THE COMPARISON BETWEEN UNIVERSAL SOIL LOSS EQUATION (USLE) AND REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE) FOR ANNUAL SOIL LOSS ESTIMATION AT CONSTRUCTION SITE

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ABSTRACT

Developers and contractors nowadays need to be aware of the extent of soil erosion at construction sites by estimating annual soil loss precisely so Erosion and Sediment Control Plan (ESCP) can be implemented with reasonable cost. Soil erosion at construction site that mainly caused by massive earthworks activities could endanger environment by clogging drains with excessive sediments and conducing flash flood in a long term run. Hence, one of the objectives of this research is to determine a suitable method either by Universal Soil Loss Equation (USLE) or Revised Universal Soil Loss Equation (RUSLE) by comparing the soil loss rates and also differentiate the methods. Simultaneously, a RUSLE software program is developed. The study is conducted by comparing annual soil loss yielded by both USLE and RUSLE on a case study at Universiti Teknologi Mara (UiTM) Jasin, Melaka construction site on a 39.99 hectares land. Rate of soil loss is estimated during earthworks activity which considered being as worst case scenario. Rate of soil loss by USLE is obtained from Environment Impact Assessment (EIA) Report done by Europasia Engineering Sdn. Bhd. while rate of soil loss by RUSLE is calculated using the Erosion and Sediment Control Guideline provided by Department of Environment (DOE). Therefore, the RUSLE software program developed is used to assist in calculations. Conclusively, RUSLE suits to be practised in construction industry in order to approximate soil erosion rate.

ABSTRAK

Pada masa kini, para pemaju dan kontraktor perlu sedar akan kadar hakisan tanah di tapak pembinaan dengan menganggarkan kadar kehilangan tanah tahunan dengan tepat supaya Pelan Kawalan Hakisan dan Mendapan dapat dilaksanakan dengan kos yang berpatutan. Hakisan tanah yang disebabkan oleh aktiviti pembinaan secara besar-besaran adalah membahayakan alam sekitar. Pemendapan tanah berlebihan yang menyumbat longkang akan mengakibatkan banjir kilat dalam tempoh jangka masa yang panjang. Oleh itu, salah satu objektif kajian ini ialah untuk mengenalpasti satu kaedah yang bersesuaian dalam membuat anggaran kehilangan tanah samada dengan menggunakan *Universal Soil Loss Equation* (USLE) atau *Revised Universal Soil Loss Equation* (RUSLE) dengan cara membandingkan pengiraan dan faktor-faktor yang terdapat dalam kedua-dua kaedah. Pada masa yang sama, satu program perisian RUSLE dimajukan. Projek tahun akhir ini melibatkan kajian kes di tapak pembinaan Universiti Teknologi Mara (UiTM) Jasin, Melaka di atas tanah seluas 39.99 hektar. Kajian ini membandingkan kadar kehilangan tanah tahunan dengan menggunakan kaedah USLE dan RUSLE. Kadar kehilangan tanah yang dianggarkan ialah semasa aktiviti kerja-kerja tanah dan dianggap sebagai senario kes paling buruk. Pengiraan data kadar kehilangan tanah yang dibuat dengan mengunakan USLE ini diperolehi dari laporan Penilaian Kesan Alam Sekitar yang disediakan oleh Europasia Engineering Sdn. Bhd. manakala kadar kehilangan tanah oleh RUSLE pula dikira dengan menggunakan garis Panduan Kawalan Hakisan dan Mendapan yang disediakan oleh Jabatan Alam Sekitar (JAS). Dengan itu, program perisian RUSLE dapat membantu pengiraan. Kesimpulannya, RUSLE ialah cara yang paling sesuai digunakan dalam industri pembinaan untuk menganggar kadar hakisan tanah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

USLE	-	Universal Soil Loss Equation
RUSLE	-	Revised Universal Soil Loss Equation
ESCP	-	Erosion and Sediment Control Plan
UiTM	-	Universiti Teknologi Mara
DOE	-	Department of Environment
ARS	-	Agricultural Research Service
DID	-	Department of Irrigation and Drainage
MSMA	-	Manual Saliran Mesra Alam
NDVI	-	Normalized Difference Vegetation Index
BMPs	-	Best Management Practice
EIA	-	Environmental Impact Assessment
PHP	-	Hypertext Preprocessor
Web SQL	-	Web Structured Query Language Database

