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Artificial Intelligent Decision Support System for Sediment Capturing through Sediment Basins

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Abstract Soil erosion in areas interested with high rainfall intensities is an essential source of generating sediments that cause dramatic impact to the eco-system, disturb navigation, fills reservoirs, and the most important pollutes water with many deleterious substances. The main sources of soil erosion are the soil disturbance by cut and fill activities, moving of machinery and wind action. One of the most significant sediment capturing devices that are widely applied in the globe is the sediment basin which is a depression used to capture the water for some time and afterwards release it to the water body. Recently, the artificial intelligence was applied to combine the scientific understanding of the process of the natural world with the heuristic rules developed by managers through observation and experience. In this paper, a Sediment Capturing System (SCS) for designing the dry sediment basins which is suitable to be applied in Malaysia has been developed. The developed system is validated in which it proves that both of the system and the expert's opinions are almost matching which denotes that the system is intelligent and behaves like a human expert.

Keywords: sediment control; artificial intelligence, rainfall, storm water

1. Introduction

Construction site erosion causes serious and costly problems, both on-site and off-site. Waterborne soil erosion process begins by water falling as raindrops and flowing over bare soil surface [1]. The sediments that result from the erosion process will result in a significant cumulative impact downstream and over longer time periods [2]. Sedimentation may clog storm sewer systems, reduce reservoir storage capacity and hence increase flood frequencies of receiving streams and rivers [3]. The sediments will cover stream bed and will dramatically alter stream ecosystems. Nutrients associated with sediments contribute to the development of algal blooms, erosion of stream banks associated with increased frequency and magnitude of runoff events destroys riparian systems, and loss of topsoil from construction areas leaves behind less fertile subsoil which hinders re-vegetation of disturbed areas.

In Malaysia, land clearance due to land development has caused soil erosion and river siltation that lead to severe pollution of water [4]. DOE Report in year 2000 reported the high suspended solids in estuaries of Kuala Sg, Kurua Sg. Manjung in Perak, Kuala Sg. Linggi and Luku in Negri Sembilan; and Kuala Sg. Sebatu, Kuala Sg. Merlimau in Melaka; and Kuala Sg. Bernam in Selangor which has been attributed to activities like road construction. A study conducted by the DOE on 120 rivers and indicated that 13 rivers (10.8 percent) were significantly polluted while 47 rivers (39.2 percent) were slightly polluted. While other study on river pollution showed that 14 rivers were significantly polluted (11.7%) compared to the previous year [1].

Sediment control may be considered as the second line of defence and includes sedimentation ponds and silt or sediment barriers [5]. In this paper, an intelligent system is developed to enable the engineers and decision makers in designing the sediment basins which are used in Malaysian construction sites to capture the sediments generated from the eroded soils. The reason of selecting the design of the sediment basin is because it is the largest Best Management Practice (BMP) as compared with other BMPs that can capture the majority of the sediments before being disposed into the adjacent water body. The design includes the dry sediment basin. There are some expert systems have been developed to manage the storm water from construction sites [6] but more emphasis regarding the design of the most important sediment trap (i.e. sediment basins) need to be considered.

2. DESIGNING THE SEDIMENT BASIN MODULES

An SB typically consists of impoundments, a dam, a riser, pipe outlet, and an emergency spillway. The size of the structure will depend upon the location, size of the drainage area, soil type, land cover/use, rainfall amount, and any unique site conditions favorable to predict high runoff volume, velocity or sediment.

3. DESIGN OF SEDIMENT BASIN

The objective of this module is to provide the design of the dry SB. The design of the dry SB comprises of four main components. They are: sizing of the SB, sizing of emergency spillway, SB trapping efficiency, and SB maintenance frequency. This module is supported by a real design example for the dry SB. Details for each of these components are provided in the following sections.

