

# Site Selection for Feasibility Study of Pump-Storage Hydropower Project in The Philippines.



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Field of Study                      Energy Technology and Management  
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ฟิลิปปินส์เป็นประเทศที่มีระดับความสูงที่แตกต่างกันทั้งประเทศเนื่องจาก เป็นภูมิประเทศแบบเกาะ แต่ภัยธรรมชาติก็เกิดขึ้นบ่อยครั้งในทุกๆปีทำให้ยากต่อการสร้างโครงสร้างใด ๆ แต่ PSP เป็นอาคารขนาดใหญ่ที่มีความสามารถสร้างพลังงานจำนวนมากด้วยต้นทุนที่ไม่แพง

งานวิจัยนี้จะเน้นที่ในขั้นตอนเบื้องต้นของการค้นหาพื้นที่ที่เหมาะสมสำหรับ โครงการไฟฟ้าพลังน้ำแบบสูบกลับผ่านการตรวจสอบสองเงื่อนไขที่สำคัญคือ ภูมิศาสตร์และธรณีวิทยา

มีพื้นที่การวิจัยสามแห่งที่ตั้งอยู่ทั่วภูมิภาคเกาะ ลูซอน (L), วิซัส (V) และมินดาเนา (M) ผลลัพธ์แสดงเฉพาะส่วนบนอ่างเก็บน้ำที่มีน้ำธรรมชาติและหัวสูงมากกว่า 300 เมตร เพื่อวิเคราะห์โครงการ ผู้เขียนใช้แบบจำลองกระแสเงินสดส่วนลด (แบบจำลองโดยมีระยะเวลาสัมปทาน 25 ปี ผลการวิจัยพบว่ามูลค่าปัจจุบันสุทธิ 1,467(L), 756 (V) และ 1,696 (M) ล้านดอลล่าสหรัฐ อัตราผลตอบแทนภายในคือ 22.56% (L), 17.48% (V) และ 20.94% (M) และโครงการคืนทุนจะเมื่อมีอายุ 4 (L), 6 (V) และ 4 (M) ปี ส่งผลให้โครงการเป็นไปได้ทางเศรษฐกิจและการเงิน

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Sornsawan Utthakrue : Site Selection for Feasibility Study of Pump-Storage Hydropower Project in The Philippines.. Advisor: Asst. Prof. THITISAK BOONPRAMOTE, Ph.D.

Pumped-storage hydropower projects (PSP) are a technology for hydroelectric energy storage. It is a design of two water reservoirs at different elevations that can create electricity as water flows from one to the other via a turbine. The PSP system is similar to a huge battery in that it can store and then release energy as needed.

The Philippines is a country with a wide range of elevations due to its island composition. Natural disasters occur frequently, making it challenging to establish any structure. But the PSP is a large building that is also capable of generating a great amount of energy at a significant cost. This research will focus on the preliminary stage of finding sites appropriate for PSP through a remote investigation of two critical conditions: geography and geology.

There are three research areas located throughout the region's islands: Luzon (L), Visayas (V), and Mindanao (M). The result shows only the upper reservoir with natural water and a head of more than 300 m. To analyze PSP, the author uses a Discount Cash Flow Model (DCF model) with a 25-year concession period. The results of this research shows that the net present value is 1,467(L), 756 (V), and 1,696 (M) million USD, the internal rate of return is 22.56% (L), 17.48% (V), and 20.94% (M), and the payback project will last 4 (L), 6 (V), and 4 (M) years. As a result, the project is economically and financially feasible.



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## LIST OF ABBREVIATIONS

DEM	Digital Elevation Model
GIS	Geographic Information System
GWh	Gigawatt hour
GWh/a	Gigawatt hour per year
HPP	Hydro Power Plant
IDC	Interest During Construction
IRR	Internal Rate of Return
km	kilometre
m	metre
mg	magnitude
M m <sup>3</sup>	million cubic metre
M USD	million US Dollar
MW	Megawatt
MWh	Megawatt hours
NPV	Net Present Value
O&M	Operation and Maintenance
PSP	Pump-storage hydropower project
PHP	Philippine Peso
TL	Transmission Line
USD	US Dollar

# CHAPTER 1

## INTRODUCTION

### 1.1 Background

The hydroelectric power plant is a technology ability to produce high energy. On the other hand, this technology requires analysis in a variety of technical, environmental, and financial sectors, including hydraulics, civil construction, environmental and social, and so on. However, this research focuses on the preliminary stage before proceeding to the next step, which is a desk study analysis of feasible sites for a pump-storage hydropower project (PSP). When this stage is completed, the developer and owner of the project can continue to the next stage.

A pump-storage hydropower project is a type of hydropower electric plant in which the technology may provide a large amount of energy over a long period of time at a cheap cost. This technology has the potential to be a "*Bang-for-buck*" technology in the modern renewable energy market. As shown in Figure 1, hydropower has a lower levelized cost of energy (LCOE) than other energy sources (0.04 USD/kWh). PSP is a technology that began in the 1890s in Switzerland and Italy and has since spread worldwide, especially to high-tech countries like Germany, the United States, Japan, and China. And this technology is included in a type of storage plant, which is generally called battery storage plants technology. As shown in Figure 2, PSP is the most efficient technique for storing capacity electricity (batteries) as compared to other sources.



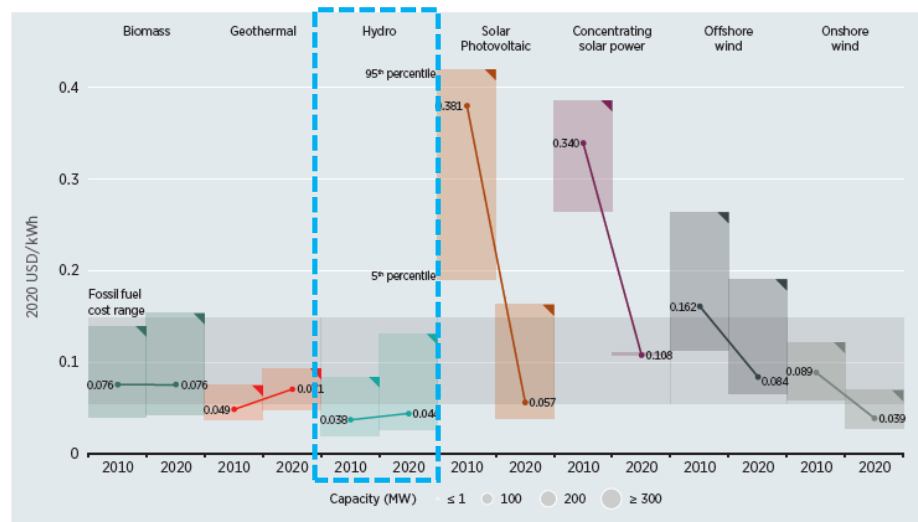


Figure 1: Global LCOEs from newly commissioned, utility-scale renewable power generation technologies, 2010-2020. [1]

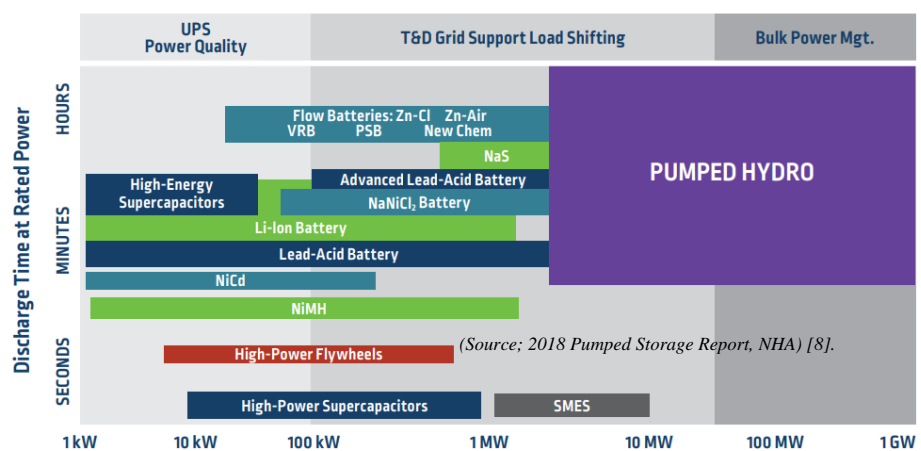


Figure 2: Electricity storage technology source capacity comparison. [2]

The Philippines has a population of around 109.6 million people, which is expanding each year, according to a 2020 population study. As a result, high population growth has an effect on excessive energy consumption. On the other hand, hydroelectricity is a renewable energy source that also supplies a significant quantity of electricity to the Philippines. The geography of the Philippines also supports the PSP because of the morphology, which has several elevations that are suitable for the PSP.

The purpose of this research is to study the possibility of a pumped-storage hydropower project (PSP) in the Philippines. The following are the key components of the Project:

- Geography; Topography and spatial data.
- Geology; Regional geological setting and hazards.
- Economics.

This research will aid in the development of the feasibility model by collecting and analyzing data in order to identify potential locations for the PSP project, which will be included in the model. This is the first step in determining a potential location. The study will divide the research area into three regional areas, as shown in Figure 3: Luzon, Visayas, and Mindanao. The high-potential area will be selected based on criteria developed from the preceding components. Economic management and finance are required for the feasibility analysis project, which is followed by the selection of the project site. The Discount Cash Flow Model (DCF) was developed based on the following assumptions: construction spending, project costs, project operations, the annual power sales price, and estimated annual power output. This preliminary research collects and analyzes data in order to identify potential areas for developing a PSP project that will be included in the financial model.

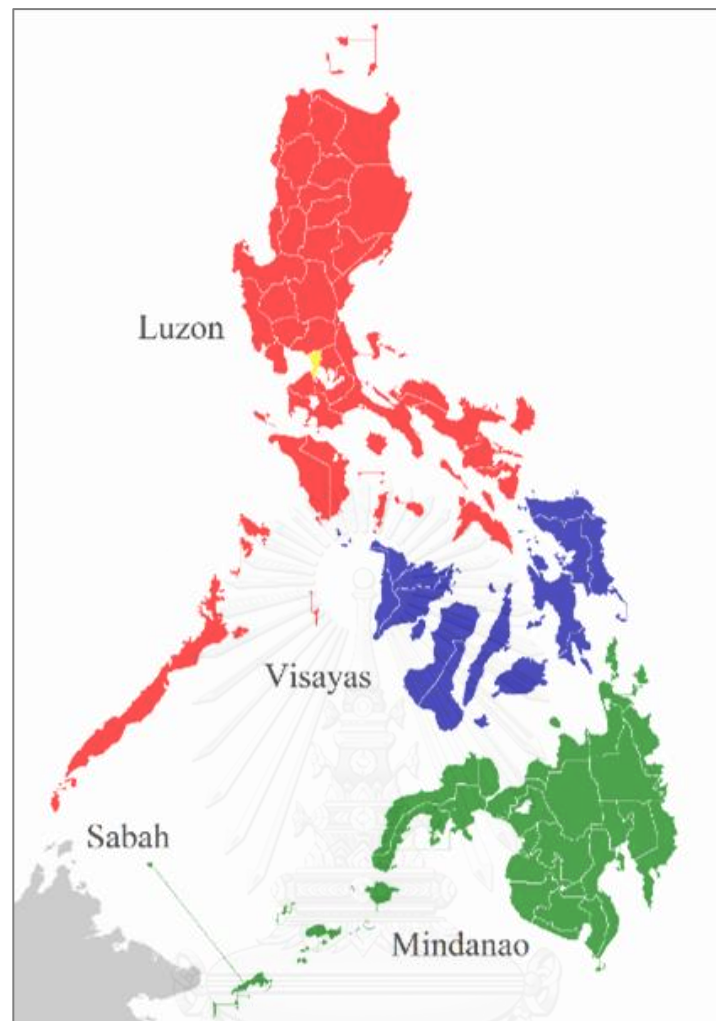


Figure 3: Map of the Philippines' Regional Geography

## 1.2 Objectives of the Study

The objective of this research is to identify a significant area that might serve as a reservoir for a PSP project and to develop a financial model for that location. To provide the importance of hydropower and accept the potential of hydropower projects;

- a) To provide a preliminary model of a possible PSP site based on basic data from desk study in the initial stage of the feasibility project.
- b) Financial model-specific supporting data for investors.

### 1.3 Scope of Study

- a) There are three case studies separated by island region, Luzon, Visayas, and Mindanao.
- b) The study area was divided into 2 sections: geography and regional geology.
- c) PSP design is an open system (1 or 2 reservoirs have to be connected to the natural water).
- d) The elevation between the upper and lower reservoirs is more than 300 m.
- e) The distance between the disaster-risk areas, such as seismicity and the PSP, exceeds 50–100 kilometers, a long distance from the epicenter of an earthquake with seismicity of  $> 7$  magnitudes.
- f) The PSP was not discovered in the active fault and active volcano.
- g) The difference in elevation of the potential reservoir is used to calculate design capacity.
- h) Estimate revenue using a separate electric pricing model for each of the three case studies based on the location's potential.
- i) PSP cost estimates by three components.
  - a. Construction Cost Estimate (CAPEX);
  - b. Costs during operation and maintenance (OPEX).
  - c. And the final cost is Pumping Cost.
- j) The construction period is 5 years.
- k) The concession operating period is 25 years.
- l) Exchange rate: PHP to USD The 4th quarter of 2021 was 50.67 PHP/USD.
- m) The discounted cash flow model for feasibility use 3 indicators;
  - a. Net Present Value: NPV
  - b. Internal Rate of Return: IRR
  - c. Payback Period: PB.

## 1.4 Methodology of Research

- a) Data collection from open sources.
- b) Separate three areas of the island and observe a mapping analysis of the case study to identify high-potential PSP sites.
- c) Feasibility study of PSP's potential by the discounted cash flow model: the DCF Model.
- d) Conclusions and recommendations



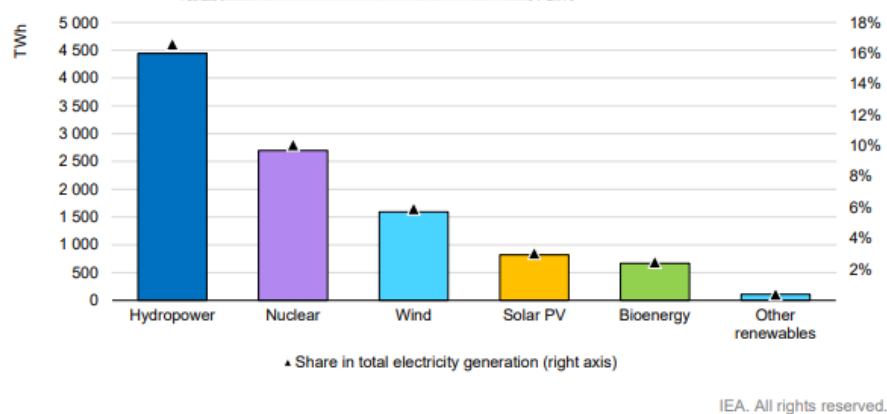
## CHAPTER 2

### LITURATURES REVIEW

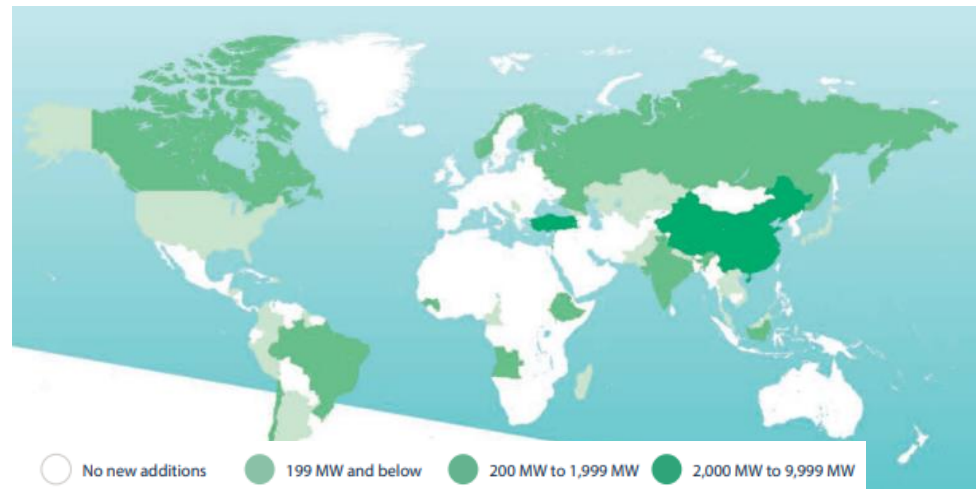
#### 2.1 The Significant of Hydropower

##### 2.1.1 Hydropower Situation in The Global

Many people are interested in renewable energy to reduce carbon emissions this year, 2021. Hydropower is also a sort of renewable energy because it may create electricity from natural sources while emitting only a minimal amount of carbon throughout the process (Figure 4). As shown in Figure 5, a large country with advanced technology is currently in dark green, with additional hydropower projects in places such as China, Canada, the United States, and Russia.



*Figure 4: Low-carbon electricity generation by technology and shares in global electricity supply, 2020. (Source; Hydropower Special Market Report Analysis and forecast to 2030, IEA.)*



*Figure 5: The status of hydropower in the global. (Source : Hydropower Status Report Sector trends and insights, 2021, International Hydropower Association.)*

The advantage of this technology is the ability to control energy by predicting the volume of water. They have a huge volume of water on reserve to supply energy at all times. This technology is distinct from others in the field of renewable energy. Because the water is regulated by the building's structure, and hydropower has a long energy life. As illustrated in Figures 6, the hydropower placed in the locations indicated by black points within the group of areas provided has the longest life, exceeding 60 years, as indicated in red, and the areas with the longest life are North America and Europe. As is well known, both countries have a strong economy and are global leaders in a variety of technologies. In this way, hydropower, which was built a long time ago, can help keep the country's economy and finances strong.

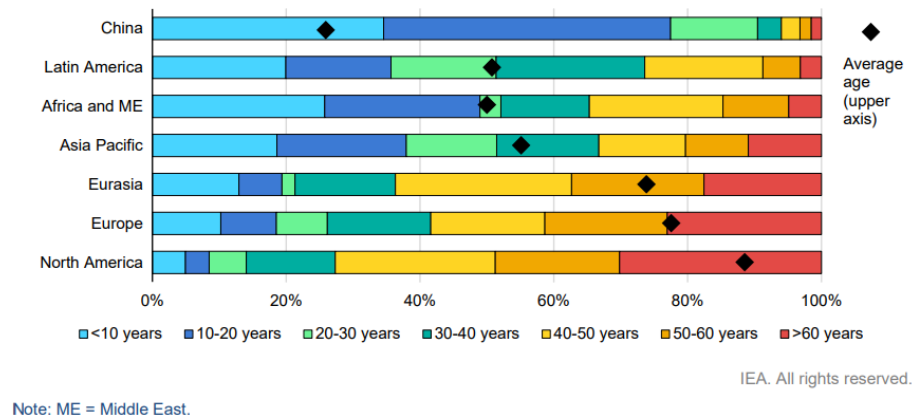
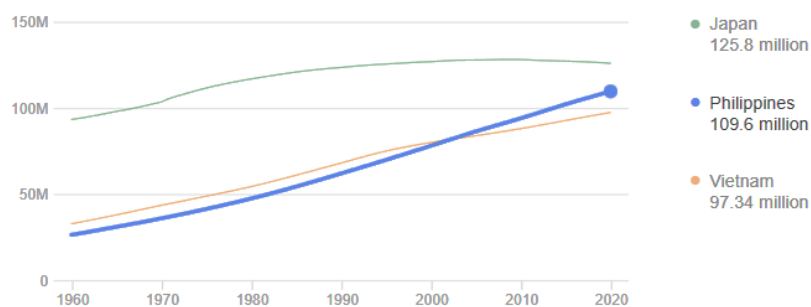


Figure 6: Age profile of installed hydropower capacity, 2020. Source; *Hydropower Special Market Report Analysis and forecast to 2030.*

### 2.1.2 Hydropower Situation in The Global Hydropower Situation in the Philippines

As illustrated in Figure 7 of the "World Bank," the population of the Philippines continues to expand every year. This figure is also related to the amount of energy consumed in the country. The significance of energy in the Philippines is the country's geography. There are islands in the whole country, and they are prevented from purchasing energy from another country, so they must generate their own. Coal, geothermal energy, and hydropower are the primary sources of energy for them. Table 2-1 contains the weekly summary report for the period October 23–29, 2021. It explains that Mindanao is the region with the highest energy reserves, mainly coal and hydropower.





Sources include: World Bank

*Figure 7: The blue line indicates the annual growth rate of the Philippines' population. , 2020.( Source; World Bank)*

*Table 1: The majority of electricity will be generated in October 2021.*

	Luzon	Visayas	Mindanao
<b>Coal</b>	64.43%	56.09%	67.10%
<b>Geothermal</b>	5.23%	35.47%	3.61%
<b>Hydropower</b>	10.33%	0.48%	26.64%

### 2.1.3 Power Sector and Hydropower Development in the Philippines

The National Water Resources Board (NWRB), which is part of the Department of Environment and Natural Resources, is the national authority in charge of the water sector. The electricity transmission system in the Philippines is organized into three primary grids that serve the main islands of Luzon, Visayas, and Mindanao. The National Grid Corporation of the Philippines (NGCP) operates three grids on behalf of the state-owned National Transmission Corporation (TransCo). The Energy Regulatory Commission (ERC).

The Philippines' gross hydropower potential in 2020 is 47,459 GWh/year, whereas the technically possible potential is 20,334 GWh/year. 18184 Gwh/year is the commercially viable potential. Approximately 17% of the technically viable potential has been developed. In light pink, Figure 8, the Philippines is ranked 13th in the SEA (South East Asia) region, with a

total of 20 countries. That result pushed the government to set an ambitious mission of developing an installed renewable energy capacity of at least 20 GW by 2040.



Figure 8: Ranking by installed hydropower capacity. Source; *Hydropower Status Report, 2021* iha (International Hydropower Association).

## 2.2 The Significant of Pump-Storage Hydropower

Pumped storage hydropower (PSH) currently accounts for more than 90% of the world's grid-scale energy storage applications, with 160 GW of installed capacity and 9,000 GWh of energy storage capacity. PSH is a mature and proven technology that can store energy in daily cycles to seasonal storage applications while also providing important grid functions to ensure power system dependability (Source; International Forum on Pumped Storage Hydropower, November 2020). The Table 2 will show the total capacity status of energy and pumped storage hydropower in each country of the world in 2017. According to this data, the country with the most capacity in this technology is Switzerland, as shown in the graph of Figure 9. (Source; [https://en.wikipedia.org/wiki/Pumped-storage\\_hydroelectricity](https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity))

Table 2: Countries with the largest power pumped-storage hydro capacity in 2017.

Country	Pumped storage	Total installed	Pumped storage
	generating capacity	generating capacity	Total generating
	(GW)	(GW)	Capacity
<b>China</b>	32	1646	1.90%
<b>Japan</b>	28.3	322.2	8.80%
<b>United States</b>	22.6	1074	2.10%
<b>Spain</b>	8	106.7	7.50%
<b>Italy</b>	7.1	117	6.10%
<b>India</b>	6.8	308.8	2.20%
<b>Germany</b>	6.5	204.1	3.20%
<b>Switzerland</b>	6.4	19.6	32.60%
<b>France</b>	5.8	129.3	4.50%
<b>Austria</b>	4.7	25.2	18.70%
<b>South Korea</b>	4.7	103	4.60%
<b>Portugal</b>	3.5	19.6	17.80%
<b>Ukraine</b>	3.1	56.9	5.40%
<b>South Africa</b>	2.9	47.3	6.10%
<b>United Kingdom</b>	2.8	94.6	3.00%
<b>Australia</b>	2.6	67	3.90%
<b>Russia</b>	2.2	263.5	0.80%
<b>Poland</b>	1.7	37.3	4.60%
<b>Thailand</b>	1.4	41	3.40%
<b>Belgium</b>	1.2	21.2	5.70%

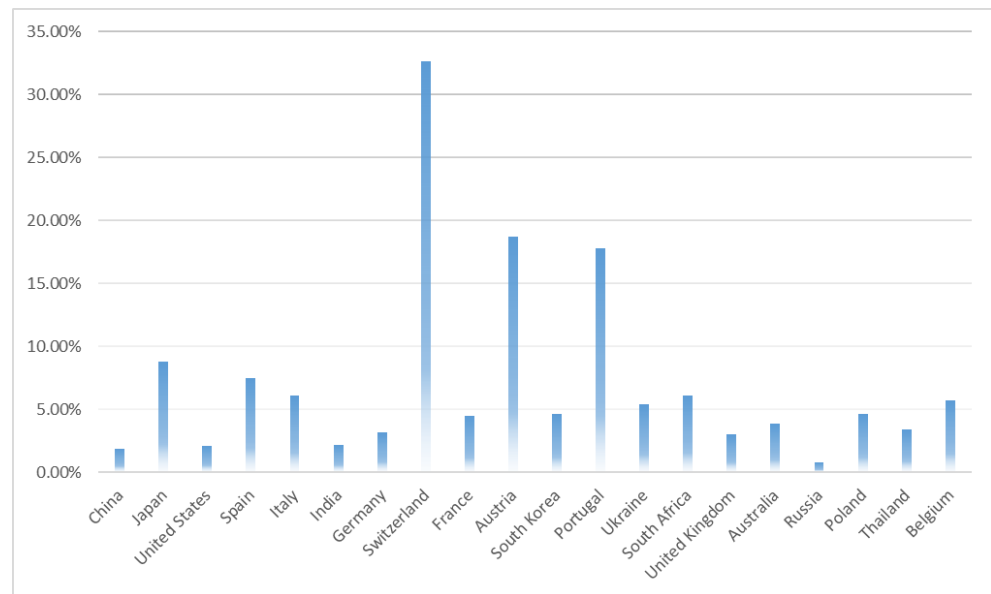


Figure 9: The graph represents the pumped-storage hydropower capacity in 2017.

### 2.2.1 Type of Hydropower Electricity

Hydroelectricity is a type of energy generating that makes use of a turbine's flow of energy through water (Figure 10). Conventional hydropower and pumped storage hydropower are the 2 main type:

- a) **Run-of-river;** Run-of-river systems, in which a turbine is pushed by the force of the river's current. To direct water flow to the hydro turbines, a weir in the water stream may be employed.
- b) **Storage hydropower** is water storage systems in which water accumulates in reservoirs created by constructing dams rivers and streams and is discharged to generate electricity using hydro turbines. (Figure 11).

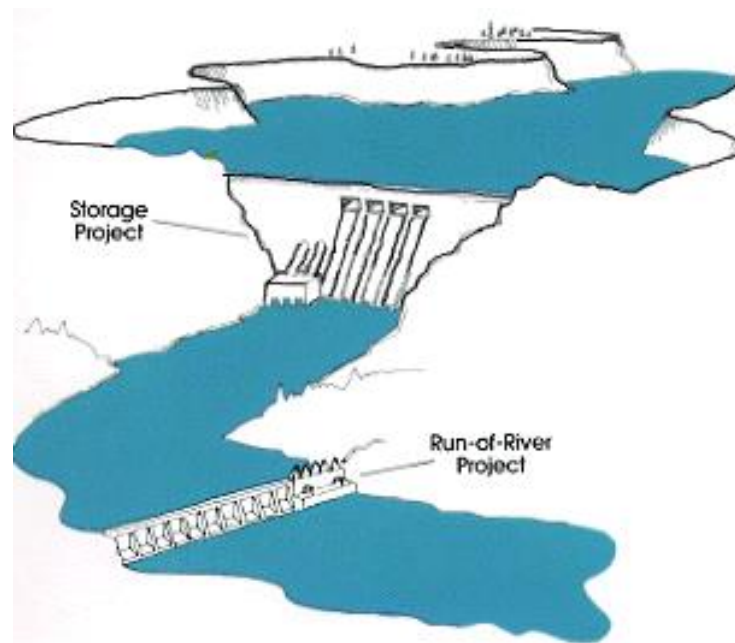


Figure 10: The location of the run-of-river and storage hydropower projects. (Source: FEW)

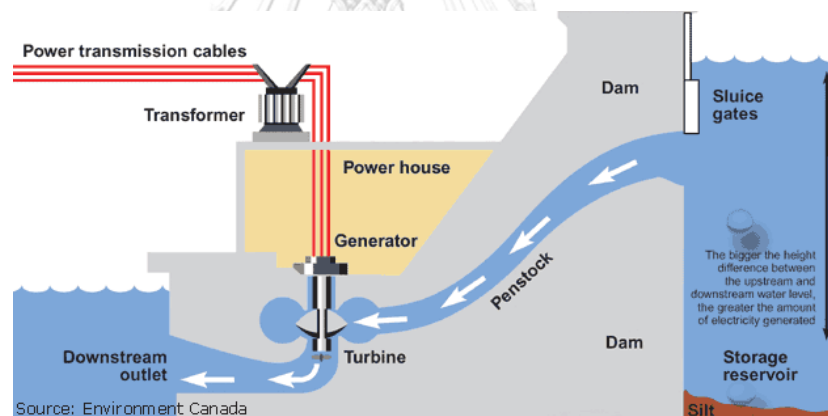


Figure 11: The main component of hydroelectric power, storage system. (Source: Environment Canada)

The pump storage hydropower project (PSP) is a hydro model that developed from the storage system. It generates an electrical system through load balancing and is utilized to store energy in this method. Water's gravitational potential energy is stored in two reservoirs. When power demand is high, water will discharge from the higher reservoir to the lower reservoir, flowing to the turbine to generate electricity, and water will be pumped back from a

lower reservoir to a higher reservoir with a loss of 15–30% of energy when power demand is low. Due to the plant's losses from the pumping process. However, by selling more electricity at peak demand and at times when electricity costs are highest, the plant can be able to enhance its profits.

