STABILITY ANALYSIS OF CONSTRUCTION DESIGN RESERVOIR SLOPES BASED ON NUMERICAL SIMULATION AT ULU JELAI HYDROELECTRIC DAM PROJECT, CAMERON HIGHLAND, PAHANG, MALAYSIA

by

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ANALISIS KESTABILAN REKA BENTUK PEMBINAAN TAKUNGAN BERDASARKAN SIMULASI NUMERIK DI PROJEK EMPANGAN HIDROELEKTRIK ULU JELAI, CAMERON HIGHLAND, PAHANG, MALAYSIA

ABSTRAK

Suatu kajian di sepanjang rizab tebing kanan Empangan Susu dilakukan untuk menganalisis kestabilan cerun takungan. Nilai faktor keselamatan (FOS) dalam keadaan resapan mantap dan resapan sementara telah ditentukan dengan menggunakan Kaedah Unsur Terhingga-Pengurangan Kekuatan Ricih (FEM SSR). Sebanyak empat belas cerun telah dianalisis dalam kajian ini. Hanya cerun A1-A2 yang dianalisis di bawah resapan sementara memandangkan ia cerun kritikal dan berhampiran dengan empangan. Analisis kestabilan dilakukan berdasarkan kajian awal, keadaan geologi dan sifat geoteknik. Program RS2 9.0 digunakan untuk menjalankan analisis cerun takungan dalam pelbagai beban berdasarkan data-data geoteknik yang diperolehi. Berdasarkan nilai faktor keselamatan (FOS) analisis resapan berkeadaan mantap untuk cerun bawah keadaan normal, dapat disimpulkan bahawa cerun adalah selamat dan stabil kerana kebanyakan FOS yang ditentukan melebihi nilai FOS minimum 1.5. Sementara itu, FOS beberapa cerun dalam keadaan banjir yang berada di bawah FOS minimum 1.5 adalah stabil. FOS untuk lereng dalam keadaan susutan aras adalah melebihi FOS minimum sebanyak 1.25. Oleh itu, cerun tersebut dikategorikan selamat dan stabil. Berdasarkan analisis resapan sementara, cerun dianalisis bawah kekonduksian hidraulik tanah yang berbeza dengan kadar penurunan yang berbeza. Cerun A1-A2 telah gagal pada kadar pengeluaran 2 m/hari dengan kekonduksian hidraulik $1x10^{-6}$ m/s memandangkan kadar penurunan dalam paras air takungan lebih besar daripada kekonduksian

hidraulik. Oleh itu, sensitiviti paras air terhadap kestabilan cerun harus diberi perhatian dan ramalan keadaan air bawah tanah yang paling kritikal perlu dititikberatkan. Penyelenggaraan tetap sistem perparitan bawah tanah diperlukan untuk mencegah pengurangan kecekapan yang disebabkan oleh pengelodakan, kemerosotan pengedap atau pertumbuhan tumbuh-tumbuhan menghalang alur keluar.

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ABSTRACT

A slope stability study alongside the right bank rim of Susu Dam reservoir was conducted to analyse the stability of the reservoir slopes. The factors of safety (FOS) under the loadings of steady-state seepage and transient seepage condition were determined by using Finite Element Method-Shear Strength Reduction (FEM SSR). A total of fourteen slopes have been analysed in this study. Only a slope A1-A2 is analysed under transient seepage since it is a critical slope which is near to dam. The analysis of stability was conducted based on desk study, geological condition and geotechnical properties. A RS2 9.0 program was used to conduct the analysis of reservoir slope under various loading based on geotechnical data obtained. Based on the FOS of steady-state seepage analysis of the slopes under normal condition, it can be concluded that slopes are safe and stable since most of the determined FOS are beyond minimum FOS 1.5. However, the FOS of some of the slope under flood condition is below minimum FOS of 1.5. Meanwhile, the FOS of the slopes under drawdown condition was beyond minimum FOS of 1.2. Thus, the slopes are also considered stable. Based on transient seepage analysis, the slope was analysed under different hydraulic conductivity of the soil slope with different drawdown rates. Slope A1-A2 was failed under drawdown rates of 2 m/d with hydraulic conductivity of $1x10^{-6}$ m/s since the rate of decreases in the reservoir water level is greater than hydraulic conductivity. Therefore, sensitivity of the water level to the stability of the slope should be given more attention and prediction of worst groundwater condition

is necessary. A regular maintenance of subsurface drainage system is required to prevent reduction of efficiency caused by siltation, deterioration of seals or growth of vegetation blocking the outlet.