4. SIZING THE DRY SEDIMENT BASIN

The objective of this sub module is to size the settling zone, sediment storage zone, and the overall SB dimensions. For most construction situations, the design storm should be a three-month ARI event and if the site is located upstream of an environmentally sensitive area or the construction duration exceeds two years, then six-month ARI event should be adopted [7].

This submodule is interconnected with the module of estimating the time of concentration since the time of concentration is necessary for the identification of total basin surface area and total basin volume. The required surface area and required surface volume data for the site are provided to the user via tabular data format (Table 1) and depends on the design storm whether it is moderate to high runoff or very high runoff. The volume of the settling zone should be half of the total basin volume.

But in areas interested in highly erodible soils, the sediment storage volume should be designed to retain a two-month soil loss.

Table 1: Sediment Basin Sizing Guidelines (Source: DID 2010)

Parameter	Design Storm	Time of Concentration of Basin Catchment (minutes)				
		10	20	30	45	60
Surface Area (m^2/ha)	Moderate to high runoff	333	250	200	158	121
	Very high runoff	n/a	500	400	300	250
Total Volume (m^3/ha)	Moderate to high runoff	400	300	240	190	145
	Very high runoff	n/a	600	480	360	300

For sizing of the settling zone, the user is required to estimate a value for the average basin width so as to calculate the settling zone length and average surface area of the settling zone. Checking of the settling zone dimensions is required in which the basin length to settling depth ratio should be less than 200:1 and if not, then the system shall ask the user to insert another value for the average basin width. The settling zone length to width ratio should be greater than 2:1. If these conditions do not exist, the system shall show a message to the user that baffles should be provided to prevent short-circuiting.

Volume of the sediment storage zone should be half of the total basin volume. For a side slope Z = 2(H): 1(V), the sediment storage length and width can be estimated. The required depth for the sediment storage zone, which must be at least 0.3 m, can be calculated as well in the system.

The overall basin dimensions such as width and length of basin at the top water level, and width and length of basin at the base of the basin can be estimated and other information like the settling zone depth, sediment storage zone depth, and side slope adopted are also provided to the user.

5. SIZING OF EMERGENCY SPILLWAY

The aim of this sub module is to size the emergency spillway. The user is required to estimate values for the orifice discharge coefficient and outlet riser pipe diameter since it is essential for the calculation of the riser discharge. This sub module is interconnected with the module of estimating the peak runoff since the peak runoff is required in the estimation of spillway discharge.

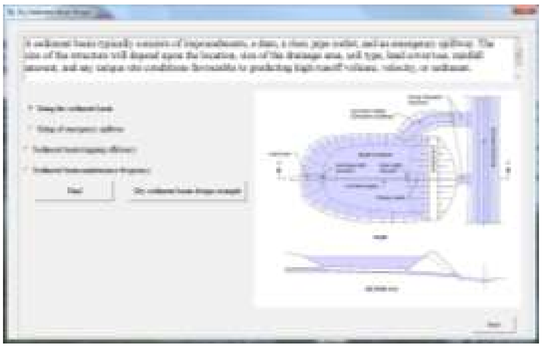
For estimating the spillway discharge coefficient, it is necessary to provide the system with trial dimensions for both of the spillway base width and the effective head on the spillway crest. The spillway discharge coefficient is provided via map based data (Figure 3) for each value of spillway base width and the effective head on the spillway crest. In this sub module, the spillway discharge coefficient multiplied by the spillway base width and the effective head of the spillway crest should be greater than or equal the value of the spillway discharge.

Finally, the user will be provided with the total basin depth including the spillway which is equal to the settling zone depth plus sediment storage zone depth plus the final value of the effective head on the spillway crest and the 0.3 meter (the least depth allowed for the sediment storage zone).

