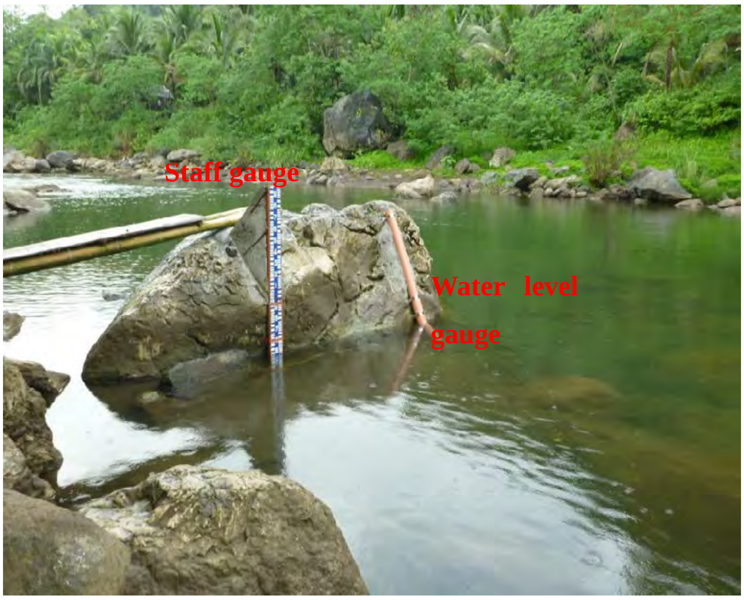


Fig. 4-10: Streamflow gauging station installation complete

4-2-2 Water level and flow measurement

(1) Flow measurement method

Flow measurements were carried out using the following method, based on the "Regulations for Flow Measurement for Hydroelectric Power Generation" ordinance of the Ministry of Economy, Trade and Industry. A conceptual diagram of the flow measurement method and the specifications of the current meter are shown below.

1) Conceptual diagram of the flow measurement method

a) Horizontal flow measurement intervals

At least 11 measurement lines (minimum distance between measurement lines of 50cm)

When water surface width is 20m; Water depth measurement intervals 0.9m, river velocity measurement intervals 1.8m, 11 measuring lines

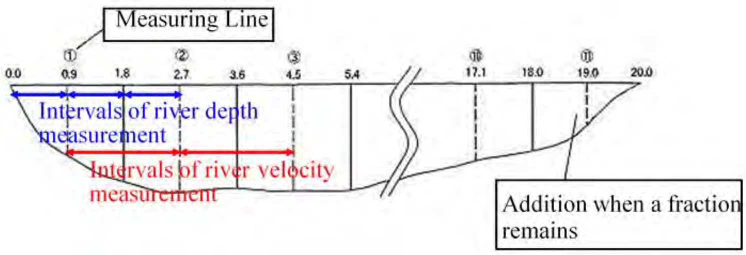


Fig. 4-11: Flow measurement intervals (horizontal) conceptual diagram

b) Vertical flow measurement intervals

Current measurements were carried out at points 20% and 80% of the depth of the river (calculated from the surface) at each point (or at 60% of the depth for single-point measurements). Measurements were carried out for at least 30 seconds.

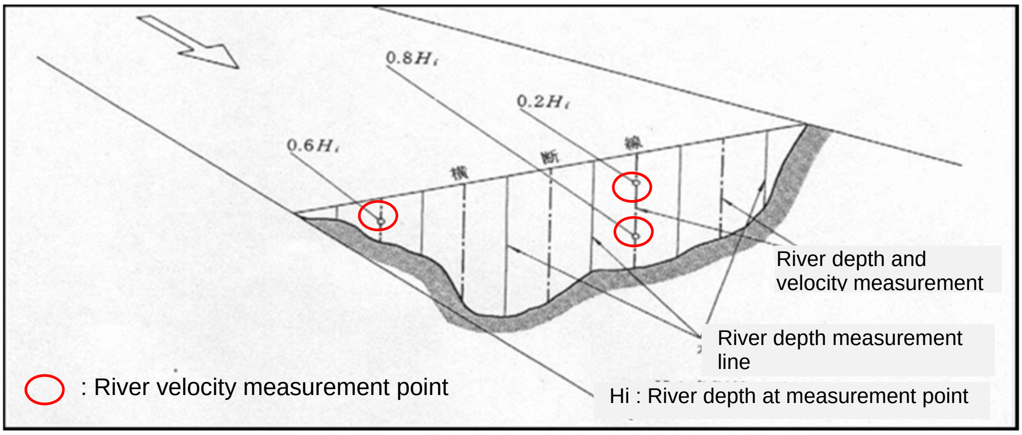


Fig. 4-12: Flow measurement intervals (vertical) conceptual diagram

2) Current meter specifications

The specifications of the devices used to measure the current are shown in Table 4-4.

Table 4-4: Current meter specifications

Model	Specifications / performance	Number
Type I (for medium/high speeds)	Manufacturer: Sanei Sokuryoki KK Measuring range: 0.15-3.30m/sec Measurement accuracy: Complies with the hydroelectric power generation regulations for accuracy in laboratory testing (±1.5%)	1
Photographs of the apparatus	  Current meter (type I)  Buzzer Current meter (type I) with buzzer	

3) Flow survey operational procedure

The details of the operational procedure for carrying out a flow survey are shown in Table 4-5. The following are the fundamental steps which must be carried out.

・ Flow measurement:

- Measurement of the river's flow rate using a current meter (twice a month)

・ Monitoring of water level gauge:

- Collection of data from the water level sensor and input of this data into a computer (once a month)

- Inspection and maintenance of the water level gauge installation (as required)

・ Periodic water level measurements:

- Visual reading of the staff gauge to determine water depth, and recording of data (twice a day at fixed times)

Table 4-5: Flow survey operation procedure

Survey Category	Person in Charge	Work Items	Work Contents	Supplementary Explanation
1. River flow measurement (Twice a month)	Local Surveyor	1) Confirmation of river condition	◇ Check river stream and waterway condition, etc. in the up and downstream of flow measurement point.	◇ Confirm the difference from previous time.
		2) Preparation for measurement	◇ Fix a tape measure on a river traverse line.	◇ Select the suitable measurement point.
			◇ Fill in a field notebook the intervals of river velocity measurement.	◇ Preparation of a field notebook.
			◇ If there are boulders disturbing river flow in a measurement section remarkably, it shall be removed and make riverbed smooth.	◇ Improvement the measurement accuracy.
		3) Water level observation (at the beginning)	◇ Observe a water level of the staff gauge when start the measurement work.	◇ H value in the H-Q curve.
		4) Water depth measurement	◇ Measure water depth at all measurement points.	◇ River cross sectional area in the quantity calculation.
		5) Velocity measurement	◇ Measure water velocity at alternate line.	◇ Average flow velocity in the quantity calculation.
		6) Water level observation (at the end)	◇ Observe a water level of the staff gauge when finish the measurement work.	◇ H value in the H-Q curve.
		7) River flow calculation	◇ Calculate the river flow quantity after finish the measurement, and plot at H-Q curve.	◇ Q value in the H-Q curve. This data is used for validity confirmation of the measurement result.
		8) Validation of measurement result	◇ Compare H-Q curve and visual condition of the river, and check whether any discrepancy from previous data or not.	◇ Improvement the measurement accuracy.
			◇ If the measurement result is further different from previous H-Q curve, re-measure. If not, finish.	
		9) Re-measurement (if necessar	◇ Compare river depth and velocity from previous measurement result, re-measure where discrepancies are confirmed, or all points.	
			◇ If the result of re-measurement still has discrepancy from H-Q curve, river cross sectional survey shall be done. If not, finish.	
		10) River cross sectional survey	◇ Incline of river water surface including survey line.	◇ Pursue a cause of the discrepancy. And improve reliability.
2. Water level recorder supervision (Once a month)	Local Surveyor	1) Check, maintenance of river stream condition	◇ Check sedimentation in the river bed disturbing water level recorder. If there is, remove it.	◇ Prevention of data loss and unexpected result.
		2) Data collection and check of the water level recorder	◇ Data collection from two sensors, they are atmospheric recorder and water level recorder to a personal computer.	◇ Not leaving data in the field to prevent contingency.
			◇ Before and after removal from protection pipe, record the time and the water level. Return the sensor to the fixed position in the protection pipe.	◇ Data and water level are needed for calibration of the sensor.
			◇ Check the data and battery of the sensor after data collection to a computer.	◇ Check the sensor condition from water level data for early detection of sensor error.
3. Water level measurement (Every day)	Employed Local People	1) Water level observation (at scheduled time)	◇ Observe water level of the staff gauge daily at scheduled time.	◇ The data will be used for supplement of water level recorder.
			◇ Put time and water level in the record sheet	
			◇ Check the staff gauge setting condition.	◇ Care of gauging station.

(2) Local field observers and technical guidance

Flow measurements, water level gauge monitoring and visual recordings of the staff gauge will all be undertaken by locally-based staff. Technical guidance for these tasks was provided during the installation of the streamflow gauging station. The guidance primarily covered the flow measurement method, water level gauge operation method and river cross-sectional measurement methods. Meetings were also held to discuss the future operation of the gauging station, and both sides confirmed the methods used for the submission and receipt of reports of results. Table 4-6 shows the basic operational parameters for the streamflow gauging station, while Figures 4-13 to 4-16 are photographs of the guidance process.

Table 4-6: Stream gauging station operational parameters

Category	Frequency	Notes
Flow measurement	Twice a month	
Water level gauge data collection	Once a month	Conducted near the start of the month together with the first flow measurement of the month
Water level staff gauge visual confirmation	Twice a day	At 7:00 and 16:00 each day

Fig. 4-13: Flow measurement (1)

Fig. 4-14: Flow measurement (2)

Fig. 4-15: Cross-sectional measurement

Fig. 4-16: Meeting

(3) Water level and flow rate measurement results

The water level and flow rate measurement results from the Wawa River Gauging Station and the existing Bayugan Gauging Station have been compiled below.

Table 4-7: Wawa River Gauging Station and Bayugan Gauging Station observation results

<table>
<tr><th>Location</th><th>Category</th><th>Data type</th><th>Observation period</th></tr>
<tr><td rowspan="3">Wawa River Gauging Station</td><td rowspan="2">Water level</td><td>Water level gauge (hourly)</td><td>8/29/2014-8/31/2015</td></tr>
<tr><td>Staff gauge (twice daily)
(7:00, 16:00)</td><td>8/29/2014-8/31/2015</td></tr>
<tr><td>Discharge</td><td>Actual flow measurements</td><td>August, 2014 – September, 2015</td></tr>
<tr><td rowspan="2">Bayugan Gauging Station</td><td>Water level</td><td>Staff gauge (thrice daily; supplied data)
(6:00, 12:00, 18:00)</td><td>8/29/2014-8/31/2015</td></tr>
<tr><td>Discharge</td><td>Actual flow measurements</td><td>April and September, 2015</td></tr>
</table>

1) Wawa River Gauging Station

a) Water level measurement

Water level measurement at the Wawa River Gauging Station was carried out hourly by the water level gauge, with the supplemental measurement of the visual observation of the staff gauge. Water level is plotted against time in Fig. 4-17 below.

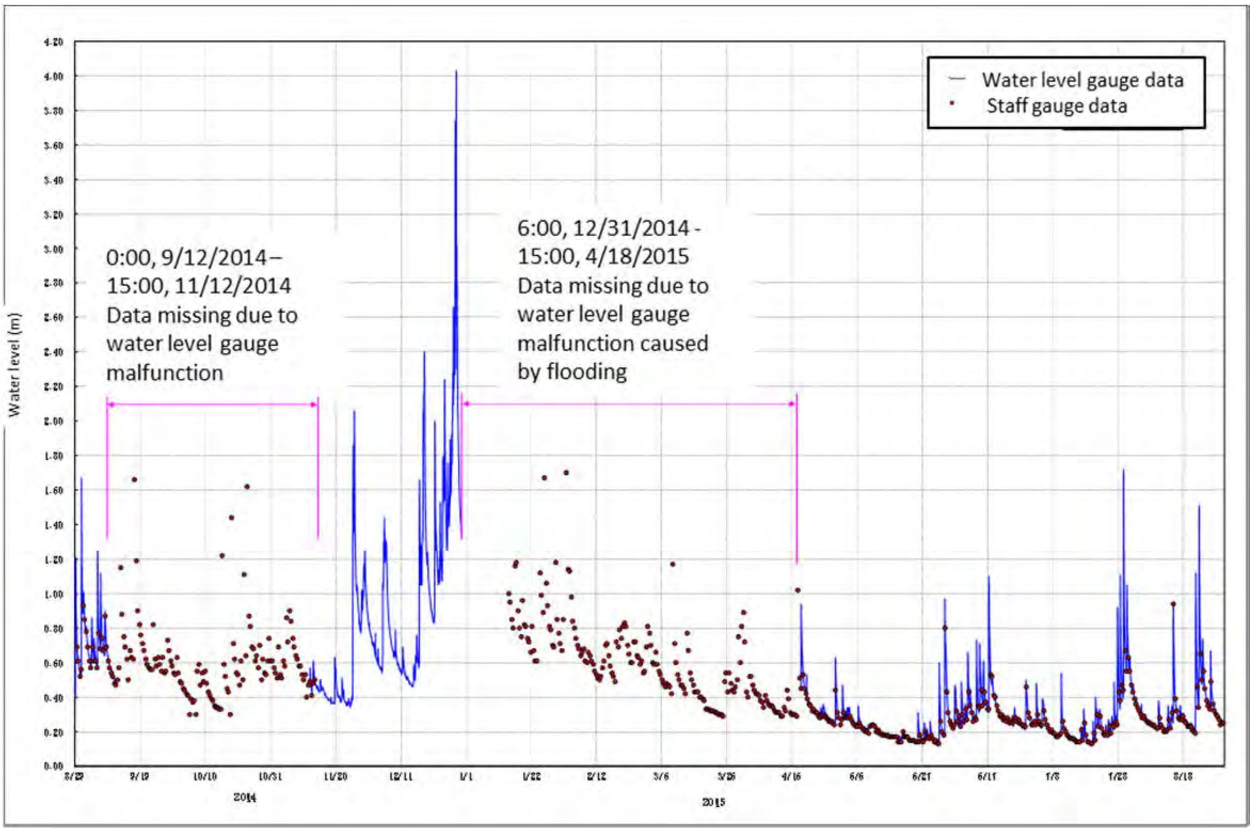


Fig. 4-17: Wawa River Gauging Station water level changes over time

b) Flow measurement

Flow measurement results are displayed in Table 4-8 below.

Table 4-8: Wawa River Gauging Station flow measurement results

Measurement number	Measurement date and time			Water level (m)	Average current (m/s)	Cross-sectional area (m^2)	Discharge (m^3/s)
	Date	Time					
		Start	End				
1	8/26/2014	09:40	10:30	0.42	0.291	11.78	3.43
2	8/26/2014	14:20	15:54	0.47	0.343	13.22	4.54
3	9/12/2014	10:00	12:00	0.56	0.320	17.31	5.54
4	9/20/2014	10:45	12:18	0.61	0.427	16.77	7.16
5	10/7/2014	11:15	12:48	0.51	0.368	13.12	4.83
6	10/12/2014	12:00	13:07	0.38	0.299	9.66	2.89
7	11/11/2014	13:45	14:49	0.50	0.344	12.54	4.32
8	11/13/2014	12:15	13:10	0.46	0.340	11.95	4.06
9	11/17/2014	12:26	13:28	0.40	0.309	10.69	3.3
10	12/14/2014	11:17	12:24	0.48	0.351	12.02	4.22
11	4/11/2015	09:37	10:36	0.31	0.301	8.43	2.54
12	4/16/2015	09:39	10:29	0.29	0.286	8.12	2.32
13	6/28/2015	10:18	10:58	0.24	0.247	7.08	1.75
14	6/30/2015	14:42	15:18	0.29	0.284	8.02	2.28
15	7/7/2015	15:33	16:30	0.21	0.195	6.63	1.29
16	7/20/2015	14:33	15:12	0.13	0.154	5.51	0.85
17	8/9/2015	09:01	09:43	0.24	0.201	7.42	1.49
18	8/17/2015	13:28	14:15	0.28	0.288	8.13	2.34
19	9/5/2015	09:21	10:06	0.30	0.267	8.68	2.32

2) Bayugan Gauging Station

c) Water level measurement

Water level measurements conducted at fixed times each day have been collated below. Water level is plotted against time in Fig. 4-18.

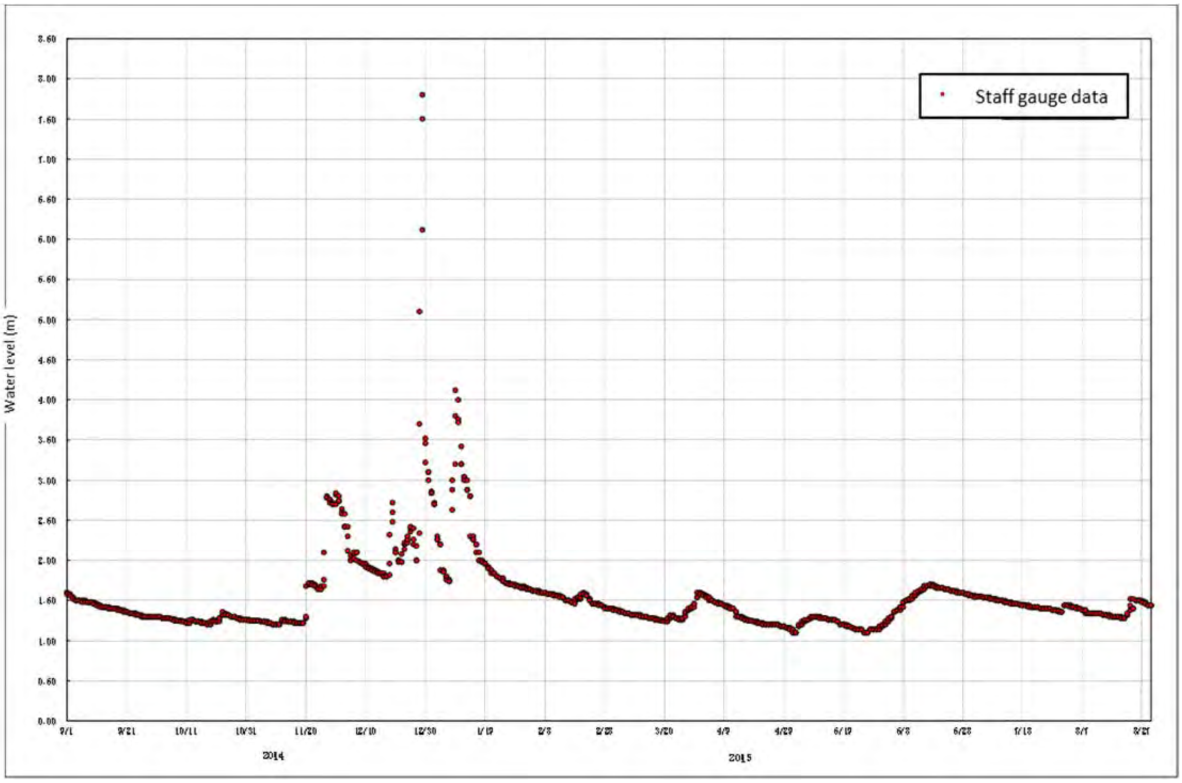


Fig. 4-18: Bayugan Gauging Station water level changes over time

d) Flow measurement

Flow measurement results are displayed in Table 4-9 below.

Table 4-9: Bayugan Gauging Station flow measurement results

Measurement number	Measurement date and time			Water level (m)	Average current (m/s)	Cross-sectional area (m^2)	Discharge (m^3/s)
	Date	Time					
		Start	End				
1	4/15/2015	10:25	10:35	1.20	0.205	29.47	6.04
2	9/14/2015	12:00	12:20	1.03	0.180	14.46	2.60
3	9/17/2015	10:20	10:30	1.14	0.201	26.98	5.42

4-2-3 H-Q curve analysis

Analysis of the H-Q curve (water level-discharge curve) was conducted based on the water level and flow trends over time, as plotted on the graphs above. The results of this analysis are outlined below.

(1) Wawa River Gauging Station

An observation of the distribution of actual data points (water level / discharge) that make up the

H-Q curve reveals no significant dispersion from the curve. The H-Q curve is an approximation based on actual measured data values; the discharge when the river is high was estimated and the curve extrapolated using Manning’s formula with measured cross-sectional river area data as a parameter. Fig. 4-18 shows the H-Q curve for the Wawa River Gauging Station.

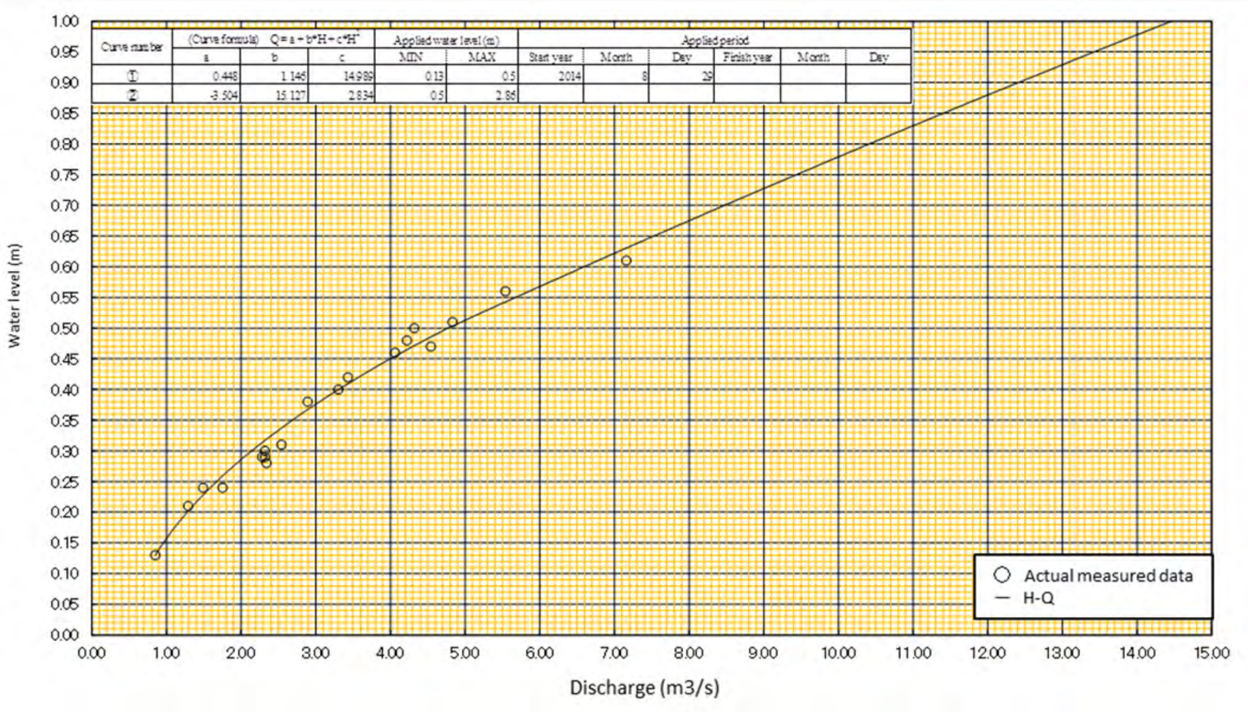


Fig. 4-19: Wawa River Gauging Station H-Q curve

(2) Bayugan Gauging Station

As with the Wawa River Gauging Station, an H-Q curve was estimated by way of an approximation based on actually measured data points. For when the river is high, discharge was extrapolated based on the flow calculating formula. Fig. 4-20 shows the H-Q curve for the Bayugan Gauging Station.

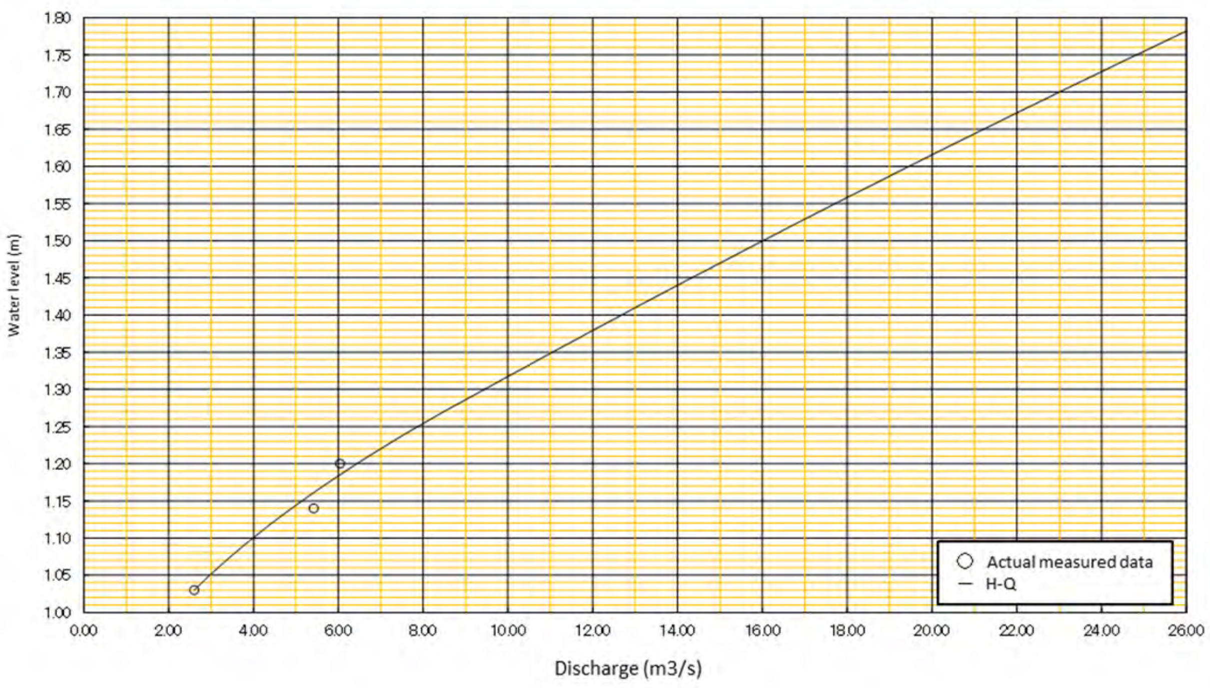


Fig. 4-20: Bayugan Gauging Station H-Q curve

4-3 Creation of a river flow duration curve

A river flow duration curve was created following the steps outlined in Fig. 4-21 below, to be used in a feasibility study of this project.

(1) Analysis and evaluation of relative flow rates between the Wawa River and Bayugan Gauging Stations

<Data to be used>

・Daily average flow data

・Period for analysis: 9/11/2014-12/31/2014; 1/15/2015-8/31/2015

(2) Calculation of flow duration at the Wawa River Gauging Station based on the correlation equation

<Data to be used>

・10 years of flow duration data from Bayugan Gauging Station

・Years: 1985, 1986, 1990, 1991, 1992, 1994, 1996, 1999, 2000, 9/2014-8/2015

(3) Calculation of flow durations at the planned construction points via catchment area ratio conversion

<Data to be used>

・Flow duration data from the Wawa River Gauging Station

・Catchment areas: Wawa River Gauging Station (108.00km^2),

Planned sites (#1: 98.20km^2), (#2: 35.20km^2), (#3: 43.50km^2)

Fig. 4-21: Steps for creation of a flow duration curve

(1) Analysis and evaluation of relative flow rates between the Wawa River and Bayugan Gauging Stations

Fig. 4-22 below is a correlation diagram between the flow rates of the Wawa River and Bayugan Gauging Stations.

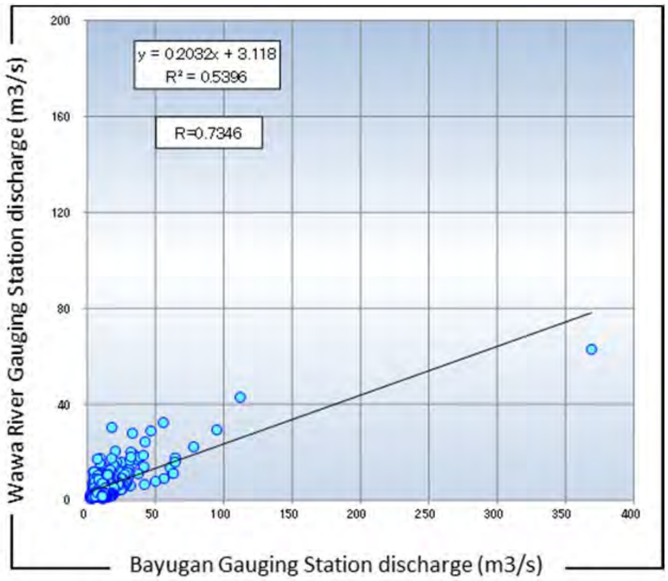


Fig. 4-22: Correlation diagram between the Wawa River and Bayugan Gauging Stations (all data)

While the two show a relatively strong correlation (R=0.7346), when the Bayugan Gauging Station records low flow, the Wawa River Gauging Station shows a tendency to record higher than expected flow. As a result, we compared the daily average flow rate measurements from each station over time (Fig. 4-23), and selected the data for use in a correlation study based on the following parameters.