CHAPTER ONE

INTRODUCTION

1.1 Research Background

Reservoir provides a variety of advantage of human use. A reservoir is water storage which is usually constructed mainly for power generation, water supply or flood prevention. In hydroelectric power, reservoir water is stored at higher level than the turbines, which are housed in power station. The water will flow through the turbine to convert the energy of flowing water into mechanical energy. A hydroelectric generator converts this mechanical energy into electricity. Reservoir also can be used to control the amount of water flowing in river during heavy rain. It wills kept low water level of the river which is the floodwater is passed to downstream over a spillway when the reservoir gets too full.

However, the impoundment and change of water level in the reservoir will have great influence on slope stability. The raised of water level and drawdown operation of the reservoir will affect the groundwater levels, likely causing increased pore pressure within the soil and weathered rock that can result in instability of the slope. The stability of the slope needs to be taken into account for dam operations due to the major impact of a riverbank failure. A reservoir failure will result in a disaster incurring fatalities and serious economic loss. Analysis of the slope stability is necessary to understand their condition and in particularly their stability, deformations and reliability.

To solve this problem, slope stability analysis is performed to obtain the factor of safety of the slope by using the finite element method (RS2 version 9.0,

Rocscience). The data obtain from surface observation and sub-surface probing is used to model the critical slopes that are anticipated to be affected by the raised water level from the reservoir and also from the expected fluctuations in reservoir level that will change the groundwater regime in the slopes during operation of the hydroelectric scheme.

1.2 Site Location

The research area is located alongside the right bank rim of the reservoir over a distance of about 3.2 km where the Ulu Jelai Hydroelectric is located. The dam is located in the State of Pahang, in the district of the Cameron Highlands about 140 km north of Kuala Lumpur and 80 km east of west coast of mainland Malaysia. Figure 1.1 presents the location of the study area and Figure 1.2 presents the layout plan of study area.

The hydroelectric project comprises of Susu Dam and 85 m high Roller Compacted Concrete (RCC) dam on Sungai Bertam, two diversion weirs on Sungai Lemoi and Sungai Telom for the diversion of flows from adjacent catchments via 7.3 km and 8 km long transfer tunnels into Sungai Bertam, a 4 km main headrace tunnel, a 372 MW Underground Power Station and the required associated water conveyance and access road systems. The hydroelectric development will generate peaking energy to the national grid. The main features of the Ulu Jelai Hydroelectric were showed in Figure 1.3 and 1.4.