### 2.2.2 Pump-Storage Hydropower Fundamentals

Pump storage is a reservoir-related technology. The upper and lower reservoirs are separate with various heights, and the lower reservoir may be a river or even the sea.

As shown in Figure 12, the structure is mainly composed of three components: (1) upper reservoir, (2) waterway or tunnel, (3) lower reservoir.

The open system and the closed system are the two types of functioning. The reservoir-connected *open system* is linked to the natural water, river, or seawater. In addition, it is a closed system in which neither reservoir is connected to the natural water source. Because it does not require a nearby reservoir, as would a normal hydroelectric power station, this approach is particularly appropriate for dry areas away from natural water supplies. PSP generates electricity by running a subsurface powerhouse, and water flows down the tunnel system due to gravity. When there isn't a high demand for energy, pump it back up to the upper reservoir.

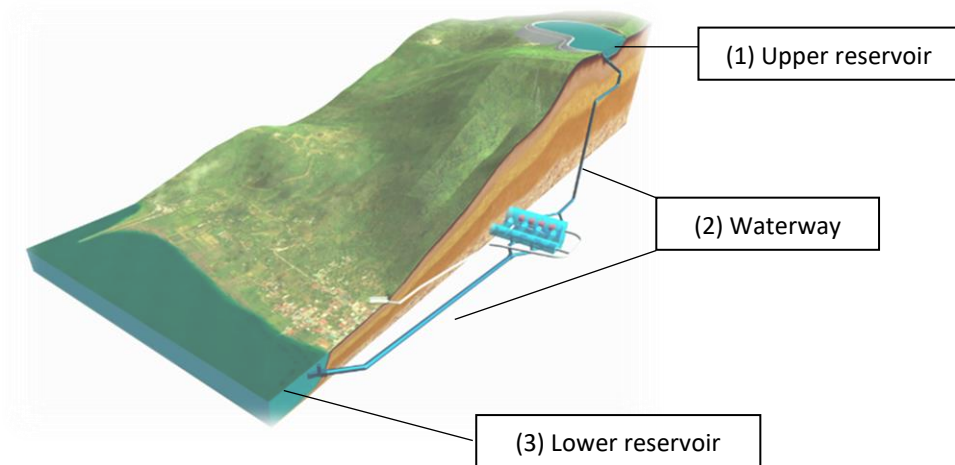


Figure 12: Example 3D model of an PSP open system, which a reservoir is constructed above, as well as a tunnel connected to an underground power plant, and supplied water to the lower natural bay. [3]

#### 2.2.2.1 Energy Storage Capability

The main parameter in the feasibility process is energy capacity, the method of calculation will be based on Kyle Webb [4]. Consider an object's mass ( $m$ ) and elevation ( $h$ ) to calculate the amount of energy that can be stored as potential energy ( $h$ ). The potential increase in energy is ;

$$E = mgh$$

( $g$ ) is gravitational acceleration =  $9.81 \text{ m/s}^2$

As illustrated in Figure 13, lifting the mass necessitates an input of work equal to (or greater than) the mass's energy increase thus, energy must be put into the mass to lift it. This energy is stored in the mass as potential energy.

Allowing the mass to fall to its original height allows us to capture the mass's potential energy. As the mass falls, potential energy is converted to kinetic energy. Kinetic energy can be used to drive machinery. Perhaps rotational energy is converted to electrical energy, which is then converted back to rotational energy.

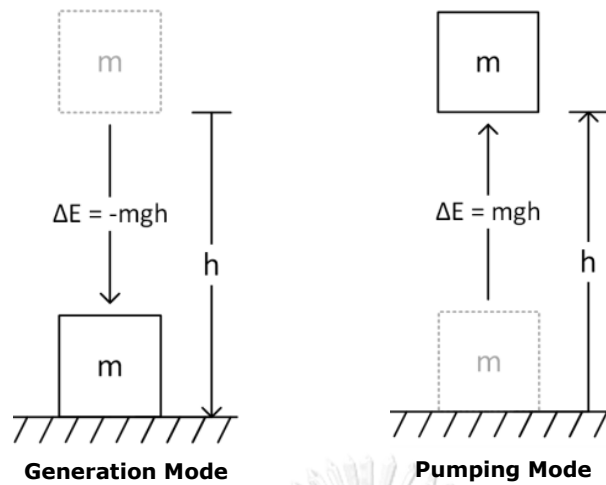


Figure 13: Combining of generation and pumping modes with potential energy.

There is a need to indicate parameters separated by a **height (h)** that is related to the hydraulic head in the storage energy section. Assume that  $h$  is the upper reservoir's depth and  $V_u$  is its capacity to store a volume of water.

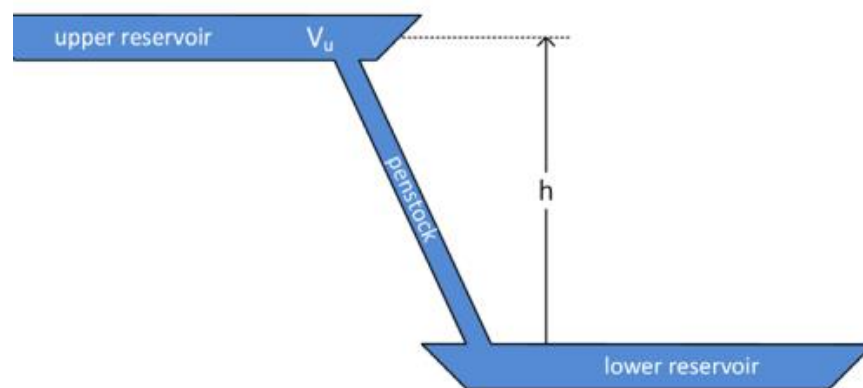


Figure 14: The illustrator of indicator  $h$  and  $V_u$  location.

**Total stored energy ( $E_t$ )** is proportional to the volume of water in the upper reservoir, gravitational acceleration, and elevation height.

$$E_t = mgh = V_u \rho gh$$

where  $\rho$  is the density of water = 1000 kg/m<sup>3</sup>



*Demonstrating that we do, in fact, have energy units*

$$[E_t] = m^3 \frac{kg \ m}{m^3 \ s^2} m = \frac{kg \cdot m}{s^2} m = N \cdot m = J$$

**The energy density ( $e_v$ )** is energy per unit volume of the stored water is;

$$e_v = \frac{E_t}{V_u} = \rho gh$$

*Demonstrating that we do, in fact, have energy units*

$$[e_v] = \frac{kg \ m}{m^3 \ s^2} m = \frac{kg \cdot m^2 \ 1}{s^2 \ m^3} = \frac{J}{m^3}$$

Although it can operate at high pressures, pumped-hydro energy storage (PHES) has a low energy density, necessitating the use of large reservoirs.

**Hydrostatic pressure ( $p$ )** at the level of the lower reservoir;

$$p = \rho gh$$

*Demonstrating that we do, in fact, have energy units*

$$[p] = \frac{kg \ m}{m^3 \ s^2} m = \frac{kg \cdot m}{s^2 \ m^2} = \frac{N}{m^2} = Pa$$

The **power** extracted from (delivered to) the water is the rate at which energy is transferred to the turbine.

$$P = e_v Q = p Q = \rho gh Q$$

Where  $Q$  is the volumetric flow rate of the water (m<sup>3</sup>/s). In the case of PSP, they must consider the diameter of the tunnel waterway. It is, however, outside the scope of this

study because it must be designed by a hydraulic engineer. Instead, in this formula, the author will use  $Q$  from the historical project to calculate power.

*Demonstrating that we do, in fact, have energy units*

$$[P] = \frac{J}{m^3} \frac{m^3}{s} = \frac{J}{s} = W$$

### 2.2.2.2 Pump-Storage Hydropower Plant Configurations

Potential energy storage in raised mass serves as the foundation for pumped-hydro energy storage (PHES), which is the energy utilized to pump water from a lower reservoir to an upper reservoir. Then the motors transform electrical energy into rotating mechanical energy. Pumps deliver energy to the water in the form of kinetic and potential energy. As water flows to the lower reservoir, the energy held in the upper reservoir's water is released. Potential energy is translated to kinetic energy, and falling water's kinetic energy spins a turbine, which turns a generator, which converts mechanical energy to electrical energy. There are three different types of generator/turbine and motor/pump configurations; they are as follows:

**a. Quaternary set,** This type consists of a pump powered by a motor and a generator powered by a turbine, with the pump and turbine completely decoupled. Prior to 1920, this configuration was the most common. It requires expensive equipment and infrastructure, but it can produce high efficiency because the pump and turbine are designed to optimize individual performance.

**b. Ternary set,** This type implements a pump turbine, as well as a motor and generator, all on a single shaft, with the pump and turbine rotating in the same direction. The turbine is rigidly coupled to the motor and generator, and the pump is clutch-coupled to the shaft. This was a popular design from the 1920s to the 1960s. Pump and turbine designs can now be individually

c. **Binary set**, A single reversible pump and turbine are connected to a single motor and generator. Because it is the least expensive configuration and requires the least amount of equipment, it is the most popular configuration for modern PHES. This type of set has a lower efficiency than ternary or quaternary sets. The study will assume that PSP implements this model to save CAPEX.

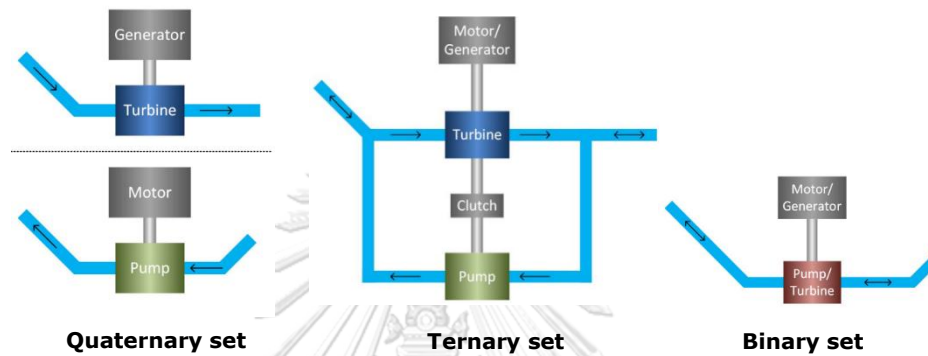


Figure 15: The illustration of the three configurations.

### 2.3 Theory of The Site Selection by Geography and Geology

The main procedure is to map data using a GIS program in order to determine the potential of PSP through public data analysis. The data necessary ;

- Geographical research, in particular topography research, will be given highest priority in the further. Enter the alternative data for each case study to select the optimal location for the research.
- The objective of the geology research on this study is to select the prospective region that is secure from the risks of an active fault, an active volcano, a landslide, and a water leak, even while defining a strong rock unit at the foundation.

### 2.3.1 Pump-Storage Hydropower and Geography

Topographic information is a type of geography information that serves as the foundation for structural design and is required to assess PSP's energy consumption. A PSP type can be built in areas where topographic features allow for the construction of higher and lower reservoirs, as well as where an acceptable head is available. The degree of freedom available for site selection is significant, and a high head location is instantly recognized. The criteria for selecting pumped and natural flow storage sites are nearly identical to those for selecting conventional hydroelectric sites. According to this theory, the Philippines is a good option for PSP because it has an estimated area of 300,000 square meters and it is consisted of islands with varying elevations in different areas, all of which are connected by natural water. That is the benefit for scope of reaseach design will consider in open system of PSP.

### 2.3.2 How to Select a Potential PSP Site Based on Geography

As shown by Kyle Webb [4] comparison calculation of energy density and upper reservoir depth, the project necessitates a high capacity (P), which must be factored into the energy density (ev), which is related to the difference in elevation of the upper reservoir's depth (h). The value of the upper reservoir's depth to energy density, which is the main parameter of energy capacity per one turbine unit, is represented in Table 3.

Table 3: The comparison of PSP's energy density and upper reservoir's depth.

	<b>PHES h = 100 m</b>	<b>PHES h = 500 m</b>	<b>PHES h = 1000 m</b>
<b>Energy Density</b>	0.273	1.36	2.73

From this result the author will use this result for research, assuming that the upper reservoir's depth for the case study needs to be at least 100 m. for a high potential location.

### 2.3.2.1 Potential PSP Location Based on Geography

This step will employ a digital elevation model (DEM) to calculate the head of water by analyzing the elevation of the mountain for the head of the upper reservoir [5]. Also, highlight the area with an elevation of more than 100 meters. GIS algorithms and the software used in QGIS are used to "highlight" the area of headwater with different color shades to generate the map, as the sample study shown in Figure 16. A low-resolution DEM will be used in this study. Because this is a country-wide analysis, it is SRTM resolution 30 m. from Diva [<https://www.diva-gis.org/>]. In the case of a small area, the method will revise the DEM to achieve high accuracy by revising it to a high resolution. This will be excluded from the study because it is beyond the scope of the investigation.

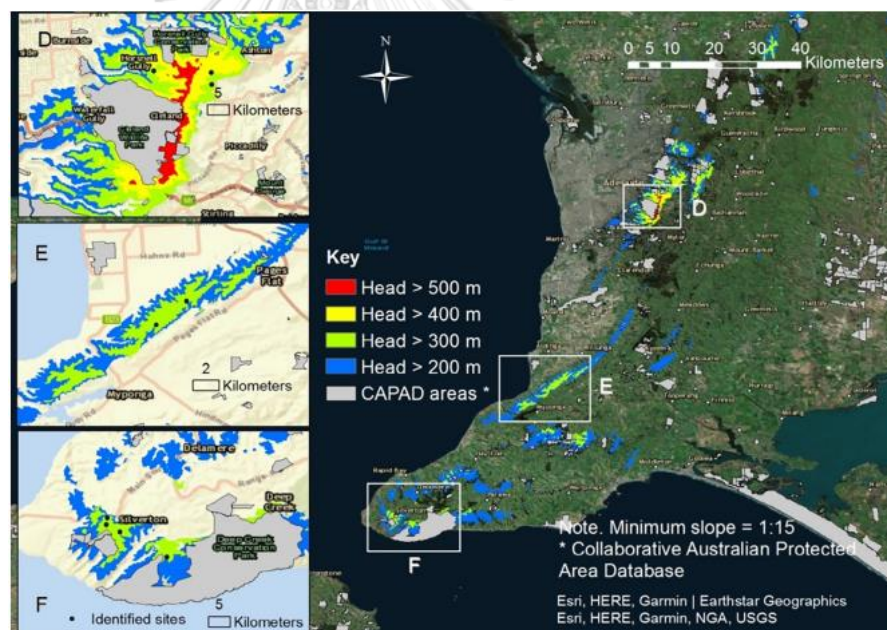


Figure 16: Highlighted promising regions for off-river pumped hydro in Mount Lofty and the Fleurieu Peninsula near the capital city, Adelaide. [5]

### 2.3.3 Optimization of Site Selection by Geology

Geological knowledge is essential even before investors selection or build a hydropower plant. Theoretically, underground work should pose little or no risk to the

surrounding area. Geology is important because it demonstrates how the rock composition of a tunnel, power plant, or reservoir can cause water leakage or how a high-quality rock can serve as an effective construction foundation. Geotechnical engineers in general are required to study geological information prior to beginning work in order to reduce the risk of causing structural damage to the building. As a result, because the leaked water originates in areas of hard rock devoid of karst zones, this process should be considered in areas of hard rock devoid of karst zones. Karst zones are geological formations that can be found in carbonate, limestone, and dolomite rocks [https://www.engineeringarticles.org/factors-affecting-the-selection-of-a-particular-type-of-dam/]. This type of rock is not recommended for foundations, but it is suitable for quarry. Foundations perform better on igneous and hard metamorphic rocks such as granite, gneiss, quartzite, and so on than on sedimentary rocks such as shale, phyllite, slate, and schist.[6]

Operators must carry out a detailed geological investigation. Furthermore, the location should be safe of geohazards such as volcanic eruptions and earthquakes. That is one of the geotechnical issues in the Philippines, because the country is located on the "**Ring of Fire**" a subduction zone where disasters occur on a regular basis, as shown in the red area of Figure 17. As a result, the pumped-storage scheme in the Philippines must be considered in the data history of seismicity records, as well as the sites of active faults and active volcanoes. However, if a firm invests in PSP, other processes such as borehole drilling and geophysical investigations may be required. This project's purpose is to conduct preliminary site assessments.



*Figure 17: The red area marked the location of the "Ring of fire".*

The best locations for PSP will be in geological structures that are stable and competent. As a result, the project should not be located in an earthquake, active fault, or active volcano risk area. This is the process that must be identified by an expert with experience. Because there is no exact number of kilometers between the PSP and the risk area, the author will use an estimate of 20 kilometers. The analysis procedure that will be used to combine all of the data is as follows research design.

#### **2.3.4 Research Design for Site Selection of PSP by Geography and Geology Desktop Study**

The author will use QGIS and Google-Earth programs for GIS data analysis, because they are free software.

a) Visit <https://www.diva-gis.org/> to download a digital elevation model (DEM) as indicated in Figure 18, in tag image file format .tif, and natural reservoir file format .shp. Then import to QGIS, the file will present similar Figure 19.

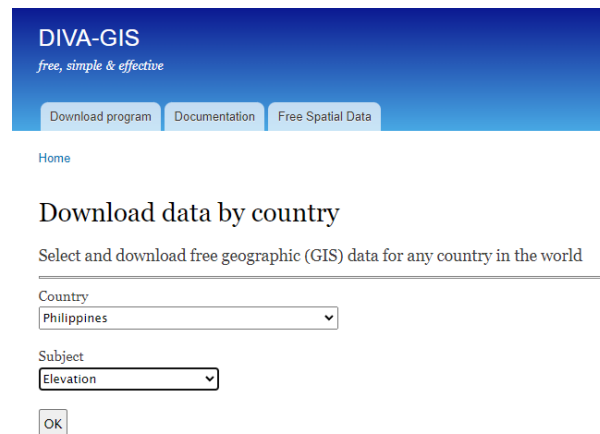


Figure 18: The source of DEM data in Diva website.

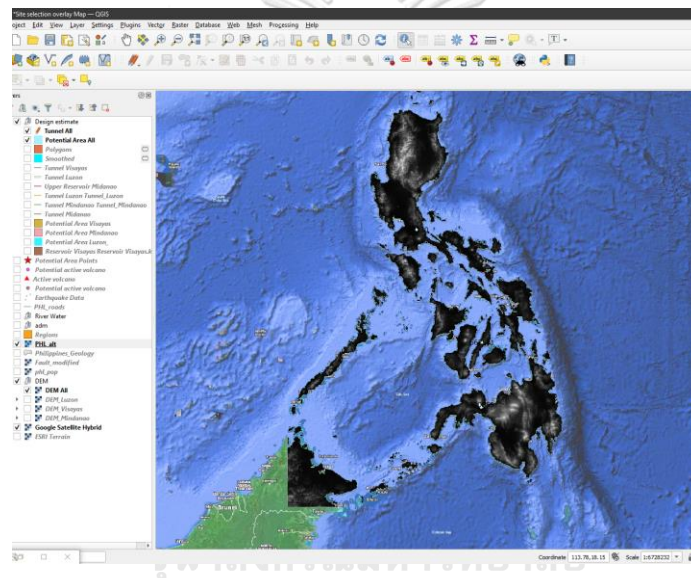


Figure 19: DEM (.tif) input to QGIS program.

b) Use the United States Geological Survey (USGS, Figure 20) to download seismicity data in a comma-separated values (.csv) format file. Collect the data coordinates of the earthquake. csv points with magnitude mag (Figure 21) over a 20-year period (2010 to 2021).



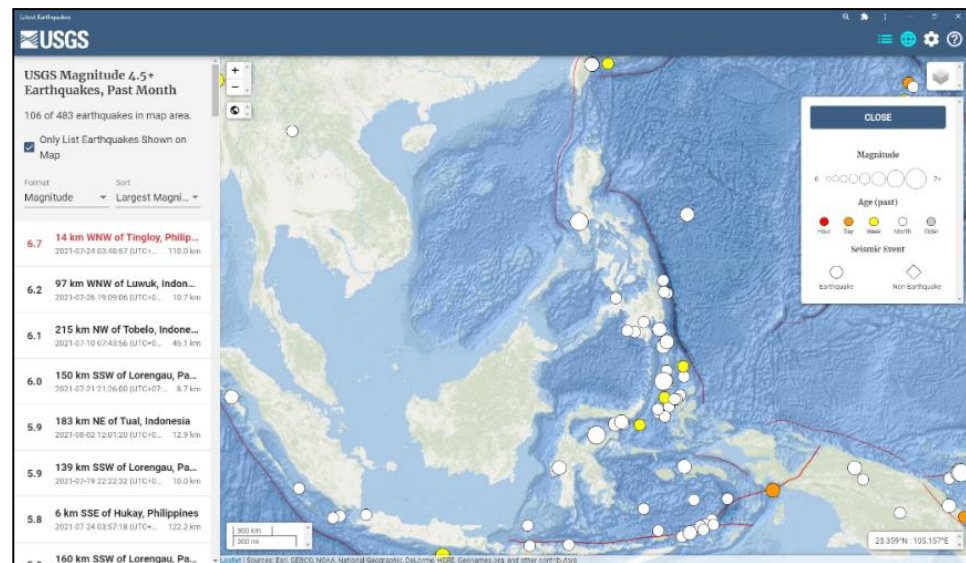


Figure 20: The source of seismic data in USGS website. (Source; Website;

<https://earthquake.usgs.gov/earthquakes/map/>)

time	latitude	longitude	mag
2020-08-25T15:23:18.408Z	4.858	127.5537	4.2
2019-11-17T18:18:17.648Z	4.8592	127.4862	4.5
2005-09-11T19:44:19.200Z	4.86	126.641	4.6
2009-05-17T05:18:04.240Z	4.861	127.577	4.7
2010-04-29T08:48:13.630Z	4.862	126.202	4.3
2015-10-21T11:33:24.610Z	4.8623	126.1898	4.6
2005-11-14T12:39:55.420Z	4.863	123.389	4.6
2008-06-10T15:48:38.900Z	4.867	125.542	4
2014-02-16T12:00:23.940Z	4.8674	126.0434	4.9
2007-08-07T09:49:12.880Z	4.868	125.549	4.6
2002-04-20T17:59:16.210Z	4.868	123.755	4.9
2017-03-28T07:07:43.930Z	4.8682	126.8312	4.7
2006-10-29T15:10:05.440Z	4.869	124.953	4.2
2001-10-21T17:00:34.980Z	4.869	125.507	4.5
2019-10-18T13:18:43.257Z	4.8699	125.2621	4.8
2008-05-31T18:35:32.600Z	4.87	127.646	3.9
2006-04-02T03:20:48.520Z	4.87	127.343	4.1
2013-10-08T21:41:54.130Z	4.874	125.7499	4.3
2009-09-18T00:52:58.840Z	4.875	126.745	4.9

Figure 21: Seismicity (.csv) input to QGIS program.

c) Download the location of regional faults and active volcanoes in the image file format (.tif) from the PHIVOLCS website (Figure 22). Collect fault line data by extracting .tif files and georeferencing them for location in QGIS.

[Website ; https://hazardhunter.georisk.gov.ph/map](https://hazardhunter.georisk.gov.ph/map)

\*\*\*PHIVOLCS is Hazard Hunter PH that is a product of GeoRisk in the Philippines, a multi-agency initiative led by the Philippine Institute of Volcanology and Seismology.

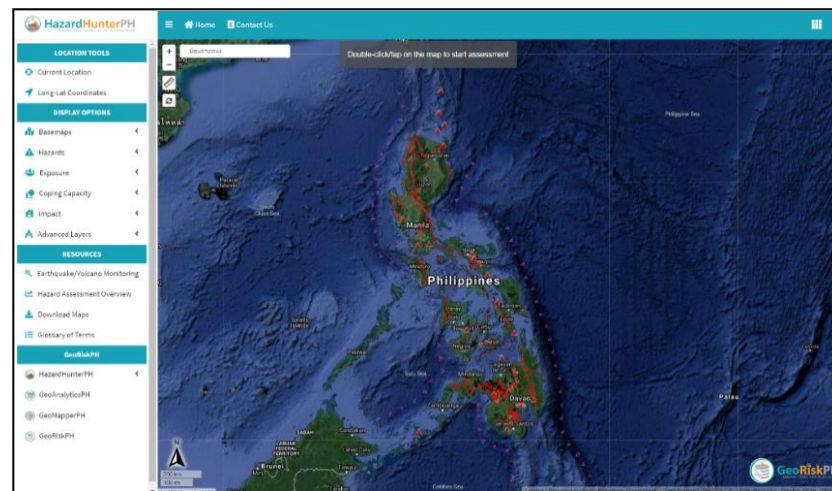


Figure 22: The source of faults and volcanic data in HazardHunterPH website.

d) Download the regional rock unit from OneGeology portal (Figure 23) in shapefile shape format (.shp).

[Website; http://portal.onegeology.org/OnegeologyGlobal/](http://portal.onegeology.org/OnegeologyGlobal/)

\*\*\* OneGeology is providing geoscience data globally, It is a worldwide project of the world's geological surveys, with the support of international organizations, regional organizations, and industrial sponsors, to realize this ambitious and interesting venture.

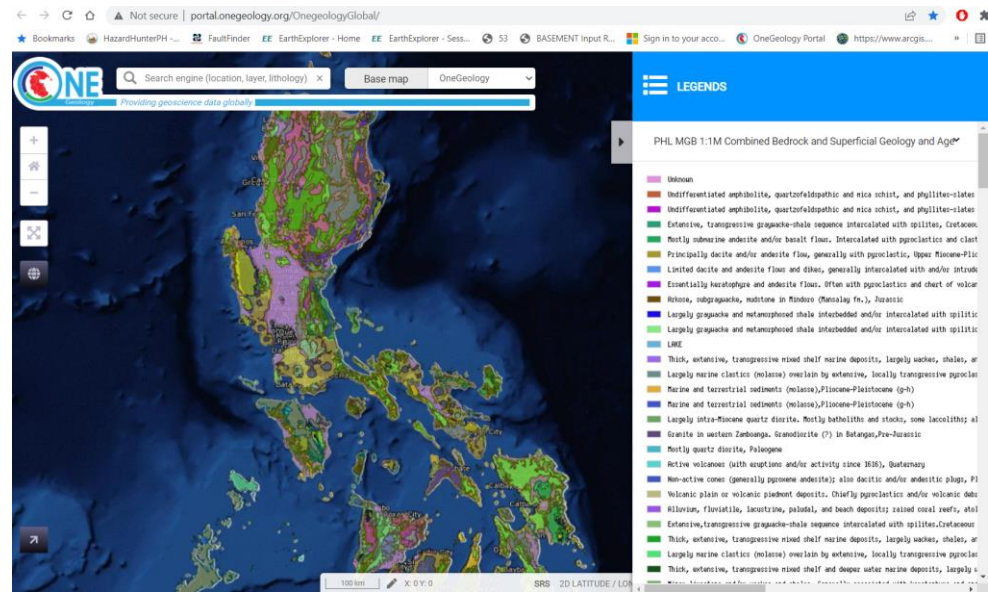


Figure 23: The source of geology rock unit data in OneGeology portal website.

e) Generate seismicity points (.csv) in the QGIS program with difference value of magnitude, The sample earthquake map is represented in Figure 24.

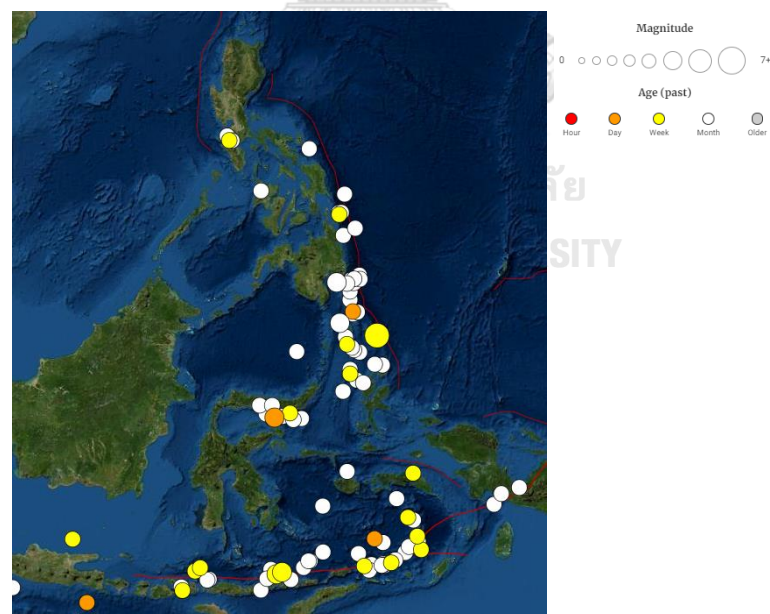


Figure 24: The example of the magnitude of the earthquake map from November 11 to December 11, 2021. (Source: USGS)

f) Start making a georeferenced raster for QGIS to use in order to display active faults as red lines as shown in Figures 25 and active volcano points in red triangles are shown in Figures 26, based on data from the Philippine Institute of Volcanology and Seismology (PHIVOLCS). Additionally, convert the .tif of the volcanic file data map to a .shp file (Points).