LIST OF SYMBOLS

A	-	Annual Soil Loss
K	-	Soil Erodibility Factor
LS	-	Topographic Factor
R	-	Rainfall erosivity factor
C	-	Cover Factor
P	-	Practice Factor which represents the Soil Conservation Operations
M	-	(% silt + % very fine sand) x (100 - % clay)
E	-	Total Storm Energy
I_{30}	-	Maximum 30-min.
I_r	-	Intensity Rainfall Intensity
V_r	-	Duration of the Increment
i	-	Storm
j	-	Number of storms
N	-	Year Period
e_r	-	Rainfall Energy per unit
OM	-	% of organic matter
S	-	Soil Structure Code
β	-	Unit less Parameters
λ	-	Sheet flow path length (m or feet)
s	-	Average slope gradient (%)

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Soil erosion is the detachment, entrainment and transport of soil particles from their place of origin by the agents of erosion such as water, wind and gravity. It is a form of land degradation and can be categorized as either geological or accelerated erosion. The geological erosion is a natural process, occurs at rates ranging from virtually imperceptible soil creep to dramatic sudden landslides. Accelerated erosion are the results from human activities such as site clearing and earthworks and normally causes adverse impact to the environment because of nutrient losses and sediment outputs. The main focus of this research is soil erosion by earthworks activities that fall under the category of accelerated erosion. Earthworks process will produce sediments in massive amount throughout construction stage that may affect the environment in damaging ways such as polluting rivers with mud, dirtying access roads, conducing flash flood and also causing in higher maintenance of water treatment system. Therefore, to estimate the amount of soil loss, Wischmeier, Smith and others has developed the Universal Soil Loss Equation (USLE) in 1965. With additional research, USLE has been revised and another equation namely Revised Universal Soil Loss Equation (RUSLE) was produced in 1997 whereby the formula remained the same but has several detailed improvements in determining factors. The improvements made are revised isoerodent maps, a time-varying approach for soil erodibility factor, a sub factor approach for evaluating the cover management factor, a new equation to reflect slope length and steepness and lastly is new conservation-practice values. Therefore, this research targets to compare and differentiate between these equations in estimating soil loss from construction site in order to prevent further soil loss and in the same time to maximise the cost of soil loss preventive measures.

1.2 Problem Statement

Soil erosion at construction sites may occur due to several factors which are rainfall intensity, the type of soil present at project site, length and steepness of slopes and lastly, the preventive measures taken to overcome soil erosion such as slope turfing and sediment basin. As briefed previously, the massive amount of soil loss produced from earthworks activities will give adverse effects towards our environment in many damaging ways such as polluting rivers with mud, dirtying access roads, conducing flash flood and also causing in higher maintenance of water treatment system. Thus, Erosion and Sediment Control Plan (ESCP) need to be implemented in most major construction projects as preventive measures but will cost respective contractors a fortune, only if the rate of soil erosion is overestimated. Hence, rate of soil loss expectation needs to be accurate and precise so that the need of ESCP can be implemented without spending extra cost for unnecessary preventive measures and also without giving harm to environment and public.

1.3 Objectives

The main objective of this research is to determine one preferable equation between USLE or RUSLE to be used accurately in estimating soil loss amount from construction works especially earthworks. Therefore, rate of soil loss is compared between these two methods on a case study of Universiti Teknologi Mara (UiTM) Jasin Campus construction site. Hence, ESCP can be done effectively by contractors without having to spend an extra unnecessary cost.

Secondly, is to evaluate the efficiency and accuracy of the preferable equation by analysing the differences between USLE and RUSLE in order for developers to use it effectively in estimating rate of soil loss at construction sites.

Last but not least, a software program is developed to cater the calculation for annual soil loss at construction sites by the method of RUSLE using Department of Environment (DOE) Erosion and Sediment Control Guideline.

