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Urbanization and sediment control using intelligent system

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Abstract
Soil erosion is one of the most important natural resources management problems in the world and the source of sediment that pollutes streams, fills reservoirs, and causes dramatic impact to the aquatic eco-system. Urbanisation is one of the significant agents of sediment generation due to soil disturbance and rainfall events. To capture the sediment generated from the construction before impacting the surrounding environment, a well-designed sediment basin is required. The use of knowledge-based systems has been significantly recognized as a way to combine scientific understanding of the process of the natural world with the heuristic rules developed by managers through observation and experience. In this paper, a rule-based decision support system has been developed for designing the dry and wet sediment basins for Malaysian construction sites using Visual Basic Tool. The design which is based on local studies and guidelines includes sizing the basin, sizing of emergency spillway, calculating the sediment basin trapping efficiency and maintenance frequency for both of the dry and wet basin. Preliminary validation, field validation and Turing test were applied for validating the developed system in which the results from this study showed 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. The system can be considered as a "green technology" tool since it minimizes environmental impact.

Keywords: Sediment; Urbanisation; Intelligent system; Stormwater.

1. Introduction

Erosion is a natural process by which soil and rock material are loosened, detached, and transported from their original place by the agents of water, wind, ice, and gravity. Natural erosion occurs primarily on a geologic timescale, but when human activities alter the landscape, the process of erosion can be greatly accelerated. 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].

Construction activities and associated grading activities typically are initiated with clearing and grubbing phases in which vegetation and other naturally occurring soil stabilising materials are removed from the construction site. The surface areas and slopes created by excavation or embankments are exposed to the erosive forces of wind and rain until the earthwork is completed and the grassy vegetation is restored or the surface is artificially stabilized [2]. Soil losses from erosion may be inconsequential when compared to the damage resulting from sediment transport and deposition into surface waterways [3]. Fish spawning areas and benthic habitats may be destroyed or damaged when sediment deposition covers stream and river bottoms [4]. Suspended solids also reduce light transmission, which limits in-stream photosynthesis and diminishes aquatic food supply and habitat. Suspended solids may also coat and abrade aquatic organisms, reduce surface water quality and suitability for various usages, and lead to diminished capacities of reservoirs or other conveyance systems via deposition. The eroded solids also may act as a transport medium for phosphorus, nitrogen, and toxic compounds [5].

The sediments that result from the erosion process will result in a significant cumulative impact downstream and over longer time periods [6]. Sedimentation may clog storm sewer systems, reduce reservoir storage capacity and hence increase flood frequencies of receiving streams and rivers [7]. 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 [8]. The Department of Environment (DOE) reported in the year 2000 that 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 have been attributed to activities like road construction. A study conducted by the DOE on 120 rivers has indicated that 13 rivers (10.8 percent) were significantly polluted while 47 rivers (39.2 percent) were slightly polluted. While another study on river pollution has showed that 14 rivers were significantly polluted (11.7%) compared to the previous measurement [1].

Efficient planning for erosion control necessitates a comprehensive consideration of site topography, drainage pattern, rainfall data, soil data, existing vegetation, off-site property (streams, lakes, and buildings), as well as accessible types and operational characteristics of the erosion control methods. There are many kinds of mitigation measures used so as to reduce the impact of construction on the receiving water body. The two most basic categories of temporary control methods for construction generated pollution are erosion control and sediment control or source management methods. Slope covering techniques (slope stabilization or erosion control) include temporary and permanent vegetation establishment, plastic sheeting, straw and wood fiber mulches, matting, netting, chemical stabilizers, or some combination of the above measures [9, 10]. Sediment control may be considered as the second line of defense and includes sedimentation ponds and silt or sediment barriers [11].

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 which can capture the majority of the sediments before being disposed into the adjacent water body. The design includes both of the dry and wet sediment basins. There are some expert systems which have been developed to manage the stormwater from construction sites [12] 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

A Sediment Basin (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. There are two types of SBs (dry and wet basins) and their suitability to be used in the site depends on the soil type (Table 1). The dry sediment basin receives the stormwater for some time and releases it, so it is dry when no stormwater received whilst the wet basin is wet all the times. Figure 1 shows the main components required in the design of the dry and wet sediment basins.

