University of Southern Queensland

Faculty of Health, Engineering and Sciences

A Civil Engineering Feasibility Study on a Sustainable Pumped Hydroelectricity Plant at Wivenhoe

A dissertation submitted by

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ABSTRACT

With the era of accessible fossil fuels quickly coming to an end it is important that research is conducted into viable more sustainable future energy alternatives one of which is sustainable pumped hydro electric generation. For a sustainable future it is pertinent to investigate the feasibility of potential alternatives before significant investment is contributed to a potentially doomed project. This project was developed to investigate the feasibility of a particular proposal, centred on sustainable pumped hydroelectricity more specifically pumped hydro powered by either solar, wind or a combination of both energy types. A three stage plan was incorporated to find the proposal with the most potential, develop a conceptual design with civil scope for this proposal and then compare it to the existing system to evaluate whether the proposed system was feasible or not. The investigations concluded that while the proposed project was physically possible in regards to constructing foundations to overcome overturning moments and implementing the required infrastructure it was economically expensive and too impractical to be considered feasible. It is impractical to invest somewhere in the vicinity of a billion dollars to upgrade a system that will not provide any economic benefit for many years to come. Renewable energy is simply not reliable enough at the current point in time to justify such a substantial economic commitment. It would also take considerable effort to incorporate the existing infrastructure as the two systems do not mesh smoothly. While the proposed project would bring about a number of beneficial aspects such as greener more sustainable energy generation method and a more sustainable future it is currently not feasible.

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Date

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CHAPTER 1 - Introduction

1.1 Introduction

With a huge question mark still hovering over the future of energy production this paper aim to give insight and a feasibility analysis for future sustainable pumped hydro electricity generation. In particular it focuses on the civil feasibility of the pumped hydro plant in South East Queensland with particular focus pertaining to the conversion of the current pumped hydro plant at Split Yard Creek (Wivenhoe Dam). As a research project this project aims to provide enough of an indication to justify additional development or rule it out completely at the current time. By developing and implementing a three stage plan the proposal with the most potential could be identified, a conceptual design focusing on a civil bound scope could be developed before a comparison between the existing system and the proposed system could be made. This ultimately formed the basis of the feasibility study which gave an overall answer to the future of sustainable pumped hydroelectricity generation in South East Queensland.

1.2 The Task

In 2016 there is still a heavy reliance on an unstainable energy system especially with the majority of the focus still resting on the fossil fuelled sector. This project aims to give the reader and the public an understanding of a potential solution. In particular South East Queensland is selected and with a civil scope in mind this project will give an initial indication for precedent of further research.

1.3 The Project Aim

The aim of this particular project is to gain an understanding whether the current pumped hydroelectric system at Wivenhoe can be converted to a Sustainable Pumped hydroelectric system. As a civil project this will involve the civil and physical feasibility including such aspects but not limited to foundations, overturning moments / wind loading, buoyancy, road access and safe reservoir techniques. There are two main sustainable energy methods focussed on throughout this project which are wind and solar power; both of these methods will be analysed with both the pros and cons highlighted and delved into further. In addition to sole generation by one method in particular a number of different combinations i.e. (25/75, Wind/Solar) will be analysed in an attempt to find the most effective system possible. Finally a comparison between the selected system and the existing system will be made in an attempt to highlight potential benefits and validated the project.

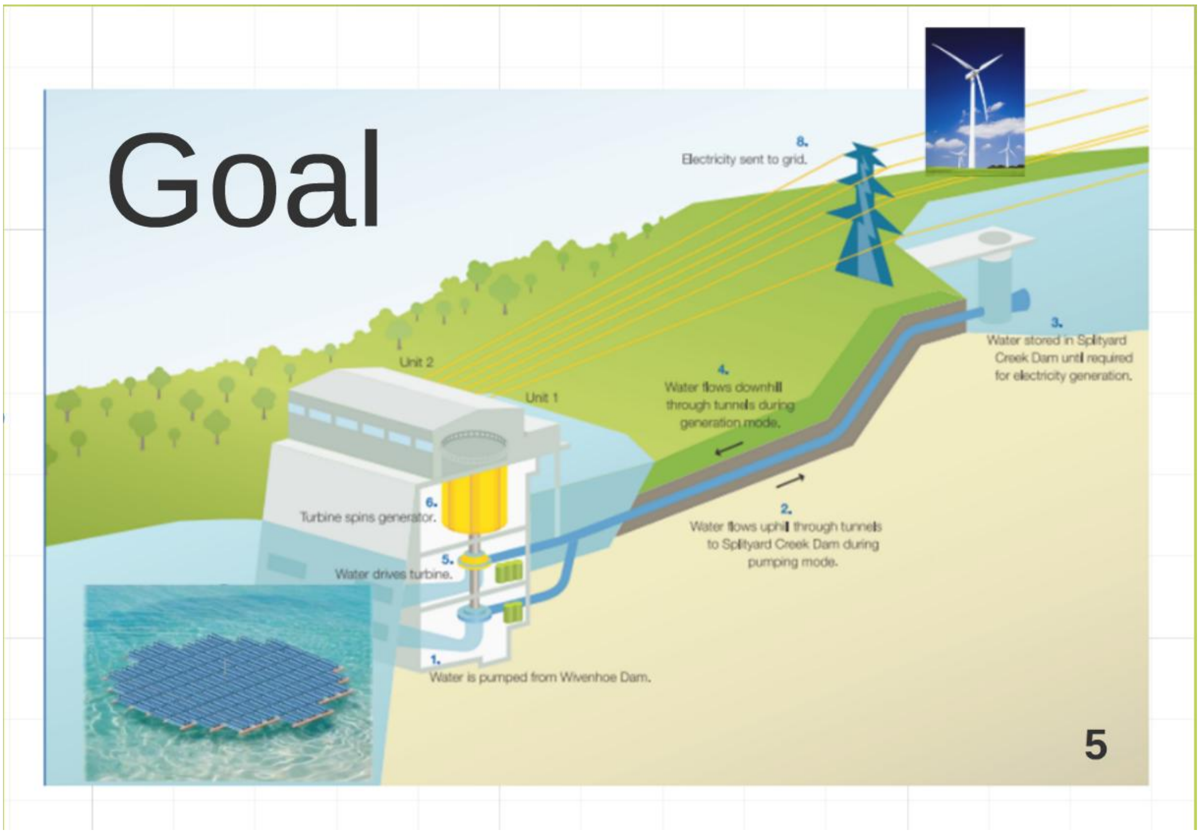


Figure 1.1; Project aim

1.4 Research and testing questions

In order to effectively complete a civil engineering study on the potential for a renewable assisted hydro electricity plant

1.4.1 Research Question 1: What criteria should be used as a basis to evaluate or develop this type of project?

Ultimately the chosen criteria will determine what the final proposal will look like; therefore it is critical that relevant and effective criteria are used.

1.4.2 Research Question 2: What technical analysis is required for the chosen proposal?

When considering the required technical analysis this could vary significantly for any proposal however as this project is **civil** based, the technical analysis will be limited to the civil scope i.e. foundation design, wind loading and overturning moments etc.

1.4.3 Research Question 3: What are the relevant conceptual design solutions for the selected proposal?

The conceptual design involves a number of significant decisions including the placement of the wind turbines or solar panels including road access and the expansion of any existing infrastructure. It is a simple termed basic outline of how the system will be put together. How does it look? What decisions were made?

1.4.4 Research Question 4: How is the proposed solution validated?

The proposed solution will be validated or justified by the scoring and physical civil feasibility of the project in conjunction with an additional comparison to the existing system. This validation will not be solely economically based but will also take into consideration a number of the other criteria seen throughout the project i.e. economical and ethical implications. Furthermore if time permits a detailed costing or tendering will be provided.

1.4.5 Research Question 5: How feasible is the conversion of the existing fossil fuel powered system at Wivenhoe to a sustainable hydroelectric plant?

After considering the above research questions it is critical to make a judgement to the actual feasibility of the project after all the considerations have been taken into account.

1.5 Dissertation Overview

1.5.1 Literature Review

This section will detail the background literature behind the project and the associated technologies. It will cover some background information pertaining to hydroelectric generation, solar and wind energy and any recent developments in the industry. In order to better understand the field of research some existing or past failed and idyllic systems will be analysed to potentially find some noteworthy characteristics that will help with design. The area chosen for this potential proposal will be examined and this will incorporate the topography and existing infrastructure right down to geological conditions. Finally the review will also give the reader an understanding of the civil scope and some of the theory behind the practices used within this project.

1.5.2 Methodology

This section will outline the procedures implemented to gain accurate and clear results. It will also include detailed justification of the importance of the chosen method as well as continuing to explain the methodology or explaining why that particular method was used to conduct this feasibility study.

1.5.3 Stage 1 – Analysis

In stage 1 a number of different energy proposals will be put forward on a basic and simple base and will be scored on a set of criteria, custom formulated for this project. This will allow qualitative data to be quantified and the best proposal or that with the most potential to be identified.

1.5.4 Stage 2 – Conceptual Design

The second stage of this project is to generate a conceptual design. This conceptual design will have a civil scope and will focus on the associated civil requirements with the proposed solar and wind energy developments. For example any road development or mapping will be examined; wind loadings and overturning moments, foundation design and buoyancy will all be considered. It will also give a brief estimation and explanation of the positioning of any proposed infrastructure.

1.5.5 Stage 3 – Validation

The final stage involves the comparison between the existing system and the proposed system. This will highlight any flaws in either system and give insight into whether the proposal positively or negatively will influence the power generation capacity in South East Queensland.

1.5.6 Discussion / Conclusion

The final section will be a brief discussion and conclusion. There will be discussion throughout the three stage plan but some key points will be re-discussed to help justify any findings. Finally the overall findings as to the feasibility or non-feasibility of the project will be outlined clearly.

CHAPTER 2 - Literature Review

2.1 Introduction

This chapter will outline the relevant literature associated with the feasibility analysis associated with the required civil works in relation to the incorporation of green energy into the current split yard creek pumped hydro operation. The first of the three main areas addressed in this dissertation is the implementation or the addition of a renewable energy source to a pumped hydro system. This could be achieved through a number of alternatives but this dissertation will focus equally on wind and solar energy. The second area of interest is the conceptual design. This area will be further broken down into a number of attributing factors which can influence the design i.e. the economical, environmental, ethical, efficiency and physical feasibility of construction of the project. Finally the third major area of focus is the potential for construction: as this is a civil project this point will be broken down further to gain an understanding of the importance of road access, geotechnical implications and restraints.

2.2 The Project

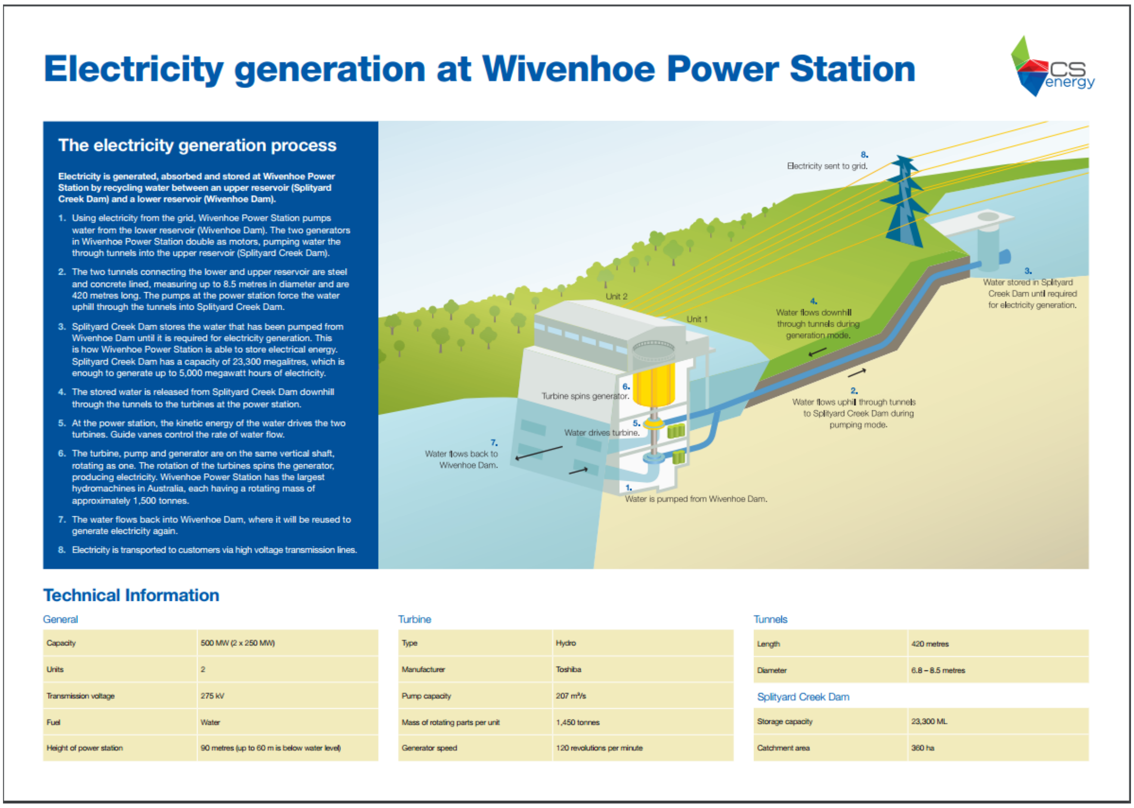


Figure 2.1: Existing pumped hydro plant at Wivenhoe

The above figure illustrates the current pumped hydroelectric system run by CS energy connecting the upper reservoir at split yard creek with the Wivenhoe Dam reservoir. The entire goal of this project is to make an assessment as to the feasibility of converting this pumped hydro system to a sustainable pumped hydro system. In simple terms this will involve pumping water from the lower reservoir to the upper reservoir using a renewable energy system such as wind or solar. The water stored in the upper reservoir will then act like a large efficient battery only losing energy whilst being stored through evaporation and minor seepage. Thus when required this kinetic energy can be released through the chutes turning the turbines in the hydro plant and generating useable mechanical energy. Therefore it is imperative to understand the initial system that exists before any conceptual design work can be completed and any possible solutions suggested. As a civil based project this particular project will focus on the civil requirements for a proposal like this such as the road requirements, buoyancy calculations regarding potential floating solar panels, moment calculations to avoid toppling wind turbines as well as the positioning of wind turbines to ensure effective energy generation. All of these civil aspects will be combined with geological, topographical and further design constraints i.e. social / ethical impacts to form the basis of feasibility analysis. Once the initial analysis has been completed a number of different proposals will be put forward, analysing potential for success and failure with the best solution recommended and then validated in stage 3. Should this project make good progress and time permitting an in-depth costing or tendering exercise will be completed at the conclusion of all other aspects adding further detail to the project. This is merely the start of a large project which could be followed up especially by keen and interested mechanical and electrical engineering students who could focus on the generation system itself and how the system could be optimised. For my civil project I will however assume that the current generation system is adequate and will only thus modify civil components such as the shape or depth of the upper reservoir etc.

2.3 Renewable Energy Options

2.3.1 Overview

It is important to understand exactly what is being considered within this project and an integral part of this is renewable energy alternatives. So what is renewable energy and why is it required? According to (Australian Renewable Energy Agency, 2012) ‘Renewable energy is energy which can be obtained from natural resources that can be constantly replenished’; therefore unlike coal it gives hope for future generations and the quest to power the globe. The current fossil fuel generation system consumes about ‘89 million barrels of oil and liquid fuels every single day’ (worldwide) (Origin, 2015) , and it is these carbon based fuels forged from sand, sediment and other vegetated material that are pressurised for thousands of years that are destroying the environment and will eventually expire. (Origin, 2015) There are a number of different renewable energy options including geothermal energy, hydropower, ocean energy, solar energy and wind energy to name but a few. These types of methods provide clean energy for use by the population. However there are a number of issues with renewable energy. To start with in previous years the development and production costs have made it extremely expensive in economic comparison to fossil fuel power supplies which has existing infrastructure. Additionally renewable energy cannot be harnessed with the click of a button and relies heavily on the weather patterns. This project will however investigate a potential solution to this issue through the use of pumped hydro to store and produce energy as required. (Australian Renewable Energy Agency, 2012)

2.3.2 Types of Hydroelectric Generation Systems: The task at hand

There are a number of different systems that can be implemented under the renewable hydro generation label. There are three main types of hydro electricity systems which are ‘impoundment’, ‘diversion’ and ‘pumped storage’. An impoundment system is the most common type of hydroelectricity facility, and involves utilising the energy from the release of a storage dam. (U.S. Department of Energy , 2013), According to the operators at Wivenhoe (which has both a pumped hydro plant as well as an impoundment system) there is a requirement of at least 30 ML per day to be released in order to support the ecosystem in the river downstream, before downstream irrigation is even considered. Thus it simply tries to make use of some of the energy from water already being released.

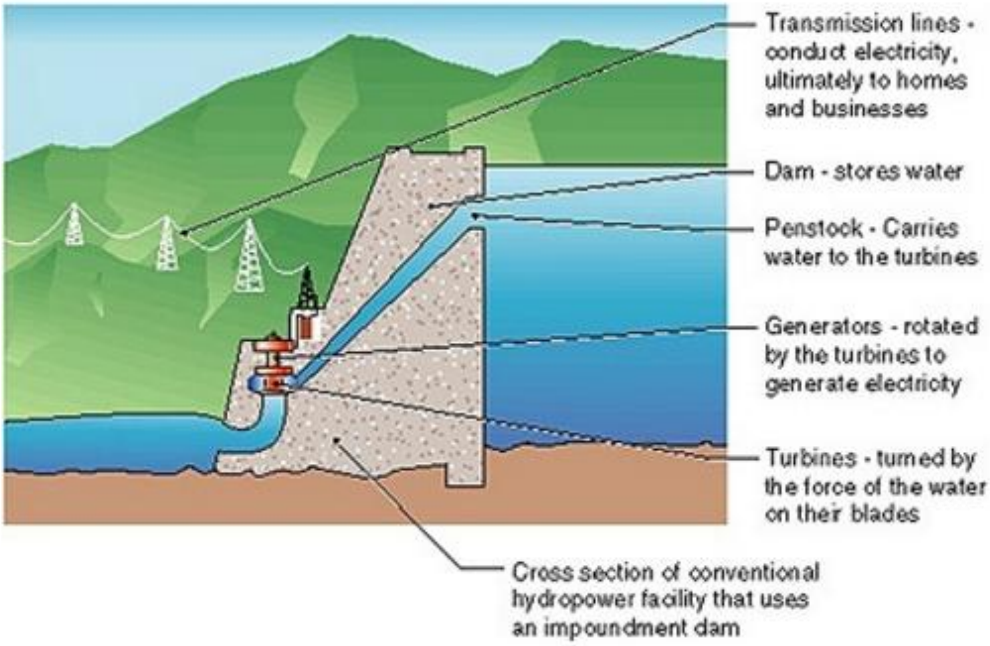


Figure 2.2; Impoundment system and the basic concepts of impoundment electricity generation. (U.S. Department of Energy , 2013)

The second type of hydroelectricity system that can be implemented is the diversion system which channels a portion of an existing watercourse or river through a hydroelectric generation plant. The most notable point about a diversion system is the lack of necessity of a dam or any storage.

Figure 2.3; Diversion system in place (U.S. Department of Energy , 2013)

A small part of the river has been diverted through the intake which runs through the hydro plant before being released at the black arrow (outlet). (U.S. Department of Energy , 2013)

The final hydro electric system is the system that will be focussed on in this project. A pumped hydro plant has the capacity to store energy like a battery through kinetic energy. Water is pumped to a higher reservoir generally in a trough of the energy requirement cycle as seen in figure 2.3, and then released back to the lower reservoir as electricity demand increases. A pumped hydro model system can be seen below in figure 2.4.

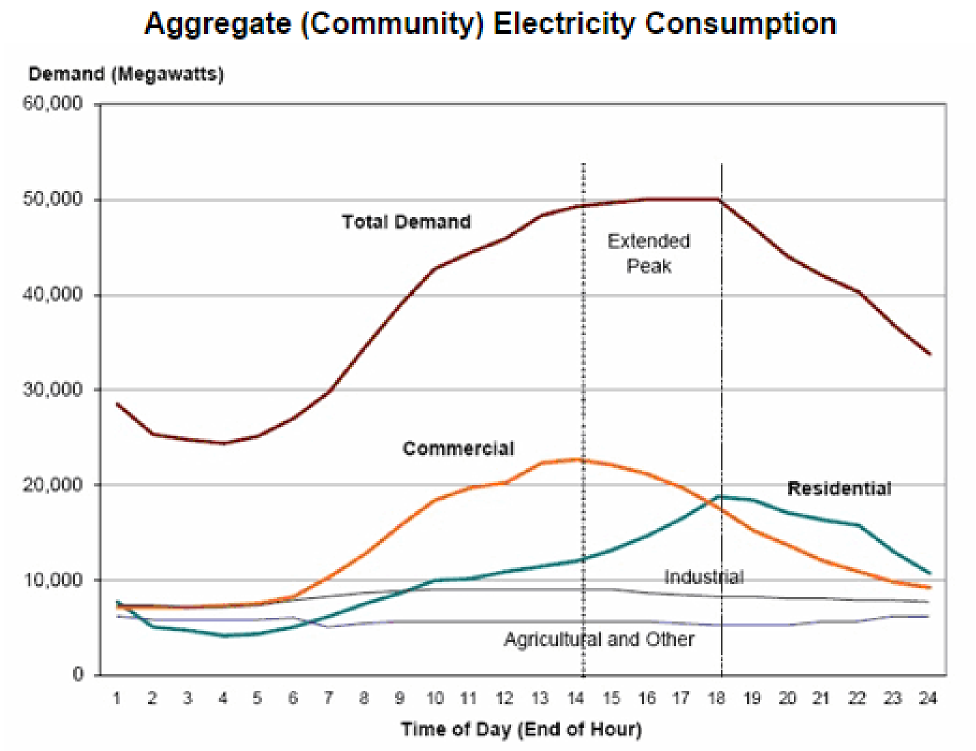


Figure 2.4; Community Electricity Consumption. (Electropaedia, 2005)

As shown in the above figure each day there is a fluctuation in the amount of power used by the community, therefore through effective pump timing and water releases for power generation, the power demand peaks can be met using pumped hydroelectricity.

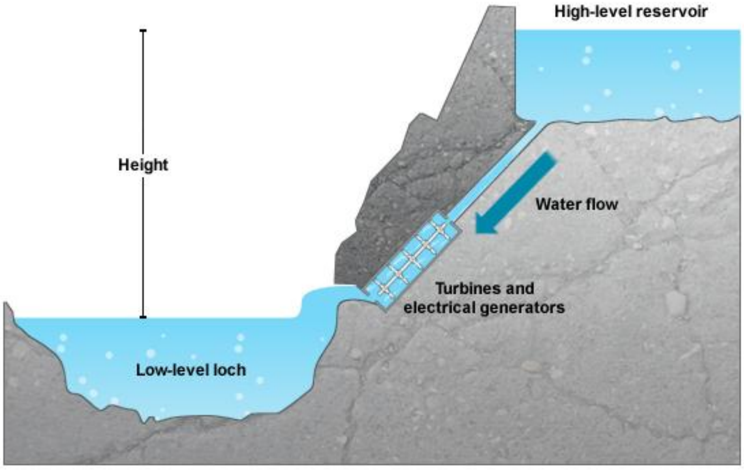


Figure 2.5; General pumped hydro power generation system (BBC, 2014)

Figure 2.5 (above) illustrates a general pumped hydro power generation system. It includes a lower and upper reservoir as well as the piping and turbines required to generate electricity. One noticeable element missing from this particular diagram is the lack of pumps or energy for pumps to reuse the water in the reservoirs. A further more in-depth explanation of the workings of a pumped hydro plant can be seen below. (BBC, 2014)

2.4 Wind power

According to (Clean Energy Council, 2014); 'Wind power is currently the cheapest source of large-scale renewable energy. It involves generating electricity from the naturally occurring power of wind.' The turbines convert the kinetic energy in wind to generate mechanical electricity through the spinning of blades on a turbine.