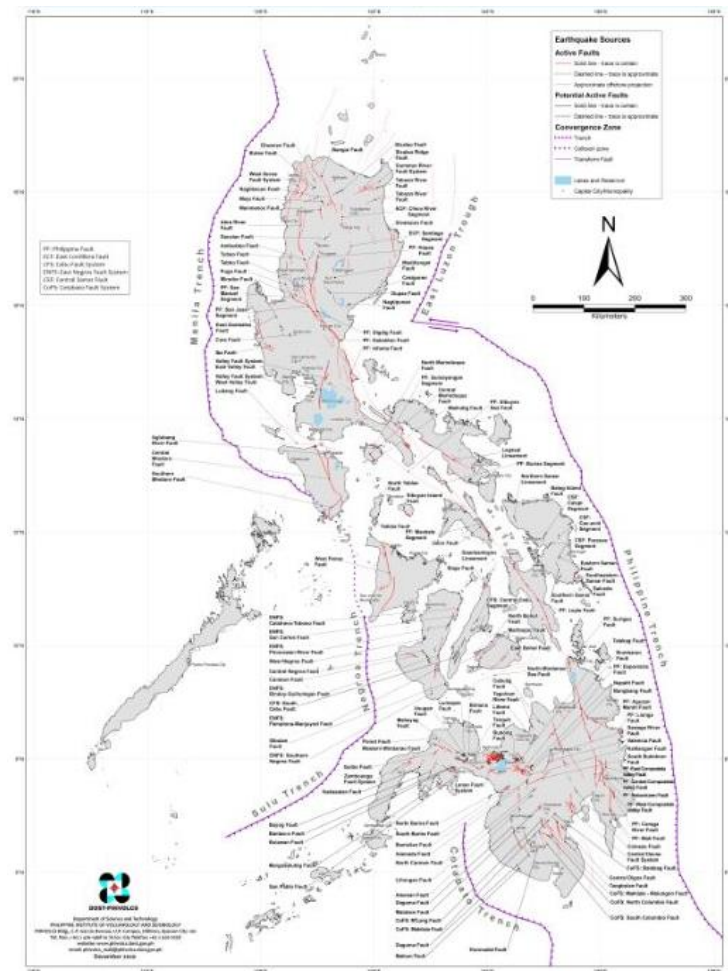


Figure 25: Distribution of active faults and trenches in the Philippines. (Source; PHIVOLCS).

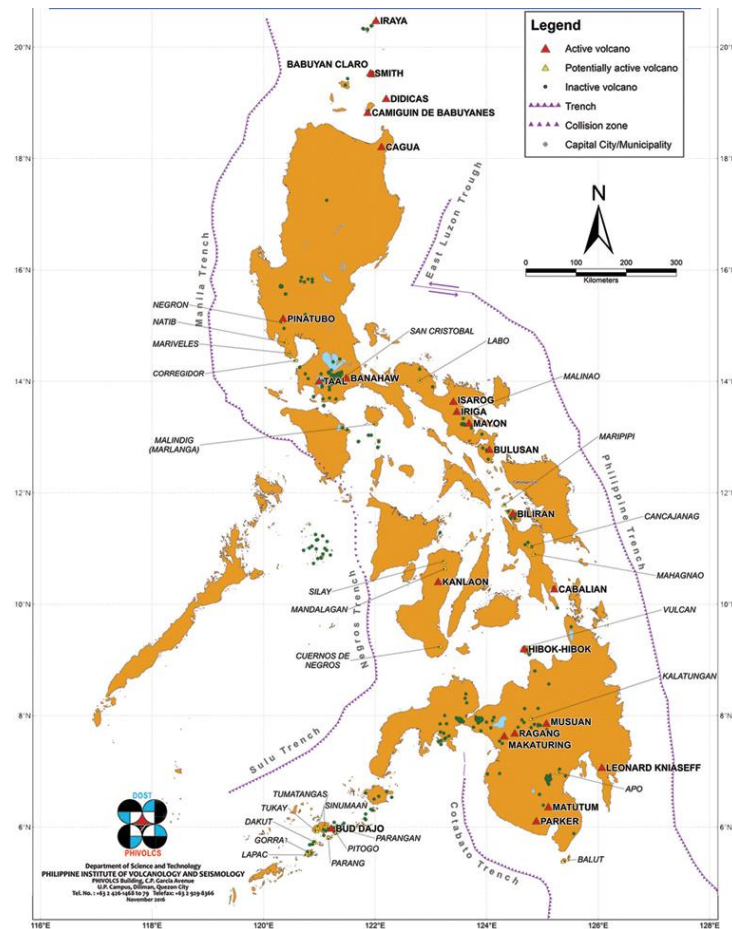


Figure 26: Map of active and potential active volcanoes of the Philippines.

(Source; PHIVOLCS).

g) Overlay all data input to the first map to see if there is a potential area for PSP, given two alternative locations for one case study. PSP's potential is using the parameters listed below;

- Elevation difference from color shade of altitude is completely different, with the lowest being 150 m and the highest being > 700 m.
- The PSP is linked to a natural reservoir.
- The PSP was not found in the fault line.
- 20 kilometers away from seismicity >7 magnitude and volcanic eruption.

h) Create the second map, which is a regional geology rock unit. (Source; ONE Geology) Then enter 2 as an alternative area. The areas are acceptable if they contain granite,

volcanic, or sedimentary rock. If limestone or dolomite is discovered, the alternative area is not acceptable.

i) Compare two alternative areas and select one for each case study to determine the difference in headwater between the upper and lower reservoirs by generating a section along the waterway in the Google Earth program.

All processes will be carried out in accordance with the flowchart depicted in Figure 27.

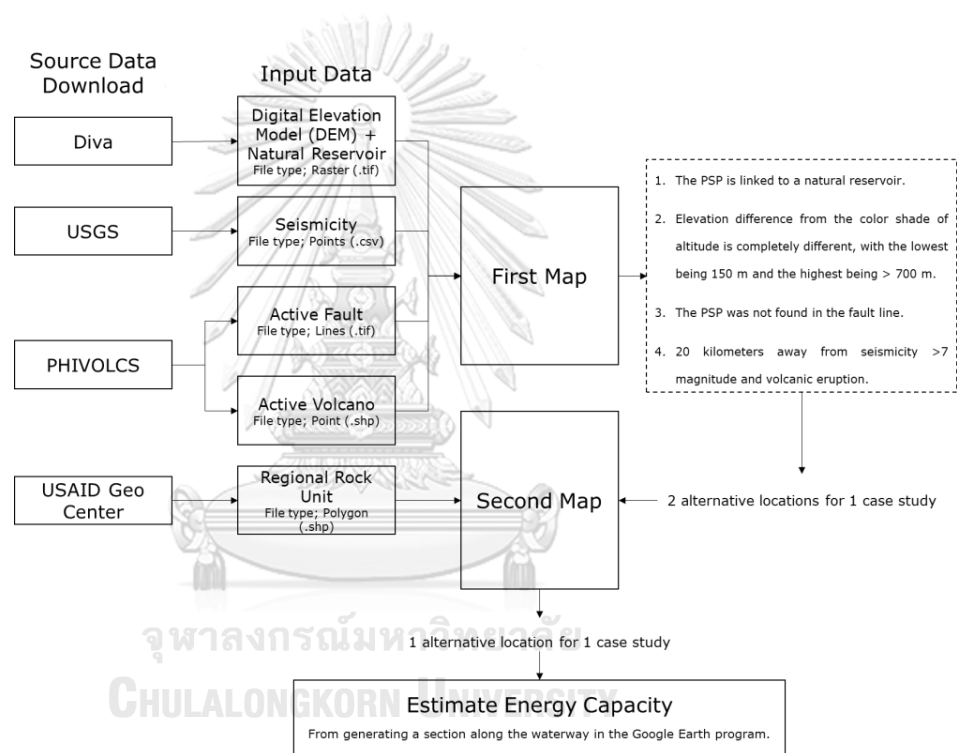


Figure 27: The flowchart of site selection process.

## 2.4 The Electric Price for PSP in the Philippines

The current electricity price in the Philippines is based on the approval given by the Energy Regulatory Commission (ERC) on the FIT-All rate petition of RE fund administrator National Transmission Corporation (TransCo) to account for adjustments in calendar year 2020. The FIT-All increase will be reflected in the bills by January. The regulatory body qualified that compared to TransCo's FIT-All application price of 0.2278 PHP/kwh, the approved subsidy charge is lower by 0.1295 PHP/kwh. But it was a misleading statement because, on consumers' electric bills, the overall impact will still be an uptick from the prevailing FIT-All charge. (PHP is Philippine Peso and FIT is Feed in tariff) The formula for calculating the "FIT-All" rate is as follows:

$$FIT \text{ All Rate (PHP/kWh)} = [FIT \text{ Differential (FD)} + Working \text{ Capital Allowance (WCA)} + Administration \text{ Allowance (AA)} + Disbursement \text{ Allowance (DA)}] / Forecast \text{ National Sales (FNS)}$$

However, the FIT-All theory cannot be applied to pump-storage hydropower because this technology is dependent on electric prices with 24-hour timing, generating power for consumers during peak and non-peak hours. So, for the author's research, the data available providing the total price per renewable energy sector, including the whole country rate per day in FIT-All, cannot be calculated by the number of hours required by the PSP.

The only source of electric prices that can be calculated for PSP is the data of ERC provisionally approved rates on February 16, 2009. Table 4, for example, show price data for different times of the year in Luzon.

Table 4: Electric price of LUZON grid on February 16, 2009.

<b>LUZON GRID</b> (in PHP/kWh)				
<b>PERIOD</b>	<b>(JANUARY - JUNE)</b>		<b>(JULY - DECEMBER)</b>	
	<b>Monday - Saturday</b>	<b>Sunday/ Holiday</b>	<b>Monday - Saturday</b>	<b>Sunday/ Holiday</b>
<b>1:00 AM</b>	2.3426	2.5022	2.3426	2.3426
<b>2:00 AM</b>	2.3426	2.3426	2.3426	2.3426
<b>3:00 AM</b>	2.3426	2.3426	2.3426	2.3426
<b>4:00 AM</b>	2.3426	2.3426	2.3426	1.8649
<b>5:00 AM</b>	2.3426	2.3426	2.3426	1.8649
<b>6:00 AM</b>	2.3426	2.3426	2.3426	1.8649
<b>7:00 AM</b>	2.3426	2.3426	2.3426	1.8649
<b>8:00 AM</b>	2.6256	2.3426	2.5022	2.3426
<b>9:00 AM</b>	5.779	2.3426	2.6256	2.3426
<b>10:00 AM</b>	6.5283	2.5022	5.9872	2.5022
<b>11:00 AM</b>	6.5283	2.5022	6.5283	2.5022
<b>12:00 PM</b>	6.5283	2.5022	5.9872	2.5022
<b>1:00 PM</b>	6.5283	2.5022	5.9872	2.5022
<b>2:00 PM</b>	6.5283	2.5022	6.5283	2.5022
<b>3:00 PM</b>	6.5283	2.5022	5.9872	2.5022
<b>4:00 PM</b>	6.5283	2.5022	5.779	2.5022
<b>5:00 PM</b>	5.9872	2.5022	5.5481	2.5022
<b>6:00 PM</b>	5.9872	2.5022	5.9872	2.6256
<b>7:00 PM</b>	6.5283	5.779	6.5283	5.5481
<b>8:00 PM</b>	6.5283	5.779	5.9872	5.5481
<b>9:00 PM</b>	5.9872	3.2594	5.779	2.6256
<b>10:00 PM</b>	3.2594	2.6256	2.6256	2.5022
<b>11:00 PM</b>	2.6256	2.5022	2.5022	2.3426
<b>12:00 AM</b>	2.5022	2.3426	2.3426	2.3426

Following Table 4, we can assume peak and non-peak hours to estimate revenue and consumption prices for pumping. Example, Peak hours are assumed to be 9:00 a.m. to 10:00 p.m. and the average electric sale price is 4.501 PHP/kWh, with non-peak hours ranging from 10:00 p.m. to 9:00 a.m. and the average cost of electricity is 2.416 PHP/kWh. Then, using this result, compute revenue and cost.

Because the global price of electricity is USD/kWh, we must also consider the exchange rate when calculating.



## 2.5 Tax of the Philippines

For both domestic and resident foreign corporations, the corporate income tax rate is 30% on net taxable income. Dividends from domestic corporations, interest on Philippine currency bank deposits, and trust fund yield are all tax-free. It is critical to understand that foreign corporations, whether resident or nonresident, are only taxed on income earned in the Philippines. [7]

Developers of Renewable Energy facilities, including hybrid and cogeneration systems that use both RE and conventional energy, for both power and non-power purposes, may be eligible for the following incentives if certified by the DOE under the Renewable Energy Act of 2008. Developers of Renewable Energy facilities, including hybrid and cogeneration systems that use both RE and conventional energy, for both power and non-power purposes, may be eligible for the following incentives if certified by the DOE under the Renewable Energy Act of 2008.

- a) Income tax holiday for 7 years.
- b) Duty-free importation of RE machinery, equipment and materials including control and communication equipment.
- c) Special realty tax rates on equipment and machinery not exceeding 1.5% of their original cost less accumulated normal depreciation or net book value.
- d) Net operational loss not previously deducted from gross income during the first 3 years of commercial operation shall be carried over as a deduction from gross income for the next 7 consecutive taxable years immediately following the year of such loss.
- e) Corporate tax rate of 10% on its net taxable income after 7 years.
- f) Accelerated depreciation of plant, machinery and equipment may be applied if the project fails to receive an ITH before full operation.

**g)** 0% Value-Added Tax rate on the sale of fuel or power generated from RE sources. Zero rated VAT on purchases of local supply of goods, properties and services needed by RE developers in the development, construction and installation of its plant facility as well as the exploration and development of RE resources and its conversion into power.

**h)** Tax exemption on carbon credits.

**i)** Cash incentive of Renewable Energy developers for Missionary Electrification. A cash generation-based incentive per kilowatt hour equivalent to 50% of the universal charge for the power needed to service missionary areas chargeable against the universal charge for missionary electrification.

**j)** Tax credit on domestic capital equipment and services.

**k)** Exemption from universal charge.

**l)** Option to pay transmission and wheeling fees per kilowatt-hour at the same rate as all other electricity transmitted through the grid. Option to pay transmission and wheeling fees per kilowatt-hour at the same rate as all other electricity transmitted through the grid. \*\*\* This step is not included in this study because it is the preliminary stage.

## **2.6 Discounted Cash Flow Model (DCF Model)**

By analyzing and evaluating financial and investment returns, we can determine the value of a project. The following factors and principles are commonly used to evaluate investment suitability.

### **2.6.1 Cash flow**

#### **2.6.1.1 Cash Inflow**

The revenue generated by the operation pattern must be calculated using the daily electricity price projection. That is, the prices must be assessed (day-ahead pricing) for each day of this time period, and the daily operation pattern must be defined. The revenue will be calculated by the annual generation hours (hrs/year), the annual energy

generation (GWh/year) for the result of energy sales (M USD), and the formula as shown in the following step;

- a) Formula for annual generation hours;

$$\text{Annual generation hours (hrs/year)} = \text{Generation hour per day} \times 365 \times \text{Availability Rate}$$

- b) Calculate annual energy generation per year using the parameters of personal consumption, capacity, and annual generation hours.

- The assumption of own-consumption (M USD) is the additional cost incurred after the PSP plant uses its own energy during the operating phase, accounting for approximately 1.5 percent of revenues and pumping costs.

$$\text{Annual energy generation} = \text{Annual generation hours} \times \text{Capacity} \times (1 - \text{own-consumption}) / 1000$$

- c) The final process is the annual price of revenue energy or energy sales (M USD). This is calculated using annual energy generation and peak hour of electric price. The formula is;

$$\begin{array}{l} \text{Energy sales} = \text{Annual energy generation} \times \text{electric price on peak hour} \\ \text{(M USD)} \qquad \qquad \qquad \text{(GWh/year)} \qquad \qquad \qquad \text{(USD/kWh)} \end{array}$$

### 2.6.1.2 Cash Outflow

In the preliminary stage, we can calculate three types of cash outflows: construction Cost Estimate (CAPEX), costs during operation and maintenance (OPEX), and pumping costs.

#### a) CAPEX (Construction Cost Estimate)

CAPEX is the cost of construction, which necessitates a variety of cost estimation methodologies. The majority of the construction costs were estimated from the ground up, with the resources required for various activities identified and costed using current

prices, supplemented by obtaining cost estimates from suppliers and subcontractors for various items where possible. This included the supply and installation of electro-mechanical equipment, with these major costs also being compared to historical data and current industry rates [3]. The cost estimate includes both direct and indirect construction costs and includes the following major sections and components in Table 5.

Table 5: Components of direct and indirect construction costs.

Type of CAPEX	Group of Work	Description
<b>Direct Cost</b>	Civil Works	Site Development
		Upper Pond
		Pressure tunnel
		Tailrace Tunnel
		Intake Lower Reservoir
	Hydromechanical Works	Power Cavern
		Contingencies
		HM in Gate chamber
		Penstock and steel liner
	Electromechanical Works	Gates and trash rack lower intake
		Contingency HM
		Generating equipment E&M
		Switchyard
		Transmission line (TL)
	<b>Indirect Cost</b>	Contingency EM
Client Administration (5% of total direct costs)		
Engineering, Site Supervision (5% of total direct costs)		
Detailed Design (3% of total direct costs)		
Land Acquisition and EIA Cost		
Project Development Cost		
Insurance (2% of total direct costs)		
Other Business Expenses (2% of total direct costs)		
Interest during Construction (IDC) (17.52% of total direct costs)		

**b) OPEX (Costs during operation and maintenance)**

Operation and Maintenance (O&M) costs comprise the total annual expenditure incurred during the operation of the project. O&M costs are split into:

- Fixed O&M costs: Fixed operating expenses related to the type and size of the plant only, but not related to the output.

- Variable O&M costs: Expenses depend on the output of the plant.

In comparison to fixed O&M costs, variable O&M costs for hydropower plants are relatively low. Cost components for regular operation and maintenance, overhauls, staff, management and administration, and insurance and fees are typically included in O&M costs, as shown in Table 6.

Table 6: Components of costs during operation and maintenance

Type of OPEX	Description
<b>Cost Item</b>	Cost of O&M (without overhauls)
	Staff Cost
	Administration and Management
	Insurances and Fees
<b>Cost for overhauls (Maintenance)</b>	Major overhaul (every 6 years) = 1.3% of CAPEX for Generating E&M Equipment
	Minor overhaul (every 12 years) = 3.7% of CAPEX for E&M Equipment

### c) Pumping cost

The other cost is pumping cost is the PSP consumer energy for storage water to upper reservoir. The pumping cost will be calculated by the pumping hours (hrs/year), the annual energy consumer (GWh/year) for the result of pumping cost (M USD), and the formula as shown in the following step[3];

#### I. Formula for annual pumping hours;

$$\text{Annual pumping hours (hrs/year)} = \text{Pumping hour per day} \times 365 \times \text{Availability Rate}$$

II. Calculate annual energy pumping per year using the parameters of personal consumption, capacity, and annual pumping hours.

- The assumption of own-consumption (M USD) is the additional cost incurred after the PSP plant uses its own energy during the operating phase, accounting for approximately 1.5 percent of revenues and pumping costs.

$$\text{Annual energy pumping} = \text{Annual pumping hours} \times \text{Capacity} \times (1 - \text{own-consumption}) / 1000$$

III. The final process is the annual price of consumer energy or pumping costs (M USD). This is calculated using annual energy pumping and non-peak hour electricity prices. The formula is;

$$\begin{array}{l} \text{Pumping costs} = \text{Annual energy pumping} \times \text{electric price on non-peak hour} \\ \text{(M USD)} \qquad \qquad \qquad \text{(GWh/year)} \qquad \qquad \qquad \text{(USD/kWh)} \end{array}$$

### 2.6.2 Discounted Rate

Money's value depreciates over time because it can be invested to create value, and there is an opportunity cost if it is not invested. As a result, the discount rate is a tool used to determine the present value of money until the value of money continues to fall. This is an important part of the valuation process because it considers the present value. The following are the most common discount rate calculations. The Weighted Average Cost of Capital (WACC) is used to calculate the discount rate based on the cost structure of borrowing, equity costs, and tax rates. Following the previous project [3], the researchers will apply **WACC 9 %**.

### 2.6.3 Net Present Value (NPV)

Net Present Value (NPV) is used to determine whether or not to make a profit. This method calculates the difference between the target of the projected profit and the rate of return, and the necessary step can be computed using the following equation.

$$NPV = \sum_{t=0}^n \frac{(B_t - C_t)}{(1 + r)^t}$$

Where;

$B_t$  : The benefit of the project in year (t)

$C_t$  : The cost of the project in year (t)

$r$  : Discount Rate

$n$  : Concession year of the project

$t$  : Calculated year

By considering investments from the results of NPV as follows:

$NPV > 0$  : Able to invest the return on investment is greater.

$NPV = 0$  : Just enough breakeven, should consider other factors besides money.

$NPV < 0$  : Should be avoided The return on investment is less.

#### 2.6.4 Internal Rate of Return (IRR)

Internal Rate of Return (IRR); is the computation of the return rate on a project's investment. This rate of return is the rate at which the net present value equals zero or the return equals the initial investment. The following equation can be used to calculate it;

$$\sum_{t=0}^n \frac{(B_t - C_t)}{(1 + IRR)^t} = 0$$

Where;

IRR : Internal Rate of Return

$B_t$  : The benefit of the project in year (t)

$C_t$  : The cost of the project in year (t)

$r$  : Discount Rate

$n$  : Concession year of the project

$t$  : Calculated year

By considering investments from the results of IRR as follows:

$IRR > r$  : Investment in that project should be made.

$IRR < r$  : investment in that project should be rejected.

### 2.6.5 Payback Period (PB)

The payback period (PB) of an investment is the amount of time it takes for the investment to break even, or the period of time during which the net return on investment equals the amount of money invested in the project. Due to the fact that this method does not consider the time value of money, PB can be calculated as follows:

For the first way, calculate payback period by using the following formula:

$$\text{Payback Period} = \text{Initial Outlay} / \text{Cash Flow}$$

In this case, if the cash flows are uneven, we can use the second formula to calculate the payback period:

$$\text{Payback Period} = \text{Full Years Until Recovery} + (\text{Uncovered Cost at the Beginning of the Recovery Year} / \text{Cash Flow During the Recovery Year})$$



## 2.7 Related Literatures

Hydroelectric power plants are a sustainable source of renewable energy. And energy demand in Southeast Asia is expected to grow more than 60% of energy demand and in ASEAN it will be the world's fourth-largest energy consumer by 2030, according to Chamorro & McNulty (2018). Especially in countries with economic growth above 5%, sooner or later has higher annual electricity demand than available energy. Urbanization and supply chain shifts, there will be an increase in energy consumption over the next 20 years, which hydropower plants are expected to play a key role in this development.

According to the “ASEAN Connectivity Master Plan 2025,” Gnanasagaran (2018), the hydropower investment potential in the ASEAN region is projected at \$ 90 billion (ASEAN 2016). Myanmar's potential is estimated to be 108 GW, whereas Lao PDR's is estimated to be 18 GW (without the main Mekong River project).

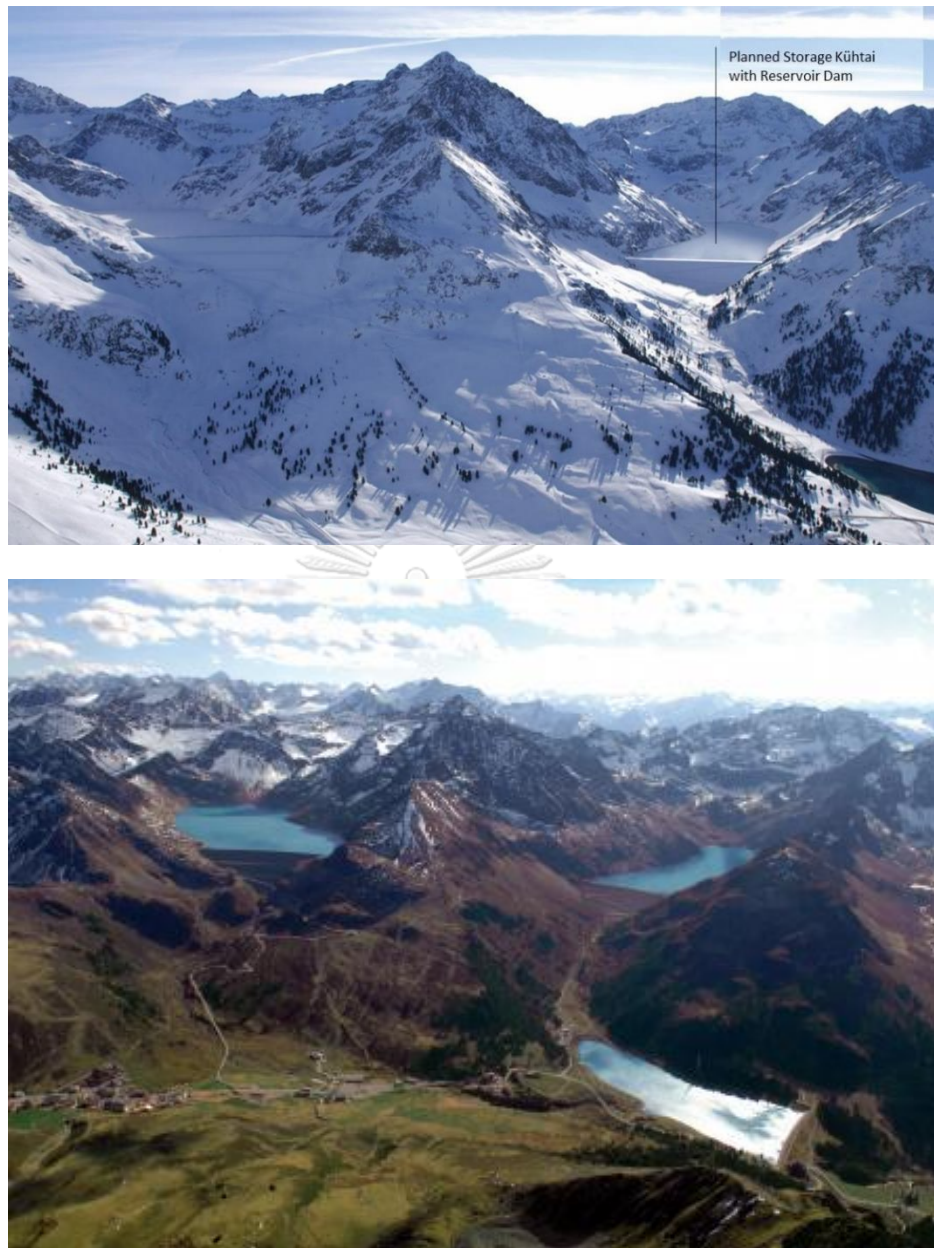
Despite significant investment costs and hazards (Ansar et al., 2014), hydropower power has historically produced the lowest cost of power when compared to other IRENA technologies (2017). Future investors are predicted to continue interested in hydroelectric electricity. The hydroelectric power plant project, on the other hand, provides additional problems in addition to increased development and operation expenses, as well as technical hurdles. For example, remote places require hydrological, geological, and topographic conditions, including earthquake-prone zones. There are also social and environmental considerations to consider (Ansar et al, 2014). It is a significant factor before beginning any hydroelectric project.

Many people are controversial and unacceptable in investing in large-scale hydroelectric projects. Because it is the world's largest hydroelectric power facility. It can also control the energy amount at all times to make it more efficient in the required time to create

big quantities of electricity. Hydropower plants are therefore still required and needed up to now.

The demand for backup power is growing popular in transport and many industries, and this PSP project is one of the largest backup power projects, also known as Hydropower Pump Storage.

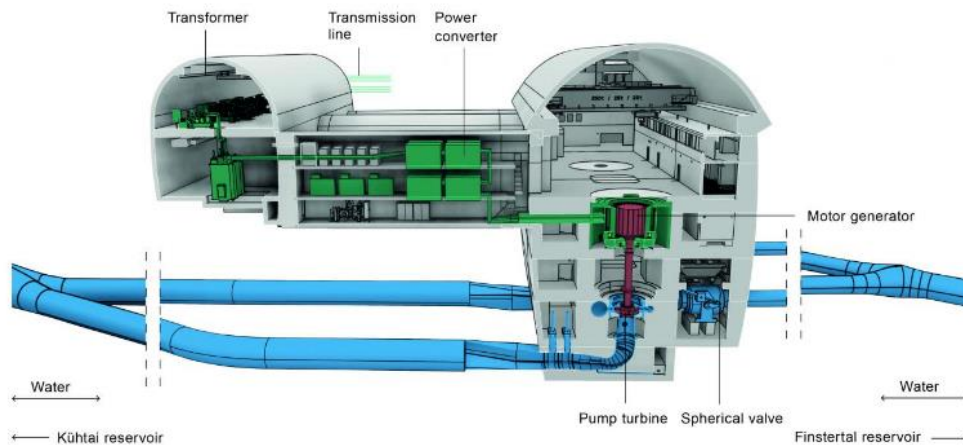
The hydroelectric plant project PSP-type Kühtai shows Figure 28 in Switzerland with a capacity of about 31 million cubic meters. The system is approx. 25 km from Kühtai's back Stubai valley, 68 km<sup>2</sup> of the catchment area, and 260 GWh/year of generation of electricity from Inflow. It is a project involving two power stations from two previous reservoirs. The second power plant's extra retention capacity enhances flexibility and improves overall system performance. The bigger the volume of water available, the longer it can create energy.