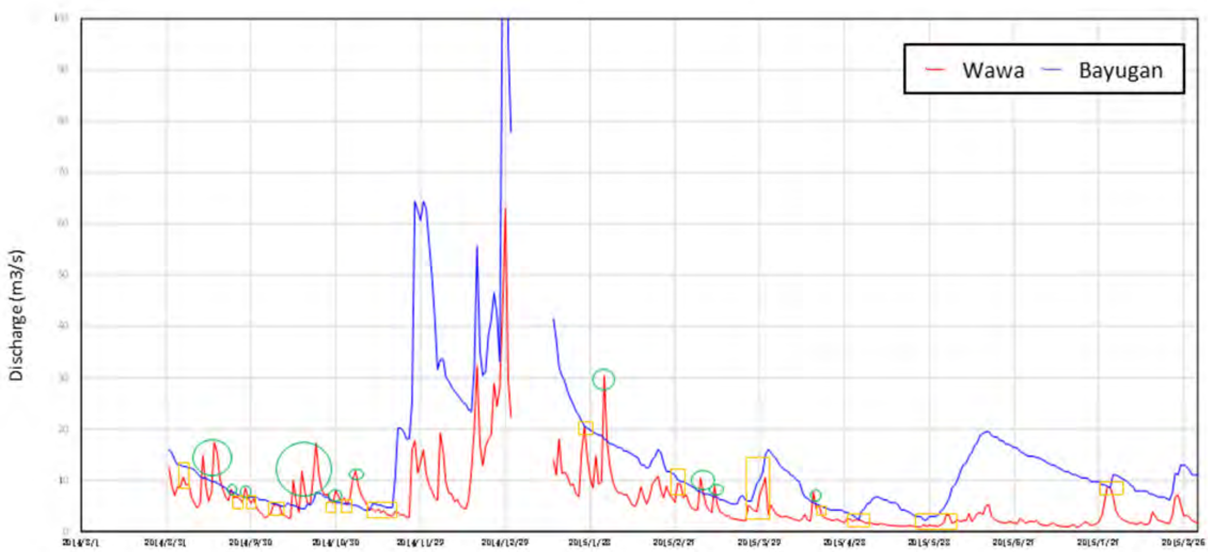


Fig. 4-23: Daily average flow rate measurements over time for the Wawa River and Bayugan Gauging Stations

- Areas on the above graph marked with ○ indicate where the Wawa River Gauging Station has recorded erroneously high flow rates in comparison to the Bayugan Gauging Station. These data points have therefore been discarded.
- Areas on the above graph marked with □ indicate where the ratio of the flow rates from the Wawa River Gauging Station and Bayugan Gauging Station is close to 1.0 (indicating almost identical values). These data points have therefore been discarded.

- Flow data obtained from both stations (actual data from measurements on the same day) indicates that the flow ratio between the two stations is 0.38 (Wawa River Gauging Station / Bayugan Gauging Station). Therefore, data points which are radically distant from 0.38 have been discarded. Consideration was also given to the fact that flow rate measurements are taken on low to medium water level days, which are vitally important to the power generation plan.

Having thus eliminated several data points, the correlation between the two sets of data was re-examined. The new correlation diagram can be seen in Fig. 4-24 below.

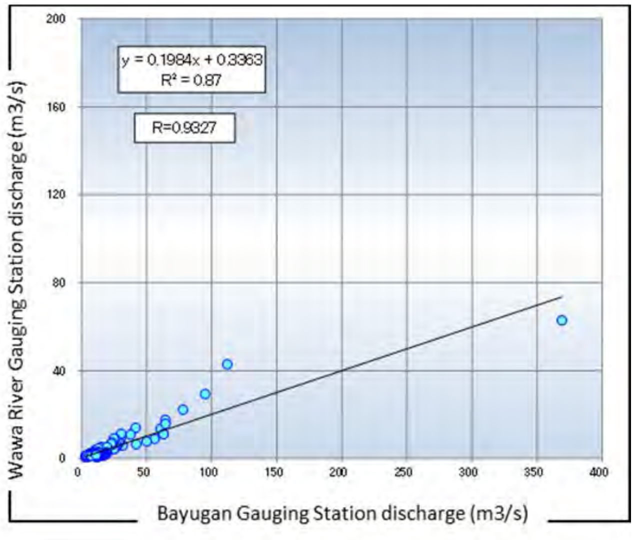


Fig. 4-24: Correlation diagram between the Wawa River and Bayugan Gauging Stations (outliers removed)

The correlation seen in Fig. 4-24 is very high (R=0.9327). As the Bayugan Gauging Station is the only pre-existing streamflow gauging station with available data to use as a comparison, it was decided that removing outliers and creating a more appropriate correlation equation would be of more value in calculating the flow duration curve of the Wawa River.

(2) Flow duration calculation for the Wawa River Gauging Station

Using the existing flow duration data from the Bayugan Gauging Station and the correlation equation established in Fig. 4-24 above ($y=0.1984x+0.3363$), we calculated the flow duration at the Wawa River Gauging Station. As a reference, one year’s worth of measured flow data from the Wawa River Gauging Station (September, 2014 to August, 2015) has also been included in the below diagram.

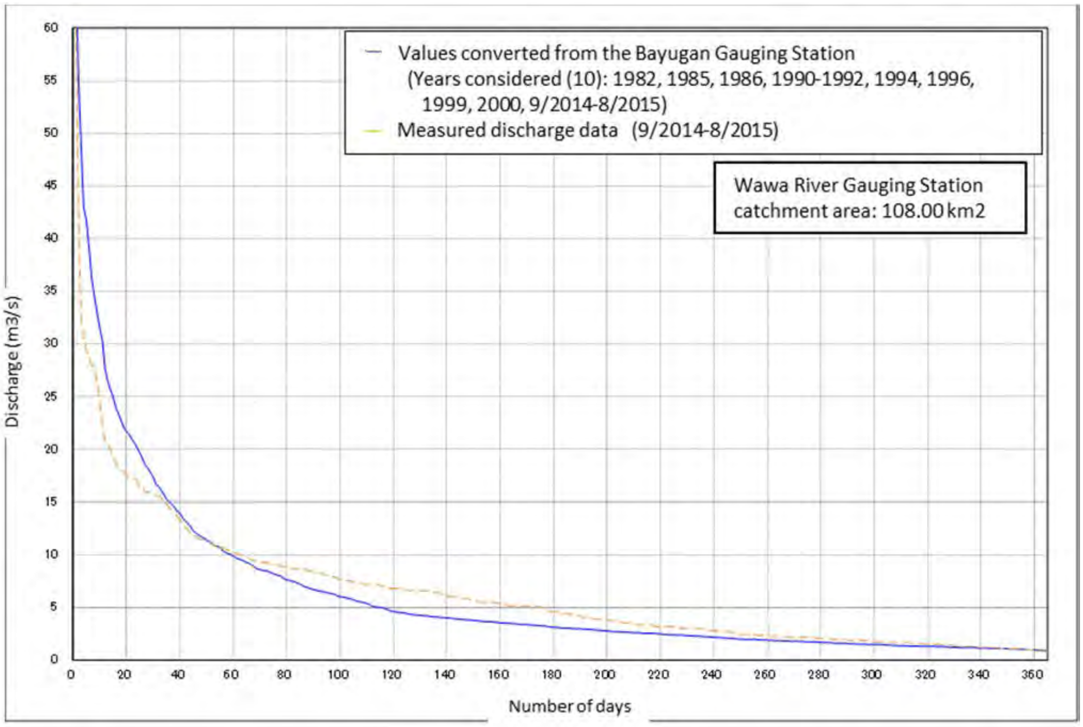


Fig. 4-25: Wawa River Gauging Station flow duration curve

The data converted from the Bayugan Gauging Station shows similar flow duration to the actually observed data at the Wawa River Gauging Station in terms of the low-discharge or droughty-discharge values, but exhibits higher values at the high-discharge to medium-discharge end of the curve.

The flow duration curve in Fig. 4-25 was used to calculate the flow duration at each of the planned water intake points. The results of these calculations are shown in the next section.

(3) Calculation of flow duration at the planned locations based on a catchment area conversion equation

Using the flow duration curve at the Wawa River Gauging Station shown in Fig. 4-25, we created similar flow duration curves at each of the planned water intake points based on catchment area conversion equations. Figures 4-26 to 4-28 show the flow duration curves for each of the planned intake weir locations. Each graph features a river flow duration curve and a flow facility utilization factor curve.[1]

[1] Flow facility utilization factor curve: A curve connecting the data points indicating (yearly water volume that can be used for power generation / (maximum usable water volume x 365)) when the flow rate at that point is set as the maximum usable water volume.

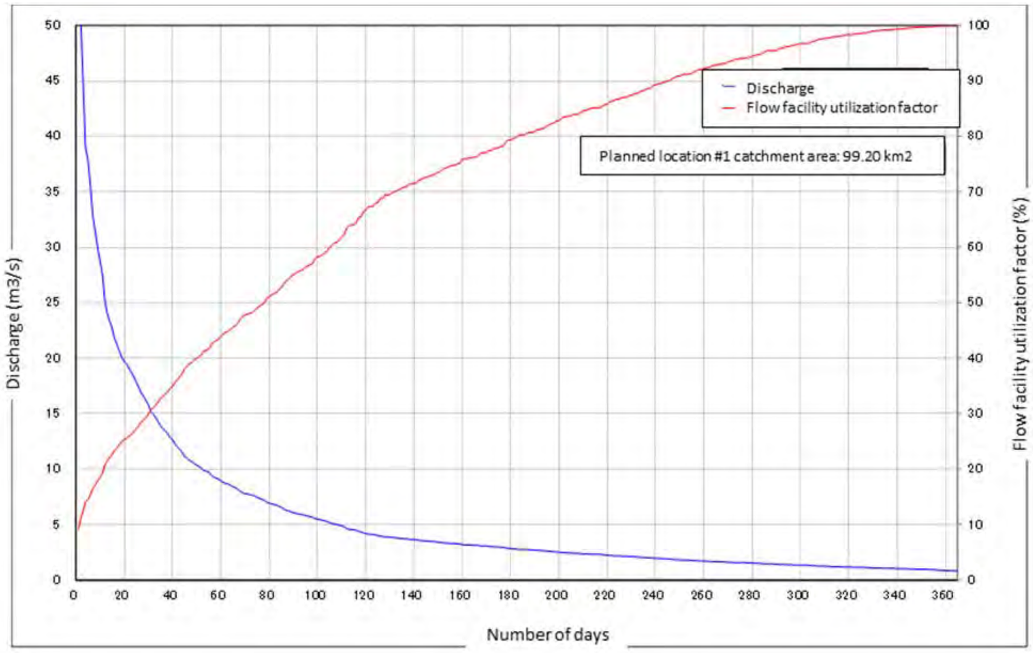


Fig. 4-26: Flow duration curve for the projected intake weir location for Wawa No.1 Power Plant

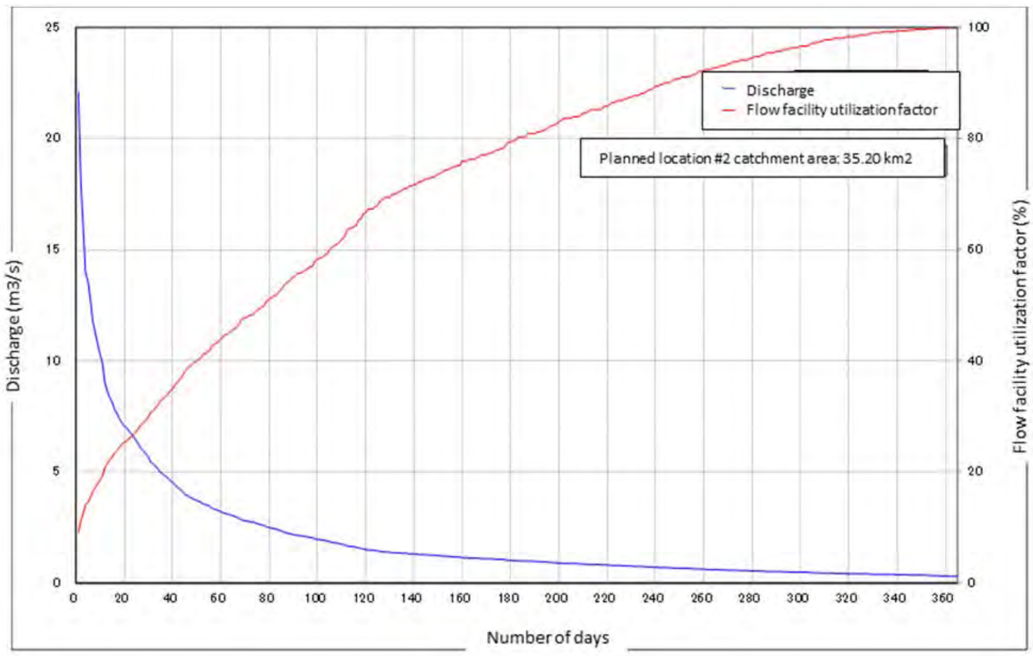


Fig. 4-27: Flow duration curve for the projected Wawa River intake weir location for Wawa No.2 Power Plant

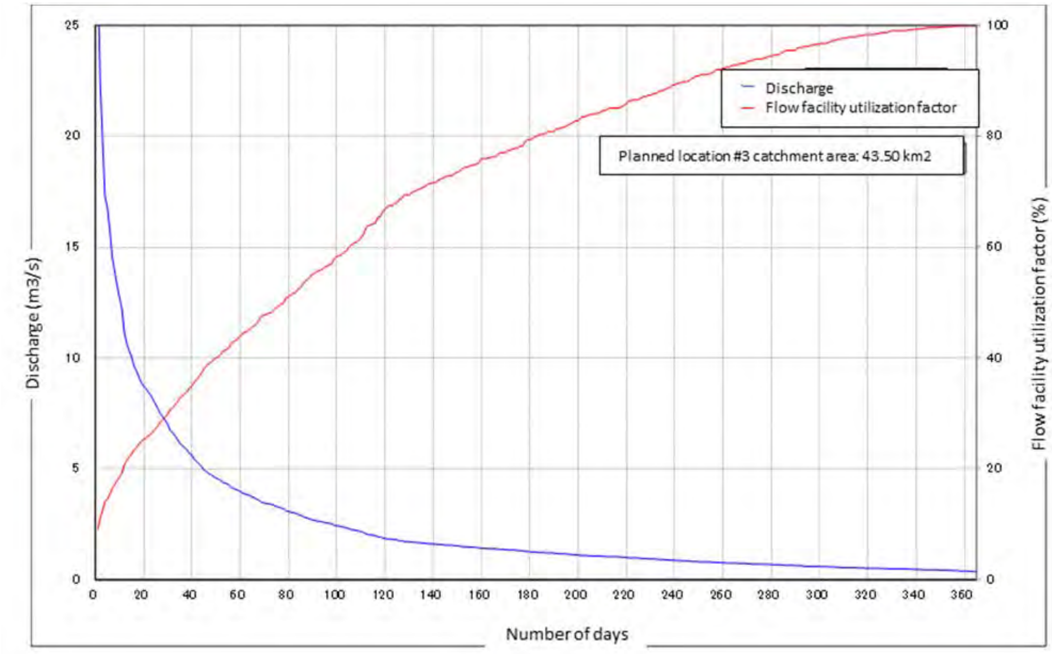


Fig. 4-28: Flow duration curve for the projected Manangon River intake weir location for Wawa No.2 Power Plant

Chapter 5 Plan for mini hydroelectric plant

5-1. Overview of the river and initial plans

5-1-1. Overview of the river

A relief map of the area around the Wawa and Manangon rivers, which are the sites for this project, is shown in Fig. 5-1. Fig. 5-2 shows the gradient of the rivers, derived from the relief map.

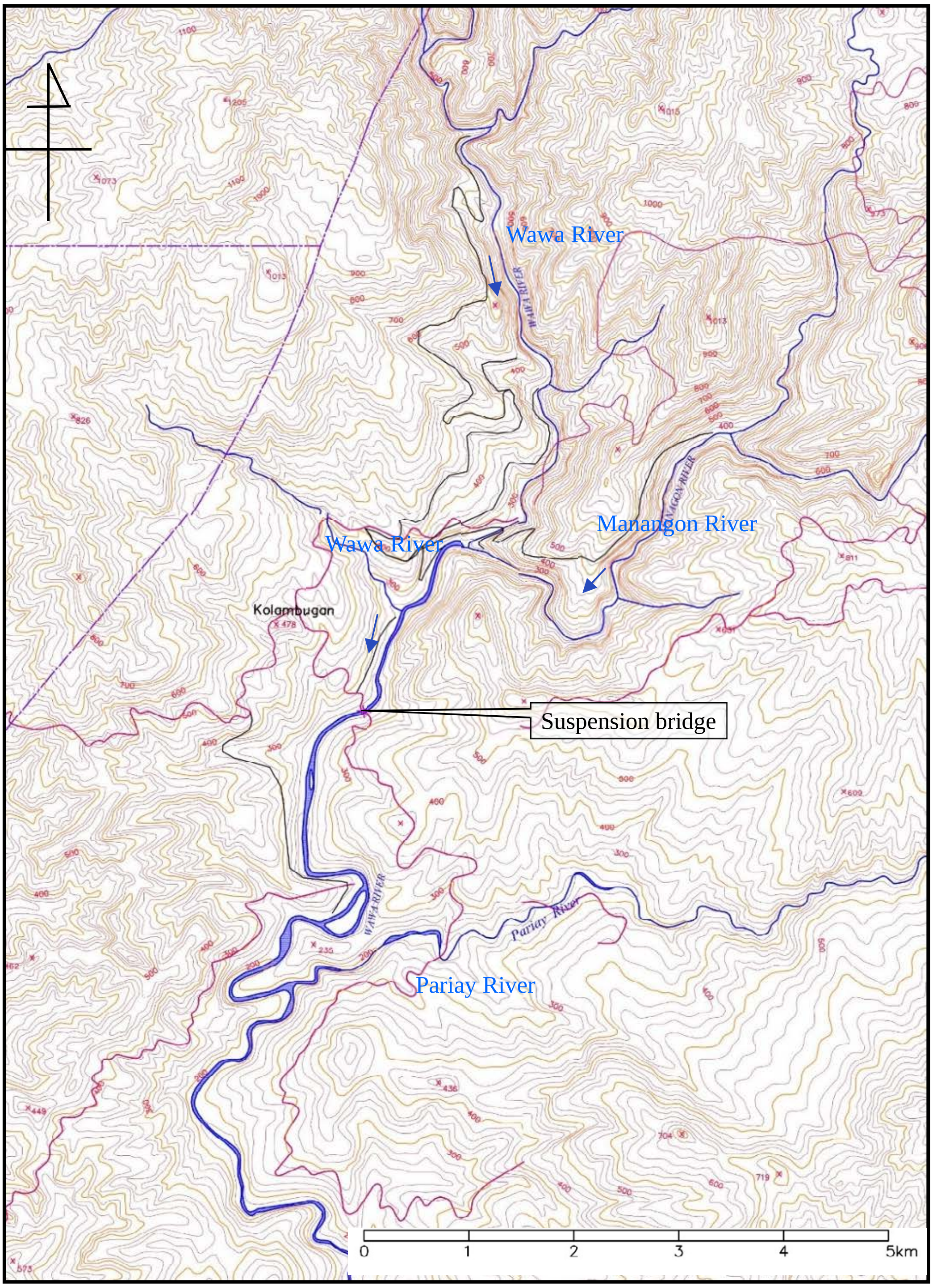


Fig. 5-1: Relief map of the project area

Source: NAMRIA 1:50,000 relief map annotated by Investigation Team

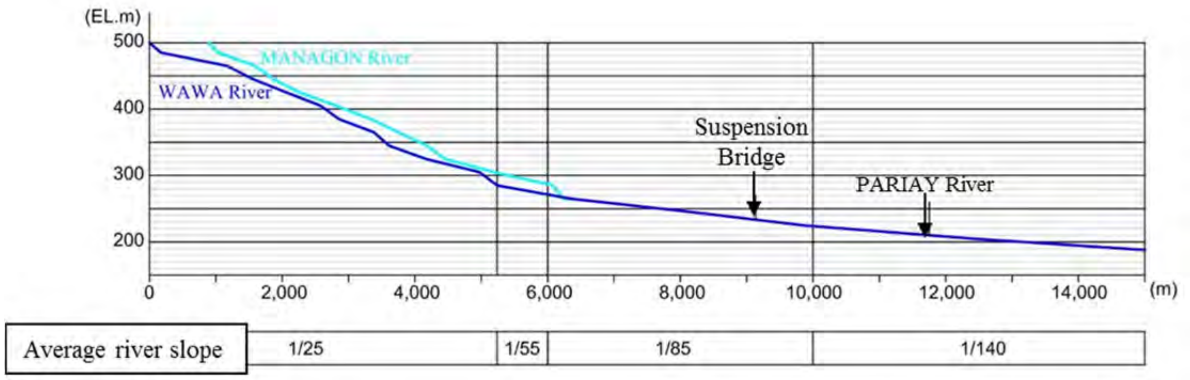


Fig. 5-2: Gradient of the upper Wawa River basin and the Manangon River

Source: Created by the Investigation Team

The Wawa and Manangon rivers, which are sites to be developed in this project, flow at a steep gradient of over 1:25 from their sources to around EL.270m, while the gradient becomes less steep downstream from their confluence, becoming less than 1:100 below EL.225m.

5-1-2. The initial plan

The initial plan[1] was for run-of-the-river power plants, Wawa No. 1 to be sited downstream from the confluence of the Wawa and Manangon rivers, Wawa No. 2 and No. 3 to be sited upstream on the Wawa and Manangon rivers respectively. The planned sites are shown in Fig. 5-3 and an outline of the plan is shown in Table 5-1.

[1]From 2012 Research on Promotion of Infrastructure & Systems Exports (Yen loans: creating private sector-financed infrastructure projects) "Report on Mini-Hydroelectric Plant Project for the Wawa River in Agusan del Sur, Philippines" (February 2013)

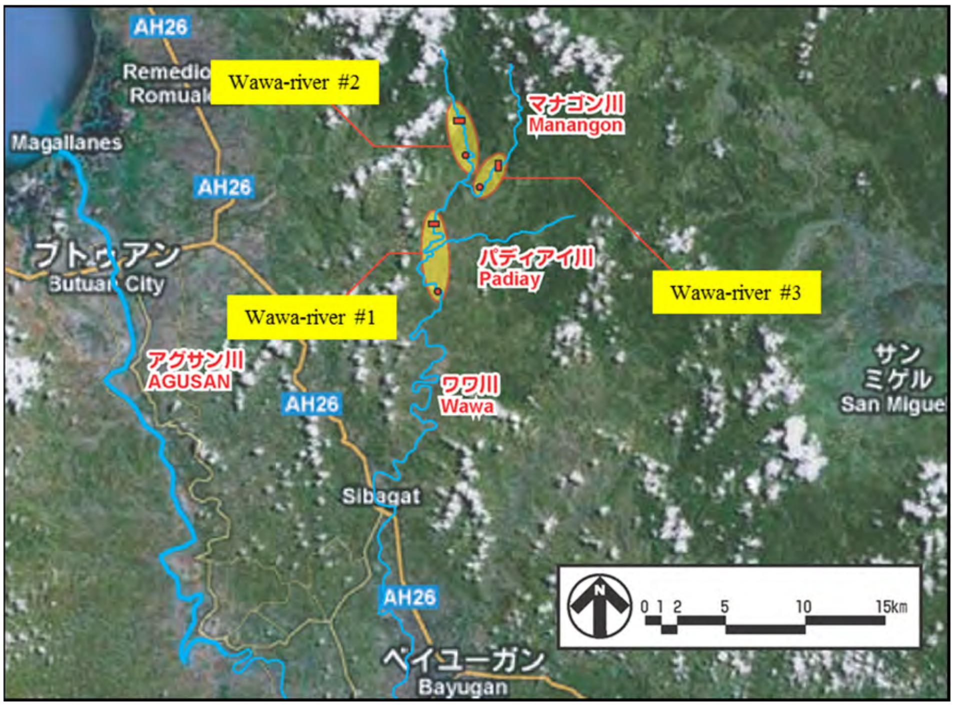


Fig. 5-3: Map of initial sites

Source: "Report on Mini-Hydroelectric Plant Project for the Wawa River in Agusan del Sur, Philippines" (February 2013)

Table 5-1: Outline of initial plan

	Units	#1	#2	#3
Catchment area	km^2	119	36	42
Gross head	m	85	110	90
Net head	M	73	99	80
Expected volume	m^3/s	16.9	7.4	8.8
Maximum output	kW	10,600	6,400	6,100
Expected power generation	MWh	43,642	24,108	22,443
Type of intake		Run-of-the-river Front stream	Run-of-the-river Tyrolean	Run-of-the-river Front stream
Intake weir	m	w180 x h14.5	w40 x h15.0	w90 x h14.5
Headrace	m	Non-pressurized φ3,000	Non-pressurized φ2,200	Non-pressurized φ2,350
Channel length	m	7,400	2,400	2,400
Penstock route	m	φ2,200	φ1,450	φ1,550
Powerhouse	m^2	Building area 500	Building area 450	Building area 450
Turbine		Francis (2 turbines)	Francis (2 turbines)	Francis (2 turbines)
Generator		3-phase synchronous	3-phase synchronous	3-phase synchronous

Source: "Report on Mini-Hydroelectric Plant Project for the Wawa River in Agusan del Sur, Philippines" (February 2013)

5-2 Wawa No. 1 Mini-hydroelectric Plant

5-2-1. Layout of generating plant

(1) Location of development on the Wawa River

The initial plan for Wawa No. 1 was to install an intake weir on the Wawa River to feed water into a powerhouse via a 7,400m headrace. As the riverbed on this section of the river has a shallow gradient of around 1:140, it would require a long headrace in order to achieve a head, which would make it an inefficient location for a run-of-the-river plant. The plan also included an intake weir with a crest length of 180m and a height of 14.5m, as the river is more than 150m wide at the location of the intake weir. This is quite large for a mini-hydroelectric plant. In this study we therefore revised the initial plan and selected a layout for power generation that provided a more effective head and would not require structures that were excessive for a mini-hydroelectric plant.

As Wawa No. 1 is planned for the area downstream from the confluence of the Wawa and Manangon rivers, planning needs to ensure that the rise in water levels caused by the installation of the intake weir does not affect the No. 2 power plant, which is planned for the Manangon River upstream from the confluence. The gradient of the river bed in this section of the Wawa River is around 1:85 to 1:140, which is shallow for the location of a run-of-the-river mini-hydroelectric plant. The location would not provide as much of a head in proportion to the length of the headrace as locations of Wawa No.2 and

Wawa No. 3, which are on sections of the river with a steep gradient of around 1:25. This is increasingly the case the further downstream the location, as the gradient of the river decreases. The team therefore decided to consider locations upstream from EL.225m, where the river gradient is at least 1:100, to plan the route of Wawa No. 1 (Fig. 5-4).