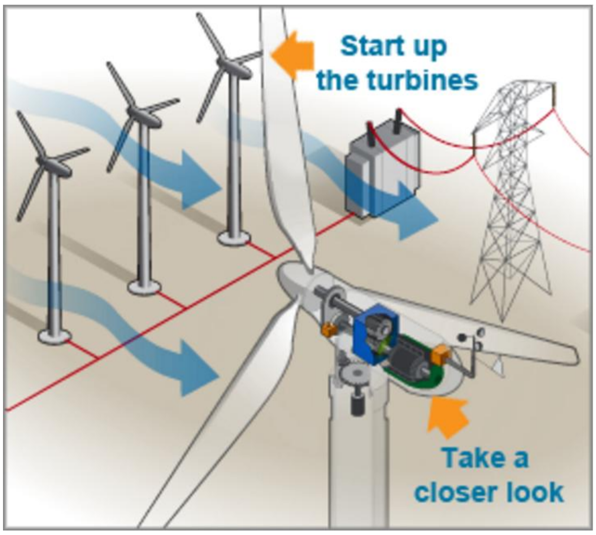


Figure 2.6; Wind turbine generation process, (Office of Energy and Efficiency & Renewable Energy, 2013)

2.5 Solar

Solar power refers to energy which is created or converted from sunlight or heat from the sun according to (Australian Renwable Energy Agency, 2012). There are two main types of generation which include solar thermal and solar photovoltaic (PV). Generally a solar thermal system will involve the heating of an area i.e. in the home or through water heating. This water heating can include solar hot water systems or can go as far as to represent the heating of water to generate steam and turn turbines in a wide scale electrical generation process. While this type of generation is generally adopted for larger operations it is not suitable for floating pumped hydro or the area that it will be implemented in. Therefore solar photovoltaic generation will be used; this method involves the direct conversion of sunlight into electricity using photovoltaic cells. This would be better suited to the area and could be implemented as floating platforms generators. (Australian Renwable Energy Agency, 2012)

2.5.1 Four Junction Photovoltaic Cells – A New Age in Efficiency

In 2016 Australia is at the forefront of solar research with the efficiency bar being raised constantly. According to (Macdonald, 2016) 'Australian Engineers have taken us closer than ever before to the theoretical limits of sunlight-to-electricity conversion, by building photovoltaic cells that can harvest an unheard of 34.5% of the Sun's energy without concentrator – setting a new world record.' With such impressive results this new technology is likely to revolutionise the solar scene providing that it can be implemented in an efficient manner with minimal economical cost. The cells works by splitting sunlight into four bands. The first band of light is the infrared band which is reflected back towards a silicon solar cell while the other bands are directed into a new three layer solar cell. This allows the cell to extract energy through each of the layers at the most efficient wavelength, while also allowing any unused light to continue through the cell until it reaches a layer at which it can be harnessed effectively. (Macdonald, 2016)

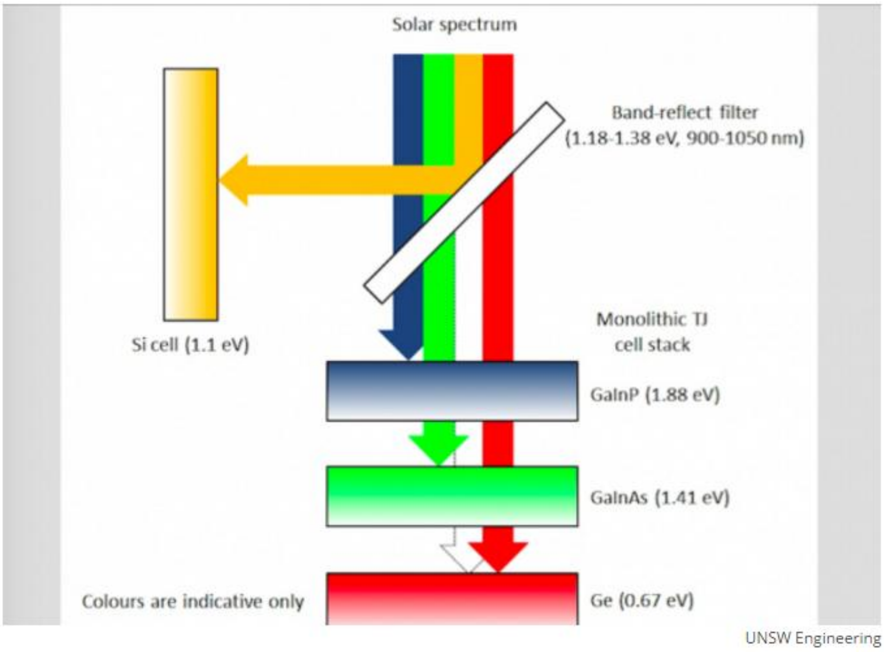


Figure 2.7; Solar generation process (Macdonald, 2016)

Figure 2.7 illustrates that as light travels through the cell it is harnessed with any unused solar energy travelling further through the cell until it can be captured. While this technology is currently expensive it is definitely worth considering as an option for this theoretically based project. (Macdonald, 2016)

2.5.2 Floating Solar

Solar power has been around for a number of years now however the concept of floating solar panels is relatively new. So what are the benefits of these panels floating? According to (WaterWorld, 2015) by implementing floating panels the panels are naturally cooled and therefore there is an increase in power production efficiency. Additionally the panels shade the water limiting the amount of evaporation that can occur and thus allowing a more reliable water source. (WaterWorld, 2015) Also states that when implemented at a winery in California's Napa Country the evaporation was reduced by up to 70%. In general terms a 3-acre storage pond covered with solar panels could save over 17.6 million litres each year.

Furthermore this type of solar panel can actually benefit the quality of water in the reservoir which is especially important in a reservoir system involving future drinking water. It does this by reducing the amount of sunlight it contact with the water and thus limits algal blooms in the area and as there is a direct correlation with algal blooms and increased treatment costs and quarantine zones it is highly beneficial to reduce such blooms.

Floating solar systems can reduce evaporation and shade the water, slowing algae growth.

Figure 2.8; Floating solar system, (WaterWorld, 2015)

In a world where land is a valuable commodity it is imperative to continually find new ways to use space in a more active way. By using floating panels valuable farming land will not be used, no additional land needs to be purchased and the cells will actually be more effective. Finally the issue regarding trees and other nearby structures shadowing the cells and reducing their effectiveness is not an issue when located over deeper water. (Baker, 2015)

2.5.3 Evaporation Mitigation

Not only would floating solar be an effective means of generating electricity (more effective than standard or roof mounted panels, by up to 56%) they would also be an effective and efficient means of mitigating evaporation. Currently there are many states within the United States that are implementing large volumes of black balls for the sole purpose of reducing evaporation in water supplies so it makes sense that a technology that not only reduces evaporation but also produces sustainable energy would be embraced. Furthermore as the current system is only slightly cheaper at approximately 150 million dollars U.S. to cover 126 acres it seems pointless to waste investment funding on black floating balls when the same job could be achieved plus additional energy generated for marginal increase in economic demand. These floating solar benefits give the solar sector a much needed boost with the combination achieving greater efficiency and evaporation mitigation. (ABC, 2015)

2.6 Diesel Power (Canary Islands)

It is difficult for islands in particular to gain a reliable source of electricity before even considering the cost of getting the energy there and then the environmental toll that all of this movement and consumption of dirty energy has on the natural world. Therefore when El Hierro of Spain's Canary Islands took a stance against the fossil fuelled world and decided to implement a sustainability plan which would mitigate the 6000 tonnes of diesel burnt each year and reduce emissions by 18 700 tonnes of carbon dioxide the minor economical loss was not even blinked at. (Guevara-Stone, 2014)

This project will avoid an annual consumption of 6,000 tonnes of diesel, which is equal to 40,000 barrels of oil that would have to be imported by boat to the island, thus creating a savings of over 1.8 million euros a year.

Diesel storage tanks, Llanos Blancos Plant, El Hierro

Figure 2.9; Diesel storage tanks, Llanos Blanco's Plant, El Hierro (Andrews, 2015)

The above figure gives an insight into the previous lifestyle of El Hierro where annually the small island would ship and then use approximately 40 000 barrels of oil worth. (Andrews, 2015)

2.7 What's used at CS ENERGY?

Currently the pumped hydroelectricity plant run by CS Energy is a reverse engineered system that allows power to be drawn from the grid to run the pumping phase and then put back through the grid when generating water via release. While this is quite a clever initiative it does not help the overall power outlook and is instead decreasing the potential efficiency of the system by drawing on power which ideally should be conserved. In addition this type of system relies on dirty fossil fuel generated power to pump the water to generate cleaner energy and therefore unless the power generated greatly outweighs the power expanded it is simply wasting energy. Exact figures have been withheld from CS ENERGY's site in an act of confidentiality. (CS ENERGY, 2012)

2.7.1 The Hydroelectric Power Generation Process

The potential for power generation using water notably originated in Greece as far back as 2000 years ago; i.e. using wooden waterwheels. Hydroelectric plants involve the use of running water to convert kinetic energy into electricity through the turning of turbines. The amount of energy that can be harvested from the water depends on the volume, velocity and head of water released to pass by the turbines. There are two types of plants those which simply divert a watercourse to flow via a generation station and thus turn turbines at varying rates with different flow volumes. These types of operating systems are very sensitive and prone to minimal energy production throughout times of drought and low rainfall. The other potential type of system is the stored system which will is the more rounded system and can ultimately generate energy regardless of surrounding weather conditions. This type of system will be detailed below. (Australian Institute of Energy, 2002)

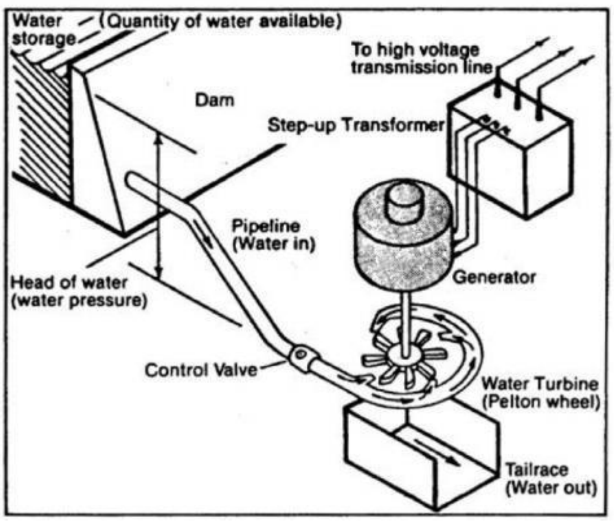


Figure 2.10; Diagram of hydroelectric plant (Australian Institute of Energy, 2002)

The main ideology behind hydroelectricity involves water being released through a pipeline to turn a water turbine which generates power before the water is released out the tailrace.

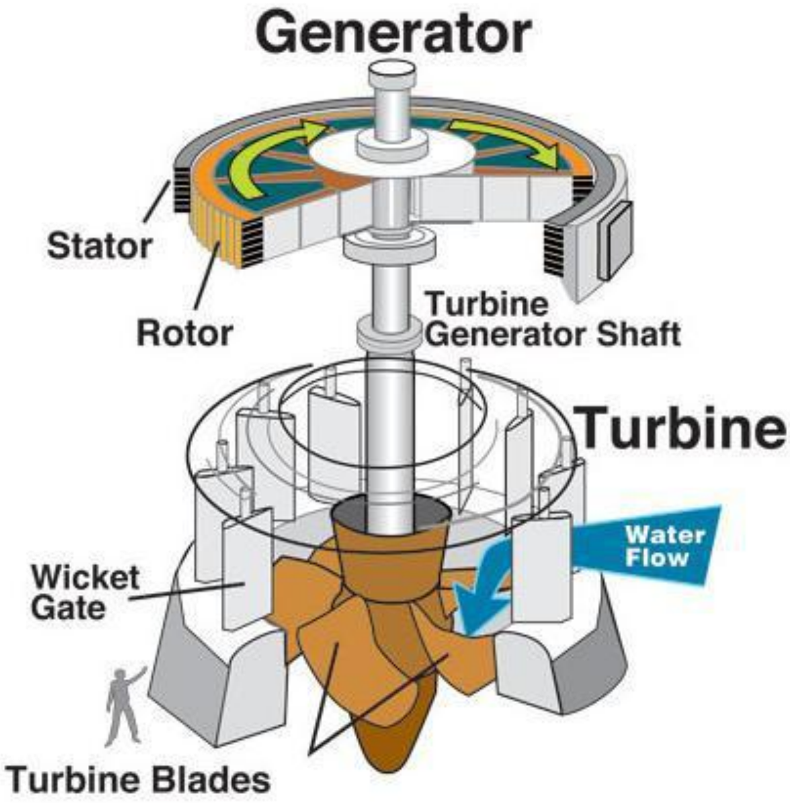


Figure 2.11; Hydroelectric production diagram (USGS, 2015)

As stated above a hydroelectric plant generates power through the turning of a turbine, but how does that create energy? The above figure illustrates a generator based on the principles of 'Faraday; these state that when a magnet is passed by a conductor a current is produced and electricity begin to flow. Therefore by releasing water through a turbine shaped like the one above the blades will spin and thus turn the generator shaft; once this shaft is rotating and thus spinning the rotor which has many field poles attached past the conductors mounted in the stator; and electricity is generated. Note: field poles are simply '**electromagnets** made by circulating direct current through loops of wire wound around stacks of magnetic steel laminations'). (USGS, 2015)

2.7.2 Pumped Hydroelectric Power

In simple terms pumped hydroelectricity involves a system made up of two interconnected reservoirs and a hydroelectric generation plant. Water is pumped from the lower reservoir to the upper reservoir before being released upon demand down pipes through a generator to produce power. In this way the upper reservoir can be used as an efficient battery only losing energy through the evaporation of water. This energy can be harnessed at any time and has the potential to match peak demands. Pumped hydro is by far the largest form of energy storage used globally and according to (Forcey, 2013) accounts for 99% of the aforementioned storage.

The greatest challenge and main source of inefficiency both economically and energy wise is the pumping of water from the lower reservoir to the upper reservoir. However in the proposed project this is where the power of wind can be harnessed and can alleviate the inefficiency. Wind has been harnessed for thousands of years to pump water according to (Energy.gov, Unknown Date) dating back to the Persians in 500BC, and is well suited to the task. Currently wind power is not being used to its full potential as the grid struggles to allow the full potential of wind generated power to be processed and therefore any loss of power leads to large inefficiencies of the entire system. By implementing wind power as pumping source this energy can be stored in the form of water to be released at later time. (Forcey, 2013)

Shoalhaven, Eraring Energy

Figure 2.12; Example of pumped hydro system involving two reservoirs at different altitudes (Forcey, 2013)

According to (Forcey, 2013) ten Gigawatts of pumped hydro is under construction in China and an additional 10 Gigawatts is under proposal in Europe; which suggests that the time is now to push for a greener alternative and begin implementing some wind assisted pumped hydroelectricity plants.

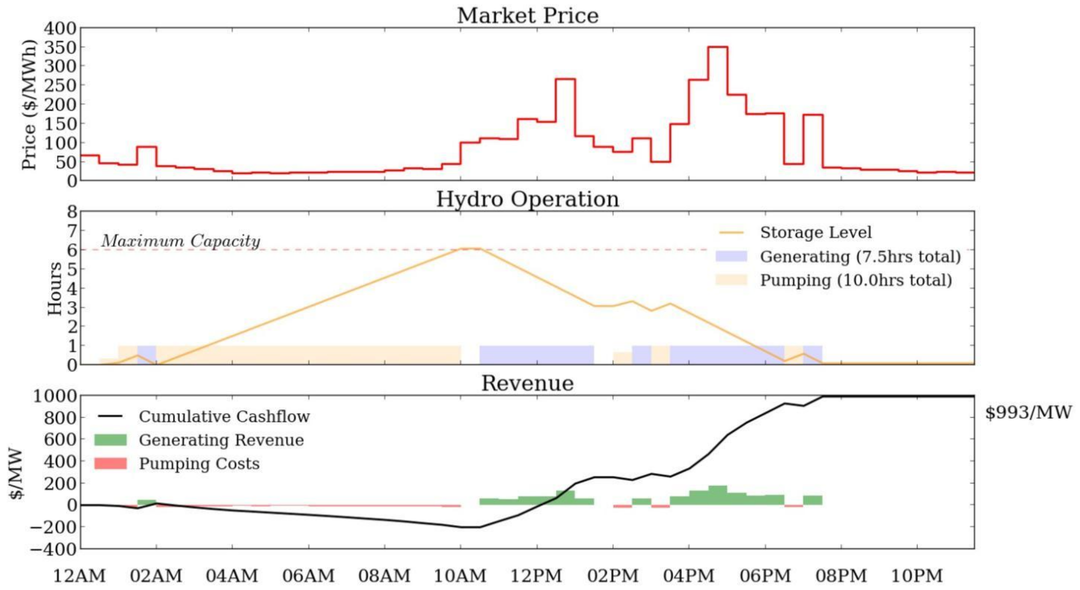


Figure 2.13; Economic study of a hydro study (Forcey, 2013)

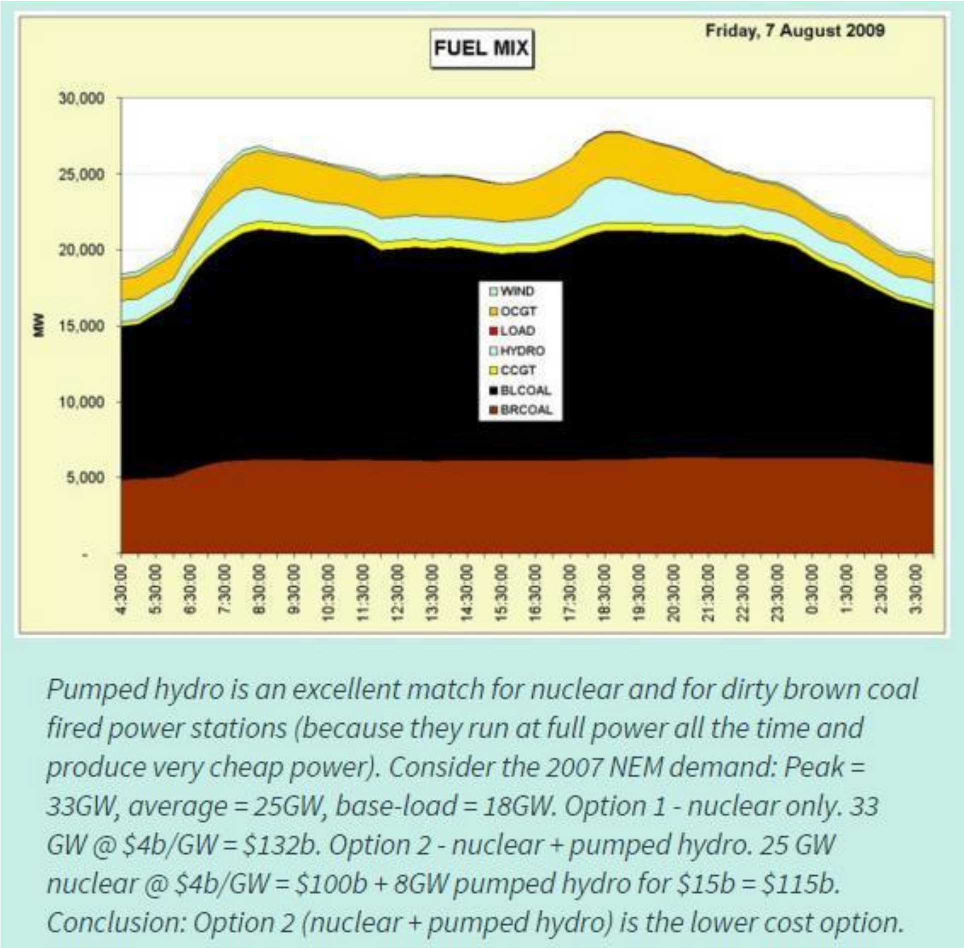
Figure 2.13 above illustrates the economic feasibility of a pumped hydroelectric operation. This will be further covered in the following sections. The economic prosperity and longevity of the operation is paramount with final approval pending upon the sustainable future of any developed plant. (Forcey, 2013)

After analysing the above case studies on the potential feasibility of wind assisted hydroelectric plants in a number of other countries there is definitely potential for further development in Australia and therefore a feasibility assessment at Wivenhoe Dam should be conducted.

2.7.3 Cost Assessment Study

The cost of economic viability of any project will always have a defining influence in the overall approval or declination of a possible project. Throughout the literature review a number of different possible projects were analysed each containing an individual cost assessment. There was a direct correlation between the results with the underlying trend of a substantial start up cost due to the required infrastructure, earthworks etc which was offset by stable future energy prices and the promise of a greener alternative.

A particularly notable study was one undertaken by (Lang, 2010) that produced the graphic seen below. This figure illustrates a potential for a combination of wind assisted stored hydro to meet any possible surge and to allow wind to be successfully and efficiently integrated into the energy grid. However while the current hydroelectricity scheme is not economically viable to make up 100% of the required power output with costs simply too high it is recommended after reviewing this study that wind assisted pumped hydro is used as an addition to nuclear power which is controversial in its own regard but in simple terms generates power in the most cost effective and environmentally friendly manner. Furthermore this particular figure while illustrating that brown coal is the most cost effective measure at the current point it does not go into detail on the ongoing social, environmental and ultimately economical costs required to maintain an adequate natural world and produce a base amount of energy. These issues will be covered in more detail in a following section.



Pumped hydro is an excellent match for nuclear and for dirty brown coal fired power stations (because they run at full power all the time and produce very cheap power). Consider the 2007 NEM demand: Peak = 33GW, average = 25GW, base-load = 18GW. Option 1 - nuclear only. 33 GW @ $4b/GW = $132b. Option 2 - nuclear + pumped hydro. 25 GW nuclear @ $4b/GW = $100b + 8GW pumped hydro for $15b = $115b. Conclusion: Option 2 (nuclear + pumped hydro) is the lower cost option.

Figure 2.14; The potential for energy production using a variety of different energy generation methods (Lang, 2010)

2.7.4 The Issues with Fossil Fuelled Power

As of 2013 fossil fuels remained the dominant resource still producing 80% of required energy and 66% of required electricity according to (World Energy Council, 2013). This is an astounding figure as there are many reports detailing the detrimental environmental, social and potentially future economical impacts on both a local and global level. The (Union of Concerned Scientists, 2011) states that coal alone is the single largest air polluter in the U.S. and leads to a number of daunting environmental impacts such as air pollution including acid rain, smog and global warming. In addition coal and fossil fuels in general make large contributions to the spoiling of water resources through cooling requirements and contaminated water systems. Furthermore due to the expected shortage of readily accessible resources and predicted exhaustion of cost efficient extractable resources the future energy prices are expected to spike dramatically, potentially crippling the nation's trade through increased energy costs, transport and possible taxes. In simple global economics suggest that if accessibility or supply decreases then without a suitable alternative to act as competition the population will be at the energy company's mercy and prices will continually increase. (Baumol, 2006)

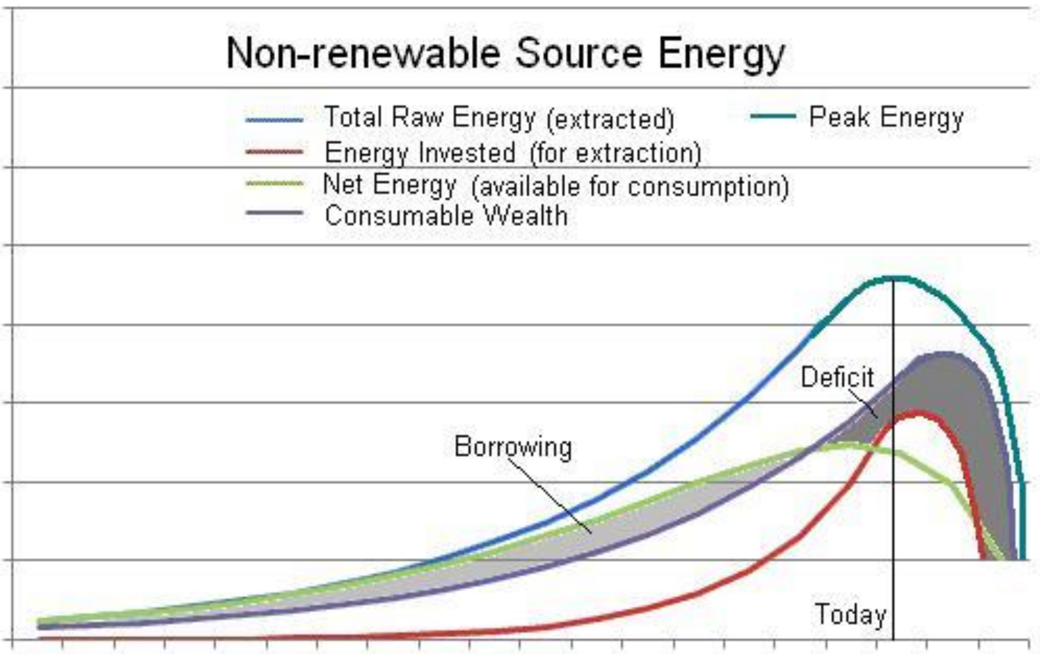


Figure 2.15; Current shortfall of existing non renewable energy (Typepad.com, 2009)

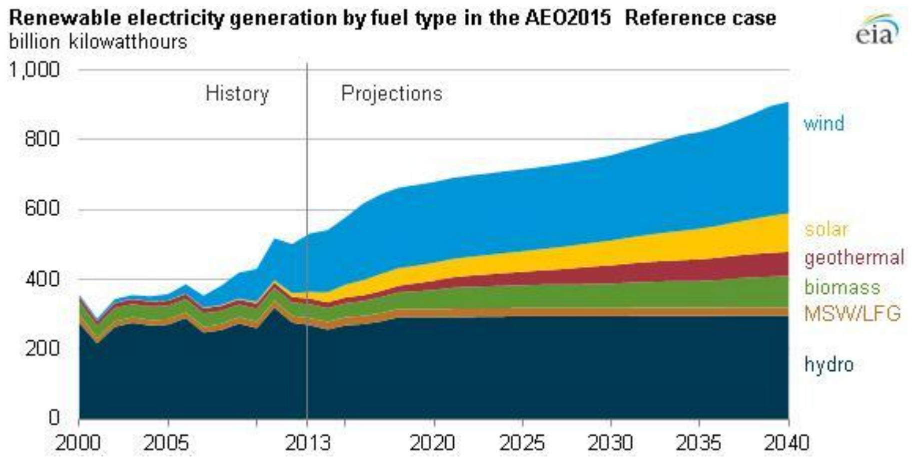


Figure 2.16: The push towards a sustainable future especially in the wind, solar and hydro sectors (Oil and Gas 360, 2015)

The two figures above illustrate precisely the issue and thus show the future for energy production. In the first figure, the fossil fuels' future is predicted to exponentially decline due to poor accessibility and increasing costs because of the additional effort required to access resources. This is compounded by the understanding of detrimental environmental impacts and more sustainable options. The second figure shows the predicted movement towards a renewable future, in particular it is notable that wind energy and hydro make up the majority of generated power and therefore these energy sources were focused on for this project.

2.7.5 Review

The entire energy system requires review with the current fossil fuelled scheme performing poorly environmentally, socially and posing serious future economic questions. Additionally as seen in the figure below the fossil fuel system currently makes up over three quarters of the energy sector and therefore any diversion from this sector will require major development and infrastructure to maintain energy production rates. It is therefore proposed that an overhaul be conducted with a shift towards renewable and more sustainable energies; in particular wind assisted pumped hydroelectricity. The aforementioned power generation technique involves the combination of wind power with hydroelectric generation. This type of power generation requires a system of two interconnected reservoirs where water can be pumped to the higher reservoir using wind power. This produced head or kinetic energy can then be harnessed through the release of the water and the velocity of the water turning a turbine to generate power.