*Figure 28: The PSP project area under construction named Project Kühtai, Above figure: PSP site in winter season, Bottom figure: PSP site in summer season.*

The PSP project "Kühtai" is not only capable of storing water for pump circulation. However, retaining water in the rear valley permits 260 kWh of energy to be produced only from the natural flow of water.

PSP's underground structures, as shown in Figure 29, include power converters (green color), waterway tunnels (blue color), turbines and motors (red color), and so on.



*Figure 29: An example of the underground power plant of the Kühtai PSP project, shown in 3D form, encompassing the main components of the power plant underground construction.*

Another challenge of pumped storage plants is that they can operate with seawater, though there are additional challenges when compared to fresh water, such as saltwater corrosion and barnacle growth. The 240 MW Rance tidal power station in France, which was inaugurated in 1966, can partially function as a pumped-storage station. When high tides occur during non-peak hours, the turbines can be used to pump more seawater into the reservoir than the high tide would have brought in naturally. It is the world's only large-scale power plant of its type. In 1999, Okinawa's 30 MW Yanbaru project was the first demonstration of seawater pumped storage. It was later decommissioned. A 300 MW seawater-based Lanai Pumped Storage Project for Lanai, Hawaii, has been considered, and seawater-based projects have been proposed in Ireland. A pair of proposed projects in northern Chile's Atacama Desert would use 600 MW of photovoltaic solar (Skies of Tarapacá) and 300 MW of pumped storage (Mirror of Tarapacá) to raise seawater 600 meters up a coastal cliff.

The most significant stage in the establishment of a PSP is site selection through preliminary area screening and appraisal of suitability based on fundamental criteria, engineering design, and budgets. Because it necessitates working with enormous volumes of spatial data while adhering to many rules and limitations, this procedure is challenging and complex. There is an enormous amount of data and some factors for PSHP site selection that make decision-making much more difficult. It is probable that the traditional method will leave out some places that are inaccessible or unvisitable.



## CHAPTER 3

### METHODOLOGY AND RESULT

The general process of work is to follow to the flowchart as a Figure 30. The methodology focuses on site selection by mapping the collected data and analysis of the potential site to PSP capacity separately for three case scenarios that follow the Island region. Then, using the data of each scenario analysis of the feasibility of PSP by estimating energy and revenue before using the discounted cash flow model (DCF).

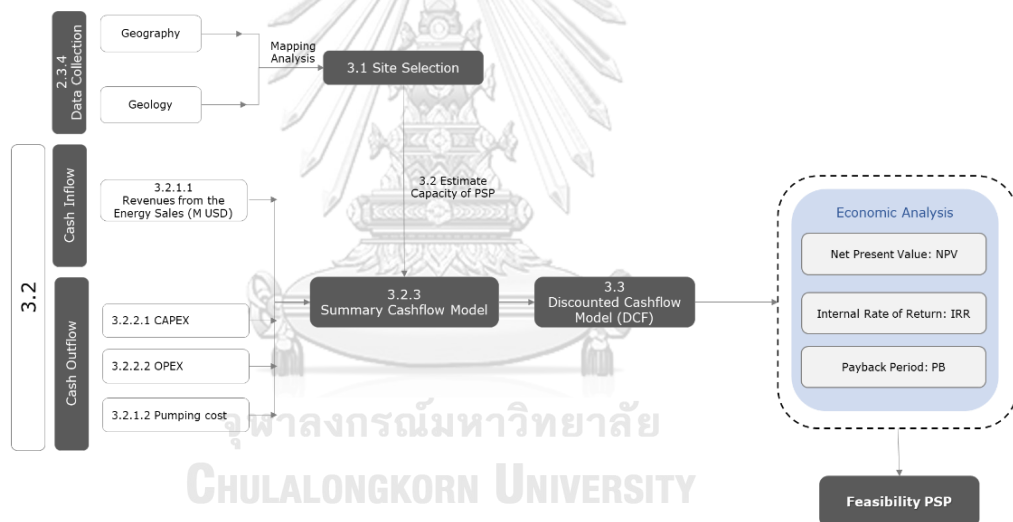


Figure 30: A flowchart of the whole research methodology.

The research will be separate to 2 parts of “Site selection” by geography with parameter of topography. And optimization the area by including geology with parameter of seismicity, fault, volcanic, and rock unit as step in Figure 31. Determine mapping of each parameter and select the potential site by GIS program.

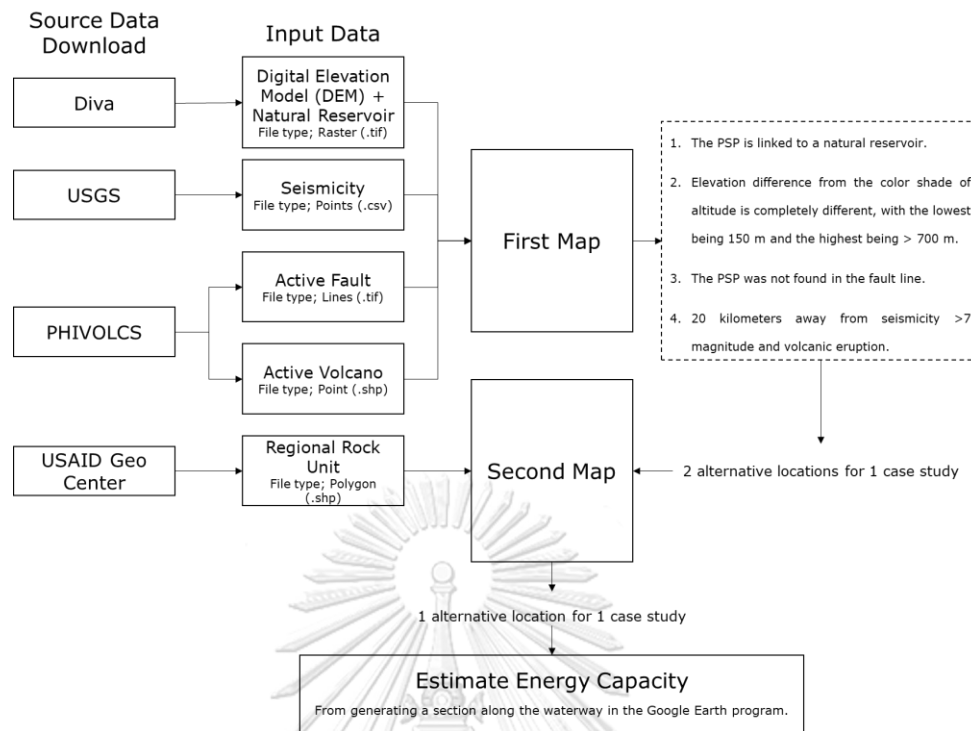


Figure 31: The flowchart of site selection process.

After collecting the data as shown in Figure 31, the data must be put into the WGS 1984 coordinate system (Lat/Lon) to overlay all the data before generating the first and second maps. The details of this step are provided in 2.3.4.

## 3.1 Site Selection Analysis

### 3.1.1 First Map - Overlay Geography and Risk of Geo-Hazard

#### 3.1.1.1 Case Study Area 1 – Luzon

This region is in the Philippines' north, where there is a large number of the country's population, and natural reservoirs are indicated by a dark blue polygon. Alternative site selections are shown as black rectangular A and B. As shown in Figure 32;

Alternative-A is located in a natural body of water known as the "Cagayan River." The estimated minimum elevation is 2 m., the maximum elevation is around 550 m., which is represented in green. The distance from alternative-A to the active volcano "Cagua" is about 70 km.

Alternative-B is located in a natural body of water known as "Laguna de Bay." The estimated minimum elevation is 2 m., the maximum elevation is around 700 m., and it is about 20 km away from the active volcano named "Banahaw" and around 30 km away from the active volcano named "Taal."

Both alternatives contain a solid red line indicating an active fault in the surrounding area. There is simply a dashed red line indicating the approximate position of the fault. The largest red points show seismicity of more than 7 mg., and both of the alternatives are not shown in this area.



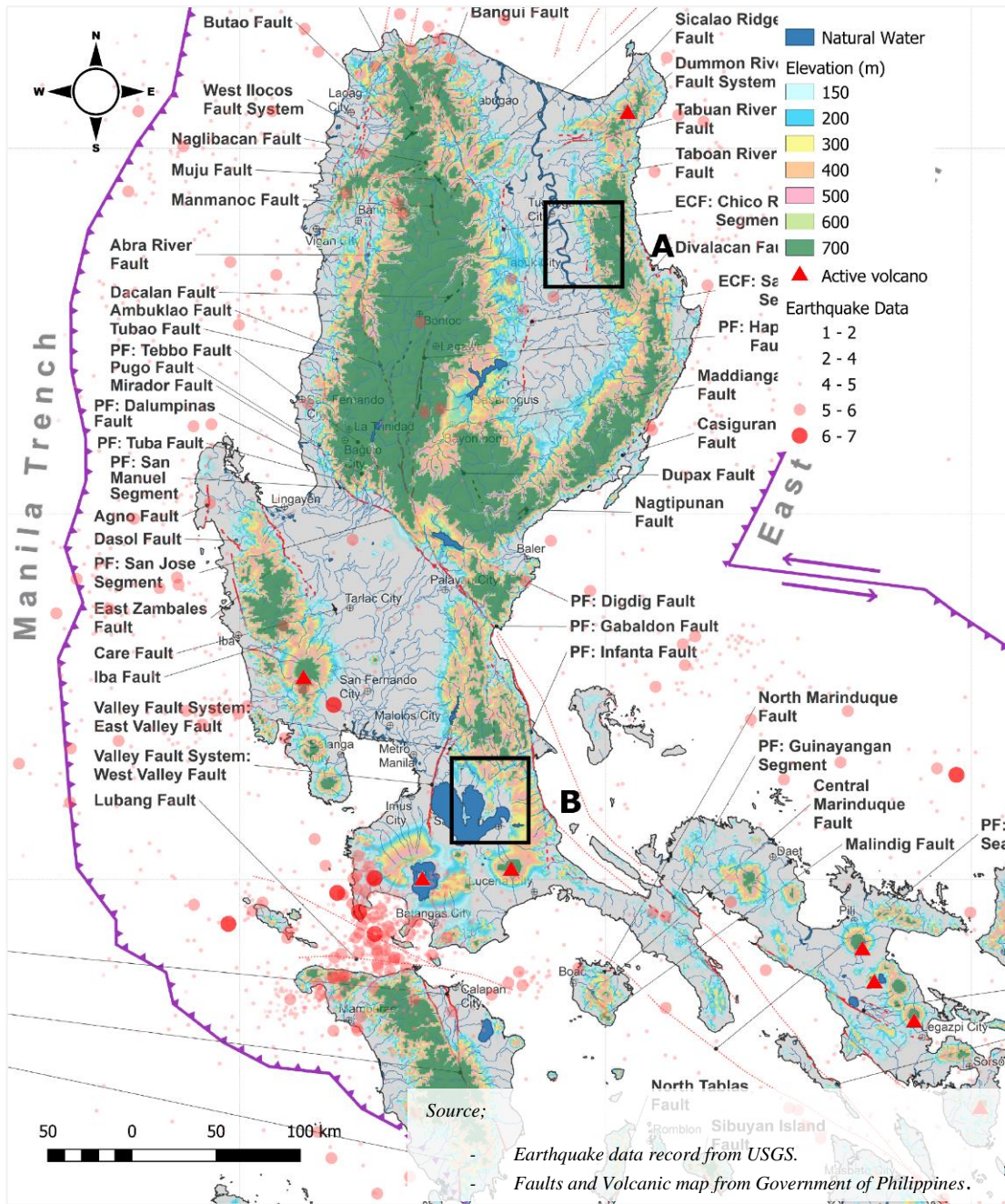


Figure 32: The first map overlay data was used for two alternatives in the Luzon area.

### 3.1.1.2 Case Study Area 2 – Visayas

The Visayas is located in the middle of the Philippines country. From Figure 33, the density of geohazards like volcanic eruptions and seismic activity in the eastern area. So the author will select 2 alternatives following the black rectangular A and B, located on different islands that are far away from any geohazard.

Because the PSP concept requires different elevations for the upper and lower reservoirs, as illustrated in Figure 33, the majority of Visayas is flat land (gray color represents an area less than 150 m), but the steep area is marked in green. As a result, there are only a few areas that represent both gray and green without any geohazards (volcanic eruption, red triangular/fault, red lines/and seismicity, red points). So, the author will choose the potential of PSP at the center part of this region, as shown in Figure 33.

Alternative-A: The estimated minimum elevation is 2 m, the maximum elevation is around 1700 m, and the distance from the active volcano "Kanlaon" is about 20 km. Alternative-B is an estimated minimum elevation of 1 m., the maximum elevation is around 840 m., and it is not close to an active volcano.

Both alternatives contain a solid red line indicating an active fault in the surrounding area. There is simply a dashed red line indicating the approximate position of the fault. The largest red points show seismicity of more than 7 mg., and both of the A & B alternatives are not located around this risk area.

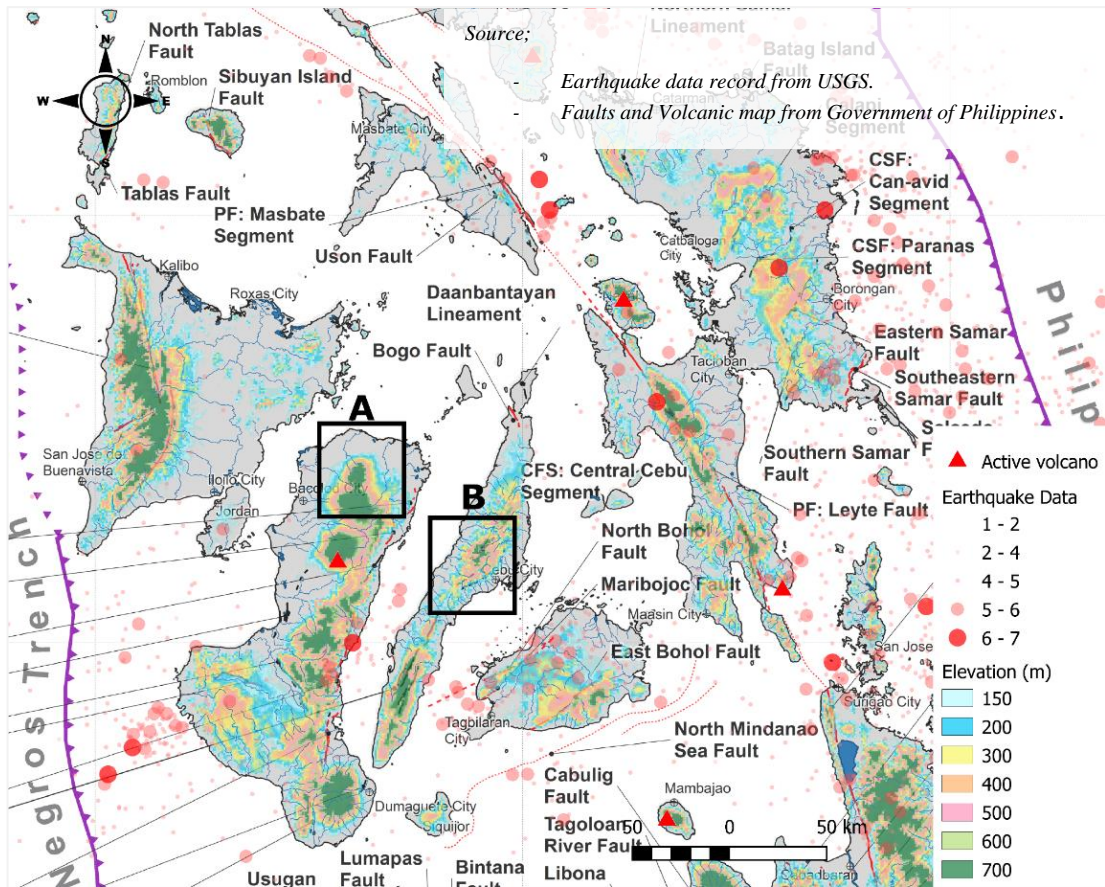


Figure 33: The first map overlay data was used for two alternatives in the Visayas area.

### 3.1.1.3 Case Study Area 3 – Mindanao

This region located in the south of the country, and surrounding by tectonic. As the Figure 34 show density of seismicity at east and south-east of the Island. Alternative site selections are shown as black rectangular A and B as shown in Figure 34;

Alternative-A was estimated minimum elevation is 0 m., the maximum elevation is around 1700 m., and the distance from the active volcano " Makaturing " is about 70 km. and active volcano "Ragang" is about 80 km.

Alternative-B was estimated minimum elevation is 0 m., the maximum elevation is around 900 m., and the distance from the active volcano " Makaturing " is about 70 km. and active volcano " Ragang" is about 60 km.

Both alternatives contain a solid red line indicating an active fault in the surrounding area. There is simply a dash red line indicating the approximate position of the fault. The largest red points indicate a seismicity of more than 7 mg., and both alternatives are not located in this risk area.

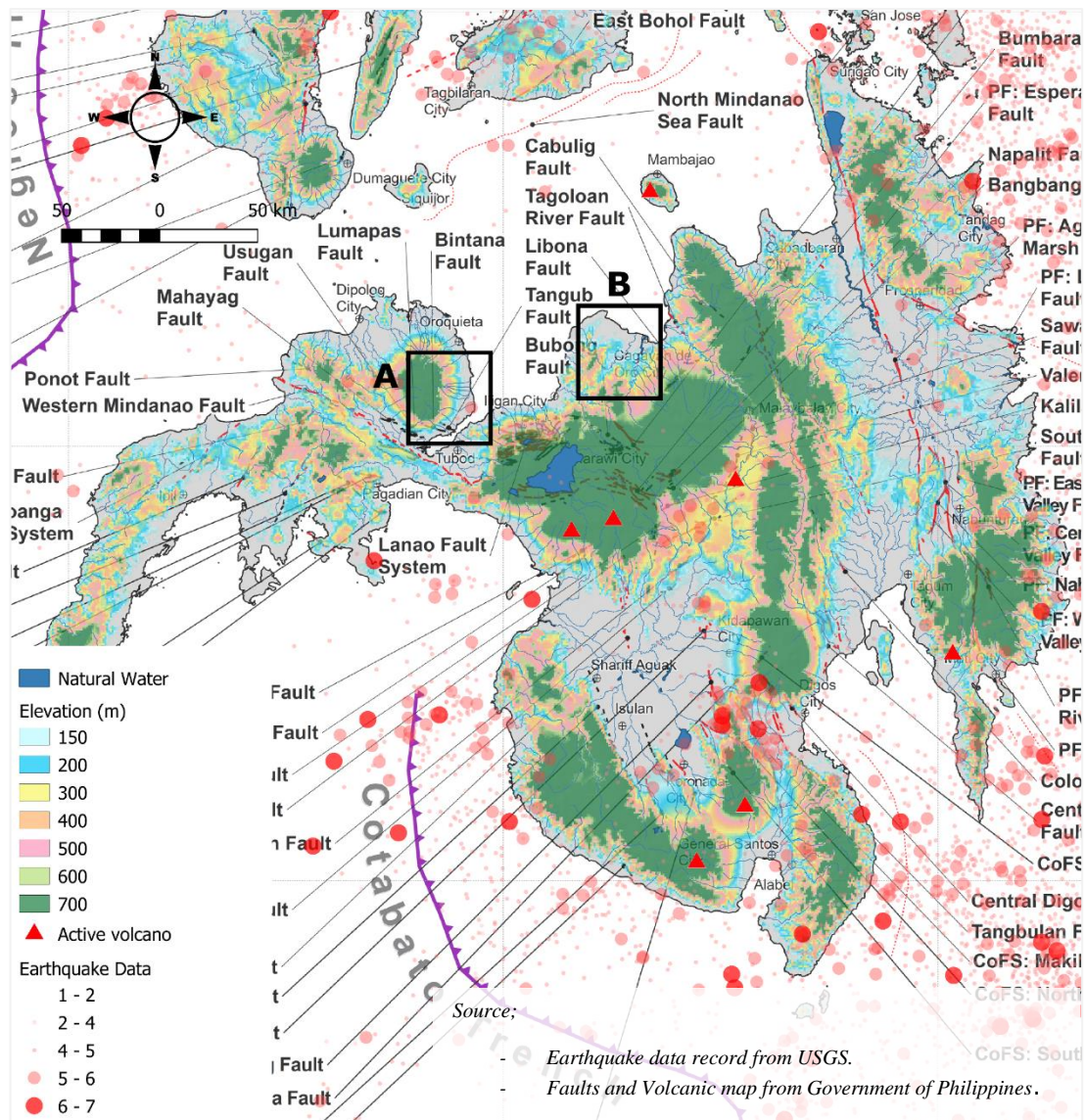


Figure 34: The first map overlay data was used for two alternatives in the Mindanao area.

### 3.1.2 Second Map - Overlay Regional Geology, Rock Units.

This stage is the final stage for initial site selection for PSP. The author will use only regional geology as the principal in chapter 2.3.3.

#### 3.1.2.1 Case Study Area 1 – Luzon

From the data comparison in Figure 35, the author will select **Alternative-B** for potential PSP of Luzon. Because;

a) The first map (Left side) ; Alternative – A has a lower supply of water less than Alternative – B. And Alternate – B is close to Laguna De Bay, which is a big lake in the northern part of the country.

b) Alternative – A, has a different elevation less than Alternative – B. The difference in elevation between the maximum and the minimum is;

➤ Alternative – A =  $550 - 2 = 578$  m.

➤ Alternative – B =  $700 - 2 = 678$  m.

c) Table 7 shows that there are limestone rocks in rock unit "N1" even the majority of the rocks are metamorphic rock and sedimentary, the site related to the natural river is still distant from the potential of the upper reservoir (green color in the left map).

Table 7: Regional geology, rock units at Luzon Island.

<b>Luzon Alternative A</b>	
<b>Rock Unit</b>	<b>Description</b>
<b>KPg1</b>	Largely graywacke and metamorphosed shale interbedded and/or intercalated with spilitic, basic and intermediate flows, and/or pyroclastic, Undifferentiated.
<b>N1</b>	Thick, extensive, transgressive mixed shelf marine deposits, largely wackes, shales, and reef limestone. Underlain by conglomerate and/or associated with paralic coal measures in places, Upper Miocene-Pliocene
<b>N3+Q1</b>	Marine and terrestrial sediments (molasse).
<b>NI</b>	Largely intra-Miocene quartz diorite. Mostly batholiths and stocks, some laccoliths; also sills, dikes, and other minor bodies. Include granodiorite and diorite porphyry facies and late Miocene dacite, Neogene.
<b>R</b>	Alluvium, fluvial, lacustrine, paludal, and beach deposits; raised coral reefs, atolls, and beach rock, Recent.
<b>SN1</b>	Largely marine classics (molasse) overlain by extensive, locally transgressive pyroclastic (chiefly tuff, tuffites) and tuffaceous sedimentary rocks, Upper Miocene-Pliocene.
<b>SN2</b>	Thick, extensive, transgressive mixed shelf marine deposits, largely wackes, shales, and reef limestone. Underlain by conglomerate and/or associated with paralic coal measures in places, Oligocene-Miocene.
<b>UV</b>	Metamorphosed submarine flows, largely spilites and basalts, some keratophyres and andesites, Undifferentiated.
<b>Luzon Alternative B</b>	
<b>Lake</b>	LAKE
<b>QVP</b>	Volcanic plain or volcanic piedmont deposits. Chiefly pyroclastic and/or volcanic debris at foot of volcanoes, Pliocene-Quaternary
<b>R</b>	Alluvium, fluvial, lacustrine, paludal, and beach deposits; raised coral reefs, atolls, and beach rock, Recent.

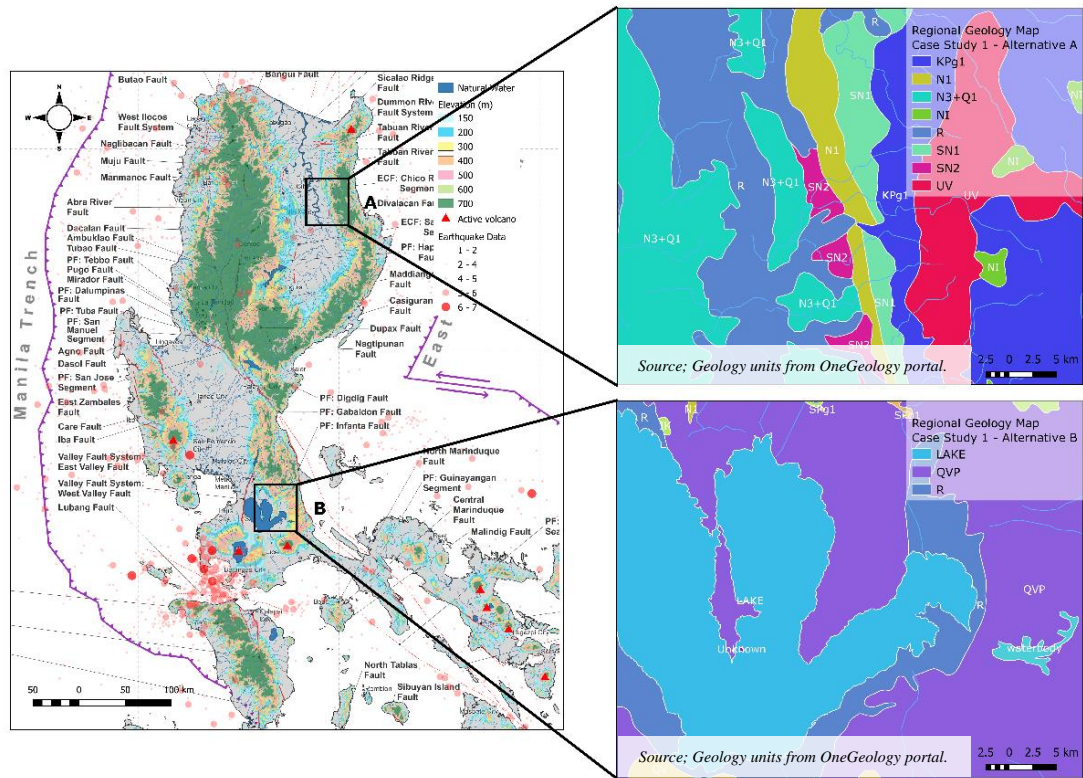


Figure 35: The second map overlay, regional geology data, was used for selected potential PSP in the Luzon area.





### 3.1.2.2 Case Study Area 2 – Visayas

From the data comparison in Figure 36, the author will select **Alternative-B** for potential PSP of Visayas. Because;

a) The first map (The left side) shows that Alternative – A has a smaller supply of water than Alternative – B. And Alternate - B close to “Malubog Lake”, which is close open pit mining and could develop into an upper reservoir in the future.

b) Alternative – A, has a different elevation less than Alternative – B. The difference in elevation between the maximum and the minimum is;

➤ Alternative – A =  $550 - 2 = 548$  m.

➤ Alternative – B =  $840 - 2 = 838$  m.

c) Table 8 indicates that there are limestone rocks in rock units "IN1" and "N1," even though the majority of the rocks are volcanic and sedimentary. However, the location associated with the natural river is still far from the upper reservoir's potential (green color in the left map). Nevertheless, Alternative-B only contains one unit "SN2" to the south of this location.

Table 8: Regional geology, rock units at Visayas Island.

<b>Visayas Alternative A</b>	
<b>Rock Unit</b>	<b>Description</b>
<b>IN1</b>	Thick, extensive, transgressive mixed shelf marine deposits, largely wackes, shales, and reef limestone. Underlain by conglomerate and/or associated with paralic coal measures in places, Upper Miocene-Pliocene.
<b>N1</b>	Thick, extensive, transgressive mixed shelf marine deposits, largely wackes, shales, and reef limestone. Underlain by conglomerate and/or associated with paralic coal measures in places, Upper Miocene-Pliocene
<b>N3</b>	Marine and terrestrial sediments (molasse), Pliocene-Pleistocene (g-h).
<b>QV</b>	Non-active cones (generally pyroxene andesite); also dacitic and/or andesitic plugs, Pliocene-Quaternary
<b>QVP</b>	Volcanic plain or volcanic piedmont deposits. Chiefly pyroclastic and/or volcanic debris at foot of volcanoes, Pliocene-Quaternary
<b>R</b>	Alluvium, fluvial, lacustrine, paludal, and beach deposits; raised coral reefs, atolls, and beach rock, Recent.
<b>SN1</b>	Largely marine clastics (molasse) overlain by extensive, locally transgressive pyroclastic (chiefly tuff, tuffites) and tuffaceous sedimentary rocks, Upper Miocene-Pliocene.
<b>Visayas Alternative B</b>	
<b>IK</b>	Extensive, transgressive graywacke-shale sequence intercalated with spilites, Cretaceous.
<b>N1</b>	Thick, extensive, transgressive mixed shelf marine deposits, largely wackes, shales, and reef limestone. Underlain by conglomerate and/or associated with paralic coal measures in places, Upper Miocene-Pliocene.
<b>N2</b>	"
<b>N3</b>	Marine and terrestrial sediments (molasse), Pliocene-Pleistocene (g-h).
<b>N3+Q1</b>	Marine and terrestrial sediments (molasse).
<b>NI</b>	Largely intra-Miocene quartz diorite. Mostly batholiths and stocks, some laccoliths; also sills, dikes, and other minor bodies. Include granodiorite and diorite porphyry facies and late Miocene dacite, Neogene.
<b>Pgl</b>	Mostly quartz diorite, Paleogene.
<b>R</b>	Alluvium, fluvial, lacustrine, paludal, and beach deposits; raised coral reefs, atolls, and beach rock, Recent.
<b>SK</b>	Extensive, transgressive graywacke-shale sequence intercalated with spilites, Cretaceous.
<b>SN1</b>	Largely marine clastics (molasse) overlain by extensive, locally transgressive pyroclastic (chiefly tuff, tuffites) and tuffaceous sedimentary rocks, Upper Miocene-Pliocene.
<b>SN2</b>	Thick, extensive, transgressive mixed shelf marine deposits, largely wackes, shales, and reef limestone. Underlain by conglomerate and/or associated with paralic coal measures in places, Oligocene-Miocene.

