University of Southern Queensland
Faculty of Engineering and Surveying

Development of a Portable High-Wall Lighting System

A dissertation submitted by

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Abstract:

Within coal mine operations, both day and night time production and use of heavy equipment is required. The current lighting systems used for operation at night are not as efficient as what they should be due to high-wall set-backs. High-wall set backs were implemented to prevent high-wall slippages in which sections of the high-wall fall into the mining pit and cause undesirable effects. As high-wall setbacks have altered the geometry of the high-walls the older models of lighting plant now provide less efficient lighting into the coal mining pit.

Currently there are few if any designs for lighting plants that can be used effectively on the high-wall in the mining pit area. This is a problem because there are major disadvantages such as obstructions in the pit, glare and reflection issues with using lighting plants inside the mining pit. Before high-wall setbacks became a significant attribute of the coal mining pits the best position for lighting of the coal mining pit was above the high-wall but now this method is no longer suitable for most conventional designs of lighting plant

The following research and design project elaborates on the key aspects that have caused the problems to do with lighting in the coal mining pit including high walls, high-wall slippages and high-wall setbacks, an overview of open cut coal mining, and a conceptual design process to develop a new design for a portable high-wall lighting plant. Hopefully by the design of the new lighting plant system it will help to overcome the issues of ineffective lighting in the pit.

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ENG4111 Research Project Part 1 &
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Chapter 1

Introduction

1.1 Project Objectives

The aim of this research and design project is to investigate problems with lighting within coal mines and hence develop a conceptual design for a new lighting plant to improve the current lighting situations for open cut coal mining operations. During night time coal production of an open cut coal mine, heavy vehicles will be operating within large mining pit areas and it can be particularly difficult to provide effective lighting within these areas. It is difficult to provide efficient lighting into the mining pit especially from above the high-wall due to high-wall set backs. High-wall set backs have changed the formations of high-walls and sloped them back at approximately forty-five degrees. The action of high-wall set backs are to prevent high-wall slippages from occurring. It is proposed to perform additional research to discover the current lighting situations and problems in open cut coal mines and to also advance the specific lighting conditions within the mining pit areas by the development of a new design for a portable high wall lighting system. This project is to discover where the current lighting methods are failing and to complete a new design for a portable high-wall lighting plant to hopefully eliminate the problems with the current lighting systems not being able to illuminate the pit in an effective manner.

1.2 Research and Design Project Outline

In order to successfully complete the aim of this research project a number of specific objectives were needed to be established and completed. Therefore to develop a new lighting system that will be able to meet all of the requirements needed for an improved lighting situation in mining pits, research into many areas was required. With the combined research into these different areas many design constraints can be applied and this will significantly enhance the outcome of the final design.

1.2.1 Coal Mining Operations

Background research into coal and coal mining operations was considered necessary, in particular, open-cut coal mining operations to give an understanding of the environment where the current lighting problems exist. Open-cut coal mining operations are also known as opencast mining or exposed coalfields.

Within coal mines the imperative component to be considered was the high-wall in which the lighting issues were directly involved. Therefore a study into the high-wall itself and high-wall slippages is a very important factor in this research. The high-wall will be the main focus for the positioning of the new lighting plant to provide optimum lighting into the coal mining pit area,

1.2.2 Accidents Caused by Poor Lighting

A review and comparison of incidents caused directly from poor lighting situations in mining pit areas during night time operation of heavy machinery will be required. This will help to show an understanding and the need for the development of a new lighting system in terms of employee safety and current working conditions. The average incident on a coal mine site, especially those concerned within the mining pit area are generally of a major scale and often include thousands of dollars worth of damage and possible serious injuries or even fatalities in the workforce.

1.2.3 Lighting Situations

A study into certain regulations and aspects governing light positioning, mining pit areas and obstructions within these areas will need to be performed to create a guide and help determine design restrictions for the properties of the new design. Also an extended study into previously designed lighting plant systems and the reasons why these models are ineffective along with ideas for better alternative options will also be necessary.

1.2.4 System Design

Once the establishment of background information regarding coal mining operations has been performed the conceptual design process can then be initialised to develop the new lighting system. After the conceptual design stage it will then be made possible to select and develop a detailed final design with precise design specifics and drawings for the portable high-wall lighting system.

Further work could include the development and ability to actually construct the final design. The constructed lighting system could then be implemented and tested in which a survey and a final assessment on the suitability of the lighting plant could be performed and hence determine the overall improvements and benefits gained from the development of the new lighting system for open cut coal mining operations

1.3 Project Methodology

1.3.1 Initial Research

There are a number of steps in the research for this design project. For the research required to complete this project there is a number of information sources and data that will need to be collected and studied. In order to accumulate the information regarding mining operations, mining vehicles, mining pit areas, high-wall information and construction, the use of selected readings and books, the internet and personal communication with technical officers and engineers at Blair Athol Coal Mine will need to be employed. The information for these many topics varies considerably over time and as technology has increased over the years. The first step would be to gain an understanding of open cut coal mining operations and their importance to society and the types of machinery that are involved with these coal mining operations. Followed by this it is important to perform research into the actual problems with lighting in the mining pit which would be due to high-wall slippages and high-wall set backs to best understand the nature of the problem and what is causing poor lighting. Research into the effect that a coal surfaces have on lighting will provide an understanding of why more efficient lighting is required and why lighting is harder then usual to provide when focused in a coal mining pit. The next step in the research would be to investigate incident reports including incidents related to high-wall slippages and mining in the pit at night. The last stage in the pre-design research would be to perform a thorough analysis of many of the previously designed lighting plant systems that are currently used for mining operations. All of the steps in the pre-design research shown above will help develop a better understanding of the problems at hand and hence should increase the potential for a better design for a new portable high-wall lighting plant.

1.3.2 Design Stage

With research into the layout of the mining pit areas and a study into all of the aspects of the high-wall and previous designs, a conceptual design can then be developed. The previous research will help set design constraints and will help determine some of the better features that could be included in the conceptual design. After an in depth conceptualization for the initial design, the best features and design ideas will become apparent and then the final design can be completed. The final design with design drawings will be created with a 3d software modeling program called Pro Engineer. If timer permits it would then be made possible to physically construct the new lighting plant system and if this were to happen it would be accomplished with the aid of engineers at Blair Athol Coal Mine. The testing stages and the entire operation would be observed under the controlled conditions and supervision of professional engineers within the coal mine site.

1.3.3 Summary of Methodology

The overall project methodology and research that will be performed includes the initial research including coal mining practices, high-wall formations, and high-wall slippages, coal mine regulations for lighting and the current lighting situations in mining pit areas. With this knowledge obtained a conceptual design can then be developed along with a final design and 3d modeled drawings. Then if time permits there will be the option to actually construct and test a new model and perform a comparison between the new model and older models.

1.4 Overview of Dissertation

The overall aim of this research and design project is to perform research into the coal mining industry and all aspects that will have an impact on the development of a new design for a portable high-wall lighting plant. Lighting is now harder to provide within the coal mining pits as the coal mining high-walls have been set back at an angle of approximately forty five degrees to help prevent high-wall slippages and the older designs cannot effectively provide lighting as they once could. Once all of the above research has been completed it will greatly aid with the development of a new design for a lighting system that will overcome the problems at hand. The next chapter provides background research into many aspects of open cut coal mining operations.

Chapter 2

Background of Open Cut Coal Mining

2.1 Introduction

In order to understand the problem at hand which is trying to provide efficient lighting into the mining pit and solve the problems with high-wall slippages and set backs, research into the background of open cut coal mining is required. In order to design a lighting plant that will overcome all of the issues involved with the current lighting situations, it is important to gain an understanding of the open cut coal mining processes. The main aspects when considering this coal mining industry include the production of coal in Australia, export of coal from Australia, the basic mining processes of an open cut coal mine and the different types of machinery that perform these mining operations. Research into open cut coal mining processes and the machinery involved with them will give an understanding of the nature of the mining pit area and how important it is that there is efficient lighting in the mining pit.

2.2 Coal and its History

Coal was discovered in Australia in the year 1791 by escaped convicts around Newcastle. Coal mining was first performed in 1799 and in the year 1800 coal became the first mineral exported from Australia to surrounding countries. Coal production increased from this stage until the depression in the 1930's in which production decreased by over a third. It wasn't until the late 1940's that coal mining operations increased back to a high level of production (Healey, 1997). Ever since this period of time the coal mining market has had its minor fluctuations in production, however the export and production of coal has always steadily been on the increase and it will continue to do so for many years to come. Coal mining and coal power stations are the fundamental providers for electricity to Australia and no other significant power provider is currently available to meet Australia's needs. Shown below in figure 2.1 is a piece of black coal and it is a mineral substance. Coal is comprised mainly of carbon and is used all around the world for many purposes such as the creation of steels and the generation of electricity for society. The two main types of coal are brown and black coal. The color of the coal is directly related to the features of the coal structure and its carbon content. Black coal is typically used in the processes f generating electricity as it is better for the environment as it has fewer impurities in the carbon structure and it burns cleaner while creating less. The earth is comprised of two different types of rock including sedimentary and igneous. Coal is classed as a sedimentary rock and is found in layers of a carboniferous system (White, 1973). In order to obtain coal for use around the world, it needs to be extracted from the earth through the processes of mining in a coal mine and then transported overseas to countries such as China and Japan for further use.

Figure 2.1 – Black Coal

2.3 Coal Mining in Queensland and Australia

Coal Mining is a very common process performed throughout many regions in Australia. The following map of the South Eastern quadrant of Queensland (Figure 2.2) illustrates the abundance of coal bound in this area of Queensland. As it is seen these coal fields are quite vast and cover a significant area of mid to South East Queensland.

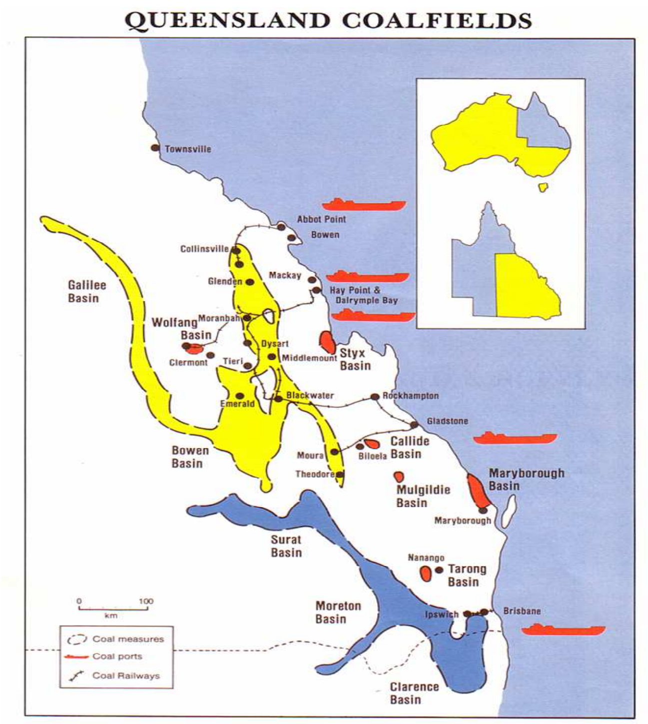

Figure 2.2 - Coal Fields in Queensland – Source: The Australian Coal Board

Below in Figure 2.3 is an image of Australia and this image represents the major black coal deposits throughout all of Australia. The major deposits of coal are found in Queensland and New South Wales.

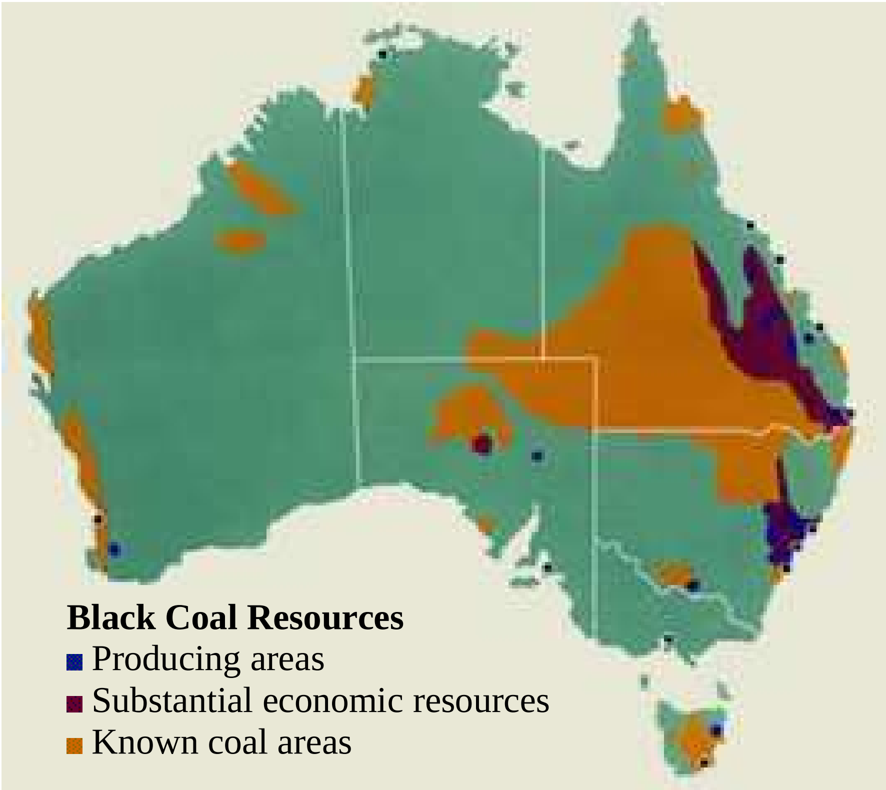

Figure 2.3 – Australian Coal Resources – Source: http://www.australiancoal.com.au/resources.htm

2.4 Production of Coal in Australia

Coal production is the act of mining, preparing and shipping coal to a particular region for use in society whether it is locally used in Australia or shipped overseas. The need for the production of coal in Australia and all around the world is steadily on the increase ever since it was discovered in 1791. Table 2.1 shows the rate of saleable coal production in Australia from the years 2004 to 2005 and the values shown are in millions of tons. Although the graph only represents a period of two years the amount of coal that was produced in these two years is phenomenal. The table represents the total amount of raw (unprocessed) black coal and saleable (cleaned and pure) black coal for underground and open cut coal mines and a summary of how much of each was produced for all mining states in Queensland.

Mining Method/ State	Black Coal, Raw		Black Coal, Saleable	
	2004	2005	2004	2005
Mining Method				
Underground	81.5	89.2	65.1	70.3
Open cut	296.3	309.6	231.6	237.5
Total	**377.8**	**398.9**	**296.7**	**307.9**
States and Australia				
NSW	152.3	158.9	117.2	124.2
Qld	215.2	229.3	169.4	173.2
S.A.	3.5	3.6	3.5	3.6
W.A.	6.3	6.4	6.3	6.4
Tas	0.5	0.6	0.4	0.4
Australia	**377.8**	**398.9**	**296.7**	**307.9**

Table 2.1 – Black Coal Production in Australia – Source: http://www.australiancoal.com.au/production.htm

Coal production in Australia is on the increase and other studies have also been completed around the world to gain possible trends into the future of coal mining and production practices.