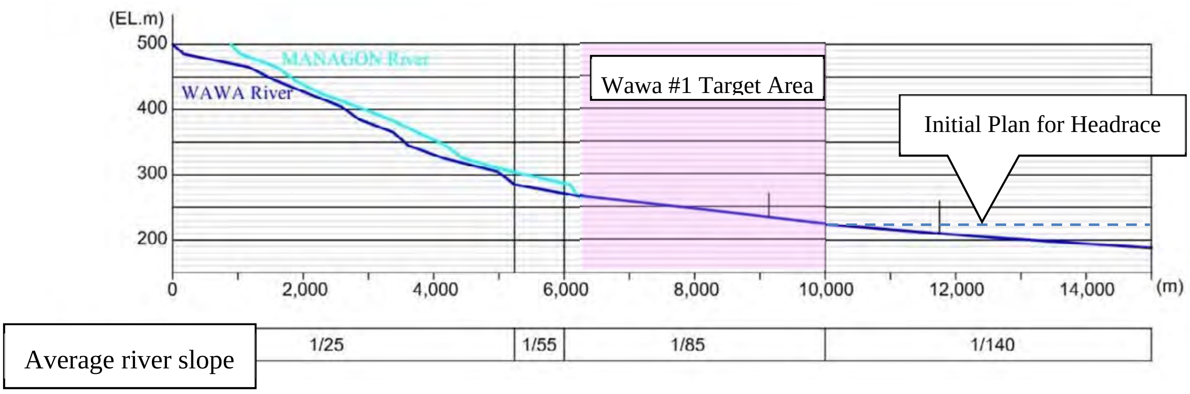


Fig. 5-4: Area considered for Wawa No. 1 plant

(2) Location of the intake weir

In selecting the location of the intake weir, the following points were considered:

- Water routes in the straight parts of the river should be as stable as possible
- It should be easy to widen and narrow both banks of the river
- The river should be wide enough for its width to be halved, so that a route can be found for it to flow on one side while work is being carried out on the other side
- It should be possible to find space to install an intake upstream from the weir
- The rise in water level caused by the weir should not affect points upstream

Based on the relief map and local research, three locations were chosen for comparison as potential sites for the intake weir, shown as A, B and C in Fig. 5-5.

Site A, the furthest upstream, was just downstream from the confluence with the Manangon River, site B was around 40m downstream from the confluence with a marsh (unnamed) which joins the right bank of the river around 800m downstream from site A, and site C, the furthest downstream, was immediately below a pedestrian suspension bridge located around 1,000m downstream from site B.

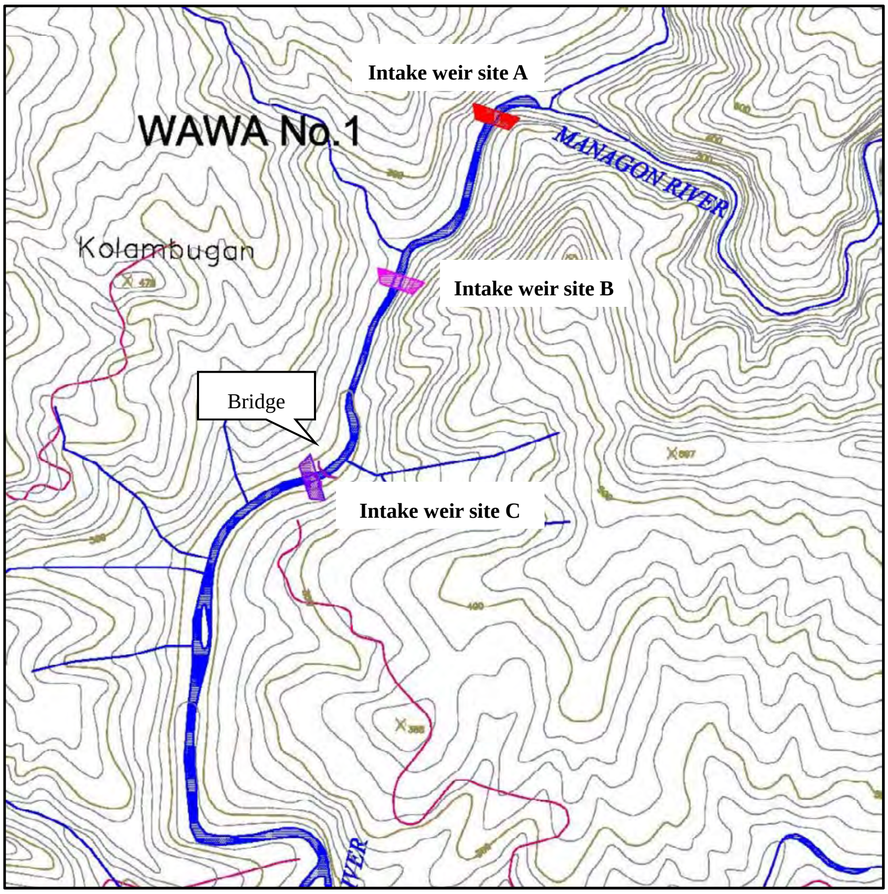


Fig. 5-5: Potential sites for Wawa No. 1 intake weir

(3) Headrace route

Since both banks of the Wawa River in the area planned for Wawa No. 1 are comparatively gentle slopes, it is economical to plan an open channel on the banks. Comparing the left and right banks of the Wawa River for the headrace route, the right bank is less suitable because of the problems discussed below. It was therefore decided to use the left bank route (see Fig. 5-6).

1) Houses on the headrace route

Houses that are part of the village of Kolambugan are scattered over the right bank of the Wawa River, so the headrace route would run into a number of homes and residential plots. Installing the headrace would necessitate the relocation of the homes. There are no houses along the headrace route on the left bank.

2) Stability of the banks

Although the banks form a comparatively gentle slope from the start of the headrace to the middle part of the route, which would make it easy to install the headrace, they become very steep, with an angle of around 45 degrees, in the vicinity of the planned location for the powerhouse, where the surface of the ground is soft and numerous gullies can be found that were presumably formed by heavy rain. If the headrace was built on the surface, there would be problems with the long-term stability of the foundations. The left bank slopes steeply close to the intake weir, but there would be no problems with stability after construction as the bank is mostly bare rock. The banks from the middle part of the headrace to the powerhouse slope gently and the ground is solid, with no signs of collapse visible.

3) Numerous marshes crossed

There are a total of five places on the right bank headrace route that cross marshland, each of which would need to be bridged. The left bank route, on the other hand, crosses only one marsh.

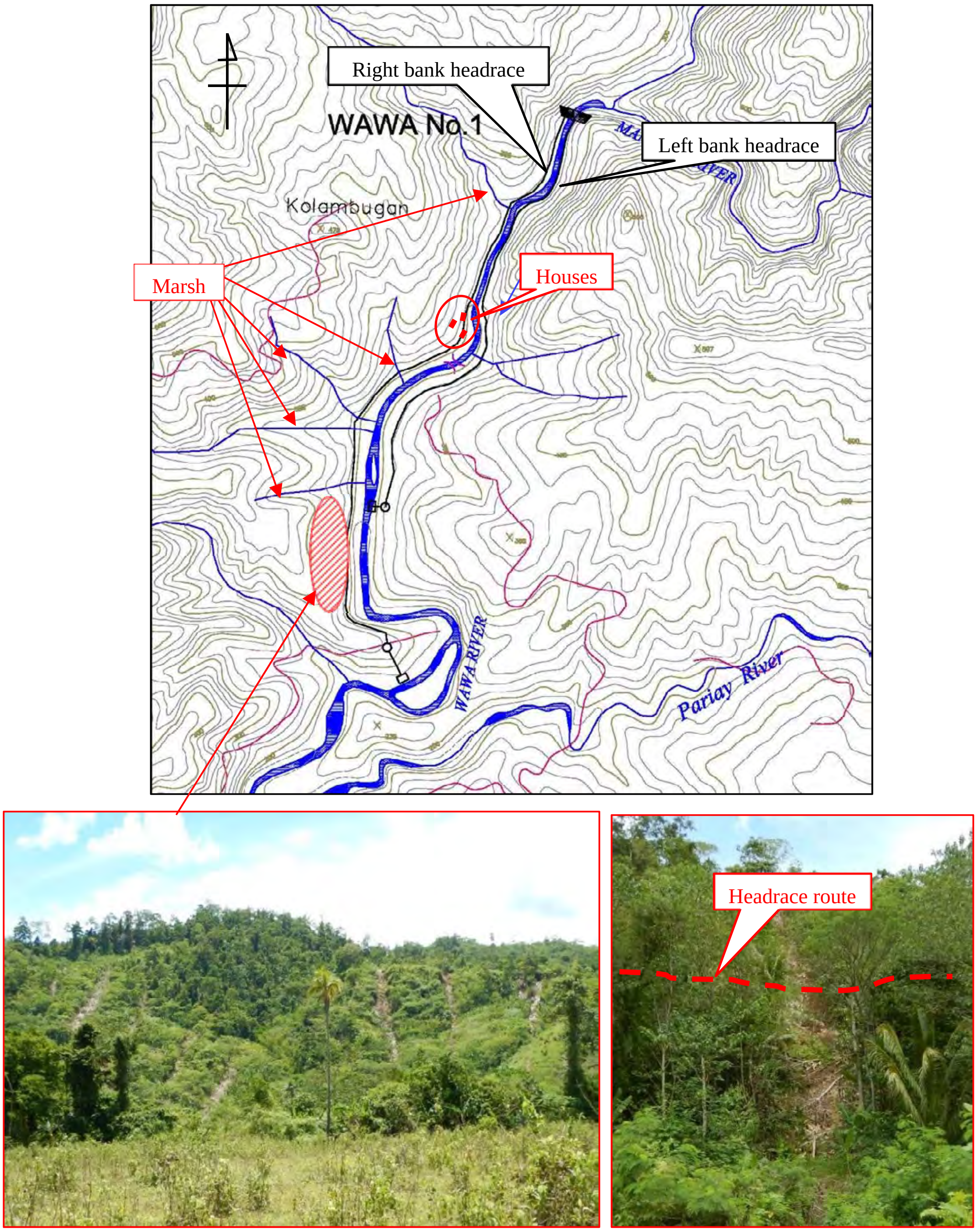


Fig. 5-6: Problems on the headrace route on the right bank of the Wawa River

(4) Powerhouse location

The following points were taken into account when considering the planned location of the powerhouse.

- It should be somewhere upstream of EL.225m because of the gradient of the Wawa River
- The powerhouse should be at the foot of a ridge suitable for building a penstock

On-site investigation found that a straight part of the Wawa River upstream from a wide bend to the left would be a suitable location for the powerhouse. This was therefore selected as a potential site. Downstream from this point the gradient of the river becomes shallower and, as the headrace would need to be built along the bend in the river, little head would be gained for the extra length of the headrace, which would render it uneconomical.

(5) Outline of proposed layout for Wawa No. 1

The proposed layout of the Wawa No. 1 powerhouse is shown in Fig. 5-7 and an outline of its features in Table 5-2.

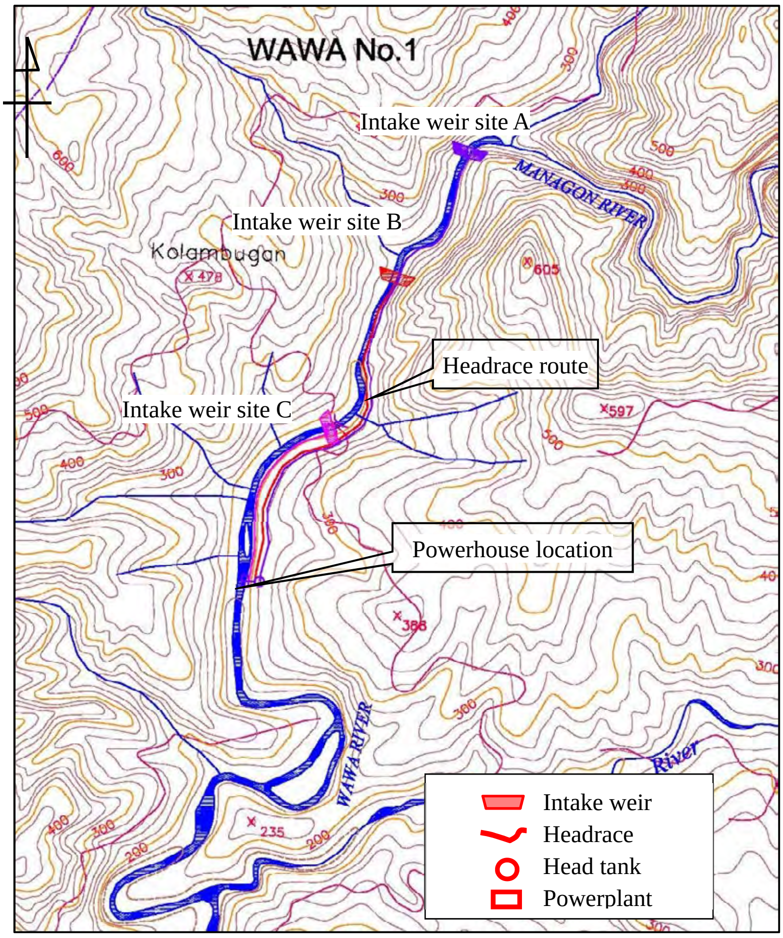


Fig. 5-7: Proposed layout for Wawa No. 1 power plant

Table 5-2: Outline of proposed layout for Wawa No. 1

Proposal		1	2	3
Intake weir		A	B	C
Catchment area	km^2	98.2	108.1	110.0
Intake water level	EL.m	267	255	245
Tailwater level	EL.m	231	231	231
Gross head	m	36.0	24.0	14.0
Lost head	m	5.5	3.7	2.5
Net head	m	30.5	20.3	11.5
Headrace route		Left bank	Left bank	Left bank
Length of headrace	m	3,500	2,800	1,750
Length of penstock	m	85	75	40
Remarks		Location of intake: downstream from junction with small tributary on right bank	Location of intake: from junction with small tributary on right bank	Location of intake: downstream from suspension bridge

5-2-2. Selection of optimum plan for power generation

(1) River flow data

As indicated in Chapter 4 Hydrological and Meteorological Survey, a river gauging station was set up on the Wawa River close to the planned location of Wawa No. 1, to take daily measurements of the water level and also monthly cross-sectional measurements of the river and measurements of the flow rate. The results of these observations were correlated with the results of river flow measurements made by the existing Bayugan river gauging station on the downstream part of the Wawa River. The correlation was used to produce river flow data for use in this project's generating plan, based on ten years of river flow data from Bayugan. Fig. 5-8 plots the curve for river flow at the Wawa River observation station derived from this analysis. The river flow at each location was derived by converting the data from Fig 5-8.

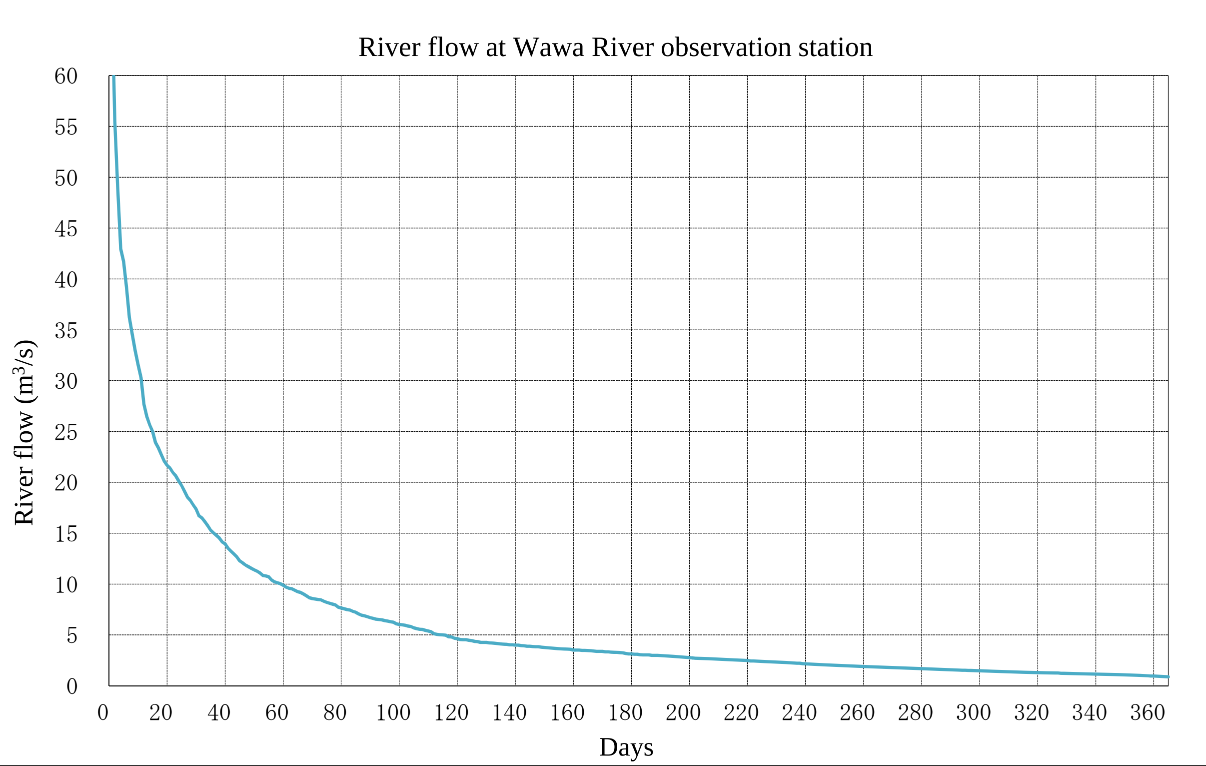


Fig. 5-8: Graph of river flow at the Wawa River observation station (Wawa River observation station)

(2) Methodology for estimating construction costs

To calculate estimated construction costs in order to select the optimum plan for power generation, construction costs were estimated in line with the "Guidelines for Estimating Construction Costs for Hydroelectric Projects" (Agency of Natural Resources and Energy, March 2013), and these were then adjusted for local construction prices using data on construction costs for the 8000kW Ashiga mini-hydroelectric project under construction by an EPCC company close to this project.

(3) Selection of optimum layout

The three proposed layouts for generating plants shown in Fig. 5-7 and Table 5-2 were compared, assuming each was developed on the same scale. The discharge assumed for this comparison was based on the flow duration curve for Wawa No. 1 (Fig. 5-9), using a discharge utilization factor of around 45%[2], which is often used to estimate the discharge by run-of-the-river generating plants.

[2]From "Guide Book for Medium and Small Hydro Power Generation (revised 5th edition)" (New Energy and Industrial Technology Development Organization)

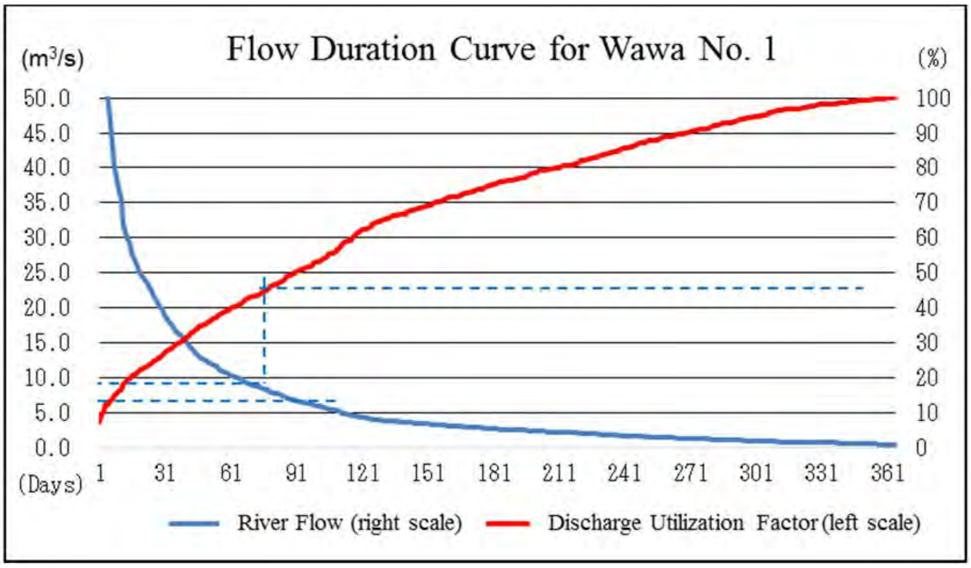


Fig. 5-9: Flow Duration Curve for Wawa No. 1

The results of the comparative analysis revealed that Case 1, in which the intake weir is constructed at position A, the furthest upstream of the candidate locations, would have the lowest construction costs per unit of power generated. As a result, Case 1 was selected as the optimal design for the plant. The results of the comparative analysis are shown in Table 5-3.

Table 5-3: Outline of proposed layout for Wawa No. 1

Proposal		1	2	3
Intake weir		A	B	C
Catchment area	km^2	98.2	108.1	110.0
Intake water level	EL.m	267	255	245
Tailwater level	EL.m	231	231	231
Gross head	m	36.0	24.0	14.0
Lost head	m	5.5	3.7	2.5
Net head	m	30.5	20.3	11.5
Headrace route		Weir height：5m Crest length：50m	Weir height：5m Crest length：50m	Weir height：5m Crest length：130m
Length of headrace	m	2,900	2,200	1,750
Length of penstock	m	85	75	40
Maximum discharge	m^3/s	8.0	8.0	8.0
Discharge utilization factor	%	46.9	49.6	50.2
Maximum output	kW	2,060	1,410	820
Generating energy	MWh/y	6,620	4,850	2,664
Construction costs	million pesos	943	851	694
Unit construction costs	pesos/kWh	142	175	242

5-2-3. Optimum scale

To find the optimum plant scale, construction costs were estimated per unit of power generated, assuming the maximum discharge was converted. It was found that unit construction costs were lowest with a discharge of 6.0-10.0m^3/s, based on a scale that provided a maximum discharge of 8.0m^3/s. The results of the calculation are shown in Table 5-4 and unit construction costs are shown in Fig. 5-10. The optimum scale within this range was found to be with a maximum discharge of Qmax = 10.0m^3/s, giving a maximum output of 2,580kW.

Table 5-4: Optimum plant scale for Wawa No. 1 plant

Proposal		1	2	3	4	5	6
Maximum discharge	m^3/s	4.0	6.0	8.0	10.0	12.0	14.0
Net head	m	30.5	30.5	30.5	30.5	30.5	30.5
Discharge utilization factor	%	68.1	55.2	46.9	40.7	36.1	32.4
Maximum output	kW	1,030	1,540	2,060	2,580	3,080	3,600
Generating energy	MWh	5,020	6,010	6,620	6,760	6,840	6,930
Construction costs	million pesos	816	882	943	993	1,109	1,210
Unit construction costs	pesos/kWh	163	147	142	147	162	175
Proposal selected					◎		

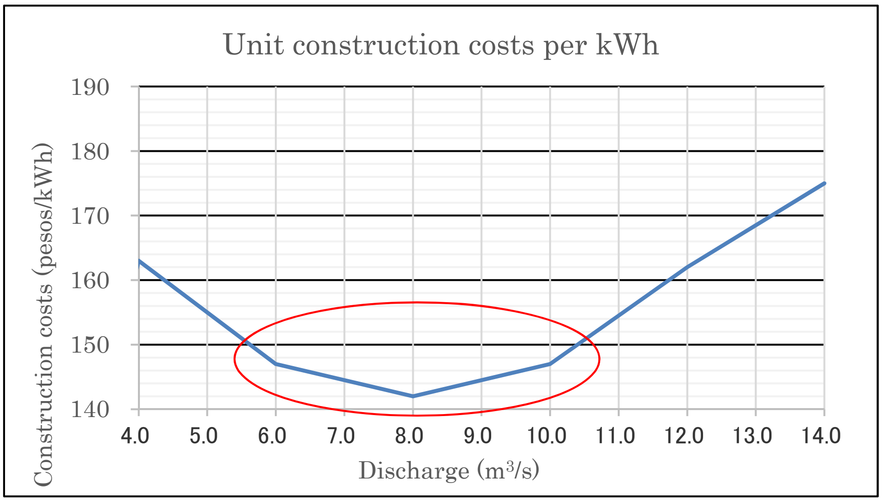


Fig. 5-10: Wawa No. 1 plant unit construction costs against plant scale

5-2-4. Basic design of generating plant

(1) Overview of plan for power generation

The intake for the Wawa No. 1 powerhouse will be just downstream from the confluence of the mainstream of the Wawa River with the Manangon River, and the powerhouse will be on the left bank of the Wawa River around 3km further downstream.

The catchment area of the intake is 98.2km^2 and the intake water level is EL.267m. The plan provides for a maximum intake of 10m^3/s to be taken from the left bank of the Wawa River and then drawn via a 2,818m-long open channel and an 84m-long tunnel into a head tank built at EL.264m on the slope of the left bank of the Wawa River, in order to generate power with a head of around 36m at a powerhouse to be built on the left bank of the Wawa River, before being discharged into the Wawa River at EL.231m.

The specifications for the power plant based on the basic design are shown in Table 5-5, and an overall map of the project is shown in Fig. 5-11. The basic plans of the main structures are also shown in the appendices of this study.

Table 5-5: Planned specifications for Wawa No. 1 plant

Overview of plan for power generation		
Powerhouse		Wawa No. 1
River	-	Wawa
Catchment area (at intake weir)	km^2	98.2
Type of generation	-	Run-of-the-river
Intake water level	EL.m	267.0
Tailwater level	EL.m	231.0
Gross head	m	36.0
Lost head	m	5.5
Net head	m	30.50
Maximum discharge	m^3/s	10.00
Maximum output	kW	2,580
Annual generating energy	kWh	6,763,704
Outline of construction		
Intake weir	m	Type: gravity Crest length: 50.0 (overflow only) Height: 5.0 Width: 15.0
Intake	m	Width: 5.0 x 2 Height: 3.0
Settling basin	m	Type: open single-tank Width: 12.0 Length: 42.4 Water depth: 5.0 (at deepest)
Headrace	m	(Open channel) Width: 2.5 Length: 2,818 (Non-pressure tunnel) Width: 2.5 Length: 84
Head tank	m	Type: open Width: 10.0 Length: 50.0 Water depth: 4.6 (at deepest)
Penstock	m	Type: Steel pipe above ground Diameter: φ2.0 Length: 72.6
Powerhouse	m	Type: Overground Width: 17.2 Length: 33.0 Height: 24.8 above ground; 9.0 below ground

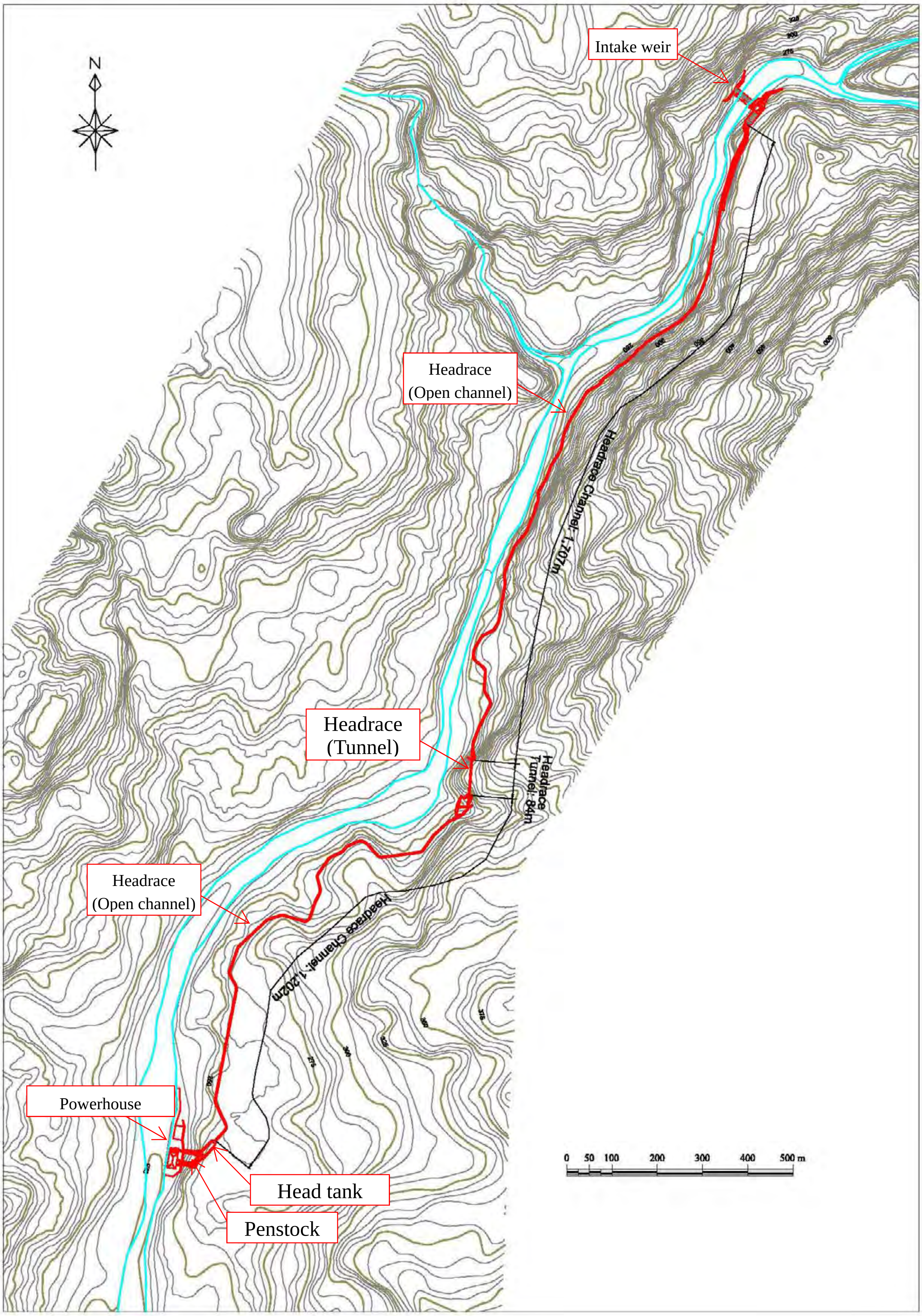


Fig. 5-11: Overall map of Wawa No. 1 plant

(2) Intake structures

1) Intake weir

After its confluence with the Manangon River, the Wawa River narrows to a width of around 15m, then makes a wide turn to the left before a straight section at a constant gradient. The site for the intake is on the straight section around 150m downstream from the junction of the Wawa and Manangon rivers, where the river is around 60m wide, allowing the intake structure to be built using the half river coffering construction method. Since both banks of the river slope at an angle of around 40 degrees, locating the intake and settling basin uphill from the riverbed would involve excavating a large volume of ground. Therefore, extending these structures around 12m into the riverbed avoided excavating a large part of the riverbank.