1.4 Scope of Works

This research takes place of a case study in construction site for Universiti Teknologi Mara (UiTM) Jasin Campus on Lot PT1016 in Mukim Semujuk, District of Jasin, Melaka. The rates of soil loss are estimated during earthworks which reckoned to be under worst case scenario. Thus, the assumption made is no preventive measures are done during earthworks and the soil is considered to be bare. The total area of the project site is 79.22 ha whereby an area to be developed in this project site is 39.99 ha and the other area to be remained in its existing is 45.23 ha. In addition, in order to achieve the desired platform level, cut and fill activities are carried out to be approximately 150,000 m^3. Additionally, there are two directions of slopes presented at project site which are slope A and slope B as showed in Figure 1.1 and Figure 1.2 whereby for each slopes there are 58 points on project site taken for annual soil loss approximation. The type of soil presented is namely Malacca-Munchong-Durian series.

The methods being used to estimate annual soil loss amount is by Universal Soil Loss Equation (USLE) and secondly by Revised Universal Soil Loss Equation (RUSLE). Comparison between USLE and RUSLE is being done whereby the soil loss estimation by USLE is done by Europasia Engineering Services Sdn. Bhd. stated in their EIA report. On the other hand, the soil loss estimation by RUSLE is calculated using guidance of Department of Environment (DOE) Erosion and Sediment Control Guideline. Basically, there are five factors to be considered in both equations and that are rainfall-runoff erosivity factor, soil erodibility factor, slope length and slope steepness factor, cover-management factor and support practice factor.

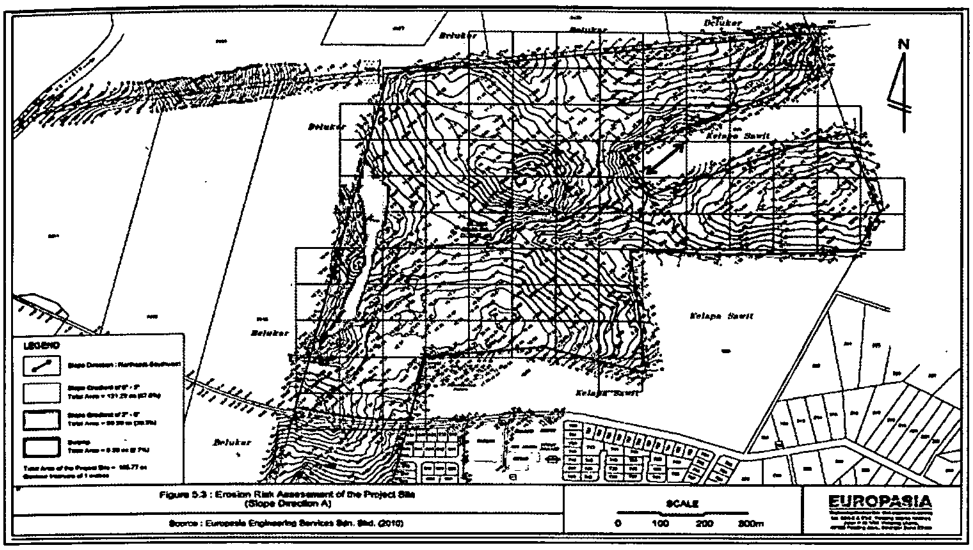

Figure 1.1: Slope Direction A at Construction Site (Based on Environment Impact Assessment (EIA) Report for the Proposed Universiti Teknologi Mara (UiTM) Jasin Campus, Melaka, 2010)