2.5 Coal Export

Coal is Australia's largest commodity export followed by oil and petrol. In the year 2005 coal export reached a substantial 25 billion dollars for the Australian Economy. The following graph shown below in Figure 2.4 gives a representation of the major Australian commodity exports for 2005 and as can be seen, coal exports are well and truly at the top of the list. Not only is Coal the most highly exported substance from Australia, Australia is also the highest exporter of coal of all of the countries in the world. A comparison of Australian export coal and other countries can be seen in Figures 2.5 (by mass) and figure 2.7 (by percentage). Australia exports more then 200 million tons of coal each year and this is equal to 28.9% of the entire amount of coal exportation around the world.

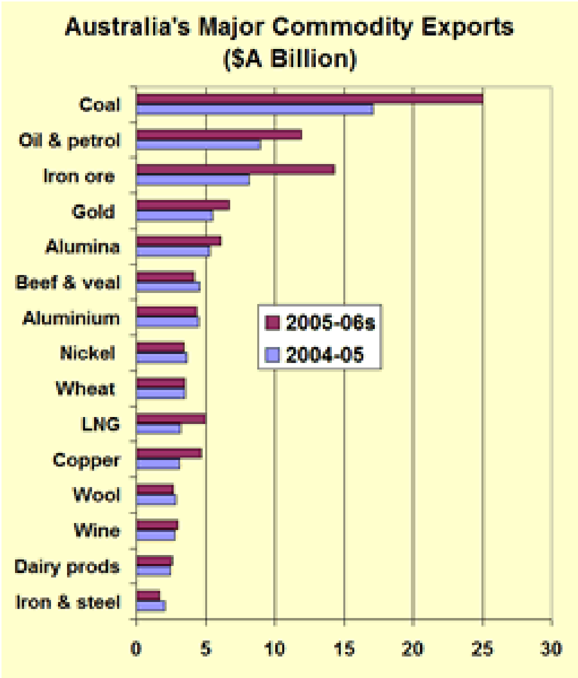

Figure 2.4 - Major Australian Commodity Exports - Source: Australian Bureau of Agricultural and Resource Economics

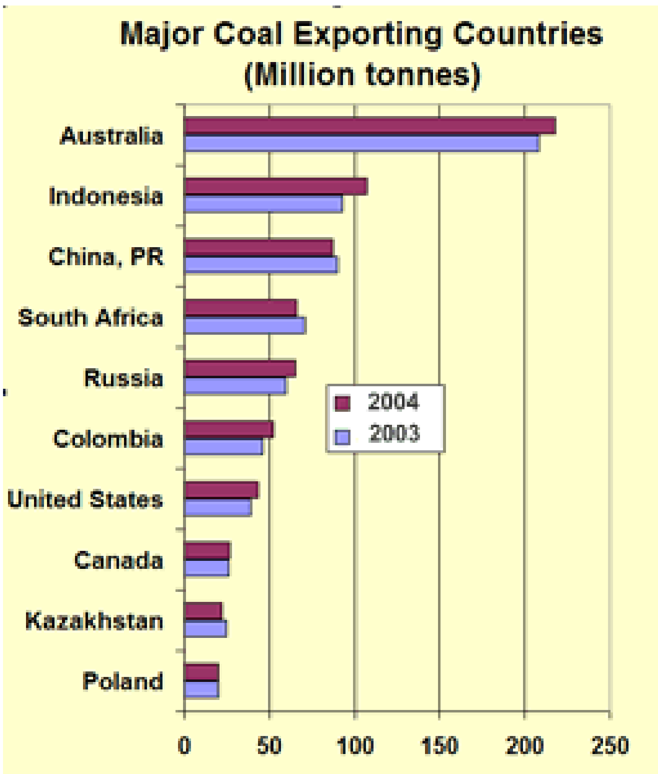

Figure 2.5 Major Coal Exporting Countries - Source: IEA Key World Energy Statistics - 2005

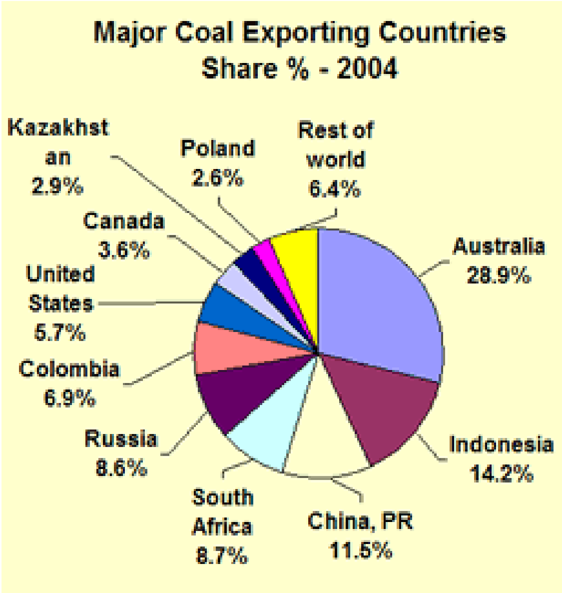

Figure 2.6 Major Coal Exporting Countries - Source: IEA Key World Energy Statistics - 2004

2.6 Open Cut Coal Mining Procedures

There are many coal mines around the world and the two main types of mining methods include underground and open cut versions of coal mines. Underground mining is a process in which the coal is extracted beneath the earth's surface in a series of tunnel formations, whereas open cut coal mines extract the coal from the earth in seams working above the earth's surface. Open cut coal mines are generally much larger operations then underground mines due to the nature of the mining operations. Underground mining operations will not be included in the scope of this research project as it is specifically aimed at open cut coal mining operations. Open cut coal mines take up large quantities of land and require very large machinery to operate efficiently. If smaller sized machinery was used to remove the coal the supply of produced coal will not meet the demand for coal. The processes for open cut mining include the removal of overburden above the surface of the coal which is comprised of mainly dirt and debris and this is performed by large draglines. In Australia draglines are typically used to remove the overburden to gain access to the coal. Once the overburden has been removed it can then be extracted from the earth by the use of an electric shovel, an excavator or a super dozer. These coal extracting vehicles can then load the coal into a transporting vehicle or haul truck for transportation to a dumping station. The coal is then moved to stockpile areas within the mine via a conveyor belt and washed and prepared for further transportation. After coal preparation and washing, the coal is then transported by a train to docks for overseas transportation by large cargo ships. Figure 2.7displays an in depth picture of the mining processes of mining coal seams. References for figure 2.7 are [1] Waste rock is drilled and blasted on each bench so it can be removed to expose the coal seam. [2&3] Large electric shovels load the waste into haul trucks for removal to a spoil in mined areas or another area of the mine which does not contain coal. [4] While dozers "clean" the coal seam, a hydraulic shovel [5] places the coal into trucks equipped with specially designed tilt trays for transport. The mining sequence repeats itself as each bench level is completed.

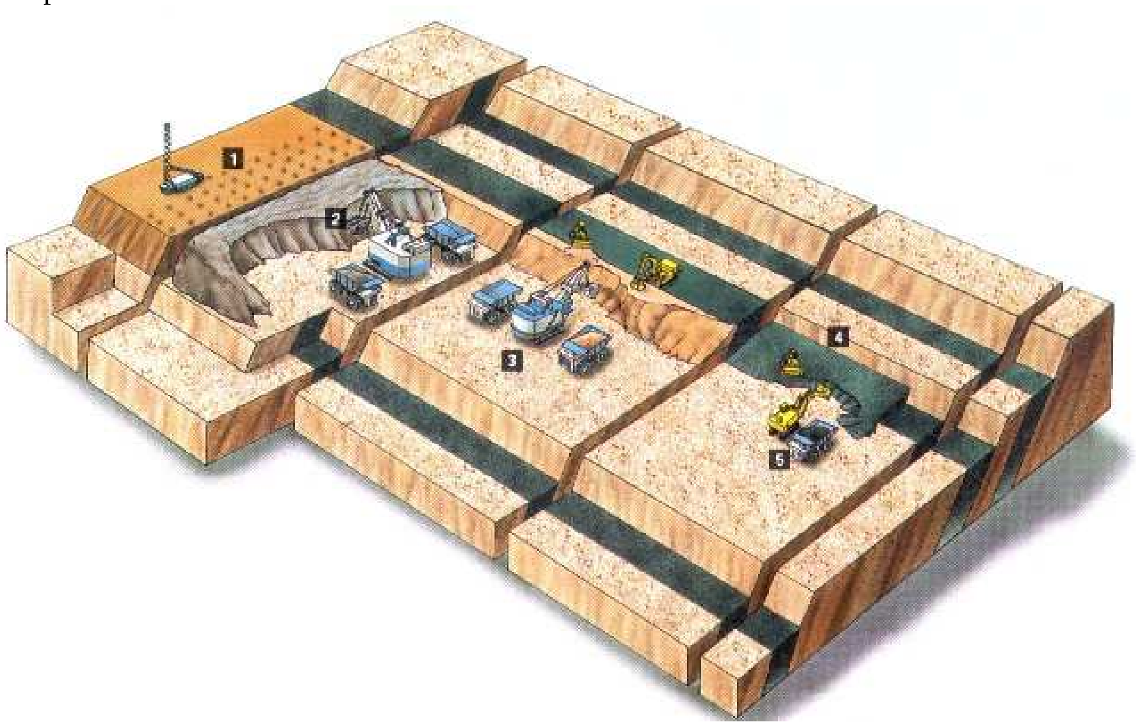

Figure 2.7 – Mining Coal Seams – Source: http://www.elkvalleycoal.ca

Figure 2.8 displays a basic setup for an open cut coal mining operation including the use of a dragline and

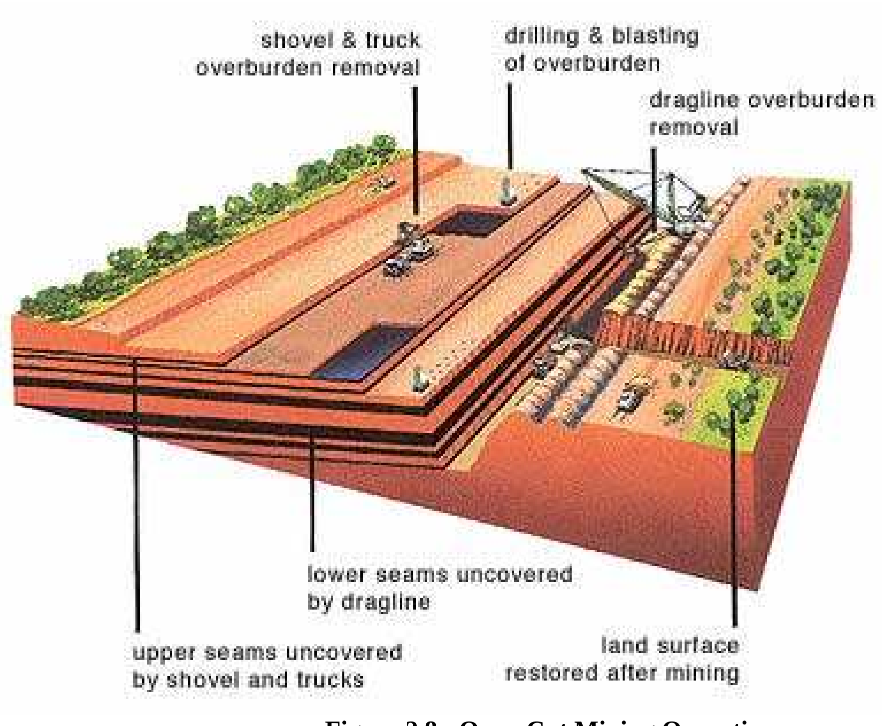

Figure 2.8 - Open Cut Mining Operations

2.7 Coal Mining Machinery

Coal mining vehicles are mainly classified into three main categories. These categories include vehicles for removing overburden, extracting coal and transporting the coal.

2.7.1 Machinery for Removing Overburden

One of the first steps in the coal mining processes involved with open cut mines is the removal of the overburden to give access to the coal. Essentially this stage is performed by a dragline in most cases. Shown below in figure 2.9 is a dragline at the Tarong coal mine. The dragline is the large machine in the centre of the image. Due to the nature and size of the operations to remove overburden the dragline is the only feasible option for machinery to perform this task. In the background of the image is the Tarong power station where coal is burned to produce heat which is used to generate electricity. A dragline has a very large boom and with the help of large steel cables and a dragline bucket, it is used to scoop up and remove over burden from above the coal in a dragging motion, hence the terminology “dragline”. A diagram illustrating these different parts of the dragline can be seen in figure 2.10.

Figure 2.9 – Dragline at Tarong Coal Mine – Source: Rio Tinto Coal Australia

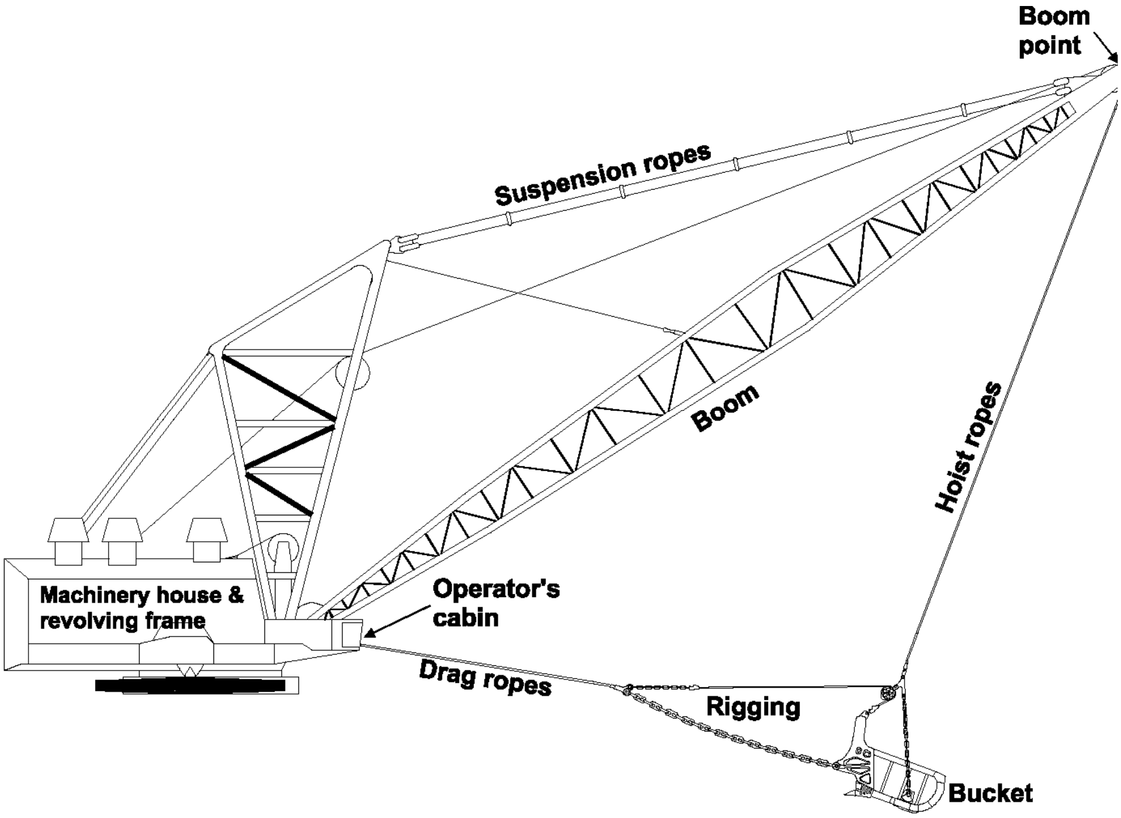

Figure 2.10 – Components of a dragline – Source: http://www.emeraldinsight.com/fig/1540070404004.png

2.7.2 Machinery for Extracting Coal

The next step in the coal mining process is to remove or extract the coal from the earth. This process can be completed by many different types of vehicles. The more commonly used ones are the 'Loader' (shown in figure 2.11), the 'Electric Shovel' (shown in figure 2.12) and the 'Excavator' (shown in figure 2.13) As can be seen by these images these vehicles are all different looking and operate in different styles however they all serve the same purpose and that is to remove the coal from the earth and load it into the haul trucks for further transportation.