The full length of the intake weir up to the intake, which is adjacent to the left bank upstream from the weir, is 57.4m, of which 7.4m is the sand flushing gate and 50.0m the overflow. By allowing a planned flood discharge of 1,130m^3/s to overflow this weir crest (intake water level EL.267.0m) [3]the overflow reaches a depth of 5.0m, meaning the planned flood level is 272.0m.

A borehole survey found that around 7m of gravel was deposited on the riverbed. It was therefore decided that the intake weir should be a floating structure, built on the riverbed gravel. This allows a significant reduction in the excavation volume and the volume of concrete used, compared to an intake weir fixed to rock. The height of the intake weir is 5.0m, assuming an excavation depth of 1m at the site of the intake, where the riverbed is at EL.263m to EL.264m. It is a gravity type concrete weir that is sheer on the upstream side and has a slope of 1:0.8 on the downstream side, with a steel sand flushing gate on the left bank measuring 5.0m wide by 4.0m tall, with the cage crest at EL.274.0m. Immediately to the right of the sand flushing gate is a fishway 2.5m wide and 16.0m long with a gradient of 1:3, from the overflow crest to the surface of the river downstream.

2) Intake

The intake takes in 10.0m^3/s of water at an intake depth of 2.5m from bed height EL.264.5m, which is 2.5m higher than the sand flushing area at EL.262.0m in front of the intake. The inlet is 10.0m wide and 28.40m long. In front of it are two steel screens 5.0m wide and 3.5m tall with a gradient of 1:0.3 and a pitch of 45mm. Downstream from the screen supports, which have concrete slab crests at EL.268.0m, are two steel regulating gates 5.0m wide and 3.0m tall with cage crests at EL.274.0m. Behind the regulating gates is a reinforced concrete curtain wall, which prevents river water from flowing into the settling basin during flooding.

The intake is located around 12m into the riverbed away from the foot of the ridge in order to avoid the need to excavate large parts of the slope on the left bank. The foundations of the intake are therefore built by driving in an "artificial bedrock" made of boulders and lean-mix concrete, on which a reinforced concrete structure is built.

The left embankment, which joins onto the intake upstream, is a reinforced concrete buttress retaining

[3]Calculated from the traces of flooding (at EL.267.66m) found in cross-sectional measurements of the river close to the intake weir, using Manning's equation (channel gradient i = 1:85; roughness coefficient n = 0.05).

wall with its crest at EL.273.5m, allowing for an extra 1.5m above the flood level of EL.272.0m. It is 57m long with a gradient of 1:0.4 on the side facing the river.

3) Settling basin

The settling basin is a settling tank 34.0m long and with a head tank width of 12.0m, set immediately downstream from the intake. Its elevation varies by 2.0m from its start at riverbed height EL.264.5m to EL262.5m, it has a gradient of 1:12 and it has a 1.0m-wide sand flushing canal at the end. At the downstream end of the settling tank is an open levee 2.9m high as far as riverbed height EL.264.9m, which maintains a normal depth of 2.1m in the headrace that adjoins it downstream. At the riverside outlet of the sand flushing canal at EL.262.0m is a steel sand flushing gate 1.0m wide and 1.5m high.

For 6.0m in the reduced section up to the open levee and the headrace inlet is a concrete slab with a crest at EL.268.0m, and at the upstream end is a steel screen 12.0m wide and 3.1m tall with a gradient of 1:0.3 and a pitch of 40mm.

As there is no bedrock around this reduced section, an "artificial bedrock" made of boulders and lean-mix concrete is installed, on which a reinforced concrete structure is built.

(3) Headrace

The headrace for the Wawa No. 1 plant is planned as an open channel on the left bank of the Wawa River. The cross section of the open channel is 2.5m wide on the inside and 2.5m high and it feeds $10m^3/s$ of intake water along a gradient of 1:1,000 at a normal depth of 2.07m.

At a point 1,707m from the start of the headrace its way is blocked by a cliff of what is likely to be at least CM class rock, which extremely difficult for it to pass through in an open water channel. The plan is therefore for the headrace to pass through an 84m-long tunnel. In cross section the tunnel is semicircular at the top and rectangular at the bottom and it is a non-pressure tunnel 2.5m wide and 2.6m high, minimizing changes in profile at the junction with the open water channel.

The total length of the headrace from the settling basin to the head tank is 2,902m.

(4) Head tank

The head tank is located on the slope of the left bank around 3km downstream from the intake, and it is a structure 50.0m long and 10m wide, starting at the end of the headrace at riverbed EL.269.1m.
It is connected by a 6.0m-long flaring section that widens from a width of 2.5m at the tunnel exit to a width of 10m at the head tank, and the bottom of the settling tank that comes after it has a chute at a gradient of 1:17, which drops 2m from EL.261.9m to EL.259.9m. At the end of the settling tank is a 1m-wide sand flushing canal, which flushes sand at the left-side opening from a steel sand flushing gate 1.0m wide and 1.5m high into a waste water pipe.
Downstream from the sand flushing canal is an open levee 3.1m high as far as EL.262.5m. The open levee has a concrete slab with a crest at EL.265.0m, and in front is a steel screen 10.0m wide and 2.5m high with a gradient of 1:0.3 and a pitch of 40mm. The downstream side of the open levee is dug in to a channel bed elevation of EL.258.0m and forms a penstock with an internal diameter of 2.0m.

The right wall of the head tank has a 33.0m-long side weir, and the overflow is fed to an energy dissipater located beside the powerhouse, via a 1.6m-bore steel pipe fitted to the downstream end of the head tank.

The effective capacity of the head tank from the lowest water level that does not cause air entrainment in the penstock at the end of the head tank when the water level falls (EL.262.50m) to the crest of the overflow levee (EL.264.00m) is around 969m^3, which is equivalent to around 1'37" of capacity at maximum discharge.

(5) Routes of the penstock and spillway

The penstock route is a single 2.0m-bore penstock connecting the head tank to the powerhouse, and the spillway route is a single 1.6m-bore steel pipe fixed to the right-hand side of the penstock facing downstream towards the upstream side of the powerhouse. At the end is an impact-type energy dissipater located next to the powerhouse.

These routes run along the slope of the left bank of the Wawa River. The penstock runs horizontally up to point IP-P1, which is 23m horizontally from its starting point, and along the central axis of the head tank, and then turns right towards point IP-P2, where it forks into 1.2m-bore pipes before being joined to the turbine in the powerhouse. It covers a horizontal distance of 60.5m and has an oblique length of 72.58m.

The pipe is laid on reinforced concrete anchor blocks at each IP point and supported by a concrete saddle in each interval between anchor blocks, with expansion pipes located immediately downstream from the anchor blocks.

(6) Powerhouse and tailrace channel

The site of the powerhouse was judged suitable because the riverbed of the Wawa River slopes at a stable and shallow gradient at this point, and the river level does not fluctuate a lot during flooding because the river is wide and opens out a long way on the right bank.

Given the riverbed level of EL.230.0m at this point, the tailwater level was set at EL.231.0m and, as the planned flood level at the location of the powerhouse site is EL.235.0m, the site of the powerhouse was set at EL.236.0m

The internal dimensions of the powerhouse are 33.0m lengthwise and 17.2m across. It has two horizontal axis Francis turbines with a capacity of 1,350kW each, the centre level of the turbines being at EL.234.6m. These discharge the water used to generate power directly into the Wawa River from a tailrace bay/channel 3.0m wide, 4.0m to 2.0m high and 8.0m long, at a rate of 5.00m^3/s from each turbine. The control room is located on the ground and upper floors above the tailrace bay.

(7) Turbine generator

1) Basic specifications

The basic specifications used to select the turbine generator are shown below.

Table 5-6: Basic specifications for Wawa No. 1 plant

Criterion	Wawa No. 1 Plant
Intake water level	EL. 267.00m
Turbine centre level	EL. 234.60m
Gross head H	EL. 36.00m
Net head He	30.50m
Maximum discharge Qmax (total)	10.0m^3/s

2) Selecting the type of turbine

Generally, the net head and maximum discharge suggest that a mini hydroelectric plant on the scale of this project would be likely to have one or two generating units. In terms of the capacity of the generating unit, a single unit would be quite adequate, but this would mean that, whenever it shut down because of a fault or for regular inspections, generation would stop. Using two units has the advantage that, even if one unit shuts down, the plant can continue generating power with the other unit. Switching between single-unit and two-unit operation depending on the intake volume, which changes according to the river flow, also allows power to be generated at a wider range of flows and increases the availability of the generating units, with the result that the volume of energy generated is higher than with a single unit. It was therefore decided to use two generating units in this project.

There are various types of turbine for mini hydroelectric plants, but generally the following types have the best performance, depending on the net head and discharge, and are widely used.

- Propeller turbine: Low head, large discharge
- Francis turbine: Low head to high head, small to medium discharge
- Pelton turbine: High head, small discharge

Each type of turbine can be either vertical or horizontal, the choice being determined by factors such as the scale of the powerhouse and the location. In general, a horizontal turbine allows the powerhouse structure to be simpler than a vertical turbine, as the generating unit is installed on the same floor as the turbine, which makes it easier to assemble, disassemble, maintain and overhaul the generating unit It also requires a smaller excavation volume during construction of the powerhouse, which allows construction costs to be reduced. Once the powerhouse reaches a certain size, more space will be needed if a horizontal turbine/generating unit is used, and so a greater volume will need to be excavated from the slope of the ridge in order to provide a location for the powerhouse. Using a vertical turbine/generating unit and so reducing the area of the powerhouse therefore allows a reduction in the overall excavation volume.

In terms of scale, Wawa No. 1 is suitable for a horizontal turbine/generating unit. The basic specifications for the Wawa mini-hydroelectric plant and the type of turbine are shown in the table below. These were selected for the reasons discussed above and based on the selection chart shown in Fig. 5-12.

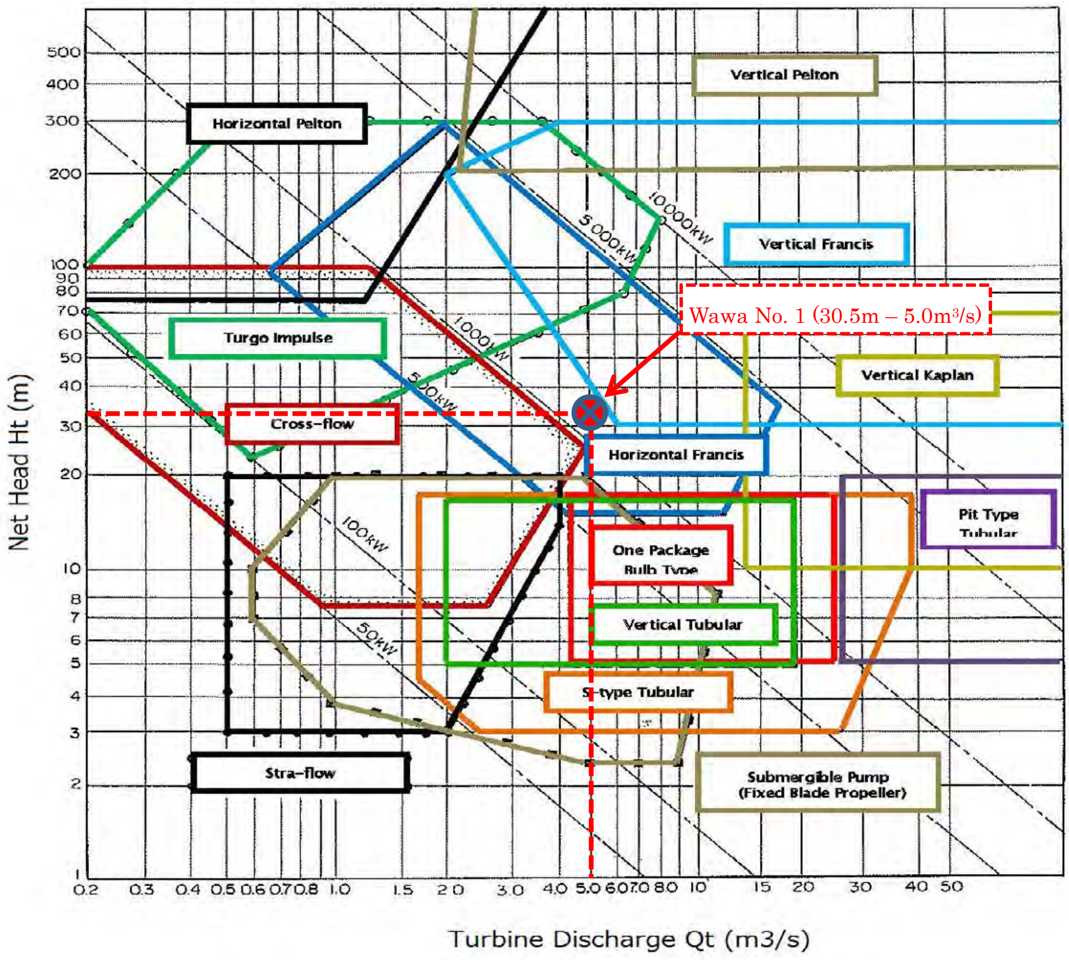


Fig. 5-12: Selection chart for type of hydraulic turbine

Source: "Guide Book for Medium and Small Hydro Power Generation" (New Energy and Industrial Technology Development Organization) edited by the Investigation Team

Table 5-7: Basic specifications and type of hydraulic turbine

Criterion	Wawa No. 1 Plant
Number of turbines	2
Net head	30.50m
Maximum discharge (per turbine)	5.0m^3/s
Type of turbine	Horizontal Francis turbines

3) Determining rating of the turbine/generating unit

The rating of the turbine for the Wawa No. 1 plant was determined as follows, based on the basic specifications shown in Table 5-7:

a) Turbine output Pt

Turbine output is calculated from the formula:

$$Pt = 9.8 \times Qt \times He \times \eta t [kw]$$
$$= 9.8 \times 5.0 \times 30.5 \times 0.91$$

$= 1,360[kW]$

where $Qt = 5.0[m^3/s]$ (discharge per turbine)

$He = 30.5[m]$ (net head)

$\eta t = 0.91$ (estimated turbine efficiency at 100% output)

b) Rated speed N

Hydraulic turbines are regulated by their specific speed (ns), which is derived by an equation using turbine output (Pt), net head (He) and rotational speed (N).

$$ns=N\cdot\frac{\sqrt{Pt}}{He^{1.25}} \ [m\text{-}kW]$$

$$N=ns\cdot\frac{He^{1.25}}{\sqrt{Pt}} \ [min^{-1}]$$

where $Qt = 5.0[m^3/s]$ (discharge per turbine)

$He = 30.5[m]$ (net head)

$Pt = 1,360[kW]$ (turbine's maximum output)

The empirical equation below, given in the standards published by the Japanese Electrotechnical Committee ("JEC"), also provides a yardstick for the specific speed of Francis turbines based on net head.

$$ns\leq \frac{23,000}{He+30}+40 \ [m\text{-}kW]$$

$$ns\leq \frac{23,000}{30.5+30}+40 = 420.2 \ [m\text{-}kW]$$

The relationship of the turbine's synchronous speed N to its specific speed ns at 60Hz, which is the frequency used in the Philippines, is shown in Table 5-8.

Table 5-8: Relationship of synchronous speed to turbine's specific speed

Synchronous speed N (min^{-1})	Number of poles p	Specific speed of turbine ns (m-kW)
600	12	308.7
514	14	264.5
450	16	231.5

By increasing the rotational speed of the generating unit, it is possible to reduce its size, which is economical. Since the yardstick for the turbine's specific speed is ns = 420.2m-kw, a rated speed N of $600min^{-1}$ can be used, but with a Francis turbine increasing speed makes it necessary to ensure the correct turbine setting level (suction head). Therefore, based on the calculation of the turbine setting level explained below, the optimum rated speed N appears to be $450min^{-1}$ or $514min^{-1}$.

c) Turbine setting level

In order to avoid cavitation in Francis turbines, which are a type of reaction hydraulic turbine, it is vital to consider the suction head that will be adequate for the water level in the tailrace channel during operation (the position of the turbine centre level in relation to the minimum water level in the tailrace channel during operation). If the speed of the turbine is increased the generating unit will be compact, which makes it economical, but the suction head will be smaller, which sometimes makes it necessary to lower the position of the levelling work for the powerhouse, thus increasing the excavation volume. Based on the riverbed elevation of the Wawa River, which is the discharge river for the Wawa No. 1 plant, on the construction height of the powerhouse and on Table 5-9, it was decided that the suction head would be Hs = 3.6m and the turbine centre level (turbine setting level) EL.234.6m.

Table 5-9: Relationship of speed to suction head

Rated speed N (min^{-1})	Suction head Hs (m)
450	3.0 to 3.6
514	2.0 to 2.5
600	0.0 to 0.5

d) Generator output Pg

The output of the generating unit is determined by the formula:

$$Pg = \frac{Pt \cdot \eta g}{pf} \text{ [kVA]}$$

$$= \frac{1{,}360 \cdot 0.95}{0.80}$$

$$= 1{,}615\text{[kVA]} \rightarrow 1{,}700\text{[kVA]}$$

where Pt = 1,360[kW] (turbine's maximum output)

ηg = 0.95 (estimated generator efficiency at 100% output)

pf = 0.80 (Generator power factor)

e) Generator rated voltage

The relationship of generator output to rated voltage is shown in Fig. 5-13, based on a report of the Institute of Electrical Engineers Japan ("IEEJ").

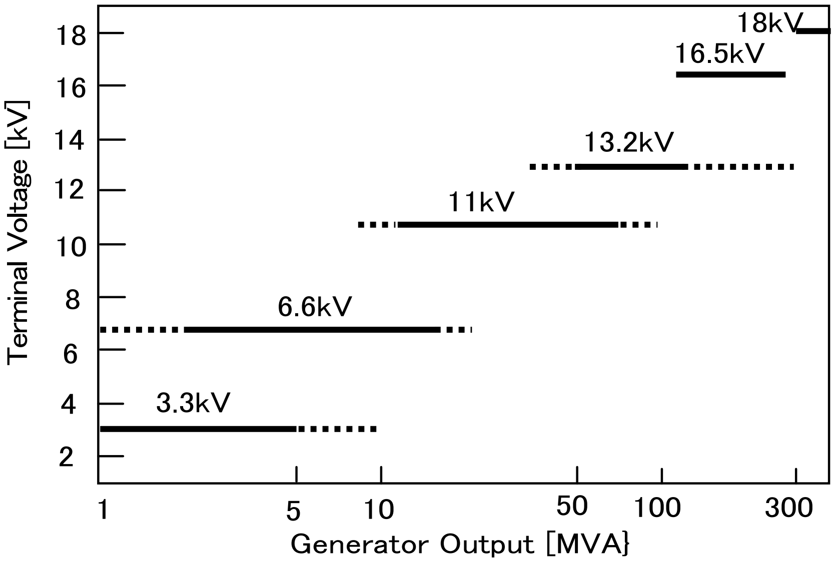


Fig. 5-13: Relationship of generator output to rated voltage

Source: IEEJ

For generators with output not exceeding 10MVA, a rated voltage of 3.3kV or 6.6kV is generally used. The Wawa No. 1 plant will use a generator rated voltage of 6.6kV in order to reduce loss by the generator and allow the main transformer to be compact by setting the rated voltage as high as possible

f) Specifications and components of generating equipment

The specifications and components of the turbine and major auxiliary mechanical equipment are shown in Table 5-10, and those of the generator and major auxiliary electrical equipment in Table 5-11.

Table 5-10: Specifications and components of turbine and major auxiliary mechanical equipment

No.	Equipment	Specifications	Remarks
(1)	Turbine		
	Type of turbine	Horizontal Francis turbines	
	Net head	30.50m	
	Maximum discharge	$5.0m^3/s$	per turbine
	Maximum output	1,360kW	per turbine
	Rated speed	$450min^{-1}$	
	Specific speed of turbines	231.5m-kW	
(2)	Turbine inlet valve		
	Type of inlet valve	Thru-flow valve	
	Nominal diameter	1,000 to 1,200mm	
	Operating method	Pressure oil operation	Same as guide vane
(3)	Governor system		
	Type of governor	Digital PID	
	Operating method	Bladder type pressure oil operation	For operating guide vane/inlet valve
(4)	Main cooling water supply system	Type of cooling water pump	For cooling generating unit
(5)	Powerhouse overhead travelling crane		

Table 5-11 Specifications and components of generator and major auxiliary electrical equipment

No	Equipment	Specifications	Remarks
(1)	Generator		
	Type of generator	Horizontal type synchronous generator	
	Rated output	1,700kVA	per turbine
	Power factor	0.80	
	Rated voltage	6.6kV	
	Frequency	60Hz	
	Rated speed	$450min^{-1}$	
(2)	Excitation system	Brushless	
(3)	Neutral point grounding device		
(4)	Control and protection system		
(5)	Powerhouse power equipment		Including batteries and diesel generators
(6)	Main transformer		
	Type of main transformer	External air-cooled	
	Rated capacity	1,700kVA	per turbine
	Rated voltage	6.6/13.2kV	
	Frequency	60Hz	
(7)	Outdoor switchgear equipment		

g) Single line diagram

The main electrical equipment for the powerhouse will comprise the No. 1 and No. 2 generation units cantered on a 13.2kV bus line, a transformer for power in the powerhouse, and metal-enclosed switchgear connected to the transmission line. The components of the main electrical equipment are shown in the form of a single line diagram in Fig. 5-14.

The power generated by the generating unit is boosted by a main transformer connected in series, connected to the bus line with a circuit breaker in between, and transmitted to the transmission line. Some of it will be stepped down by the powerhouse power transformer to provide electricity for use in the powerhouse. When the generating unit is shut down, power will be received from the transmission line via the bus line to provide electricity in the powerhouse. If both the generating unit and the transmission line are shut down, an emergency diesel generator will provide electricity for use in the powerhouse.

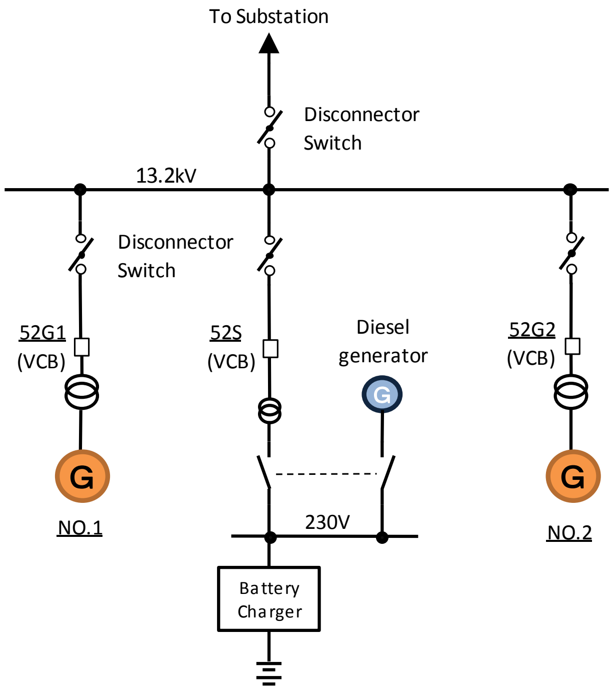


Fig. 5-14: Single line diagram

5-2-5. Calculation of maximum output and generating energy

The maximum output and annual generating energy were calculated using the specifications derived from the basic design for the generating system and the river flow at the location of the intake weir for the Wawa No. 1 plant. The calculations produced generating output of 2,580kW and annual generating energy of 6,764MWh. Table 5-12 shows the efficiency of the turbines, generators and transformers, and Table 5-13 the generating output for typical flows.

Table 5-12: Efficiency of turbines, generators and transformers

Percentage of maximum discharge	%	100	90	80	70	60	50	46
Discharge per unit	m^3/s	5.0	4.5	4.0	3.5	3.0	2.5	2.3
Turbine efficiency ηg	%	91.2	88.8	86.4	83.3	78.9	66.7	60.0
Generator efficiency ηg	%	95.7	95.5	95.1	94.6	94.0	92.4	91.5
Transformer efficiency ηg	%	99.0						

Table 5-13 Generating output during typical flows

River flow %	River flow at Wawa River No.1 intake weir	The amount of water used (m3/s)		Turbine efficiency ηg		Generator efficiency ηt		Transformer efficiency η tr		Output P (kW)	
		Turbine No. 1	Turbine No. 2	Turbine No. 1	Turbine No. 2	Turbine No. 1	Turbine No. 2	Turbine No. 1	Turbine No. 2	Turbine No. 1	Turbine No. 2
Maximum river flow	61.22	5.00	5.00	0.912	0.912	0.957	0.957	0.99	0.99	1291.0	1291.0
10	13.34	5.00	5.00	0.912	0.912	0.957	0.957	0.99	0.99	1291.0	1291.0
20	7.63	5.00	2.33	0.912	0.617	0.957	0.917	0.99	0.99	1291.0	390.0
30	4.86	4.56	0.00	0.890	0.000	0.955	0.000	0.99	0.99	1147.0	0.0
40	3.48	3.18	0.00	0.808	0.000	0.942	0.000	0.99	0.99	716.0	0.0
50	2.75	2.45	0.00	0.650	0.000	0.922	0.000	0.99	0.99	434.0	0.0
60	2.26	1.96	0.00	0.000	0.000	0.000	0.000	0.99	0.99	0.0	0.0
70	1.76	1.46	0.00	0.000	0.000	0.000	0.000	0.99	0.99	0.0	0.0
80	1.40	1.10	0.00	0.000	0.000	0.000	0.000	0.99	0.99	0.0	0.0
90	1.10	0.80	0.00	0.000	0.000	0.000	0.000	0.99	0.99	0.0	0.0
100	0.79	0.49	0.00	0.000	0.000	0.000	0.000	0.99	0.99	0.0	0.0
*Deduct the river maintainance flow amout 0.3 m3/s from the river flow.							ΣP 356 days			199,269	82,552
							Annual amount of power generated ΣE 356 days (kWh)			6,763,704	

5-3 Wawa No. 2 Mini-hydroelectric Plant

5-3-1. Layout of generating plant

(1) Location of development on the Wawa and Manangon rivers

The study of the Wawa No. 2 plant looked at sites #2 and #3 in the initial plan, comparing proposals for stand-alone developments at each site with a proposal to develop both sites as a single, combined power plant.

In the initial plan, both sites were planned for fast flowing stretches of river with a gradient of around 1:25, site #2 on the Wawa River and site #3 on the Manangon River. They are therefore likely to result in high head generation projects with an efficient head. Consequently it was decided to consider the area shown in Fig. 5-15 for possible plans in this study, as in the existing plan.