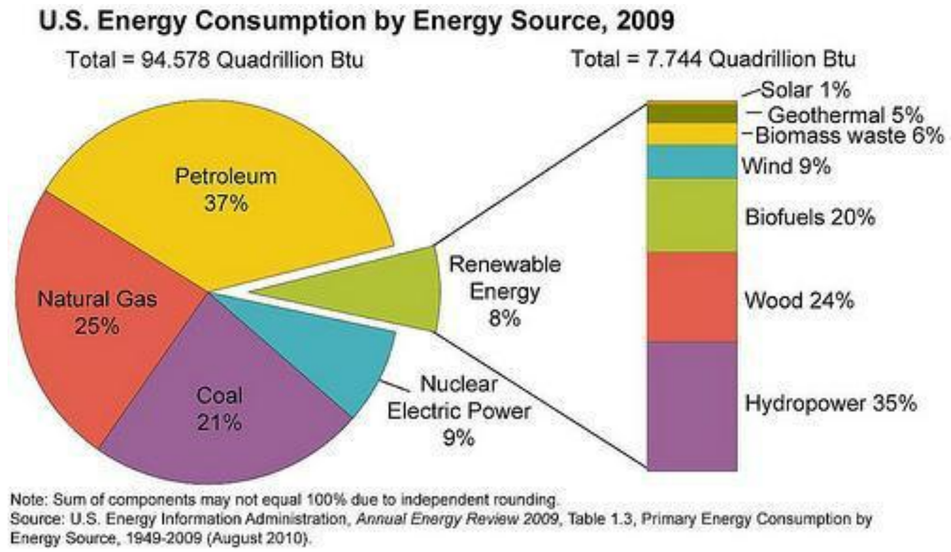


Figure 2.17; The U.S. energy consumption by energy source in 2009, highlighting that renewable energy only accounted for 8% of total energy 35% of which was from hydropower (Wikidot, 2010)

This particular type of renewable energy system has been trialled and analysed overseas including Ramea and in the North West Pacific (America) with the outcome suggesting a feasible option worth further development. The finding suggested while the initial start up cost was a significant investment the long term sustainability and reliable source of energy was ultimately worth the original funding; especially as a replacement for current diesel powered coastal communities. Finally with so many current and future issues with fossil powered energy and the continual expected development of the renewable sector it is not surprising that it is time for Australia to begin a greener motion.

2.8 Conceptual Civil Design Requirements

2.8.1 Overview

When considering a feasibility study it is crucial to obtain adequate research into the subject matter; as this particular project is civil based the conceptual design and civil requirements must be considered. This means taking a look into the past to see what has been successful and also whether there have been any major failures in the selected area. This type of historical understanding can allow the designer to avoid errors which have previously been encountered. It is also important to give some insight into the area. This could include the topography, existing infrastructure and a number of other underlying factors that can influence the overall success of the proposal. Finally this particular piece of review will take into account the smaller civil projects within the scope of the entire project; these include further dam excavation, road construction, restraints and or floating platforms and an analysis into the breakdown of turbine foundations.

2.8.2 Existing Idyllic systems

The energy generation and storage conundrum has been on everyone's minds since the emergence of renewable energies in recent years, these are however limited by the dependence on weather events such as consistent wind. This is certainly not ideal for a society which is dependent on the use of electricity for everyday life. Therefore if renewable energy can be implemented to generate the majority of required electricity then an effective and efficient storage method must also be perfected. Currently it is neither cost effective nor efficient to store energy in batteries and instead it would be much more effective to travel back in time and store kinetic energy through water head. (Roach, 2015)

El Hierro of the Canary Islands

An example of an existing idyllic system currently in place is that on El Hierro the smallest and least know of Spain's Canary Island off the coast of Africa. This particular system is made up of five wind turbines installed at the north-eastern tip of El Heirro and has a total capacity of 11.5 megawatts. Not only is this enough power for the 10 000 residents it also powers the desalination plants the islands residents rely on for fresh water. With such a crucial commodity totally reliant upon the islands often inconsistent and gusty wind supply, how is a reliable energy source secured? Water is pumped to the upper reservoir using inconsistent wind energy and then electricity is produced via hydroelectric generation when required. Furthermore not only will this particular system meet all of the demands from the island it will also generate revenue. This funding from the sale of energy to the global scene will lift the islands budget between 1 and 3 million Euro's per year. With a sustainable system producing a surplus of useable and clean power the total cost of the project will quickly be paid for. This island can be used as a model situation with many other islands around the globe also just a step away from self sufficiency. (Andrews, 2015)

In generation mode the station's four 2.83 MW Pelton turbines (total 11.32 MW) operate under a gross head of about 655 m at a flow rate of 2 m³/s. In pumping mode, the two 1,500 kW and fourteen 500 kW pump sets provide a pumping capacity of up to 10 MW.

Figure 2.18: Required pumping energy calculation (Hydro Review, 2012)

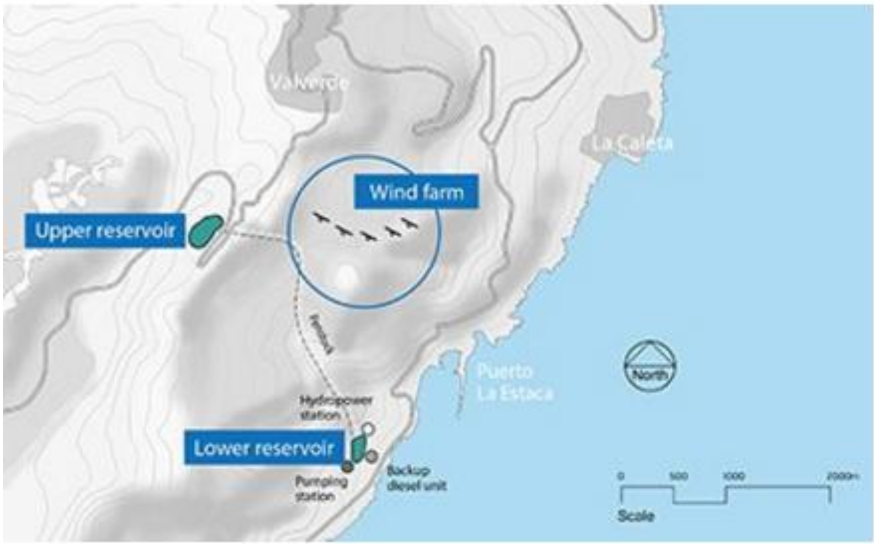


Figure 2.19: Infrastructure map of the El Hierro system (Trembath, 2015)

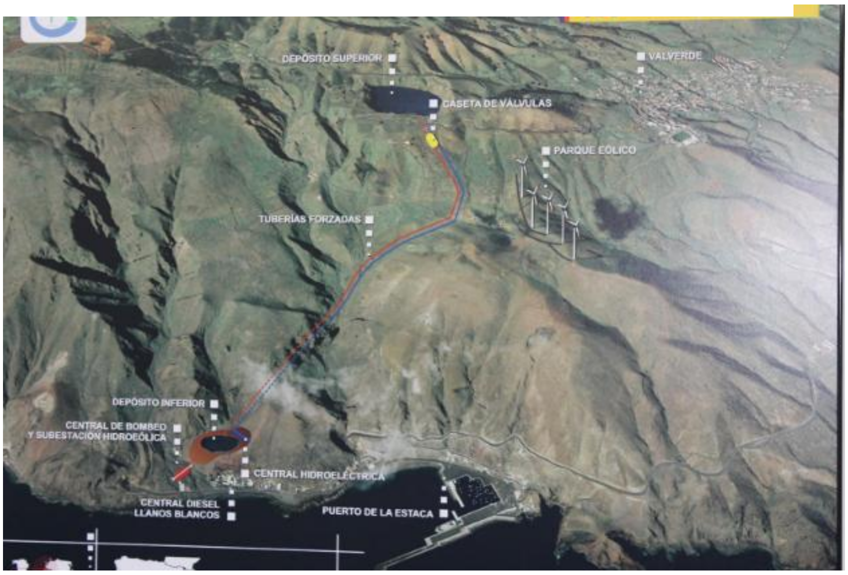


Figure 2.20: 3D topographical map of the land formations around the El Hierro pumped hydro setup (Andrews, 2015)

The second figure for this particular project clearly illustrates the set out regarding the pumped hydro system and gives a plan view showing the wind farm and how it interconnects the upper and lower reservoirs to the coastline. This is supported by a more topographically accurate representation on the right which illustrates how the land formations have affected the design.

Figure 2.21: Geo-membrane for waterproofing (minimises seepage) (Hydro Review, 2012).

Figure 2.21 also illustrates how the battery (reservoir) efficiency was increased. The reservoir was lined with a high-density polyethylene geo-membrane for waterproofing thus ensuring that any effort expended pumping the water to this point was not wasted through leaks.

2.8.3 Existing Failed systems

Limited information in this regards makes it difficult to learn from previous mistakes. It is a very new concept with recent failures not clearly documented. However with this acknowledged the recent renewable energy failure in South Australia should be considered. While not hydroelectric generation the failure of wind generation can still be directly linked to the proposed system which incorporates wind energy. Recently South Australia has been hit by a massive price spike due to the lack of power generation from its renewable sector which makes up more than 40% of the energy system according to (Owen, 2016). The spike came as a prolonged period of calm weather not only meant the state's wind turbines were not producing energy they were in fact consuming it in attempt to avoid any degradation to the infrastructure. Ultimately supply and demand trends lead to the steep energy price spike that has left many business's on the brink of shutdown. In addition according to Mr Willox 'we will see similar episodes again, and not just in SA.' He also went on to urge 'Changes in the pattern of energy demand and the ongoing build-up of wind and solar make life increasingly difficult for base load electricity generators across the country' (Owen, 2016)

2.8.4 The Area

Figure 2.22; Google search image of the selected area (GoogleEarth, 2016)

After analysing the area in question the upper and lower reservoirs can both be identified, as can a number of existing infrastructures?

2.8.5 Geological Map

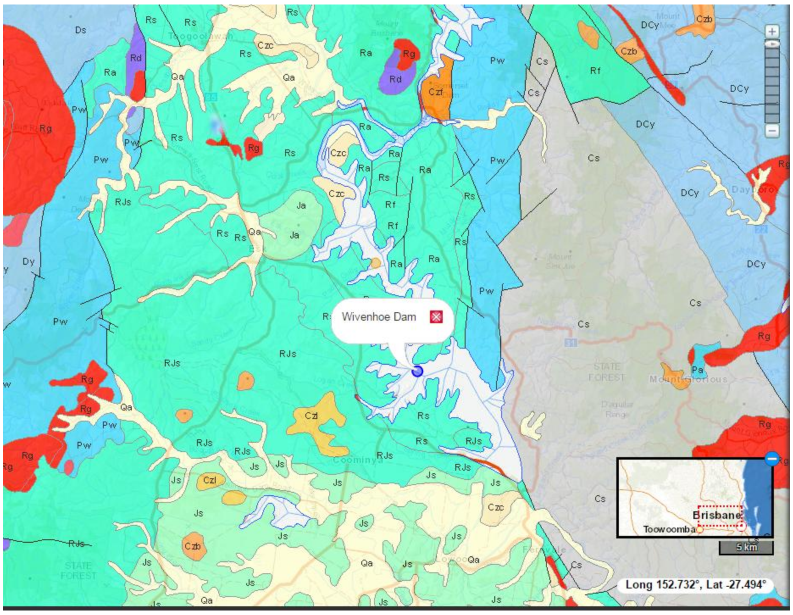


Figure 2.23; Geological map of the area (Geoscience Australia, 2016)

Figure 2.24: The associated legend for the above geological map, providing an understanding of the likely geotechnical conditions (Geoscience Australia, 2016)

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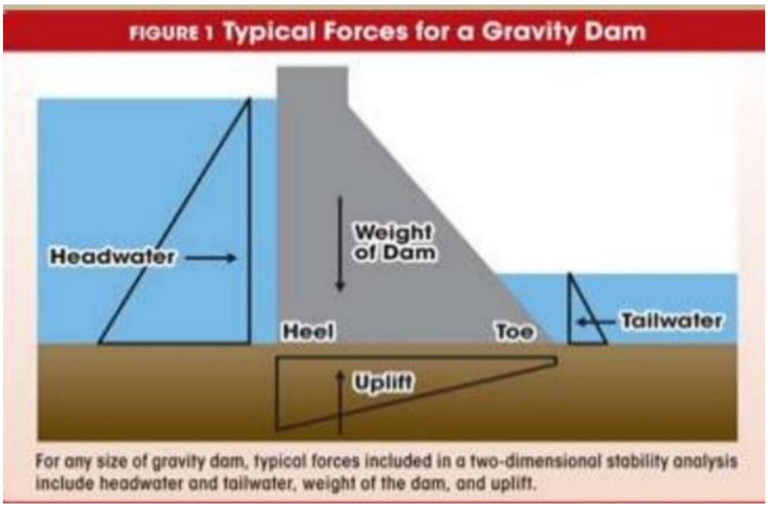
2.9 Potential required alterations/projects

2.9.1 Dam Excavation / Wall Expansion

The below figures illustrate the way that the overturning moment on the potential extension of the existing dam wall will be conducted. The hydrostatic force on the dam wall will drastically increase with any increase in depth and therefore should it prove that this type of measure is required and the current infrastructure is not adequate then additional reinforcing methods will be required i.e. concrete casting the current earth and rock wall to improve the strength of the wall. In addition by draining the dam and reshaping the current interior face from vertical to tapered the force could be redirected and ultimately mitigating some of the pressure. It is to be noted that after some research it was discovered that the existing infrastructure was adequate and thus because no additional infrastructure was built this equations were not required.



For any size of gravity dam, typical forces included in a two-dimensional stability analysis include headwater and tailwater, weight of the dam, and uplift.

Figure 2.25; Hydrostatic forces on a dam wall (Tandon, 2014)

- When the upstream face is vertical the intensity is Zero at the water surface and equal to γH at the base; where γw is the unit weight of water and H is the depth of water. The resultant force due to this external water
- $P = \frac{1}{2}\gamma H^2$, acting at H/3 from base.

Equation 2-1; External water pressure equation (Tandon, 2014)

When drainage galleries are provided to relieve the uplift, the recommended uplift at the face of the gallery is equal to the hydrostatic pressure at toe ($\gamma_w H'$) plus a 1/3rd of the difference of the hydrostatic pressure at the heel and at the toe [$\gamma_w H' + 1/3(\gamma_w H - \gamma_w H')$] |It is also assumed that the uplift pressure are not affected by the earthquake forces.

Equation 2-2; Hydrostatic pressure and uplift (Tandon, 2014)

Silt Pressure

- It has been explained under ' **Reservoir Sedimentation'** that silt gets deposited against the upstream face of the dam. If h is the height of silt deposited, then the force exerted by this silt in addition to external water pressure, can be represented by Rankine's formula as:
- $\mathbf{P_{silt} = \frac{1}{2}\, \gamma\, sub_w\, h^2\, Ka}$ and it acts at h/3 from base
- Where, Ka Is The Coefficient Of Active Earth Pressure of silt
- $\mathbf{K_a} = \dfrac{1 - \sin \Theta}{1 + \sin \Theta}$
- Where Θ is the angle of internal friction of Soil, and cohesion is neglected.
- $\gamma\ sub_w$ = Submerged unit weight of silt material
- h= height of silt deposited.

Equation 2-3; Silt pressure equation (Tandon, 2014)

Weight of the Dam

- The weight of the dam body and its foundation is the major resisting force. In two dimensional analysis of a **gravity dam, a unit length of the dam is considered. The Cross-Section can be divided into rectangles and triangles. The weight of each along with their C.Gs can be determined. The resultant of all these downward forces will represent the total weight of the dam acting at the C.Gs of the dam.**

Equation 2-4; Weight of dam (downward force) calculation (Tandon, 2014)

2.9.2 Road Construction

The roads required for this project will be discussed in more detail below but using both the designated standards followed by the use of CIRCLY an adequate road can be designed in a way that will be cost effective. This road will then be mapped out on plans provided see below for a more detailed subsection.

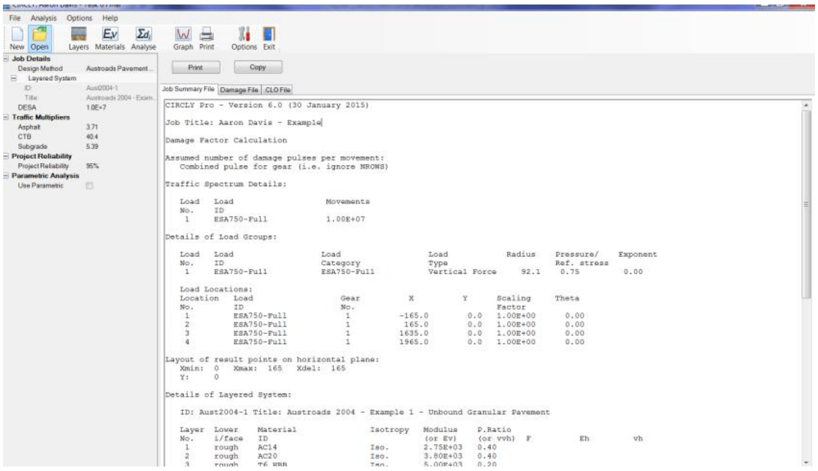


Figure 2.26; Example of trialled circly output

2.9.3 Restraints and Floating platforms

While floating solar panels have been around for awhile they were simply such undeveloped technology that required time to minimise the number of issues associated. Therefore 10 years on from the initial use by the French with a Ciel et Terre system the time has arrived to implement this technology at an increased rate (Boyd, 2016). Additionally, according to (Nield, 2016) 'the support modules of the mounting platform are made from a metal – free, recyclable, high density polyethylene material that is resistant to both corrosion and the Sun's ultraviolet rays.' This is an exciting technology but with the above considered in addition with the information that the solar plants do not have a detrimental impact on the water quality in any way, shape or form a question mark retains over the floating capacity of the system and thus buoyancy calculations will be made below. Finally the Japanese system has been designed to weather typhoons and is anchored to the bottom of the reservoir giving a precedent for the project and potential insight into an effective methodology. (Nield, 2016)

2.9.4 *Costing of Floating Platforms*

The floating platforms are more expensive in comparison to simple land mounts, the final cost is considered comparable if the land requires purchase or any type of civil earthworks in order to be effective and efficient. (Boyd, 2016)

2.9.5 Turbine Foundations: Land Vs Water

Simply it would be more efficient and effective to place the wind turbines on land. Generally in projects wind turbines are only placed in water foundations to harness coastal air currents and while this increases the effectiveness, in this case it would do nothing. In addition the construction of the turbine foundations in water would be far more difficult, requiring expensive equipment according to (Aagaard, 2012) that would far outweigh the cost of creating and maintaining an access road to the top of the nearest hill in which the turbines can not only be installed easier but will also have access to more wind. (Wind Prospect Group, 2013) In both cases the issue of ethical or social acceptance of the structures remains prevalent and rather than mask the structures placing them in the water would likely enhance the contrast of the natural landscape and probably draw more unwanted attention in the form of complaints. Furthermore should the turbines be built in the water not only will the wind load need to be considered as seen later in this report but an additional pressure prism from the water would need to be considered along with the issue of damage through flood waters.

NOTE: The wind loading standard that will be used in the projects is AS/NZ 1170.2 – 2011 which is the latest and most up to date national standard for wind loads. These wind loadings will be simplified in an attempt to still illustrate the use of standards but without over complication. This is just a theoretical project at this stage.

Figure 2.27; Offshore wind turbine construction

The above figure illustrates just some of the difficulties with assembling a large scale turbine at sea. These cranes and floating platforms are expensive to transport and in the case of the project would be difficult to get in the dam as that would require transport across country. (Riebeek, 2009)

2.10 Analysis Criteria

2.10.1 Environmental Assessment

With any project it is crucial to consider the environment and the impact that any construction or works can have on it. This often means completing environmental impact assessments and providing adequate attempts to minimize and mitigate the aforementioned issue. Furthermore, due to the nature of this project which aims at incorporating renewable energy into the energy sector at a new efficiency it would be a pointless conservation act if it were to go and destroy other aspects of the natural world. Therefore according to (Beder, 1993) it is of the utmost importance that the project is designed in a matter that minimises the use of materials, energy, labour additionally it is crucial that the project does not degrade any natural ecosystem or disrupt any integral natural patterns. With the importance of the measure highlighted above the environmental impacts and mitigation measures can be briefly covered. This requires evaluations to be conducted at various stages of the work and analyse the current impacts and how any following detrimental impacts can be successfully diminished. (Merz, Unknown Date)

2.10.2 Economical Cost

The economical cost of the project will be a defining factor in ultimately determining the potential or feasibility of the overall project. It takes into the account the cost of the project initially while also giving an indication as to the expected returns with some idea as to value for money provided. This project will not focus on specific prices for the project unless time permits but a general idea will still be provided, in order to give the reader a general understanding as to the cost effectiveness of the project. It is at this stage that it is also important to remember that this is a civil based project and thus it would be difficult to design and cost the energy generating system parts as well as the mechanical surveying that is involved with the process.

2.10.3 Physical Constructability / Civil Implications:

A number of physical constructability constraints are going to be considered within the scope of this project. As a civil project they will focus on such elements including the topography of the surrounding area, roads, geo-tech conditions to name a few and will consider any potential issues that could arise. This section needs to be broken down into a number of other sections in order to be more manageable and provide an accurate representation of the project.

2.10.4 Roads

Road access to the area is critical for a successful operation not only during the construction of the project but also after the completion. Access is required for regular maintenance and access if the plant is to be run with employees on site. For this reason, the existing infrastructure needs to be identified and any required road networks need to be identified along with potential issues i.e. steep terrain. Furthermore according to (British Columbia Government, 1996) 'The Industrial Roads ACT'(Canada) access could be provided using an:

> *'access road' which means a road of a temporary nature used to reach sources of material or parts of a construction project, or for fire protection in timbered areas, and access to mining claims.'* Or through an *'Industrial road; means a road on crown or private land used primarily for transportation by motor vehicle of a) natural resources, whether raw, processed or manufactured or b) machinery, materials or personnel.'* (British Columbia Government, 1996)

This could be an important assessment as it would minimise the economic cost and continual maintenance of the road but still allow good access to designated sites critical for the operation of the pumped hydroelectricity plant.

2.10.5 Topographic Conditions

The topographic conditions of an area will have an impact on a number of construction roles. It may limit access to some parts of the area restricting some transportation or building techniques/equipment. In addition, it could have a major impact on the cost of the project if large scale bulk earth works are required. This factor needs to be considered before any decision regarding a plan is made. Therefore, topographic maps of the area will need to be consulted and areas of interest highlighted. There are a number of methods of understanding the topography of an area which include 'Google earth', 'Geosciences Australia' (Geoscience Australia, 2016) also provides a number of topographical maps which are ideal for planning purposes. Finally physical investigation should not be overlooked. This type of data gathering can highlight issues associated with ageing maps such as developmental change (bulk earthworks, dams, etc) which when identified pose no major risk to development however if not discovered until construction can potentially detrimentally influence the entire feasibility of the project both economically and physically.

2.10.6 Geo-technical / Geological conditions

The geotechnical conditions have the potential to undermine the entire project so to speak. It has been highlighted that the current reservoir at split yard creek may not be large enough. Thus in order to expand excavation would be required, and while it is assumed that this excavation will be possible geotechnical research needs to be considered in order to gain a more accurate understanding of the possible cost of such a task. For example, should the project require large amounts of blasting obviously the cost along with the environmental, social and ethical implications of the project will increase significantly? The geotechnical makeup of the area could also influence the ability to install adequate foundations and fitments in the area. The recent geological stability study undertaken around the Split yard creek reservoir and Wivenhoe Dam area from the 2011 flood commission will be called on regularly and the data within assumed to be correct, however should this feasibility assessment be taken to a more developmental approach additional reports would need to be prepared with further investigation into specialised areas required. (Krotewicz, 2011)

2.10.7 Buoyancy

According to the oxford online dictionary (Oxford Dictionaries, 2016) ‘Buoyancy is the ability or tendency of something to float in water or other fluid’. This will be an important aspect and calculation for the potential for floating photovoltaic solar cells on the dam. With this calculation the required flotation can be calculated and compared with the weight of an average panel thus providing a rough estimate to the floating capacity of a system. While there are some pre manufactured floating cells it is a good chance to illustrate further civil competency and perhaps highlight an area of unnecessary economic spending.

Buoyancy Formula

Liquid exerts a force on objects immersed or floating in it. This force is equal to the weight of the liquid that is displaced by an object. This is also known as Archimedes' principle. The unit for the buoyant force (like other forces) is the Newton (N).

buoyant force =(density of liquid)(gravitational acceleration)(volume of liquid)

= (density)(gravitational acceleration)(height of liquid)(surface area of object)

$F_b = \rho g V = \rho g h A$

F_b = buoyant force of a liquid acting on an object (N)

ρ = density of the liquid(kg/m^3)

g = gravitational acceleration(9.80 m/s^2)

V = volume of liquid displaced (m^3 or liters, where 1 m^3 = 1000 L)

h = height of water displaced by a floating object(m)

A = surface area of a floating object(m^2)

Equation 2-5; Buoyancy formula

An example of a buoyancy formula is seen above and can be used as template to make calculations regarding the feasibility of floating photovoltaic generation cells. (SoftSchools.com, 2015)

2.10.8 Moment – Thrust block / foundation

The moment calculations regarding wind turbines will also need to be calculated to calculate the required foundation on each turbine. This may also be combined with structural knowledge obtained through CIV4508 and the associated wind loading standard. This can be used to calculate required cement quantities and prices. Furthermore, if time permits and infrastructure is required the thrust blocks for the pipeline can be calculated. Note: A thrust block is used to hold the pipe steady and ensure that it does not break any fitments.