2.7.2.1 The Loader

The Loader is used for a number of purposes as it extracts coal from the earth but it can also be used to help clean up the areas that are about to be mined and prepare them to be mined for other vehicles such as the electric shovels. This is the processes of cleaning the coal seam. Essentially a loader is put to best use in wider coal faces to be mined that are not quite as high. Loaders are best used for smaller mining operations.

Figure 2.11 – Loader Source: Visit to Blair Athol Coal

2.7.2.2 The Electric Shovel

The Electric Shovel is very common in open cut coal mining operations and is the best choice for larger mining operations. The shovel can be used for very large coal faces that are both wide and high as well, where it would be harder for other types of coal extracting vehicles to remove the coal.

Figure 2.12 - Electric Shovel (Right) - Source: Visit to Blair Athol Coal

2.7.2.3 The Excavator

The excavator is best used on top of a coal face. The excavator is best suited for mining relatively tall, but thin sections of coal; however larger excavators have been used which can remove very large quantities of coal much like electric shovels.

Figure 2.13 - Excavator – Source: http://englishrussia.com/images/coal_mine/2.jpg

2.7.3 Vehicles for Transporting Coal

One of the final stages of coal mining practices is to transport the coal from the mining pit to an actual dumping station or loading zone. In order to do this transporting vehicles are required. Shown in figure 2.14 is a common 'Haul Truck'. These vehicles come in a variety of sizes and the one shown in this picture would probably weigh around four hundred tons when completely loaded with coal. Other vehicles have also been used and are still employed in the coal mining industry today; an example of another type of vehicle used is a standard semi trailer truck. However the basic haul truck with its dumper action makes it a much easier and efficient method of loading and unloading coal.

Figure 2.14 - Common Haul Truck – Source: http://www.wma-minelife.com/coal/graphics/Truck004.JPG

2.8 Open Cut Coal Mining Summary

The coal mining industry is a very important part of Australia. It plays a major role in Australia's economy as it is Australia's largest commodity export. Coal export alone creates around twenty five billion dollars a year. The demand for coal from Australian mines is one of the largest in the world so it is very important that the industry is kept as efficient as possible regarding all aspects of mining operations. In order to keep up with the demand for coal it is recognizable why the large machines described above were designed to be able to do this. With the nature of the mining operations and the combination of all of the vehicles that work together to perform these operations it identifies why efficient lighting is an important factor to help aid in the processes of mining with vehicles of this magnitude. The next chapter will explain the issues with poor lighting in more detail.

Chapter 3

High-Wall Research and Analysis

3.1 Introduction

Due to the very high demand for coal around the world there is much pressure on mines to operate around the clock and in all weather conditions to keep up with the supply of coal. Coal mines will normally operate in both day and night conditions and it is the operation at night where the main problems exist. The major issue with working at night and the factor that needs to be considered is vision and providing effective lighting within the large mining areas. High-wall set backs are making the ability of providing efficient lighting into the coal mining pit at night more difficult. It is due to high-wall slippages and high-wall set backs that the regular lighting methods from above vertical high-walls are no longer used as the high-wall formations have changed and are no longer vertical as they once were. These changes to the current lighting situations have resulted in less efficient lighting in the mining pits and as a result there is lesser visibility. This chapter of research is important to gain an understanding of why the high-walls have changed and why the previously used locations for lighting systems are no longer providing effective lighting into the mining pit. In turn the research in this chapter will also show the need for a new lighting system to be developed as well as help set some of the constraints for the development of the new design. These constraints will be directly related to the high-wall layout and the reasons why older designs are ineffective. Furthermore it can be realized that efficient lighting within the mining pit areas is imperative to ensure the safety of all employees in the area and to prevent damage to the expensive equipment employed for use for coal mining operations.

3.2 High-Walls, Slippages and Set Backs

As the current problems to do with inefficient lighting in the coal mining pits are directly related to the change of the high-wall formations and high-wall slippages it is important that an investigation into as many aspects regarding high-walls is performed. The important aspects that need to be considered are the high-walls themselves, high-wall slippages and high-wall set backs.

3.2.1 High-Walls

High-walls are the section of the mining pit area in which are not currently being mined, but will be in the near future. A high-wall consists basically of coal and overburden. Overburden is essentially dirt and debris which lies on top of the coal itself. As seen in figure 3.1 high-walls are quite large. On average, typical high-wall heights range anywhere from thirty to sixty meters at Blair Athol Coal, however the heights of the high-walls can vary significantly according to the location of the mine site, as different mines have different size seams of coal. The larger the seam of coal at the mine will determine how much higher the high-wall will be.

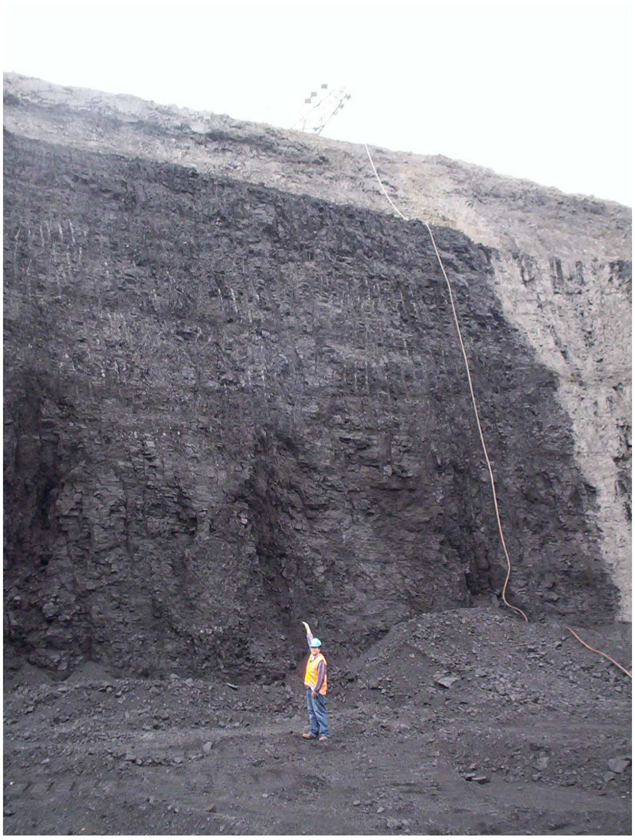

Figure 3.1 - High-Wall Height – Source: Visit to Blair Athol Coal

Actual high-wall design is a very complicated process however and the basic principles and equations used to calculate this type of mechanism can be found in most soil mechanics text books and readings. High-wall design and the angles at which the high-walls are cut are very important to the development of the new lighting system as it sets one of the most important design constraints and ideas of the new lighting plant. Thomas (1973) describes the processes and mathematics behind soil and soft rock slope design and the shear strength of the slope:

An elementary treatment will be given to illustrate the effects of rock joint strength and groundwater pressure. It is obvious that when one portion of a rock or soil slope slides over another that resistance to this movement will be experienced. There will be friction between the two surfaces and because the surfaces are not truly plane there will be other forces needed to shear off irregularities on them and to slide broken pieces of rock over each other. The rock or soil then has a shear strength which enables it to stay in position on an inclined plane. The shear strength of a slope or inclined face is normally expressed by the Coulomb Equation:

$$S = c + \sigma \tan \Phi$$

Where (S) is the shear strength, (c) is the cohesion along the failure plane or the shear strength under zero normal stress, (σ) is the stress normal to the failure plane and (Φ) is the angle of friction of the material along the failure surface. The values of (S), (c) and (Φ) can be found by field tests with a shear box in which a sample of soil or rock is split and the split surfaces are pushed across one another. Reduction of the slope angle, or increased values of (σ), the normal stress, would prevent further slip. In practical terms this could be achieved by lessening the angle of slope or by imposing an artificial restraint such as a retaining wall. The friction angle (Φ) can be visualized in two ways. It is the maximum slope at which a loose granular material will remain at rest or in other words its angle of repose. It is also the angle of the slope at which a block of rock would be just on the point of sliding. The cohesion, (c), is a function of the irregularity and the initial physical bonding of the two sliding surfaces. Just before a slide, the cohesion can be high and would yield a peak strength. However once the rock or soil starts to slide, the value of (Φ) drops to give a residual strength for the difference between the value of (Φ) for intact rock and for broken rock, so when a failure occurs it can be sudden and violent. This is more likely to occur in hard rocks such as porphyry or granite. In softer rocks or earth slopes which have little difference between peak and residual strengths the slides will be more gentle unless in wet conditions.
(Hoek, 1973) gives values of (Φ) in his paper for a range of rocks and some of these are listed below in Table 3.1 to show their effect.

Rock Type	Value of Φ for		
	Intact Rock	Residual Strength	Joint Roughness
Granite	50–64	31–33	—
Porphyry	—	30–34	40
Sandstone	45–50	25–34	27–38
Schist	26–70	—	—
Shale	45–64	27–32	37

Table 3.1 - Values of (Φ) – (Thomas, 1973)

3.2.2 Changing High-Walls

There are a number of different types of lighting plants available for use on coal mining sites at the moment; however the ability of the lighting plant to provide efficient lighting into the mining pit is due to changing high-walls. High-wall slippages and high-wall setbacks are making the current lighting systems less effective at providing light into the pit. As mentioned previously, a high-wall is a wall of coal that is yet to be mined and is usually covered with overburden. A high-wall slippage is essentially when the large wall of coal and dirt actually start to lose their strength and parts of it break off into the mining pit area. As high-wall slippages are potentially dangerous to miners in these areas, mining operations are now attempting to reduce the problems of high-wall slippages by setting back the high-walls. Mining high-walls are set at an angle of approximately forty-five degrees, as noted from personal communication with mining engineers at Blair Athol Coal. This decision was part of a complex geotechnical slope design procedure in which an analysis of the coal strength in the high-walls is used in shear strength equations for the high-wall. The CSIRO has performed research which has concluded that the coal surface design and strength of the coal to be used ranges from 3.1MPa for weak coal to 6MPa for strong coal. This process is explained similarly in section 3.2.1 above and basically the process and the equation of the shear strength of a slope will help determine a suitable angle for high-wall design. The factor of safety for the design of high-walls using these methods should be at least 1.3. The problem with the new high-wall formations is that current lighting systems above the high-wall are no longer able to provide efficient lighting into the mining pits. This effect will be shown in more detail in section 3.2.4 of this chapter. The issue of high-wall slippages and employee safety as well as the cost of machinery is far too great and now the previous method of vertical high-walling is becoming less common in the open cut coal mining industry.

3.2.3 High-Wall Slippages

High-wall slippages, otherwise known as geographical failures of the high-wall are becoming a more and more recognized problem in the open cut coal mining industry. A high-wall slippage can simply be described as a section of the high-wall consisting of either coal and/or debris slipping into the mining pit. High-wall slippages can be potentially very dangerous to the operators within the mining pit area and have the potential to cause heavy damage to machinery which in turn leads to down time and repair costs. Over time high-wall slippages have became a more noticed problem and this has led to the desire to create methods of reducing the frequency of these slippages. High-wall setbacks have been introduced from in depth geotechnical studies of high-walls and essentially this is the act of sloping high-walls back at an angle to reduce the shear forces acting on the wall. The high-wall set backs are directly responsible for the previous designs of lighting plant being less effective as lighting plants above the high-wall. Figure 3.2 below shows an image of a high-wall slippage incident in which an excavator is being used to remove the debris from the pit. It can also be seen how the actual section of high-wall that has collapsed was part of an almost vertical high-wall. It is due to high-wall slippages such as this, that have led to the decision of high-wall set backs setbacks of approximately forty-five degrees.

Figure 3.2 - High-Wall Slippage

A brief explanation of the mathematics and theories behind slippages will be presented. Thomas, (1973) describes the failure properties of slopes as they are mathematically predicted:

3.2.3.1 Prediction of Failure

The failure of slopes of intact and homogeneous material can be mathematically predicted. The most advanced mathematical treatments is one in which the whole zone is considered to fail in plastic flow. An easier approach is obtained if the slope is considered to fail on a cylindrical rotational path. The method of slices (Bishop, Fellenius) is used when the method of failure is considered to fail in a simple shear along the failure plane. The segment of slope involved is divided into slices and the forces on each slice are analyzed separately. Addition of all by integration is used to give the factor of safety against failure. Figure 3.3 below gives a basic description and indicates the path in which it fails for a number of different slope failures.

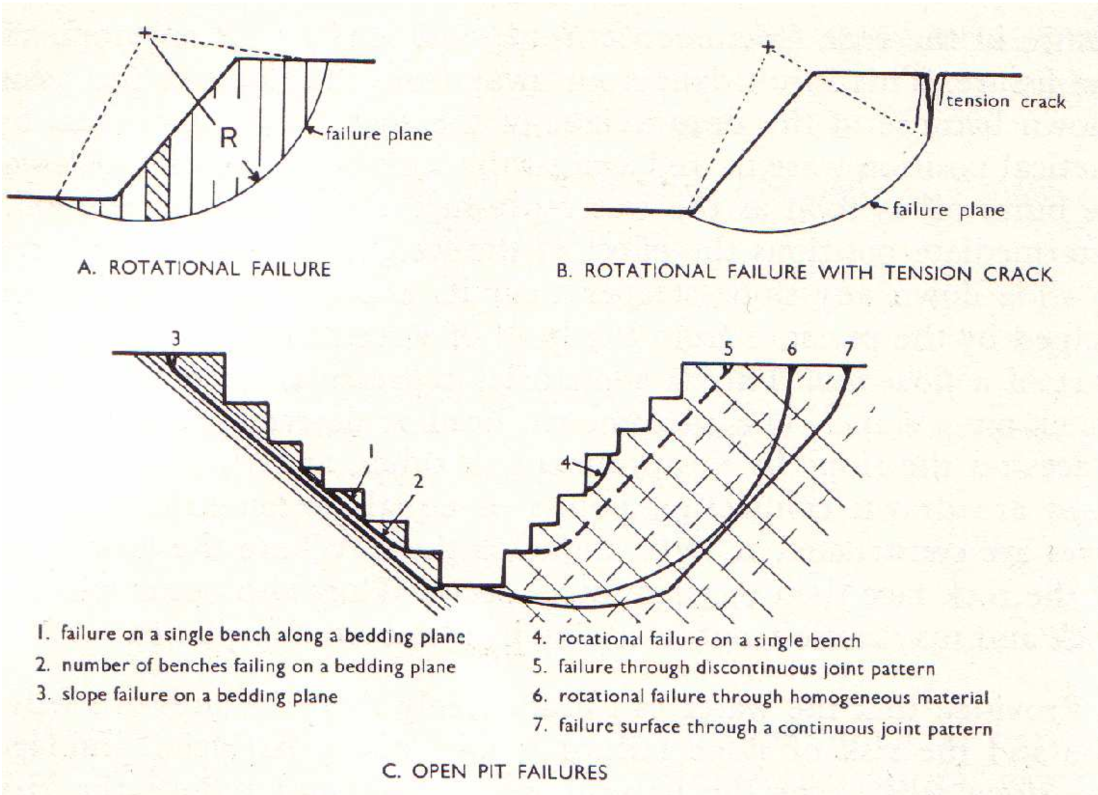

Figure 3.3 - Slope Failures

Most of these approaches need advanced mathematical techniques and an accurate measurement of the input parameters. For many years engineers have had design charts available to give them approximate safe slopes with a minimum amount of calculations. Hoek, (1973), extended this work and has produced a series of design charts of the form shown in figure 3.4 and figure 3.5 which help determine a factor of safety for slope failure for both soft rock slopes with circular failure and jointed rock slopes with plane failure.