Table 1. Sediment basin types and design considerations [13].

Soil description	Soil type	Basin type	Design consideration
Coarse-grained sand, sandy loam: less than 33 percent < 0.02 mm	C	Dry	Settling velocity, sediment storage
Fine-grained loam, clay: more than 33 percent < 0.02 mm	F	Wet	Storm impoundment, sediment storage
Dispersible find-grained clays as per type F, more than 10 percent of dispersible material	D	Wet	Storm impoundment, sediment storage, assisted flocculation

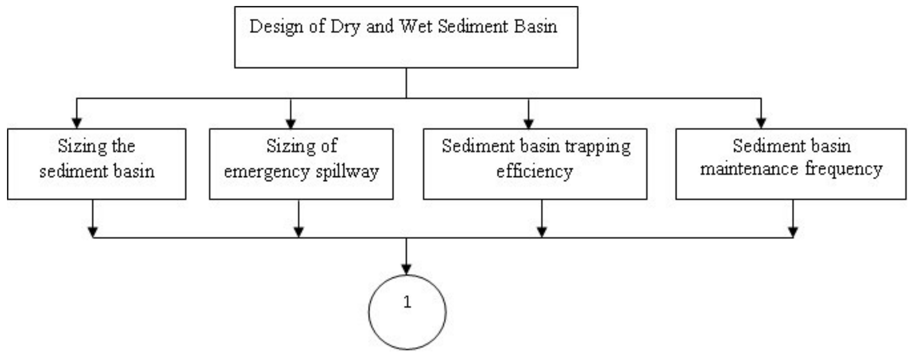


Figure 1. Sedimentation basin design.

2.1 Design of dry sediment basin

The objective of this module is to provide the design of the dry SB (see Figure 2). 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.