2.10.9 Efficiency

The efficiency of the system is a crucial requirement and involves making the entire system as effective as possible. This means not wasting resources on unnecessary or inefficient practices such as a poor seal on the top reservoir releasing water after being pumped without generating any energy. In addition, this section can consider the design as a whole and the required development to arrive at a functioning system.

2.10.10 Ethical / Social Implications

The ethical and social implications of the project must be considered prior to any construction. These types of implications can have a large effect on the considered effectiveness of the project and with the potential to impact many people's livelihoods and way of life must be considered as a high prior i.e. should access be required to a nearby area through private property this would be a significant social implication especially if this was fenced farming land or cropping which could disrupt the current practices etc.

CHAPTER 3 Methodology

3.1 Planning to Achieve the Research Objectives

The research questions in this dissertation will be answered using a combination of the previous and following chapters. The first research question; ***'What criteria should be used as a basis to evaluate or develop this type of project'*** will be answered on a literary based agenda. After reading (US Army Corps of Engineers, 1989) the following criteria were all selected to be considered; economic, environmental, efficiency, social and ethical implications. These criteria were then incorporated in stage 1 of the feasibility study to select the proposal with the most potential. A conceptual design would later be based around this proposal. It is also important to note that the above source was used as a guide for a well rounded feasibility study.

The second research question; ***'what technical analysis is required for the chosen proposal?'*** will be answered partly with literature review to give an overview of the civil requirements for this feasibility study. The appropriate civil requirements will later be designed on a technical level in stage 2. A previous feasibility study conducted by (Grontmij, 2012) on a Wind farm was particular useful when establishing the civil scope for this project.

The third research question; ***'what are the relevant conceptual design solutions for the selected proposal?'*** will be answered in stage 2. Stage 2 will incorporate the technical requirements of this dissertation and will use a number of standards, codes and engineering practices learnt over the past years to gain accurate and reliable results. Wherever issues arise in regards to technical aspects, qualified USQ staff will be consulted.

The fourth research question is; ***'how is the proposed solution validated?'*** This question is directly linked to the validation of the proposal. Stage 3 will be the validation component of this dissertation and according to (Alex Barth, 2011) the best way to validate this development is to highlight the benefits in contrast with the existing or past methods. For example using transports the previous method to the car was the horse and cart an easy justification. Therefore a direct comparison in table and point form will be made between the proposed system and the existing system on an economical, environmental, ethical / social and efficiency basis. This will either prove or disprove that the proposal will be of significant benefit as a whole.

The final research question: ***'how feasible is the conversion of the existing fossil fuel powered system at Wivenhoe to a sustainable hydroelectric plant?'*** This research question will be answered using the answers to all of the previous objectives as well as any other informative breakthroughs encountered while preparing this dissertation to make an informed decision on the feasibility of this project. In addition some economical calculations will be considered to help justify any conclusions. For example by calculating the repayments on a loan for the development of the project and comparing them to the expected income from the energy system could give some valuable insight.

3.2 Research and testing methodology

For the research and testing methods that have not previously been covered a short explanation has been included below. In addition to this site visit there is an additional report or photographic log.

What resources should be used to gather the relevant information?

While this project is theoretically based it is important that it remains realistic and accurate and therefore the methods of data or information collection are critical. It should involve both previous research as well as some field observation (new research).

3.2.1 Site Visit 1

The first site visit was to the hydroelectric plant located within the wall at Wivenhoe power station. This power station is run by SEQ water and is powered by the water constantly released from the dam. However due to the relatively shallow nature of the dam and low head the energy generated at this plant is very small. Further details on this site visit will be covered later within the dissertation with a full site visit report provided. This was a very useful method of gaining data as not only could I gain crucial inside knowledge to geotechnical aspects of the area through passing on knowledge from experienced operators I was also able to gain a good understanding as to the operative requirements of this type of system. In addition I gained valuable information regarding the depth of the dam, average release and potential for flood mitigation. While SEQ water doesn't control split yard creek they do impact on the system by altering the depth of the dam. This site visit also gave me valuable insight into the impact that this type of system can potentially have on the environment, economy and other factors as illustrated below.

3.2.2 Potential Site Visit 2

CS Energy Pumped hydro system at split yard creek / Wivenhoe

3.2.3 Google Earth

Google earth has been implemented to gain a better understanding of the lay of the land in hard to access places around the dam. This type of software also gives a good indication of relative distance from one area to another and allows the user to have a better understanding of the area as a whole.

3.2.4 BOM:

The 'Bureau of Meteorology is very helpful when considering a suitable position for the placement of the wind turbines. By using previous year's data general wind patterns can be created and thus the effectiveness of the wind turbines can be maximised. In addition through implementing a cloud cover search the number of days that would be inefficient for power a photovoltaic system could be calculated. This will be discussed further during the analysis of results and justification of any decisions made.

3.2.5 Circly

Circly is a program predominantly used by civil road designers in an attempt to adequately and efficiently design roads. It allows thickness of many different road base layers to be determined and gives an understanding as to the strength of the road.

3.2.6 ASNZ 1170.2 Wind Loading Code

This is the current up to date standard used to calculate the structural adequacy of a building or structure when subjected to an areas wind loads.

3.2.7 AutoCAD

AutoCAD was implemented to draft the conceptual design drawings seen in stage two of the overall project.

3.2.8 Smart Draw

Smart Draw was used to develop the schematic diagrams seen later in the dissertation.

3.3 Methodology – Tasks

Phase 1	**Start-up Phase**
1A	Resources check – Confirm site visit
1B	Software check – Ensure all software required for modelling etc is available
Phase 2	**Stage 1 - Analysis Phase**
2A	A number of proposed sites will be analysed using generated criteria sheets as seen below. This will give an understanding as to the civil feasibility of each potential proposal and will involve a number of technical calcs to accompany the criteria sheet in order to generate reasonable justifications. A site analysis at the current hydroelectric system at Wivenhoe Dam will occur which will be used to gain a better understanding of the current reservoir system and any requirements or difficulties that are expected to arise ranging from topography to geological features. The initial criteria sheets have been outlines below with 50% of the weighting given to civil aspects with the other 50% of the proposal resting on social, ethical, environmental and economical implications. - This will help to form justified recommendations for the final selected site. - Further information will be gathered using online resources, however there is no substitute for actual observations and they will therefore be included. A second site visit to the privately run (CS ENERGY) pumped hydro plant at split yard creek is a possibility and negotiations are taking place.
Phase 3	**Stage 2 – Conceptual Design (Of Proposed Solution)**
3A	The best proposal from the above section will be selected with justifications through technical calculations provided. A basic conceptual design will be outlined giving the details such as proposed roads, solar systems in what areas and wind farms erected in select locations.
3B	Any civil projects such as the proposed roads will be designed using the required software i.e. circly for pavement design. Wind loading codes (AS/NZ 1170.2 – 2011) will be implemented to understand the forces acting on the wind turbine and the required foundations and whether any further restraints

	will be required. Furthermore the potential pumped water will be calculated and compared to the existing capacity of the upper reservoir. If it proves to exceed this capacity there are a number of alternatives to increase the volume of the reservoir mainly including excavation or raising the dam wall. Both of which will need to be analysed in depth.
Optional	A detailed financial modelling of the final project can be carried out and will give an understanding of cost per power production. This will only be undertaken if time and resources permit however if possible it can be used to give an insight into the time required to recoup the initial investment.
Phase 4	**Stage 3 – Validation of Proposed solution**
4A	In order to validate this system not only does it need to have the civil capacity to be feasible it also needs to be comparable to the current system. Therefore as a validation technique an additional major comparison will be made between the existing system and the proposed system. However this will not focus on the civil capacity and instead will be centred on the economical, environmental, ethical, social and capacity of effectiveness implications. Each of these elements will be compared to the two systems with justifications as to the feasibility of the final proposal. See the attached justification table below for further understanding.
4B	Time permitting the energy generation capabilities will be compared to the energy demand. This should be done in order to gain a better understanding of the potential for energy requirements to be met by the hydro system.
Phase 5	**Write-up Phase**
5A	Draft dissertation – prepare a draft submission for Supervisor review and feedback
5B	Finalise dissertation- make any necessary amendments based on above feedback and finalise.

Table 3.1; Methodology

Scoring / Criteria	5	4	3	2	1
Economical	Less than $50/KW	$60/KW	$70/KW	$80/KW	$100+/KW
	No Major Works Required	Minimal Major Works Required	Some Major Works Required	Significant Major Works Required	Excess Major Works Required
Environmental	No disruption to existing ecosystem	Minimal disruption to existing ecosystem, minor rehabilitation work required	Some disruption to existing ecosystems, some rehabilitation work required	Significant disruption to existing ecosystem, significant rehabilitation and trade off schemes required	Major disruption to existing ecosystem, threats to future sustainability of area require excessive rehabilitation and trade off schemes
Social	No social disruption to surrounding residents, no rehabilitation required	Minor social disruption to surrounding residents, minor rehabilitation required	Some social disruption to surrounding residents, some rehabilitation required	Significant social disruption to surrounding residents, substantial rehabilitation required	Major social disruption to surrounding residents, major rehabilitation required
Ethical (Detrimental Liveability Effect)	No ethical disruption to ability to live or work in the area, no tradeoffs required	Minimal ethical disruption to ability to live or work in the area, minor tradeoffs required	Some ethical disruption to ability to live or work in the area, some tradeoffs required	Significant ethical disruption to ability to live or work in the area, substantial tradeoffs required	Major ethical disruption to ability to live or work in the area, major tradeoffs required
Effectiveness: Useable Days Per Year	Less than 25	25-75	75-125	125-175	More than 175

Table 3.2; Stage 1 criteria sheet

Stage 2: Methodology

In stage two there will be a number of civil aspects covered in an attempt to create a conceptual design for the selected system. The major aspects that will be covered are:

- Wind and Solar positioning and quantities
- Foundation requirements for subjected wind loads
- Geotechnical understanding of the area applied to all criteria i.e. foundations and road development
- Buoyancy Requirements for the floating platform
- Road path in regards to topography and required access
- Dam capacity and any recommendation

Proposal Comparison	Proposed Solution	Current Solution
Economical		
Environmental		
Social		
Ethical (Detrimental Liveability Effect)		
Pumping Capacity (Effectiveness)		

Table 3.3; Stage 3 validations

NOTE: Civil Feasibility will not be considered in this particular comparison as the current system is already in place and therefore does not need to be considered, and the proposed solution has already been evaluated and selected as the best option.

3.4 Brief Site Report 1

Site Visit 1: Report

Project Site Report

On the 24th of March 2016 I attended a site visit to the current hydroelectric generation plant in the wall at Wivenhoe dam. Currently the site is run by SEQ water which run the dam, control the release levels and remotely run the hydroelectric plant. The following report will detail what was covered throughout the site visit, explain a number of the photos attached and also raise some important points highlighted by the operators at SEQ water. Notice that it is not in the usual format of a report and instead uses the photos as explanation headings.

Figure 3.1; Photo 1 - Entry

This particular site visit took me to the hydroelectric generation plant within the wall at Wivenhoe dam. According to the operator this particular plant has the capacity to run at approximately 5MW's however due to a decrease in flow in recent times it has been running at 1.5 – 2 MW and during my site visit was operating at 1.65 MW/day.

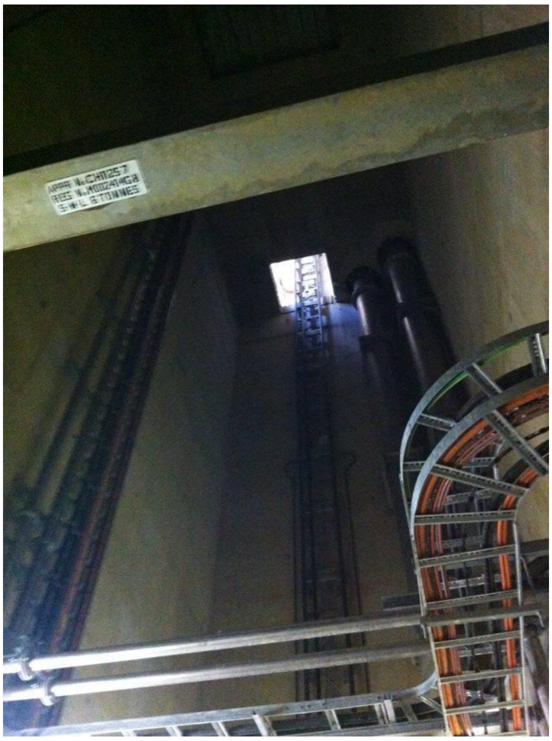


Figure 3.2; Photo 2- Lift Entrance

Illustrating the depth of the hydro plant. According to the operator this particular plant cannot generate as much power as those in the US due to the shallowness of the dam and the lack of Ice melts which give additional run to a river system. Therefore as this is a horizontal feed hydroelectricity plant the overall generation capacity is substantially smaller in comparison to a vertically fed dam. For this reason it is definitely recommended that a pumped hydro plant investigated at the Split yard creek reservoir which provides and elevation head of approximately 60 metres.

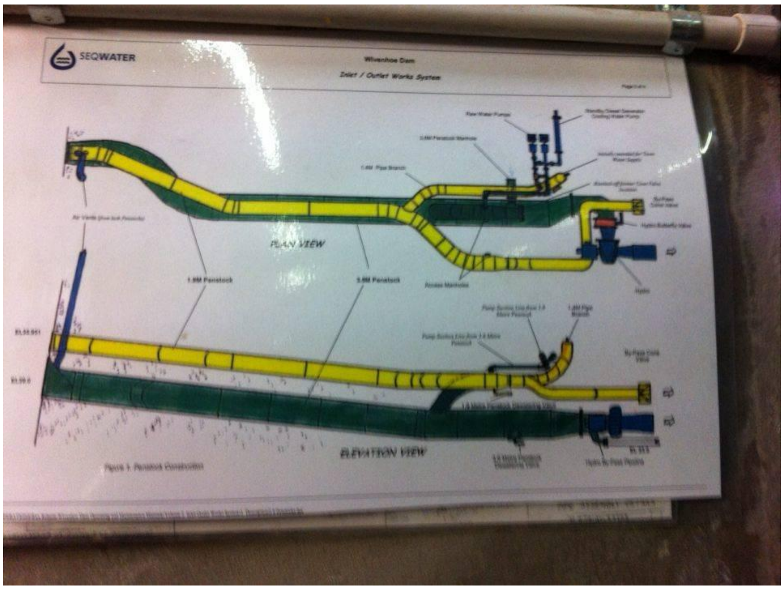


Figure 3.3; Photo 3- Schematic of horizontal hydro

Figure 3.4; Photo 4- Gallery Entrance

The gallery can give access to the inner workings of feed and turbine thus allowing maintenance to be conducted. The bottom two pictures show the main aspects of the hydro plant where the power generation is completed before being allowed to re-enter the watercourse through the outlet (seen on the right) downstream.

Figure 3.5; Photo's 5 & 6 Turbine generator

Figure 3.6; Photo 7- Dissipation Chamber

An important aspect of the current hydro plant in the wall at Wivenhoe is the dissipation chamber. Should the hydro plant be out of use the water needs to be released still without significant damage or erosion through increased turbidity to the foundations of the dam wall and surrounding geological formations? Therefore a dissipation chamber has been put into place which basically acts as a white-water 'room' trapping the water until it settles enough to exit the through the square opening seen below.

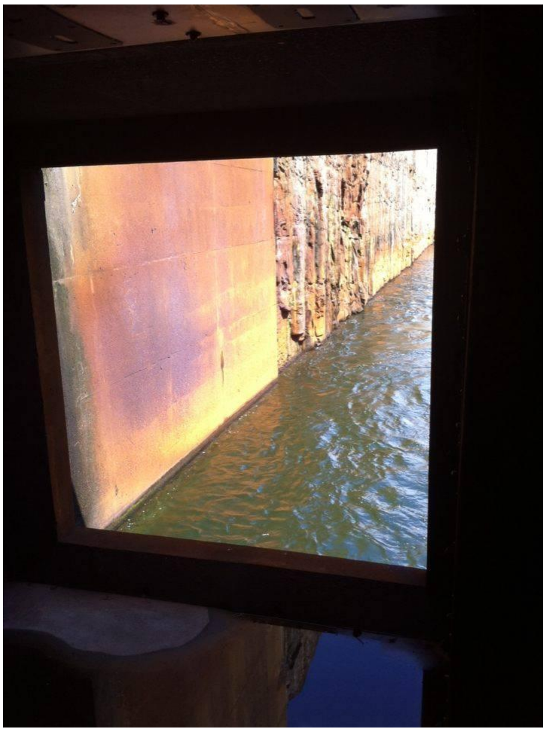


Figure 3.7; Photo 8 - Dissipation chamber exit

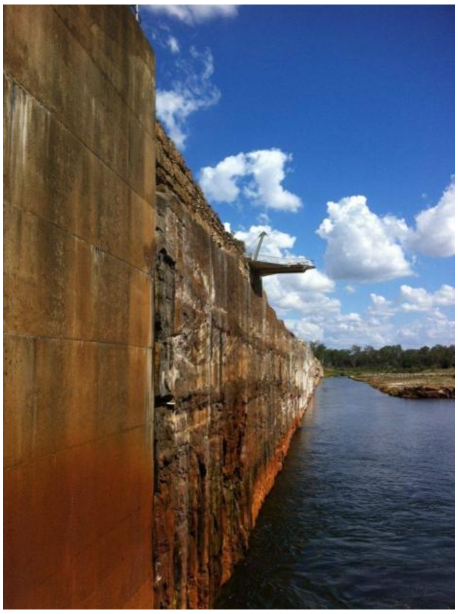


Figure 3.8; Photo 9 - Dam wall fixed flush to sandstone

The geological formation of an area is a crucial part of any civil design and therefore great consideration concerning this aspect must be made when selecting a proposed site. Unfortunately Wivenhoe dam is based in an area which is primarily sandstone with large amounts of distinct layering. This makes it prone to weathering and erosion in high water events. The bottom picture illustrates the erosion that occurred in 2011 floods when the water rose above the bottom shelf and ripped out large pieces of sandstone leaving behind the white discolouration of unstained rock. Additionally this type of material makes shoring and fixing the dam very difficult and with such catastrophic potential in the event of failure it is critical that the dam's foundations are adequate.

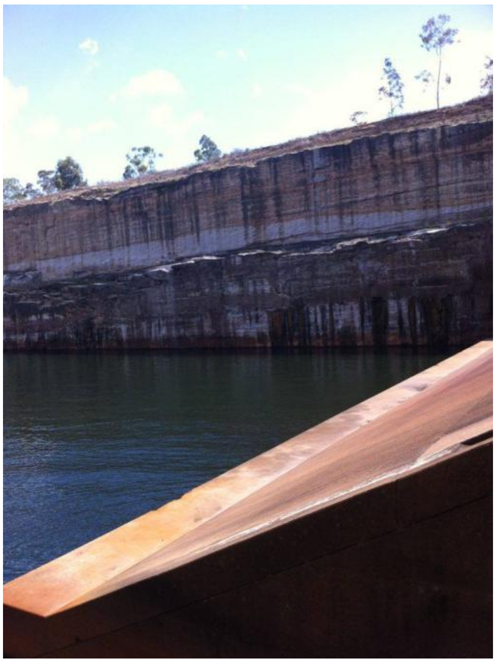


Figure 3.9; Photo 10 - Erosion from 2011 floods

These photographs illustrate the cooling system in place on the current hydro system. The system uses water running through the generator and pumps it around as a cooling method before releasing it back into the river system. In the left photograph the increased turbidity is clear and this is worth noting as with increased aeration the floatation capacity of the water dramatically decreases creating areas of no floatation. This is a potential hazard that was highlighted during the site visit and is also the potential to detrimentally influence the surrounding environment. Finally the figure below (right) shows the way that the unmanned hydro plant can be operated from an external source. By manipulating the desired energy output or the required water the other factors can be calculated with software. As a mining requirement 30ML per day must travel down the Brisbane River to support the downstream ecosystems, this must be combined with the demand for irrigation by downstream farmers who rely on the water for their livelihood.

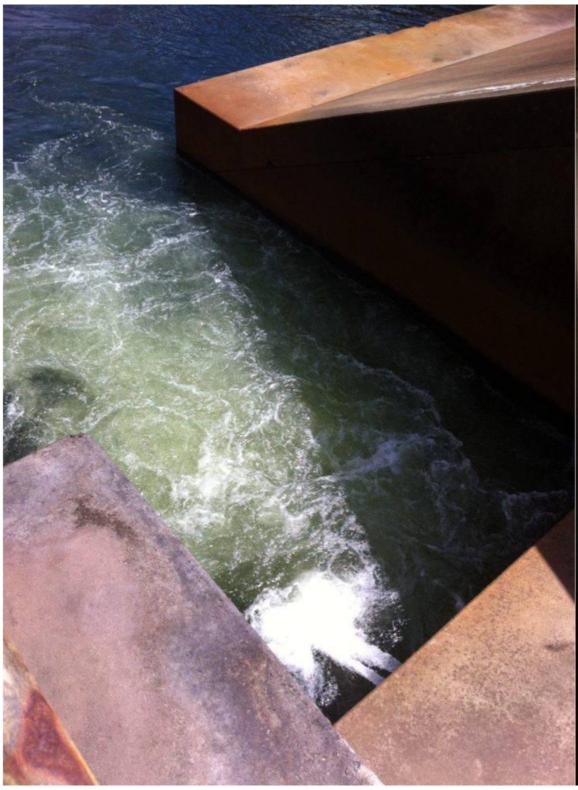


Figure 3.10; Photo 11 - Coolant water release

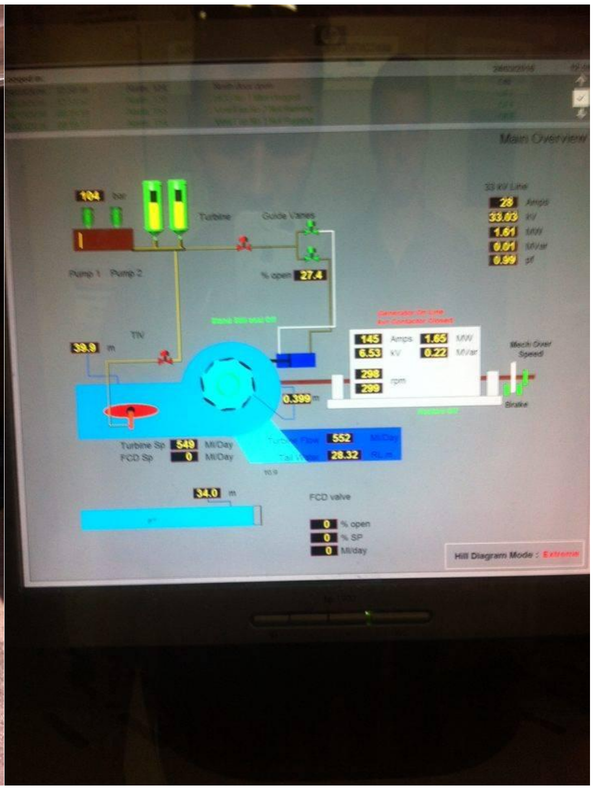


Figure 3.11; Photo 12 - Control Panel

Figure 3.12; Photo 13- Wivenhoe horizontal hydro generation diagram

Once again the above picture briefly outlines how the hydro system works and how the spillway can be implemented to release water in the event of a flood. It also illustrates the release of water at a submerged state. Finally the picture below outlines the transportation of the produced energy to a more sophisticated power station for dispersion.

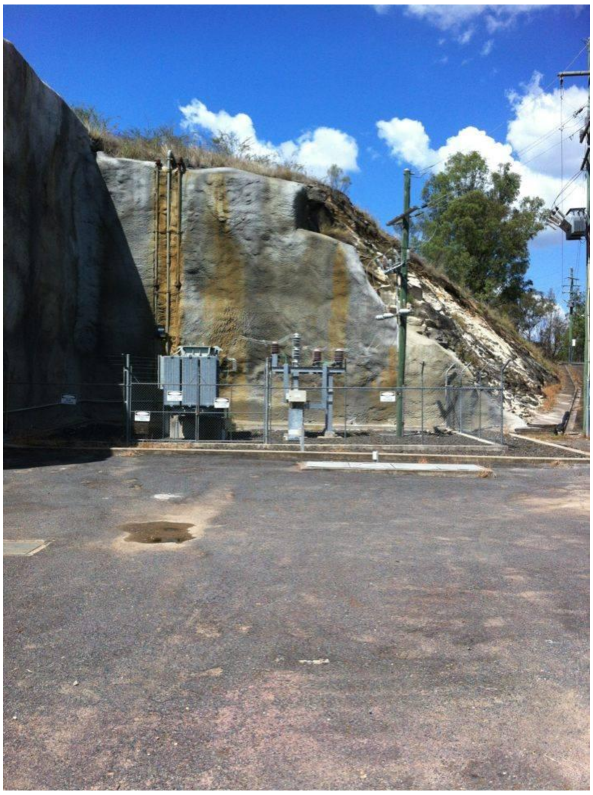


Figure 3.13; Photo 14 – Power back into the grid

3.5 Purpose

While the method of the project has been explained above it is equally if not more important to give an understanding or justification as to why the thesis has been conducted, and why the results are of any importance to the real world. It is this reasoning behind the project that defines the quality or usefulness of the research. The basis of the 'methodology' is distinctly different from the method used and therefore it is crucial to keep the following questions in mind when preparing the project; what is the purpose of this project? What are the real world applications of these projects findings? Finally how will this benefit the modern world?