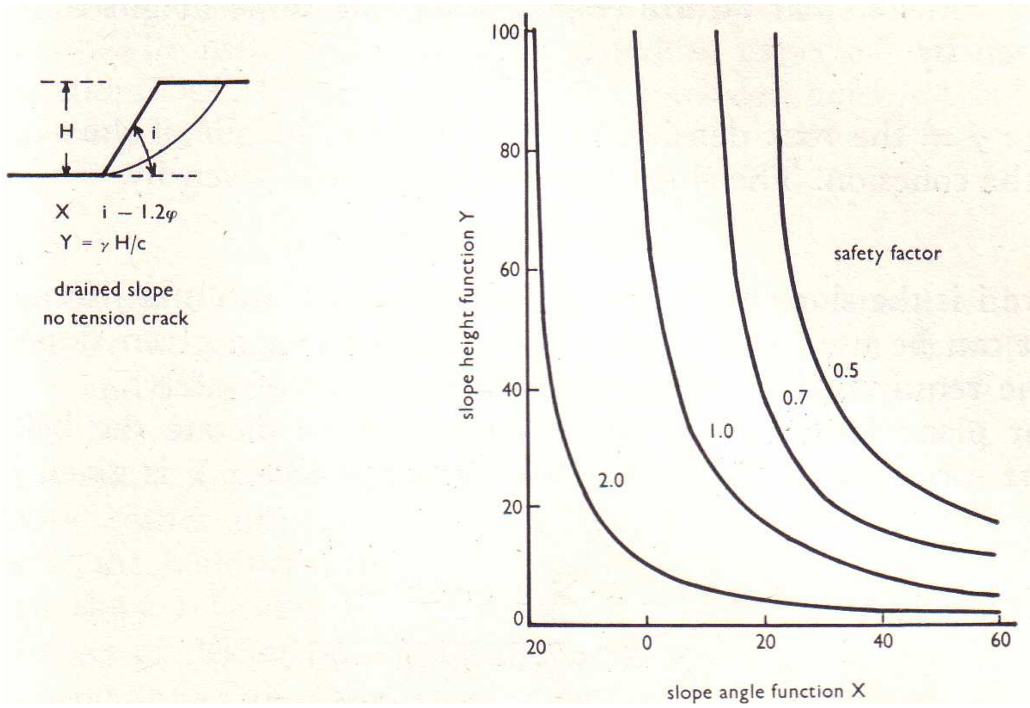

Figure 3.4 - Design Chart for Soft Rock Slopes with Circular Failure

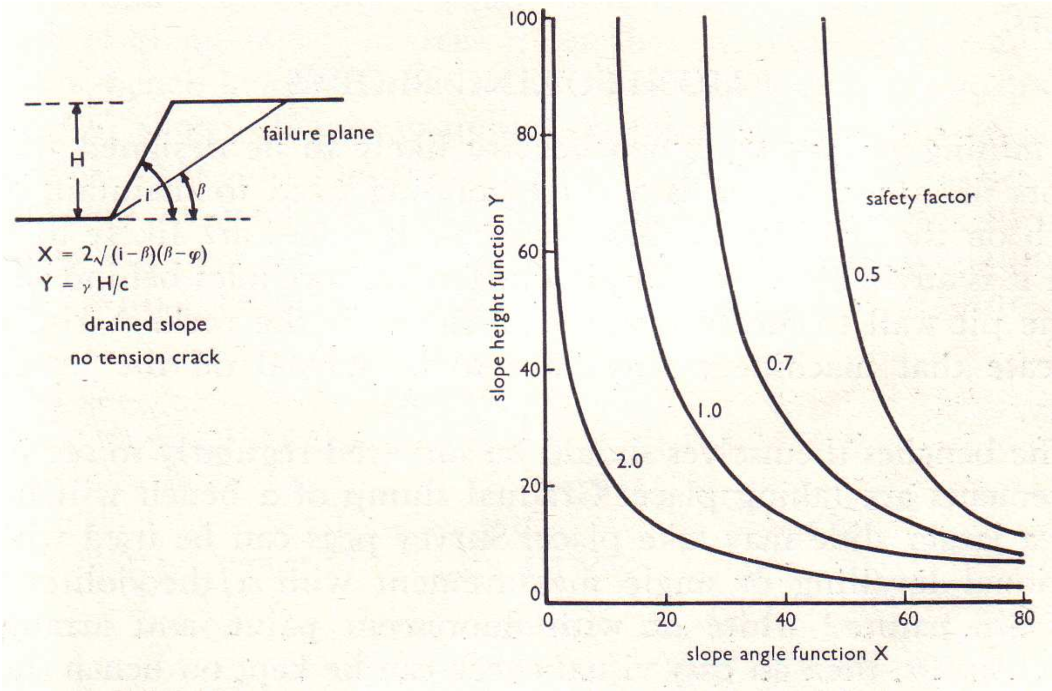

Figure 3.5 - Design Chart for Jointed Rock Slopes with Plain Failure.

3.2.4 High-Wall Set backs

It is due to high-wall slippages that high-wall setbacks were introduced to the geotechnical design of mining high-walls in a hope to reduce the occurrence of high-wall slippages. A high-wall set back is the action of altering the high-wall at an angle to reduce the chance of significant parts of the high-wall slipping into the mining pit. The processes involved with setting the high-wall back at an angle are very complicated in nature as previously mentioned and are beyond the scope of this project however an elementary description is needed. Below in figure 3.6 is a simple representation to help clarify the action of setting back the original high-wall.

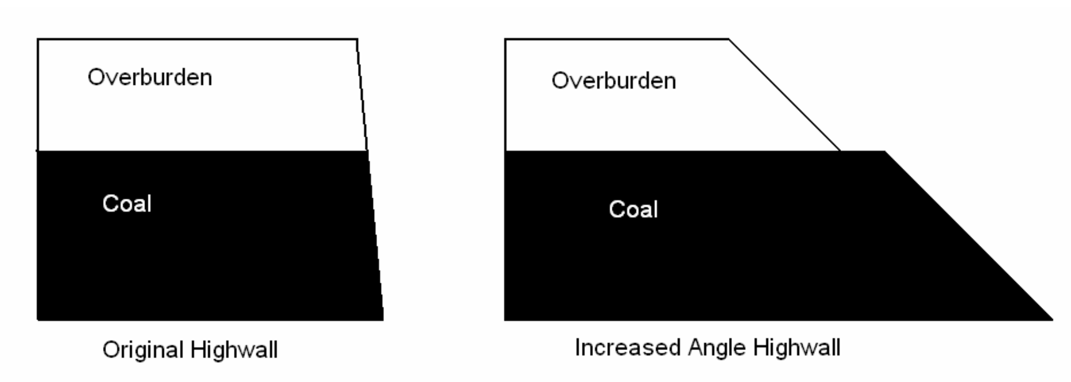

Figure 3.6 - Simple Representation of a High-Wall Setback

The images in Figures 3.7 and 3.10 show the coal mining pit at Blair Athol Coal Mine, Australia. Both of these images were taken from a visit I made to Blair Athol Coal located in Central Queensland in 2006 and both of these images clearly show the entire coal mining pit area and a clear picture of the high-wall. The positioning of the current lighting plants above the high-wall have been marked in figure 3.7 with red ovals and as can be seen they are a significant distance away from the actual mining pit area where the machines are operating. The distance that the light from these lighting plants has to be projected combined with the current unsuitable angle of the sloped high-wall make the old designs of lighting plants used above the high-wall very ineffective. Lighting from this angle will leave sections of the pit completely in darkness if only lighting from above the high-wall is used and this is why. The yellow lines in this image represent the rays of effective lighting and the area contained by the red lines in the image is the region that will receive hardly any lighting at all from the lighting plants in their current position. It is for these reasons that Blair Athol Coal has researched into other systems of lighting that can be employed for use with in the mining pit. The image in figure 3.8 shows the actual angle of the high-wall, which in this case has been built at approximately forty to forty-five degrees. The coal face that is being mined is almost vertical. As the coal face is constantly being mined and its geometry is always changing. The safety procedures for the coal face being mined is that the boom of the machinery being operated must be higher then the height of the coal face. This will stop the machine from being buried by a coal face collapse.

Figure 3.7 - Coal Mining Pit at Blair Athol Coal Mine in Australia


Figure 3.8 - Coal Mining Pit at Blair Athol Coal Mine in Australia

3.3 Conclusion

Coal mining operations are very complicated and large in nature and employee safety and equipment care are of the utmost importance of every mining operation. As knowledge of high-wall slippages and high-wall set backs have increased it has brought upon changes to the coal mining pit areas and this has affected external factors such as lighting. As these conditions change the previous designs of lighting plants will need to be altered also to incorporate these factors as well as to ensure that efficient lighting is provided into the mining pit areas. The next chapter will explain the properties of light more specifically to do with absorption of light and it will include the current lighting regulations for coal mining in Australia.

Chapter 4

Current Lighting Systems

4.1 Introduction

With the current layout of open cut coal mining pits and the current lighting situations regarding the high-wall set backs, it is important to gain an understanding of the basic types of lighting systems currently employed by coal mines and determine why they are no longer efficient. The various figures shown throughout chapter three of this research project display the mining pit areas and the high-wall changes; however they only show how the effective lighting into the mining pit has been decreased due to the high-wall setbacks. Basically lighting can be provided to the mining pit areas from above the high-wall and inside the actual mining pit. Most types of lighting plants are very similar with only small variations in shape, but the general design and methods of lighting are similar between models. A study into the different types of lighting plants on the market today will help determine some of the better aspects of each design with a possibility to incorporate some of these previous ideas into the new design for the lighting plant system. As there are so many different brands of lighting plants and most designs are similar in nature an overview of the different types available will be listed in this section however the versions selected are well known in the industry and all have their significant beneficial factors. To start off the chapter below are the general coal mine lighting regulations for Australia. These were needed to be included in the research to discover what is required of lighting in coal mines and are current up o the year 2006 across all states.

4.2 Coal Mine Lighting Regulations

The following regulation was implemented for use in 1999 for coal mining operations both above ground and underground in Australia and it clarifies requirements of the regulation that must be incorporated in lighting practices within mines around Australia for optimum safety and lighting within coal mining areas. This regulation is still current for today's mining practices for both surface and underground mining operations.

4.2.1 Coal Mines (General) Regulation 1999 - REG 18

18 Lighting

Lighting that:

(A) is adequate to allow employees to work safely, and
(B) does not create excessive glare or reflection, and
(C) is adequate to allow persons who are not employees to move safely within the workplace, and
(D) Facilitates safe access to and egress from the workplace, including emergency exits, must be provided at a mine or declared plant.

(Consolidated Regulations, 2006)

The next few sections will give a basic overview of many of the types of lighting systems currently available and the disadvantages with these systems due to the current high-wall formations.

4.3 Mid-Nite Lighting System

Shown in Figure 4.1 is a 'Mid-Nite Lighting System' setup and this system is very commonly used in mine sites around the world. This lighting system can be used both in the mining pit area and above the high-wall. The design is relatively simple in nature and basically consists of a motor, generator, boom, hydraulic system, controls and the light source itself. All components are connected and all situated as one piece that can be readily folded and packed up for easy transportation. Before the decision was made to apply high-wall setbacks this particular type of lighting system was very effective at providing lighting into the mining pit however now is less efficient at this task. The bendable boom allows for further reach over the high-wall and can be raised vertically and extended out horizontally for maximum reach of the light source into the mining pit. The reason why this particular model of lighting plant is no longer effective is because the boom on the lighting plant cannot reach over the high-wall far enough. With the angled section of the high-wall this will result in a large portion of the mining pit remaining not illuminated.

Figure 4.1 - Mid-Nite Lighting Plant – Source: Visit to Blair Athol Coal

4.4 Praying Mantis Lighting System

Shown in Figure 4.2 is a similar type of lighting plant to that in figure 4.1 and it is often referred to as a "Praying Mantis Lighting System" due to the nature of its design. As it can be seen the beam stretches out much like the formation of the body of a praying mantis. But the idea of the lighting plant, the components required and its functionality is much the same as the 'Mid-Nite Light' setup. This design was also suitable for use to light up the coal mining pit from above the high-wall but also faces the same issues regarding light produced as the Mid Nite Lite system

Figure 4.2 – Praying Mantis Lighting Plant – source: www.allight.com

4.5 The Terex Amida Mobile Lighting Tower

Shown in Figure 4.3 is the Terex Amida mobile lighting tower system. As can be seen it also similar to the popular Mid-Nite Lighting system however this version of lighting plant would generally be used in the mining pit area. Lighting plants in the mining pit are preferably avoided as they will result in problems with glare and shadows and are also obstacles to avoid, which are all undesired side effects of lighting within the mining pit area.

Figure 4.3 – Terex Amida Lighting System - Source:http://www.lighttowerspares.com

4.6 Kubota Lighting System

The Kubota System is another type of lighting system that can be used from within the mining pit area and can be driven to different locations for use. It provides efficient lighting within the mining pit area however unfortunately faces the issues regarding shadows, glare and obstructions within the mining pit areas. Another issue with using this lighting system is that it will require training and employees to relocate the lighting plant within the mining pit and this brings up other issues regarding human safety. The issues that will effect the use of this lighting system in the mining pit is the 50 meter minimum distance between vehicles requirement that is be required for all vehicles in the mining pit. Also there is a regulation that states that there is required to be a 10 meter distance between machinery and personnel from the edge of the high-wall and low-wall.

Figure 4.4 Kubota Lighting System - Source:http://www.minasco.com.au/Kubota-lighting-plant-2.jpg

4.7 Lunar Lighting Tower System

Shown in Figure 4.5 is the reasonably new design for a lighting system and it is called a 'Lunar Lighting Tower System'. These lighting systems are mainly used within and around the mining pit areas, rather then on top of the high-wall like many of the other types of lighting plants. This type of lighting plant is becoming more and more commonly used due to the problems of high-wall setbacks to avoid placing inefficient lighting from above the high-wall, however there are numerous negative points about this type of lighting system also. This type of lighting plant can be considered quite expensive in nature and may require more maintenance then other typical lighting systems as they are more fragile in nature. Lunar lighting representatives have stated that the lighting towers, completely assembled are approximately $125,000 each. The light bulbs used in the lighting plant are around $1000 each and the bags that cover the light bulbs to give the lunar effect are around $100. The maintenance issues with these lighting systems is that if the bag I deflated before the light is switched off the light bulb will burn a hole through the bag and it will need to be replaced. Another problem with these types of lighting systems is that they are very bright and as they are located within the mining pit itself they can cause large amounts of glare, reflection and cast large shadows within the mining pit area and to an extent conflict with the coal mining lighting regulations shown above that were set for mine lighting in Australia. Lunar lighting systems are also classified to be an obstruction within the mining pit areas and there are regulations as to how close they can be placed within an operating vehicle as they quarrel with operator’s ability to operate machinery around the mining pit areas. The lighting plant should not be placed within 50 meters of working machinery.