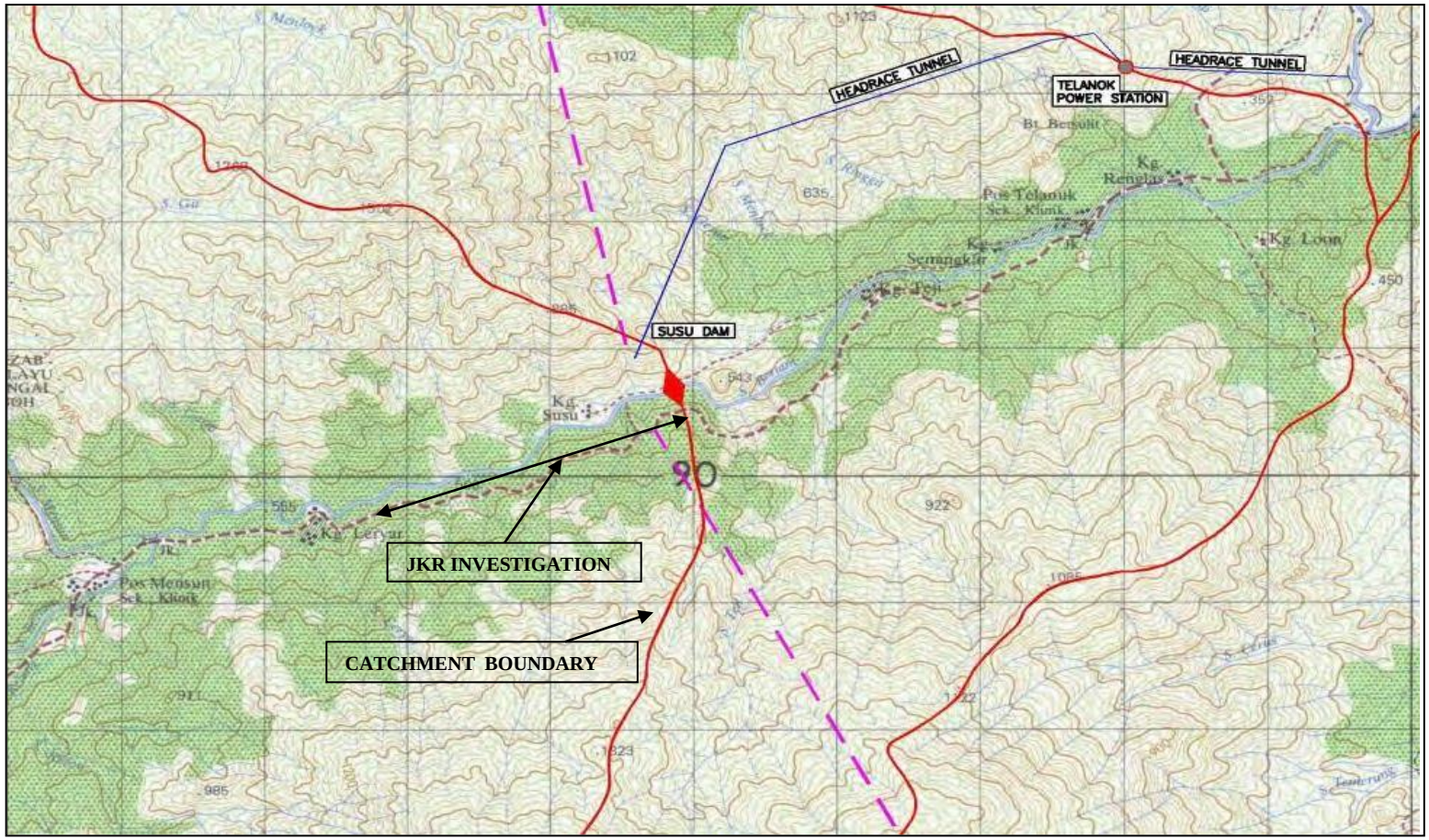

Figure 1.1 The location map of study area, after SMEC (2014)