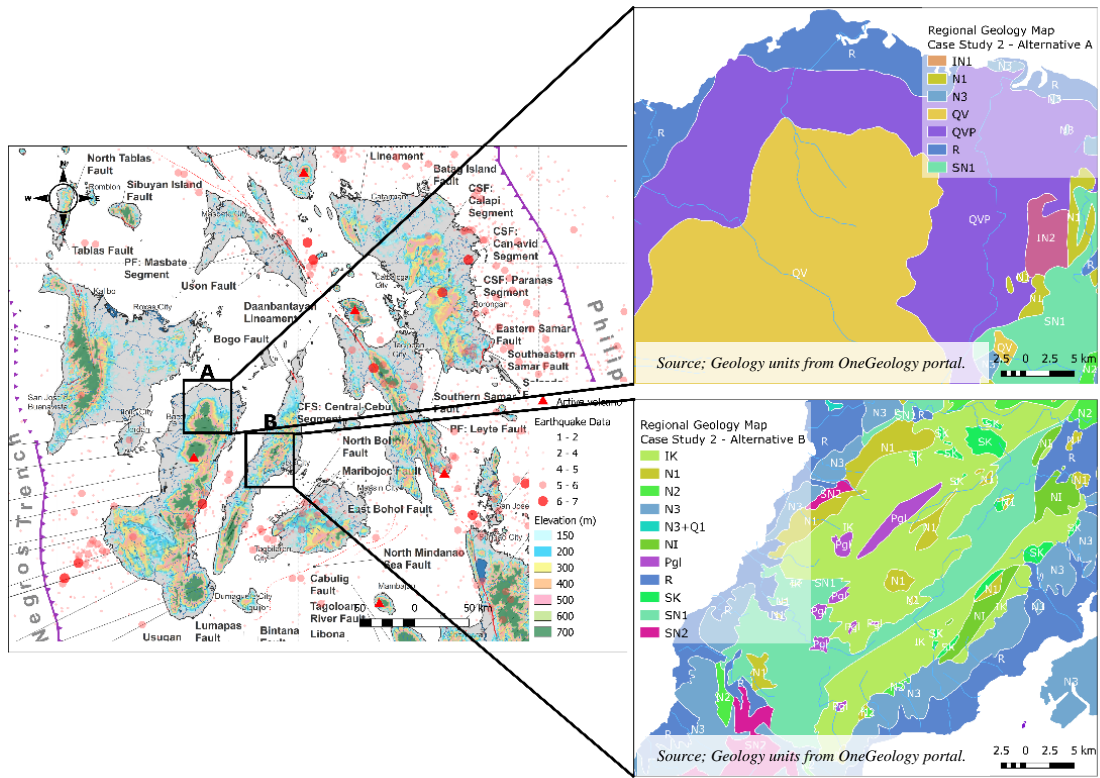


Figure 36: The second map overlay, regional geology data, was used for selected potential PSP in the Visayas area.

### 3.1.2.3 Case Study Area 3 – Mindanao

From the data comparison in Figure 37, the author will select **Alternative-A** for potential PSP of Mindanao. Because;

a) The first map (on the left) indicates that Alternative – A has a supply of contaminated sea water from "Panguli Bay." In spite of Alternative-proximity B's to "Macajalar Bay," which has a higher concentration of seawater.

b) Alternative – B, has a different elevation less than Alternative – B. The difference in elevation between the maximum and the minimum is;

➤ Alternative – A =  $1,700 - 0 = 1,700$  m.

➤ Alternative – B =  $900 - 0 = 900$  m.

c) Table 9 shows that the rock units of the first two alternatives are suitable for PSP construction, so the author will apply just the criteria from the first map.

Table 9: Regional geology, rock units at Mindanao Island.

Mindanao Alternative A	
Rock Unit	Description
N3+Q1	Marine and terrestrial sediments (molasse).
QV	Non-active cones (generally pyroxene andesite); also dacitic and/or andesitic plugs, Pliocene-Quaternary
QVP	Volcanic plain or volcanic piedmont deposits. Chiefly pyroclastic and/or volcanic debris at foot of volcanoes, Pliocene-Quaternary
R	Alluvium, fluvial, lacustrine, paludal, and beach deposits; raised coral reefs, atolls, and beach rock, Recent.
SN1	Largely marine clastics (molasse) overlain by extensive, locally transgressive pyroclastic (chiefly tuff, tuffites) and tuffaceous sedimentary rocks, Upper Miocene-Pliocene.
Unknown	Marine and terrestrial sediments (molasse).

Mindanao Alternative B	
<b>KPg1</b>	Largely graywacke and metamorphosed shale interbedded and/or intercalated with spilitic, basic and intermediate flows, and/or pyroclastic, Undifferentiated.
<b>N3</b>	Marine and terrestrial sediments (molasse), Pliocene-Pleistocene (g-h)
<b>N3+Q1</b>	Marine and terrestrial sediments (molasse).
<b>NI</b>	Largely intra-Miocene quartz diorite. Mostly batholiths and stocks, some laccoliths; also sills, dikes, and other minor bodies. Include granodiorite and diorite porphyry facies and late Miocene dacite, Neogene.
<b>QVP</b>	Volcanic plain or volcanic piedmont deposits. Chiefly pyroclastic and/or volcanic debris at foot of volcanoes, Pliocene-Quaternary
<b>R</b>	Alluvium, fluvialite, lacustrine, paludal, and beach deposits; raised coral reefs, atolls, and beachrock, Recent.
<b>SN1</b>	Largely marine clastics (molasse) overlain by extensive, locally transgressive pyroclastic (chiefly tuff, tuffites) and tuffaceous sedimentary rocks, Upper Miocene-Pliocene.
<b>SN2</b>	Thick, extensive, transgressive mixed shelf marine deposits, largely wackes, shales, and reef limestone. Underlain by conglomerate and/or associated with paralic coal measures in places, Oligocene-Miocene.
<b>UC</b>	Undifferentiated ultramafic and mafic plutonic rocks. Predominantly peridotite associated with late gabbro and/or diabase dikes, Cretaceous-Paleogene.

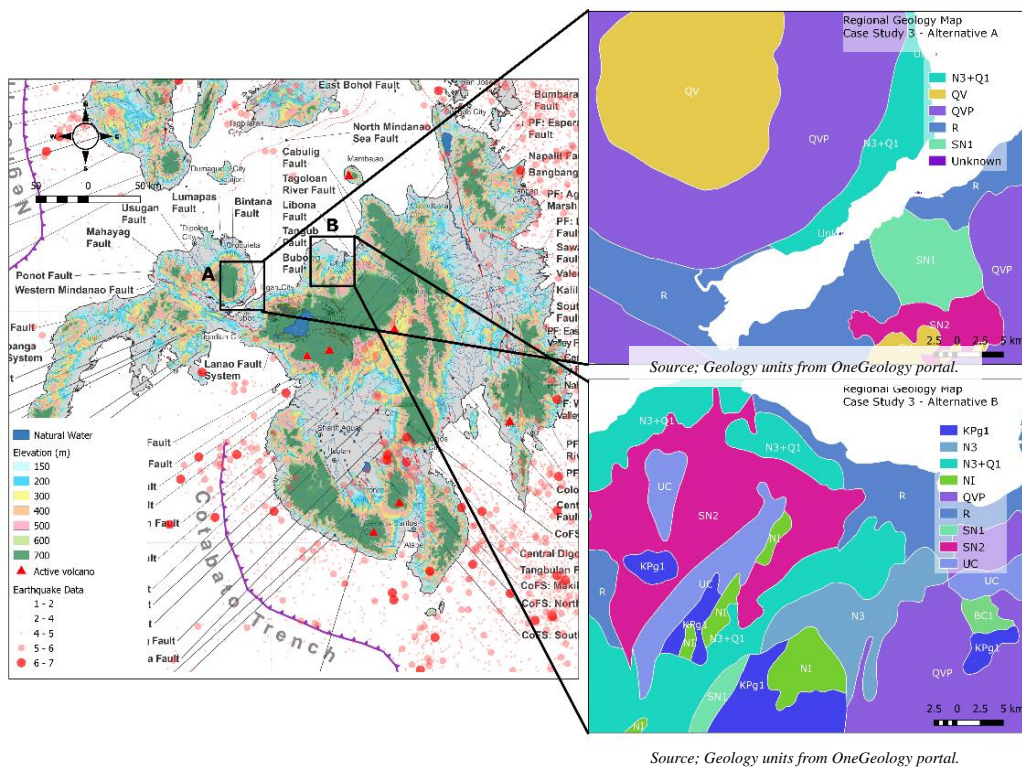
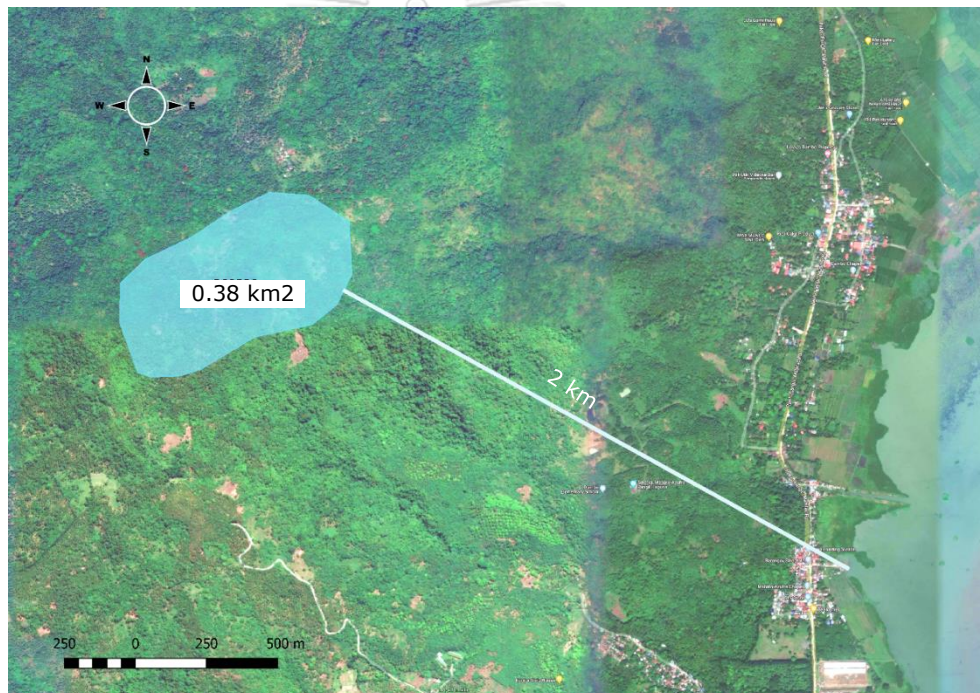


Figure 37: The second map overlay, regional geology data, was used

for selected potential PSP in the Mindanao area.

### 3.1.3 Estimate Energy Storage Capacity

This stage does not have research criteria because it is outside of the scope of the project, and the engineering designer must compute the slope. But the author will calculate energy capacity by using the differential between the upper and lower reservoirs. Then a random waterway, and will cut cross-sections at the highest and lowest points in "Google Earth" for the reader to visualize. The estimate reservoir of PSP is shown in all of the below figure, the blue polygon is upper reservoir, the blue line is random waterway, and all case studies are connected natural water at lower reservoir.



*Figure 38: A satellite image of Luzon in a 2D terrain view at **Luzon**, along with a cross-section along an estimated tunnel line. The blue line represented the elevation of the terrain along the tunnel. Source: Google Earth.*

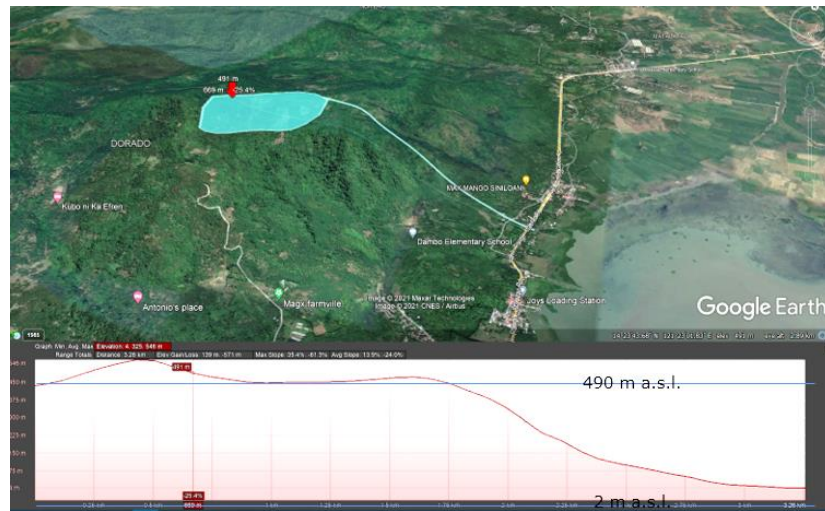


Figure 39: A satellite image of Luzon in a 3D terrain view at **Luzon**, along with a cross-section along an estimated tunnel line. The red line represented the elevation of the terrain along the tunnel. Source: Google Earth.

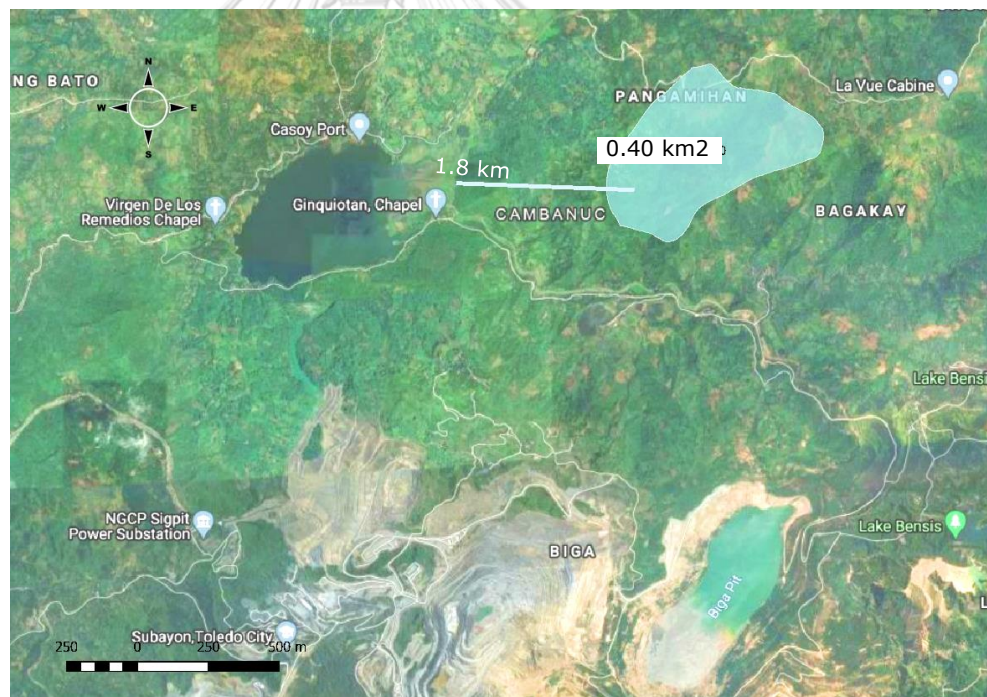
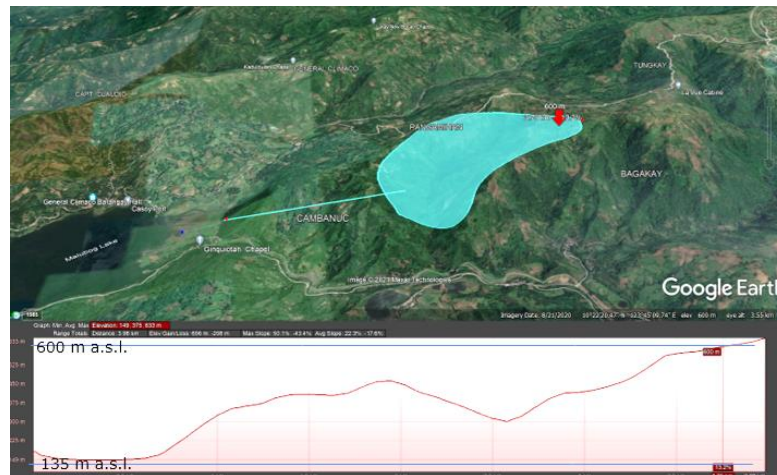


Figure 40: A satellite image of Visayas in a 3D terrain view at **Visayas**, along with a cross-section along an estimated tunnel line. The red line represented the elevation of the terrain along the tunnel. Source: Google Earth.



*Figure 41: A satellite image of Visayas in a 3D terrain view at Visayas, along with a cross-section along an estimated tunnel line. The red line represented the elevation of the terrain along the tunnel. Source: Google Earth.*

The special feature of this location is its approach to an open-pit mine that has the potential to expand to the upper reservoir, as seen in Figure 42, assuming no operations occur in the future. The advantageous usage of this technology can result in significant cost savings associated with the excavation phase of the construction process.

This technology is already in use in the development of gold mines in Australia. The building of the Kidston Pumped Storage Hydro Project at the Kidston Clean Energy Hub in Queensland will create over 500 direct jobs and will support remote and regional businesses and communities during these difficult economic times.



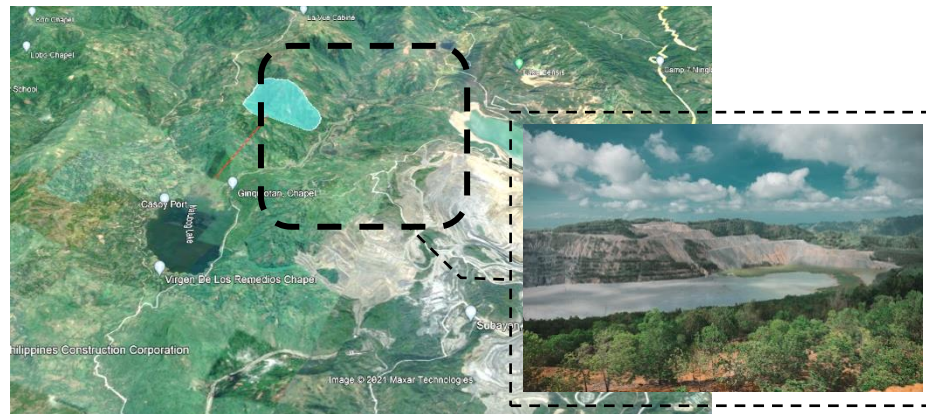


Figure 42: Another potential location with cheaper excavation costs is the upper reservoir at **Visayas**, where is located in an open-pit mine at the same elevation. Source; Google Earth.

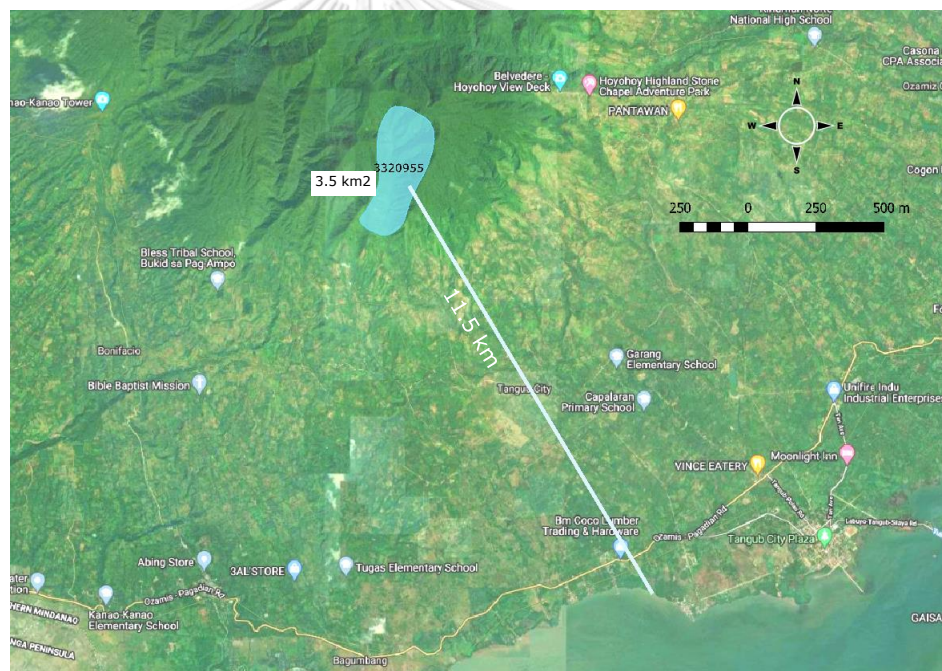


Figure 43: A satellite image of Mindanao in a 2D terrain view at **Mindanao**, along with a cross-section along an estimated tunnel line. The red line represented the elevation of the terrain along the tunnel. Source: Google Earth.

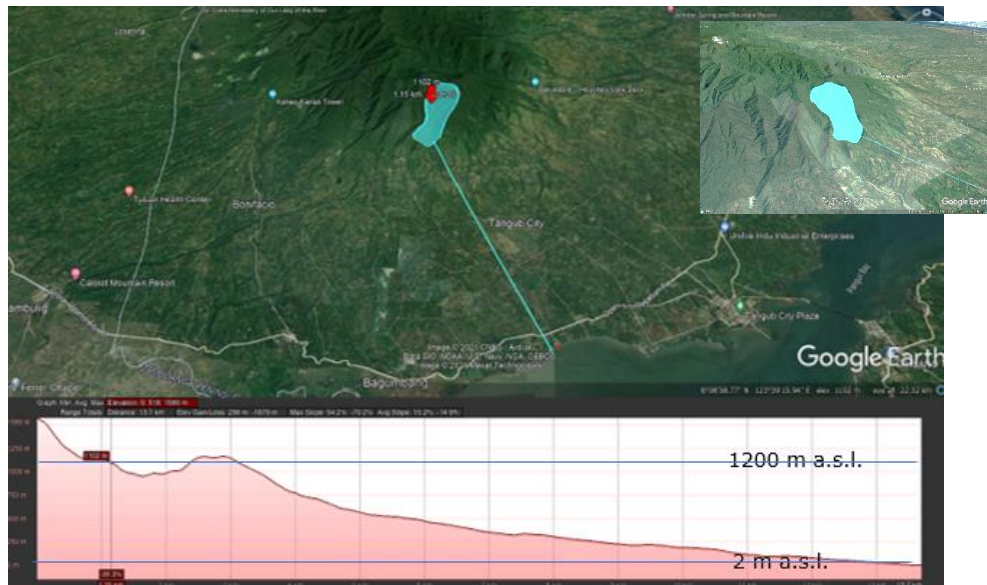


Figure 44: A satellite image of Mindanao in a 3D terrain view at Mindanao, along with a cross-section along an estimated tunnel line. The red line represented the elevation of the terrain along the tunnel. Source: Google Earth.

### 3.1.3.1 Conclusion of Estimate Energy Storage Capacity

In the storage energy section, Figure 45, it is necessary to indicate parameters separated by a height ( $h$ ) that corresponds to the hydraulic head. Assume that  $h$  is indicator differential elevation of the upper and lower reservoir, and  $V_u$  is its capacity to store water.

The summary of  $h$  of all case will be provided in Table 10, and this number will be used to determine the energy density in the next step.

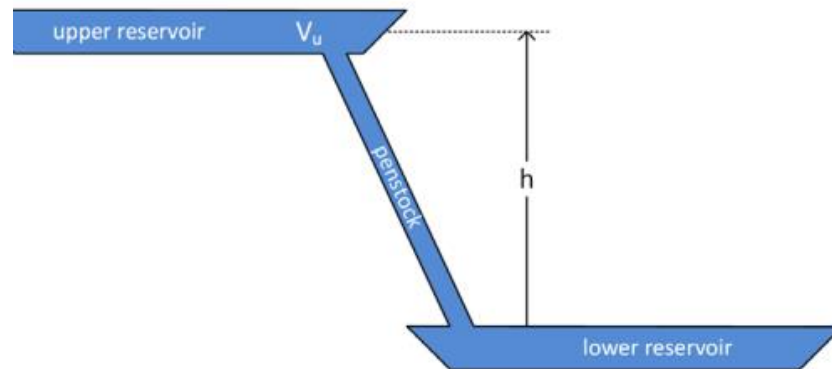


Figure 45: The figure of the indicator differential elevation of the upper and lower reservoir ( $h$ ).

Table 10: Different highs of the lower and upper reservoirs.

Case Study Area	Lower Reservoir	Upper Reservoir	$h$
	m.	m.	m.
1. Luzon	2	490	488
2. Visayas	135	600	465
3. Mindanao	2	1100	1098

is;

The energy density ( $e_v$ ) is energy per unit volume of the stored water

$$e_v = \frac{E_t}{V_u} = \rho gh$$

Where  $\rho$  is the density of water = 1000 kg/m<sup>3</sup>

$g$  is gravitational acceleration = 9.81 m/s<sup>2</sup>

Sample calculated in case study 1;

$$e_v = 1000 \text{ (kg/m}^3\text{)} \times 9.81 \text{ (m/s}^2\text{)} \times 488 = \underline{4,787,280 \text{ J/m}^3}$$

The summary of energy density of all case will be provided in Table 11, and this number will be used to determine the power in the next step.

Table 11: The water density of each case study.

Case Study Area	The energy density
	J/m <sup>3</sup>
1. Luzon	4,787,280.00
2. Visayas	4,561,650.00
3. Mindanao	10,771,380.00

The rate at which energy is transferred to the turbine (from the pump) is the **power (P)** extracted from (delivered to) the water is;

$$P = e_v Q = pQ = \rho ghQ$$

Where  $Q$  from the historical project [9] is 49.1 m<sup>3</sup>/s.

Sample calculated in case study 1;

$$P = 4,787,280 \text{ (J/m}^3\text{)} \times 49.1 \times 100,000 = \underline{235} \text{ MW}$$

After all calculations are complete, the result of this research in terms of power pump/turbines per unit is shown in Table 12.

Table 12: The power of pump/turbines per unit.

Case Study Area	Power / turbine	Rounds a number up and down to an integer.
	MW	MW
1. Luzon	235	200
2. Visayas	224	220
3. Mindanao	529	500

\*\*\*Visayas will round numbers up and down to a smaller integer than other areas due to the area's lower elevation and smallest reservoir.

## 3.2 Cash Flow Estimation for Case Studies

The PSP is feasible because it utilizes a discounted cash flow model (DCF) to generate electricity through simulated sales, a scenario in which electricity is generated during peak and non-peak hours.

Three research areas have been established for the region's islands: Luzon (L), Visayas (V), and Mindanao (M). According to the elevation of each PSP's reservoir as determined in Chapter 3.1, with the assumption of a unit turbine and pump design, will apply to this step. For economic and financial considerations, the project feasibility can be assumed to be an expected capacity size, as shown in Table 13. The author will design the three scenarios by reducing power from Table 13 by hundreds of digits, with the exception of Visayas, which will be reduced by tens of digits because this area has the lowest area reservoir and is more difficult to discover prospective area than other regions.

Table 13: Assumptions of capacity for PSP.

	Pump/Turbines	Pump/turbines per unit	Installed capacity
	Unit	MW	(MW)
1. Luzon	4	200	800
2. Visayas	3	220	660
3. Mindanao	5	500	2500

### 3.2.1 Calculated Price of Electricity

Associated with PSP theory Calculated prices must take into account the consumer's daily schedule, including peak and off-peak hours. Electricity prices for PSP can only be calculated using data from the ERC's provisionally approved rates on February 16, 2009. Table 14 is the price data for various times of the year, segmented by region.

Table 14: Electric price of LUZON, Visayas and Mindanao grid on February 16, 2009.