Figure 4.5 – Lunar Lighting System – Source: www.lunarlighting.com.au

4.8 Skid Lighting System

Figure 4.6 shows a ‘Skid Lighting System’ that is used above the high-wall. As can be seen from the picture this type of lighting system is very large and bulky in nature and could be considered very expensive to create. The amount of steel required to make this lighting plant would be a lot more then the amount required for a conventional lighting plant system because of the 20 meter solid boom. This system also has many other components attached to it such as extra generators. This particular lighting system serves not only as a lighting system but it also helps lower the electric shovel cable over the high-wall and it is due to these factors that make it very hard to move this form of lighting plant around the mine site. These factors also make the use of this type of lighting system unsuitable to be used solely as a lighting plant.

Figure 4.6 - Skid lighting System – Visit to Blair Athol Coal

4.9 Super Skid Lighting System

The Super Skid System is a design of lighting plant that can be used on top the high-wall, in the mining pit area and can actually be lowed over the high-wall itself. The image showed in figure 4.7 shows a clear representation of the lighting plant ready for use. This lighting system weighs approximately 7500 kilograms which is considerably heavy to be permanently suspended over the high-wall and this is partly due to all of the components of this design being positioned as a single unit. The problem with the lighting plant weighing this much is that there will need to be a form of support above the high-wall that can secure this weight to prevent it from slipping into the mining pit. The components to this design include a motor, generator, hydraulic system, lights and a fuel tank. The most noticeable attribute about this design is the ability for this lighting plant to be lowered over the high-wall which is a major factor for the design of the new portable high-wall lighting plant. The Lighting plant does not come standard with a trailer system however and will need to be transported by specific vehicles on site.

Figure 4.7 – Super Skid Lighting System – Source: Allight.com

4.10 Conclusion

As can be seen there are many different varieties of Lighting plants available and the lighting plants shown and talked about are only a few among many that are currently available. The many different types of lighting systems have both positive and negative attributes among all of the designs so it is important to recognize each of these when trying to determine the overall best properties that can be included in a single design. If many of the shown designs are used above the high-wall and the high-walls are very large, it makes lighting from above the high-wall with most of these systems very inefficient with the current high-wall formations. Also if these designs are used within the mining pit they still face the problems of obstructions within the mining pit, shadows being cast in the mining pit, glare and blinding the drivers operating within these areas. Essentially a lighting plant design that can solve all of these problems while eliminating all issues regarding lighting into the mining pit needs to be developed. These issues will be explained further in the conceptual design in chapter 6.

Chapter 5

Related Mine Site Incidents

5.1 Introduction

Most accidents relating to mine site areas are very serious in nature and all are considered very important as nothing is more valuable then the safety of employees. When dealing with the mining pit area and the development of a portable new lighting system it is necessary to perform an investigation into the types of accidents that have brought upon the need for the development of a new lighting system and the types of accidents that will hopefully be prevented by the development of a new lighting system. The two main accident investigations that will be focused upon for this type of research include accidents involving high-wall slippages which have led to the necessary actions of high-wall set backs and also accident reports that are directly involved within the mining areas during night time operation where visibility is much poorer then at daylight. A summary of all of the different types of high potential incidents for the years 2005-2006 for surface coal mines is represented in figure 5.1. This pie graph shows that falls and slips of ground are a total of 5.1% of all accidents relating with open cut coal mining, falling and flying material is 4% and Vehicle incidents are 9.5%. Not all of these values represent the exact percentages for issues regarding poor lighting and high-wall slippages but these types of incidents fall under these categories..

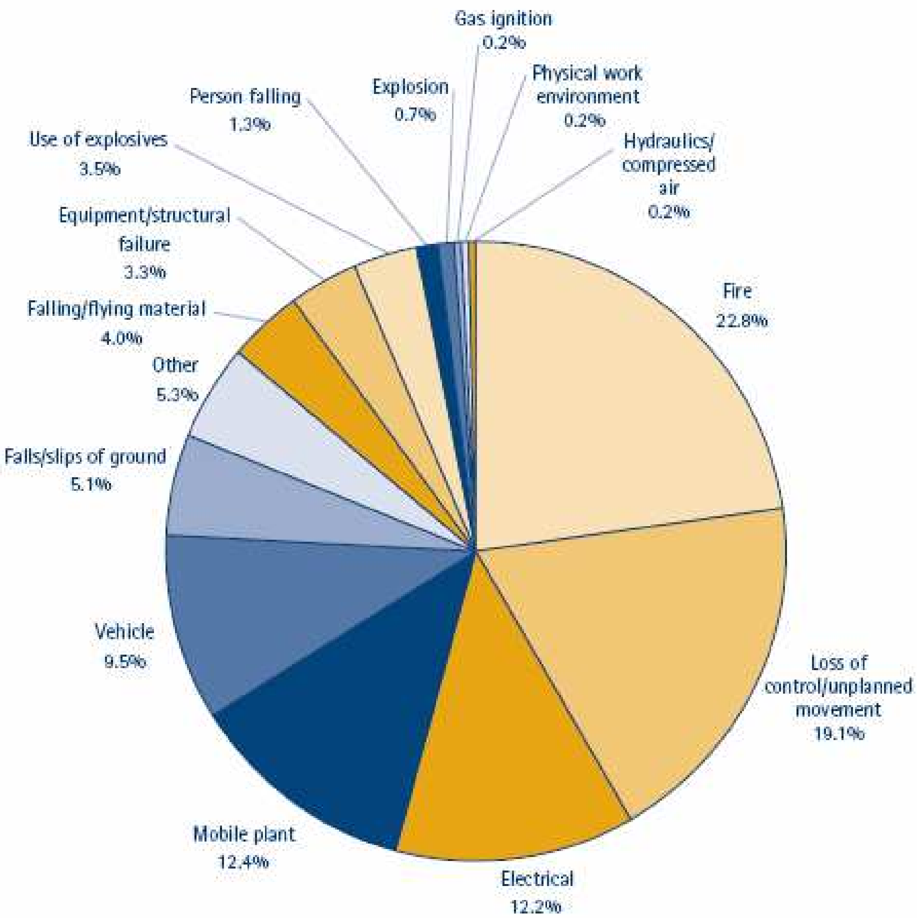

Figure 5.1 – Summary of Surface Coal mining High Potential Incidents 2005-2006 – Source: http://www.nrw.qld.gov.au/mines/publications/pdf/annual_report0506.pdf

5.2 Incidents Related to High-Wall Slippages

From my research of incident reports from Blair Athol Coal over the past few years regarding high-wall slippages it is estimated that there was normally at least one high-wall slippage incident for every month of the year. This research into the incident reports also included the steps have been put in place to help prevent this from happening and in most cases the recommended actions was to send the analysis of the high-wall slippage to geotechnical advisors. According to employees at Blair Athol Coal, High-wall slippages are a very common problem on their mine site. Fortunately Blair Athol Coal has provided me with access to many incident investigation reports involving high-wall slippages and accidents that have occurred due to poor visibility in the mining pit. It will soon be seen that many high-wall slippages occur and each individual high-wall slippage is taken seriously. On mine sites the regulations for incidents are that all high-wall slippage is to be reported as they are a random occurrence and it's a major safety issue. The incidents of high-wall slippages that will be listed below are all significant size slippages in which equipment damage and down time was a possibility.

5.2.1 High-Wall Incident Investigation Reports

This section shows some of the details regarding high-wall slippages in different ramps of the coal mining pit at Blair Athol Coal. If many incidents are investigated and reported upon at one coal mining site and the situations are similar between most open cut coal mining sites there is most certainly going to be similar types of incidents throughout the different mine sites. A ramp is a region that allows access to the mining area as well as being a part of the area where operations are performed in the coal mining pit. Some of the main details that are recorded in the following incident reports are the dates in which the incidents occur, the different conditions and nature of the slippage, the material that the high-wall is comprised of and any down-time and injury that has occurred from the incident.

1) 14th February 2005

Investigation Finding: A section of the weathered basalt and green clay in the end wall of Ramp 4 East has collapsed. This slumped coal comes close to the access road to the top of the coal.

Immediate Actions Taken: Access to Ramp 4 East top of coal has been closed off to all vehicles in this area. Clean up of area and windrow to be setup near slippage area to restrict vehicle access.

2) 14th March 2005

Investigation Finding: Weak sandstone overburden has failed in the high-wall of Ramp 4 West Strip 12. The material has failed within the 15 meter high-wall exclusion zone.

Immediate Actions Taken: Consideration to lay back the high-wall even further for the next strip to be mined to a minimum of forty-five degrees.

3) 22nd April 2005

Investigation Finding: A significant amount of material has slipped out of the high-wall in Ramp 3 North.

Immediate Actions Taken: Witches hats have been placed around the base of the failure. Further advice from geo-technologists will be needed for future actions regarding this failure.

4) 30th December 2005

Investigation Finding: Cracking has widened in the weathered basalt in Ramp 3 North Strip 14 and some material has fallen from the wall onto the coal bench. In this area the catch bench below the first pass has been well maintained and the wall is laid back to forty-five to- fifty-five degrees for the first and second pass respectively. There will be a six meter catch bench at top of coal. It is likely that more material will fall out of the wall in the areas of cracking.

Immediate Actions Taken: Continued evaluation and reporting of the area to be taken out for the next week. Reports and pictures of the incident are to be sent to geo-technologists for further advice.

5) 4th April 2006

Investigation Finding: Reporting of a high-wall failure in Ramp 5 in which material has slumped in the overburden wall. It was reported as a block failure due to pit leaning, bedding and joints.

Immediate Actions Taken: A catch bench is to be placed under the failure and some soft markings. A report and photos have been sent to geo-technologists for further advice.

6) 17th May 2006 – Critical High Risk Incident

Investigation Finding: As operations were commencing after crib, a dozer was doing some clean-up at the excavator face while a haul truck was getting into position to be loaded. The Truck was moving clockwise into position to be loaded by the excavator when a section of the high-wall failed and some rocks rolled into the path of the operators. The truck stopped at the same time the dozer noticed the rocks and set about to clean them up. The dozer operator however did not see the haul truck parked and collided with it damaging the access ladder into the haul truck.

Immediate Actions Taken: The circuit was stopped and made safe. All involved personnel were assessed by paramedics for injuries and fitness for duty. The incident scene was preserved for further investigation.

Learning's for Others: Eyes on the path when reversing all equipment and ensure appropriate training is issued for people to recognize the fifty meter clearance in the field.

7) ***9th June 2006***

Investigation Finding: There was a noticed high-wall slippage at the end of the current Ramp 5 strip.

Immediate Actions Taken: A rill has been placed to prevent personnel from entering the area. A report and photos have been sent to geo-technologists for further advice.

5.2.2 Conclusion

The above incident reports are only some of the numerous incidents in which high-wall slippages have been reported at Blair Athol Coal. What can be concluded from the above incident reports is that high-wall slippages are a random and continuing occurrence and that they can be a major risk to both machinery and personnel in these areas. It can also be seen why geo-technologists and mining organizations have issued the need for mining high-wall setbacks and continued high-wall setbacks where required. The need for high-wall setbacks is to help reduce the severity and frequency of these types of slippages. The next section regarding mine site incidents will detail some of the accidents that have occurred in mine site areas due to poor visibility and more specifically those accidents where inadequate lighting were experienced.

5.3 Operator Incidents within the Mining Pit Area

The similarity between all of the incident reports that were studied during my research is that most are directly related to night time driving and accidents caused by poor visibility at night. Lighting plays an important part in order for workers to operate safe at night and the operators not effectively being able to see objects around them clearly could be very harmful. The following section will give a few examples of incidents that are directly related to coal mining operations in the mining pit at night from several different mines around Australia.

5.3.1 Incidents Related to Poor Lighting and Positioning

The following examples of accidents all occurred during night time hours and the main issues with the incidents were that there was poor visibility and illumination of the region of the incident and obstructions from lighting sources. Some of the information that is included in the incident reports varies from the type of damage, whether it be to machinery or to employees, the seriousness of the accident, the circumstances of the accident and methods put in place to stop the particular accident from reoccurring.

1) 8th October 2001 – Source: http://www.nrw.qld.gov.au

Investigation Finding: An access ramp was being constructed in an open cut mine using a truck & shovel operation. At 10.50pm, while reversing the first load of the shift to a dump area, an operator of a rear dump truck drove over the rill on the edge of the dump resulting in the truck rolling over and coming to rest at the bottom of a 15m drop. As the truck rolled down the embankment, a rock entered the cab through the quarter panel window on the driver's side and smashed a hole through the passenger side window when the truck came to rest. The operator, who was restrained by his seat belt, received no injuries.

Cause of Incident: The position of the lighting plant meant that the truck operator could not turn normally and therefore was unable to drive close to the dump area to observe any potential hazards, the height and size of the rill was inadequate and not identified as a risk by the operators, the dozer operator on night shift did not inspect his work area for hazards prior to allowing the trucks to commence and the dozer operator on night shift did not inspect his work area for hazards prior to allowing the trucks to commence.

Actions to be Taken: Develop/review procedures and standards for dump design and set-up particularly during hours of darkness. The standards must include widths and grades, lighting plant set-up and height and placement of rills. The material used to construct a rill must be consolidated to a standard that will stop the motion of a truck. Develop handover process/checklists for operating procedures and supervisors that include key standards for work areas.

2) 18th January 2003

Investigation Finding: A shovel operator was loading haul trucks on Ramp 1 South around 1am and he swung around to refill the bucket and picked up the electric shovel cable causing it to tear off the rear of the machine shutting it down instantly. The supervisor and electricians were called to the scene and a shutdown of the area and investigation were initialized.

Cause of Accident: It was found that there was inadequate lighting around the area where the shovel was operating in the pit.

Actions to be Taken: Replacement operation of electric shovel cable and investigation into better lighting systems for pit areas

3) 29th December 2005

Investigation Finding: Haul truck 841 had become bogged on top of coal at Ramp 3 South (undergrounds), while removing roof coal with the 3500 excavator. The truck became bogged on top of the old underground mines in the area when a soft spot was uncovered.

Cause of Accident: More lights in the area were required as the driver could not notice the breaking through of the underground section occurring. It's not unusual for this type of incident to occur.

Actions to be Taken: Dozer 531 was bought down from the dump area to tow the truck clear of the area so that the soft spot could be backfilled. Witches hats were used to demarcate area. When underground diggings are exposed they are to be demarcated and backfilled. Training for operators to be aware of there surroundings in underground areas was advised.

4) 1st June 2006

Investigation Finding: A 541 Dozer collided with a high-wall cable skid due to lack of vision and poor lighting. The operator was driving on top of the high-wall and realized he had run over an object. He exited from the vehicle to determine what had happened and noticed that a skid had been run over.

Cause of Accident: It was found that there was inefficient lighting in the area to be performing these tasks and possibly driver fatigue.

Actions to be Taken: It was determined that more lighting is needed when working in the area and better lighting systems should be placed on the dozer.

5) 21st August 2006

Investigation Finding: A shovel in ramp 3 north had shutdown for break down maintenance and all vehicles in the area including trucks 841, 842, 844 were instructed to park in a safe area by the high-wall. As truck 844 was reversing the vehicle to park near the high-wall it collided with the side of a 531 dozer tearing off the tilt ram hydraulic hoses.