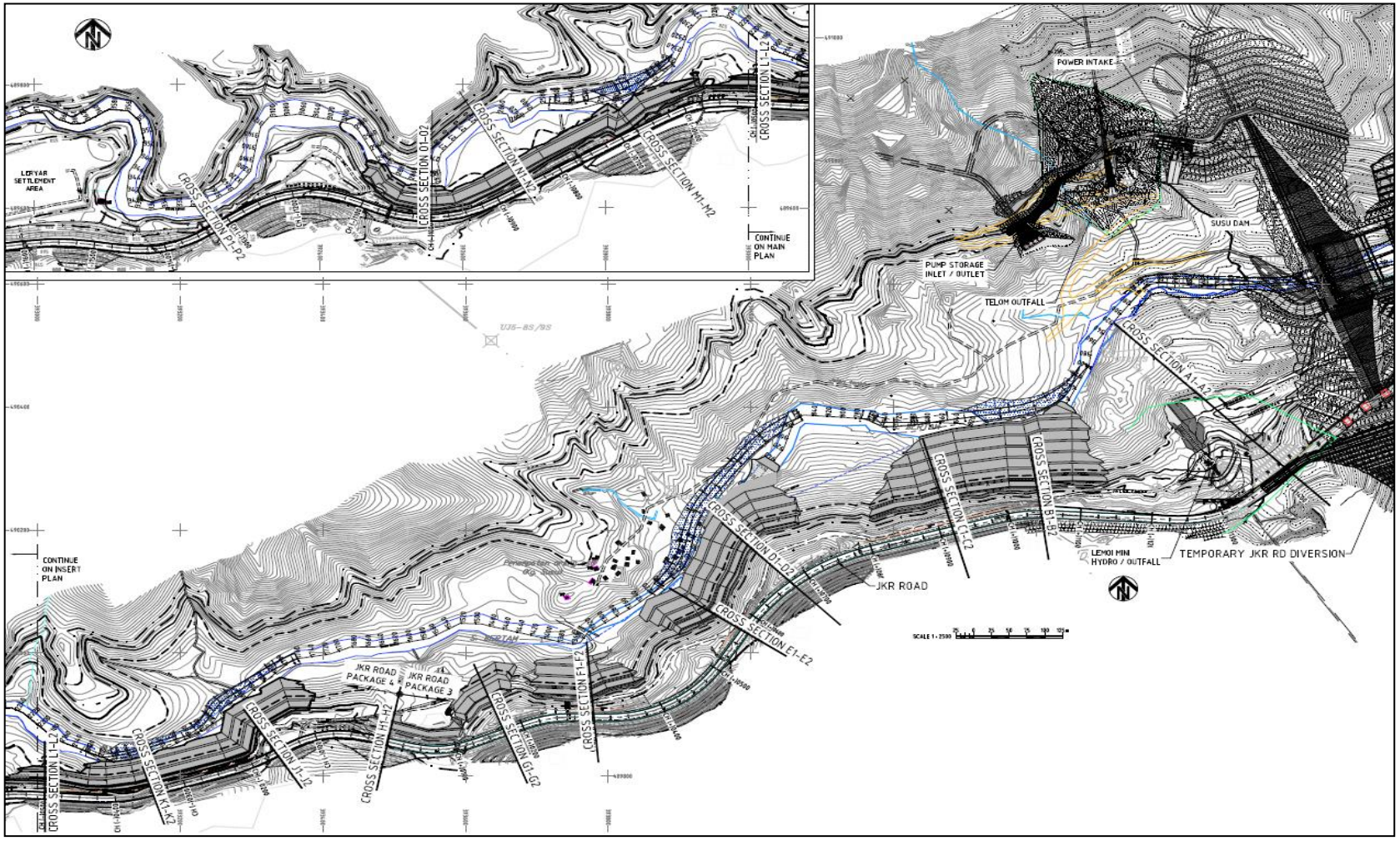

Figure 1.2 The layout plan of Ulu Jelai Hydroelectric dam, after SMEC (2014)