The first question raised above is the purpose of this project. However before the purpose can be explained adequately, it is important to understand the underlying problem. In the current day and age there is still a heavy reliance on fossil fuel generated power and while this is currently meeting the demand the supply is becoming more and more economically challenging to access. This issue is compounded by the associated environmental impacts of not only obtaining but harnessing the power from the fossil fuels. According to (What's YOUR Impact, 2016) in 2011 87% of all human produced carbon dioxide were generated through the burning of fossil fuels. This is a enormous amount and gives reason to pose the questions as to why? Why do we need to rely so heavily on fossil fuels especially with the knowledge that not only is the practice not sustainable, it is destroying the planet? There are so many alternatives for energy generation, but in a realistic sense the world will not prioritise the environment over the economy, therefore an efficient and effective sustainable energy source must be found. This project aims at identifying that energy source. (What's YOUR Impact, 2016)

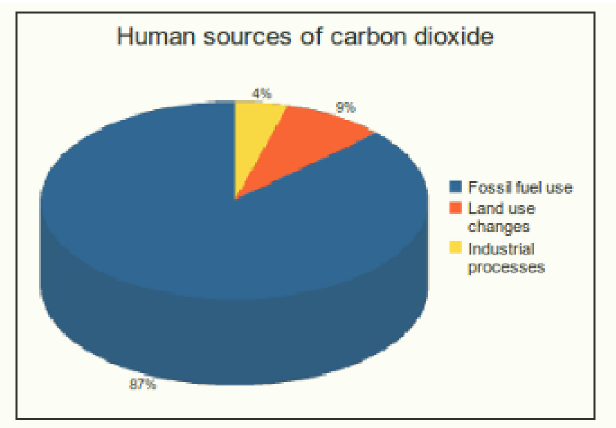


Figure 3.14; Human sources of carbon dioxide

Figure 3.14 shows the breakdown of the human produced carbon dioxide in 2011, with 87% produced by fossil fuels the remainder was generated through the clearing of forests which alarmingly compounds the issue through not only releasing carbon dioxide but by diminishing the planets ability to mitigate carbon dioxide. The final 4% is attributed to industrial processes for example the manufacture of cement. N.B. The 87% figure includes the burning or use of fuel in cars, planes and industrial facilities. (What's YOUR Impact, 2016)

With the response to the first question above under consideration it is easy to justify the real world application of this project and how it would benefit the world. As a sustainable energy resource implementer South East Queensland would not only be breaking its dependency on the fossil fuelled energy sector it would be on the cutting edge of the greener energy sector. The simple fact is that the current system is not only detrimental to the natural world it is also getting more and more economically unviable as resources are depleted and additional effort is required to access the necessary fossil fuels.

This project understands the need for change, but what direction should the energy sector move to? There are so many alternatives with both pros and cons; it is imperative for the success of the system that the correct type of sustainable energy system is put into place for the selected area. This project will use a systematic approach to decide on the most efficient and effective future system and ultimately make judgements as to the future feasibility of the conceptual design.

3.6 Justification: Why did you use this particular methodology?

After reviewing a number of literary resources it was decided to use the above methodology to gain an accurate estimation or understanding of the potential feasibility of the project. In addition with the guidance from Dr Steven Goh a three stage plan has been adopted to get the most rounded and accurate outcome. According to (American Speech-Language-Hearing Association, 2016) the first step should be to conduct a preliminary analysis. This has been conducted and not only was extensive research into the subject matter carried out, idyllic and failed systems highlighted to learn from but a number of different proposals were also put forward. This allowed me to gain a more rounded understanding of where the different proposals lacked or had strong points and thus I could ultimately pick the best proposal which actually wasn’t what I was expecting it to be. The criteria system used was an effective method as it allowed the results or grading of the proposals to give a quantifiable value to generally qualitative data.

The next step was to take the design brief from sheerly theoretical and apply some restraints and real world parameters associated with the particular site. For example by understanding the sites geological composition I was able to ascertain that a gravity spread footing would not be adequate or practical and thus I designed an anchor deep footing that relied heavily on grouted piles. I was also able to understand the civil implications of the foundations after calculating the wind loadings and overturning moments under critical load for the wind turbines. All of the civil considerations were an important or more so critical part of the project as they really define the civil scope and aim of the project; is this project feasible (in order to be feasible it first needs to be possible). It is important to distinguish the difference between possible and feasible. While it may be possible to travel to the moon it is not feasible to travel to the moon for work each day.

The final stage in the methodology was to compare the proposal to the existing system**.** This is an important aspect as it gives the reader an understanding or grounds to the benefit that the proposal will provide. It is important to remember that this is a feasibility study on a conversion from one particular system to another and thus it is critical that the proposal is actually better than the existing or it would in fact have a detrimental impact. After this comparison is complete with both the pros and cons of both systems evaluated a conclusion as to the final judgement of feasibility of the project can be made. It is important that this conclusion clearly states whether the project should or should not go ahead, otherwise the project has not achieved its aim.

CHAPTER 4 Stage 1: Analysis

This section highlights the major analysis that was undertaken during the project in order to generate a more accurate conceptual design before validating the project work.

4.1 Stage 1 – Feasibility Analysis

In order to gain an understanding of the potential for the project and the options at hand it was important to undertake a general feasibility analysis. This involved the use of a criteria table which allowed analysis and comparisons to be made between multiple potential solutions to the current issue. This table can be seen below along with a number of potential viable combinations of power generation.

While a number of tables or power generation alternatives will be presented the breakdown or scoring justification will only be provided for the 100% options, as these ultimately make up the other proposals and thus any negative or positive attributes will be carried into the following proposals at the associate scale.

Option 1: 100% Solar (Per system)

Criteria \ Scoring/System	5	4	3	2	1
Economical (Million $)	Less than 300	325	350	375 ✓	More than 400
	No Major Works Required	Minimal Major Earth Works Required ✓	Some Major Works Required	Significant Major Works Required	Excess Major Works Required
Environmental	No disruption to existing ecosystem	Minimal disruption to existing ecosystem, minor rehabilitation work required	Some disruption to existing ecosystems, some rehabilitation work required ✓	Significant disruption to existing ecosystem, significant rehabilitation and trade off schemes required	Major disruption to existing ecosystem, threats to future sustainability of area require excessive rehabilitation and trade off schemes
Social	No social disruption to surrounding residents, no rehabilitation required	Minor social disruption to surrounding residents, minor rehabilitation required ✓	Some social disruption to surrounding residents, some rehabilitation required	Significant social disruption to surrounding residents, substantial rehabilitation required	Major social disruption to surrounding residents, major rehabilitation required
Ethical (Detrimental Liveability Effect)	No ethical disruption to ability to live or work in the area, no tradeoffs required ✓	Minimal ethical disruption to ability to live or work in the area, minor tradeoffs required	Some ethical disruption to ability to live or work in the area, some tradeoffs required	Significant ethical disruption to ability to live or work in the area, substantial tradeoffs required	Major ethical disruption to ability to live or work in the area, major tradeoffs required
Effectiveness: Unusable Days Per Year	Less than 25	25-75	75-125 ✓ **120**	125-50	More than 175

Table 4.1; Option 1: 100% Solar

When considering multiple options it is critical to give high priority to the economical feasibility of a project. According to (Australian Solar Quotes, 2016) assuming the current trend remained the same it would cost approximately $375 000 000 to generate 250 MW of power each day. However 250 MW is the max required energy to run one of the two systems and therefore the total funding required for the panels and installation would reach $750 000 000. At three quarters of a billion dollars this is a significant investment that needs to be thoroughly investigated. However in this particular case due to the proposed floatation of the solar panels the extent of civil works required is minimal. With only simple access to the water's edge and fitments through the form of dolphins or piers/piles required. However there would still be significant additional cost through the floatation and fitments cost and installation and a great degree of difficulty in engineering an efficient installation process.

Environmentally this particular development has the potential to influence the current ecosystem in the dam by significantly decreasing the volume of sunlight and radiation penetrating the water an issue some members of the community feel could be very hazardous for the existing aquatic life. This particular issue is very difficult to rehabilitate and instead appropriate design can negate a large amount of the potential disruption. In fact according to (WaterWorld, 2016) by placing the panels in deep water and providing adequate shade the water quality could be increased. In addition as total cover will not occur the water around the edges will still obtain enough natural light to sustain the existing ecosystem.

The social implications of the proposed system have the potential to negatively influence those locals who regularly use the site as a recreation facility. By installing floating solar panels the wide open recreation potential of the site will be decreased and those who enjoy the freedom of kayaking and other such activities could be influenced. However as the dam is not used for high speed water sports or other activities that require the 100% open water it is highly likely that the proposal would not have a large detrimental impact on those in direct connection with the dam. The nearby Somerset Dam could easily accommodate all water sport and fishing enthusiasts and therefore there would be no noticeable detrimental impact. Furthermore any minor disruption to recreational use would be offset by the economic activity bought to the area, both during the construction phase and whilst in operation.

Ethical: the detrimental liveability effect from solar panels is minimal. Unlike the second option (which will be investigated in further detail below), in which large amounts of sound pollution are produced this method is silent and relatively friendly in regards to aesthetic appearance. With this acknowledged the sheer volume of panels put into place may make some of the local residents uneasy and could potentially lead to some social disturbances and complaints or protests being made.

Efficiency: It is crucial to select a method of generation that can be used both effectively and regularly in order to design an efficient and feasible energy system. Therefore the Bureau of meteorology has been used to gather historical data for the area which can be used to make justifications and predictions as to the effectiveness of the conceptual design. According to (Bureau of Meteorology, 2005) there are 113.1 clear sunny days in the chosen area while this does not include partially sunny days which are also useable to some degree therefore it is more accurate to consider the unusable days. The area in question has 119.2 days with full cloud cover on annual average, which gives an indication on the amount of time the infrastructure would go unused. Furthermore according to (Bureau of Meteorology, 2016) the area receives on annual average 7.4 hours of sunlight per day, but can be considered to have a 'very high' UV index of approximately 8. See the figures below

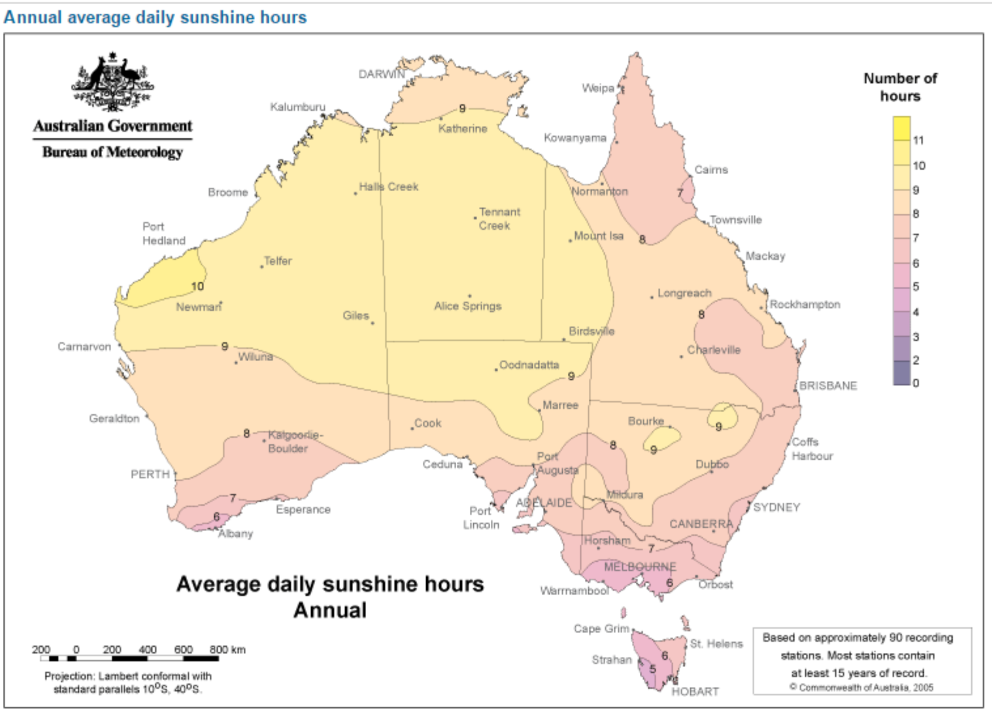


Figure 4.1; Average daily sunshine hours (annual)

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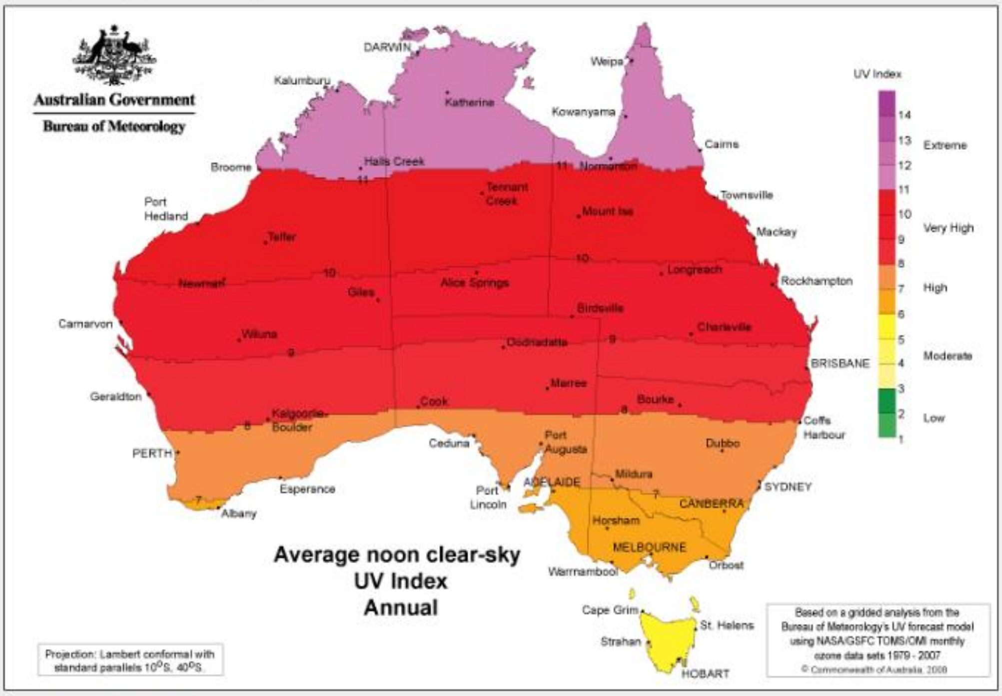
Average solar ultraviolet (UV) Index

These maps show the values of the average annual, average monthly and average seasonal solar ultraviolet (UV) Index over Australia.

Period: Annual   Download: Grid



Product Code: IDCJCM0045

Figure 4.2; Average solar ultraviolet (UV) index (Bureau of Meteorology, 2016)

Monthly climate statistics

All years of record

About Climate statistics | Data file of statistics for this site (csv) | Site selection menu

Summary statistics BRISBANE REGIONAL OFFICE

A summary of the major climate statistics recorded at this site is provided below. There is also an extended table with more statistics available. More detailed data for individual sites is available.

Site information

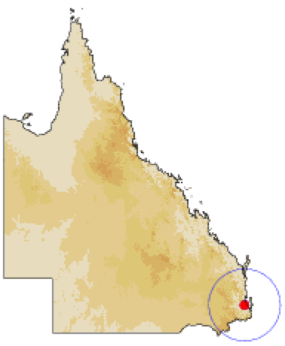
Site name: BRISBANE REGIONAL OFFICE
Site number: 040214
Latitude: 27.48 °S **Longitude:** 153.03 °E
Elevation: 38 m
Commenced: 1840 **Status:** Closed 01 Jul 1994
Latest available data: 30 Jun 1994

Additional information

Additional site information

Nearest alternative sites

1. 040913 BRISBANE (0.9km)
2. 040236 NUDGEE (7.6km)
3. 040223 BRISBANE AERO (10.6km)



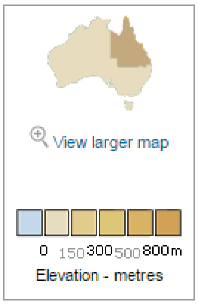


Figure 4.3 Monthly climatic statistics for selected area

View: ◉ Main statistics ○ All available | Period: Use all years of data ▾ | Text size: ◉ Normal ○ Large

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years		Plot	Map
Temperature																	
Mean maximum temperature (°C)	29.4	29.0	28.0	26.1	23.2	20.9	20.4	21.8	24.0	26.1	27.8	29.1	25.5	99	1887 1986		
Mean minimum temperature (°C)	20.7	20.6	19.4	16.6	13.3	10.9	9.5	10.3	12.9	15.8	18.1	19.8	15.7	99	1887 1986		
Rainfall																	
Mean rainfall (mm)	159.6	158.3	140.7	92.5	73.7	67.8	56.5	45.9	45.7	75.4	97.0	133.3	1148.8	142	1840 1994		
Decile 5 (median) rainfall (mm)	126.0	115.8	110.1	60.6	51.8	43.5	37.9	29.4	39.5	61.2	83.3	116.0	1106.7	138	1840 1994		
Mean number of days of rain ≥ 1 mm	8.4	8.8	9.4	6.8	5.8	4.5	4.2	4.0	4.4	5.9	6.5	7.7	76.4	132	1841 1994		
Other daily elements																	
Mean daily sunshine (hours)	7.4	6.6	6.5	7.2	6.9	6.8	7.4	7.9	8.2	8.0	8.4	8.1	7.4	26	1951 1983		
Mean number of clear days	4.0	3.5	6.7	8.7	10.7	12.1	15.2	15.4	14.1	9.2	7.4	6.1	113.1	35	1951 1986		
Mean number of cloudy days	14.3	13.4	12.8	8.7	10.0	8.1	7.4	5.9	5.9	9.9	10.7	12.1	119.2	35	1951 1986		
9 am conditions																	
Mean 9am temperature (°C)	25.6	25.3	24.1	21.5	17.7	14.7	13.7	15.4	18.8	21.7	24.1	25.5	20.7	35	1951 1986		
Mean 9am relative humidity (%)	66	69	71	70	70	70	67	63	61	60	60	62	66	35	1951 1986		
Mean 9am wind speed (km/h)	7.8	7.5	7.3	6.8	7.3	8.4	8.1	7.6	7.0	7.1	7.1	7.1	7.4	35	1951 1986		
9am wind speed vs direction plot	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF				
3 pm conditions																	
Mean 3pm temperature (°C)	27.4	27.4	26.7	25.1	22.2	20.1	19.5	20.7	22.5	24.0	25.8	27.1	24.0	35	1951 1986		
Mean 3pm relative humidity (%)	59	60	59	55	52	51	46	44	46	52	55	57	53	35	1951 1986		
Mean 3pm wind speed (km/h)	14.4	13.6	13.1	11.0	9.5	9.9	10.5	11.7	13.3	14.3	14.5	14.9	12.6	35	1951 1986		
3pm wind speed vs direction plot	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF	PDF				

Figure 4.4; Climatic statistics for chosen area i.e. mean number of clear days (Bureau of Meteorology, 2016)

Option 2: 100% Wind

Criteria \ Scoring/System	5	4	3	2	1
Economical (Million $)	Less than 300	325 ✓	350	375	More than 400
	No Major Works Required	Minimal Major Works Required	Some Major Works Required ✓	Significant Major Works Required	Excess Major Works Required
Environmental	No disruption to existing ecosystem	Minimal disruption to existing ecosystem, minor rehabilitation work required	Some disruption to existing ecosystems, some rehabilitation work required ✓	Significant disruption to existing ecosystem, significant rehabilitation and trade off schemes required	Major disruption to existing ecosystem, threats to future sustainability of area require excessive rehabilitation and trade off schemes
Social	No social disruption to surrounding residents, no rehabilitation required ✓	Minor social disruption to surrounding residents, minor rehabilitation required	Some social disruption to surrounding residents, some rehabilitation required	Significant social disruption to surrounding residents, substantial rehabilitation required	Major social disruption to surrounding residents, major rehabilitation required
Ethical (Detrimental Liveability Effect)	No ethical disruption to ability to live or work in the area, no tradeoffs required	Minimal ethical disruption to ability to live or work in the area, minor tradeoffs required	Some ethical disruption to ability to live or work in the area, some tradeoffs required	✓ Significant ethical disruption to ability to live or work in the area, substantial tradeoffs required	Major ethical disruption to ability to live or work in the area, major tradeoffs required
Effectiveness: Unusable Days Per Year	Less than 25	25-75 ✓ Ranging from 7 to 43.8 calm recordings.	75-125	125-50	More than 175

Table 4.2; Option 2 - 100% Wind

Economical Impact: The second potential solution involving the installation of a number of wind turbines can be achieved approximately 50 million dollars cheaper per system. Therefore saving the project a total of 100 million dollars in infrastructure costs, bringing the total cost for a 500MW system to $650 000 000 dollars. This is still a significant investment especially due to the associated costs of developing roads and the area for construction and maintenance purposes. Additionally while it is assumed the turbines will be placed on previously owned land this could potentially have an effect in combination with the cost of transporting the equipment to a suitable location (most likely the top of the nearby mountain) involves significant expenses through road development for construction and maintenance. (Levine, 2003)

Environmentally this is a renewable and sustainable option that will reduce the dependency on fossil fuel powered energy and can therefore be considered as a cleaner, greener alternative. However there will still be some minor environmental disruption associated with the construction of the infrastructure as well as the required development for construction. Throughout the entire process all standards will be followed with environmental assessment sheets being considered at a regular basis and the environment considered in all planning and development stages. In addition to this according to (Union of Concerned Scientists , 2013), there can be major impacts on wildlife and habitat with birds, bats and other flying insects / marsupials at risk. However according to the same site these figures are not high enough to pose risk to species populations and does therefore not pose enough significant detrimental impact to question the development.

This solution will not have a social impact on the surrounding residents. The construction will be over a short period of time and this project will have no impact on the current recreational facilities in the area. It is highly likely that the majority of the population will be unaware of the existence and will not be socially impacted in anyway shape or form. However ethically there is the potential for some detrimental impacts on the liveability of surrounding residents.

According to (James Richard, 2014) 'The World Health Organisation (WHO) has concluded that observable effects of night-time, outdoor noise levels of 40 dBA or higher will lead to diminished health.' 'Yet, the wind industry commonly promotes 50 dBA as an appropriate limit for homes, even though the World Health organisation has identified such high levels as a cause of serious health effects.' (James Richard, 2014).

However according to the same source the majority of disturbances were experienced by those living within two miles of the turbines (approximately 3.3 km). Therefore considering the potential sites are approximately 10Km from the nearest town the risk of affecting residents is minimal.

The effectiveness of the project is of incredible importance. This particular technology is much more efficient as wind can be harnessed both during the hours of daylight and throughout the night. The Bureau of meteorology suggests that the amount of unusable days or time ranges from 2 to 12% depending on the hour of the day. This is still far smaller than the solar powered system and thus gives the overall proposal hope for success. In addition the wind roses seen in the figures below give the reader an indication of the types of expected winds, and potential wind speeds that could be harnessed in the area. This particular data is crucial in order to create an effective and efficient system that generates the most from the potential natural resources.

(Bureau of Meteorology , 2008)

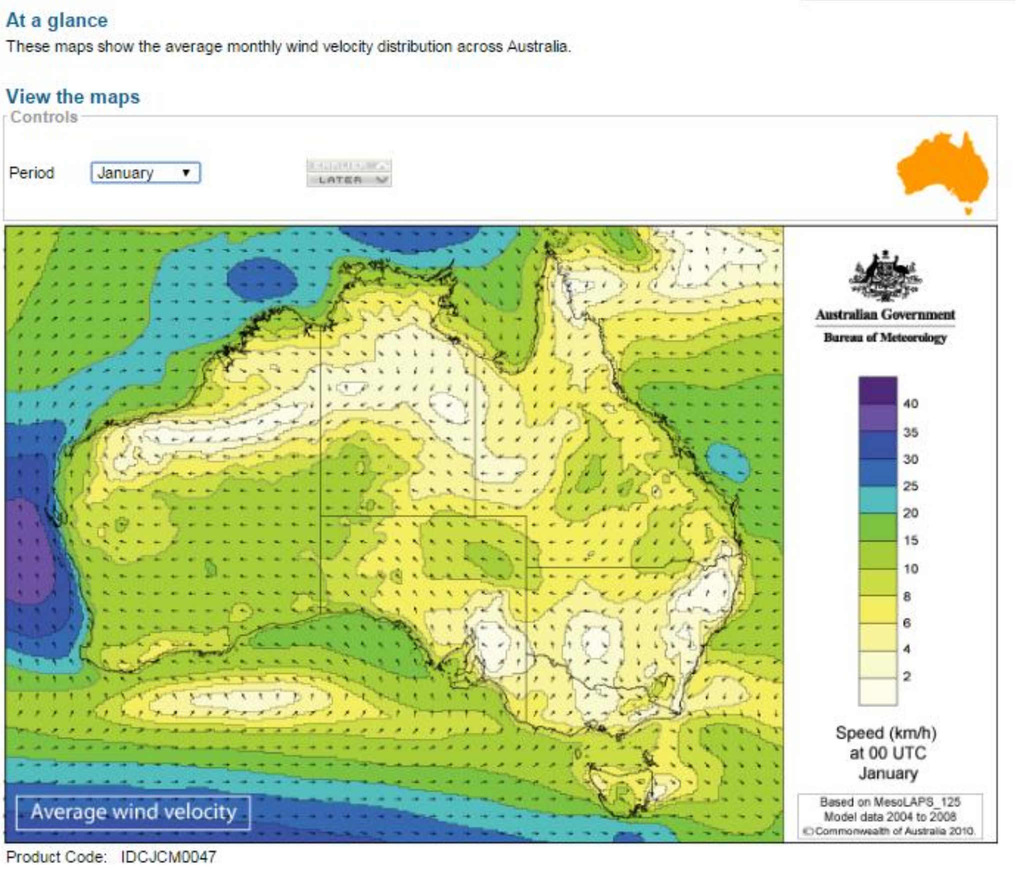


Figure 4.5; Predicted wind speeds for Australia

The above figure gives a general understanding of the predicted wind speeds expected in various parts of Australia. This gives the project a more realistic grounding when considering generation predictions. (Bureau of Meteorology , 2008)

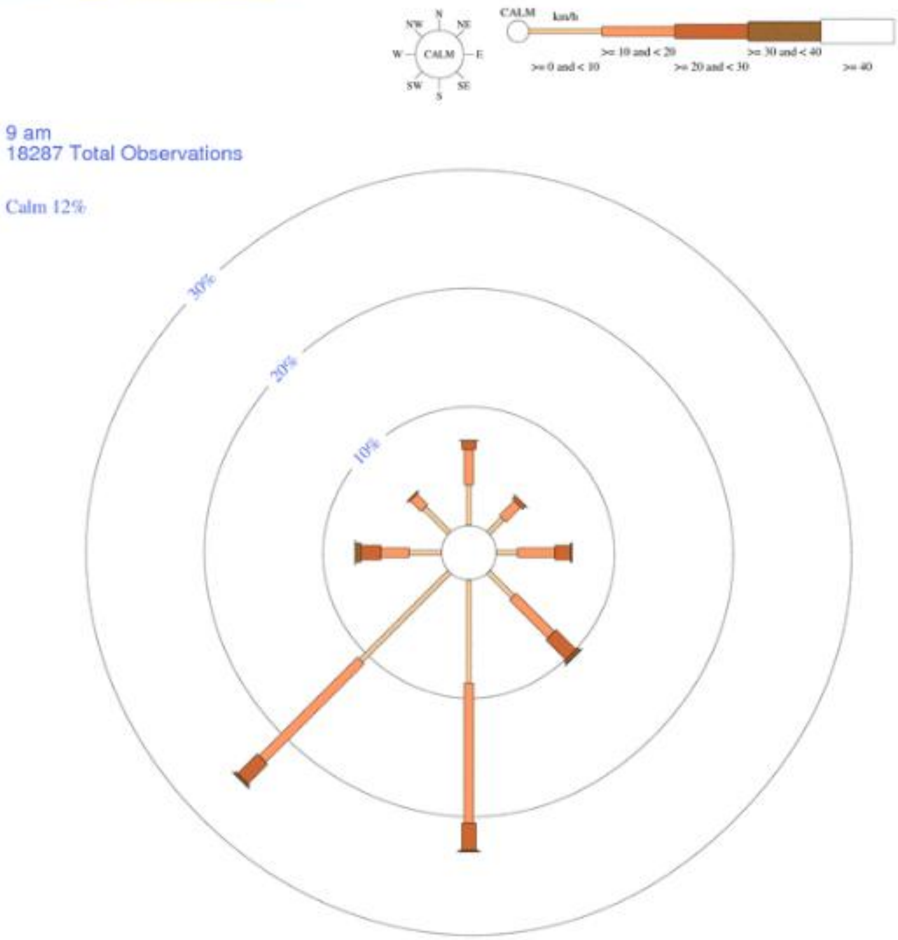
Wind speed and direction rose

Product ID code: **IDCJCM0021**

Location: BRISBANE AERO
Latitude: 27.42°S
Period: 9am Annual
Download: PDF | Wind Frequency Data

Longitude: 153.11°E
Start year: 1950

Site Number: 040223
Elevation: 4 metres (above sea level)
End year: 2000



Australian Government
Bureau of Meteorology

Wind directions are divided into eight compass directions. The circles around the image represent the various percentages of occurrence of the winds. For example, if the branch to the west just reaches the 10% ring it means a frequency of 10% blowing from that direction. The scale factor can be ignored when interpreting these wind roses.
An observed wind speed which falls precisely on the boundary between two divisions will be included in the lower range (eg 10km/h is included in the 1-10 km/h range).
Calm has no direction. An asterisk(*) indicate that calm is less than 1%.
Only quality controlled data have been used.