<b>LUZON GRID</b> (in PHP/kWh)				
<b>PERIOD</b>	<b>(JANUARY - JUNE)</b>		<b>(JULY - DECEMBER)</b>	
	<b>Monday - Saturday</b>	<b>Sunday/ Holiday</b>	<b>Monday - Saturday</b>	<b>Sunday/ Holiday</b>
<b>1:00 AM</b>	2.3426	2.5022	2.3426	2.3426
<b>2:00 AM</b>	2.3426	2.3426	2.3426	2.3426
<b>3:00 AM</b>	2.3426	2.3426	2.3426	2.3426
<b>4:00 AM</b>	2.3426	2.3426	2.3426	1.8649
<b>5:00 AM</b>	2.3426	2.3426	2.3426	1.8649
<b>6:00 AM</b>	2.3426	2.3426	2.3426	1.8649
<b>7:00 AM</b>	2.3426	2.3426	2.3426	1.8649
<b>8:00 AM</b>	2.6256	2.3426	2.5022	2.3426
<b>9:00 AM</b>	5.779	2.3426	2.6256	2.3426
<b>10:00 AM</b>	6.5283	2.5022	5.9872	2.5022
<b>11:00 AM</b>	6.5283	2.5022	6.5283	2.5022
<b>12:00 PM</b>	6.5283	2.5022	5.9872	2.5022
<b>1:00 PM</b>	6.5283	2.5022	5.9872	2.5022
<b>2:00 PM</b>	6.5283	2.5022	6.5283	2.5022
<b>3:00 PM</b>	6.5283	2.5022	5.9872	2.5022
<b>4:00 PM</b>	6.5283	2.5022	5.779	2.5022
<b>5:00 PM</b>	5.9872	2.5022	5.5481	2.5022
<b>6:00 PM</b>	5.9872	2.5022	5.9872	2.6256
<b>7:00 PM</b>	6.5283	5.779	6.5283	5.5481
<b>8:00 PM</b>	6.5283	5.779	5.9872	5.5481
<b>9:00 PM</b>	5.9872	3.2594	5.779	2.6256
<b>10:00 PM</b>	3.2594	2.6256	2.6256	2.5022
<b>11:00 PM</b>	2.6256	2.5022	2.5022	2.3426
<b>12:00 AM</b>	2.5022	2.3426	2.3426	2.3426
<b>VISAYAS GRID</b> (in PHP/kWh)				
<b>PERIOD</b>	<b>(JANUARY - DECEMBER)</b>			
	<b>Monday - Saturday</b>	<b>Sunday/Holiday</b>		
<b>1:00 AM</b>	2.6158	2.6158		
<b>2:00 AM</b>	2.2181	2.2181		
<b>3:00 AM</b>	2.2181	2.2181		
<b>4:00 AM</b>	2.2181	2.2181		
<b>5:00 AM</b>	2.2181	2.2181		
<b>6:00 AM</b>	2.2181	2.2181		
<b>7:00 AM</b>	2.2181	2.2181		
<b>8:00 AM</b>	2.934	2.2181		

<b>9:00 AM</b>	3.4157	2.2181
<b>10:00 AM</b>	3.6322	2.6158
<b>11:00 AM</b>	3.6322	2.934
<b>12:00 PM</b>	3.6322	2.934
<b>1:00 PM</b>	3.6322	2.934
<b>2:00 PM</b>	3.6322	3.0516
<b>3:00 PM</b>	3.6322	2.934
<b>4:00 PM</b>	3.6322	2.934
<b>5:00 PM</b>	3.5332	2.934
<b>6:00 PM</b>	6.4755	3.6322
<b>7:00 PM</b>	6.4755	6.4755
<b>8:00 PM</b>	6.4755	6.4755
<b>9:00 PM</b>	6.4755	3.6322
<b>10:00 PM</b>	3.6322	3.5332
<b>11:00 PM</b>	3.0516	3.0516
<b>12:00 AM</b>	2.934	2.6158

**MINDANAO GRID**  
(in PHP/kWh)

PERIOD	(JANUARY - JUNE)		(JULY - DECEMBER)	
	Monday - Saturday	Sunday/ Holiday	Monday - Saturday	Sunday/ Holiday
<b>1:00 AM</b>	2.8514	2.8514	2.0306	2.0306
<b>2:00 AM</b>	2.7198	2.8514	2.0306	2.0306
<b>3:00 AM</b>	2.7198	2.7198	2.0306	2.0306
<b>4:00 AM</b>	2.7198	2.7198	2.0306	2.0306
<b>5:00 AM</b>	2.8514	2.7198	2.0306	2.0306
<b>6:00 AM</b>	2.7198	2.7198	2.0306	2.0306
<b>7:00 AM</b>	2.7198	2.7198	2.0306	2.0306
<b>8:00 AM</b>	2.8514	2.7198	2.0306	2.0306
<b>9:00 AM</b>	2.9466	2.7198	2.8514	2.0306
<b>10:00 AM</b>	2.9643	2.8514	2.9466	2.0306
<b>11:00 AM</b>	2.9643	2.8514	2.9466	2.7198
<b>12:00 PM</b>	2.9643	2.8514	2.9466	2.7198
<b>1:00 PM</b>	2.9643	2.8514	2.9466	2.7198
<b>2:00 PM</b>	2.9643	2.9466	2.9466	2.7198
<b>3:00 PM</b>	2.9643	3.292	2.9466	2.7198
<b>4:00 PM</b>	3.292	3.292	3.292	2.7198
<b>5:00 PM</b>	3.292	3.292	3.292	2.8514
<b>6:00 PM</b>	3.292	3.292	3.292	3.292
<b>7:00 PM</b>	3.292	3.292	3.292	3.292
<b>8:00 PM</b>	3.292	3.292	3.292	3.292
<b>9:00 PM</b>	3.292	3.292	2.9643	2.9643
<b>10:00 PM</b>	2.9643	2.9466	2.9466	2.8514
<b>11:00 PM</b>	2.9466	2.8514	2.8514	2.7198
<b>12:00 AM</b>	2.8514	2.8514	2.0306	2.0306

Source of data; <https://www.psalm.gov.ph/home/ercrates>

Then, using this data record (Table 14), we can calculate the price of electricity using the steps outlined below.

a) The author will collect the average price of peak and non-peak hours in each area, subdivided into two scenarios: Monday-Saturday and Sunday/Holiday. The peak hour is assumed to be between 9:00 a.m. and 10:00 p.m. (13 hours) and off-peak hours between 10:00 p.m. and 9:00 a.m. (11 hours) as shown in the Table 15.

Table 15: The average electric price (PHP/kWh) scenario for the grids of Luzon, Visayas, and Mindanao, on February 16, 2009.

		Non Peak hour (10.00 pm.-9.00 am.)	Peak hour (9.00 am.-10.00 pm.)
<b>Luzon</b>	Monday - Saturday	2.562	5.970
	Sunday/Holiday	2.270	3.032
<b>Visayas</b>	Monday - Saturday	2.569	4.499
	Sunday/Holiday	2.366	3.617
<b>Mindanao</b>	Monday - Saturday	2.494	3.098
	Sunday/Holiday	2.430	2.971

b) Use this exchange rate, PHP to USD by rate in the fourth quarter of 2021, which is 50.67 PHP/USD to each area, then average price for non peak and peak hour. The result will present in Table 16 to Table 18.

Table 16: The average electric price in USD/kWh for the grids of Luzon.

	Non Peak hour (10.00 pm.-9.00 am.)	Peak hour (9.00 am.-10.00 pm.)
<b>Monday - Saturday</b>	0.0506	0.1178
<b>Sunday/Holiday</b>	0.0448	0.0598
<b>Average Price</b>	<b>0.0477</b>	<b>0.0888</b>



Table 17: The average electric price in USD/kWh for the grids of Visayas.

	<b>Non Peak hour (10.00 pm.-9.00 am.)</b>	<b>Peak hour (9.00 am.-10.00 pm.)</b>
<b>Monday - Saturday</b>	0.05070	0.08880
<b>Sunday/Holiday</b>	0.04670	0.07138
<b>Average Price</b>	<b>0.04870</b>	<b>0.0801</b>

Table 18: The average electric price in USD/kWh for the grids of Mindanao.

	<b>Non Peak hour (10.00 pm.-9.00 am.)</b>	<b>Peak hour (9.00 am.-10.00 pm.)</b>
<b>Monday - Saturday</b>	0.04923	0.06117
<b>Sunday/Holiday</b>	0.04797	0.05863
<b>Average Price</b>	<b>0.04860</b>	<b>0.0599</b>

c) Then, forecast average prices from 2009 to 2020, and use this rate for each area by inputting the inflation rate, and apply from this inflation equation.

$$\text{Inflation Rate} = \frac{CPI_{\text{Current Year}} - CPI_{\text{Last Year}}}{CPI_{\text{Last Year}}} \times 100$$

Where; CPI is Consumer Price Index

To this equation for inflating the cost in the current situation.

$$CPI \text{ current year} = [(Inflation \text{ Rate}/100) * CPI \text{ last year}] + CPI \text{ last year}$$

Sample; In 2009, the non-peak hour price in Luzon was 0.0468, and the inflation rate in 2010 was 3.790 percent.

$$CPI \text{ 2010} = [(3.790\%/100) * 0.0468] + 0.0468 = 0.04770 \text{ USD/kWh}$$

Then, in Table 19, a summary forecast from 2009 to 2020 is presented, with the yellow color indicating the price in 2009 and the green color highlighting the price for applying to the calculated price in the generation and pumping process.

Table 19: Electric price with escalated price increases from 2009 to 2020. (USD/kWh)

	2020	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010	2009
<b>Inflation Rates</b>	<b>2.640%</b>	<b>2.480%</b>	<b>5.210%</b>	<b>2.850%</b>	<b>1.250%</b>	<b>0.670%</b>	<b>3.600%</b>	<b>2.580%</b>	<b>3.030%</b>	<b>4.720%</b>	<b>3.790%</b>	<b>4.220%</b>
<b>Luzon</b>												
Non Peak Tariff	0.0478	0.0478	0.0478	0.0478	0.0478	0.0478	0.0478	0.0478	0.0477	0.0477	0.0477	0.0477
Peak Tariff	0.0891	0.0891	0.0891	0.0890	0.0890	0.0890	0.0890	0.0890	0.0889	0.0889	0.0889	0.0888
<b>Visayas</b>												
Non Peak Tariff	0.0489	0.0488	0.0488	0.0488	0.0488	0.0488	0.0488	0.0488	0.0488	0.0487	0.0487	0.0487
Peak Tariff	0.0804	0.0803	0.0803	0.0803	0.0802	0.0802	0.0802	0.0802	0.0802	0.0802	0.0801	0.0801
<b>Mindanao</b>												
Non Peak Tariff	0.0488	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0486	0.0486	0.0486
Peak Tariff	0.0601	0.0601	0.0601	0.0600	0.0600	0.0600	0.0600	0.0600	0.0600	0.0599	0.0599	0.0599

### 3.2.1.1 Power Generation Process (Revenues)

The revenue generated by the operation method must be calculated using the projected daily electricity price. That is, the prices for each day of this time period must be assessed (day-ahead pricing), and the daily operation pattern must be defined. The revenue will be calculated using the annual generation hours (hrs/year), annual energy generation (GWh/year), and the formula shown in the following step;

a) Calculate the annual generation hours for each of the three case studies. Apply between 9 a.m. and 10:00 p.m. It is 13 hours per day, and it generates all year (365 days) with a 98% availability assumption.

$$\text{Annual generation hours (hrs/year)} = \text{Generation hour per day} \times 365 \times \text{Availability Rate}$$

$$\begin{aligned} \text{Annual generation hours case study 1} &= 13 \times 365 \times 98\% \\ &= \underline{4650.1} \text{ hrs/year.} \end{aligned}$$

b) Calculate annual energy generation per year using the parameters of personal consumption, capacity, and annual generation hours.

- The assumption of own-consumption (M USD) is the additional cost incurred after the PSP plant uses its own energy during the operating phase, accounting for approximately 1.5 percent of revenues and pumping costs.

$$\text{Annual energy generation} = \text{Annual generation hours} \times \text{Capacity} \times (1 - \text{own-consumption})/1000$$

Example of case study 1;

$$\begin{aligned} \text{Annual energy generation} &= 4650.1 \times 800 \times (1 - 1.5\%) / 1000 \\ &= \underline{3664.3} \text{ GWh/year} \end{aligned}$$

The annual energy generation value of each case study will be presented in Table 20.

Table 20: The annual energy generation value (GWh/year).

	Luzon	Visayas	Mindanao
<b>Installed Capacity</b>	800	660	2500
<b>Annual energy generation</b>	<u>3664.279</u>	<u>3023.030</u>	<u>11450.871</u>

c) Energy sales (M USD) = Annual energy generation (GWh/year) \* tariff of peak hour (USD/kWh) The final process is the annual price of revenue energy or energy sales (M USD). This is calculated using annual energy generation and peak hour of electric price. The formula is;

$\text{Energy sales (M USD)} = \text{Annual energy generation (GWh/year)} \times \text{electric price on peak hour (USD/kWh)}$
--

Example of case study 1;

$$\begin{aligned} \text{Energy sales (M USD)} &= 3664.3 * 0.0891 \\ &= \underline{326.6 \text{ M USD}} \end{aligned}$$

*The revenue forecast for the first case study is 326.6 million US dollars.*

The conclusion of revenue for 3 case is presented in Table 21.

Table 21: Energy sales price of each case study. (USD/kWh/year)

	Luzon	Visayas	Mindanao
<b>Installed Capacity</b>	800	660	2500
<b>Energy sales (M USD)</b>	326.6	242.9	688.0

### 3.2.1.2 Pumping Process (Cost)

The other cost is pumping cost is the PSP consumer energy for storage water to upper reservoir. The pumping cost will be calculated by the pumping hours (hrs/year),

the annual energy consumer (GWh/year) for the result of pumping cost (M USD), and the formula as shown in the following step;

a) Calculate the annual pumping hours for each of the three case studies. Apply between 10:00 p.m. to 9:00 a.m. It operates 11 hours per day, 365 days a year, with a 98 percent availability assumption. The annual pumping hours formula is as follows;

$$\text{Annual pumping hours (hrs/year)} = \text{Pumping hour per day} \times 365 \times \text{Availability Rate}$$

$$\text{Annual pumping hours} = 11 * 365 * 98\% = \underline{3934.7} \text{ hrs/year.}$$

b) Calculate annual energy pumping per year using the parameters of personal consumption, capacity, and annual pumping hours.

- The assumption of own-consumption (M USD) is the additional cost incurred after the PSP plant uses its own energy during the operating phase, accounting for approximately 1.5 percent of revenues and pumping costs.

$$\text{Annual energy pumping} = \text{Annual pumping hours} \times \text{Capacity} \times (1 - \text{own-consumption})/1000$$

Example of case study 1;

$$\text{Annual energy pumping} = 3934.7 * 800 * (1 - 1.5\%) / 1000$$

$$= \underline{3195.0} \text{ GWh/year}$$

The annual energy pumping value of each case study will be presented in Table 22.

Table 22: The pumping energy value (GWh/year).

	Luzon	Visayas	Mindanao
<b>Installed Capacity</b>	800	660	2500
<b>Annual energy pumping</b>	3194.976	2635.856	9984.301

c) The final process is the annual price of consumer energy or pumping costs (M USD). This is calculated using annual energy pumping and non-peak hour electricity prices. The formula is;

$$\text{Pumping costs (M USD)} = \text{Annual energy pumping (GWh/year)} \times \text{electric price on non-peak hour (USD/kWh)}$$

Example of case study 1;

$$\begin{aligned} \text{Pumping cost (M USD)} &= 3195 * 0.0478 \\ &= \underline{7719.5} \text{ M USD} \end{aligned}$$

The conclusion of pumping cost is presented in Table 23.

Table 23: Pumping cost of each case study. (USD/kWh/year)

	Luzon	Visayas	Mindanao
<b>Installed Capacity</b>	<b>800</b>	<b>660</b>	<b>2500</b>
<b>Pumping Costs (M USD)</b>	152.850	128.788	486.802

### 3.2.2 Cost Estimate

Construction necessitates a variety of methodologies for cost estimation. The majority of construction costs were estimated from first principles, with the resources required for various activities identified and costed using current prices, supplemented by obtaining cost estimates for various items from suppliers and subcontractors. This

included the supply and installation of the electro-mechanical equipment, with these major costs also being evaluated against historical data and current industry rates.

CAPEX and OPEX are the cost estimation principles. The computation assumes starting with Case Study 1 (Luzon) and applying the value to Case Study 2 (Visayas) by decreasing by 17% of Luzon and Case Study 3 (Mindanao) by increasing by 60% of Luzon. This approximate design for a similar design is currently under construction. It consists of an upper reservoir, a waterway, and various other infrastructure components. A cost estimate will apply from the Belisama project to Case Study 1.

#### **3.2.2.1 CAPEX (Construction Cost Estimate)**

The construction requires various methodologies for the preparation of the cost estimate. The majority of the construction costs were estimated from first principles, where the resources required for various activities were identified and cost using current prices, augmented by requesting cost estimates from suppliers and subcontractors for various items where possible. This included the supply and installation of the electro-mechanical equipment, where these major costs were also evaluated against historical data and current rates being experienced in the industry. The cost estimate for CAPEX is for both direct and indirect construction costs and allows for the following main sections and components in Table 25. And the CAPEX's results of 3 cases are provided in Table 26.

The author will increase and decrease the ratio for CAPEX by the value of the area of the upper reservoir divided by the length of the waterway from Luzon to Visayas and Mindanao by calculating the following in Table 24. And the CAPEX of Luzon will use the same value as the previous project [3].

Table 24: CAPEX components including ;

	<b>A</b> <b>(Area, km2)</b>	<b>L</b> <b>(Length, km)</b>	<b>A / L</b>	<b>X%</b>
<b>Luzon</b>	0.38	2,000.00	190	
<b>Visayas</b>	0.40	1,800.00	222	-17%
<b>Mindanao</b>	3.50	11,500.00	304	-60%

\*\*\* For example; X% of Visayas = ((A/L of Visayas - A/L of Luzon)/ A/L of Luzon)\*100

Table 25: CAPEX components including ;

<b>Type of CAPEX</b>	<b>Group of Work</b>	<b>Description</b>
<b>Direct Cost</b>	Civil Works	Site Development
		Upper Pond
		Pressure tunnel
	Hydromechanical Works	Tailrace Tunnel
		Intake Lower Reservoir
		Power Cavern
		Contingencies
		HM in Gate chamber
		Penstock and steel liner
	Electromechanical Works	Gates and trash rack lower intake
		Contingency HM
		Generating equipment E&M
		Switchyard
		Transmission line (TL)
	<b>Indirect Cost</b>	Contingency EM
Client Administration (5% of total direct costs)		
Engineering, Site Supervision (5% of total direct costs)		
Detailed Design (3% of total direct costs)		
Land Acquisition and EIA Cost		
Project Development Cost		
Insurance (2% of total direct costs)		
Other Business Expenses (2% of total direct costs)		
Interest during Construction (IDC) (17.52% of total direct costs)		

Table 26: CAPEX result of 3 case;

<b>Cost Estimate</b>	<b>Luzon</b>	<b>Visayas</b> <i>(-17% of Luzon)</i>	<b>Mindanao</b> <i>(+60% of Luzon)</i>
<b>Direct Cost</b>	[USD]	[USD]	[USD]
<b>Civil Works</b>			
Site Development	52,732,276	43,767,789	84,371,642
Upper Pond	132,981,625	110,374,749	212,770,600
Pressure tunnel	26,425,775	21,933,393	42,281,240
Tailrace Tunnel	98,573,250	81,815,798	157,717,200



Intake Lower Reservoir	11,960,950	9,927,589	19,137,520
Power Cavern	73,173,575	60,734,067	117,077,720
Contingencies	68,741,149	57,055,154	109,985,838
<b>Total Civil Works</b>	<b>464,588,600</b>	<b>385,608,538</b>	<b>743,341,760</b>
<b>Hydromechanical Works</b>			
HM in Gate chamber	3,750,000	3,112,500	6,000,000
Penstock and steel liner	30,000,000	24,900,000	48,000,000
Gates and trash rack lower intake	3,744,363	3,107,822	5,990,981
Contingency HM	2,999,549	2,489,626	4,799,279
<b>Total Hydromechanical Works</b>	<b>40,493,913</b>	<b>33,609,947</b>	<b>64,790,260</b>
<b>Electromechanical Works</b>			
Generating equipment	137,760,000	114,340,800	220,416,000
Switchyard	-	-	-
Transmission line (TL)	2,500,000	2,075,000	4,000,000
Contingency EM	11,220,800	9,313,264	17,953,280
<b>Total Electromechanical Works</b>	<b>151,480,800</b>	<b>125,729,064</b>	<b>242,369,280</b>
<b>Total Direct Costs</b>	<b>656,563,313</b>	<b>558,078,816</b>	<b>558,078,816</b>
<b>Indirect Cost</b>	[USD]	[USD]	[USD]
Client Administration	32,828,166	27,247,377	52,525,065
Engineering, Site Supervision	32,828,166	27,247,377	52,525,065
Detailed Design	19,696,899	16,348,426	31,515,039
Land Acquisition and EIA Cost	5,000,000	4,150,000	8,000,000
Project Development Cost	10,000,000	8,300,000	16,000,000
Insurance	13,131,266	10,898,951	21,010,026
Other Business Expenses	13,131,266	10,898,951	21,010,026
Interest during Construction	115,029,892	95,474,811	184,047,828
Total Indirect Costs	241,645,656	200,565,894	386,633,049
<b>Total Project Costs</b>	<b>898,208,968</b>	<b>758,644,710</b>	<b>944,711,865</b>
	[USD]	[USD]	[USD]
<b>Total Direct Costs</b>			
Civil Works	464,588,600	385,608,538	743,341,760
Hydromechanical Works	40,493,913	33,609,947	64,790,260
Electromechanical Works	151,480,800	125,729,064	242,369,280
	656,563,313	558,078,816	558,078,816
<b>Total Indirect Costs</b>			
Indirect Costs (without IDC)	126,615,763	105,091,083	202,585,221
Indirect Costs (including IDC)	241,645,656	200,565,894	386,633,049
<b>Total Project Costs (without IDC)</b>	<b>851,920,225</b>	<b>720,225,053</b>	<b>870,649,875</b>
<b>Total Project Costs (including IDC)</b>	<b>966,950,117</b>	<b>815,699,864</b>	<b>1054697702</b>

### 3.2.2.2 OPEX (Costs during operation and maintenance)

Operation and Maintenance (O&M) costs comprise the total annual expenditure incurred during the operation of the project. O&M costs are split into:

- Fixed O&M costs: Fixed operating expenses related to the type and size of the plant only, but not related to the output.
- Variable O&M costs: Expenses depend on the output of the plant.

For hydropower plants, the variable O&M costs are rather small compared to fixed O&M costs. O&M costs typically include cost components for regular operation and maintenance, overhauls, staff, management and administration, and insurance and fees. The cost estimate for OPEX's main sections and components is in Table 27. And the OPEX's results of 3 cases are provided in Table 28.

Table 27: OPEX components including ;

Type of OPEX	Description
Cost Item	Cost of O&M (without overhauls)
	Staff Cost
	Administration and Management
	Insurances and Fees
Cost for overhauls (Maintenance)	Major overhaul (every 6 years) = 1.3% of CAPEX for Generating E&M Equipment
	Minor overhaul (every 12 years) = 3.7% of CAPEX for E&M Equipment

Table 28: OPEX Result ;

		Luzon	Visayas	Mindanao
<b>Installed Capacity</b>	MW	800	660	2500
<b>Overall Project Cost (financial cost excluded)</b>	USD	690,000,000	572,700,000	1,104,000,000
<b>CAPEX for E&amp;M Equipment</b>	USD	137,760,000	114,340,800	220,416,000
<b>Cost of O&amp;M (without overhauls)</b>				
<b>Spare parts for E&amp;M and HM equipment</b>	USD/year	2,640,000	2,178,000	8,250,000
<b>Maintenance and repair of civil structures</b>	USD/year	250,000	207,500	400,000

<b>Total</b>	<b>USD/year</b>	2,890,000	2,385,500	8,650,000
<b>Cost for overhauls</b>				
<b>Minor overhaul (every 6 years)</b>	USD	1790880	1486430.4	2865408
<b>Major overhaul (every 12 years)</b>	USD	5097120	4230609.6	8155392
<b>Staff Cost</b>				
<b>O&amp;M Personal at site</b>	USD/year	2,237,580	2,237,580	2,237,580
<b>Other office costs at site</b>	USD/year	200,000	166,000	320,000
<b>Total</b>	<b>USD/year</b>	2,437,580	2,403,580	2,557,580
<b>Administration and Management</b>				
<b>Staff costs</b>	USD/year	1,179,240	1,179,240	1,179,240
<b>Other office expenses</b>	USD/year	200,000	166,000	320,000
<b>Total</b>	<b>USD/year</b>	1,379,240	1,345,240	1,499,240
<b>Insurances and Fees</b>				
<b>Insurance premium</b>	USD/year	1,725,000	1,431,750	2,760,000
<b>Total</b>	<b>USD/year</b>	1,725,000	1,431,750	2,760,000
<b>Cost Item</b>				
<b>Cost of O&amp;M (without overhauls)</b>	USD/year	2,890,000	2,385,500	8,650,000
<b>Staff Cost</b>	USD/year	2,437,580	2,403,580	2,557,580
<b>Administration and Management</b>	USD/year	1,379,240	1,345,240	1,499,240
<b>Insurances and Fees</b>	USD/year	1,725,000	1,431,750	2,760,000
<b>Total</b>		<b>8,431,820</b>	<b>7,566,070</b>	<b>15,466,820</b>

### 3.2.3 Summary Cash Flow Model

This process will use inflation to forecast the value of electricity prices for 25 years after construction is complete. The cash inflow will use only energy sales, and the cash outflow will be CAPEX, OPEX, and pumping costs as in the flowchart of Figure 46.

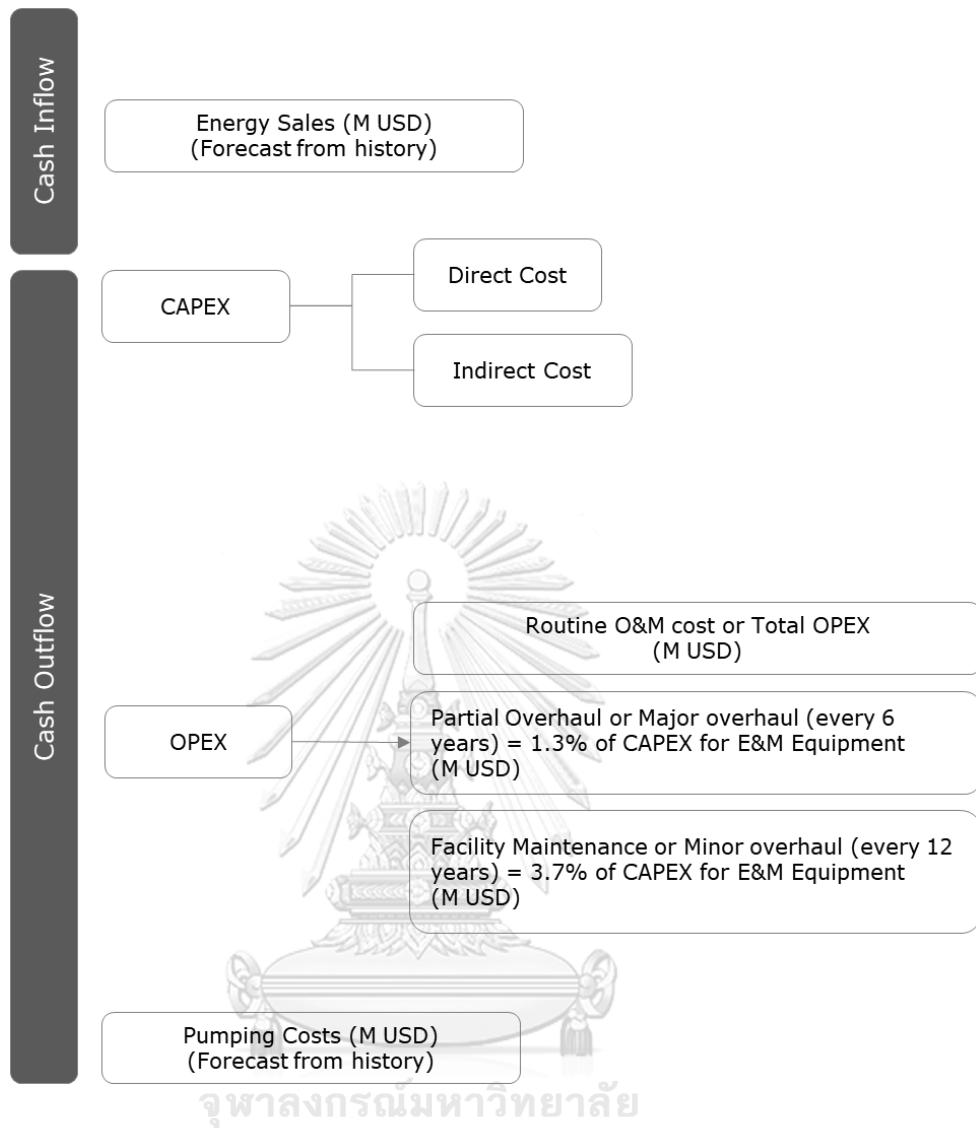


Figure 46: Cash Inflow and cash outflow flowchart.

Table 29 shows the inflation rate to apply to the average inflation history in the last 12 years (2009-2020). (Source; Worlddata)

Table 29: Inflation rates for consumer Goods in the Philippines.

<b>Year</b>	<b>Inflation rates</b>
<b>2020</b>	2.64%
<b>2019</b>	2.48%
<b>2018</b>	5.21%
<b>2017</b>	2.85%
<b>2016</b>	1.25%
<b>2015</b>	0.67%
<b>2014</b>	3.60%
<b>2013</b>	2.58%
<b>2012</b>	3.03%
<b>2011</b>	4.72%
<b>2010</b>	3.79%
<b>2009</b>	4.22%
<b>Average</b>	<b>3.09%</b>

### 3.2.3.1 Cash Inflow

This method is based on data from Chapter 3.2.1.1, which was determined by generation energy and peak hour, and calculated with a 3.09% inflation forecast for the next 25 years (Table 29). The result of cash inflow will be represented in Table 30 to Table 32 (Green Column).

### 3.2.3.2 Cash Outflow

This procedure is based on data from Chapter 3.2.1.2, which was determined by energy pumping and non-peak tariffs, with 3.09 % inflation expected over the next 25 years, including CAPEX and OPEX from Chapter 3.2.2. The results of of cash outflow will be represented in Table 30 to Table 32 (Orange Column).