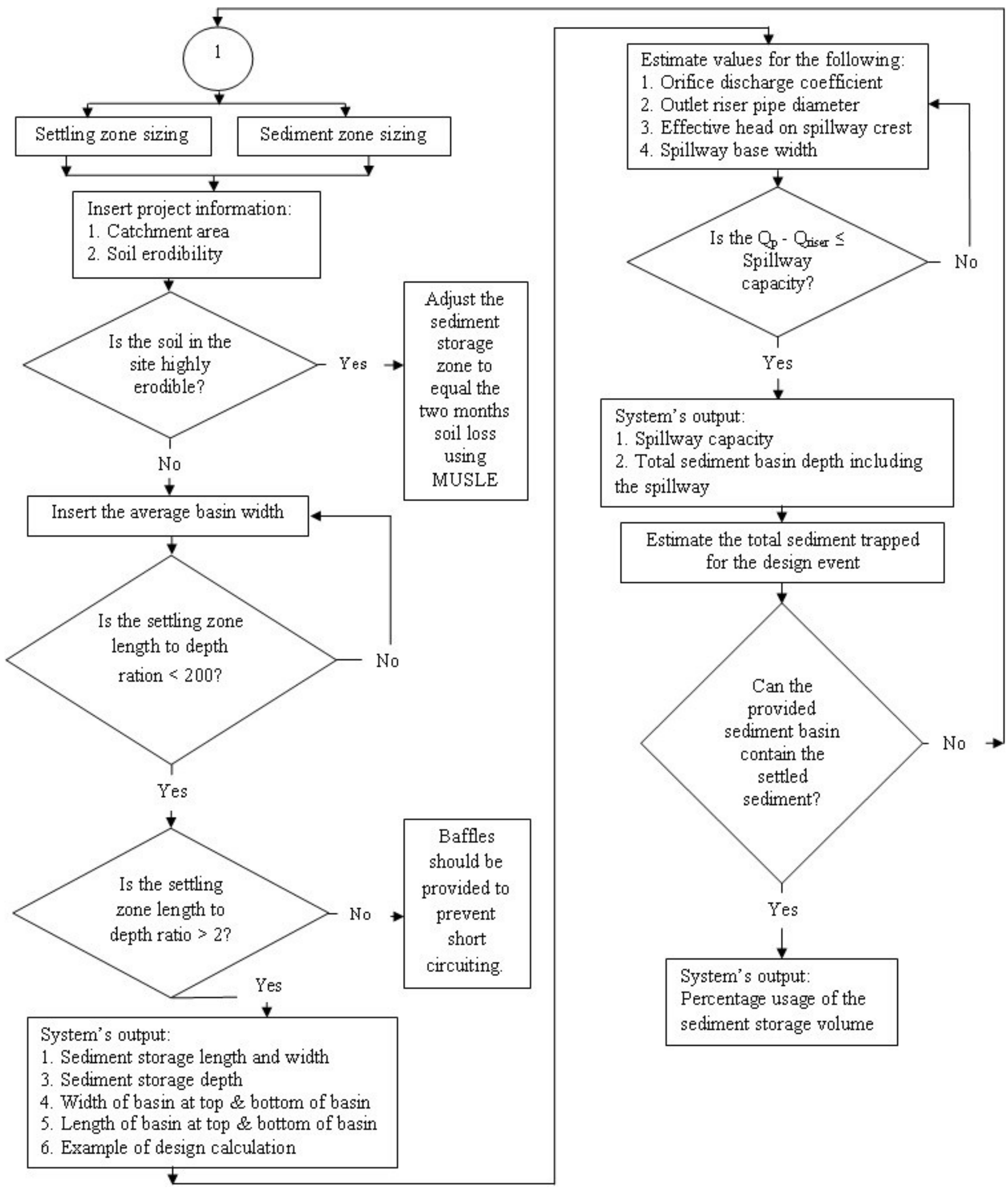


Figure 2. Flow chart for dry sediment basin design.

2.1.1 Sizing the dry sediment basin

The objective of this submodule 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 [13].

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 2) 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. In areas with high erodible soil, the sediment storage volume should be designed to retain a two-month soil loss from the disturbed area of the catchment using the Modified Universal Soil Loss Equation MUSLE (equation 1) [13].

$$Y=89.6(VQ_P)^{0.56}(K.LS.C.P) \tag{1}$$

where, Y: Sediment yield per storm event (tonnes), V: Runoff volume in cubic meter, Q_P: Peak discharge in m^3/s, K: Soil erodibility factor, LS: Slope length and slope steepness factor, C: Cropping management factor, P: Erosion control practice factor.

Table 2. Dry SB sizing guidelines [14].

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

$$L_1=V_1/(W_1*D_1) \tag{2}$$

where, L_1: Settling zone length, W_1: Settling zone width, D_1: Settling zone depth.

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 using equations 3 and 4 respectively. The required depth for the sediment storage zone, which must be at least 0.3 m, can be calculated from eq. 5.

$$L_2=L_1-2(D_1/2)Z \tag{3}$$

where, L_2: Sediment storage length, Z: Sediment storage zone side slope.

$$W_2=W_1-2(D_1/2)Z \tag{4}$$

where, W_2: Sediment storage width.

$$V_2=Z^2(Y_2)^3-Z(Y_2)^2(W_2+L_2)+Y_2(W_2*L_2) \tag{5}$$

where, V_2: Sediment storage volume, Y_2: Sediment storage depth.

In this submodule, the overall basin dimensions like 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 using equations 6, 7, 8, and 9 respectively. Other information like the settling zone depth, sediment storage zone depth, and side slope adopted are also provided to the user.

$$W_{TWL}=W_1+2(Z)(Y_1/2) \quad (6)$$

where, W_{TWL}: Width of basin at top water level.

$$L_{TWL}=L_1-2(Z)(Y_1/2) \quad (7)$$

where, L_{TWL}: Length of basin at top water level.

$$W_B=W_1-2(Z)((Y_1/2)+Y_2) \quad (8)$$

where, W_B: Width of basin at the base.

$$L_B=L_1-2(Z)((Y_1/2)+Y_2) \quad (9)$$

where, L_B: Length of basin at the base .