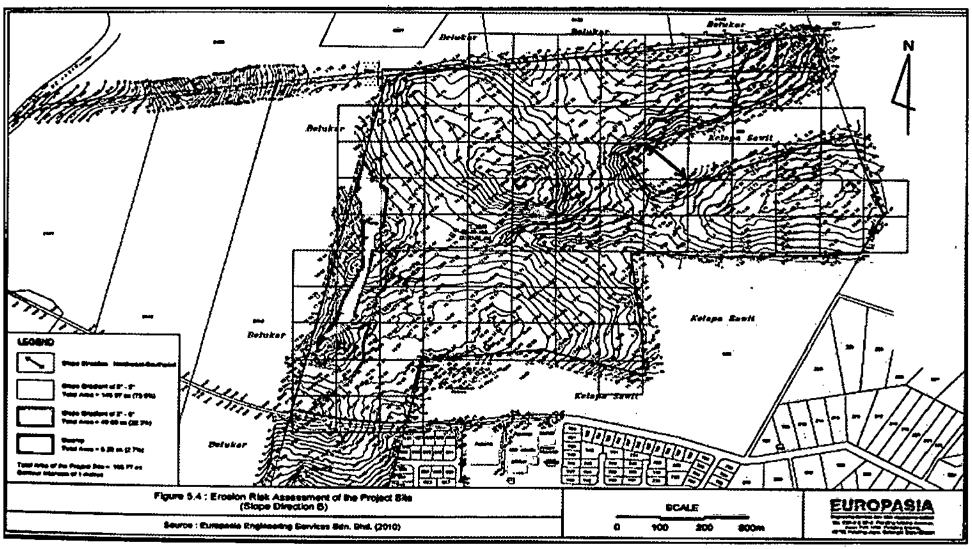

Figure 1.2: Slope Direction A at Universiti Teknologi Mara (UiTM) Jasin Campus Construction Site (Based on Environment Impact Assessment (EIA) Report for the Proposed Universiti Teknologi Mara (UiTM) Jasin Campus, Melaka, 2010)

1.5 Research Significance

The significance of this research is to determine either USLE or RUSLE desired to be used in soil loss estimation for construction projects particularly. As mentioned previously, massive soil loss from construction project will give negative effects to the environment therefore contractors are obligated to take preventive measures against this phenomenon by implementing a costly ESCP. Hence, hopefully by determining the most accurate way to calculate soil loss from construction project, contractors would make full use of the cost spent for ESCP without damaging our precious environment.

CHAPTER 2

LITERATURE REVIEW

2.1 Background

Erosion is the detachment of a portion of the soil profile or soil surface. This can occur by either the impact of raindrops, or by the shear forces of water flowing across the soil surface. Soil particles can be transported over a short distance (such as the splash from a raindrop impact), or a longer distance (to the bottom of the slope, or into a water conveyance) before being deposited. The transportation and deposition process is called sedimentation.

Erosion and sedimentation are natural processes. These processes occur daily, on all land, as the result of wind, and water. However, the effect of natural erosion is usually only noticeable on a geologic time scale. Disturbance of the soil surface, including activities like construction, farming, or logging, greatly increases the amount of sediment loss from the site due to erosion according by Price and Karesh, 2000 in DOE (1996).

Sediments that escape the site may eventually enter a stream or wetland, and changes the characteristics of a water body. These changes may result in physical hindrances to navigation or increased flood risks. Sedimentation in wetlands can alter the hydrology or destroy hydric vegetation. Sedimentation that occurs in streams can cover up habitat that certain integral parts of the food web rely on. Sediment may also smother nesting sites for fish or amphibians, or cover mussel beds that filter significant quantities of pollutants from water that ultimately becomes our drinking water according by Price and Karesh, 2000 in DOE (1996).

The average erosion from a designated area over a designated time may be computed by using the Revised Universal Soil Loss Equation (RUSLE). RUSLE is an erosion model developed by the U. S. Department of Agriculture to provide decision support in soil conservation planning. It is a set of mathematical equations used to determine what conservation practices might be applied to a landscape to reduce or limit the amount of erosion and sediment loss.

The original application for RUSLE was agriculture, primarily cropland production. Subsequent revisions have widened the program's applicability to be useful to other land-disturbing activities like mining, forest management, and construction sites.

The four major factors that RUSLE uses to compute the amount of soil loss from a site are: climate, soil erodibility, topography, and land use. The important climatic variables are the amount of rainfall and the intensity of the rainfall. Soils differ in their inherent erodibility, which is based on their properties such as texture, structure, porosity, and chemistry.

Climatic and soil variables are independent of the activities we undertake at a worksite, however, the length of time that a bare area is exposed to precipitation is considered within the climate factor of RUSLE and may considerably affect the soil loss from the worksite. In this way, phasing and sequencing the surface disturbing activities at a worksite reduces the erosion and reduces the amount of sediment that must be controlled by other means according by Price and Karesh, 2000 in DOE (1996).