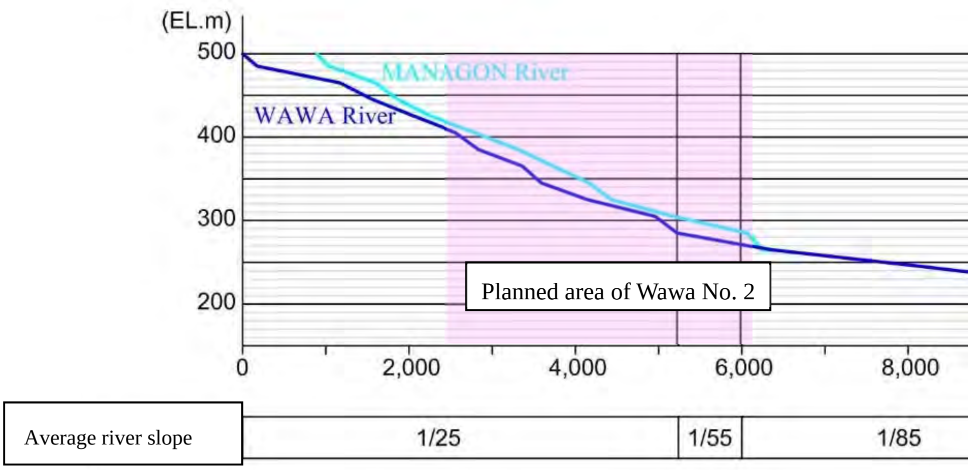


Fig. 5-15: Area considered for Wawa No. 2 plant

(2) Location of the intake weir

The same approach was taken in choosing the location of the intake weir as was used to choose the location of the intake weir for Wawa No. 1. Fig. 5-16 is a map showing the location of sites for the intake weir.

① Wawa River intake weir

The upstream part of the Wawa River has only a limited number of sites suitable for the installation of an intake weir, as a lot of it has sheer cliffs on both sides. The location selected from these as intake weir site #2 in the initial plan is a location where the river banks widen slightly in a straight section of river downstream from the confluence with a small tributary (unnamed) that flows into the left bank of the Wawa River.

② Manangon River intake weir

The upstream part of the Manangon River has only a limited number of sites suitable for the installation of an intake weir, as a lot of it has sheer cliffs on both sides. The location selected from these as intake weir site #3 in the initial plan is a location where the river banks widen slightly downstream from the confluence with a small tributary (unnamed) that flows into the left bank of the Manangon River.

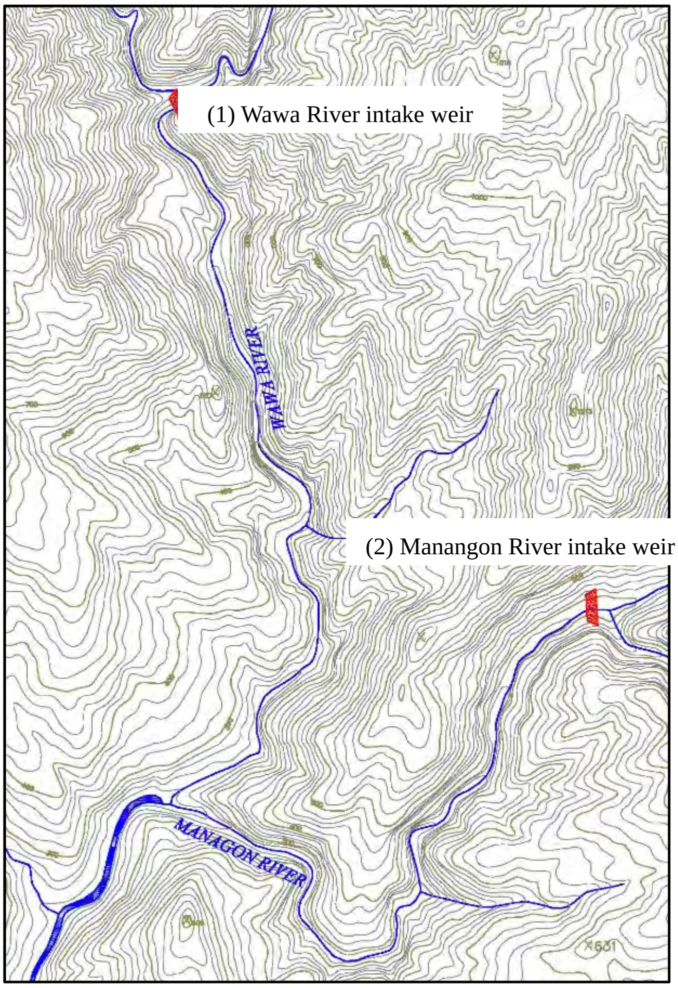


Fig. 5-16: Potential sites for Wawa No. 2 intake weir

(3) Headrace route

① Headrace route from Wawa River intake weir

Both banks of the river slope at a very sharp gradient, with sheer cliffs on a steep gradient of more than 50 degrees in many places. The initial plan provided for exposed steel pipes above ground on steep slopes, but not only does this sort of terrain make it very difficult to plan a headrace route above ground from the intake weir to the powerhouse for reasons of construction, but it is easy to foresee that maintenance after it is built will require a lot of cost and effort. It is therefore reasonable to make the headrace into a tunnel.

The headrace route from the Wawa River intake weir could conceivably run along either the right bank or the left bank. As either route would require a tunnel, the selected route will need at least 50m covered.

② Headrace route from Manangon River intake weir

Like the upper Wawa River, the Manangon River has sheer cliffs on its banks and it would be very difficult, in terms of construction, to build a headrace along the contour of the intake water level. As the Manangon River bends dramatically to the right, feeding water through a tunnel on the right bank in a straight line to the head tank enables the route to make a short cut past the bend.

③ Headrace route for the combined proposal

A route was considered for a combined proposal, which would combine river water taken from intakes on the Wawa and Manangon rivers in a headrace and feed it to a single powerhouse. Among the potential sites for the powerhouse described below, a route was selected to a site on the right bank of the Manangon River, which would provide a higher head.

(4) Site of powerhouse

① Wawa River

Considering penstock routes on the upper Wawa River for a headrace routed along either the right bank or left bank of the river, the terrain dictates that there are only a limited number of places where the powerhouse could be built. Both banks of the Wawa River have a succession of sections that rise into sheer cliffs, and so there are no suitable sites other than powerhouse site #2 in the initial plan. Consequently, both banks of the Wawa River close to EL.325m were chosen as potential sites for the powerhouse.

② Manangon River

The site for the powerhouse is on the right bank of the Manangon River, because a headrace route from the Manangon River intake weir is only feasible on the right bank. While it would be preferable to locate the powerhouse where it would obtain the maximum head, the location of site A for the Wawa No. 1 intake weir close to the junction of the Wawa and Manangon rivers means that the powerhouse needs to be built at a height that avoids any impact from their backwater.

As a result of a desk-based study using relief maps as well as local inspections, it was decided to locate the penstock on a ridge facing the junction with the Wawa River and to build the powerhouse close to EL.275m, around 250m upstream from the confluence.

(5) Outline of proposed layout for Wawa No. 2

The proposed layout of the Wawa No. 2 powerhouse is shown in Fig. 5-17 and an outline of its features in Table 5-14.

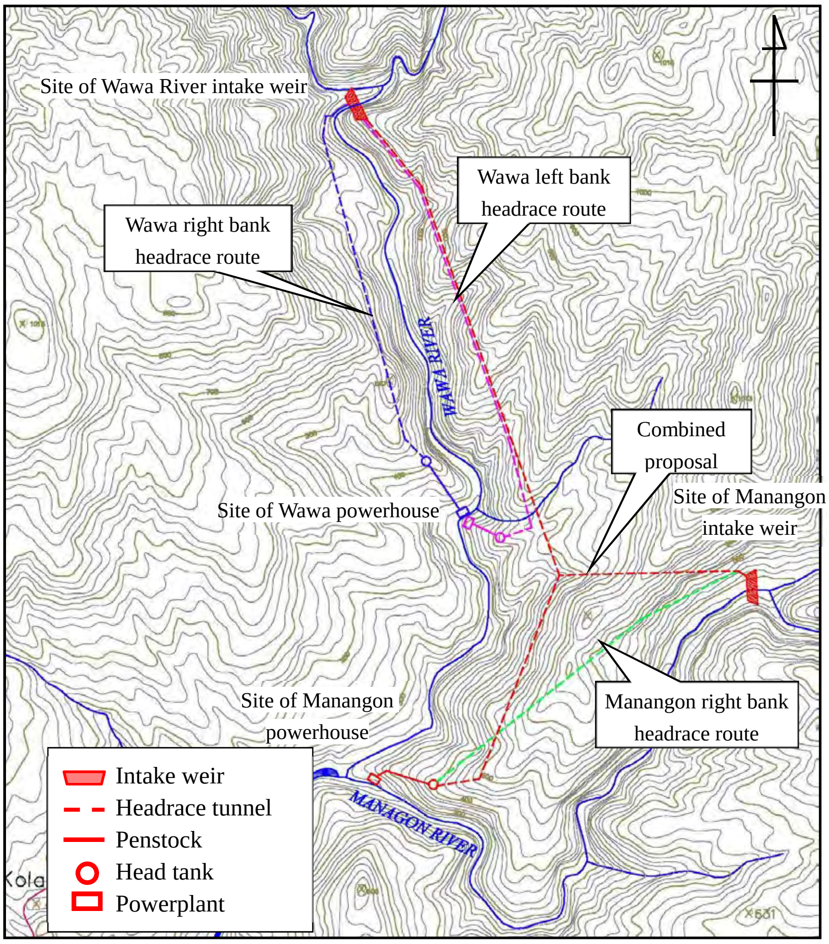


Fig. 5-17: Proposed layout for Wawa No. 2 power plant

Table 5-14: Outline of proposed layout for Wawa No. 2

Proposal		1	2	3	4
Powerhouse		Wawa River		Manangon River	
Headrace route		Right bank of Wawa River	Left bank of Wawa River	Right bank of Manangon River	Left bank of Wawa River and right bank of Manangon River
Catchment area	km^2	35.2	35.2	43.5	78.4
Intake water level	EL.m	440	440	440	440
Tailwater level	EL.m	325	325	275	275
Gross head	m	115	115	165	165
Lost head	m	4.9	4.6	4.4	9.5
Net head	m	110.1	110.4	161.8	155.5
Intake weir		Weir height: 6m Crest length: 50m	Weir height: 6m Crest length: 50m	Weir height: 5m Crest length: 40m	Wawa and Manangon intake weirs
Length of headrace	m	2,280	2,970	2,530	5,640
Length of penstock	m	410	215	420	420

5-3-2. Selection of optimum plan for power generation

(1) River flow data

As for the study of the Wawa No. 1 powerhouse, the flow duration curve for the site of the Wawa River gauging station (Fig. 5-8) was converted for the catchment area and used for this study (Fig. 5-18 and Fig. 5-19).

(2) Methodology for estimating construction costs

The methodology was the same as for the Wawa No. 1 powerhouse.

(3) Selection of optimum layout

Estimated construction costs and annual generating energy were calculated for the same scale of development in each of the proposals shown in Table 5-14 and the proposal offering the lowest estimated construction costs per kWh was chosen as the optimum layout. As for the study of the Wawa No. 1 powerhouse, the discharge used for the comparison was based on a discharge utilization factor of around 45% using the flow duration curves for the Wawa River and Manangon River intake weirs (Fig. 5-18 and Fig. 5-19).

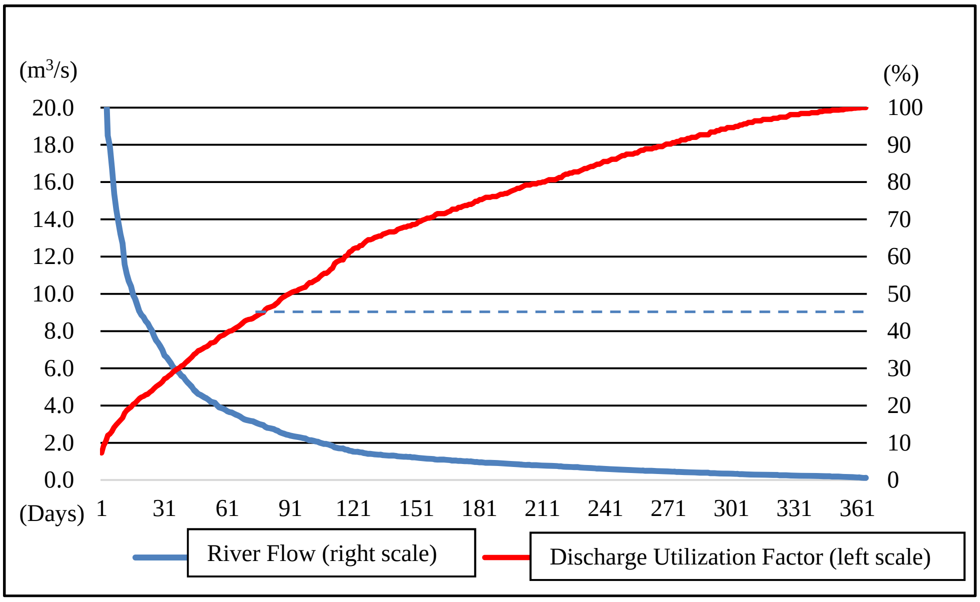


Fig. 5-18: Flow duration curve converted for Wawa intake weir

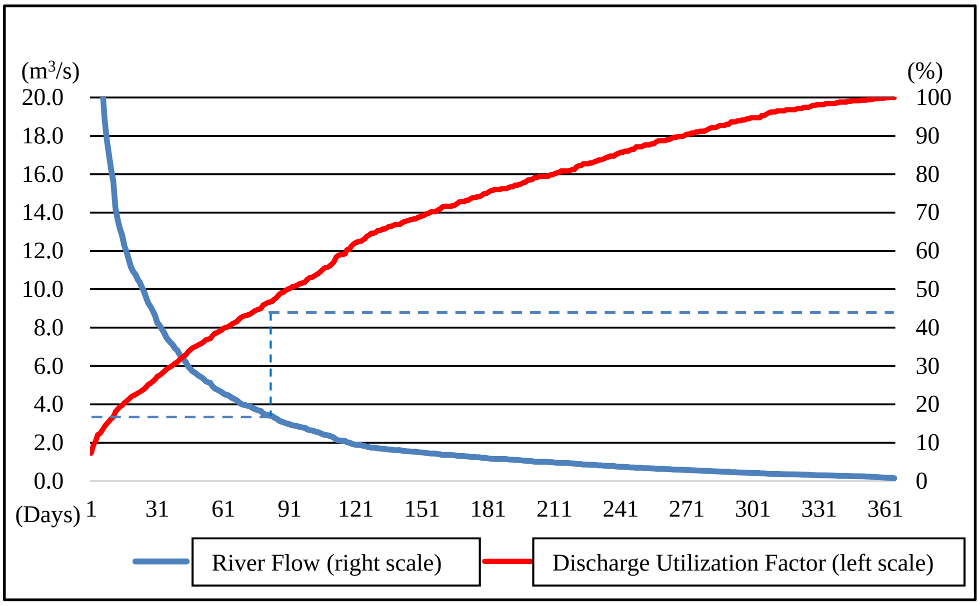


Fig. 5-19: Flow duration curve converted for Manangon River intake weir

The comparison found that unit construction costs for stand-alone development of Wawa No. 2 would be lower for the right bank proposal than for the left bank proposal. It also found that, if both Wawa No. 2 and Wawa No. 3 were developed, it would be cheaper to develop them as a combined project rather than developing two powerhouses as separate projects. This study gave preference to the scale of the plant resulting from the development and so used the joint development proposal (proposal 4). The results of the study for each proposal are shown in Table 5-15.

Table 5-15: Comparison of layouts for Wawa No. 2

Proposal		1	2	3	4	[For reference]
Powerhouse		Wawa River		Manangon River		Assuming stand-alone development of Wawa and Manangon Rivers
Headrace route		Right bank of Wawa River	Left bank of Wawa River	Right bank of Manangon River	Combined proposal: left bank of Wawa and right bank of Manangon	
Catchment area	km^2	35.2	35.2	43.5	78.7	
Intake water level	EL.m	440	440	440	440	
Tailwater level	EL.m	325	325	273	273	
Gross head	m	115	115	167	167	
Lost head	m	4.9	4.6	5.2	11.5	
Net head	m	110.1	110.4	161.8	155.5	
Intake weir		Weir height: 6m Crest length: 50m	Weir height: 6m Crest length: 50m	Weir height: 5m Crest length: 40m	Wawa and Manangon intake weirs	
Length of headrace	m	2,280	2,970	2,530	5,640	
Length of penstock	m	410	215	420	420	
Maximum discharge	m^3/s	3.0	3.0	3.7	3.0 + 3.7	
Discharge utilization factor	%	45.0	45.0	45.0	45.0	
Maximum output	kW	2,800	2,800	5,200	9,000	8,000
Annual generating energy	MWh/y	8,570	8,590	17,300	30,000	25,870
Construction costs	million pesos	1,264	1,339	1,205	2,149	2,469
Construction costs per kWh	pesos/kWh	147	156	70	72	95

5-3-3. Optimum scale

To find the optimum plant scale for Proposal 4 (combined proposal for the Wawa and Manangon rivers), construction costs were estimated per unit of power generated, assuming the maximum discharge was converted. It was found that unit construction costs were lowest for a maximum discharge of around Qmax = 5.6-7.6m^3/s. The results of the calculation are shown in Table 5-16 and unit construction costs are shown in Fig. 5-20. The optimum scale within this range was found to be with a maximum discharge of Qmax = 7.6m^3/s, giving a maximum output of 10,200kW.

Table 5-16: Optimum plant scale for Wawa No. 2 plant

Proposal		1	2	3	4	5
Maximum discharge	m^3/s	4.4	5.6	6.7	7.6	10.5
Discharge utilization factor	%	55	50	45	40	35
Maximum output	kW	5,900	7,500	9,000	10,200	14,100
Generating energy	MWh	26,500	29,100	30,000	30,800	32,500
Construction costs	million pesos	2057	2101	2149	2167	2665
Unit construction costs	pesos/kWh	77.6	72.2	71.6	71.6	82.0
Proposal selected					◎	

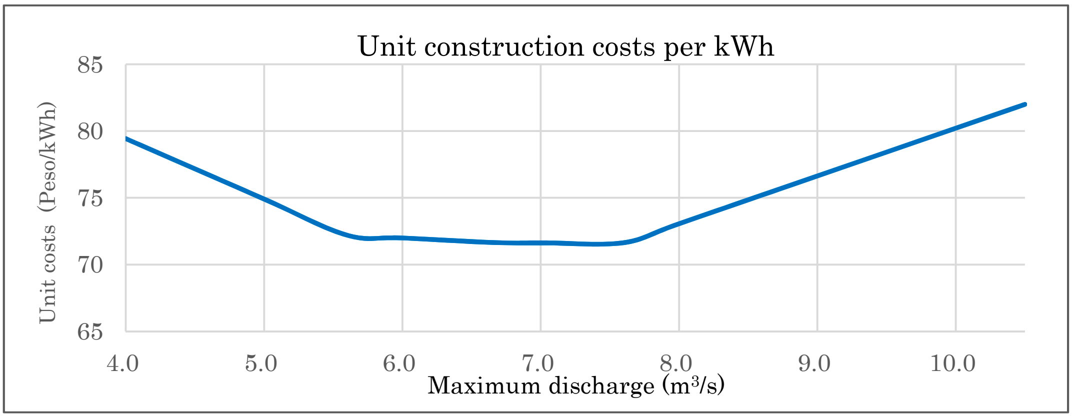


Fig. 5-20: Wawa No. 1 plant unit construction costs against plant scale

5-3-4. Basic design of generating plant

(1) Overview of plan for power generation

Two sites were chosen for the intake for the Wawa No. 2 powerhouse, on the main stream of the Wawa River and on the Manangon River where it joins the left bank of the lower Wawa River, and the site of the powerhouse is on the right bank of the Manangon River close to the confluence of the two rivers.

The catchment area of the intake site on the main stream of the Wawa River is 35.2km^2 and the intake water level is EL.440m. A maximum intake of 3.4m^3/s is taken from the left bank before being fed into the hillside on the left bank of the Wawa River through tunnel No. 1, which is around 3,112m long.

The catchment area of the intake site on the Manangon River is 43.5km^2 and the intake water level is EL.438m. A maximum intake of 4.2m^3/s is taken from the right bank before being fed into the hillside on the right bank of the Manangon River through tunnel No. 2, which is around 1,068m long and joined with tunnel No. 1. After the intakes are combined, they are fed through tunnel No. 3, which is around 1,456m long, to a head tank close to EL.435m on the ridge between the two rivers, from where a head of around 162m is obtained to generate power at a powerhouse on the right bank close to the junction of the Wawa and Manangon rivers, before the water is discharged into the Manangon River at EL.273m.

The specifications for the power plant based on the basic design are shown in Table 5-17, and an overall map of the project is shown in Fig. 5-12. The basic plans of the main structures are also shown in the appendices of this study.

Table 5-17 Wawa No. 2 Powerhouse Plan Specifications

<table>
<tr><th colspan="4">Overview of Powerhouse Plans</th></tr>
<tr><td colspan="2">Powerhouse Name</td><td colspan="2">Wawa No. 2</td></tr>
<tr><td>River Name</td><td>–</td><td colspan="2">Wawa River, Manangon River</td></tr>
<tr><td>Catchment area (at intake weir)</td><td>km^2</td><td colspan="2">Wawa River : 35.2
Manangon River: 43.5</td></tr>
<tr><td>Power generation method</td><td>–</td><td colspan="2">Run-of-river method</td></tr>
<tr><td>Intake water level</td><td>EL.m</td><td colspan="2">Wawa River : 440.0
Manangon River: 438.0</td></tr>
<tr><td>Tailwater level</td><td>EL.m</td><td colspan="2">273.0</td></tr>
<tr><td>Gross head</td><td>m</td><td colspan="2">167.0</td></tr>
<tr><td>Head loss</td><td>m</td><td colspan="2">11.5</td></tr>
<tr><td>Net head</td><td>m</td><td colspan="2">155.5</td></tr>
<tr><td>Maximum discharge</td><td>m^3/s</td><td colspan="2">7.60
(Wawa River intake weir : 3.40)
(Manangon River intake weir: 4.20)</td></tr>
<tr><td>Maximum output</td><td>kW</td><td colspan="2">10,200</td></tr>
<tr><td>Annual generating energy</td><td>kWh</td><td colspan="2">30,823,608</td></tr>
<tr><th colspan="4">Overview of facilities</th></tr>
<tr><td>Intake weir</td><td></td><td>Wawa River
Type: Gravity type
Crest length: 33.0
Height: 9.0
Width: 20.0</td><td>Manangon River
Type: Gravity type
Crest length: 35.0
Height: 6.0
Width: 15.0</td></tr>
<tr><td>Intake</td><td>m</td><td>Wawa River
Width: 4.0
Height: 2.5</td><td>Manangon River
Width: 5.0
Height: 2.5</td></tr>
<tr><td>Settling basin</td><td>m</td><td>Wawa River
Width: 10.0
Extension: 44.0
Water depth: 3.5</td><td>Manangon River
Width: 10.0
Extension: 44.0
Water depth: 3.5</td></tr>
<tr><td>Headrace</td><td>m</td><td colspan="2">[Non-pressure tunnel]
Width: 1.9m
Extension:
・ Tunnel No. 1 (Wawa River intake weir – junction) : 3112.2
・ Tunnel No. 2 (Manangon River intake weir – junction) : 1068.3
・ Tunnel No. 3 (junction – head tank) : 1456.2</td></tr>
<tr><td>Head tank</td><td>m</td><td colspan="2">Type: Open
Width: 10.0
Extension: 50.0
Water depth: 2.98</td></tr>
<tr><td>Penstock</td><td>m</td><td colspan="2">Type: Steel pipe overground installation
Pipe diameter: φ1.5
Extension: 417.0</td></tr>
</table>

Powerhouse	m	Type: Overground Width: 19.0 Length: 30.0 Height: overground 11.7, underground 12.0

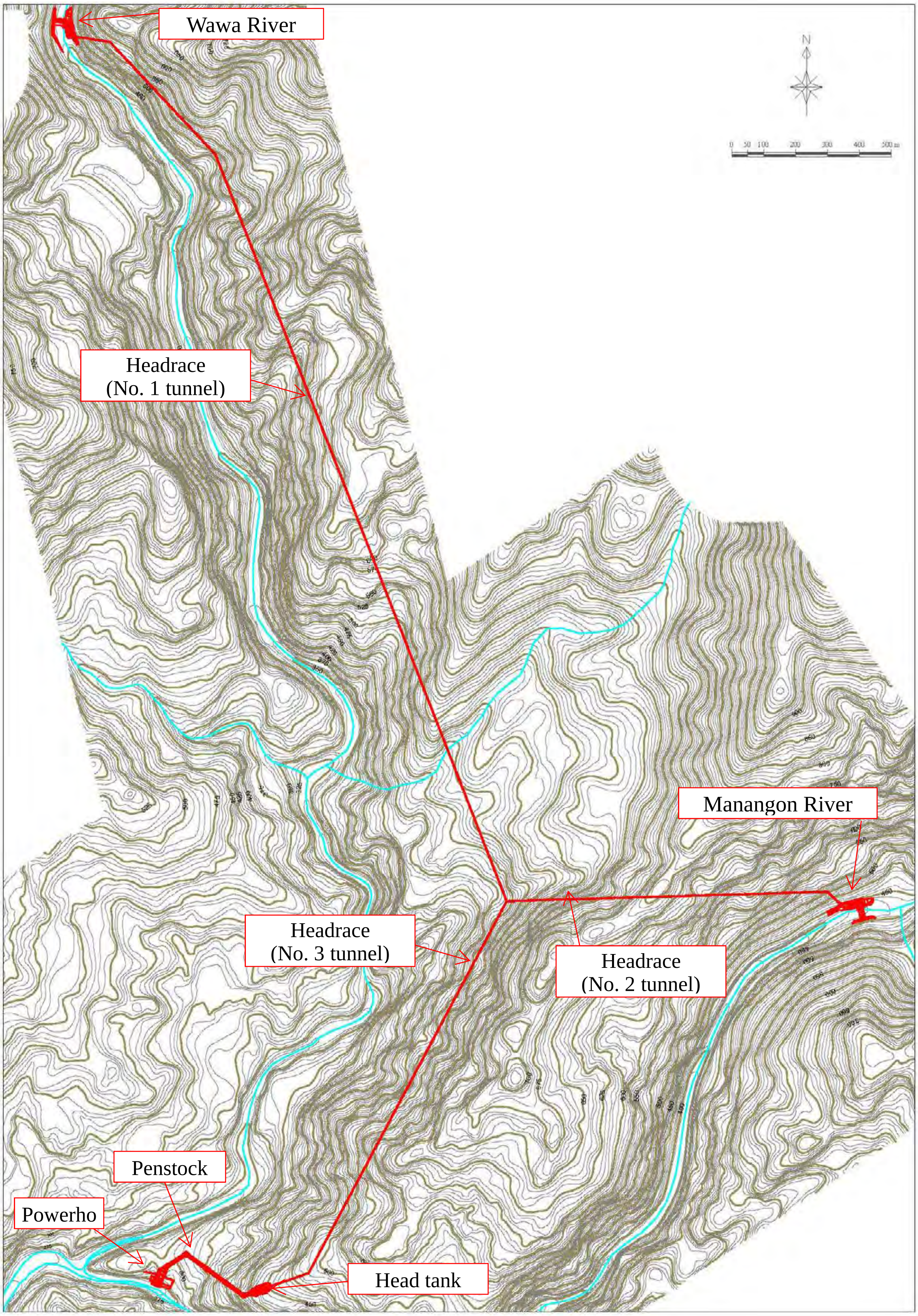


Fig. 5-21 Overall Plan of Wawa No. 2 Powerhouse

(2) Wawa River intake structures

1) Intake weir

The width of the river at the intake location is about 40-50m, which is appropriate for building the intake structures using the half river coffering construction method. The nearby left bank slope is about 45 degrees, and since the excavation volume would be enormous if an intake/settling basin of about 15m in width were to be installed at the foot of the mountain, lengthy excavation of the slope was avoided by projecting these structures about 10m inside the riverbed.

The total length of the intake weir up to the intake adjoining the intake weir upstream left bank is 38.4m, comprising sand flushing gate section 5.4m and overflow section 33.0m. If a designed flood discharge of 625m^3/s is caused to overflow at this weir crest (intake water level EL.440.0m), the overflow water depth would be 4.5m and the designed flood level EL.444.5m.

The intake weir height is 9.0m, assuming an excavation depth of 2m to the bedrock line at river level EL. 433m at the water intake point. It is a "gravity type concrete weir" with a vertical upstream face, downstream face with a gradient of 1:0.8, equipped with one steel sand flushing gate 3.0m in width/4.0m in height on the left bank, EL. 446.0m at gate lifting slub. It is provided with a fishway along the right bank of the flushing gate, from the overflow crest to the downstream river surface, with width 2.5m/gradient 1:3/length 26.5m.