Table 30: The result of cash inflow and cash outflow estimation in Case Study 1, Luzon.

Year	Cash Inflow				Cash Outflow				Total Cost	
	Energy	Price Fix Rate	Forecast of price with inflation rate	Total Generation Revenues	Energy consumed	Price Fix Rate	Forecast of price with inflation rate	Pumping Costs		Total O&M Costs (OPEX)
	GWh/year	USD/kWh	USD/kWh	[M USD]	GWh/year	USD/kWh	USD/kWh	[M USD]	[M USD]	
1	3664.279	0.089	0.092	336.648	3194.976	0.048	0.049	157.573	8.432	166.00
2	3664.279	0.089	0.095	347.051	3194.976	0.048	0.051	162.442	8.432	170.87
3	3664.279	0.089	0.098	357.774	3194.976	0.048	0.052	167.462	8.432	175.89
4	3664.279	0.089	0.101	368.830	3194.976	0.048	0.054	172.636	8.432	181.07
5	3664.279	0.089	0.104	380.226	3194.976	0.048	0.056	177.971	8.432	186.40
6	3664.279	0.089	0.107	391.975	3194.976	0.048	0.057	183.470	10.223	193.69
7	3664.279	0.089	0.110	404.088	3194.976	0.048	0.059	189.139	8.432	197.57
8	3664.279	0.089	0.114	416.574	3194.976	0.048	0.061	194.984	8.432	203.42
9	3664.279	0.089	0.117	429.446	3194.976	0.048	0.063	201.009	8.432	209.44
10	3664.279	0.089	0.121	442.716	3194.976	0.048	0.065	207.220	8.432	215.65
11	3664.279	0.089	0.125	456.396	3194.976	0.048	0.067	213.623	8.432	222.05
12	3664.279	0.089	0.128	470.498	3194.976	0.048	0.069	220.224	13.529	233.75
13	3664.279	0.089	0.132	485.037	3194.976	0.048	0.071	227.029	8.432	235.46
14	3664.279	0.089	0.136	500.024	3194.976	0.048	0.073	234.044	8.432	242.48
15	3664.279	0.089	0.141	515.475	3194.976	0.048	0.076	241.276	8.432	249.71
16	3664.279	0.089	0.145	531.403	3194.976	0.048	0.078	248.731	8.432	257.16
17	3664.279	0.089	0.150	547.824	3194.976	0.048	0.080	256.417	8.432	264.85
18	3664.279	0.089	0.154	564.751	3194.976	0.048	0.083	264.340	10.223	274.56
19	3664.279	0.089	0.159	582.202	3194.976	0.048	0.085	272.508	8.432	280.94
20	3664.279	0.089	0.164	600.192	3194.976	0.048	0.088	280.929	8.432	8.60
21	3664.279	0.089	0.169	618.738	3194.976	0.048	0.091	289.610	8.432	298.04
22	3664.279	0.089	0.174	637.857	3194.976	0.048	0.093	298.559	8.432	306.99
23	3664.279	0.089	0.179	657.567	3194.976	0.048	0.096	307.784	8.432	316.22
24	3664.279	0.089	0.185	677.886	3194.976	0.048	0.099	317.294	13.529	330.82
25	3664.279	0.089	0.191	698.833	3194.976	0.048	0.102	327.099	8.432	335.53

Table 31: The result of cash inflow and cash outflow estimation in Case Study 2, Visayas.

Year	Cash Inflow			Cash Outflow			Total Cost			
	Energy	Price Fix Rate	Forecast of price with inflation rate	Total Generation Revenues	Energy consumed	Price Fix Rate		Forecast of price with inflation rate	Pumping Costs	Total O&M Costs (OPEX)
	GWh/year	USD/kW <sub>h</sub>	USD/kWh	[M USD]	GWh/year	USD/kW <sub>h</sub>	USD/kWh	[M USD]	[M USD]	
1	3023.030	0.080	0.083	250.418	2635.856	0.049	0.050	132.767	7.566	140.33
2	3023.030	0.080	0.085	258.156	2635.856	0.049	0.052	136.870	7.566	144.44
3	3023.030	0.080	0.088	266.133	2635.856	0.049	0.054	141.099	7.566	148.67
4	3023.030	0.080	0.091	274.356	2635.856	0.049	0.055	145.459	7.566	153.03
5	3023.030	0.080	0.094	282.834	2635.856	0.049	0.057	149.954	7.566	157.52
6	3023.030	0.080	0.096	291.573	2635.856	0.049	0.059	154.587	9.053	163.64
7	3023.030	0.080	0.099	300.583	2635.856	0.049	0.060	159.364	7.566	166.93
8	3023.030	0.080	0.103	309.871	2635.856	0.049	0.062	164.288	7.566	171.85
9	3023.030	0.080	0.106	319.446	2635.856	0.049	0.064	169.365	7.566	176.93
10	3023.030	0.080	0.109	329.317	2635.856	0.049	0.066	174.598	7.566	182.16
11	3023.030	0.080	0.112	339.493	2635.856	0.049	0.068	179.993	7.566	187.56
12	3023.030	0.080	0.116	349.983	2635.856	0.049	0.070	185.555	11.797	197.35
13	3023.030	0.080	0.119	360.797	2635.856	0.049	0.073	191.289	7.566	198.85
14	3023.030	0.080	0.123	371.946	2635.856	0.049	0.075	197.200	7.566	204.77
15	3023.030	0.080	0.127	383.439	2635.856	0.049	0.077	203.293	7.566	210.86
16	3023.030	0.080	0.131	395.288	2635.856	0.049	0.080	209.575	7.566	217.14
17	3023.030	0.080	0.135	407.502	2635.856	0.049	0.082	216.051	7.566	223.62
18	3023.030	0.080	0.139	420.094	2635.856	0.049	0.084	222.727	9.053	231.78
19	3023.030	0.080	0.143	433.075	2635.856	0.049	0.087	229.609	7.566	237.18
20	3023.030	0.080	0.148	446.457	2635.856	0.049	0.090	236.704	7.566	244.27
21	3023.030	0.080	0.152	460.252	2635.856	0.049	0.093	244.018	7.566	251.58
22	3023.030	0.080	0.157	474.474	2635.856	0.049	0.095	251.558	7.566	259.12
23	3023.030	0.080	0.162	489.135	2635.856	0.049	0.098	259.331	7.566	266.90
24	3023.030	0.080	0.167	504.249	2635.856	0.049	0.101	267.345	11.797	279.14
25	3023.030	0.080	0.172	519.831	2635.856	0.049	0.105	275.606	7.566	283.17



Table 32: The result of cash inflow and cash outflow estimation in Case Study 3, Mindanao.

Year	Cash Inflow				Cash Outflow				Total Cost [M USD]	
	Energy GWh/year	Price Fix Rate USD/kW <sup>h</sup>	Forecast of price with inflation rate USD/kWh	Total Generation Revenues [M USD]	Energy consumed GWh/year	Price Fix Rate USD/kW <sup>h</sup>	Forecast of price with inflation rate USD/kWh	Pumping Costs [M USD]		Total O&M Costs (OPEX) [M USD]
1	11450.871	0.060	0.062	709.250	9984.301	0.049	0.050	501.844	15.467	517.31
2	11450.871	0.060	0.064	731.166	9984.301	0.049	0.052	517.351	15.467	532.82
3	11450.871	0.060	0.066	753.759	9984.301	0.049	0.053	533.337	15.467	548.80
4	11450.871	0.060	0.068	777.050	9984.301	0.049	0.055	549.817	15.467	565.28
5	11450.871	0.060	0.070	801.061	9984.301	0.049	0.057	566.806	15.467	582.27
6	11450.871	0.060	0.072	825.814	9984.301	0.049	0.059	584.321	18.332	602.65
7	11450.871	0.060	0.074	851.332	9984.301	0.049	0.060	602.376	15.467	617.84
8	11450.871	0.060	0.077	877.638	9984.301	0.049	0.062	620.990	15.467	636.46
9	11450.871	0.060	0.079	904.757	9984.301	0.049	0.064	640.178	15.467	655.65
10	11450.871	0.060	0.081	932.714	9984.301	0.049	0.066	659.960	15.467	675.43
11	11450.871	0.060	0.084	961.535	9984.301	0.049	0.068	680.353	15.467	695.82
12	11450.871	0.060	0.087	991.246	9984.301	0.049	0.070	701.375	23.622	725.00
13	11450.871	0.060	0.089	1021.876	9984.301	0.049	0.072	723.048	15.467	738.51
14	11450.871	0.060	0.092	1053.452	9984.301	0.049	0.075	745.390	15.467	760.86
15	11450.871	0.060	0.095	1086.003	9984.301	0.049	0.077	768.423	15.467	783.89
16	11450.871	0.060	0.098	1119.561	9984.301	0.049	0.079	792.167	15.467	807.63
17	11450.871	0.060	0.101	1154.155	9984.301	0.049	0.082	816.645	15.467	832.11
18	11450.871	0.060	0.104	1189.819	9984.301	0.049	0.084	841.879	18.332	860.21
19	11450.871	0.060	0.107	1226.584	9984.301	0.049	0.087	867.893	15.467	883.36
20	11450.871	0.060	0.110	1264.486	9984.301	0.049	0.090	894.711	15.467	910.18
21	11450.871	0.060	0.114	1303.558	9984.301	0.049	0.092	922.358	15.467	937.82
22	11450.871	0.060	0.117	1343.838	9984.301	0.049	0.095	950.859	15.467	966.33
23	11450.871	0.060	0.121	1385.363	9984.301	0.049	0.098	980.240	15.467	995.71
24	11450.871	0.060	0.125	1428.170	9984.301	0.049	0.101	1010.530	23.622	1034.15
25	11450.871	0.060	0.129	1472.301	9984.301	0.049	0.104	1041.755	15.467	1057.22

### 3.3 Feasibility Study by Discount Cash Flow Model (DCF)

The result of revenue and cost will apply to estimate the economic value by “Discounted Cash Flow Model” (DCF Model). The value to input the DCF is;

#### a) Revenue from Electric Sales Production

This value is calculated using the annual price, which varies each year. Refer to the table below (Green color column);

Revenue of Case study 1; Table 30

Revenue of Case study 2; Table 31

Revenue of Case study 3; Table 32

#### b) Construction Cost Estimate without interest during construction (CAPEX without IDC)

CAPEX without IDC of Case study 1; Luzon is 851.92 M USD.

CAPEX without IDC of Case study 2; Visayas is 720.225 M USD.

CAPEX without IDC of Case study 3; Mindanao is 870.650 M USD.

#### c) Costs during operation and maintenance (OPEX)

OPEX of Case study 1; Luzon is 8.432 M USD.

##### ▪ Cost for overhauls (Maintenance)

- Major overhaul = 1.3% of CAPEX without IDC= 10.223 M USD.

- Minor overhaul = 3.7% of CAPEX without IDC= 13.529 M USD.

OPEX of Case study 2; Visayas is 7.566 M USD.

- Cost for overhauls (Maintenance)
  - Major overhaul = 1.3% of CAPEX without IDC= 9.053 M USD.
  - Minor overhaul = 3.7% of CAPEX without IDC= 11.797 M USD.

OPEX of Case study 3; Mindanao is 15.467 M USD.

- Cost for overhauls (Maintenance)
  - Major overhaul = 1.3% of CAPEX without IDC= 18.332 M USD.
  - Minor overhaul = 3.7% of CAPEX without IDC= 23.622 M USD.

**d) Pumping Cost**

This value is calculated using the annual price, which varies each year.

Pumping cost of Case study 1; Table 30

Pumping cost of Case study 2; Table 31

Pumping cost of Case study 3; Table 32

\*\*\* *Cash outflow* = *OPEX* + *Pumping cost*

**e) Weighted Average Cost of Capital (WACC)**

The Weighted Average Cost of Capital (WACC) is used to calculate the discount rate based on the cost structure of borrowing, equity costs, and tax rates. Following the previous project [9], this research will apply WACC 9 % same to discount rate.

**f) Discount Factor**

For the economic analysis a discount rate(*r*) of 9% is considered in the free project cash flow.

The discount factor (%) = $\frac{1}{(1 + r)^t}$
---

**g) Discount Factor Concession and Depreciation Period**

Concession and depreciation period is 25 years.

**h) Depreciation**

Depreciation per year will use CAPEX without interest during construction divide 25 years.

**i) Gross Income**

Gross Income = Cash Inflow – (Cash Outflow + Depreciation)

**j) Taxes**

Annual tax from years 8 to 25 = 10% of gross income, following the information in 2.5.1 and 2.5.5.

**k) Net Income After Tax**

Net Income After Tax = Gross Income – Tax

**l) After Tax Cash Flow**

After Tax Cash Flow = Depreciation per year + Net Income After Tax

**m) Cash Flow Discounted**

Cash Flow Discounted = After Tax Cash Flow \* Discount Factor

All of the above values will be applied to the table, and the DCF model will be calculated using Excel. Summarize the three cases in the table from 33 to 35.

Table 33: The DCF model of Case Study 1: Luzon.

Year	Cash Inflow		Cash Outflow		Depreciation	Gross Income	Taxes	Net Income After Tax	After Tax Cash Flow	Discount Factor	Cash Flow Discounted	Cash Flow Cumulated	PB		
	[M USD]	[M USD]	[M USD]	[M USD]									Y1	Y2	
0		851.92													
1	336.65	166.005	34.08	136.57		136.57		136.57	170.64	100%	170.64	-851.92	1	0.00	
2	347.05	170.874	34.08	142.10		142.10		142.10	176.18	100%	161.63	-681.28	1	0.00	
3	357.77	175.893	34.08	147.80		147.80		147.80	181.88	92%	153.09	-505.10	1	0.00	
4	368.83	181.068	34.08	153.68		153.68		153.68	187.76	84%	144.99	-323.22	1	0.00	
5	380.23	186.402	34.08	159.75		159.75		159.75	193.82	77%	137.31	-135.46	1	0.00	
6	391.98	193.693	34.08	164.21		164.21		164.21	198.28	71%	128.87	58.37	0	0.70	
7	404.09	197.571	34.08	172.44		172.44		172.44	206.52	65%	123.14	256.65	0	0.00	
8	416.57	203.415	34.08	179.08		179.08	17.91	161.17	195.25	60%	106.81	463.17	0	0.00	
9	429.45	209.440	34.08	185.93		185.93	18.59	167.34	201.41	55%	101.08	658.42	0	0.00	
10	442.72	215.651	34.08	192.99		192.99	19.30	173.69	207.77	50%	95.66	859.83	0	0.00	
11	456.40	222.055	34.08	200.26		200.26	20.03	180.24	214.31	46%	90.53	1067.59	0	0.00	
12	470.50	233.753	34.08	202.67		202.67	20.27	182.40	216.48	42%	83.89	1281.91	0	0.00	
13	485.04	235.460	34.08	215.50		215.50	21.55	193.95	228.03	39%	81.07	1498.39	0	0.00	
14	500.02	242.476	34.08	223.47		223.47	22.35	201.12	235.20	36%	76.72	1726.41	0	0.00	
15	515.48	249.708	34.08	231.69		231.69	23.17	208.52	242.60	33%	72.60	1961.62	0	0.00	
16	531.40	257.163	34.08	240.16		240.16	24.02	216.15	250.22	30%	68.70	2204.21	0	0.00	
17	547.82	264.849	34.08	248.90		248.90	24.89	224.01	258.09	27%	65.00	2454.44	0	0.00	
18	564.75	274.563	34.08	256.11		256.11	25.61	230.50	264.58	25%	61.14	2712.52	0	0.00	
19	582.20	280.940	34.08	267.19		267.19	26.72	240.47	274.54	23%	58.20	2977.10	0	0.00	
20	600.19	8.596	34.08	557.52		557.52	55.75	501.77	535.84	21%	54.22	3251.64	0	0.00	
21	618.74	298.041	34.08	286.62		286.62	28.66	257.96	521.11	19%	50.11	3787.49	0	0.00	
22	637.86	306.990	34.08	296.79		296.79	29.68	267.11	501.19	18%	49.30	4079.52	0	0.00	
23	657.57	316.216	34.08	307.27		307.27	30.73	276.55	501.19	16%	46.65	4380.71	0	0.00	
24	677.89	330.823	34.08	312.99		312.99	31.30	281.69	501.19	15%	43.51	4691.34	0	0.00	
25	698.83	335.531	34.08	329.23		329.23	32.92	296.30	330.38	14%	41.76	5007.10	0	0.00	
										13%		5337.48	0	0.00	

Total Costs (without IDC): 851.92 M USD NPV 1,467 M USD  
 Discount Rate: 9.0% IRR 22.56%  
 Concession Period: 25 years Payback Period 4 years  
 Depreciation Period: 25 years  
 Taxes (year 8-25): 10%

Table 34: The DCF model of Case Study 2: Visayas.

Total Costs (without IDC):		720.23	M USD	NPV	756	M USD						
Discount Rate:		9.0%		IRR	17.48%							
Concession Period:		25	years	Payback Period	6	years						
Depreciation Period:		25	years									
Taxes (year 8-25):		10%										
Year	Cash Inflow	Cash Outflow	Depreciation	Gross Income	Taxes	Net Income After Tax	After Tax Cash Flow	Discount Factor	Cash Flow Discounted	Cash Flow Cumulated	Y1	Y2
	[M USD]	[M USD]	[M USD]	[M USD]	[M USD]	[M USD]	[M USD]		[M USD]	[M USD]		
0		720.23				-720.23	-720.23	100%	-720.23	-720.23	1	0.00
1	250.42	140.333	34.08	76.01		76.01	110.08	100%	110.08	-610.14	1	0.00
2	258.16	144.436	34.08	79.64		79.64	113.72	92%	104.33	-496.42	1	0.00
3	266.13	148.665	34.08	83.39		83.39	117.47	84%	98.87	-378.95	1	0.00
4	274.36	153.025	34.08	87.25		87.25	121.33	77%	93.69	-257.62	1	0.00
5	282.83	157.520	34.08	91.24		91.24	125.31	71%	88.78	-132.31	1	0.00
6	291.57	163.040	34.08	93.86		93.86	127.93	65%	83.15	-4.38	1	0.00
7	300.58	166.930	34.08	99.58		99.58	133.65	60%	79.69	129.28	0	0.03
8	309.87	171.854	34.08	103.94	10.39	93.55	127.62	55%	69.81	256.90	0	0.00
9	319.45	176.931	34.08	108.44	10.84	97.59	131.67	50%	66.08	388.57	0	0.00
10	329.32	182.164	34.08	113.08	11.31	101.77	135.84	46%	62.55	524.42	0	0.00
11	339.49	187.559	34.08	117.86	11.79	106.07	140.15	42%	59.20	664.56	0	0.00
12	349.98	197.352	34.08	118.55	11.86	106.70	140.78	39%	54.56	805.34	0	0.00
13	360.80	198.855	34.08	127.87	12.79	115.08	149.16	36%	53.03	954.50	0	0.00
14	371.95	204.766	34.08	133.10	13.31	119.79	153.87	33%	50.19	1108.37	0	0.00
15	383.44	210.859	34.08	138.50	13.85	124.65	158.73	30%	47.50	1267.10	0	0.00
16	395.29	217.141	34.08	144.07	14.41	129.66	163.74	27%	44.95	1430.83	0	0.00
17	407.50	223.617	34.08	149.81	14.98	134.83	168.90	25%	42.54	1599.74	0	0.00
18	420.09	231.779	34.08	154.24	15.42	138.81	172.89	23%	39.95	1772.63	0	0.00
19	433.07	237.175	34.08	161.82	16.18	145.64	179.72	21%	38.10	1952.35	0	0.00
20	446.46	244.270	34.08	168.11	16.81	151.30	185.38	19%	36.05	2137.72	0	0.00
21	460.25	251.584	34.08	174.59	17.46	157.13	191.21	18%	34.12	2328.93	0	0.00
22	474.47	259.124	34.08	181.27	18.13	163.15	197.22	16%	32.28	2526.15	0	0.00
23	489.14	266.897	34.08	188.16	18.82	169.34	203.42	15%	30.55	2729.58	0	0.00
24	504.25	279.141	34.08	191.03	19.10	171.93	206.00	14%	28.38	2935.58	0	0.00
25	519.83	283.172	34.08	202.58	20.26	182.32	216.40	13%	27.55	3151.98	0	0.00

Table 35: The DCF model of Case Study 3: Mindanao.

Year	Cash Inflow	Cash Outflow	Depreciation	Gross Income	Taxes	Net Income After Tax	After Tax Cash Flow	Discount Factor	Cash Flow Discounted	Cash Flow Cumulated	PB	
											Y1	Y2
0	[M USD]	[M USD]	[M USD]	[M USD]	[M USD]	[M USD]	[M USD]		[M USD]	[M USD]		
1	709.25	870.65	34.83	157.11		-870.65	-870.65	100%	-870.65	-870.65	1	0.00
2	731.17	517.311	34.83	163.52		157.11	191.94	100%	191.94	-678.71	1	0.00
3	753.76	532.818	34.83	170.13		163.52	198.35	92%	181.97	-480.36	1	0.00
4	777.05	548.804	34.83	176.94		170.13	204.96	84%	172.51	-275.41	1	0.00
5	801.06	565.284	34.83	183.96		176.94	211.77	77%	163.52	-63.64	1	0.00
6	825.81	582.273	34.83	188.34		183.96	218.79	71%	154.99	155.15	0	0.29
7	851.33	602.653	34.83	198.66		188.34	223.16	65%	145.04	378.31	0	0.00
8	877.64	617.843	34.83	198.66		198.66	233.49	60%	139.22	611.80	0	0.00
9	904.76	636.457	34.83	206.36	20.64	185.72	220.55	55%	120.65	832.34	0	0.00
10	932.71	655.645	34.83	214.29	21.43	192.86	227.68	50%	114.27	1060.03	0	0.00
11	961.53	675.427	34.83	222.46	22.25	200.22	235.04	46%	108.22	1295.07	0	0.00
12	991.25	695.819	34.83	230.89	23.09	207.80	242.63	42%	102.49	1537.70	0	0.00
13	1021.88	724.998	34.83	231.42	23.14	208.28	243.11	39%	94.21	1780.80	0	0.00
14	1053.45	738.515	34.83	248.54	24.85	223.68	258.51	36%	91.91	2039.31	0	0.00
15	1086.00	760.857	34.83	257.77	25.78	231.99	266.82	33%	87.03	2306.13	0	0.00
16	1119.56	783.890	34.83	267.29	26.73	240.56	275.39	30%	82.41	2581.51	0	0.00
17	1154.16	807.634	34.83	277.10	27.71	249.39	284.22	27%	78.03	2865.73	0	0.00
18	1189.82	832.112	34.83	287.22	28.72	258.50	293.32	25%	73.88	3159.05	0	0.00
19	1226.58	860.211	34.83	294.78	29.48	265.30	300.13	23%	69.35	3459.18	0	0.00
20	1264.49	883.360	34.83	308.40	30.84	277.56	312.38	21%	66.22	3771.56	0	0.00
21	1303.56	910.178	34.83	319.48	31.95	287.53	322.36	19%	62.70	4093.92	0	0.00
22	1343.84	937.825	34.83	330.91	33.09	297.82	332.64	18%	59.35	4426.57	0	0.00
23	1385.36	966.325	34.83	342.69	34.27	308.42	343.24	16%	56.19	4769.81	0	0.00
24	1428.17	995.707	34.83	354.83	35.48	319.35	354.17	15%	53.19	5123.98	0	0.00
25	1472.30	1034.152	34.83	359.19	35.92	323.27	358.10	14%	49.34	5482.08	0	0.00
		1057.222	34.83	380.25	38.03	342.23	377.05	13%	47.66	5859.14	0	0.00

Total Costs (without IDC): 870.65 M USD      NPV 1,696 M USD  
Discount Rate: 9.0%      IRR 20.94%  
Concession Period: 25 years      Payback Period 4 years  
Depreciation Period: 25 years  
Taxes (year 8-25): 10%

## CHAPTER 4

### CONCLUSION AND RECOMMEDATION

This investigation, as noted by the author in the introduction, is the preliminary stage in establishing the viable placement of PSP. The pump storage hydropower project is a large construction that supports the long-run energy. And it can supply-demand of a career in the country. However, hydropower project feasibility requires further information, such as slope design, hydraulics, power electric scenarios, civil design, environment, and so on. But this study works only 2 sectors; Geography and Geology to select the potential area. Then using DCF to summarize the feasibility as shown in Table 37.

Table 36: Summarize the total cost (without IDC) for DCF model of 3 Cases.

	<b>Luzon</b>	<b>Visayas</b>	<b>Mindanao</b>
<b>Total Costs (without IDC) [M USD]</b>	851.92	720.23	870.65

Table 37: Summarize the DCF model of 3 Cases.

<b>Case Study</b>	<b>NPV</b>	<b>IRR</b>	<b>PB</b>
<b>Luzon</b>	1,467	22.56%	4
<b>Visayas</b>	756	17.48%	6
<b>Mindanao</b>	1,696	20.94%	4

Mindanao, in particular, The location has the ability to produce a large amount of energy while also delivering advantages. This region does not have the same amount of energy consumption as Luzon. As a result, if we need to create this PSP in the future, other



considerations such as infrastructure planning and city density will need to be extensively investigated. And additional research on the cost of purifying seawater for the purpose of producing electricity is necessary.

The economic and financial research analyst for three PSPs is based on the Belisama PSP [9] which includes all parameters as well as a fully simulated energy and revenue model using 2018 data. The results may vary in the future, depending on the market share price of LCOE. And base on DCF by apply discount factor, WACC, and inflation in next 25 years.

The project's economic analysis increases sensitivity analysis to determine the robustness of the project's economics by adjusting the primary input parameters and determining the impact on the project's economic key indicators. The variables under consideration include the influence on the cost side (CAPEX, O&M, and pumping costs) and the revenue side (energy generation), including depreciation and inflation.

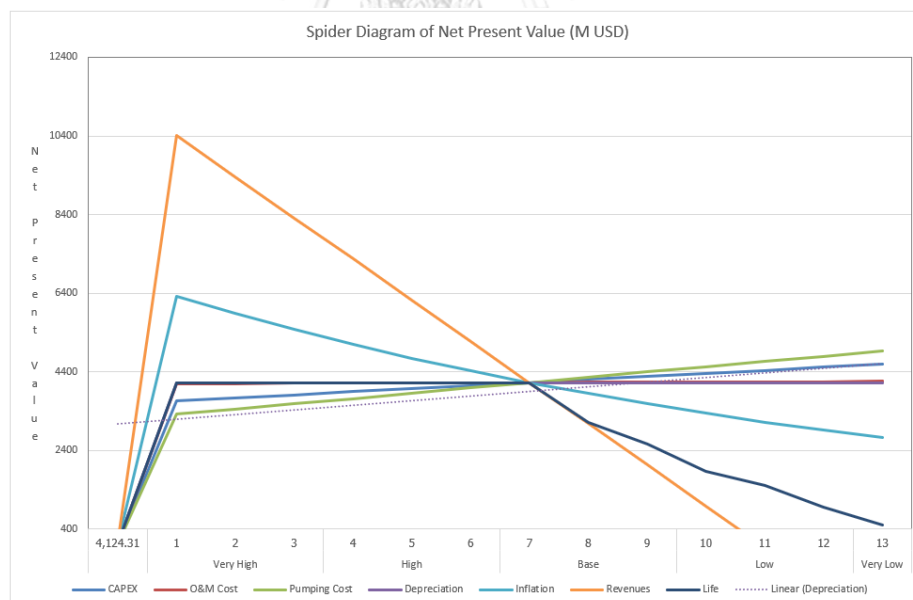


Figure 47: Spider diagram of net present value with various indicators.

The author's contribution to this work is to give options for "Water Management" in developed countries. Numerous benefits from this research could have a positive impact on the environment, promoting clean energy and preserving the country's energy stability.

The final suggestion is that not only this research can produce the best PSP, but there are several dimensions that require deep learning prior to beginning the project, such as topography survey with high resolution (centimeter), investigation geology, electro-mechanical and hydro-mechanical equipment, civil design, risk assessment, and simulation of operational aspects. In the site inspection, the investor and consultant might use high-resolution resolution data to select new areas with the highest PSP potential.

The operation process will be less expensive due to "Hybrid" technology; at this time, pump-storage hydropower projects can use another technology to assist generated electricity in the pumping stage, such as solar and wind technology. This is the future energy-saving technology in combination.


## REFERENCES

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# APPENDIX A

## QGIS TO VIEW WMS

To add a WMS layer from the menu, choose **Layer > Add Layer > Add WMS/WMTS Layer**. Alternatively, click on the  button on the **Manage Layers Toolbar**. In the **Add Layer(s) from a WM(T)S Server** pop-up box click the **New** button, and then in the **Create a new WMS connection** pop-up add a name for your service, such as OneGeology shapefile exemplar (fcgi) using MapServer 6 and the service URL (with no parameters) as below and then click 'OK'.