2.1.2 Sizing of emergency spillway

The aim of this submodule is to size the emergency spillway. In this submodule, 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 submodule is interconnected with the module of estimating the peak runoff since the peak runoff is required in the estimation of spillway discharge (equation 10). The riser discharge is estimated using equation 11.

$$Q_{Spillway}=Q_{10}-Q_{riser} \quad (10)$$

where, $Q_{Spillway}$: Spillway discharge in m^3/s. Q_{10}: Discharge of 10-year ARI estimated from the Rational Method in m^3/s, Q_{riser}: Riser discharge in m^3/s estimated from equation 11.

$$Q_{riser}=C_oA_o(2g(Y_1/2))^{1/2} \quad (11)$$

where, C_o: Orifice discharge coefficient, A_o: Outlet riser pipe area, g: Acceleration due to gravity (m/sec^2).

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 submodule, the spillway discharge coefficient multiplied by the spillway base width and the effective head of the spillway crest (equation 12) should be greater than or equal the value of the spillway discharge and if not, then the system shall ask the user to re-insert another trial dimension for both of the spillway base width and the effective head on the spillway crest.

$$Q_{spillway}=C_{SP}*B*H_P \quad (12)$$

where, C_{SP}: Spillway discharge coefficient (can be obtained from Figure 3), B: Spillway base width (m), H_P: Effective head on spillway crest (m).

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).

2.1.3 Dry sediment basin trapping efficiency

The objective of this submodule 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 [13]. That is why the total sediment trapped for the design event shall be 70 percent multiplied by the total sediment loss estimated from equation 13 [13]. 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.

$$A=R.K.LS.C.P \tag{13}$$

where, A= Computed soil loss per unit area. R= Rainfall factor converted to erosion index units (EI- units) for the period of consideration. The EI is a measure of the erosive force of a specific rain event. K= A soil erodibility factor depending on soil type. The erosion rate per unit of erosion index for a specific soil, on a plot of 9 percent slope and 22.1 m (72.6 ft) long. L= Slope length factor, the ratio of soil loss from the field slope length to that from 22.1 m length on the same soil type and gradient. S= Slope gradient factor; the ratio of soil loss from the field gradient to that from a 9 percent slope, on the same soil type and soil length. C= Cropping management factor, the ratio of soil loss from a field with specific cropping and management to that from the fallow condition on which the factor K is evaluated. P= Erosion control practice factor; the ratio of soil loss with contouring, strip-cropping or terracing to that with straight row farming, up-and-down slope.

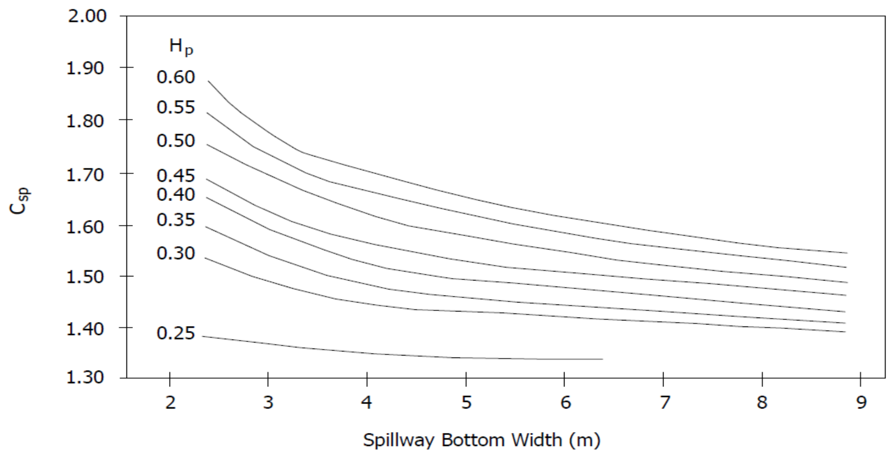


Figure 3. Spillway discharge coefficient [14].