Cause of Accident: The investigation found that there was insufficient lighting in the pit area and that the operator of the dozer should have had his lights on, even though parked for maintenance.

Actions to be Taken: Use spotters when reversing in unlit areas, better lighting in pit and machine operators to keep lighting on at all times when inside the mining pit area. Review training and pit policies to make employees aware of these situations.

5.3.2 Conclusion

All of the incidents listed above have all had one thing in common and this is that they have all occurred at night and the causes leading to the accidents were directly or partly related to having poor visibility of the working area due to inefficient lighting. These points show that most of the above accidents are against the regulations set out for lighting in Australia for open cut coal mines. The accidents shown above were of a significant risk to machinery and employees working in the area however these accidents were only minor compared to some of the fatal accidents that I have come across in my research. Due to the graphic nature of these incidents, I have chosen not to include these incidents in the scope of this project. Accidents are a part of mining and of course not all are caused by poor lighting, however these incidents are still a large issue and everything that can be done to reduce the incidents caused from poor lighting needs to be completed.

5.4 Incidents Investigation Conclusion

Mining incidents are a very important issue to mining operations and can be very serious in nature as was just shown in the above incident report findings. The main two types of incidents concerned with this project were incidents regarding high-wall slippages and the possible dangers with them and also incidents that have occurred in the actual mining pit. Both of these types of incidents were needed to be researched to help show the seriousness of the issues regarding high-wall slippages and the inadequate lighting situations in the coal mining pit. With that in mind it certainly makes the statements that high-wall setbacks were a necessary action to prevent high-wall slippages and in turn has led to the need for new lighting systems for illumination of the mining pit. The next chapter will culminate a lot of the factors and information gained in the previous chapters to help set the guidelines for the design of the new portable high-wall lighting plant.

Chapter 6

Conceptual Design

6.1 Introduction

This chapter contains many of the key ideas that will lead toward completing the final design for the new portable high-wall lighting plant. The conceptual design chapter includes a significant amount of the entire decision making process including the dimensioning, materials selection, positioning for use, and component selection and analysis for the new lighting plant design. When considering the best options for all of these factors it was important to gain an understanding of the previous versions of lighting plant that were researched, along with the current high-wall formations and lighting situations. The importance of researching these sections was so that it was possible to come up with the best conceptual ideas for each section of the new design and make it possible to overcome the current problems with high-wall setbacks and inefficient lighting. For any conceptual design there will be a number of objectives that the design must achieve. When taking into account the current lighting issues and the previous lighting plant designs I have decided upon a number of qualities that the new lighting plant must possess. The main qualities that the new lighting plant must include are that it must be portable and easy to transport, strong and reliable, it must provide efficient lighting and it must do this from a suitable and safe position. The next few sections in this chapter will explain the important design considerations for each aspect of the design and will conclude with the best option for each aspect of the design.

6.2 Positioning for the New Lighting Plant

The positioning of the lighting plant will play an important part when considering the design of the new lighting plant. Positioning is important due to the nature and size of coal mining operations. The main factors that positioning of the lighting plant will effect with regard to lighting situations include how efficient the lighting will be, the amount of shadows being produced, obstructions within the mining pit, glare and reflection.

6.2.1 Poor Lighting Plant Positioning

Knowing the layout of a mining pit including the low-wall, high-wall, coal seam and the mining pit itself, it is then necessary to determine the best suitable location for the lighting plant to be positioned. The best method to decide the location would be a process of elimination of the areas that are inappropriate for use. Efficient and safe lighting would not be possible from above the low-wall, above the coal face being mined and on the machinery itself.

Lighting above the low-wall (previously mined section) is not suitable for a lighting system as this section of the mining pit is unstable and consists of rocks and debris. The low-wall is also not accessible by vehicles which would make it almost impossible to transport and relocate the lighting plants as necessary.

Lighting from above the coal face is also unsuitable as this section will change in geometry quite regularly due to the mining processes and will also represent falling hazards.

Lighting on the equipment itself isn't completely ineffective however due to the rough nature of mining and the damage risks to the lights on the machinery. Other issues such as the fact that some of the machinery wont always be in the area and the machinery will me moving around a lot, it wont always provide effective lighting in the area, although it will help. The last issue is that coal dust and mud cause the machinery to get quite dirty at times and this will include the lighting systems on the vehicles.

So this leaves positioning for a new lighting system to be placed either in the mining pit itself or on the high-wall.

6.2.2 Lighting from within the Mining Pit

As mentioned earlier the mining pit area is a very populated area with many different types of machinery operating and moving around the mining pit area at all times. Although there is room to place lighting plant systems within the mining pit areas this would create hazards and obstacles for the operators to avoid. The Lunar Lighting Systems described earlier can be used within the mining pit area reasonably effectively however there are still numerous disadvantages with these systems such as it being an obstacle in the mining pit area, shadows being cast from being low to the ground mixed with the rough mining surface. This position will also create glare and reflection issues with the operator's windows and mirrors. With these disadvantages in mind an alternative position needs to be considered and this is lighting from on the high-wall.

6.2.3 Lighting from on the High-Wall

The high-wall has always been the most favored position for lighting systems as it eliminates hazards and obstacles from within the mining pit. The high-wall is also located in an efficient area of the mining pit to provide lighting directly onto the coal face and throughout the rest of the mining pit without hindering operator's vision with shadows, bright lights and glare. These factors are very important due to the nature of the mining operations being performed and miners at Blair Athol Coal agree that this position does help eliminate these issues. Many different instruments and equipment including electric shovel cables and pumping systems are regularly lowered over the high-wall as it is easily accessible by vehicles and is out of the way of other machinery. Although all these factors make this position appealing the current problem with high-wall set backs is still an issue and this will be explained in the next section.

6.2.4 Final Decision for Lighting Plant Positioning

After all options for lighting plant positioning being considered, lighting from on the high-wall itself appears to be the best location for the new lighting system, as there are more positive attributes in this location then any other positions. To overcome the issue of high-wall set backs, I have concluded that the lighting plant should be designed in a way that it can actually be lowered over the high-wall itself. The processes of lowering large heavy constructs over the high-wall is common practice in open cut coal mining operations as they lower the large electric shovel cables and pumping stations over the high-wall on a regular basis. Shown below in figure 6.1 is a simple representation of where the proposed new position of the lighting plant will be located. This position will allow very efficient lighting into the mining pit as it will be positioned perfectly to provide rays of lighting in almost all directions of the mining pit without interfering with any operators.

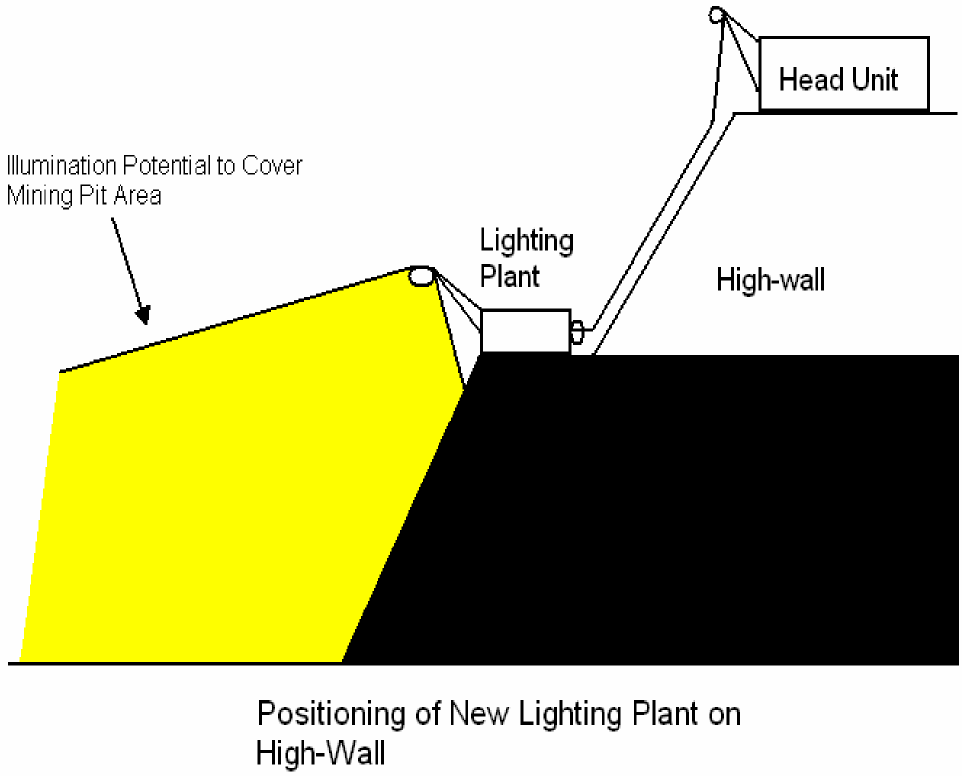

Figure 6.1 - Lighting Plant Positioning

The next section will include an analysis and selection of the components and major parts that will be included in the final design.

6.3 Components for the New Design

The overall engineering, component design and selection of the current lighting systems are quite good for each design. The problem exists not with the actual functioning of the designed systems but effectively getting the lighting from these systems into the mining pit. Basically the design that I have developed incorporates many of the positive aspects of previous designs and alters them so that the final design will be more effective then its predecessors. This means that the new design will have similar attributes to the previous designs however designed slightly different to take more advantage of the positive attributes.

6.3.1 The Two Major Constructs of the New Design

The new lighting plant system will essentially be constructed as two separate parts, a 'Head Unit' and the actual 'Lighting Plant' itself connected by electrical wiring and support cables. The assumed required components for the two entities are listed below along with an explanation of the expected applications of each component of the design.

<u>Head Unit:</u>

The 'head unit' is essentially the base of the lighting plant. The head unit will rest on the very top of the high-wall in a completely safe area so that employees can gain easy access to the controls so that they can be able to operate the lighting plant without having to worry as much about their well being. The head unit itself and all components will be situated within a trailer setup for easy transportation and ease of use. Most of the more complicated components of the high-wall lighting system will be contained in the head unit and they include:

- Frame/Trailer
- Substation / Lighting Plant Controls
- Motor
- Generator
- Cable Reel

<u>Lighting Plant:</u>

The actual lighting plant itself will be a simple construct consisting of lights and wheels connected to a light frame. The lighting plant can be designed so that it is light and strong enough to be lowered over the angled slope of the high-wall with ease. The lighting plant can be lowered over the high-wall with the use of a cable reel situated on the head-unit and can be controlled by the operator as it is lowered down using the substations controls. The cable reel will need to lower the lighting plant, electric wiring and some form of protective piping for the wiring over the edge of the high-wall. This method of lowering objects over the high-wall is very common practice in the mining industry as they lower the electric shovel cable over the high-wall using the Skid lighting system and also "Legra Pump Systems" to remove excess water from the mining pits. Therefore the ideology of a lighting system that can be lowered over the high-wall is also considered to be safe practice for the mining industry in all aspects. As seen in figure 11.1 there is a small flat ledge on the angled slope of the high-wall. Most high-walls have this ledge where the coal meets the overburden and it is approximately five meters in length which is a perfect position for the lighting plant to rest upon, even though it is not restrained to sitting only on this ledge. The few components that will be required for the lighting plant are listed below and include:

- Frame
- Lights
- Wheels

6.3.2 Components

Lights:

The overall design of the lighting system itself is of a smaller size then most of the lighting systems I have researched so that it can be lowered over the high-wall. To meet the requirements of the design to be light and smaller in size, I recommend that three 2000 Watt Metal Halide Lights be used. Other lighting systems can use anywhere from three to up to fifteen or more light bulbs in there design. The amount of Wattage for each light bulb varies with each design but most are 1500-2000 Watts. This will give a light output of approximately 580,000 Lumens which is rated for current lighting systems of this nature. In order for the lights to function correctly it is important that the other components in the design generate enough power to effectively to produce the appropriate level of lighting.

Motor:

The functionality of the motor is to provide power to the generator so that it can produce an electric current to run the lighting system and it is positioned on the head unit of the new design. In general, diesel engines are used for this type of system like most other lighting systems available. The design of the motor I will be recommending is that previously used by the Mid-Nite lighting system. The engine to be used will be a Perkins 403C-11 fuel efficient 3-cylinder diesel engine. This engine is a 1.3 liter engine that can generate up to 21 KW of power at 3400 rev/min. The engine has a life expectancy of around 6000 hours. The dimensions of the engine include a length of 491 mm, a width of 406 mm and a height 576 mm. The engine has a dry weight of 87 kg.

Generator:

The generator set as mentioned earlier is powered by the diesel engine and its functionality is to generate electrical power to the lights and cable reel. The generator used will also be a Perkins generator set and it is rated at 7kw, 240 Volts, 50 Hz and 1500 RPM.

Cable Reel:

The electric cable reel that I have selected for this purpose is a Hannay Reel. The motor is a DC electric motor and is rated at 6000 Watts total power at 12 volts with a circuit breaker of 25 amps.

6.3.3 System Diagram

Now that an analysis and summary of all of the components have been completed it is possible to draw a system diagram to show how each of these components form together to create the overall system design. Below in figure 6.2 is a system diagram showing all components and how they interact with each other for this system. Generally the motor is connected to the generator. From the generator the power is redirected to a substation in which the operator of the lighting system can activate both the cable reel and lighting system from one substation with the use of controls on the substation. The substation will allow this process using a series of switches. There will be a switch to activate power to the cable reel and a separate switch to lower or pull up the cable reel over the high-wall. The substation will also have a switch to activate the lighting system.

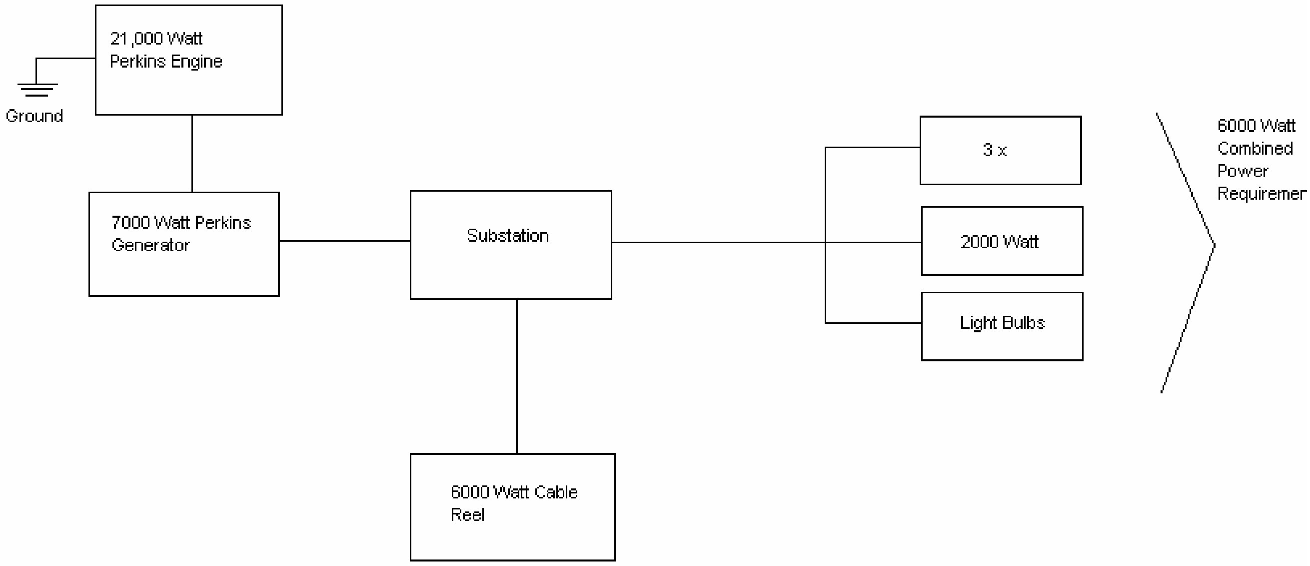

Figure 6.2 System Diagram of New Design

The Motor and Generator setup that has been selected for this design should have enough power to run the entire system. As the motor is connected in series with a generator rated to produce 7000 Watts of power there will be at least 7000 Watts of power available to run the other parts of the system. The cable reel system is rated at 6000 Watts so it is less power then what is being produced by the generator so the generator and motor will be efficient at running the cable reel. There are 3 x 2000 Watt light bulbs which are all rated at 2000 Watts each. Therefore the total power needed to run the 3 lights is also 6000 Watts and is under the energy producing capabilities of the chosen motor and generator setup.