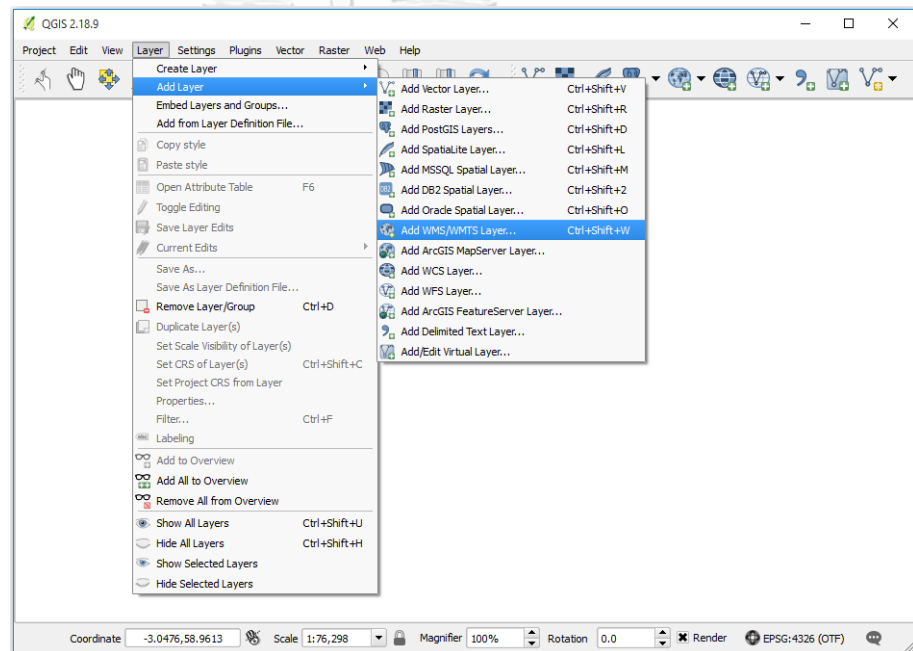


Figure 1 - QGIS menu option for adding a WMS.

We recommend using no parameters (above), so that you get the latest version of the WMS service. If you are testing your own system and you want to test a particular version you can add that version as a parameter; such as:

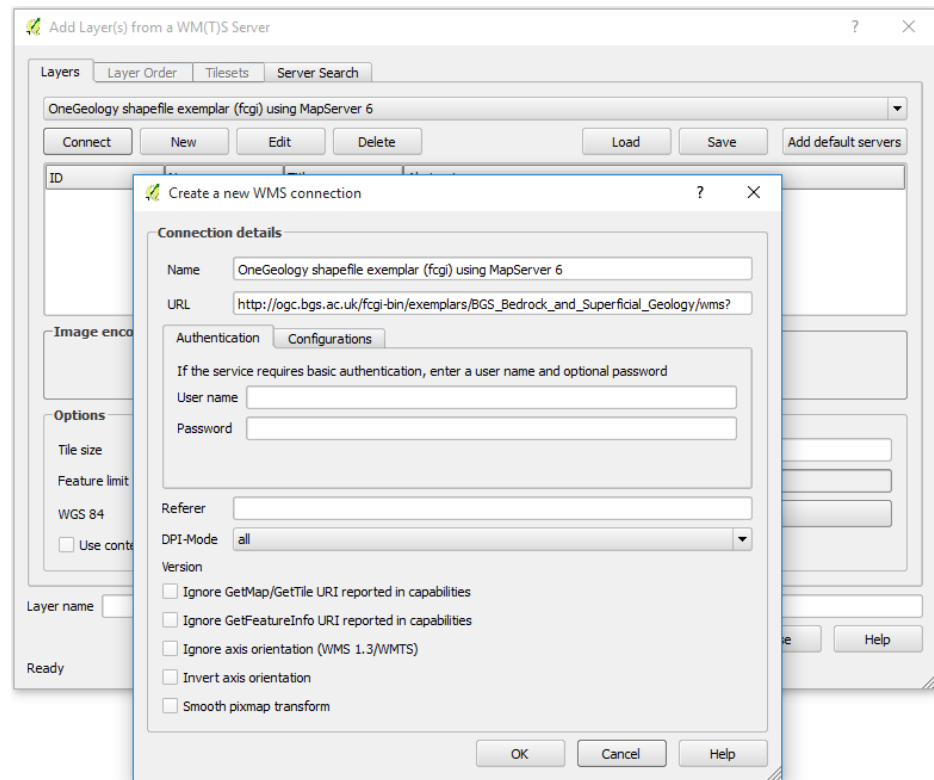


Figure 2 - Adding a new WMS Service.

As with most other clients at this stage all you've done is add the WMS service to the list of available WMS services. To add a layer you need to select the WMS service from the **Add Layer(s) from a WM(T)S Server** pop-up box, and click 'Connect'. This will show you a list of the layers being served from the WMS service.

If you are behind a firewall, you may also need to add information about your proxy server. This is done through the **Settings > Options** menu in the **Network** section.

Click on the layer you want and click 'Add', this will add that layer in the background, but keep the pop-up window to allow you to add another layer. Press **Ctrl** and click again on a selected layer to deselect it.

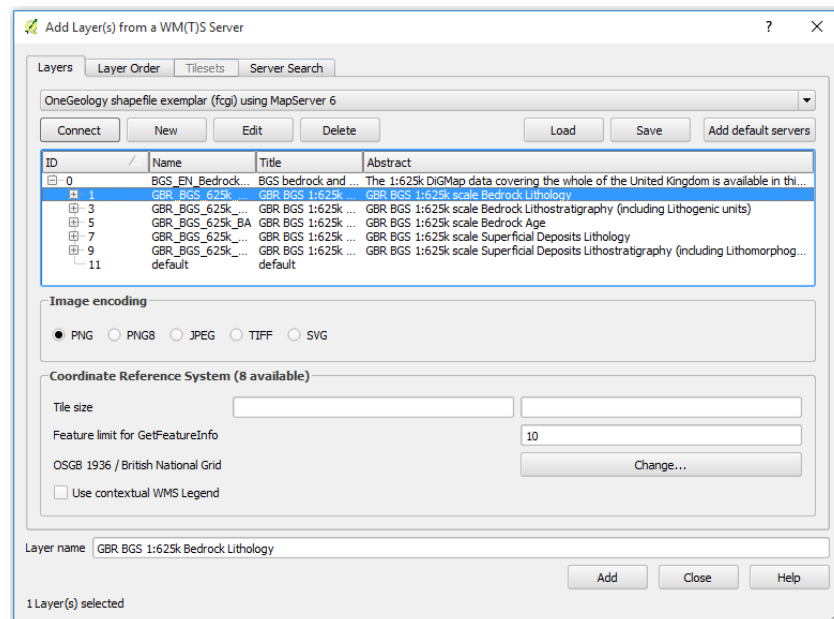


Figure 3 - Selecting layers.

Note, if you select several layers (using **Ctrl** or **Shift** keys) and then click Add, QGIS will show those selected WMS layers as a single 'derived' layer in the GIS. In this example we have joined the bedrock lithostratigraphy and the superficial lithostratigraphy geology layers to create a single layer which we name 'Lithostratigraphy'. Note you can rename any WMS layer to one that suits your needs, change the layer CRS, and change the layer image encoding (the default is png).

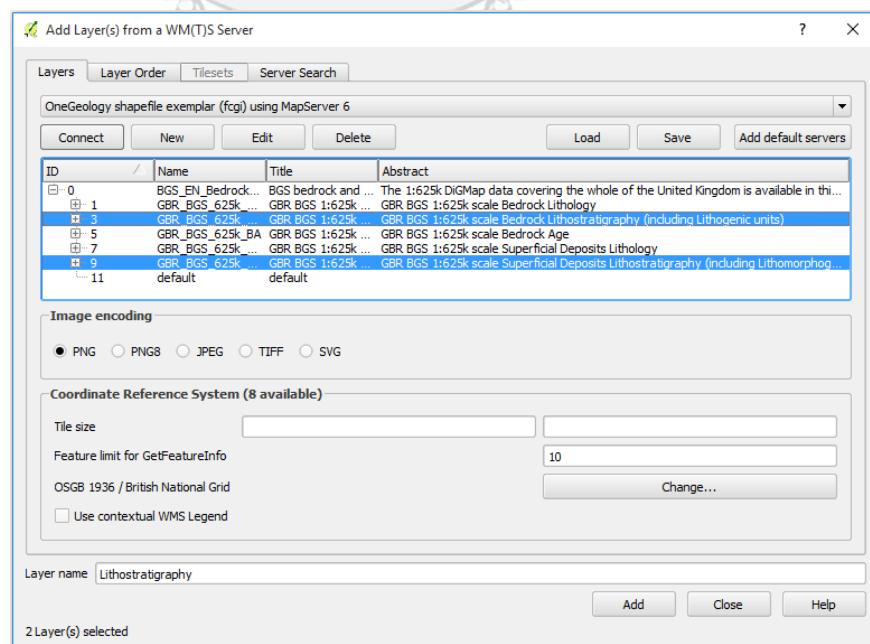


Figure 4 - Creating derived layers.

If the selected layer is set to be query able in the WMS service, you may use the identify tool to retrieve information on any feature in the map.

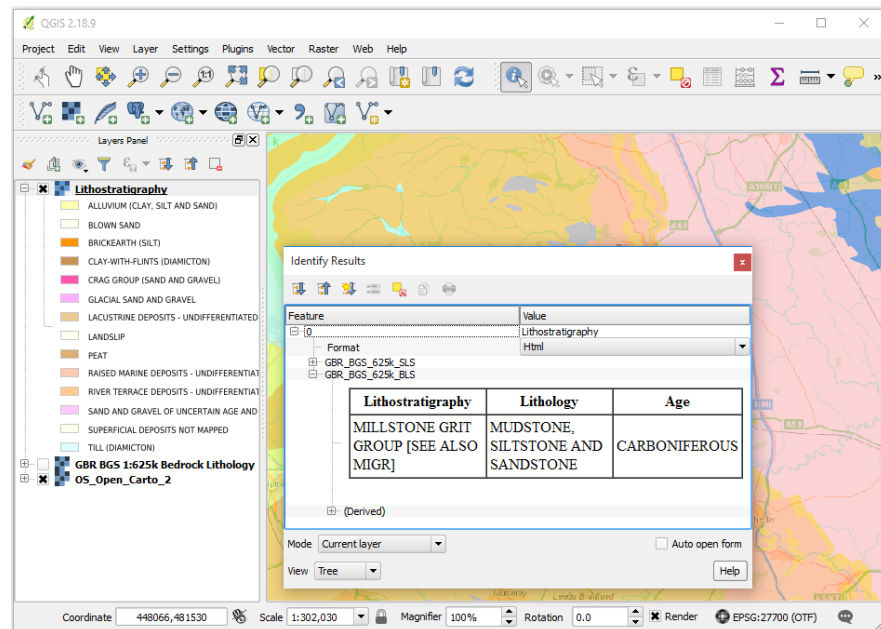


Figure 5 - WMS feature identification.

You may right click on any layer in the layer list and go to **Properties** to get the metadata for that layer and the service that serves it.

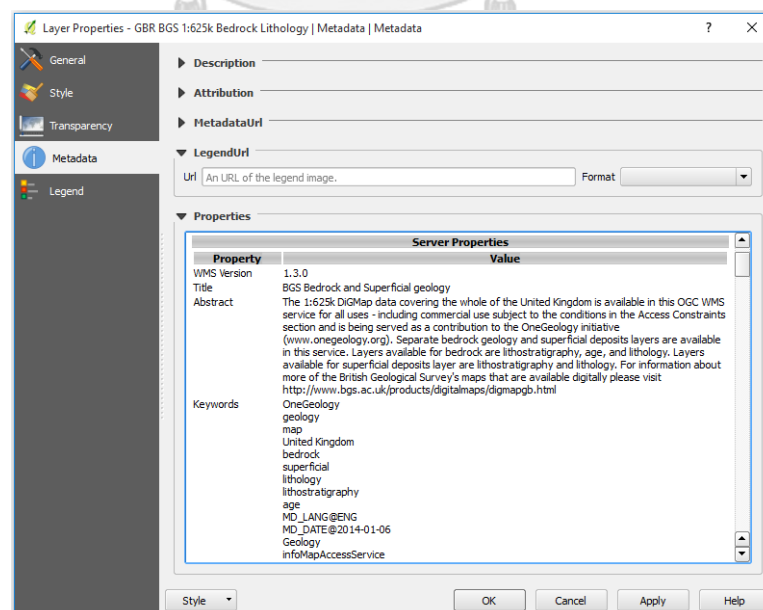



Figure 6 - Layer properties metadata.

## 1. Using QGIS to access simple feature WFS

To add a WFS layer you need to go through a similar process as you do to add a WMS layer, that is, you must first add the WFS service by clicking on the  tool on the **Manage Layers Toolbar**, then connect to the service, then select the layer you want to add. Even if the WFS service URL is the same as a WMS connection you already have listed you will need to add the WFS service URL.

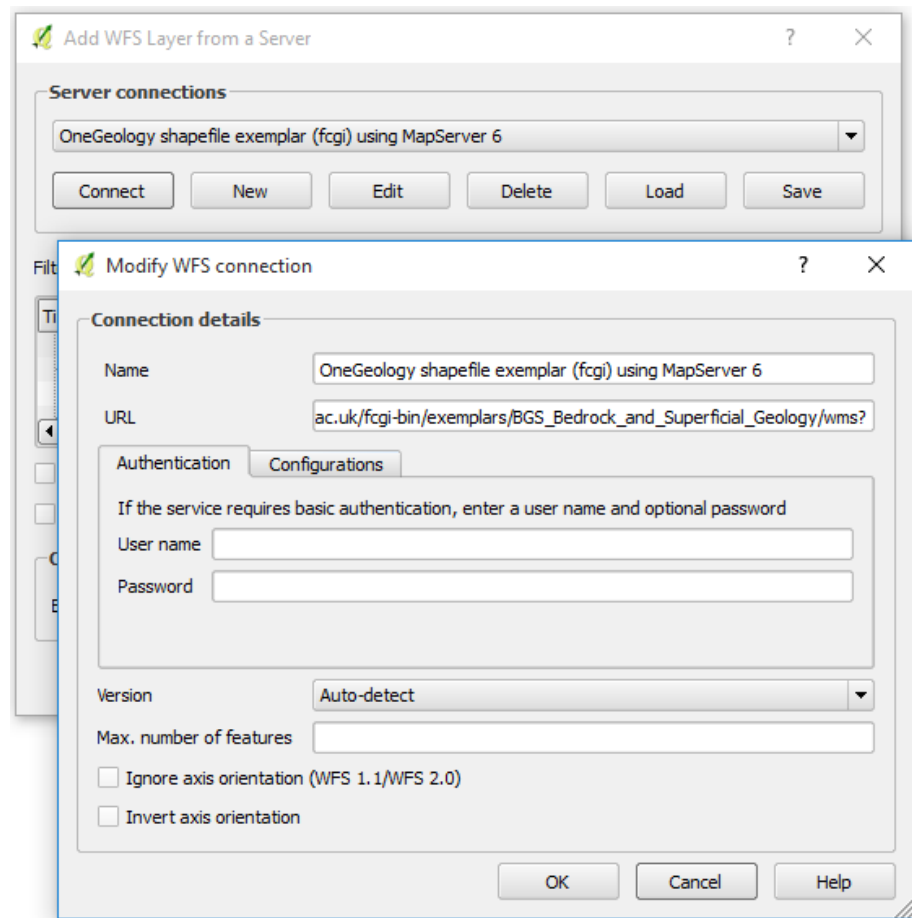


Figure 7 - Adding a new WFS service.

When you add a WFS layer you can choose to request all the features of that layer, or you may choose to request only those features that overlap the current extent, depending on whether the option **Only request features overlapping the view extent** is enabled. This will allow you to download and add to your map only the features relevant to your area of interest. However, if you change your extent by panning or zooming the map, new features will be fetched for your new view extent.



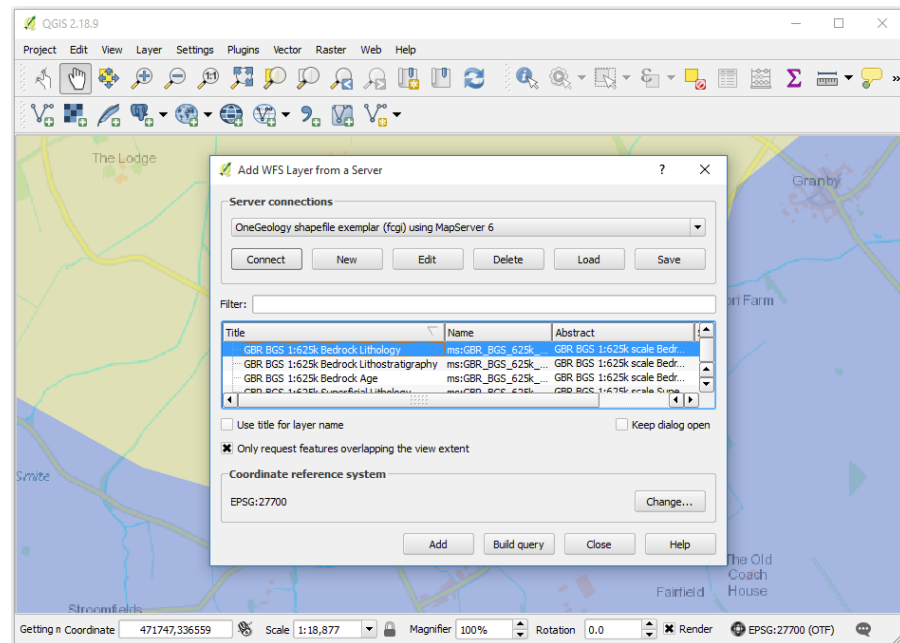


Figure 7 - Adding a new WFS service.

Below we have zoomed to the full extent of the WFS layer, therefore all features for that layer have been returned. Individual feature attributes can be inspected by using the **Identify** tool or by opening the **Attribute Table**.

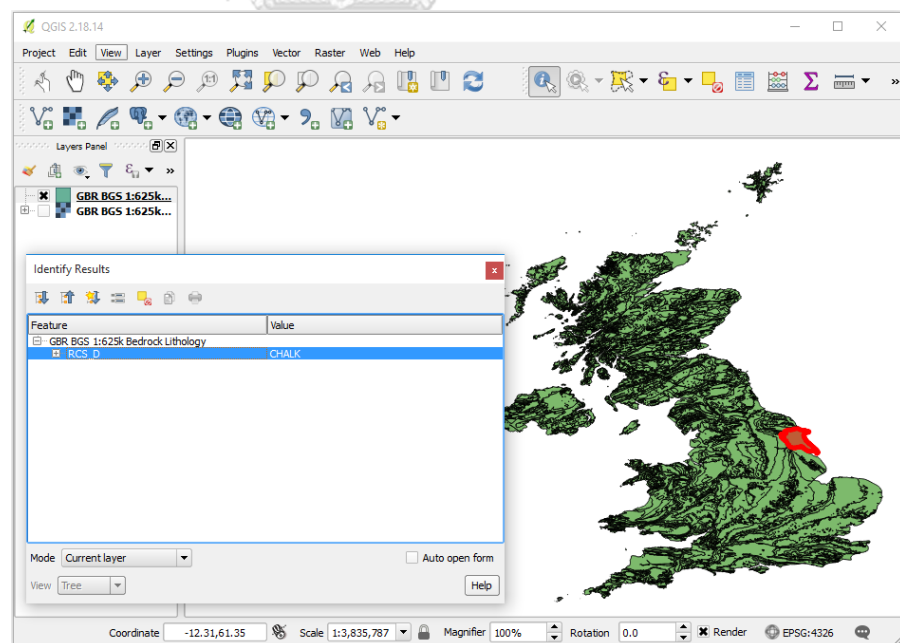


Figure 8 - Identifying WFS features.

When we view a WFS service, it should be noted that we actually download a representation of the data itself, not an image. We can therefore save a copy of that data for re-use elsewhere. Simple right click on the layer and go

to **Save As**. Exporting formats include **ESRI Shapefile** and **GeoJSON**. Exported data can be limited to selected features or to features in the current map extent.

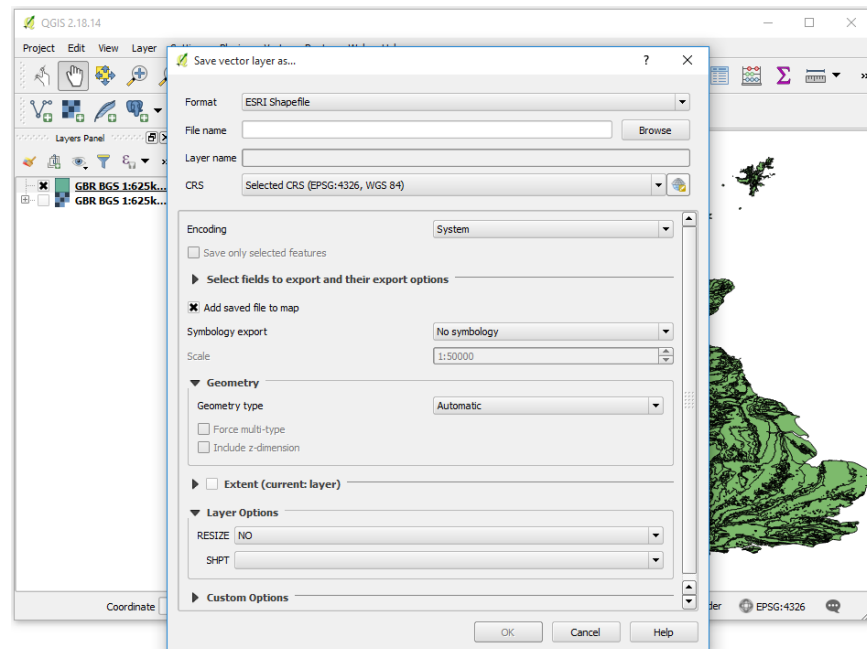



Figure 9 - Exporting WFS layer.

## 2. Using QGIS to view WCS

Adding a WCS layer is again a similar process than adding a WMS layer:

- Add the WCS service by clicking on the  button on the **Manage Layers Toolbar**
- Connect to the service
- Select the layer you want to add

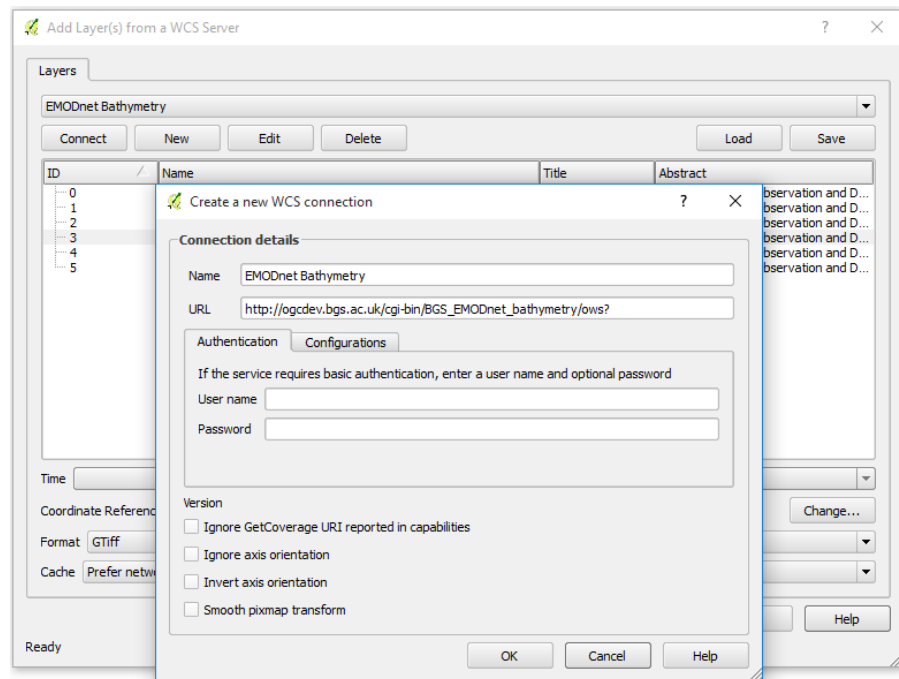


Figure 10 - Creating a connection to a WCS service.

Only one layer can be selected at a time. After selecting it, and choosing your favourite format, click 'Add'. Repeat this process if you want to add more layers and then click 'Close'.

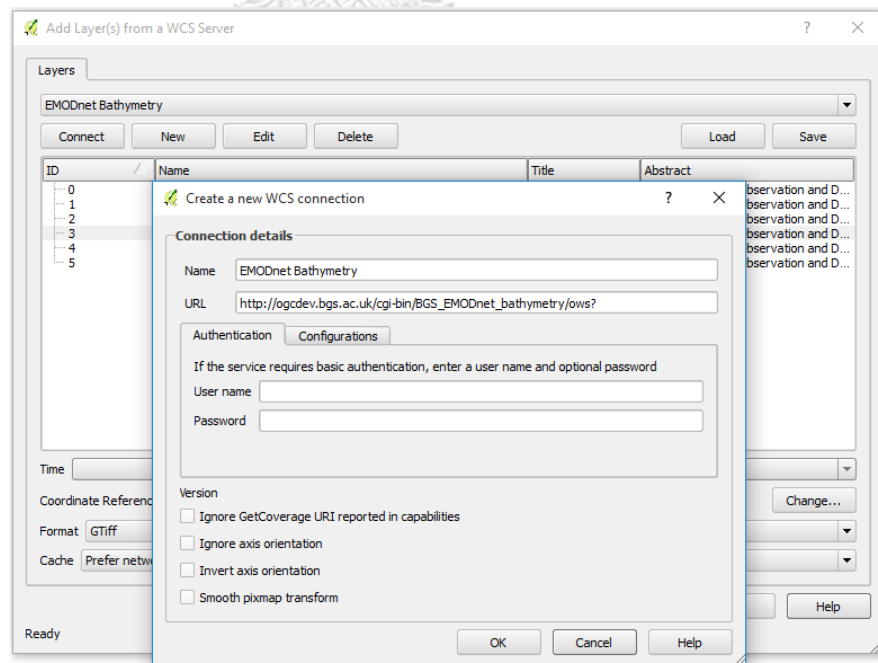


Figure 11 - Adding a WCS layer

Your layer(s) should now be displaying on the map.

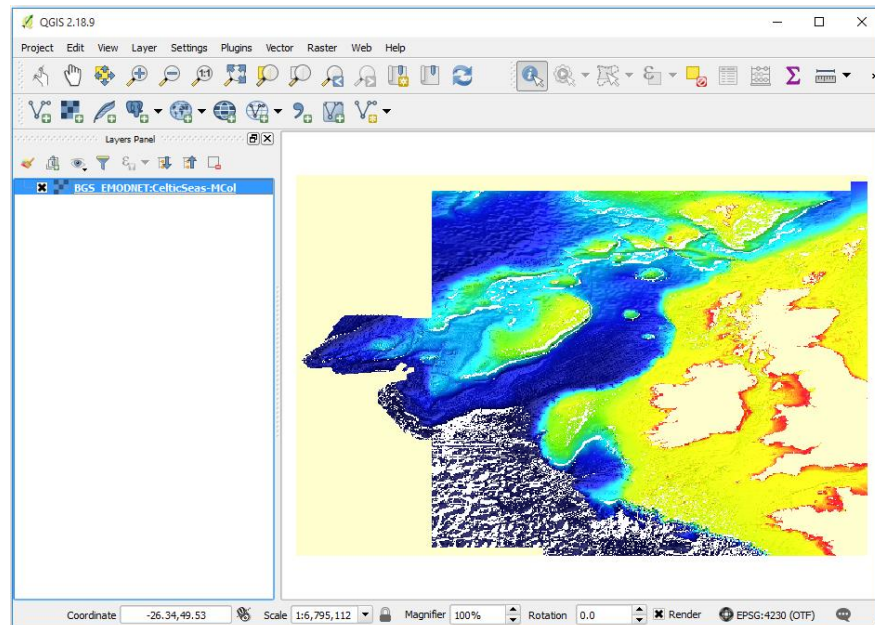


Figure 12 - Displaying a WCS layer

WCS layers can be exported as rasters. To do so, right click on the layer and go to **Save As**. You can choose to crop the exported raster by specifying an extent or getting the current map extent.

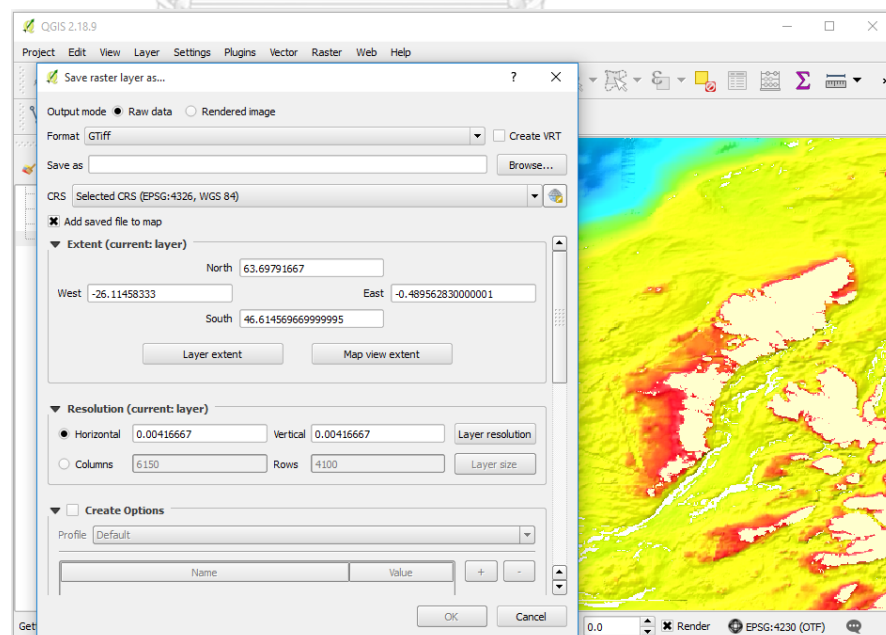


Figure 13 - Exporting a WCS layer

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