Image last updated April 2016

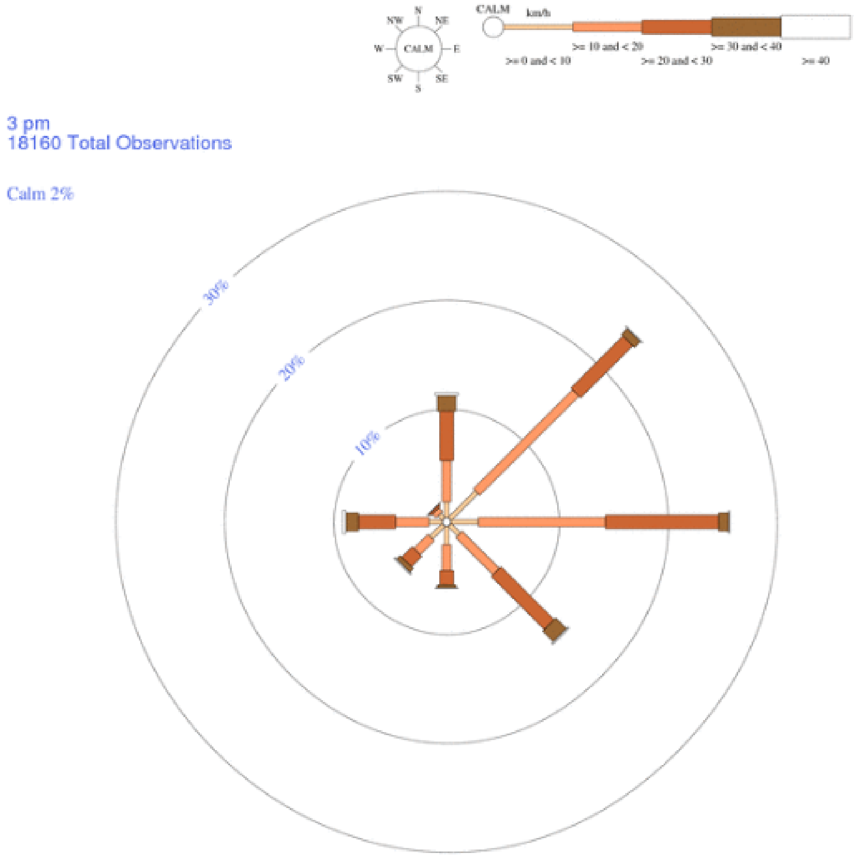
Figure 4.6- Annual 9am wind speed and direction rose for selected area (Bureau of Meterology, 2016)

Wind speed and direction rose

Product ID code: **IDCJCM0021**

Location: BRISBANE AERO
Latitude: 27.42°S **Longitude:** 153.11°E
Period: 3pm Annual **Start year:** 1950
Download: PDF | Wind Frequency Data

Site Number: 040223
Elevation: 4 metres (above sea level)
End year: 2000



Australian Government
Bureau of Meteorology

Wind directions are divided into eight compass directions. The circles around the image represent the various percentages of occurrence of the winds. For example, if the branch to the west just reaches the 10% ring it means a frequency of 10% blowing from that direction. The scale factor can be ignored when interpreting these wind roses.
An observed wind speed which falls precisely on the boundary between two divisions will be included in the lower range (eg 10km/h is included in the 1-10 km/h range).
Calm has no direction. An asterisk(*) indicate that calm is less than 1%.
Only quality controlled data have been used.

Image last updated April 2016

Figure 4.7Annual 3pm wind speed and direction rose for selected area (Bureau of Meterology, 2016)

The above figures or wind roses give the reader an understanding of the usual and predictable wind patterns in the selected area. This data should be revisited throughout the conceptual design stage to ensure that the most of all potential energy can be harnessed.

Option 3: 65% Solar: 35% Wind

Scoring/System / **Criteria**	**5**	**4**	**3**	**2**	**1**
Economical (Million $)	Less than 300	325	350 ✓	375	More than 400
	No Major Works Required	Minimal Major Works Required ✓	Some Major Works Required	Significant Major Works Required	Excess Major Works Required
Environmental	No disruption to existing ecosystem	Minimal disruption to existing ecosystem, minor rehabilitation work required	Some disruption to existing ecosystems, some rehabilitation work required ✓	Significant disruption to existing ecosystem, significant rehabilitation and trade off schemes required	Major disruption to existing ecosystem, threats to future sustainability of area require excessive rehabilitation and trade off schemes
Social	No social disruption to surrounding residents, no rehabilitation required	Minor social disruption to surrounding residents, minor rehabilitation required ✓	Some social disruption to surrounding residents, some rehabilitation required	Significant social disruption to surrounding residents, substantial rehabilitation required	Major social disruption to surrounding residents, major rehabilitation required
Ethical (Detrimental Liveability Effect)	No ethical disruption to ability to live or work in the area, no tradeoffs required	Minimal ethical disruption to ability to live or work in the area, minor tradeoffs required ✓	Some ethical disruption to ability to live or work in the area, some tradeoffs required	Significant ethical disruption to ability to live or work in the area, substantial tradeoffs required	Major ethical disruption to ability to live or work in the area, major tradeoffs required
Effectiveness: Unusable Days Per Year	Less than 25	25-75	75-125 ✓	125-50	More than 175

Table 4.3: Option 3 - 65% Solar, 35% Wind

Option 4: 65% Wind: 35% Solar

Criteria \ Scoring/System	5	4	3	2	1
Economical (Million $)	Less than 300	325	✓ 350	375	More than 400
	No Major Works Required	Minimal Major Works Required	✓ Some Major Works Required	Significant Major Works Required	Excess Major Works Required
Environmental	No disruption to existing ecosystem	Minimal disruption to existing ecosystem, minor rehabilitation work required	Some disruption to existing ecosystems, some rehabilitation work required ✓	Significant disruption to existing ecosystem, significant rehabilitation and trade off schemes required	Major disruption to existing ecosystem, threats to future sustainability of area require excessive rehabilitation and trade off schemes
Social	No social disruption to surrounding residents, no rehabilitation required ✓	Minor social disruption to surrounding residents, minor rehabilitation required	Some social disruption to surrounding residents, some rehabilitation required	Significant social disruption to surrounding residents, substantial rehabilitation required	Major social disruption to surrounding residents, major rehabilitation required
Ethical (Detrimental Liveability Effect)	No ethical disruption to ability to live or work in the area, no tradeoffs required	Minimal ethical disruption to ability to live or work in the area, minor tradeoffs required	✓ Some ethical disruption to ability to live or work in the area, some tradeoffs required	Significant ethical disruption to ability to live or work in the area, substantial tradeoffs required	Major ethical disruption to ability to live or work in the area, major tradeoffs required
Effectiveness: Unusable Days Per Year	Less than 25	25-75 ✓	75-125	125-50	More than 175

Table 4.4: Option 4 - 65% Wind, 35% Solar

Option 5: 50% Solar: 50% Wind

Criteria \ Scoring/System	5	4	3	2	1
Economical (Million $)	Less than 300	325	350 ✓	375	More than 400
	No Major Works Required	Minimal Major Works Required	✓ Some Major Works Required	Significant Major Works Required	Excess Major Works Required
Environmental	No disruption to existing ecosystem	Minimal disruption to existing ecosystem, minor rehabilitation work required	Some disruption to existing ecosystems, some rehabilitation work required ✓	Significant disruption to existing ecosystem, significant rehabilitation and trade off schemes required	Major disruption to existing ecosystem, threats to future sustainability of area require excessive rehabilitation and trade off schemes
Social	No social disruption to surrounding residents, no rehabilitation required ✓	Minor social disruption to surrounding residents, minor rehabilitation required	Some social disruption to surrounding residents, some rehabilitation required	Significant social disruption to surrounding residents, substantial rehabilitation required	Major social disruption to surrounding residents, major rehabilitation required
Ethical (Detrimental Liveability Effect)	No ethical disruption to ability to live or work in the area, no tradeoffs required	Minimal ethical disruption to ability to live or work in the area, minor tradeoffs required ✓	Some ethical disruption to ability to live or work in the area, some tradeoffs required	Significant ethical disruption to ability to live or work in the area, substantial tradeoffs required	Major ethical disruption to ability to live or work in the area, major tradeoffs required
Effectiveness: Unusable Days Per Year	Less than 25	25-75	75-125 ✓ Approximately 80	125-50	More than 175

Table 4.5:Option 5- 50% Solar, 50% Wind

4.2 Justification:

It is clear from the above analysis tables that the best option would be to split the generation capacity into two thirds wind generation and one third solar power. This is because wind power is by far the better option but as a precaution in the case of prolonged periods of still weather as currently seen in South Australia the solar panels could still provide a portion of the required power. In fact according to (Owen, 2016) the wind turbines in South Australia in the recent calm period were actually using more power than they were generating. This therefore justifies the use of a more rounded system with multiple generation techniques implemented. It is acknowledged that it will likely have a larger initial investment cost as the quantity of differing resources and materials is increased; however it should ultimately deliver a more sustainable and reliable system. This type of split would also give the best combination of ethical, social and environmental conditions.

CHAPTER 5 Stage 2: Conceptual Design

5.1 The Existing Infrastructure

In order to produce an effective conceptual design the existing infrastructure within the area must be incorporated as much as possible, therefore it is crucial to identify this infrastructure.

Figure 5.1:Aerial photograph of existing infrastructure

5.2 Proposed Additional Pipeline

A required recommendation if this proposal is going to go ahead is the installation of an additional pumping pipe. This additional pipeline would allow more pumping time for the less intense renewable energy and thus allow an equivalent energy generation potential. This will be focused on later in the dissertation.

Figure 5.2: Proposed additional pipeline (UnknownAuthor, 2010)

5.3 Conceptual Design

Figure 5.3: Conceptual Design

Where  = 10 turbines for a total of 110 turbines satisfying the required 109 turbines.

Required area covered is 577.5 acres for floating solar to supply 35 % of the required 500 MW system. This equates to approximately 245 thousand panels.

The floating solar panels negation of evaporation will be used in a positive manner in the upper reservoir with the majority of the 105 hectares or 260 acres covered with the platforms. This provides almost half of the required solar area with only beneficial aspects felt in the upper reservoir. (Queensland Government, 1984)

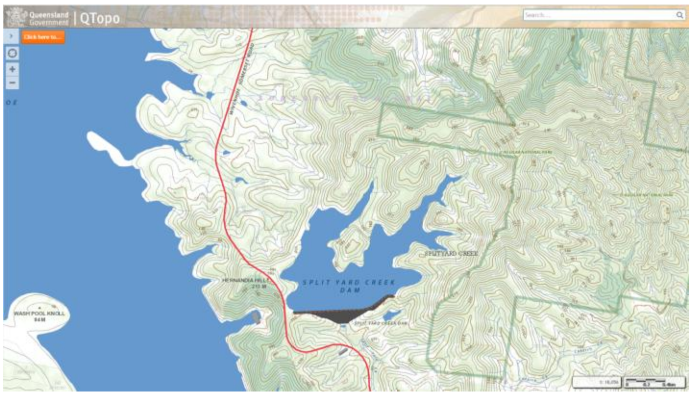


Figure 5.4: Topographic map of the area

5.4 Proposed Road Network:

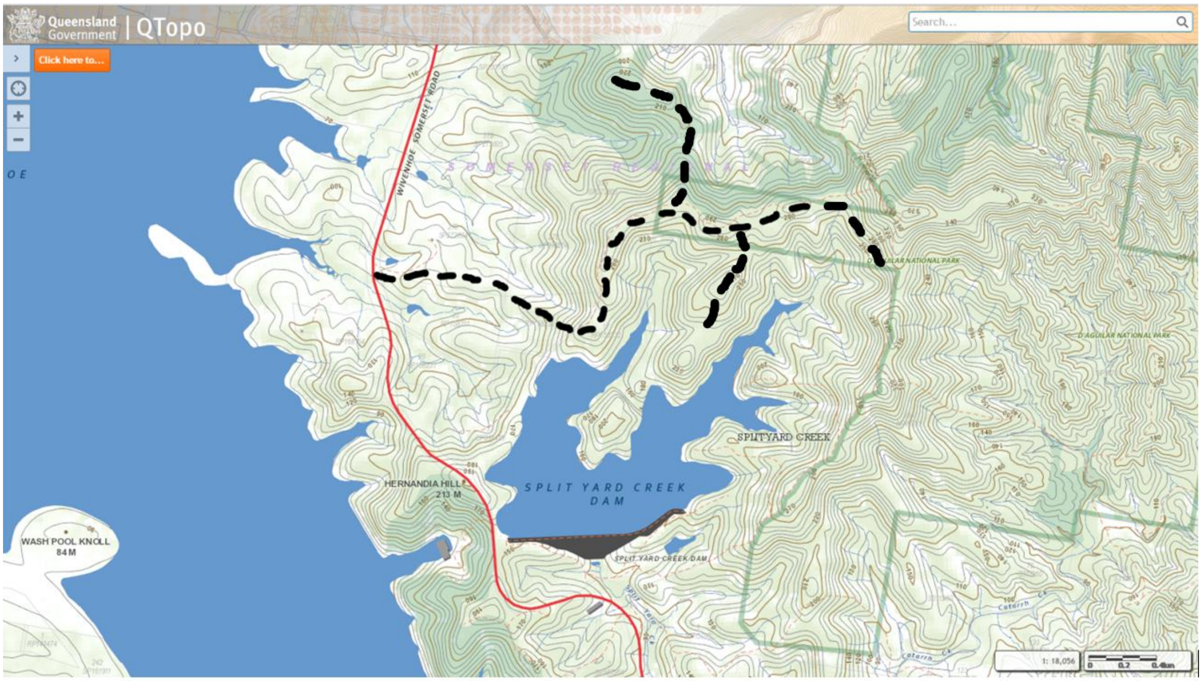


Figure 5.5: Proposed road network

In order to build the proposed wind turbines road access will be required. (Department of Transport and Main Roads, 2016). According to the Road Planning and Design Manual Edition 2 Volume 3 – Austroads Guide to Road Design: 'Very-low Volume Roads – On very low volume rural roads, that is roads with a design traffic volume of less than 250 vpd, the selection of carriageway formation can include:

- Fully unsealed road
- Single lane seal with unsealed shoulders either side to allow for vehicles to pass
- Two-lane seal'

Therefore, it is proposed to provide a single lane seal with unsealed shoulders through the marked path on the topographical map above. It is recommended to not be a concrete based pavement due to the high silica content in the igneous rocks in the area with the potential for chemical weathering of the infrastructure.

In addition, the above path has been planned to avoid creek crossing or potential water courses. This not only minimises the budget with regards to culverts and bridges but also allows more reliable access to the area, which is important especially as high winds associated with storms have the potential to damage infrastructure that will need to be seen to immediately rather than waiting for minor creeks flooding to subside. The planned root also uses the topography to give a more favourable outlook regarding access for heavy vehicles, hill climbs and vertical curve regulations as seen in . (Department of

Transport and Main Roads, 2016). Furthermore by opting to take the route with more accommodating topography the threat of erosion from water running along the road is minimised and a simply crown or superelevation can ensure that adequate drainage is provided and the infrastructure protected. (Austroads, 2012) ; Guide to Pavement Technology (Part 2: Pavement Structural Design)

5.5 Wind Loading - Using AS/NZS 1170.2:2011

Wind Loads Determination

According to figure 3.1 (A) 'Wind Regions' – AS1170.2:2011 the proposed structures are in region B.

See appendix B for annotated wind region map.

- According to Building Code Australia (BCA) table B1.2a, the Importance level has been assumed as 3 'Most public or large buildings'. Therefore based on this for non-cyclonic (and cyclonic) due to the nearby proximity of Region C. the annual probability of annual exceed is 1:1000.
- The annual probability of exceeding the serviceability event can be considered as 1:25 or assuming the turbines act in similar manner to a column height/500. This gives 80:500 – from AS 1170.0 2003 Appendix C

Using table 3.1 from AS 1170.2 2011 – Regional Wind Speeds

Regional Wind Speed (VR)= 60 M/S

The wind direction multiplier (Md) for all directions in Regions B, C and D shall be as follows;'

a) 0.95 For determining the resultant forces and overturning moments on complete buildings and wind actions on major structural elements.

When considering the Terrain category this particular scenario can be categorized by TC1 – 'Very exposed terrain with few or no obstructions'. This is due to the heights of the turbines and the required clearing for construction. In addition, the mountainous terrain would have an impact if the turbines were not already positioned along the top of the ridge.

Using table 4.1- 'Terrain/Height Multipliers for Gust Wind Speeds In Fully Developed Terrains – All Regions' from As1170.2:2011 with the aid of linear interpolation for accuracy of results the Mz,cat value can be taken as 1.272

(Raymond, 2015)

Assuming no shielding Ms (Shielding multiplier) can be taken as 1.0

The topographical multiplier (Mt) can be taken from table 4.4 – Hill Shape Multiplier at Crest (for Gusty Winds Speeds) in an attempt to give an accurate and safe design. This figure can be taken as approximately 1.48 due to the steep terrain in the area.

$$V_{sit,\beta} = V_R M_d (M_{z,cat} M_s M_t)$$

Equation 5-1: Vsit,B

=60*0.95(1.272*1*1.48)

=107.31 m/s as the critical wind speed for the area.

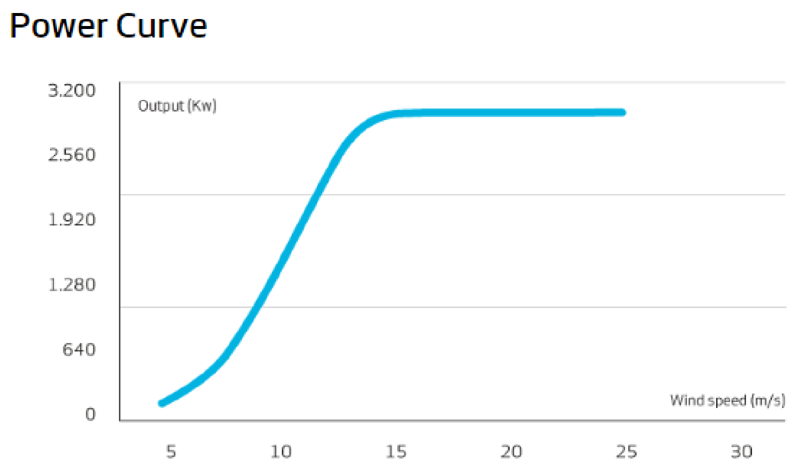


Figure 5.6: Power curve (output vs. wind speed) (Vestas, 2016)

While this may sound like a positive attribute to have for a wind harnessing piece of infrastructure the above figure provided by (Vestas, 2016), illustrates the power curve of a 3MW wind turbine. This type of wind speed basically renders the turbine useless with the cut out speed easily surpassed. This type of wind speed could easily damage the equipment if under operation whilst occurring.

5.5.1 Overturning Moment

The critical wind speed calculated above can be used to find the theoretical critical force applied to each turbine in an attempt to overturn the structure.

With a wind speed of **107.31 m/s**

Pressure = Air Density * 0.5*V^2

Where air density can be taken as 1.2256 kg/m^3 gives;

P= 1.2256 * 0.5 * 107.31^2

P= 7056.7 N/m^2 (Pa)

P=7.0567 kPa

Converting this pressure to a force = 80*9*7056.7

F = 5 080 824 N

This force then applied at the largest lever arm (at the top of the turbine) gives the largest over turning moment:

Over turning moment = 5 080.8 kN * 80

Over turning moment = **406 465 kNm**

With this enormous amount of pressure potential subjected to each turbine it is important that the foundations are properly secured to avoid toppling of the structure.

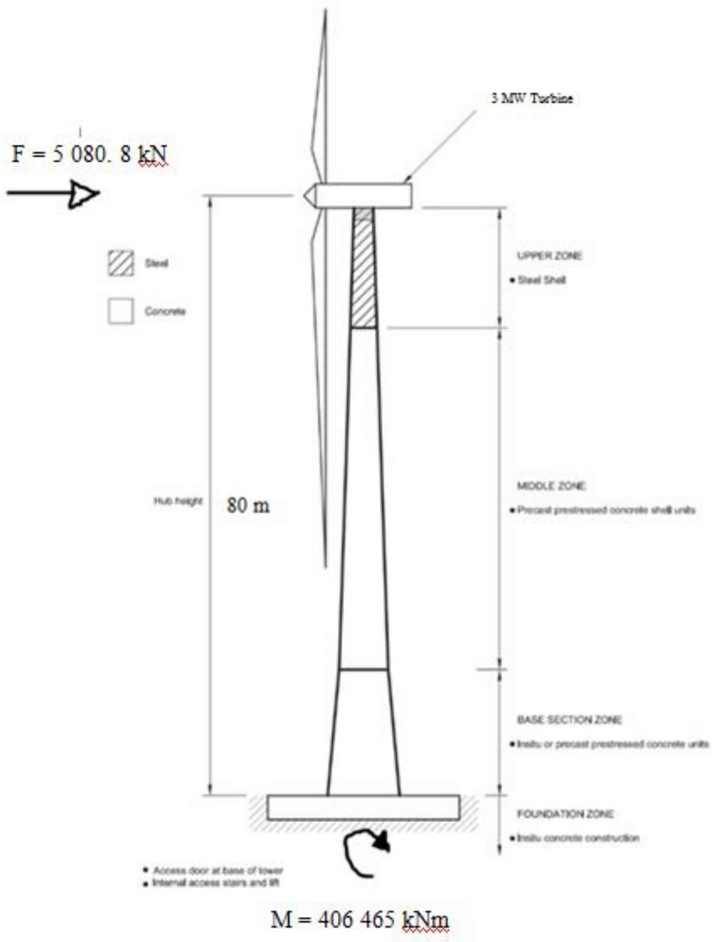


Figure 5.7: Loadings and overturning moment on proposed wind turbine

Height = 80m (Miceli, 2015)

5.6 Foundation Design

Figure 5.8: Foundation options

(Contech Engineered Solutions, 2016)

The above figure illustrates the variety of different foundation types that can be implemented. As it is important to choose the most effective foundation type for the terrain the geological conditions of the area must be considered. It is also recommended that upon further development of the conceptual design a complete geotechnical report is prepared for the area in question.

The three potential solutions are tensionless pier foundations, anchor deep foundations and gravity spread footer, and each of these will be discussed before a final decision is made for the selected foundation in the area under investigation.

5.6.1 'Tensionless Pier Foundation':

The first option is the 'Tensionless Pier Foundation'; this particular type of foundation 'consists of a large diameter cast-in-place annular pier' which is supported with a number of corrugated metal pipes in the form of stays and filled with spoil from the excavation process. This type of footing resists the horizontal loads and overturning moment by horizontal resistance of the soil that surrounds the annular pier but does not rely on the base of the footing.