6.3.4 Summary of System Components

In summary, the system components for the new design will be comprised of a motor, generator, cable reel and lights all setup on a trailer frame setting. All of these components when used together will be used to create power and enable the workings of the cable reel, hydraulic system and most importantly the actual lights. A system diagram has been shown to describe how each part has been placed and used within the system. The next section will incorporate the dimensioning and sizing aspects for the new design.

6.4 Dimensional Analysis

When determining specific dimensions for the design of a lighting plant, the main aspect that needs to be considered is the available space in the area where the lighting system will be used. Unfortunately not all coal mines are the same size, but most importantly the high-wall dimensions will be varied. Different high-wall sections can vary significantly from say ten meters in height to thirty meters in height. So the fixed dimensions of the lighting system may need to be varied to adapt to the different size high-walls at different mine sites. For this design I will simply use dimensions with regards to Blair Athol Coal and the high-walls experienced at their site. As there are two major constructs for the new lighting plant design, each will need to be examined separately.

6.4.1 The Head Unit

The constraints for the dimensions of the head unit will only require that it be large enough to contain all of the selected components. The section above the high-wall in which the head unit rests is normally a very large area that is yet to be mined and thus will not restrict the dimensions of the head unit to a great degree. The recommended trailer sizes and component sizes are shown below in figure 6.3. These dimensions are for a prototype design however and may change when actually constructed if needed, however all of the selected components fit on this structure. Essentially the trailer will be 2000 mm wide and a total length of 3750 mm.

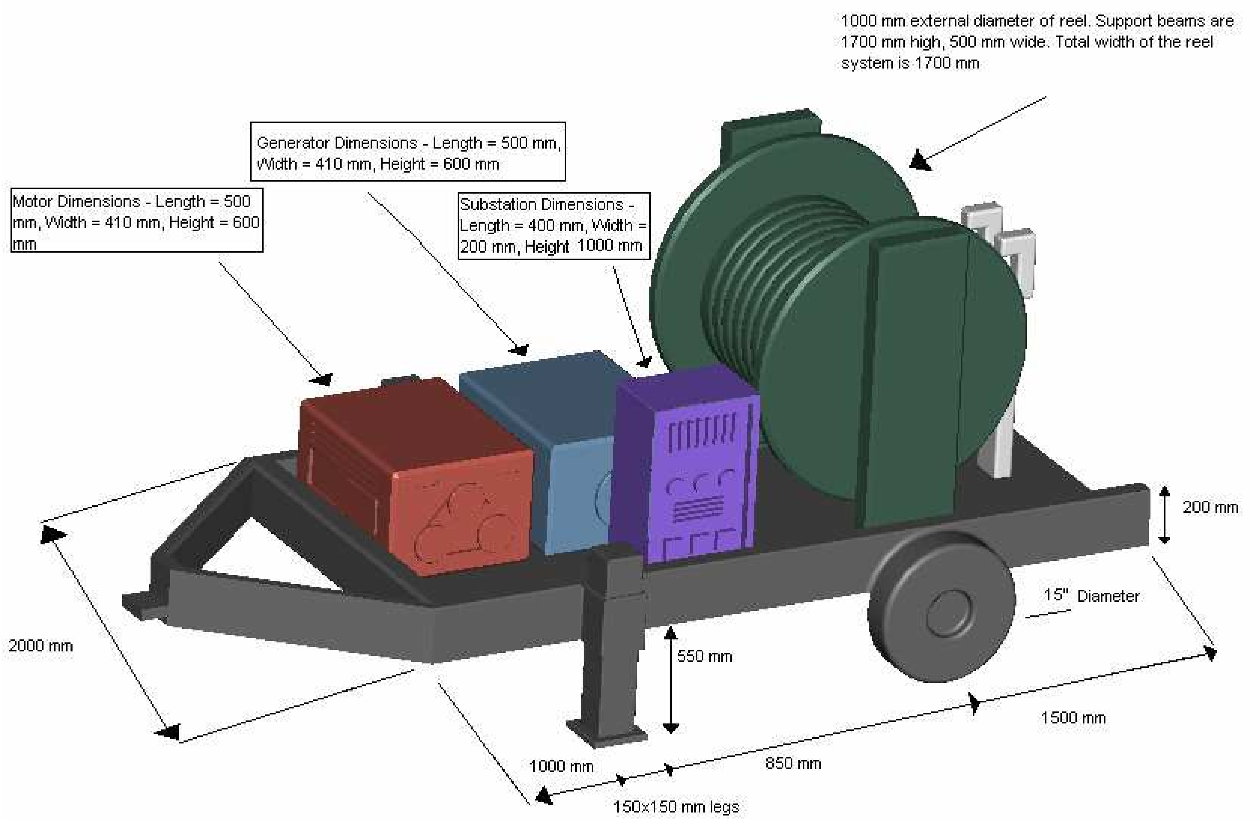

Figure 6.3 – Head Unit Dimensions

6.4.2 The Lighting plant

The dimensions of the lighting plant are more important to restrict as this is the object that will be lowered over the varied size high-wall sections. Depending on the size of the high-walls, the lighting plant size may also need to be altered to compensate for this, but for an initial design analysis the dimensions shown below in figures 6.4 and 6.5 should be suitable for mining high-walls similar in size to Blair Athol Coal mining pit high-walls.

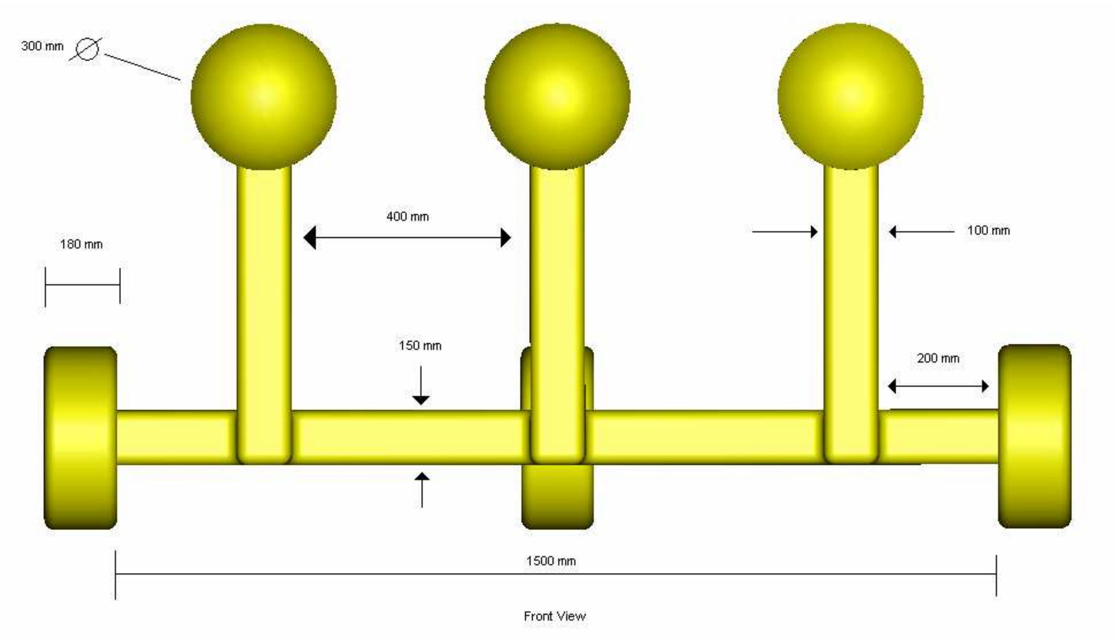

Figure 6.4 – Lighting Plant Dimensions (Front View)

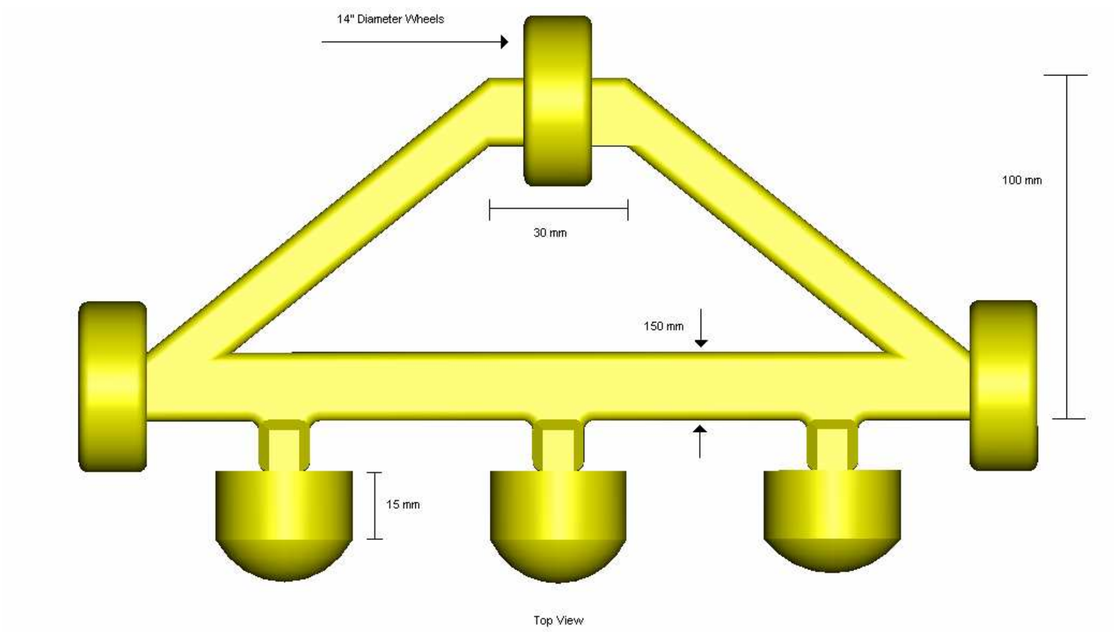

Figure 6.5 – Lighting Plant Dimensions (Top View)

The next section includes the materials selection and decision making processes for both components for the design of the new lighting plant system.

6.5 Materials Selection

Materials selection is a very important factor to consider when designing almost everything. Different materials can be used to show many different properties including strength, weight, corrosive resistance and many more. There are different types of materials for use in today's including plastics, metals and ceramics. Metals have very extensive use in society both in there original form and as an alloy. An alloy is a mixture of one or more metals to form a single substance which shows the combined properties of all the metals in the alloy mixture. A perfect example of where the methods of alloying are useful is when a material that is both strong and light in weight is required. An alloy of metals can then be created to give these qualities. In order to select the appropriate materials for the design of the new lighting plant an analysis of the design requirements and aspects will need to be performed. The design factors that need to be considered for the development of a lighting plant to be used on the high-wall are the mass of the lighting system components, the corrosive and abrasive resistance needed and the strength of the material, provided that these qualities don't come at too great of an expense. All of these material properties need to be considered separately for each component as both components serve different purposes. If they are investigated separately a better decision can be made for the material to be used for each part. A summary of the different material properties and how they will affect the design are given below.

6.5.1 Corrosive/Abrasive Resistance

As open cut coal mines are fully exposed to nature and the environment all forms of weather will be experienced including stormy conditions. As both of the major components will be exposed to these conditions the correct material to help protect the device needs to be selected to avoid corrosion. The other issue that needs to be considered is the nature of coal and debris. The high-wall consists of both of these substances along with other chemical based substances such as sulphur and debris. The material to be selected for both components will need to incorporate the resistance to corrosion and abrasion when dealing with these external substances. There are however other methods such as coatings and paints to help protect the selected material, however due to the nature of mining operations these are less reliable.

6.5.2 Strength of Material

The head unit will need to be designed and constructed strong enough to support the weight of all components resting on top of the trailer, but more importantly needs to be able to withstand the forces of supporting the lighting plant. The strength of the lighting plant also needs to be strong enough not to buckle while being suspended over the high-wall.

6.5.3 Materials Selection for the Head Unit

The head unit is the base of support for all major components and will essentially be in the form of a trailer. The head unit will not only need to be constructed sturdy enough to support all of the components such as the motor and generator but it will also be the only object supporting the weight of the lighting plant on the high-wall and the support cables. The mass of the head unit will therefore need to be relatively heavy and this will need to be considered when selecting the correct material. Steel is recommended for the base of the head unit as it is strong enough and heavy enough to support the components on the trailer and the weight of the lighting plant. The steel will be coated with a protective paint to help resist corrosion due to the weather conditions experienced.

6.5.4 Materials Selection for the Lighting Plant

The lighting plant will be constructed with an aluminium frame. Aluminium will be best served for the purposes of the lighting mechanism as it is relatively light in strength when compared with its strength and it has good corrosion resistance properties.

6.5.5 Materials Selection Summary

Now that all aspects involved with materials selection have been analyzed an engineering based decision can be made to determine the best material for the head unit and lighting plant separately.

The head unit in terms of its frame and base for all components would best be made from steel as it is strong, relatively heavy in weight, reasonably cheap and can resist the conditions that it will be experienced at an open cut coal mine.

The lighting plant frame and boom will be made from aluminium as it is strong, light in weight and corrosion resistant.

Chapter 7

New Portable High-Wall Lighting Plant Design

7.1 Introduction

The conceptual design chapter included research into many aspects that will need to be considered for the application into the final design. The final design chapter will sum up all of the features that were decided upon in the conceptual design chapter and also provide a few 3d modeling images created with Pro Engineer and these images represent the 2 major constructs of the new design for the portable high-wall lighting plant. The different aspects that were considered to develop the final design included research into the best positioning of the lighting plant on the coal mine site, all of the required components in order for the new design to function correctly, dimensioning analysis of the component and materials selection process.

7.2 Positioning for the New Lighting Plant

After all options for lighting plant positioning being considered, lighting from on the high-wall itself appears to be the best location for the new lighting system, as there are more positive attributes in this location then any other positions. To overcome the issue of high-wall set backs, I have concluded that the lighting plant should be designed in a way that it can actually be lowered over the high-wall itself. The processes of lowering large heavy constructs over the high-wall is common practice in open cut coal mining operations as they lower the large electric shovel cables and pumping stations over the high-wall on a regular basis. Shown below in figure 6.1 is a simple representation of where the proposed new position of the lighting plant will be located. This position will allow very efficient lighting into the mining pit as it will be positioned perfectly to provide rays of lighting in almost all directions of the mining pit without interfering with any operators.