2) Intake

The intake draws in water at a depth of 2.0m at 3.40m^3/s from a site altitude of EL.438.0m, 5.0m higher than the flushing channel at the front face of the intake (EL.433.0m), with an inflow width of 4.0m and length of 13.59m. The front face is provided with one steel screen of width 4.0m/height 3.0m/gradient 1:0.3/pitch 45mm. One steel regulating gate is provided with width 4.0m/height 2.5m/cage crest EL.446.0m downstream of the screen base at concrete slab top end EL.441.0m. A steel reinforced concrete curtain wall extends up behind the regulating gate, preventing the inflow of river water to the settling basin in the event of flood.

In order to avoid large-scale excavation on the left bank slope, the intake is positioned about 10m from the foot of the mountain inside the riverbed. For this reason, the intake foundation will be constructed by first laying an "artificial rock bed" from boulders and lean-mix concrete, and then building a steel reinforced concrete structure on top of this.

The left bank revetment extending upstream of the intake will be a steel reinforced concrete buttressed retaining wall with its crown at EL.446.0m, 1.5m higher than the flood level of EL.444.5m, extending 44m with a gradient of 1:0.4 on the river side.

3) Settling basin

The settling basin is installed downstream of and directly connecting to the intake, with an elevation difference of 3.0m from its starting point at a site altitude of EL.438.0m to EL.435.0m, and a gradient of 1:9, with a 1.0m-wide sand flushing ditch at the tip. It is a settling tank with a length of 28.0m and tank width of 10.0m. At the downstream end of the settling tank, a submerged weir is provided with a height of 3.8m up to a site altitude of EL.438.8m, ensuring a uniform flow depth of 1.21m in tunnel

No. 1 continuing downstream. At the sand flushing ditch river side outlet at a site altitude of EL.434.0m, one steel sand flushing gate is provided with width 1.0m/height 1.5m.

A concrete slab is provided at EL.441.0m at the reducer section 8.0m up to the submerged weir section and entrance of tunnel No. 1, and one steel screen of width 10.0m/height 2.2m/gradient 1:0.3/pitch 40mm is provided at the upstream end.

As the area around this reducer section has no bedrock, it will be constructed by first laying an "artificial rock bed" from boulders and lean-mix concrete, and then building a steel reinforced concrete structure on top of this.

(3) Manangon River intake structures

1) Intake weir

The width of the river at the intake location is about 50-60m, which is sufficient for building the intake structures using the half river coffering construction method. The neighboring right bank slope is about 60 degrees, and since the excavation volume would be enormous if an intake/settling basin of about 15m in width were to be installed at the foot of the mountain, a lengthy excavation of the slope will be avoided by projecting these structures about 10m inside the riverbed.

The total length of the intake weir, excluding the 15.5m intake section adjoining the upstream right bank is 40.4m, comprising sand flushing gate section 5.4m and overflow section 35.0m. If a designed flood discharge of 515m^3/s is caused to overflow at this weir crest (intake water level EL.438.0m), the overflow water depth would be 3.5m and the designed flood level EL.442.0m.

The intake weir height is 6.0m, assuming an excavation depth of 2m to the bedrock line at river level EL. 434m at the water intake point. It is a "gravity type concrete weir" with a vertical upstream face, downstream face with a gradient of 1:0.8, equipped with one steel sand flushing gate 3.0m in width/4.0m in height on the left bank, EL. 444.0m at cage crest, and a fishway along the left bank of the flushing gate, from the overflow crest to the downstream river surface, with width 2.5m/gradient 1:3/length 19.0m.

2) Intake

The intake draws in water at a depth of 2.5m at 4.20m^3/s from a site altitude of EL.436.0m, 2.0m higher than the flushing bay at the front face of the intake (EL.434.0m), with an inflow width of 5.0m and length of 17.85m. The front face is provided with one steel screen of width 5.0m/height 3.0m/gradient 1:0.3/pitch 45mm. One steel regulating gate is provided with width 5.0m/height 2.5m/cage crest EL.444.0m downstream of the screen base at concrete slab top end EL.439.0m. A steel reinforced concrete curtain wall extends up behind this regulating gate, preventing the inflow of river water to the settling basin in the event of flood.

In order to avoid large-scale excavation on the right bank slope, the intake is to be positioned about 10m from the foot of the mountain inside the riverbed. As there is bedrock in this area, an "artificial rock bed" is unlikely to be necessary.

The right bank revetment extending upstream of the intake will be a steel reinforced concrete retaining wall with its crown at EL.444.0m, 2.0m higher than the flood level of EL.442.0m, extending

38m with a gradient of 1:0.4 on the river side.

3) Settling basin

The settling basin is installed downstream of and directly connecting to the intake, with an elevation difference of 3.0m from its starting point at a site altitude of EL.436.0m to EL.433.0m, and a gradient of 1:9, with a 1.0m-wide sand flushing ditch at the tip. It is a settling tank with a length of 28.0m and inflow width of 10.0m. At the downstream end of the settling tank, a submerged weir is provided with a height of 3.6m up to a site altitude of EL.436.6m, ensuring a uniform flow depth of 1.42m in tunnel No. 2 continuing downstream. At the sand flushing ditch river side outlet at a site altitude of EL.432.0m, one steel sand flushing gate is provided with width 1.0m/height 1.5m.

A concrete slab is provided at EL.439.0m at the reducer section 8.0m up to the submerged weir section and entrance of tunnel No. 2, and one steel screen of width 10.0m/height 2.4m/gradient 1:0.3/pitch 40mm is provided at the upstream end.

As the area around this reducer section has no bedrock, it will be constructed by first laying an "artificial rock bed" from boulders and lean-mix concrete, and then building a steel reinforced concrete structure on top of this.

(4) Headrace

The headrace at the Wawa No. 2 powerhouse has been planned as a tunnel. Aqueduct tunnels with a small discharge cross section generally employ a "hood-type" cross section, semi-circular at the top and rectangular at the bottom, and a concrete jacketing hood-type is also used in this location. The dimensions are 1.90m width at the inner cross section (the smallest constructed cross section), 2.30m height, and 0.20m concrete lining thickness.

① Tunnel No. 1: 3,112m from Wawa River intake point to junction at unnamed valley.
Intake water volume of 3.40 m^3/s is caused to flow in at a bed gradient of 1:1,000, uniform flow depth of 1.21m.

② Tunnel No. 2: 1,068m from Manangon River intake point to junction at unnamed valley.
Intake water volume of 4.20 m^3/s is caused to flow in at a bed gradient of 1:1,000, uniform flow depth of 1.42m.

③ Tunnel No. 3: 1,456m from junction to head tank.
To construct for a maximum discharge from both intake points until after the junction of 7.60m^3/s, in the same cross section, the bed gradient is a rather sharp 1:600, and uniform flow depth is 1.94m.

The flow characteristic curves for these three tunnels are shown in Figure 5-22.

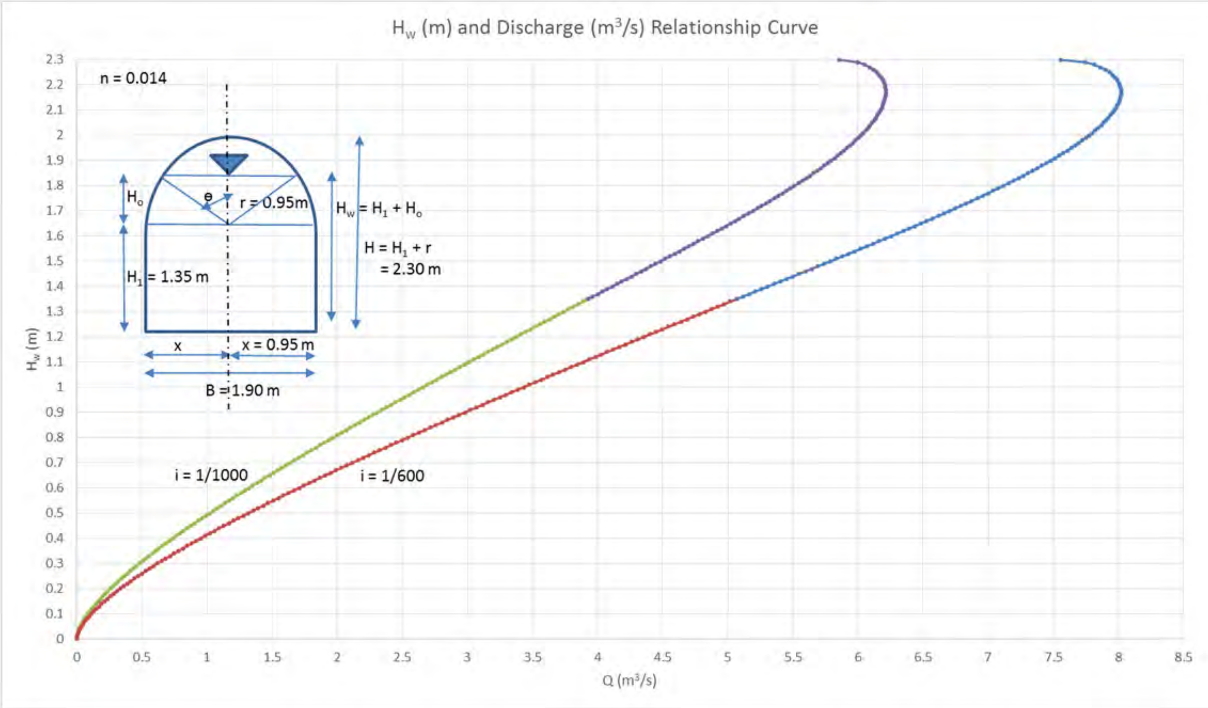


Fig. 5-22 Wawa No. 2 Headrace Tunnel Flow Characteristic Curves

(5)Head tank

The head tank is a structure positioned about 4km downstream from the Wawa River intake point, at the far mountainside of the ridge sandwiched by the Manangon River flowing in from the left bank, starting at a site altitude of EL.432.52m at the end of Tunnel No. 3 with a length of 50.0m/width of 10m.

Connected by a 6.0m-long flaring section broadening from the 1.9m-wide tunnel exit to the 10m-wide head tank, at the settling tank a bed slope is provided with a falling gradient of 1:17, from a site altitude of EL.432.52m to EL.430.32m (height differential of 2m). At the end of the settling tank, a 1m-wide sand flushing ditch is provided, and sand is flushed from a 1.0m-wide/1.5m-high steel sand flushing gate at the left-side opening to a surplus water pipe outlet.

Downstream of the sand flushing ditch, a 1m-high submerged weir is provided up to a site altitude of EL.431.5m. At the submerged weir section, a concrete slab is laid with its top end at EL.435.5m, one steel screen of width 10.0m/height 4.0m/gradient 1:0.3/pitch 40mm is provided at the front face, the downstream side of the submerged weir section is excavated up to a site altitude of EL.428.25m, becoming a penstock outlet with an internal diameter of 1.5m.

A 28.0m-long side-overflow weir is provided on the left wall of the head tank, and surplus water is taken via side-overflow through a surplus water steel pipe with an inner diameter of 1.2m installed at the downstream tip of the head tank, to an energy dissipater located beside the powerhouse building.

The effective capacity of the head tank, from the minimum water level (EL.431.50m) at which air entrainment does not occur at the penstock inlet at the tip of the head tank when the water level falls, to the overflow spillway crest height (EL.434.46m), is approx. 1,237m^3, which equates to approx. 2 min. 40 sec. volume of the maximum discharge.

(6) Penstock route and spillway

The penstock route comprises a single penstock pipe with an inner diameter of 1.5m connecting the head tank to the powerhouse, and the spillway comprises a single steel pipe of 1.2m diameter alongside the penstock pipe, with a center-to-center distance of 2.3m, and at the end an impact-type energy dissipater is located adjacent to the powerhouse building.

For these pipes, linear pipes are selected that pass through the ridge "horseback", from the starting point at a horizontal distance of 30m to the right of point IP-P2, 253m to the left of IP-P5, and 351m to IP-P7, curving to the left here with anchor blocks installed. They are penstock pipes with a horizontal distance of 377.5m and sloped length of 417.7m. At the end of the penstock, there is a Y-junction at point IP-P8 8.5m upstream/10.07m sloped length from the peripheral wall of the powerhouse building, with an inner diameter of 0.9m, joining with the hydraulic turbine.

Between the anchor blocks, concrete supporting tables are located at 8-9m intervals to support the steel pipes, and immediately downstream of the anchor blocks an expansion pipe is installed.

(7) Powerhouse and tailrace channel

The powerhouse is located about 250m upstream of the junction of the Wawa River and Manangon River, and is also separated from a waterfall about 150m upstream. The riverbed gradient is stable and the river is wide, and as there is relatively flat land on the right bank side, the site was deemed to be suitable.

From the river level at EL.272.5m at this point, the tailwater level is EL.273.0m, and taking into consideration a designed flood discharge of 575 m^3/s at the powerhouse location, EL.280.0m was decided for the powerhouse leveled ground surface.

The powerhouse has internal dimensions of length 28.0m and width 10.5m. It is equipped with two vertical axis Francis turbines at a turbine central height of EL.275.0m and single unit capacity of 5,100kW; the generated used water volume of 3.80m^3/s/unit is discharged directly into the Manangon River from the forebay/tailrace channel (width 3.0m/height 5.5m-1.5m/length 8.5m). Control rooms are located above the forebay, under- and aboveground.

(8) Hydraulic turbine generator

1) Basic data

The basic power generation data for selection of the hydraulic turbine generator is shown below.

Table 5-18 Wawa No. 1 Powerhouse Basic Specifications

Item	Wawa No. 1 Powerhouse
Intake water level	EL. 440.00m
Turbine center level	EL. 275.00m
Gross head H	EL. 167.00m
Net head He	155.50m
Maximum discharge Qmax	7.6m^3/s

2) Selection of type of hydraulic turbine

Based on the planned net head and maximum discharge, either one or two generators could be envisaged for the Wawa No. 2 powerhouse, but as with the Wawa No. 1 powerhouse, it was decided to use two generators in order to enhance generation availability in the event of equipment malfunction and routine maintenance, or in the case of low river flow rate.

The type of hydraulic turbine was selected based on Figure 5-23. Taking into consideration the overall excavation volume for the powerhouse, a vertical turbine generating unit was chosen.

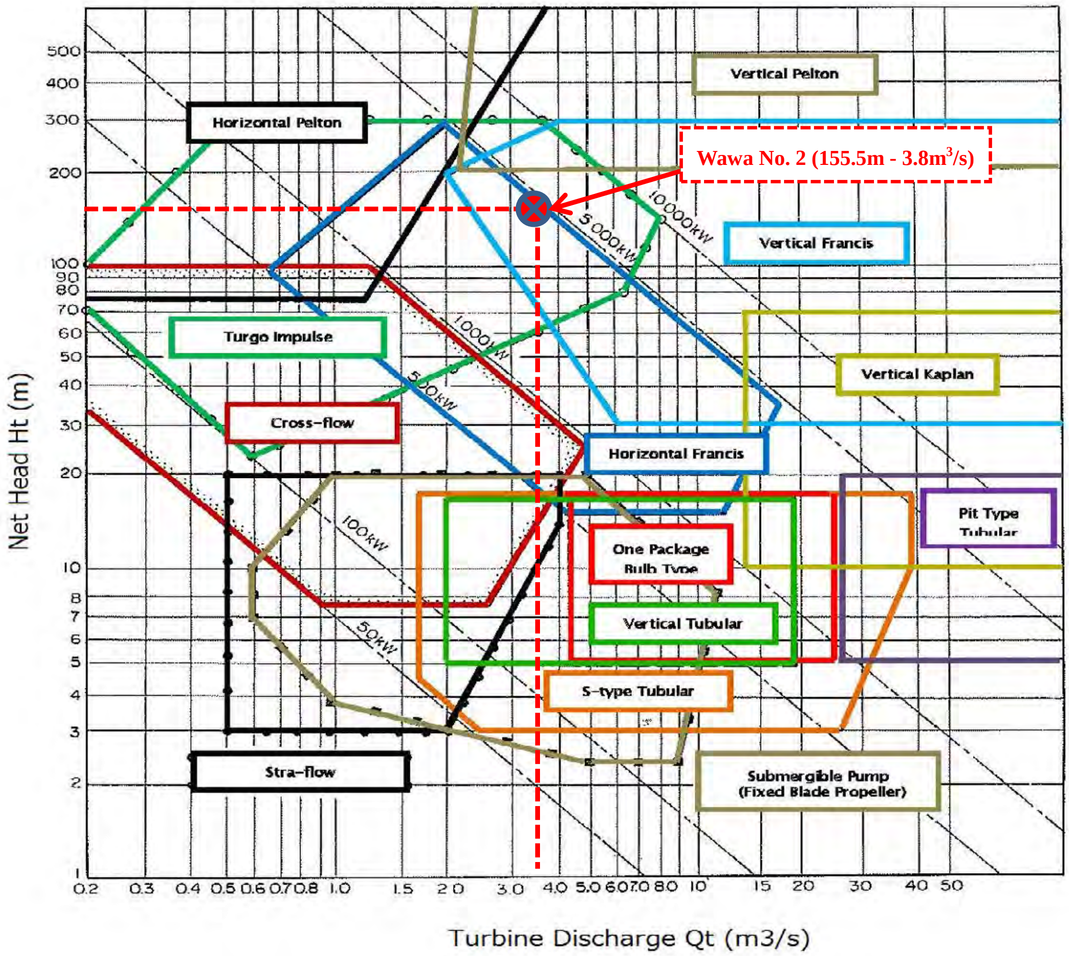


Fig. 5-23 Selection of type of hydraulic turbine

Source: Compiled by the investigation team based on Guide Book for Medium and Small Hydro Power Generation (New Energy and Industrial Technology Development Organization)

Table 5-19 Basic specifications, type of hydraulic turbine

Item	Wawa No. 2 Powerhouse
Qty	2 units
Net head	155.10m
Maximum discharge (per unit)	$3.8m^3/s$
Type of hydraulic turbine	Vertical Francis turbine

3) Determination of turbine/generator rated capacity

Based on the basic turbine specifications in Table 5-19, the rated capacity for the Wawa No. 2 powerhouse turbine was determined as follows.

a) Turbine output Pt

The turbine output was calculated using the following outline formula.

$Pt = 9.8 \times Qt \times He \times \eta t$ [kw]

$= 9.8 \times 3.8 \times 155.5 \times 0.925$

$= 5{,}357$[kW] → 5,350[kW]

Here, $Qt = 3.8[m^3/s]$ (flow per unit)

$He = 155.5[m]$ (net head)

$\eta t = 0.925$ (envisaged turbine efficiency at 100% output)

b) Rated speed N

A relational expression is applied to the hydraulic turbine for specific speed ns, comprising turbine output (Pt), net head (He) and rotating speed (N).

$ns = N \cdot \frac{\sqrt{Pt}}{He^{1.25}}$ [m-kW]

$N = ns \cdot \frac{He^{1.25}}{\sqrt{Pt}}$ $[min^{-1}]$

Here, $Qt = 3.8\ [m^3/s]$ (flow per unit)

$He = 155.5$ [m] (net head)

$Pt = 5{,}350$ [kW] (turbine maximum output)

Regarding the Francis turbine, based on net head the guideline specific speed is derived from the empirical formula set out in the guidelines of the Japanese Electrotechnical Committee (below, "JEC").

$ns \leq \frac{23{,}000}{He+30} + 40$ [m-kW]

$ns \leq \frac{23{,}000}{155.5+30} + 40 = 164.0$[m-kW]

The relationship between the hydraulic turbine generator's synchronous speed N and specific speed ns, at the frequency of 60Hz applicable in the Philippines, is shown in Table 5-20.

Table 5-20 Relationship between synchronous speed and hydraulic turbine specific speed

Synchronous speed N [min^{-1}]	Number of poles p	Turbine specific speed ns [m-kW]
900	8	119.9
720	10	95.9
600	12	79.9

The size of the generating unit can be reduced by raising its rotating speed, which is economical. In addition, as the guideline specific speed ns is ≦ 164.0m-kw, a rated speed N of 900min^{-1} could be adopted, but in the case of a Francis turbine, a higher rotating speed makes it necessary to secure the turbine setting level (suction head). Therefore, based on the results of consideration of the turbine setting level described below, a rated speed N of 720min^{-1} was judged to be optimal.

c) Turbine setting level

With the Francis turbine, which is categorized as a reaction hydraulic turbine, consideration needs to be given to sufficient suction head relative to the tailrace channel level during operation as a counter-measure against cavitation (the turbine center level position relative to the minimum tailrace channel level during operation). With higher rotating speeds, the generating unit becomes more compact and economical, but conversely in some cases the suction head reduces and the excavation volume for the powerhouse increases. For this reason, at the Wawa No. 2 powerhouse the suction head was set at Hs = 2.0m, and the turbine center level (turbine setting level) at EL.275.0m, based on Table 5-21.

Table 5-21 Relationship between rotating speed and suction head

Rated speed N [min^{-1}]	Suction head Hs [m]
900	-0.5 to -1.0
720	2.0 to 2.5
600	3.5 to 4.0

d) Generator output Pg

The generator output was calculated using the following outline formula.

$$Pg = \frac{Pt \cdot \eta g}{pf} \text{ [kVA]}$$

$$= \frac{5{,}350 \cdot 0.96}{0.80}$$

$$= 6{,}420\text{[kVA]} \rightarrow 6{,}450\text{[kVA]}$$

Here, Pt = 5,350[kW] (turbine maximum output)

ηt = 0.96 (envisaged generator efficiency at 100% output)

pf = 0.80 (generator power factor)

e) Generator rated voltage

The relationship between generator output and rated voltage is shown in Figure 5-24, with reference to the report of The Institute of Electrical Engineers Japan (below, "IEEJ").

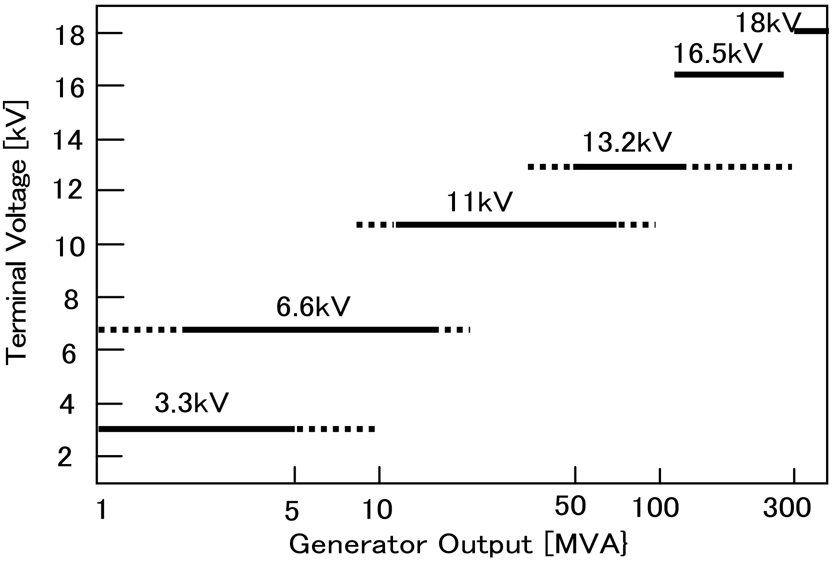


Fig. 5-24 Relationship between generator output and rated voltage

Source: IEEJ

In generating units of 10MVA or lower, typically a rated voltage of 3.3kV or 6.6kV is used. At the Wawa No. 1 powerhouse, a generator rated voltage of 6.6kV will be used in order to mitigate generator loss by using as large a rated voltage as possible, and to make the main transformer compact.

f) Specifications/composition of powerhouse equipment

The specifications and composition of the hydraulic turbine, major auxiliary mechanical equipment, generating unit and major auxiliary electrical equipment are shown in tables 5-22 and 5-23.

Table 5-22 Specifications and composition of hydraulic turbine and major auxiliary mechanical equipment

No.	Equipment	Specifications	Remarks
(1)	Hydraulic turbine		
	- Type of hydraulic turbine	Vertical Francis turbine	
	- Net head	155.5m	
	- Maximum discharge	$3.8m^3/s$	Per unit
	- Maximum output	5,350kW	Per unit
	- Rated speed	$720min^{-1}$	
	- Turbine specific speed	96.1m-kW	
(2)	Turbine inlet valve		
	- Inlet valve type	Thru-flow valve	
	- Nominal diameter	900 – 800mm	
	- Operating method	Pressure oil operation	Guide vane operation and common use
(3)	Governor system		
	- Governor type	Digital PID	
	- Operating method	Bladder type pressure oil operation	For guide vane/inlet valve operation
(4)	Main cooling water supply system	Cooling water pump method	For generating unit cooling
(5)	Powerhouse overhead travelling crane		

Table 5-23 Specifications and composition of generating unit and major auxiliary electrical equipment

No.	Equipment	Specifications	Remarks
(1)	Generator		
	- Generator type	Vertical synchronous generating unit	
	- Rated output	6,450kVA	Per unit
	- Power factor	0.80	
	- Rated voltage	6.6kV	
	- Frequency	60Hz	
	- Rated speed	720min^{-1}	
(2)	Excitation system	Brushless	
(3)	Neutral point grounding system		
(4)	Control and protection system		
(5)	Powerhouse auxiliary power supply equipment		Incl. battery, diesel generator equipment
(6)	Main transformer		
	- Main transformer type	Outdoor air cooling type	
	- Rated capacity	6,450kVA	Per unit
	- Rated voltage	6.6/13.2kV	
	- Frequency	60Hz	
(7)	Outdoor switchgear equipment		

g) Single line diagram

The major power equipment in the powerhouse comprises the No. 1 and No. 2 generators, primarily with a 13.2kV bus line, as well as indoor power supply transformer and metal closing type switchgear connected to a transmission line. The composition of the major power equipment is shown using a single line diagram in Figure 5-25.

The power generated by the generator undergoes voltage boosting by the main transformer connected in series, connected to a bus line via a breaker, and sent to the transmission line. In addition, part of the power undergoes step-down by means of the powerhouse power transformer, and supplies the power used inside the powerhouse. Meanwhile, if the generating unit stops operating, power is received from the transmission line via the bus line to provide for powerhouse power. If both the generating unit and transmission line stop operating, an emergency diesel generator supplies power to the powerhouse.

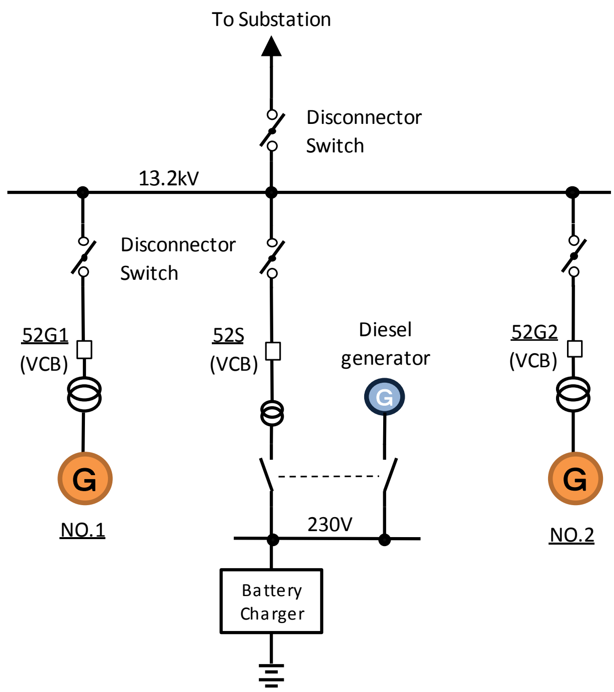


Fig. 5-25 Single line diagram

Source: Investigation team

5-3-5. Calculation of maximum output and power generation volume

A calculation was made of the power generation specifications derived from the results of the basic design of the generation equipment, as well as the maximum output and annual generating energy using the flow duration at the Wawa No. 2 powerhouse intake weir. This produced a generation output of 10,200kW and annual generating energy of 30,824MWh. Table 5-24 shows the hydraulic turbine, generator and transformer efficiency, and Table 5-25 shows the generation output at the typical flow rate.