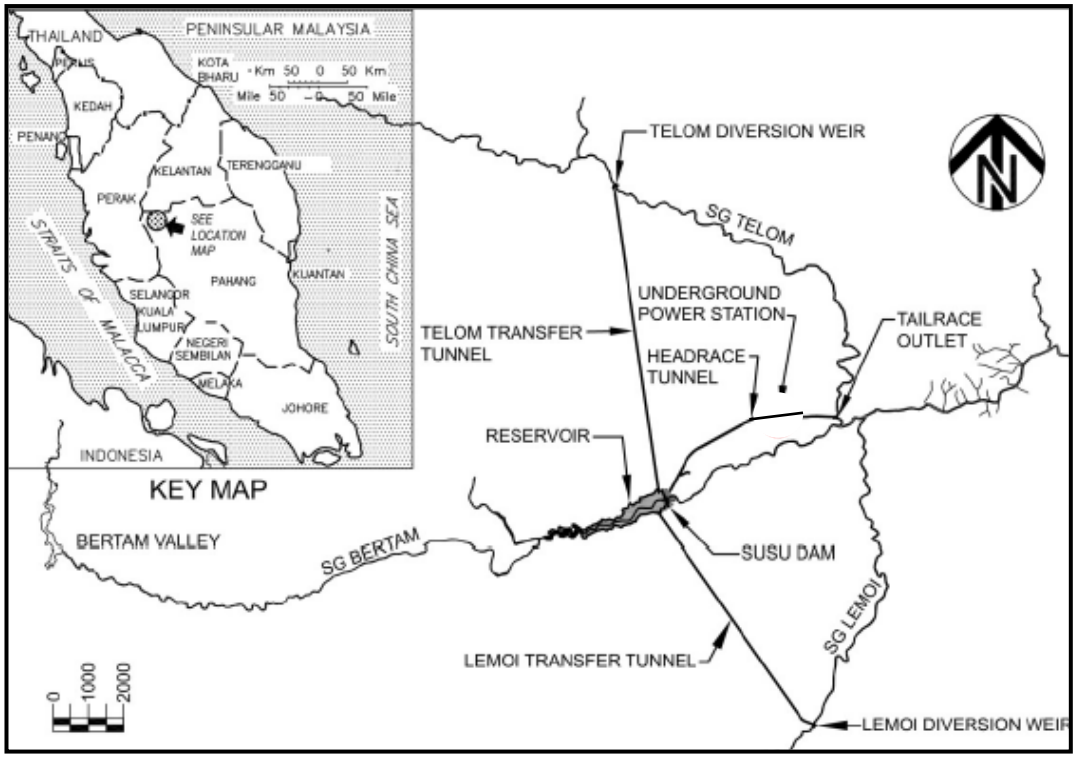

Figure 1.3 The main features of the Ulu Jelai hydroelectric project (SMEC, 2014)

Figure 1.4 Ulu Jelai Hydroelectric Dam (Sika, 2019)

1.3 Problem Statement

Jabatan Kerja Raya (JKR) Authority owns and maintains a recently opened section of the road from Ringlet down the Sg. Bertam valley and passing close to the Susu dam site. This road runs alongside the right bank rim of the proposed reservoir over a distance of about 3.2 km. The highway is about 10 m above the planned full supply level of the reservoir at EL 540 m. These intervening slopes are at natural gradients of 20 to 40 degrees. Figure 1.5 shows the photo of the right bank of reservoir slope.