2.1.4 Dry sediment basin maintenance frequency

The objective of this module is to estimate the SB maintenance frequency. This can be achieved by calculating the number of storm events needed for the SB to be maintained (i.e. the total SB volume divided by the total sediment trapped).

2.2 Design of wet sediment basin

The objective of this module is to design the wet SB as illustrated in Figure 4. 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. Like the dry SB, the design of the wet SB consists of four main components. They are: sizing the SB, sizing of emergency spillway, SB trapping efficiency, and SB maintenance frequency. Details of each of these components are provided in the following sections.

2.2.1 Sizing the wet sediment basin

In this submodule, the sizing of the settling zone, sediment storage zone, and overall wet SB dimensions were performed. This submodule has been interconnected with the module of rainfall design since the rainfall depth is necessary for the estimation of the settling zone volume and total basin volume. The required settling zone volume and total basin volume for the site were provided via tabular data format as shown in Table 3. The sediment storage volume should be designed to retain a two-month soil loss from the disturbed area of the catchment using (equation 1) described earlier.

Sediment storage zone volume should be one-third of the total basin volume. For a side slope Z = 2(H): 1(V), the sediment storage length and width can be estimated using equations 3 and 4 respectively. The required depth of the sediment storage zone, which must be at least 0.3 m, can be calculated from equation 5. The overall basin dimensions like width and length of basin at the top water level and width and length of basin at the base of the basin were estimated using equations 6, 7, 8, and 9 respectively as described earlier. Other information like the settling zone depth, sediment storage zone depth, and side slope adopted are also provided to the user.