Table 5-24 Hydraulic turbine, generator and transformer efficiency

Maximum discharge rate	%	100	90	80	70	60	50	40	36
Single unit flow rate	m^3/s	3.80	3.42	3.04	2.66	2.28	1.90	1.52	1.37
Turbine efficiency ηg	%	92.5	91.8	90.3	88.0	85.3	82.5	78.8	77.0
Generator efficiency ηt	%	96.8	96.5	96.3	96.0	95.4	94.5	93.1	92.6
Transformer efficiency ηtr	%	99.0							

Table 5-25 Power generation output at typical flow rate

River flow %	River flow at Wawa River No.1 intake weir	The amount of water used (m3/s)		Turbine efficiency ηg		Generator efficiency ηt		Transformer efficiency η tr		Output P (kW)	
		Turbine No. 1	Turbine No. 2	Turbine No. 1	Turbine No. 2	Turbine No. 1	Turbine No. 2	Turbine No. 1	Turbine No. 2	Turbine No. 1	Turbine No. 2
Maximum river flow	61.22	5.00	5.00	0.912	0.912	0.957	0.957	0.99	0.99	1291.0	1291.0
10	13.34	5.00	5.00	0.912	0.912	0.957	0.957	0.99	0.99	1291.0	1291.0
20	7.63	5.00	2.33	0.912	0.617	0.957	0.917	0.99	0.99	1291.0	390.0
30	4.86	4.56	0.00	0.890	0.000	0.955	0.000	0.99	0.99	1147.0	0.0
40	3.48	3.18	0.00	0.808	0.000	0.942	0.000	0.99	0.99	716.0	0.0
50	2.75	2.45	0.00	0.650	0.000	0.922	0.000	0.99	0.99	434.0	0.0
60	2.26	1.96	0.00	0.000	0.000	0.000	0.000	0.99	0.99	0.0	0.0
70	1.76	1.46	0.00	0.000	0.000	0.000	0.000	0.99	0.99	0.0	0.0
80	1.40	1.10	0.00	0.000	0.000	0.000	0.000	0.99	0.99	0.0	0.0
90	1.10	0.80	0.00	0.000	0.000	0.000	0.000	0.99	0.99	0.0	0.0
100	0.79	0.49	0.00	0.000	0.000	0.000	0.000	0.99	0.99	0.0	0.0
*Deduct the river maintainance flow amout 0.3 m3/s from the river flow.							ΣP 356 days			199,269	82,552
							Annual amount of power generated Σ E 356 days (kWh)			6,763,704	

5-4. Calculation of approximate construction costs

The approximate construction costs in this plan have been calculated based on the specifications and work volume for the respective structures determined from the basic design of the power generation facilities. The construction unit prices used in the calculation of construction costs are based on the construction cost calculation materials used when designing the Asiga mini-hydro power project currently being implemented by EPCC in Agusan del Norte, while also reflecting price inflation. For the hydraulic power generation equipment, the installation of Japanese-made equipment is envisaged, so price estimates from Japanese manufacturers have been used. The following tables show a breakdown of the approximate construction costs for the Wawa No. 1 and No. 2 powerhouses.

Table 5-26 Project cost breakdown for Wawa No.1, No.2 Power plants

Unit: PHP 1,000

No.	Item	Estimated Cost	
		Wawa No. 1	**Wawa No. 2**
1.	**Preparatory works**	64,571	255,861
2.	**Civil works & building works**	741,750	1,589,003
3.	**Electro mechanical works**	**130,859**	**256,199**
4.	**Engineering services**	58,859	135,053
5.	**Administrative expenses**	84,974	178,085
	Total	**1,081,013**	**2,414,201**

Source: Created by the study team

5-5. Power transmission plans

5-5-1. Site situation

(1) Wawa River mini-hydro power plant and nearby power facilities

The Wawa River mini-hydro power plant is located in Agusan del Sur close to the border between Agusan del Sur and Agusan del Norte, and therefore the local network of the Agusan del Sur Electric Cooperative (ASELCO) and the Agusan del Norte Electric Cooperative (ANECO), as well as the power facilities of the higher-level National Grid Corporation of the Philippines (NGCP) were investigated. (Figure 5-26)

- Bayugan Substation : The ASELCO Bayugan substation is located 30.0km directly south of the Wawa River mini-hydro power plant.
- Ampayon Substation : The ANECO Ampayon substation is located 17km west-southwest of the Wawa River mini-hydro power plant.
- Planned Taguibo Power Plant : There is a plan for a Taguibo power plant 9.5km to the west.

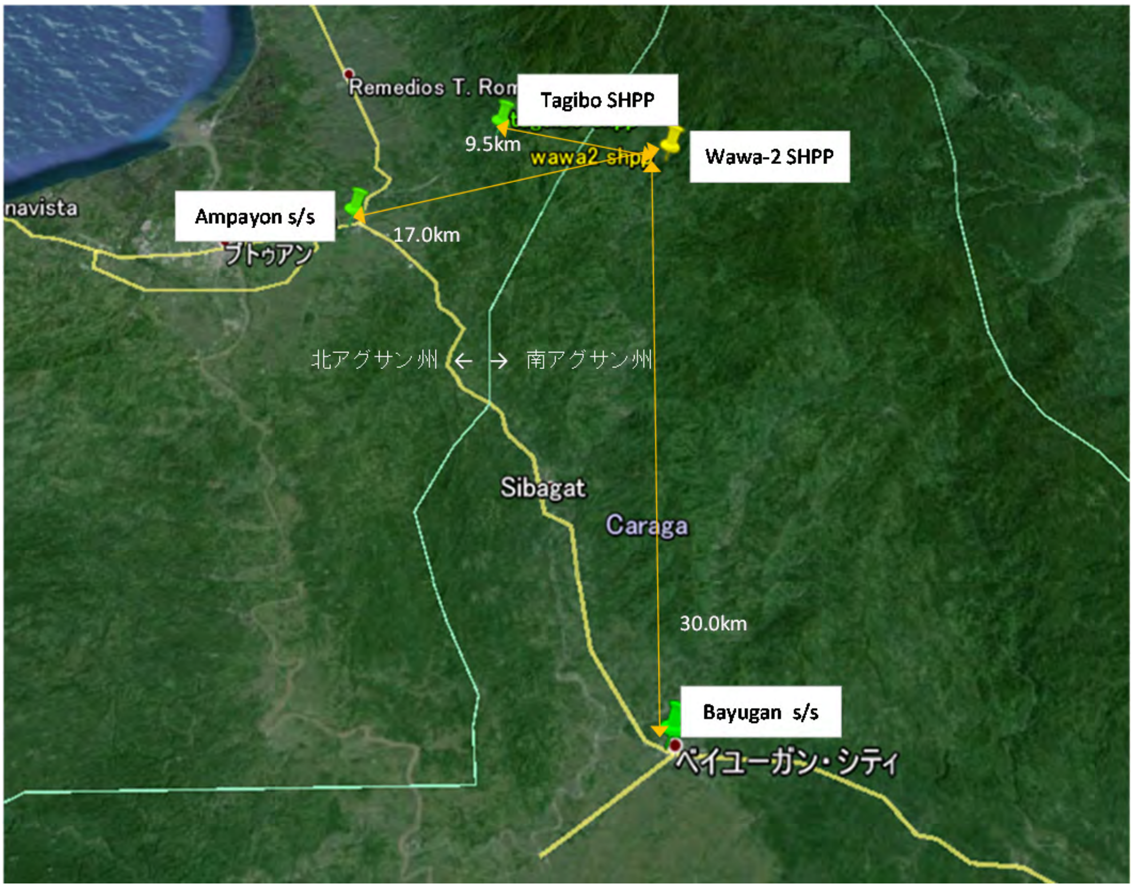


Fig. 5-26 Wawa River mini-hydro power plant and nearby power facilities

Source: Investigation team based on Google Earth

(2) Agusan del Sur and Agusan del Norte electric power network

The Mindanao electric power network is divided into the network owned and managed by NGCP (Fig. 5-27) and the networks owned and managed by the power distribution cooperatives established in each province – in Agusan del Sur, the Agusan del Sur Electric Cooperative (ASELCO), and in Agusan del Norte, the Agusan del Norte Electric Cooperative (ANECO) (Fig. 5-28, 5-29). There are three voltage levels: core transmission voltage 138kV, local transmission voltage 69kV, and distribution voltage 13.2kV. The core network and local networks are connected by interconnected substations.

The power system in the planned area of the Wawa mini-hydro power plant is shown in Figure 5-30.

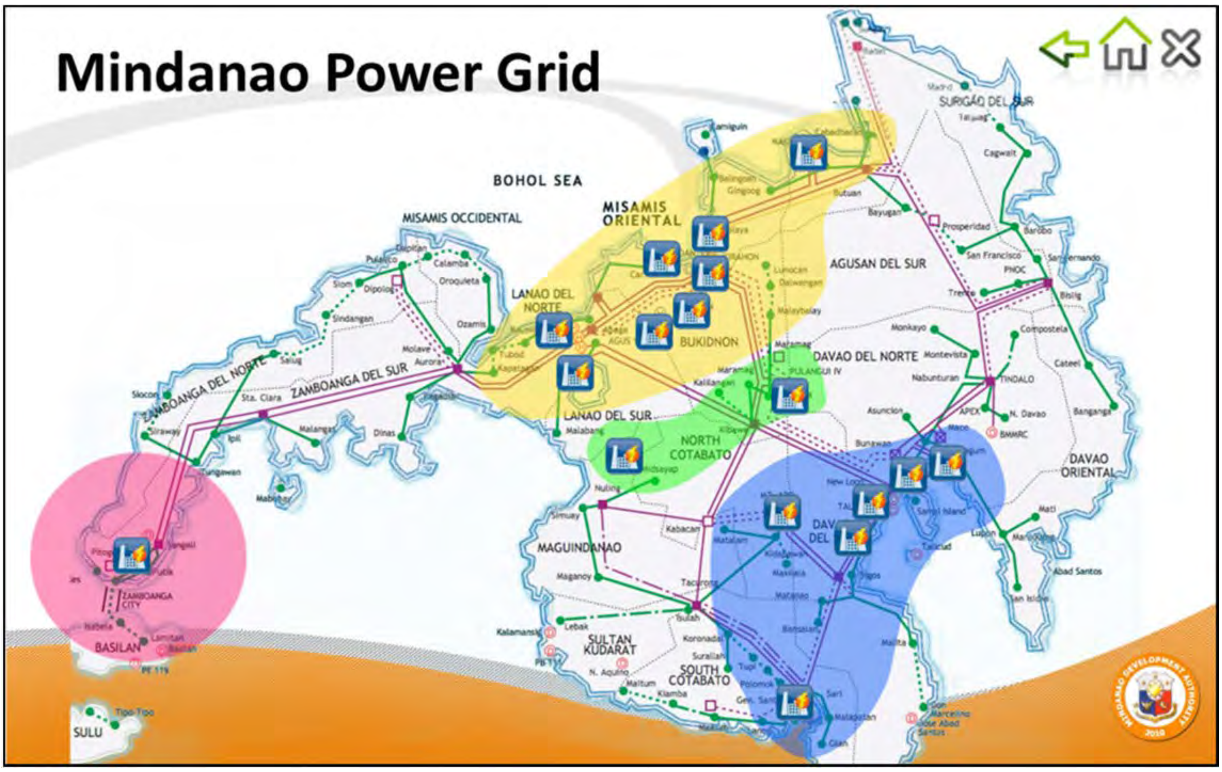


Fig. 5-27 Network owned and managed by NGCP

Source: Mindanao Power Grid (from Mindanao Development Authority 2010)

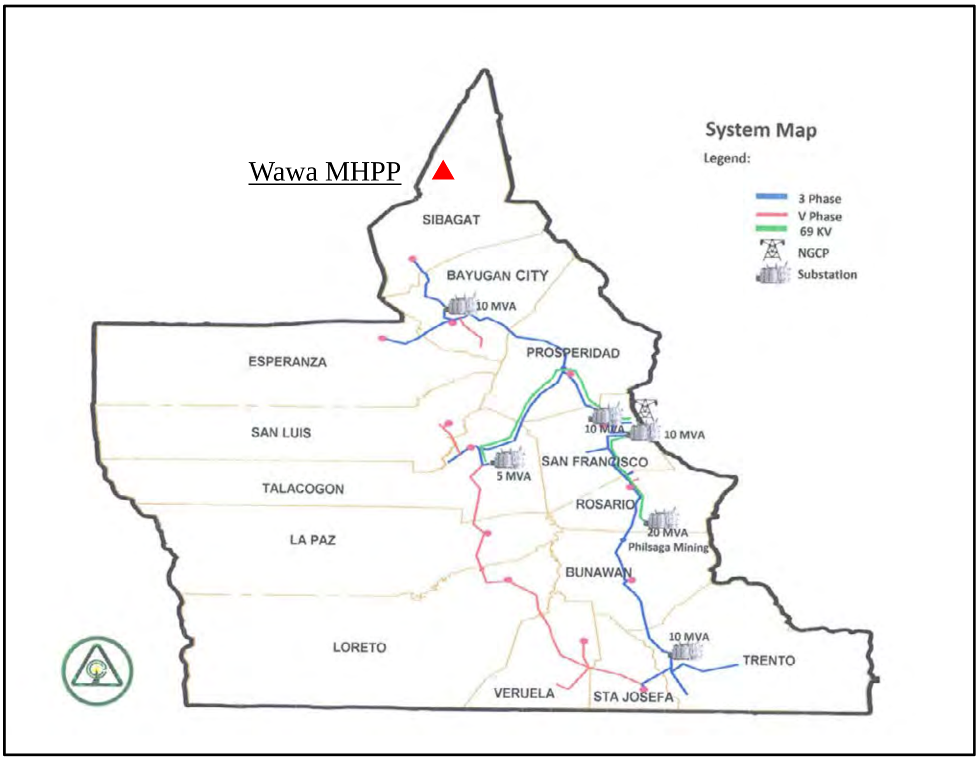


Fig. 5-28 ASELCO electric power network and Wawa River mini-hydro power plant

Source: Map provided by ASELCO; Wawa MHPP added by investigation team

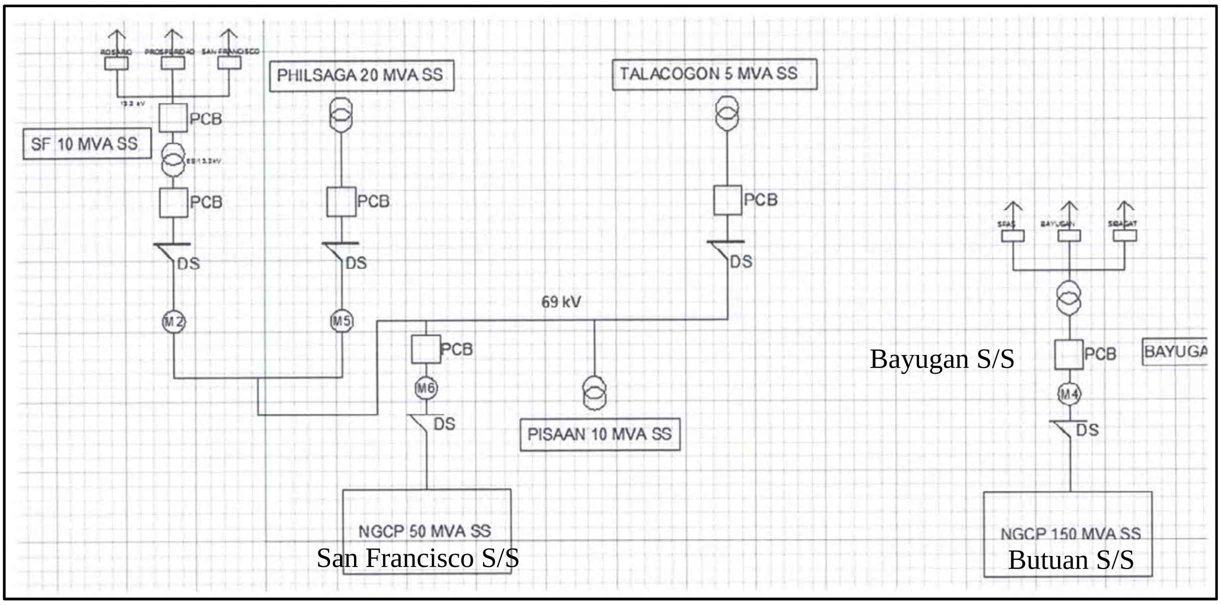


Fig. 5-29 ASELCO electric power network

Source: Map provided by ASELCO; additions by investigation team

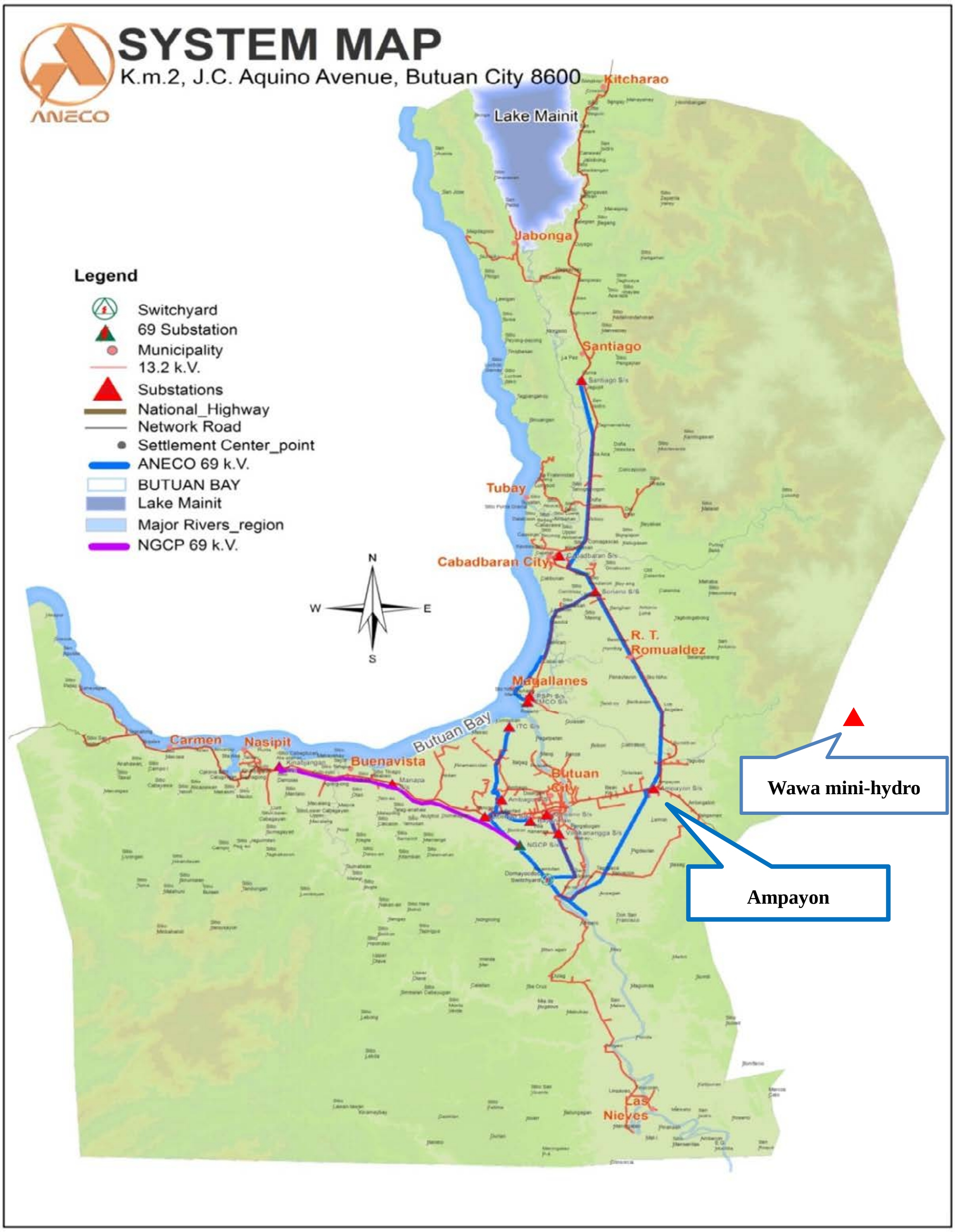


Fig. 5-30 ANECO electric power network and Wawa River mini-hydro power plant
Source: ANECO annual report (Dec. 31, 2014) ERC Form DU-A01); Wawa MHPP added by investigation team

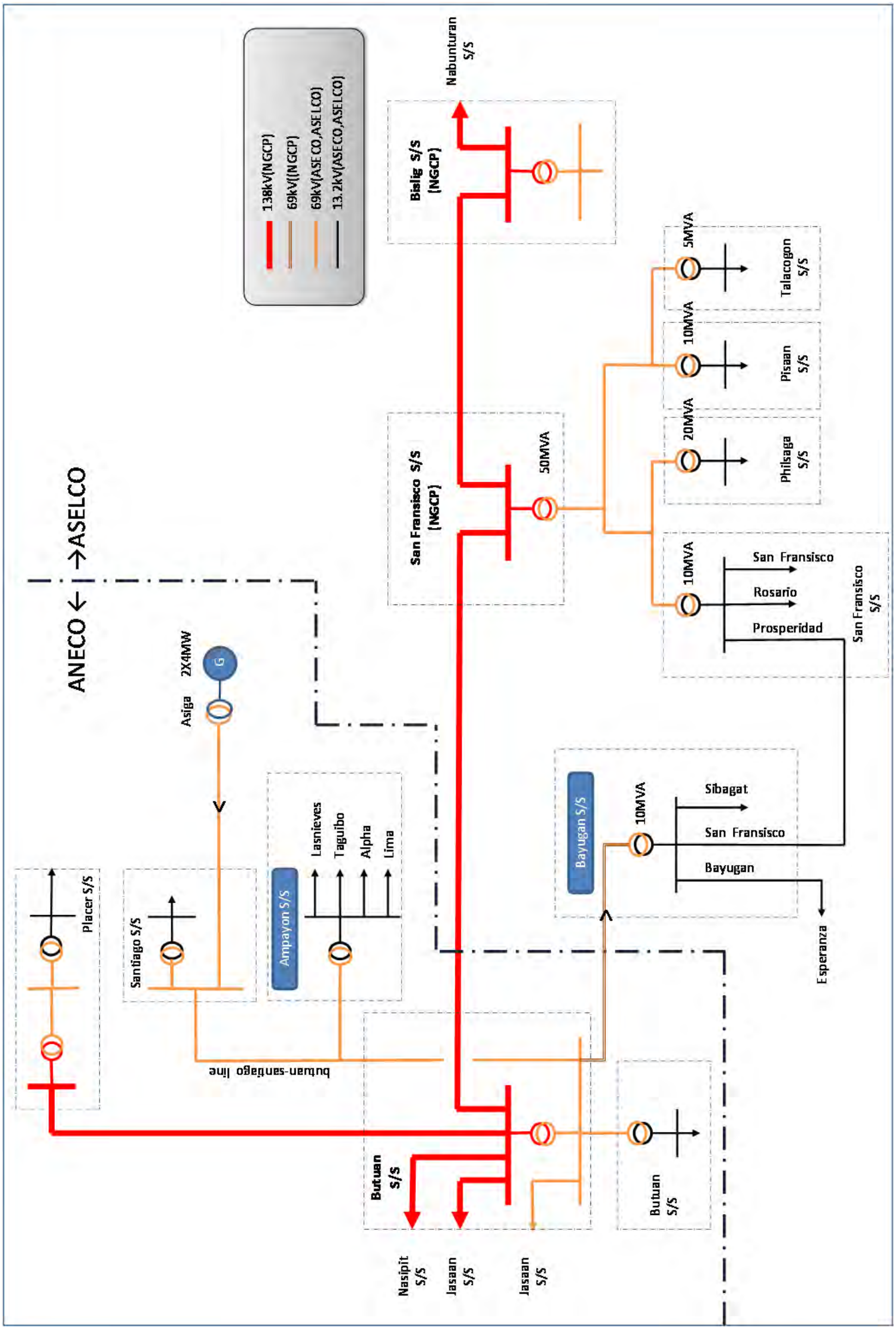


Fig. 5-31 Electric power network around Wawa mini-hydro power plant

Source: Investigation team based on NGCP core network diagram and ANECO/ASELCO local network diagrams

(3)Bayugan substation

The Bayugan substation is ASELCO's distribution substation located in Bayugan city, Agusan del Sur province, approx. 30.0km directly south of the Wawa River mini-hydro power plant.

Power is received from the NGCP Butuan substation via the NGCP 69kV Butuan/Bayugan line, with one 10MVA transformer connected. There is no primary bus line but a secondary 13.2kV bus line; power is distributed to the Sibagat, Esperanza and San Francisco distribution lines. The San Francisco distribution line is connected to the San Francisco substation, and is released mid-way in the vicinity of Prosperidad.


Fig. 5-32 Bayugan substation

Source: Investigation team photos

Table 5-27 Bayugan substation operating performance

Item	Year	Unit	Average	Remarks
Active power	2015/12	MW	6	
Outage frequency	2015	Times/day	1	Data from interview

Source: Investigation team based on ASELCO interview

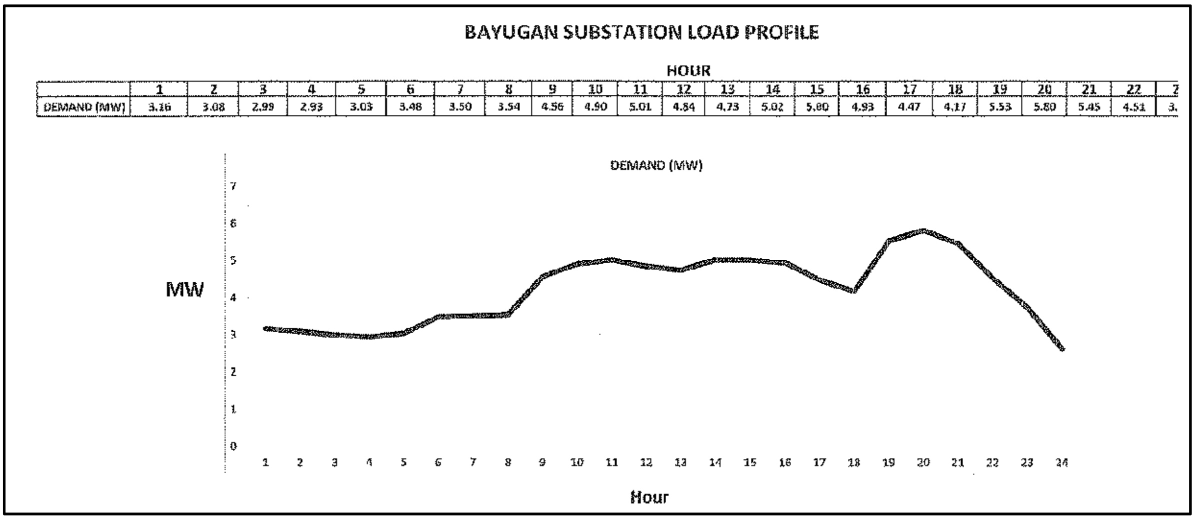


Fig. 5-33 Bayugan substation demand curve (Jan. 2016)

Source: ASELCO

(4) Ampayon substation

The Ampayon substation is ANECO's distribution substation located in the suburbs of Butuan city, Agusan del Norte province, approx. 17km directly west-southwest of the Wawa River mini-hydro power plant.

The high voltage side goes into a T-junction mid-way along the 69kV transmission line Butuan/Santiago line, and is connected to a 10MVA transformer via a disconnector. There is no primary bus line. The low voltage side comprises a 13.2kV bus line, and power is distributed to four distribution lines: LASNIEVES, TAGUIBO, ALPHA and LIMA. (Fig. 5-34), (Table 5-28)

Fig. 5-34 Ampayon substation

Source: Investigation team photos

Table 5-28 Ampayon substation 2014 performance

Item	Year	Unit	Average	Maximum	Minimum
Bus line voltage	2014	kV	13.6	13.69	13.15
Active power	2014	MW	8.81	10.29	7.15
Reactive power	2014	MVar	3.032	2.765	2.686
Power factor	2014	%	93.89	96.32	92.67
Outage **frequency**	2014	Times/month	7	28	2
Outage **time**	2014	Hours/month	0.29	0.76	0.0058

Source: Investigation team based on interview with ANECO

(5)Plan for new Taguibo mini-hydro power plant

There is a plan for a Taguibo power plant 9.5km to the west of the Wawa River mini-hydro power plant. The following is an outline of the plan.