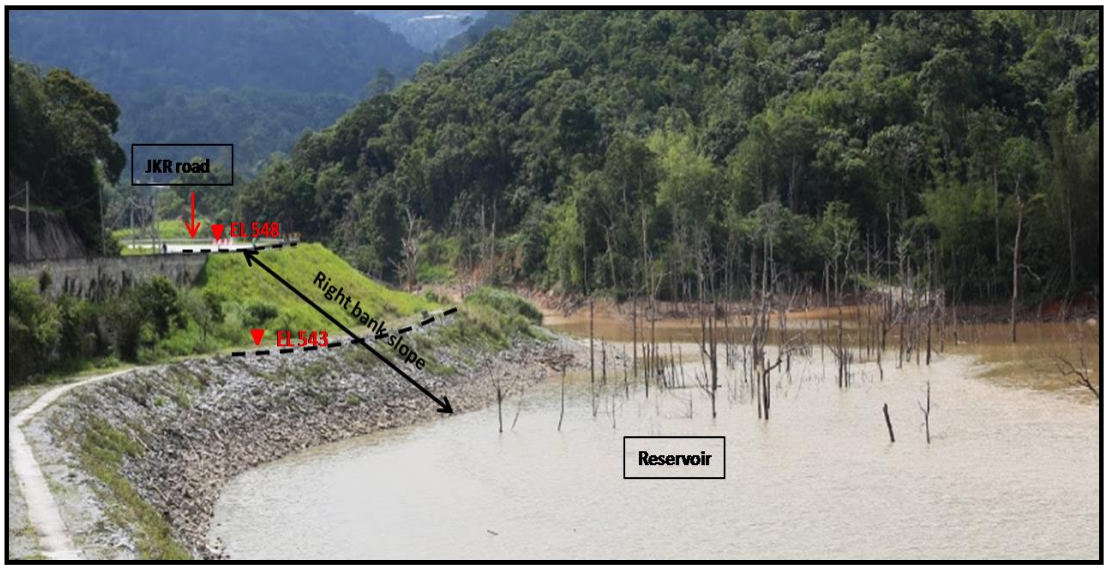

Figure 1.5 Photo of right bank slope of reservoir

The performance of this road is potentially affected by the filling of the reservoir and the fluctuations of reservoir level during operations of Susu Dam. The raised water level and drawdown operation of the reservoir will affect the groundwater levels. Pore pressure gaps and hydraulic gradients are potentially occurring as a consequence of rapid water level changes.

A decreased or fully vanished supporting water load combined with an increased pore pressure within the soil and weathered rock that can result in instability either the slopes below or above the road and the road bench itself. The change of the adjacent external water level causes the significant movements of water within the soil slope body and the seepage forces were found to adversely affect the stability. This relationship was also explained by Tohari et al. (2007).

It is necessary to undertake a comprehensive and detailed assessment of the slope stability along the highway to ensure traffic safety of the section of the highway affected by operation of the Ulu Jelai Hydroelectric. The shear strength reduction technique is used to define the stability of the slope. This method will reduce the strength until failure occurs.

1.4 Objectives of Study

The objectives of this study are listed as below.

i. To determine the representative geological and geotechnical properties of study area based on secondary data.
ii. To analyse the slope stability condition by using Finite Element Method-Shear Strength Reduction (FEM-SSR).
iii. To investigate the effect of water level variation on slope stability.

1.5 Approach of Study

In order to achieve the objectives of this study, the desk study is conducted to obtain sufficient information regarding the operational of the dam, geotechnical

design, geotechnical properties and geological condition of the reservoir slope. In this study, the entire data included laboratory testing data is provided by the company.

Then, the safety of the slope was evaluated based on its current construction design, the geological characteristics of the foundation and the physical properties of the construction materials. Next, the reservoir slope is modeled in RS2 9.0 by developing the cross-section models of the dam based on the information obtain from desk study. The properties of the soil materials were defined based on the laboratory test which is done by the Test Sdn. Bhd. Of Alam.Shah.

The reservoir slope is modeled under various conditions by using finite element method-shear strength reduction in order to determine its stability. Finally, after all the analyses were done, the results of the reservoir slopes were discussed.

1.6 Limitation of Study

All the geotechnical properties of the slope were obtained based on the secondary data that is provided by the contractor since the laboratory tests were done by the contractor. Then, the data obtained were used as input data for soil properties in RS2 9.0 program. Besides that, the slope stability analyses of the reservoir slopes model conducted using RS2 9.0 is in two-dimensional form. The failure criterion used in these models is Mohr-Coulomb and the hydraulic conductivity model used is based on the Van Genuchten (1980). The accuracy and a lot of various proven model parameters of different soil classes as compared to the other model are the reason the model is chosen.

1.7 Thesis Outline

The organization of this thesis is set out as follow. Chapter 1 Introduction presents the introduction to the case study such as general geology of the site, design and safety features of the structure studied, problem statements, objectives, significance, limitation and approach of the study. Chapter 2 Literature Reviews explains the concept and theory related to slope stability analysis such as basic requirement of slope stability analysis and condition of the analysis.

Chapter 3 Methodology explains the procedure used in determining the result starting from the desk study until modeling stages in related slope stability program and analyses the model slope. Chapter 4 Result and Discussion discusses about the result of the slope stability analysis. Lastly, Chapter 5 concludes the work presented and makes a case for the model in light of the objectives listed above. In addition, the recommendations for future studies are also mentioned in this chapter.