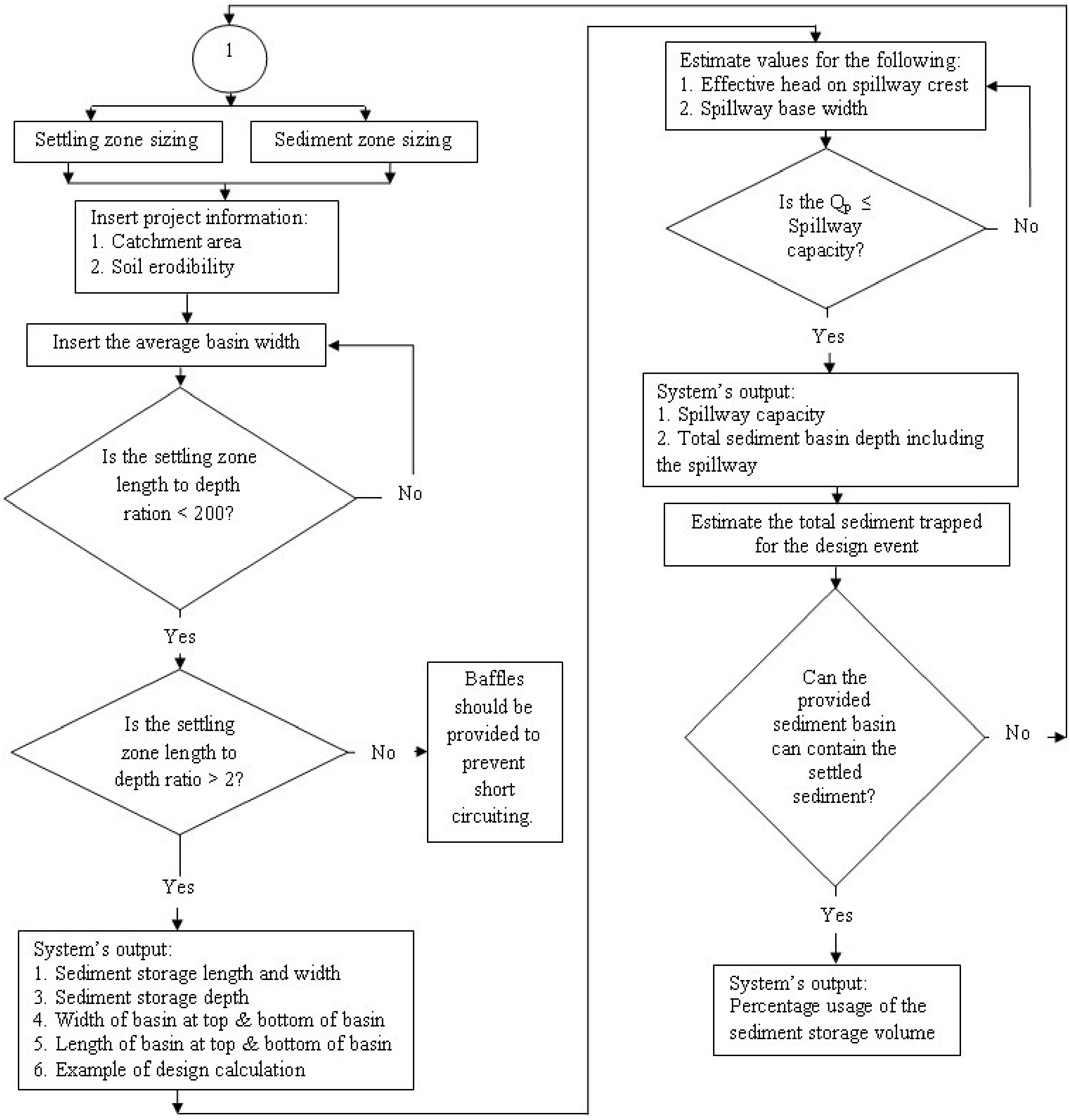


Figure 4. Flow chart for wet sediment basin design.

Table 3. Wet SB Sizing Guidelines [13, 14].

Parameter	Site Runoff Potential	Volume (m^3/ha of Catchment)				
		Magnitude of design storm event in mm				
		20	30	40	50	60
Settling Zone Volume	Moderate to high runoff	70	127	200	290	380
	Very high runoff	100	167	260	340	440
Total Volume	Moderate to high runoff	105	190	300	435	570
	Very high runoff	150	250	390	510	660

2.2.2 Sizing the emergency spillway

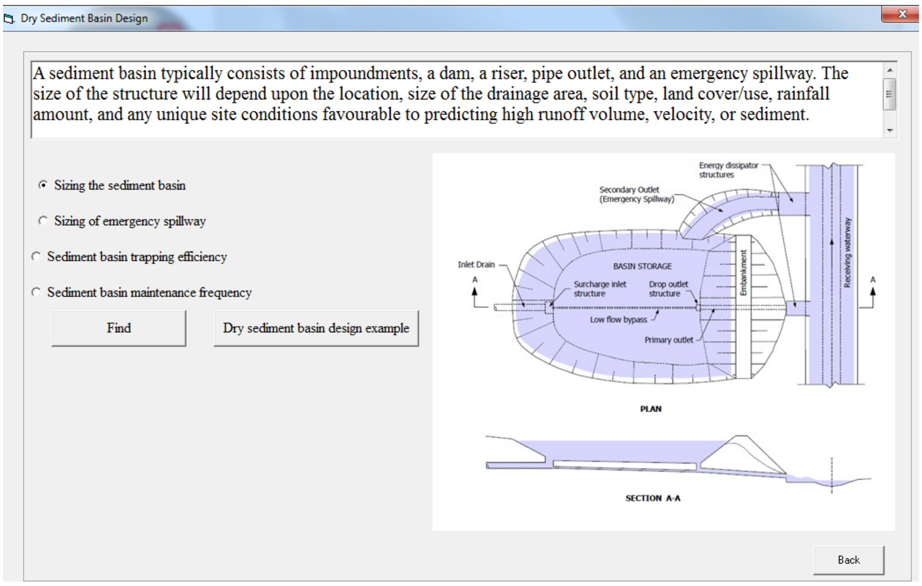
The objective of this module is to size the emergency spillway. It is recommended that the emergency spillway be designed for a 10-year ARI design storm. This submodule is interconnected with the module of estimating the peak runoff in which the peak runoff equals the spillway discharge.