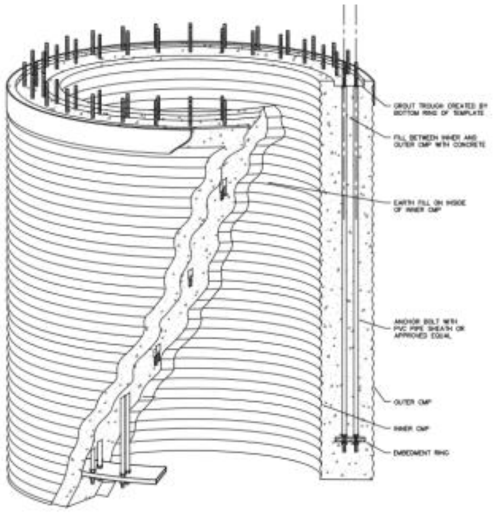


Figure 5.9: Tensionless Pier Foundation

5.6.2 'Anchor Deep Foundation':

The anchor deep foundation is suitable for both soft rock and hard rock conditions and a combination involving the two. The foundation relies on steel piles been driven deep into the rock bedding to anchor the structure and resist any applied forces. This type of foundation is not suitable for soft soil conditions where the piles would simply shear through the material. The 12 to 20 anchors within the foundation, range from approximately 10 to 15 meters in length (depth) are installed by drilling a shaft into the rock before hammering the pile in afterwards to be grouted. The post tensioned anchors resist the imposed forces through friction (bond stress) along the length of the pile. It is important that normal operational loads do not produce stress reversals in the sub grade interface or the soil or rock beneath could potentially be subjected to fatigue or cycle degradation. (Contech Solutions, 2016)

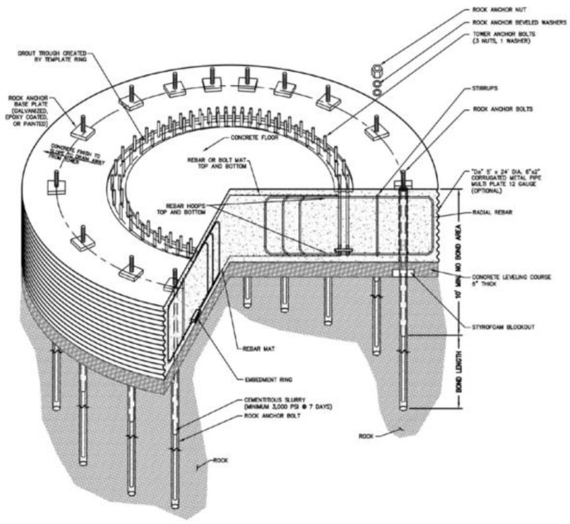


Figure 5.10: Anchor Deep Foundation (Contech Solutions, 2016)

5.6.3 'Gravity Spread Footer':

The gravity spread footer is mainly designed for soft soil type conditions with conditions suiting extensive excavation. This particular foundation design relies on the weight of the spread footing, the weight of the material above and the bearing capacity of the soil surrounding the base of the foundation to resist the horizontal and overturning moments subjected to the wind turbine.

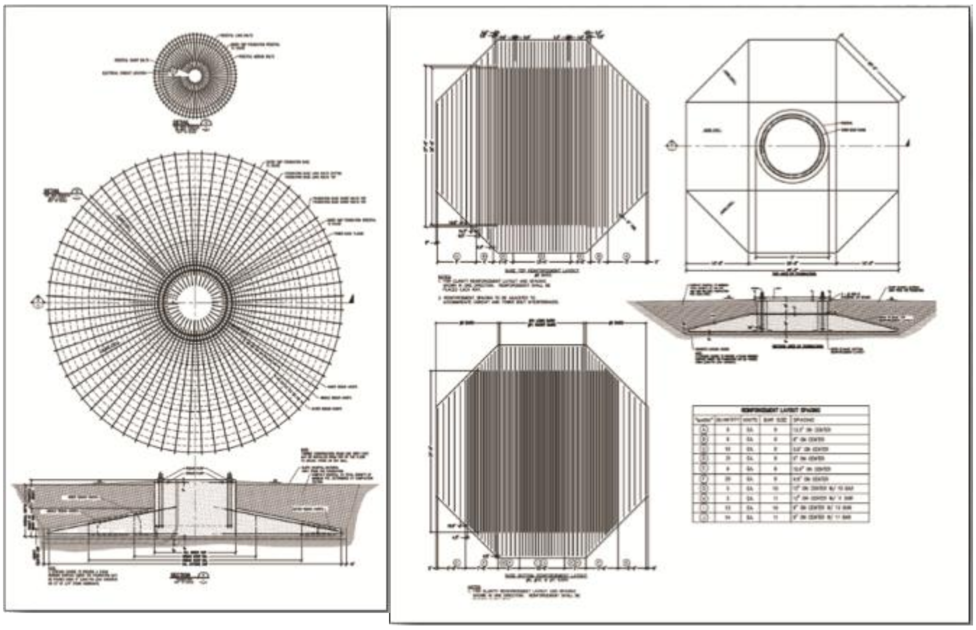


Figure 5.11: Gravity Spread Footing Design (Terracon Consulting Engineers and Scientists, 2013)

Site Conditions						
Site Conditions	**Tensionless Pier Foundation (Deep)**	**Rock Anchor Foundation (Deep)**	**Soil Anchor Flight Auger (Deep)**	**Soil Anchor Auger Cast Pile (Deep)**	**Soil Anchor Helical (Deep)**	**Gravity Spread Foundation (Shallow)**
Valley/Plains	B	Not Recommended	B	A	A	B
Hills	A	C	A	B	B	B
Mesa	A	A	D	Not Recommended	Not Recommended	B
Mountain	A	A	Not Recommended	Not Recommended	Not Recommended	C
Ground Conditions						
Hard Rock	A	A	Not Recommended	Not Recommended	Not Recommended	C
Soft Rock	A	A-	C	Not Recommended	D	B
Very Dense/Hard Soil	A	Not Recommended	A	D	C	B+
Soil with Boulders and Cobbles	A-	Not Recommended	Not Recommended	Not Recommended	Not Recommended	B
Soil Dry to Moist	A-	Not Recommended	A-	D	A	B
Silty Soil Dry to Moist	B+	Not Recommended	B+	B	A-	B-
Clay Soil Day to Moist	A-	Not Recommended	C	D-	C	B
Granular Soil Shallow Ground Water	D	Not Recommended	Not Recommended	A	A	C+
Silty Soil Wet	D	Not Recommended	D	B	B+	C+
Clay Soil Wet	C+	Not Recommended	D	D	B	B
Organic Soil	D	Not Recommended	C	B	B	C+

Table 5.1: Foundation attributes

(Terracon Consulting Engineers and Scientists, 2013)

The above table was used to help select the most appropriate foundation for the area.

5.6.4 Selected Foundation:

The final decision is to select an anchor deep foundation approach. There are several reasons for this but a major contributing factor is the geological conditions of the area. The anchor deep foundation utilises piles and does not require extensive excavation as the other designs; this is particular cost effective when considering the rocky igneous materials (Andesite) of the area. This type of footing will harness the strength of the surrounding rock to achieve a stable foundation that will overcome the horizontal and overturning moments applied by the wind forces in the most effective and efficient manner for the area. Note the tensionless pier foundation could have been implemented to form a successful foundation but it is not economically comparable to the selected design and was thus not selected. It is ultimately the reduction or elimination of blasting requirements, the maximization of material and resource efficiencies and the superiority in mountain and remote access sites that lead to the selection of this particular foundation type and thus a conceptual design has been created below using AutoCAD. (San-Shyan Lin, 2010)

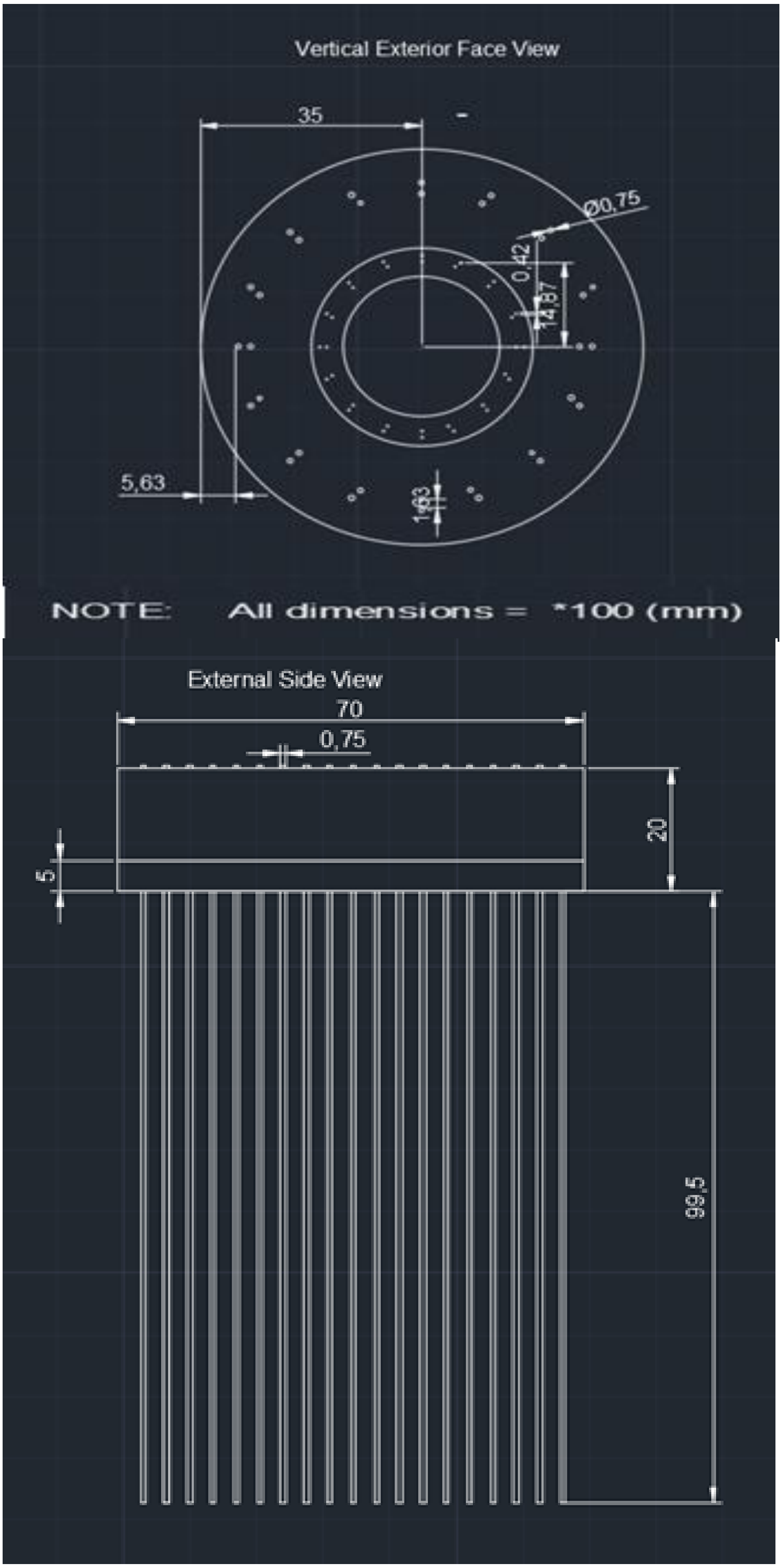


Figure 5.12: Own Foundation Design (Deep Anchor Style)

5.7 Geological Formation of the Area:

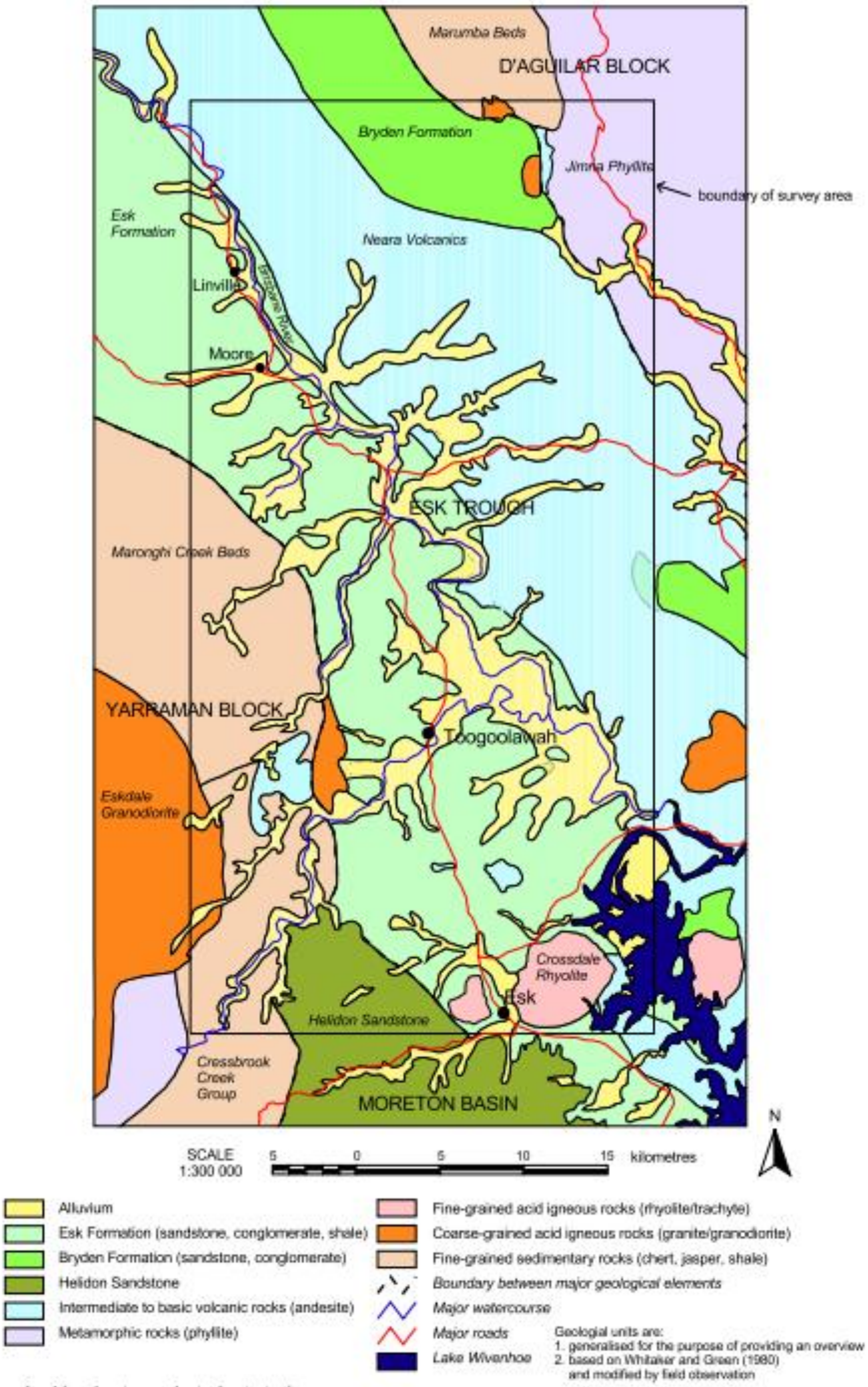


Figure 6 Map showing geological units in the survey area

Neara Volcanics Rtn	Intermediate to basic volcanic rocks	40 977	rolling rises to steep hills	volcanic conglomerate, andesite, agglomerate, minor mudstones	MESOZOIC Middle Triassic

Figure 5.13: Geological conditions of the area (Pointon, 1999)

5.7.1 Neara Volcanic Outcrop

As seen in the above illustration the area in question is located within the Esk trough. This is a part of a distinct geological formation or trough known as the Neara Volcanic Outcrop. With the majority of the material in the outcrop of andesitic nature it is no surprise the andesitic flows, boulders beds and minor tuffs in combination with volcanic conglomerates from large magma flow poses a number of issues when considering major excavation. (Pointon, 1999)

5.7.2 Associated Implications and Recommendations

This will have a number of impacts on the site and the potential for development in the area. To start with due to the degree of difficulty associated with excavation in geological conditions of the area any footing design which incorporates a large amount of excavation such as the gravity spread footing should be avoided. This is because the extensive excavation would make the overall footing extremely expensive. Therefore footing design has been influenced. It is recommended that anchor deep footings incorporating driven or bored and grouted piles are implemented and thus have been designed. The geological conditions of the area have also impacted on the potential for road development. Some concrete pavements have the potential to react poorly to the aforementioned igneous or andesitic materials and thus to avoid chemical weathering concrete pavements should be avoided. These are the major implications associated with the proposed design; however it is important to ensure that extensive geotechnical testing is conducted before any major construction takes place as there could be exceptions throughout the large band of geological formations. Finally all drainage should be considered with as little erosive potential as possible.

5.8 Solar Design:

There are a number of benefits associated with floating solar panels including the saving of space. This can be a substantial economic saving in some cases where land prices are high. Additionally, the addition of floating solar modules to reservoirs can decrease the evaporation rate by up to 70% according to, (Paritosh Sharma, 2015). This is compounded by an increased efficiency witnessed in the operation of the solar cells through natural cooling from the water beneath. With the main positive aspects acknowledged the major issue associated with the concept is the buoyancy, and overcoming wind forces.

5.9 Buoyancy:

It is important to understand how the energy harnessed from the solar panels will be collated. As this is not an electrical project details will not be provided however a conceptual diagram has been provided below to give the reader a general understanding of the system. (Ciel Terre, 2016)

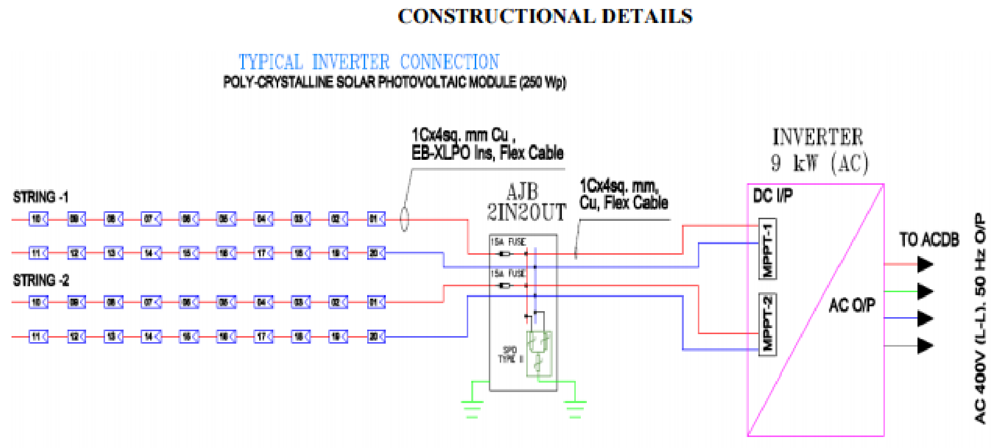


Figure 5.14: Typical Inverter Connection

(Paritosh Sharma, 2015)

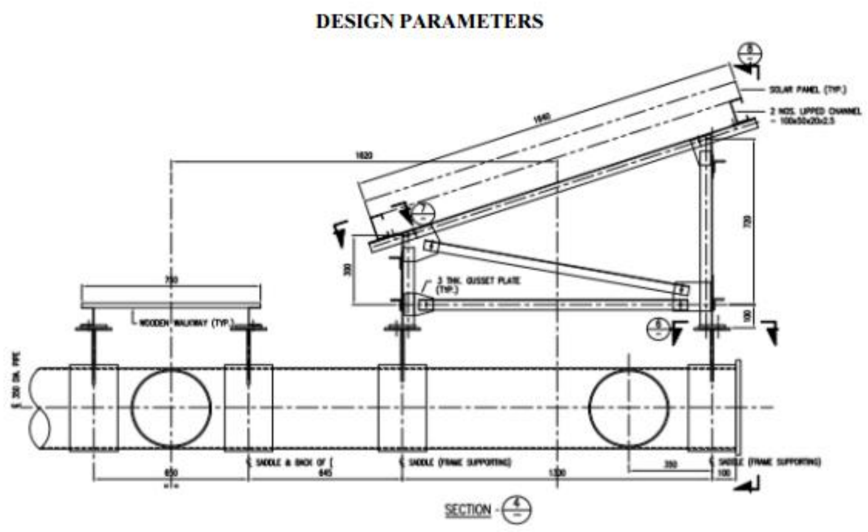


Figure 5.15: Basic floating platform design (Paritosh Sharma, 2015)

Based on the design seen above the conceptual drawings will allow the panels to not only be strung together but also function as a stand-alone module. These panels have an additional feature to negotiate minor winds. The fin shall be applied especially to those in the upper reservoir where there is no risk of flooding. In the lower reservoir a number of restraints shall be used to ensure that the modules do not drift from the selected area.

5.9.1 Wind Effect – Fin

In order to negate the wind effect originally it was proposed to develop a fin on the bottom of the structure. This would have provided enough drag to mitigate any wind effect and avoid any movement of the modules (i.e. floating away). However this would have been quite difficult to incorporate with my design of the three cylinders underneath the module for buoyancy but the major flaw in this design was actually due to the dam's purpose. Wivenhoe is not only used as water storage for South East Queensland it is also part of a major flood mitigation system for the Brisbane and Stanley River systems. This could prove to be a huge problem during times of flood with large velocities entering the dam and large amounts of water being released. Ultimately there would be a chance of so much drag being created by the fin and the fast moving water that it would take the modules through the open flood gates and out to sea. Therefore it is proposed that instead of water drag the modules should instead be fixed deep into the banks using a similar pile foundation to that seen in the wind turbine foundation section and fixed to the modules with heavy duty wire rope. (Roznitsky, 2014)

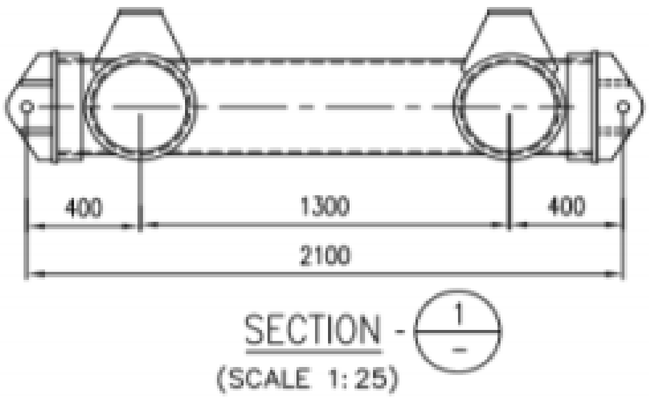


Figure 5.16: Side view and floatation tubing *(Paritosh Sharma, 2015)*

With each module carrying four PV panels and as seen in the above conceptual design a total of approximate 245 000 panels are required this gives a total number of modules required as 61 250 to produce 35% of each system. The modular platform panels are approximately 5.6m by 2.1m in size and weigh roughly 140 kg each.

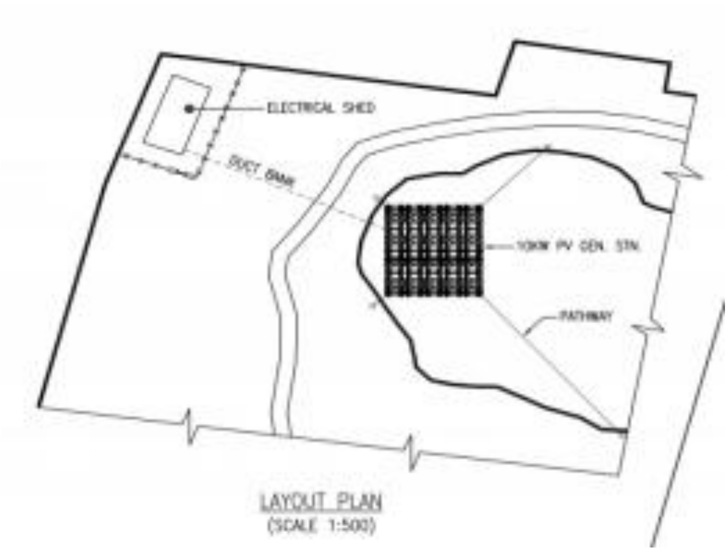


Figure 5.17: Intergrid connection (Paritosh Sharma, 2015)

According to (Brightstar Solar, 2014) each panel (1.92m x 0.925m) is approximately 25 kg's, then each module containing four panels will be the weight of the panels (100kg) plus the weight of the frame itself approximately 140kgs can be dispersed over the 5.6 x 2.1 m frame. (Paritosh Sharma, 2015)

Converting the weight to a force= (100 + 140) x 9.81

= 2 354.4 N

Which is 2.3544 kN

So buoyant force must be greater than the downward force.

Area = (pi*D^2)/4

= (pi*0.3^2)/4

=0.071 m^2

Volume =2.1 * Area

=0.1491 m^3

Total Volume of four sections = 4 * 0.1491

= 0.5964 m^3

Fb= p g V

= 1000 * 9.81 * 0.5964

= 5 850.7 N

Which is equal to a buoyant force of 5.8507 kN which is greater than 2.3544 kN of the standard weight.

This raises the question as to why not use half of the buoyancy to support the panels? While this would provide enough buoyancy to support the frame and the panels the panels require cleaning and thus are designed with a walkway suitable to be stood on for ease of access. This walkway would however be useless if when stood on the entire frame sunk. Additionally, in order to keep the design well balanced a total of four chambers were selected.