6. Sediment Basin Trapping Efficiency and Maintenance Frequency

The objective of this sub module is to estimate the trapping efficiency of the SB. It is recommended to trap at least 70 percent of coarse sediment greater than or equal to 0.02 mm particle size for the water quality design storm. That is why the total sediment trapped for the design event shall be 70 percent multiplied by the total sediment loss. Checking of the SB capacity shall be performed by checking that the total SB volume is larger than the total sediment trapped for the design event and if not, the system shall inform the user via message that the provided SB cannot contain the settled sediment. The percentage usage of the sediment storage volume is also estimated by dividing the total sediment trapped for the design event by the total sediment basin volume. In estimating the sediment basin maintenance frequency, the calculation of the number of storm events needing the SB to be maintained (i.e. the total SB volume divided by the total sediment trapped) is required.

SEDIMENT CAPTURING SYSTEM (SCS) DEVELOPMENT



The main interface of the SCS is shown in Figure 1

Figure 1: SCS Interface for Designing the Sediment Basin

Select "sizing of sediment basin" option as shown in Figure 2. First of all, the user is required to insert the area of the catchment in hectares. The value of the required surface area and the total volume required are inserted by clicking the "required surface area" and the "required total volume" buttons respectively. Double click the values of required surface area and total volume to be uploaded to the system. A soil erodibility map will be presented once the "Soil erodibility" button is clicked. The user is required to estimate a value for the average basin width and if the value estimated is not appropriate, then the user will be asked to insert another value of basin width.

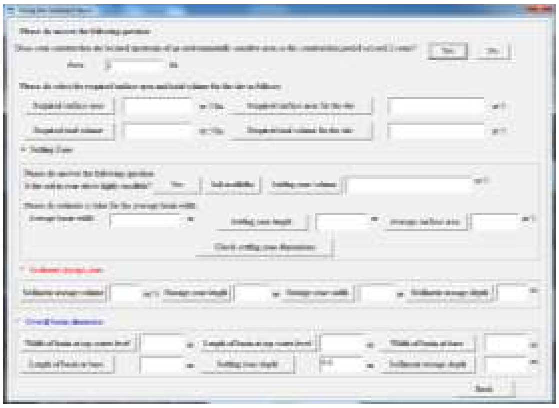


Figure 2: Sizing of the Sediment Basin Interface

a. Size the emergency spillway. For estimating the spillway discharge, the user is required to estimate values for the orifice discharge coefficients and the outlet riser pipe diameter. Besides, estimate values for the spillway discharge coefficient and effective head. Click the "Check for spillway capacity" button and the system will check the suitability of the inserted values, and if they are not suitable, the user will be asked to insert other values.
b. In estimating the SB trapping efficiency, the total sediment trapped for the design event will be estimated directly once the user clicks the "Total sediment trapped for the design event" button. Checking for SB capacity is an important consideration in the design of SBs. Click the "Check sediment basin capacity" button for checking. And to estimate the SB maintenance frequency, the number of storm events required for taking up the sediment volume will be estimated once the "number of storm events required for taken up the sediment volume" button is clicked.

7. SCS Validation

The developed system is validated using refined validation. The refined validation it composes of two main parts, the Field validation and the Turing test. The following paragraphs clarify each of the validation techniques in some more details.

8. Field Validation

In field validation, the date used is collected from construction site located in the north parts of Kuala Lumpur, Malaysia and more specifically in Kelantan. Results of the field validation are presented in Figure 3 below in which they show very high matching between the field results and the system's results.