In summary, the system components for the new design will be comprised of a motor, generator, cable reel and lights all setup on a trailer frame setting. All of these components when used together will be used to create power and enable the workings of the cable reel, hydraulic system and most importantly the actual lights. A system diagram has been shown to describe how each part has been placed and used within the system. The next section will incorporate the dimensioning and sizing aspects for the new design.

7.3 Components for the New Design

The required constructs for the lighting plant will include a head unit and lighting mechanism. This design will include all of the following for each part of the design.

7.3.1 The Head Unit

- Frame/Trailer
- Substation / Lighting Plant Controls
- Motor
- Generator
- Cable Reel

7.3.2 The Lighting plant

- Frame
- Lights
- Wheels

7.4 Dimensional Analysis

For all dimensioning relating to both parts of the design refer to chapter 6 for a summary and illustrations for the conceptual design.

7.5 Materials Selection

It was decided to construct the trailer from Steel and to construct the Lighting Mechanism from aluminium.

7.6 Design Illustrations

Pro engineer was used to create the 3d images shown below. Figure 7.1 represents the 3d modeled image for the head unit and figure 7.2 illustrates the 3d image of the lighting plant.

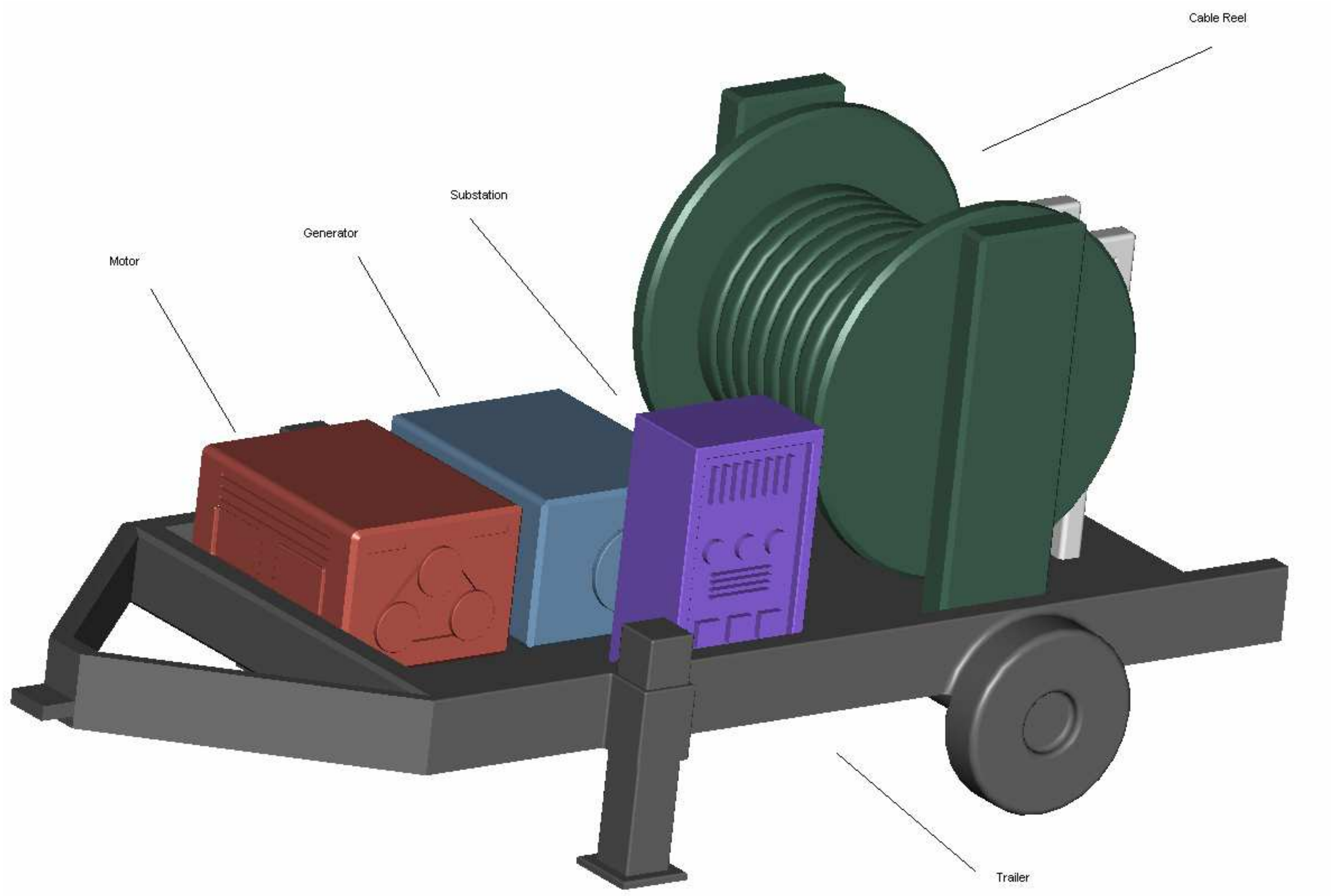

Figure 7.1 The Head Unit for the New Design

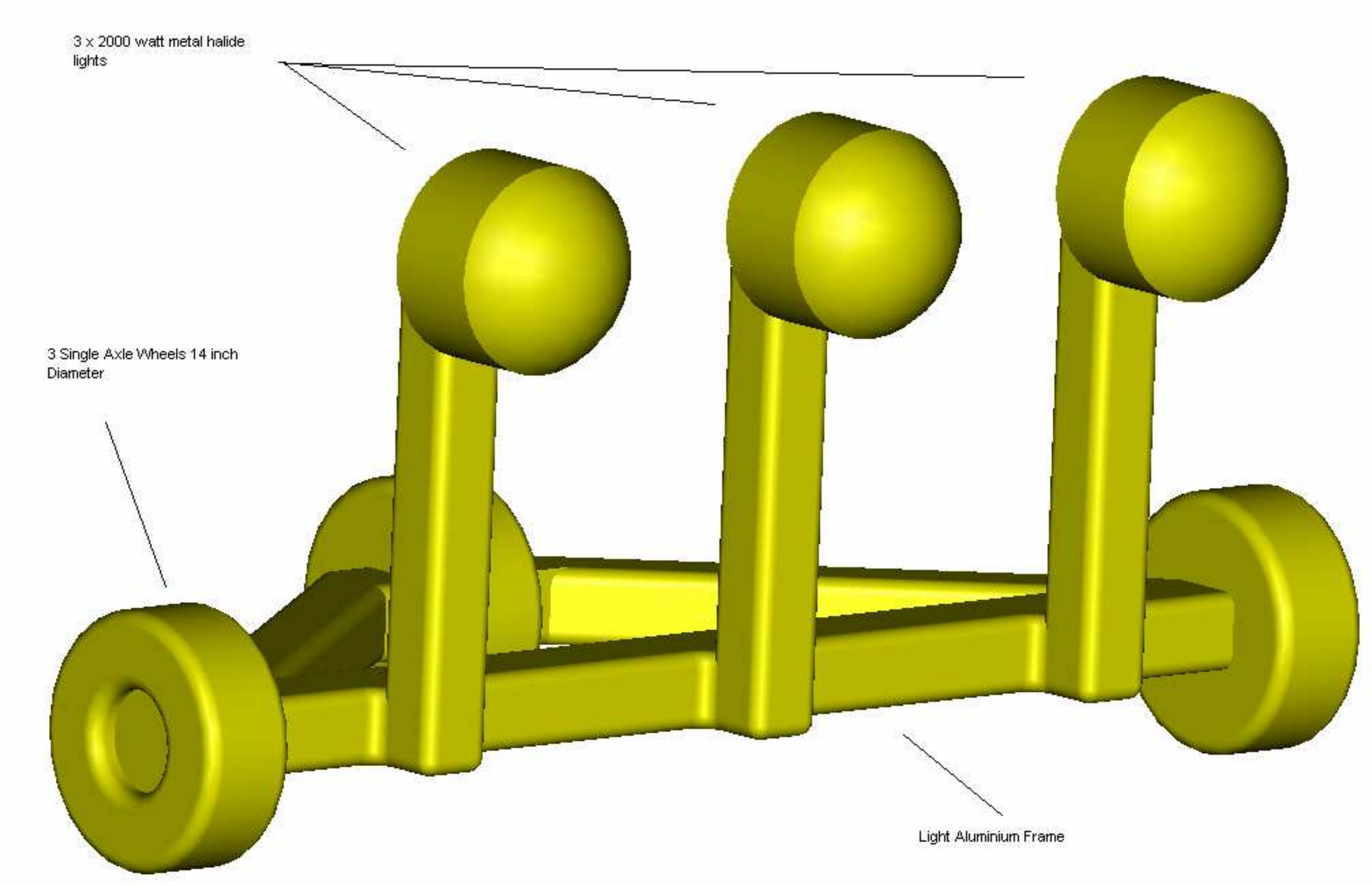

Figure 7.2 – The Lighting Plant

Chapter 8

Conclusion

When taking into account the nature of the mining operations being performed, the safety of the employees working in these areas and the size and cost of the vehicles involved with these operations it directly proves why efficient lighting is a very important aspect of coal mining operations at night. Visibility could be considered one of the most important factors to be able to mine and an imperative ability for operators of heavy machinery. Therefore the development of a new lighting system is undeniably a necessary consideration and an important step towards more efficient lighting and safe coal mining operations and practices at night.

8.1 Sustainability

With the implementation of a new lighting system the current issues including employee safety and work efficiency will be greatly improved within the mining pit areas. By implementing a new lighting system the mining pit will be more illuminated and therefore miners within the area will be able to have a much higher quality of visibility within the area. This will result in a much safer working environment while at the same time increasing the overall effectiveness of the mining operations in these areas. The overall effects of improved lighting, safety and worker efficiency will greatly increase the overall sustainability of the mine. If the current situation is overlooked for too long and the current lighting situations within the mining pit areas aren't improved there will be a higher cause for dramatic issues with human safety and potentially costly law suits against the mining operations and this effect could raise up to millions of dollars for these mines. The law suits that would be involved could be directly related to poor lighting and inefficient safety methods to improve the situation in the mining pit areas. The results of incorrect safety aspects and lighting within the mining pit areas are an important issue and should be taken seriously to maintain employee safety and further financial stability of the mining operations.

8.2 Ethical Responsibility

Employee safety is by far the most important aspect of mining operations along with essentially every industry in society. It is the mine owner's responsibility to provide a safe working environment and this especially means having efficient lighting while working with heavy machinery in the large open cut coal mining pits. By keeping the mining pit areas as illuminated as possible to enhance overall visibility in the area, the employer will be accepting and implementing the ethical responsibilities needed to provide a safer working environment for employees. With the development of a new lighting plant it will improve lighting dramatically within the mining pit and therefore the ethical responsibilities to provide a safer working environment will be fulfilled.

If the lighting regulation for Australian mines which was displayed earlier is examined in more depth it can be seen that every point within those regulations is directly related to increase the safety of the employee. These regulations also show the need for employers to provide the safest possible working conditions for all employees which is directly related to the ethical responsibilities of the employer.

8.3 Conclusion

With the lack of current lighting systems available for use in open cut mining operations in today's mining scene and the ineffectiveness of the current lighting systems, it can be seen why the development of a new lighting system is imperative to the mining industry. The safety of all employees is and always will be the main consideration of every mining operation and with that in mind an investigation into these matters was important to my research and to help prove the need for new lighting systems to be developed.

Coal mine operations are very large and complicated in nature and are almost constantly in operation. This means that for half the time that the machinery is operating it will be in the dark. Because of the nature of the mining pit and the machinery being operated within the mining pit areas, lighting plays a very important role in the mining processes at night. Without the use of an efficient and bright lighting source for the mining pit areas, the level of hazards and possible danger to the machine operators dramatically increase.

The overall aim of this research project was to investigate these coal mining operations and the lighting situations within coal mining pit areas and to then develop a conceptual design for a high-wall lighting plant and hence try to overall improve the lighting efficiency within the mining pit in the best method possible.

It is certain that the main problem with inefficient lighting into the coal mining pit areas is due to high-wall set backs. High-wall set backs were a necessary addition to mining sites to help prevent high-wall slippages and the possibility of harm to employees and machinery. Although high-wall set backs have reduced high-wall slippages significantly it has resulted in the loss of completely efficient lighting into the coal mining pit areas. From these facts it was then decided that the development of a new lighting plant system would be required to help overcome these problems and would be a very important step to keep efficient lighting into the coal mining pit.

After discovering all of the issues and problems limiting lighting into the coal mining pit area and learning about mine sites, the mining pit area and all its surrounding features I was able to develop a conceptual design for a new portable high-wall lighting plant. Although the design has not been finalized with exact components as of yet the ideology behind how the lighting plant itself and all the issues it solves are still recognizable. Great interest has been shown by Blair Athol Coal in the actual construction of a new lighting plant such as the one I have developed and it is something I will definitely be looking into in the near future.

Chapter 9

Further Work

Over the period of this year the issues of high-wall set backs continue to be a problem for mines around Australia. Blair Athol Coal had yet discovered a way to implement totally efficient lighting methods for the coal mining pit areas so it was simply decided to purchase Lighting systems at great expense to the mining organization. Although much research has been completed on the design of slopes and high-walls to help aid in its shape and positioning to avoid high-wall slippages they feel that it is still not enough to ensure the safety of the employees and machinery in the area and it has only just recently been decided to increase the angles of the high-wall slopes further back to help further prevent high-wall slippage. This means that lighting from above the high-wall will be made even more difficult once again and the current lighting systems available will be made more redundant. However this also makes the ideology of the design in which I have developed to be even more valuable. As my design can be used on the high-wall and the slope the angle at which the high-wall is set back is not an important factor as it is designed to compensate for this problem.

Further work for this research project would include construction and implementation of the new lighting plants to eliminate the problems with inefficient lighting into the coal mining pit areas. A comparison between the effectiveness of the new design compared with the older designs could then be completed. As mentioned earlier Blair Athol Coal mine and Gregory Coal Mine operations are greatly interested in the findings of my research and the ideas I have presented to them and it is something that they and I would most definitely like to be involved with in the future.

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1) Knowledge obtained from two different work experiences at Blair Athol Coal Mine and initial investigation into this matter. Personal communication with employees at Blair Athol Coal Mine, Queensland, has aided greatly with information and general aims and directions for the proceedings of this research project.

Appendix A

University of Southern Queensland
Faculty of Engineering and Surveying

ENG4111/2 Research Project
PROJECT SPECIFICATION

FOR:	Scott Leslie McKie
TOPIC:	Development of a Portable High-Wall Lighting System
SUPERVISORS:	Dr Selvan Pather
SPONSORSHIP:	Faculty of Engineering & Surveying
PROJECT AIM:	To investigate current lighting situations during night time coal mine operations and to perform research to improve the specific lighting conditions within the mining areas by the development of a new portable high-wall lighting system.

PROGRAM: **Issue A, 27 March 2007**

1. Conduct background research into coal mining operations, in particular open-cut mines.

2. Review rules and regulations governing light positioning, mining pit areas and obstructions within these areas.

3. Review and compare incidents caused directly from poor lighting situations in mining pit areas during night time operation of heavy machinery.

4. Develop conceptual designs for portable high-wall lighting system.

5. Select and develop detailed final design of lighting system.

As time permits:-

6. Construction and testing of portable high-wall lighting system.

7. Survey and assessment of trialed version of design.

8. Hence determine overall possible improvements gained from implementation of new portable high-wall lighting system.

Agreed:

____________ (Student) ________________(Supervisor)

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