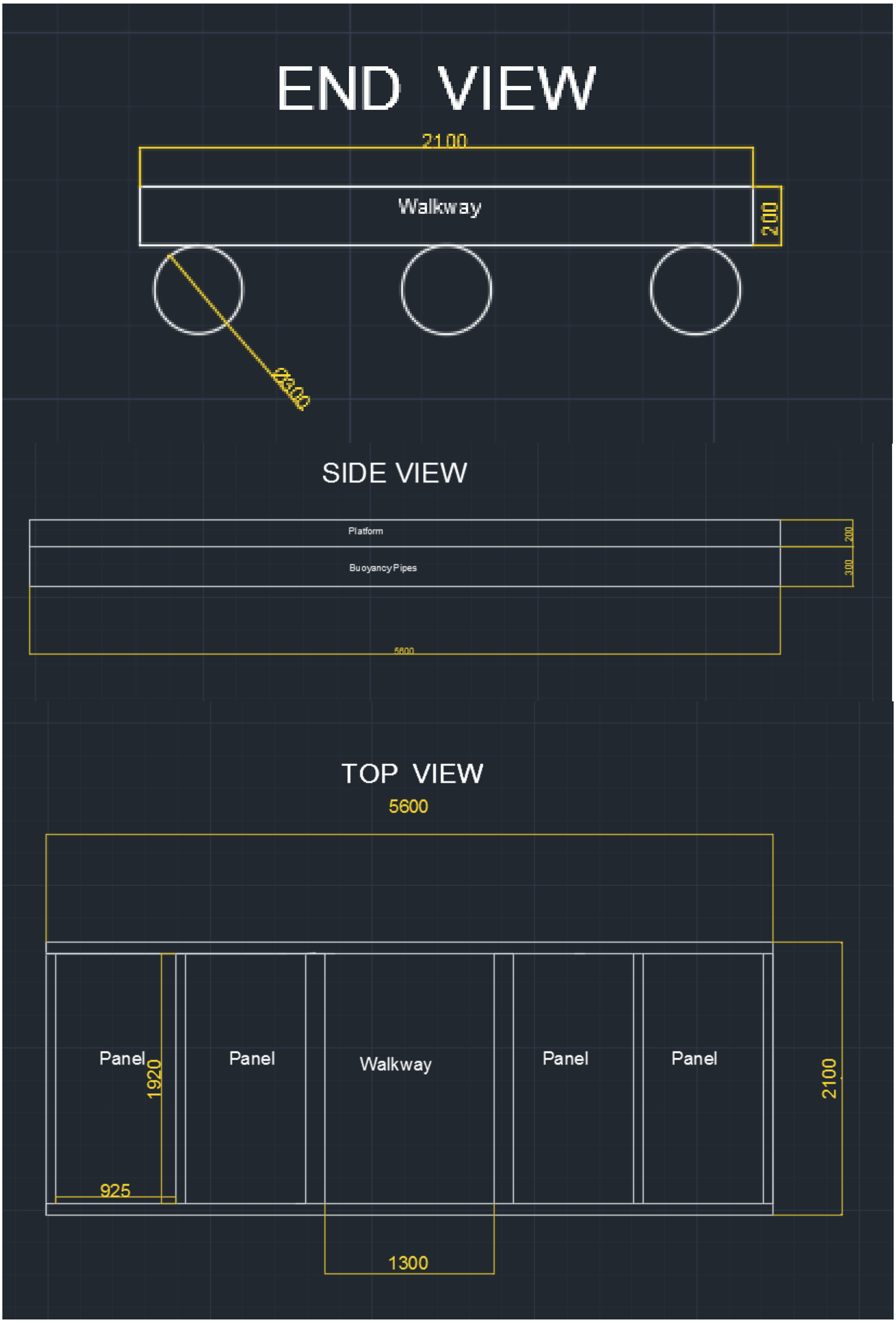


Figure 5.18: Floating solar platform design (Own Design)

CHAPTER 6 Stage 3: Validation Breakdown

Proposal Comparison	Proposed Solution	Current Solution
Economical	- Extensive economical investment required which will take a significant period of time before any economic return is encountered – potentially never - Possibly cheaper to operate when neglecting energy losses in pumping. - Difficult to harness the wildly erratic renewable energy sources and incorporate this energy into the grid without overloading or under loading the system. - - 'As a civil project this particular aspect was not covered'	- Already in place – no additional infrastructure required - 15% more expensive to operate in comparison to wind energy - Shortage of natural resources will lead to ever increasing energy prices - No additional power is generated instead the system existing system is just used as a battery; storing fossil fuel generated power until it is required within the grid.
Environmental	- A cleaner greener alternative that could be on the forefront of a major swing towards a sustainable energy sector for the future.	- Does not encourage a major swing to a cleaner greener alternative - Utilises fossil fuel generated energy: - Large volumes of water released back into the ecosystem
Social / Ethical (Detrimental Liveability Effect)	- Some social implications in regards to the use of some recreational area for energy generation (floating solar panels), and through potential noise pollution from installed wind turbines: minimal effect - On a positive note: provides a large number of jobs both through construction and maintaining the proposed system.	- No additional social implications for the area. - Still effected by the effects of coal powered energy generation at the Tarong Power Station. - Increased heavy vehicle traffic from the Tarong power station carting fly ash. - Potential cause of global warming effecting the liveability of the planet.
Pumping Capacity (Effectiveness)	- Additional pipe is required to allow sustainable methods to pump 100% of the possible time. - Cannot pump at the same efficiency as fossil fuelled power due to the inconsistent nature of the renewable energy	- 50 / 50 pumping to generation ratio can be sustained with one pipe. - Generation capacity constantly met.

Table 6.1: Stage 3- Validation table

6.1 Idealistic Project Costing Justification:

If the project can pump at full capacity 50% of the time to allow for 50% generation (this means the infrastructure is being fully utilised) then the system has the potential to pump approximately 8942.4 ML/day. This is enough water to produce around 1700 Megawatt hours per day. Therefore in order to take an idealistic approach using the peak prices as pumped hydroelectricity is design for using the current peak electricity prices of 49.2855 per kwh the total income can be expected to $837 850. (Synergy, 2016) However this is far too idealistic and can only be achieved with fossil fuelled assistance, and it is important to incorporate the other associated costs and understand that the peak price will not always be realised and thus a compromise between the 49 c at peak and the 13c of peak must be achieved. Therefore a scaling factor of inefficiency of 0.35 will be applied to give a total income of $293 250 per day. Using this figure a year's income could be approximated at 107 million dollars.

To understand the feasibility the existing interest rates of 5.26% will be applied for a loan of $1.25 billion dollars to purchase the required infrastructure and install it. Note this is more than the previous figure as it accounts for the floating platforms and a rough estimate for the road development, foundations installation and additional pipeline with associated pumping capacity. Using a calculator and a 25 year design life, monthly repayments of $7.498 would be required to be made. This is possible with expected income of 8.9 million dollars per month. However this figure does not take into account any loss of income in the multiple years taken to construct the project and it also does not have any security in the fact it relies on peak pricing 100% pumping capacity. This figure also fails to take into account the wages required to maintain and operate the facility while also not incorporating the costs of any unforeseen maintenance or repairs within the 25 year design life. This could potentially increase the economic stress significantly. While theoretical economics govern that this project could be successful (NPV calculations were also carried out) it is highly likely that any investor undertaking this investment would go bankrupt before the completion of the project. Ultimately the project has potential in an idealistic scenario; however the erratic and unpredictable nature of renewable energies restricts the reliability and ability to invest in the area.

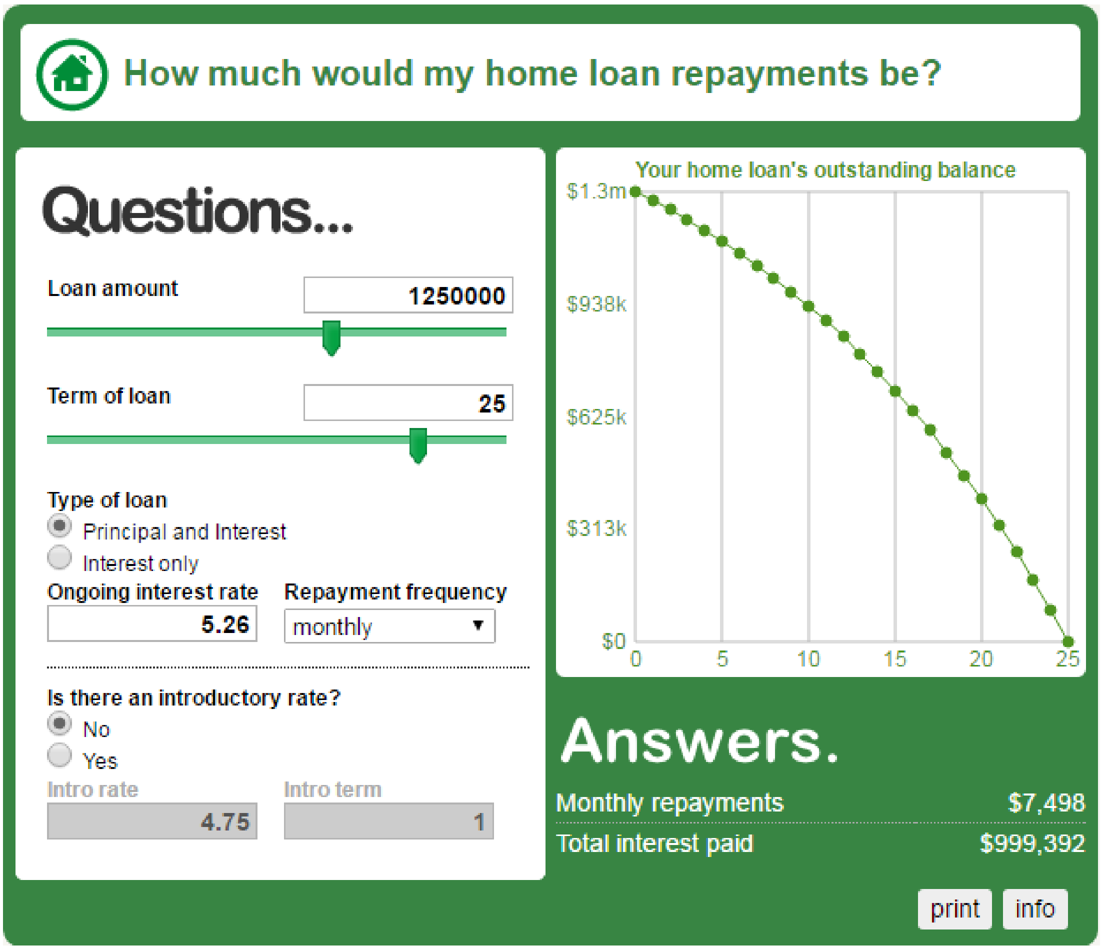


Table 6.2: Economic Analysis Payoff time (mozo, 2016)

In order to take a conservative approach it was assumed that the project would be funded on loaned funding. When considering NPV the economic theoretics supported the feasibility but the shear inconsistency and unpredictable nature of renewable energies limits investment.

CHAPTER 7 Discussion and Conclusion

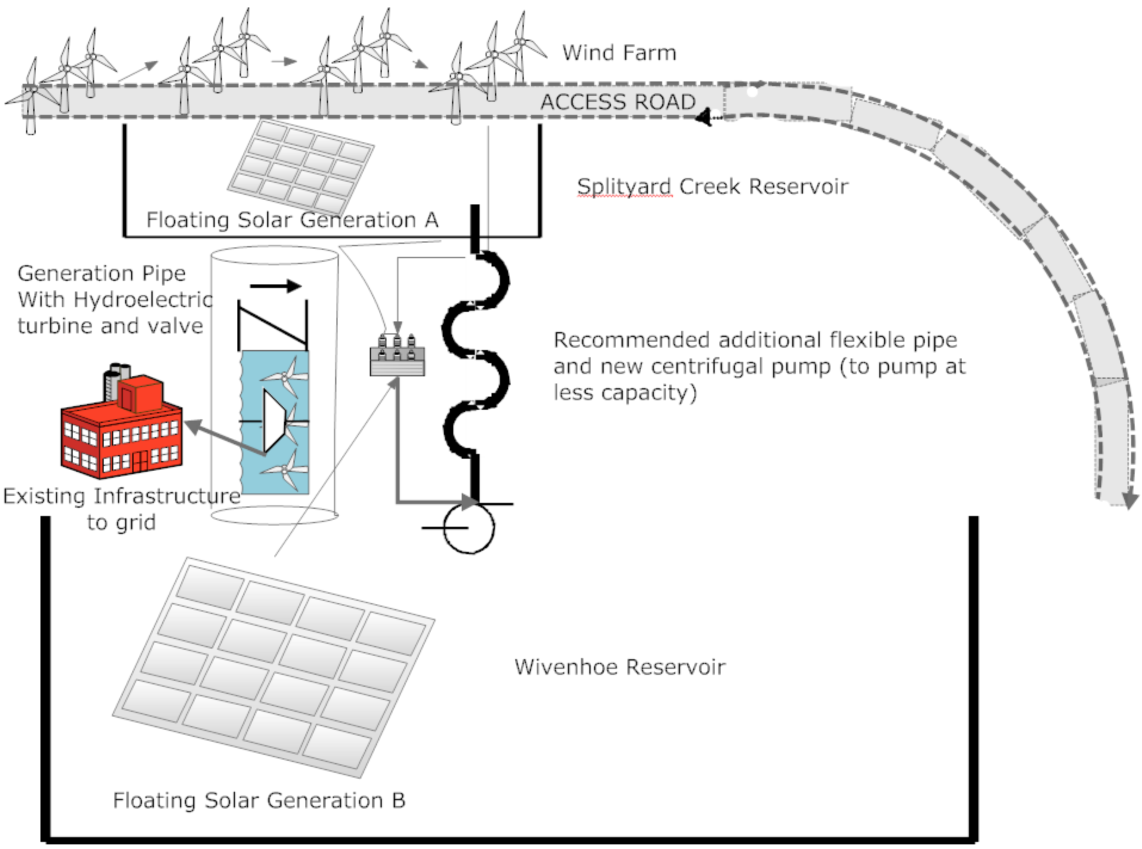


Table 7.1: Schematic design of the final proposal

The above schematic design of the final proposal provides a simple illustration of the workings behind the proposal.

7.1 Schematic Discussion

The above schematic illustrates a basic configuration of the proposed project. Unfortunately topography could not be incorporated without negatively influencing the clarity of the system. There will be a wind farm on the ridge line above split yard creek made up of 109 three megawatt wind turbines. This will supply 65 % of the required energy and will be supplemented by two solar banks one in the upper reservoir of Split yard Creek with almost 100% coverage gives a total of approximately 250 acres of coverage. This constitutes approximately 43% of the required 577.5 areas of solar coverage and therefore represents about 106 thousand solar panels. The rest of the solar power will come from the second solar bank fixed in the lower reservoir of Wivenhoe dam. The schematic illustrates the energy generated by the renewable means cabled to substation styled facility to be utilised in pumping at the centrifugal pump. Note the proposed centrifugal pump and additional flexible pipeline are a requirement due to the erratic and less intense pumping capacity of renewable energies. It is simply not possible to generate energy and pump the required water to the upper reservoir using the one 8.5 m diameter pipe. Therefore with the addition of the flexible pipeline and centrifugal pump water can be pumped 100% of the potential time i.e. when the sun is generating solar and the wind generating wind energy. This will help to keep the upper reservoir full enough to continue generating energy in twin hydro generation chambers. This project has been developed as two individual systems run in parallel. The energy generated through the turning of the turbine in the 8.5m diameter pipe will be transported using the existing infrastructure (the twin 275KV transmission lines connect the power station to the states grid system.

7.2 Achieving the Objectives 'Research Questions'

After completing the three stage summary it is important to reflect on the final product and establish whether the initial objectives or research questions set out earlier in the report were achieved. The first research question; ***'What criteria should be used as a basis to evaluate or develop this type of project'*** was answered in stage one of the method of the project when implemented in the form of the criteria sheet. With this in mind it is important to acknowledge that this question was actually answered while undertaking chapter two of this report the literature review. While documentation of all of the research undertaken in previous feasibility analysis is not largely included in the report extensive research was undertaken to ensure the results would be accurate in an industry styled environment. (US Army Corps of Engineers, 1989) Was particular useful when deciding on appropriate criteria to base the decision on feasibility and was kept in high esteem throughout the duration of the project. The final criteria sheet used involved economic, environmental, efficiency, social and ethical implications to make justifiable decisions.

The second research was question ***'what technical analysis is required for the chosen proposal?'*** This question was answered in the chapter two of the literature review where the civil aspects were clearly explained from other existing both failed and ideal systems. From this point the appropriate civil factors were considered for the proposed project. I.e. coastal conditions would not need to be considered for a development at Wivenhoe. In addition as the research question states for the chosen proposal it is for the proposal with the most potential in this case a 65:35 % generation ratio of wind to solar was selected and thus both types of energy generation methods need to be considered. The technical analysis required includes road development, geological consideration, topographical consideration, foundation design, wind loading, buoyancy force calculation and solar flotation. This will incorporate a number of technical standards and codes as well as involves a host of engineering practices and methodologies learnt over the past four years.

The third research question was; ***'what are the relevant conceptual design solutions for the selected proposal?'*** Stage two of the three stage plan focuses on this research question and it forms the bulk of all technical work within this project. The question was answered by taking the relevant civil scope from the second research question and generating a conceptual design for each of these aspects. Based on other feasibility studies the level of depth could be estimated and then matched for example when considering the foundation requirements. First a historical study of known wind patterns was undertaken to position the turbines before using technical standards to calculate critical loads and convert them to overturning moments. At this point using the known topographical and geological conditions (steep terrain with andesitic conditions) to take an informed view of the developmental requirements a foundation design could be developed as seen in stage 2 – anchor deep foundations with piles was used. Again this is proposal specific to that with the most potential i.e. 65:35 ratio of wind to solar and all results illustrated that while due to some complications the civil scope would be overall economically demanding it was possible.

'How is the proposed solution validated?' This is the fourth research question or objective and was answered by comparing the conceptual design developed in stage two to the existing system currently used between Split yard creek and Wivenhoe dam. This basically showed that while environmentally and ethically far superior the proposed solution was let down severely in the economical sector. It will always be difficult to justify the commitment of substantial funding to an energy generation system that while environmentally dirty is not broken so to speak. In addition stage 3 highlighted the major and key flaw in the whole design which is due to the sporadic nature of renewable energy it is extremely difficult to incorporate existing infrastructure designed for fossil fuel powered energy in a renewable system. For example the existing pipe network would not allow enough pumping time and thus an additional pipe and pump would be required. This section was very useful and allowed an understanding of the project beyond simple criteria analysis.

The fifth and final research question requires the incorporation of all of the above answers. ***'How feasible is the conversion of the existing fossil fuel powered system at Wivenhoe to a sustainable hydroelectric plant?'*** This must be answered clearly and concisely and therefore to ensure the final message is not lost the conversion of the existing system to a sustainable system is not feasible. This can be justified by looking at the significant economic commitment which requires millions of dollars in repayment every month just to reach the 25 year design life and relies on a list of favourable assumptions to meet these targets.

7.3 Findings

With the conceptual design seen above it is important to discuss the major findings. The proposed infrastructure is structurally sound; but **the proposed project it is not feasible.**

First and foremost, the most detrimental factor for the overall proposal is the extensive expense associated. In addition this expense would actually be far greater as currently only the associated infrastructure has been considered. There would be a number of additional costs in regards to the purchase of any required land, the installation of some of the equipment (connecting the power infrastructure to the grid) and with all of the civil aspects which would require large amounts of labour and plant i.e. the foundations, road development etc. Finally a major cost that was not considered for the solar system was the fabrication of the floating module to support and keep the solar panels afloat this would likely be of similar cost to the actual panels. The economic cost plays a defining role in the overall statement of the feasibility of the project and thus it will be revisited later in this section.

In addition to the economic cost there are a number of additional issues for the area. The area itself is simply not the best place for wind energy as the wind in the area is gusty and erratic which makes it difficult to produce energy consistently. With this acknowledged as seen in the South Australian case study during times of calm periods wind turbines can actually use more energy than they produce. This is because to avoid equipment degradation through large periods of still weather the turbines are actually spun mechanically with energy generated externally. For this reason it is recommended that a site closer to the cost with more steady consistent coastal air currents is harnessed.

On a solar note while generation capacity could be enhanced through more intense solar radiation exposure i.e. in central Australia the site itself is actually quite a positive attribution to the chosen area. The benefits of this type of system include a significant reduction in evaporation. This in itself is noteworthy as the lit review shows considerable investments have been made elsewhere to reduce evaporation by incorporating floating black inflatable balls and is definitely appropriate for a major water supply source such as Wivenhoe dam that has historically sunk to very low levels notable in late 2000's to under 10%. This proposal is much more beneficial in comparison to that type of investment as not only is evaporation reduced in the same manner but energy is also produced. Furthermore by incorporating the floating solar design the effectiveness of solar generation is increased by up to 56% due to the cool body underneath the solar panels and the associated decrease in solar radiation overload (when solar panels overheat they actually lose their efficiency and thus when placed on a hot roof top they are not effective). With all of these positive aspects surfacing around solar panels it illustrates while theoretics show that wind energy is more effective in some cases solar is better suited. The proposed solar system was not without a major flaw which came through the flood mitigation capacity of Wivenhoe Dam. The floating solar modules would require a large amount of fitment strength to ensure the modules were not washed away in times of flood. This ultimately ruled out a shear key styled wind mitigation strategy which was considered in the original design but was decided against after the consideration of the increased drag and associated loading in times of flooding. Instead the string of modules would need to be fixed deeply into the bank with a pile styled foundation and then attached with equally appropriate fitments such as wire rope. It is recommended that if any further work is conducted into this feasibility study a stronger emphasis on a solar based system is taken even if not at full capacity i.e. covering the upper reservoir at Split Yard Creek with floating panels.

In order to gain a more accurate understanding of the potential for further development it is first and foremost important to continue this conceptual design in regards to the electrical and mechanical implications of connecting to the grid and pumping water to the upper reservoir. If this was to go ahead it is recommended to install an additional pipe to accommodate the inconsistent nature of renewable energy. Currently the existing system uses the one pipe to pump water to the upper reservoir utilising a pump and then release water through spinning a turbine to generate power. And while this is possible when using energy from fossil fuels burnt in a different location and loaded onto the grid to provide instant power at full capacity renewable energies do not have this capacity. Therefore with a limited potential for major and consistent energy generation it is critical that all low levels of energy are harnessed for pumping. However this is a practice that is simply not possible if pumping cannot occur while power generation is happening (utilising the one pipe for both activities). In order to be effective the renewable systems will need to be pumping as close to 100% of the time as possible and therefore an additional pumping pipe should be installed. This pipe could utilise the existing pumping infrastructure and would mean that the existing pipe is solely used for the generation of electricity. Finally this conceptual design relied on the incorporation of the existing infrastructure into the proposed system but after more careful consideration it is likely that the existing pump would not be able to operate effectively under reduced power load, and thus not only is an additional pipeline required a more appropriate pump is necessary. A potential system has been illustrated above in stage two of the feasibility analysis.

There are a number of beneficial aspects associated with this proposal which include the participation in groundbreaking movement towards a more sustainable future incorporating a practice that can be used for generations to come without destroying the natural environment. In addition the proposed solution has a number of beneficial social and ethical implications which even though have their own minimal downfalls are nothing in comparison to the existing fossil fuelled system.

In order to maintain a sense of equality it is important to acknowledge the shortfalls of this project. It was originally planned to make an additional site visit to CS Energies Split yard creek operation. However due to confidentiality requirements and the nature of the company after much consultation the soonest available site visit was in December 2016. Therefore the findings from this site visit could not be included in this dissertation. This was the major downfall in the project and leads on to the further work section.

After considering all of the important aspects such as the improved environment benefits of converting the system to a more sustainable pumped hydro system it is unfortunate that the detrimental aspects simply outnumber the positive characteristics. While the civil scope is achievable the challenging topography, geological conditions, inconsistent supply of renewable energy resources and extensive economical costs associated with the development ultimately govern that the project is not feasible at the current time. Any private company undertaking this type of project would probably suffer financial distress before any major economic returns were seen from this substantial investment.

7.4 Further Work

As this project comes to an end the potential for future work should be acknowledge. Some further work that would be beneficial to this project would be the additional site visit to CS Energies operation at Split yard creek. In addition some mechanical and electrical engineering investigation would make a more rounded feasibility study. This could solve the issues associated with incorporating the solar and wind power into the system and investigate pump efficiencies etc.

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CHAPTER 9 Appendix A

Project Specification

For: Aaron Davis

Title: A Civil Engineering Feasibility Study on a Sustainable Pumped Hydroelectricity Plant at Wivenhoe.

Major: Civil engineering

Supervisors: Dr Steven Goh

Enrolment: ENG4111-ONC S1,2016
ENG4112-ONC S2,2016

Project Aim: To gain an understanding of the feasibility for development in the Wivenhoe area in the search of a better more sustainable energy alternative.

Programme: Issue B, 5th September 2016

1. Complete some background research regarding use of floating solar panels and wind turbines used for water pumping.
2. Complete research into successful and failed sustainable pumped hydro electric systems around the world.
3. Complete research on the area including geological and topographical conditions.

Stage 1

4. Create a number of possible proposals regarding generation methods and methods of implementation i.e. site selection.
5. Generate a number of different proposals
6. Using a systematic approach grade each proposal using 5 main criterion i.e. cost, ease of build, environmental, efficiency and ethical / social implications.
7. Explain each grading detailing the strengths and limitations of each proposal.

Stage 2

8. Conceptually design the project; (what will be built? Where will it be built? Etc).
9. Include a number of civil aspects such as foundation design, wind loading and road mapping while keeping in mind the topographical and geological conditions of the area. In addition the buoyancy requirements for floating solar panels should be calculated and some understanding of the pumping and storage capacity of the system should be achieved.

Stage 3

10. Validation of proposal using the same criteria as stage 1 to create a comparison with the existing system and the proposed design. As the civil components have been covered in stage 2 this should focus on the strengths and weaknesses of both the existing and proposed energy generation systems.

If time and resources permit:

11. Visit the current Wivenhoe operation in a formal site visit to gain a better understanding how it could be improved.
12. Create a detailed project costing allowing a final price to be illustrated.
13. On the basis of multiple proposals estimated analysis can take place with relationships and conclusions explained.

9.1 Appendix B : Wind Regions