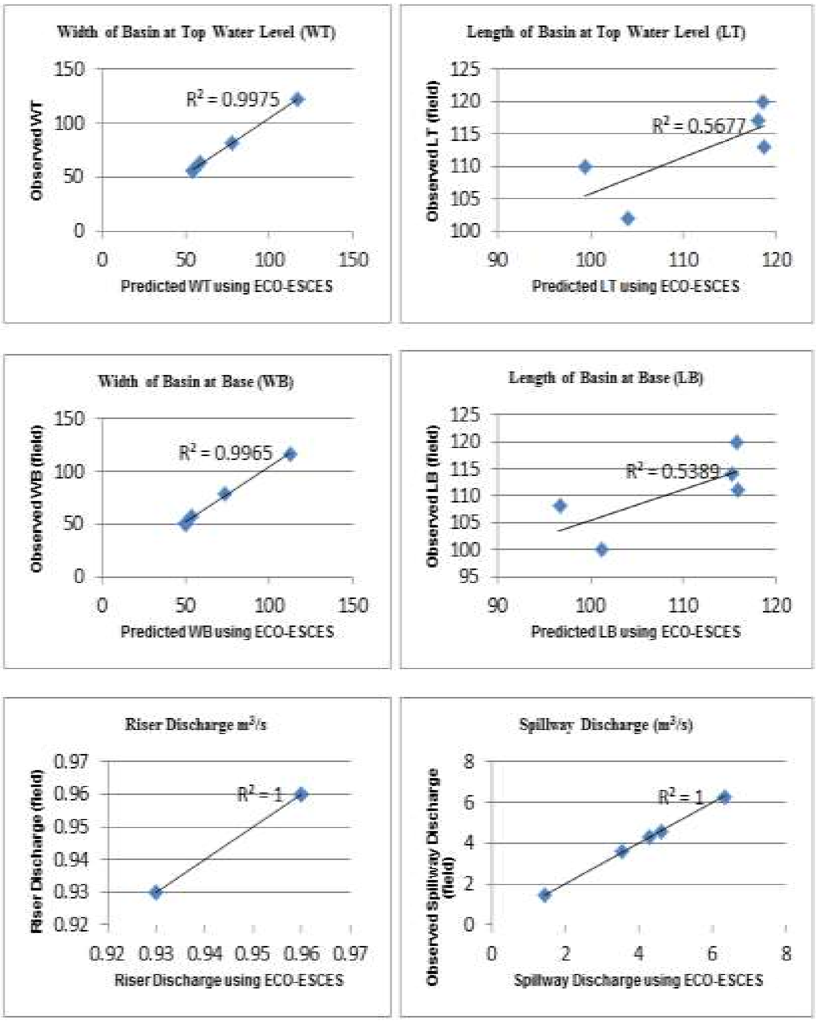


Figure 3: Results of Field Validation

9. Turing Test

To evaluate the developed system using the Turing Test, 10 sets of problem causes are randomly samples from the entire system. The Chi-Square Test is used to perform the Turing Test which is a statistical tool was applied. The following hypothesis was adopted:

Ho: There exists no distinguishable difference between system and experts.
H1: Some evidence exists for differential ability between system and experts in this task.
For checking these hypotheses with the Chi-Square test, the SPSS software was used.
Table 3 below presents the results obtained from the Turing Test.

Table 3: Results of the Turing Test

Event		Chi-Square value	Degree of Freedom (DF)	P-Value
Compatible	Non-compatible			
16	1	0.567	1	0.452

As shown in Table 4 above, the Chi-Square value obtained from the SPSS software equals to 0.567 with DF equals to 1. Results from the Chi-Square test indicate that there was no significant difference between the expected outcome and observed outcome of the external expert opinions and the system in solving the same problems. The P-Value accompanied with the Chi-Square test equals to 0.452 which is higher than 0.05 (the level of significance). Thus, the null hypothesis is accepted. This means that SCS is able to function/ perform as good as human experts.

10. Conclusions

SCS is transparent and flexible software which allows the user to perform the design easily by minimizing the consultation cost and time. The system developed can be considered as a training tool for the engineers to guide them in designing the dry sediment basin. Furthermore, the system can be considered as part of the "green Technology" since it helps in minimizing environmental impact (i.e. capturing the sediments and minimizes water pollution). It is recommended that the next version of the system involves the design of the wet sediment basin so as to obtain an integrated system that deals with the design anywhere in Malaysia and in other tropical countries that share the same climate. Furthermore, it is recommended to include the design of other best management practices such as silt trap, silt fence and other sediment control practices.

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