By using RUSLE, it can be seen that a combination of erosion prevention, consisting of leaving original vegetation whenever possible and re-establishing vegetative cover as quickly as conditions allow, as well as sediment controls, like clean water diversions, silt fences, and sediment basins can prevent sediment loss from a construction site (or any other site) during most storm events according by Price and Karesh, 2000 in DOE (1996).

2.2 Introduction of Soil Erosion

Soil erosion is the detachment, entrainment, and transport of soil particles from their place of origin by the agents of erosion, such as water, wind, and gravity. It is a form of land degradation and can be categorised as either geological or accelerated surface soil erosion. The latter is a result from human activities that expose the soil surface and thus enabling erosive agents such as rain to wash away topsoil.

Dislodged soil particles are often stored within depressions in the land but may be dislodged during storm events. The amount of silt or sediment delivered into water systems through the processes of entrainment, transportation, and deposition is a function of changes in surface drainage patterns, terrain roughness, vegetation, and climatic conditions.

Water is the most significant agent of soil erosion. The removal of vegetative cover and the breakdown of soil structure through compaction and loss of organic matter often reduce infiltration and accelerate runoff and the entrainment of soil particles. The amount and sizes of soil particles transported as sediment increase as the volume and velocity of runoff increase.

2.3 Soil Erosion in Construction Sites

Bare eroding slopes (Figure 2.1) and drains choked with sediment (Figure 2.2) can often be observed at construction sites in developing areas throughout Malaysia. A number of measurements made indicate that massive amounts are transported from development sites. Sediment chokes urban waterways exacerbating flooding and often necessitating expensive river de-silting and training works (DOE, 1996).

Urban development in Malaysia was particularly rapid in Kuala Lumpur and their neighbouring urban centres in the past few decades. An untoward environmental effect of urban growth in the Kuala Lumpur area has been the frequent occurrence of excessive soil losses from construction sites and from sites cleared of vegetation but awaiting development. There has also been deterioration in a number of watercourses due to severe siltation. Detailed investigations of sediment yields have been carried out in Kuala Lumpur and Penang according by Douglas, 1978 in DOE (1996). Areas undergoing construction usually experience sediment yields 2 to 3 orders of magnitude greater than those under natural land cover conditions. In such catchments, the importance of extreme events is significant that between 35 and 80% of the annual load occurred in a single month. Small bare areas/construction sites such as on deeply weathered rock, particularly granites, can yield huge quantities of sediment in short periods of time.

Gullies are the major sediment source on exposed construction sites. Gullies increase in size more rapidly on fill materials than on cut slopes. Down cutting is the dominant gully enlargement process in cut material, while sidewall retreat dominates on fill (DOE, 1996).

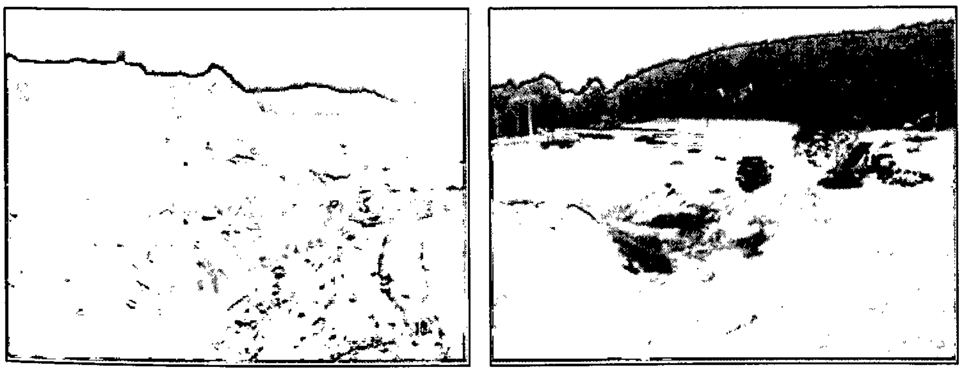

Figure 2.1: Large-scale earth works without erosion control (DOE, 1996)