- Output 2 × 2 [MW]
- Power line Connected to Ampayon substation low voltage side via dedicated line
- Cable line length Approx. 11 [km]
- Transmission voltage level 13.2 [kV]

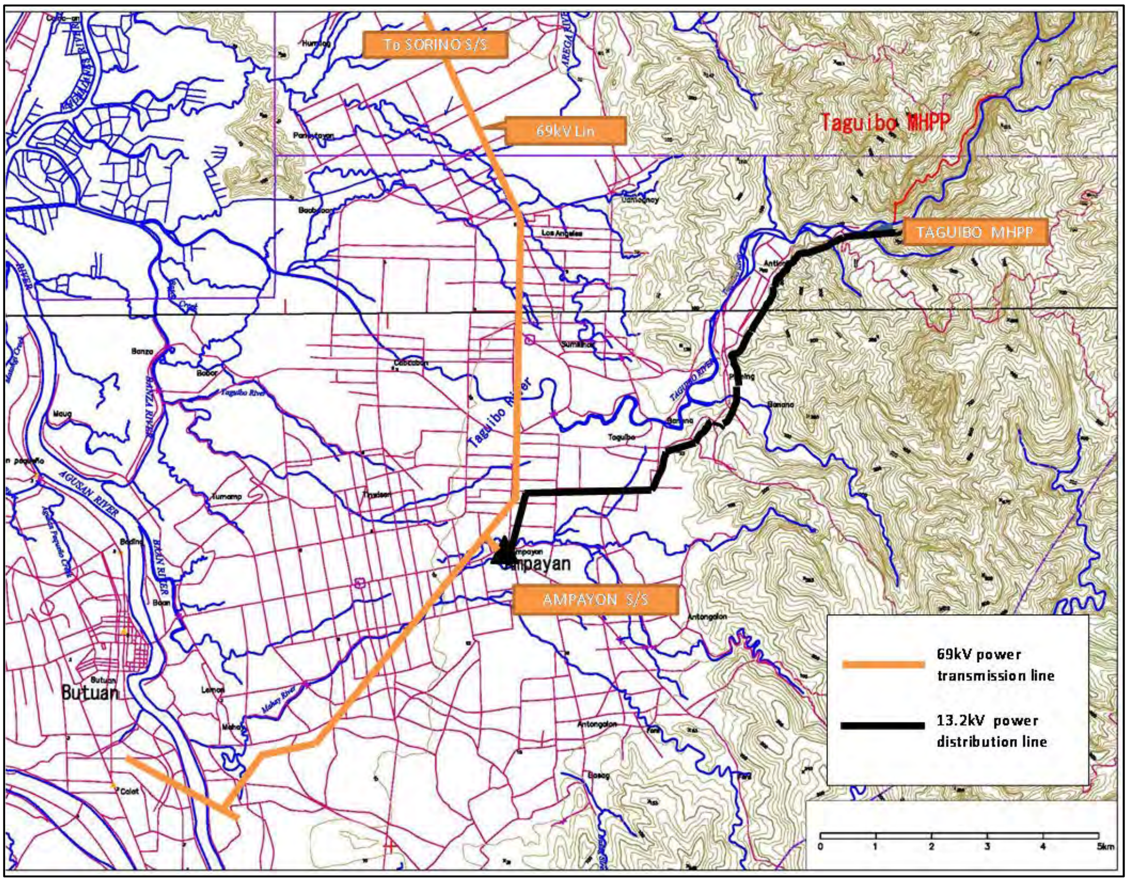


Fig. 5-35 Power line route from Taguibo mini-hydro power plant

Source: Investigation team

(6) Distribution line near Wawa River mini-hydro power plant

There is no distribution line in the vicinity of the planned location for the Wawa River mini-hydro power plant.

When visiting the Ampayon substation to conduct an investigation, we obtained the specifications and performance history of the Taguibo distribution line that sends power from the Ampayon power distribution substation, and provide this here for reference.

Taguibo distribution line specifications

- Voltage level 13.2 [kV]
- Cable line length 14.73 [km]
- Cable classification ACSR 1/0
  Stranding (Al/Stl): 6/1, Diameter: 0.398 inches, allowable ampacity: 242A
- Capacity 10 [MVA]

Table 5-29 Overview of Taguibo distribution line 2014 performance (actual)

Item	Year	Unit	Average	Maximum	Minimum
Distribution cable voltage	2014	kV	13.5	13.68	13.1
Distribution line current	2014	A	3,903.7	4,184.21	3,715.26
Distribution line active power	2014	MW	52.7	57.24	48.67
Distribution line reactive power	2014	MVar	16.45	4.503	19.211
Power factor	2014	%	95.0	99.69	91.88
Outage frequency	2014	Times/month	38	64	17
Outage **time**	2014	Hours/month	0.67	0.79	0.42

Source: Investigation team based on interview with ANECO

5-5-2. Selection of transmission voltage

There are three voltage levels in Mindanao: core transmission voltage 138kV, local transmission voltage 69kV, and distribution voltage 13.2kV.

When selecting the transmission voltage for the Wawa River mini-hydro power plant, three patterns were considered: standalone construction of Wawa No. 1 powerhouse, standalone construction of Wawa No. 2 powerhouse, and construction of both powerhouses.

Note also that below, the transmission line connecting the power generation facilities to the electric power network is referred to as the power line.

(1)Basic data

The basic data used in this paragraph is as follows.

Wawa No. 1 Powerhouse output: 2.6 [MW]

Wawa No. 2 Powerhouse output: 10.2 [MW]

Nominal distribution line voltage 13.2 [kV]

Nominal transmission line voltage 69.0 [kV]

(2)Basic calculation formula

Calculation of electric current

Electric current $I = P/(\sqrt{3} \cdot V \cdot \cos\theta)$

P : Transmission power (generated power) [kW]

V : Power line voltage (nominal value) [kV]

$\cos\theta$: Power factor, set as 0.9 here

(3) Power line specification used in our consideration

The power line specification used in our consideration was ACSR (Aluminum Conductors Steel Reinforced), widely used by NGCP, ANECO and ASELCO.

ACSR 1/0 specification (example of Taguibo distribution line: from interview with ANECO)

Wire : Aluminum 6 wires / steel 1 wire

Diameter : 10.11 [mm]

Nominal cross-section area : 62.44 [mm^2]

Ampacity : 242 [A]

Maximum resistance value : 0.5343 [Ω/km]

ACSR 336.4 specification (transmission line, example of Butuan/Bayugan line: from interview with ASELCO)

Wire : Aluminum 26 wires / steel 7 wires

Diameter : 18.31 [mm]

Nominal cross-section area : 198.44 [mm^2]

Ampacity : 529 [A]

Maximum resistance value : 0.1693 [Ω/km]

Source: For ampacity, Southwire Company website; for other values, Midal Cable Company website

(4) Evaluation based on transmission current

When current flows to the power line, heat is generated proportional to the square of the internal resistance of the power line and electric current. As the power line lengthens when heat is added, the amount of deflection increases and this poses the risk of electric shock to the human body and grounding incidents through contact with trees. When the temperature rises further, mechanical strength declines and the potential for breaking occurs, so a permissible value is set for the current. The ampacity shown in the power line specification table is the electric current when air temperature is 25℃ and when the power line reaches 75℃. Taking into consideration the climate of the Philippines, the safety factor (margin of safety ratio) is assessed as 2.

Table 5-30 Evaluation based on transmission current

<table>
<tr><td colspan="2"></td><td colspan="2">Wawa No. 1
Powerhouse
Standalone</td><td colspan="2">Wawa No. 2
Powerhouse
Standalone</td><td colspan="2">Wawa No. 1 + No. 2
Powerhouse
Total</td></tr>
<tr><td colspan="2">Transmission voltage: V [kV]</td><td>13.2</td><td>69.0</td><td>13.2</td><td>69.0</td><td>13.2</td><td>69.0</td></tr>
<tr><td colspan="2">Transmission power: P [MW]</td><td colspan="2">2.6</td><td colspan="2">10.2</td><td colspan="2">12.8</td></tr>
<tr><td colspan="2">Current calculation: I [A]</td><td>131</td><td>25</td><td>496</td><td>95</td><td>627</td><td>120</td></tr>
<tr><td colspan="2">Current factoring in safety margin ratio: I [A]</td><td>262</td><td>50</td><td>992</td><td>190</td><td>1254</td><td>240</td></tr>
<tr><td rowspan="2">Evaluation</td><td>Using ACSR 1/0
Ampacity 242 [A]</td><td>△</td><td>○</td><td>×</td><td>○</td><td>×</td><td>○</td></tr>
<tr><td>Using ACSR 336.4
Ampacity 529 [A]</td><td>○</td><td>○</td><td>×</td><td>○</td><td>×</td><td>○</td></tr>
</table>

In the case of standalone transmission from the Wawa No. 1 powerhouse, the power line could be connected to a distribution line with a voltage of 13.2kV, but in the case of standalone transmission from Wawa No. 2 powerhouse and transmission from Wawa No. 1 and No. 2 powerhouses combined, it would be impossible to connect the power line to the distribution line.

(5) Evaluation based on power consumption of distribution substation

Due to the characteristics of electricity, the supplied power volume and consumed power volume must be simultaneous and the same volume. As the consumption volume changes according to customer circumstances, the supplied volume must be altered in order to maintain simultaneity/identical volume. As the supplied volume equals the power generation volume, when the generated power is greater than the power consumption the output is inhibited.

According to our interviews with ANECO and ASELCO, the power consumption of the distribution substation averages 8.8MW in the case of ANECO's Ampayon substation (minimum: 7.15MW), and averages 6MW at ASELCO's Bayugan substation.

Table 5-31 Evaluation based on power consumption of distribution substation

<table>
<tr><td colspan="2"></td><td>Wawa No. 1
Powerhouse
Standalone</td><td>Wawa No. 2
Powerhouse
Standalone</td><td>Wawa No. 1 + No. 2
Powerhouse Total</td></tr>
<tr><td colspan="2">Transmission power: P [MW]</td><td>2.6</td><td>10.2</td><td>12.8</td></tr>
<tr><td rowspan="2">Evaluation</td><td>Connection to Ampayon substation: power consumption 7.15 [MW]</td><td>○</td><td>×</td><td>×</td></tr>
<tr><td>Connection to Bayugan substation:
Power consumption 6 [MW]</td><td>○</td><td>×</td><td>×</td></tr>
</table>

During standalone power transmission from the Wawa No. 1 powerhouse, both the Bayugan substation and Ampayon substation are less than the power consumption, so there is no inhibiting of generated power, but with standalone power transmission from the Wawa No. 2 powerhouse and combined transmission from the Wawa No. 1 and No. 2 powerhouses, output is inhibited. For this reason, it is not possible to connect to the secondary bus line of the distribution substation.

(6)Overall evaluation

Table 5-32 Overall evaluation

	Wawa No. 1 Powerhouse Standalone	Wawa No. 2 Powerhouse Standalone	Wawa No. 1 + No. 2 Powerhouse Total
Transmission power: P [MW]	2.6	10.2	12.8
Transmission voltage: V [kV]	**13.2**	**69.0**	**69.0**
Current calculation: I [A]	131	95	120
Current factoring in safety margin ratio: I [A]	262	190	240
Cable classification & size	**Using ACSR 1/0** Ampacity 242 [A]	**Using ACSR 1/0** Ampacity 242 [A]	**Using ACSR 1/0** Ampacity 242 [A]

With standalone power transmission from the Wawa No. 1 powerhouse, the transmission voltage is 13.2kV, so power can be transmitted to the Bayugan and Ampayon substations.

With standalone transmission from the Wawa No. 2 powerhouse and transmission from the Wawa No. 1 and No. 2 powerhouses combined, as the power cannot be entirely consumed within either powerhouse, the voltage is 69.0kV and connection is made to the transmission line. Connection is made to the primary side of the Bayugan substation and Ampayon substation, or a T-junction connection is made mid-way along the transmission line.

(7)Reference (transmission loss)

For reference, we calculated the transmission loss in the case of combined transmission from the Wawa No. 1 and No. 2 powerhouses, both when transmitting at distribution line voltage (13.2kV) and transmission line voltage (69.0kV). The calculation formula for transmission loss is as follows.

1) Calculation formula for transmission loss

Transmission loss $p = I^2 r$

p : transmission loss [kW]

I : Current [A]

r : Power line resistance [Ω]

2) Transmission current

Transmission current calculated in the preceding paragraph is used

When transmitting at distribution line voltage: 617.2 [A]

When transmitting at transmission line voltage: 118.1 [A]

3) Power line resistance

For power line resistance, the value from the power line specification table is used

ACSR 1/0.0.217 [Ω/1,000ft] = 0.71194 [Ω/km]

0.3048 [m/ft] → 3.28084 [ft/m]

4) Unit transmission loss (transmission loss per 1km)

When transmitting at distribution line voltage: p = 617.2^2 * 0.71194 / 10^3 = 271.203[kW/km]

When transmitting at transmission line voltage: p = 118.1^2 * 0.71194 / 10^3 = 9.93 [kW/km]

The loss when transmitting at distribution line voltage is about **27 times** that when transmitting at transmission line voltage.

5) Assuming the transmission distance to be 20km,

When transmitting at distribution line voltage: p = 271.203 * 20 ≒ 5,400 [kW]

When transmitting at transmission line voltage: p = 9.93 * 20 ≒ 200 [kW]

5-5-3. Selection of power line connection point

(1) Consultation with ASELCO regarding power line connection point

Upon consulting about connecting Wawa mini-hydro power plant 12.8MW to ASELCO's electric power network, the following reply was received:

- The nearest substation to the Wawa mini-hydro power plant is the Bayugan substation, but this substation cannot consume power at 12.8MW. If it were to be connected, the output would be inhibited.
- If connecting to the 69kV Butuan/Bayugan transmission line, the transmission line is owned by NGCP so consultation would need to be made with NGCP.
- If connecting to the ASELCO electric power network, connection would be made to the San Francisco substation, so a long-distance power line would need to be laid.

(2) Consultation with NGCP regarding power line connection point

Following ASELCO's advice, we consulted with NGCP, the following reply was received.

- There is no problem with connecting the Wawa mini-hydro power plant 12.8MW power line to the 69kV Butuan/Bayugan transmission line. Connection via T-junction is possible.
- Regarding connection to the 69k Butuan/Santiago transmission line, ANECO is the owner so consultation would need to be made with ANECO.

(3) General matters for selection of power line route

When selecting the power line route, in order to avoid the problem of grounding through tree contact→transmission line outage→stoppage of power generation, during construction it is important to select a route where there is no contact or the risk of contact with trees, or the risk of trees falling, as well as a route through which vehicles can pass, taking into consideration an inspection of the transmission line after construction and the ease of tree felling/trimming.

There are two routes with access to vehicles: one goes to Sibagat city in Agusan del Sur, and the other goes to the Ampayon district of Butuan city in Agusan del Norte. Traffic conditions are best on the route from the Ampayon district.

(4) Selection of power line route

For the Wawa mini-hydro power plant 12.8MW power line, the following two routes can be considered.

[Proposal -1] Connect to the 69kV Butuan/Bayugan transmission line via a T-junction with the Wawa mini-hydro power plant power line in the vicinity of the Wawa Bridge on the Pan-Philippine Highway.

The power line route and connection point are shown in Figures 5-36 and 5-37.

The distance from the Wawa No. 2 mini-hydro powerhouse to the 69k Butuan/Bayugan transmission line is about 40km. However, as the map is unclear, in some segments the distances are not accurate.

The features of this proposal are as follows.

- Power generated from the Wawa mini-hydro power plant is consumed by priority in the Bayugan area of Agusan del Sur, and the surplus power is sent to the Butuan area.
- When connecting the power line, it would be necessary to stop the 69kV Butuan/Bayugan transmission line, so the Bayugan substation would stop operation and power would be cut to the Sibagat, Esperanza and San Francisco distribution lines.

Fig. 5-36 Connection of power line to 69kV Butuan/Bayugan transmission line via T-junction

Source: Investigation team based on Google Earth

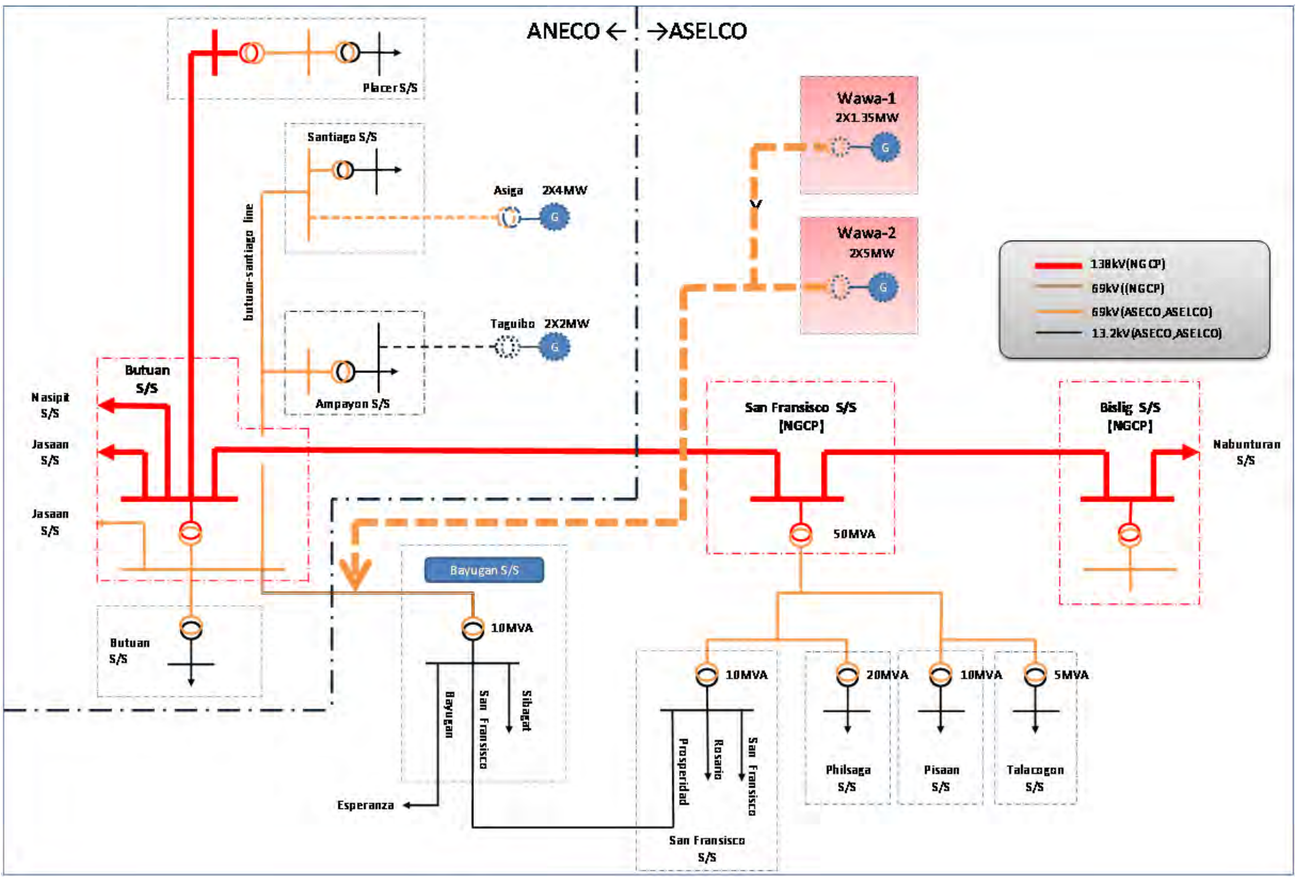


Fig. 5-37 Proposal for connection of power line to 69kV Butuan/Bayugan transmission line via T-junction

Source: Investigation team

[Proposal -2] Connect to the 69kV Butuan/Santiago transmission line via a T-junction with the Wawa mini-hydro power plant power line in the vicinity of the south side of the Taguibo Bridge on the Pan-Philippine Highway.

The power line route and connection point are shown in Figures 5-38 and 5-39.

The distance from the Wawa No. 2 mini-hydro powerhouse to the Butuan/Santiago transmission line is about 30km.

The features of this proposal are as follows.

- Power generated from the Wawa mini-hydro power plant is consumed in the Butuan City area of Agusan del Norte.
- The 69kV Butuan/Santiago transmission line is already connected via T-junction for the Ampayon substation. By making a T-junction with the Wawa mini-hydro power plant power line, the transmission line will comprise 4 terminals. As transmission line protection becomes complex, this would need to be confirmed with ANECO.
- When connecting the power line, it would be necessary to stop the 69kV Butuan/Santiago transmission line, so the Ampayon substation would stop operation. Therefore, and power would be cut to the four distribution lines LASNIEVES, TAGUIBO, ALPHA and LIMA.

Fig. 5-38 Route for connection to 69kV Butuan/Santiago transmission line via T-junction

Source: Investigation team based on Google Earth

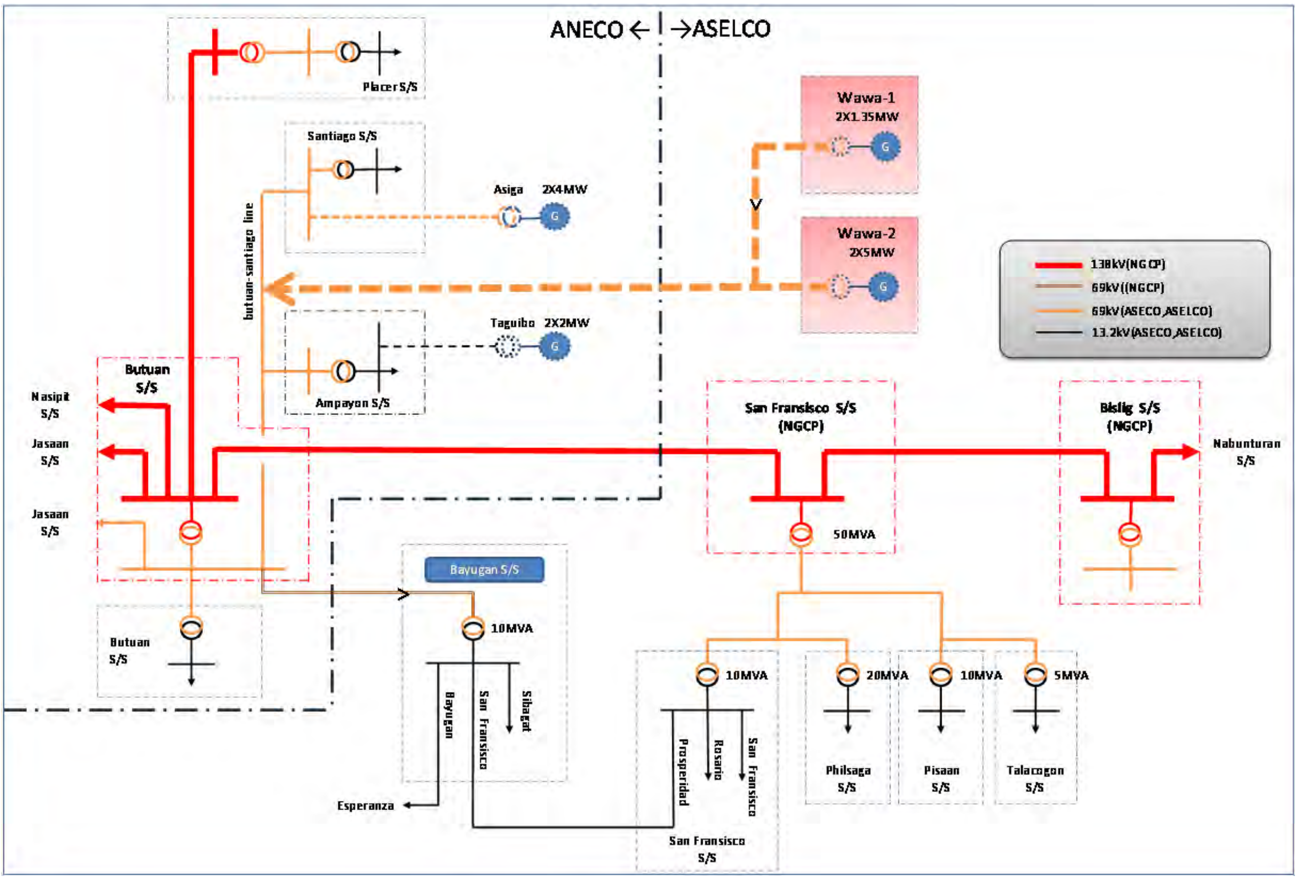


Fig. 5-39 Proposal for connection to 69kV Butuan/Santiago transmission line via T-junction

Source: Investigation team

(5)Other

In the proposal for connection to the 69kV Butuan/Santiago transmission line via a T-junction, mid-way along the route there is a plan for construction of the Taguibo mini-hydro power plant. If a plan were made to combine the Taguibo mini-hydro power plant and Wawa mini-hydro power plant power lines, this would reduce the transmission line construction costs and mitigate the transmission loss. (Fig. 5-40)

Specifically, the transmission voltage for the Taguibo mini-hydro power plant would be 69kV rather than 13.2kV, and design/construction would be carried out to connect the Wawa mini-hydro power plant power line. By constructing the Wawa mini-hydro power plant between Taguibo and Wawa, a significant saving in construction costs could be expected in comparison to separate power transmission.

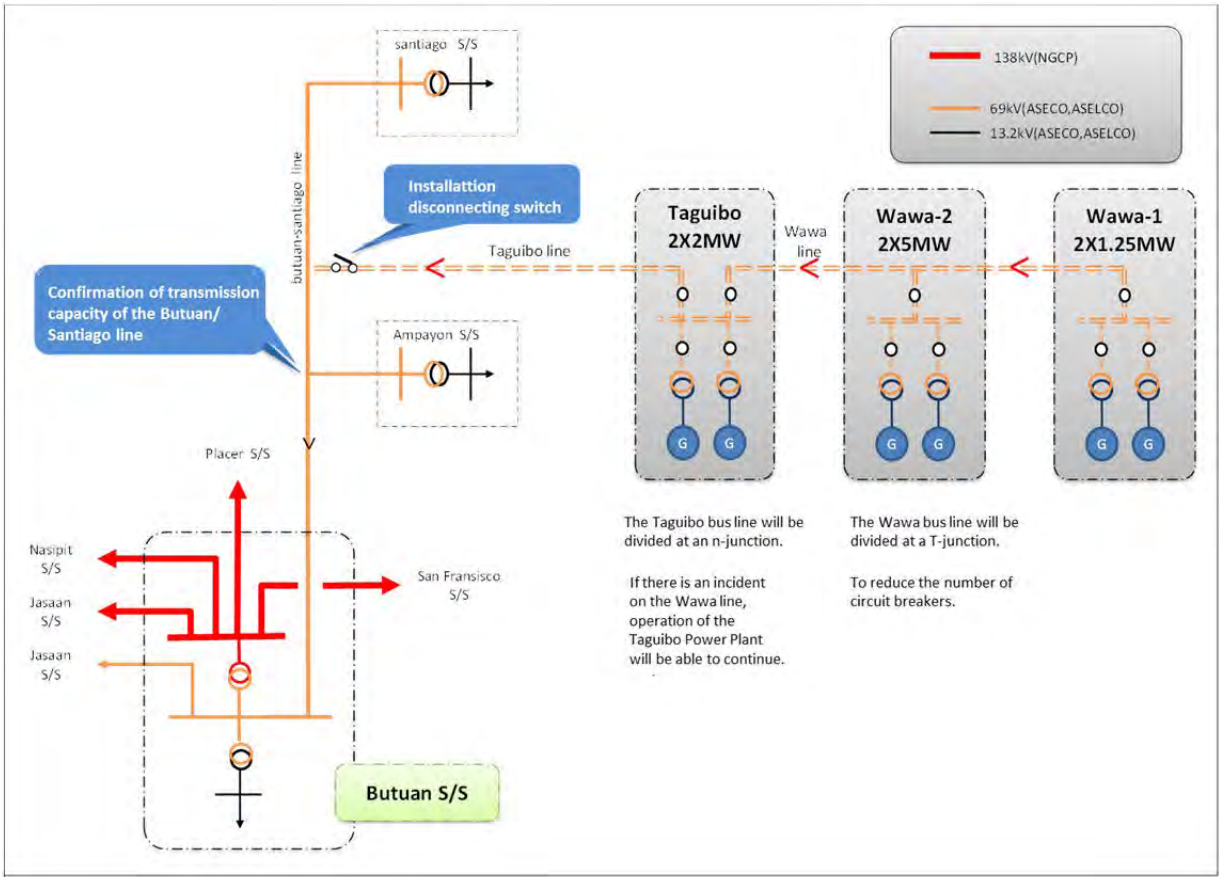


Fig. 5-40 Proposed composition of Taguibo mini-hydro power plant Wawa mini-hydro power plant power line

Source: Investigation team

5-5-4. Matters of concern

- The location of the powerhouse is Agusan del Sur, and if the connection point was in Agusan del Norte, consideration would need to be given to the impact of the administrative districts being different.
- Consideration would need to be given to the fact that in both connection point proposals 1 and 2, power that is not entirely used up at the distribution substation would be sent to the Butuan district.