For estimating the spillway discharge coefficient, the user is required to provide the system with a trial dimension for both of the spillway base width and the effective head on the spillway crest. Spillway discharge coefficient is presented to the user via a map based format (Figure 3) for each value of spillway base width and the effective head on the spillway crest. Spillway discharge is estimated using equation 12 described earlier. Checking of the spillway capacity is performed in which the spillway discharge coefficient multiplied by the spillway base width and the effective head of the spillway crest should be greater than or equal to the value of the spillway discharge. If not, then the system asks the user to re-insert another trial dimension for both the spillway base width and the effective head on the spillway crest. Finally, the user is 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.

3. Using the decision support system for sb design

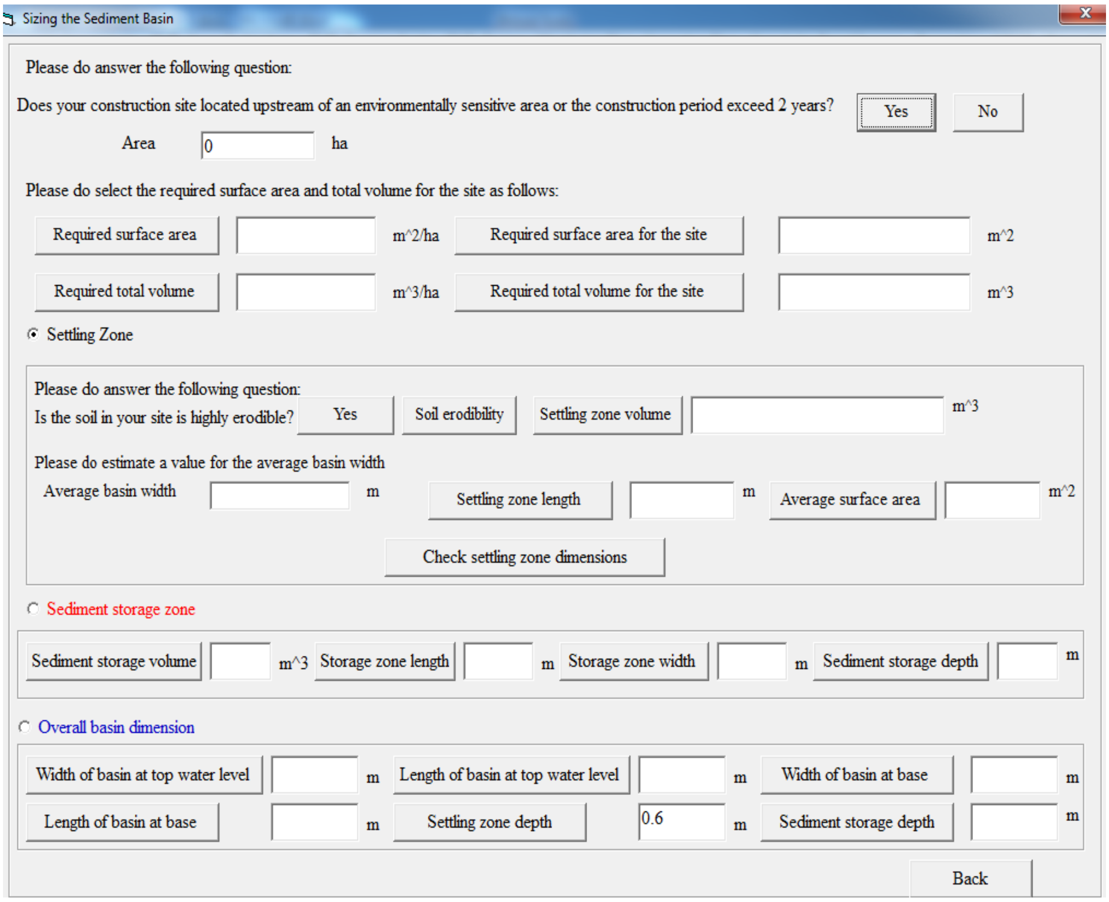
The main interface for the design of dry SB is shown in Figure 5a

a. Select "**sizing of sediment basin**" option as shown in Figure 5b. 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.
b. Size the emergency spillway as shown in Figure 5c. 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.
c. 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.
d. 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.

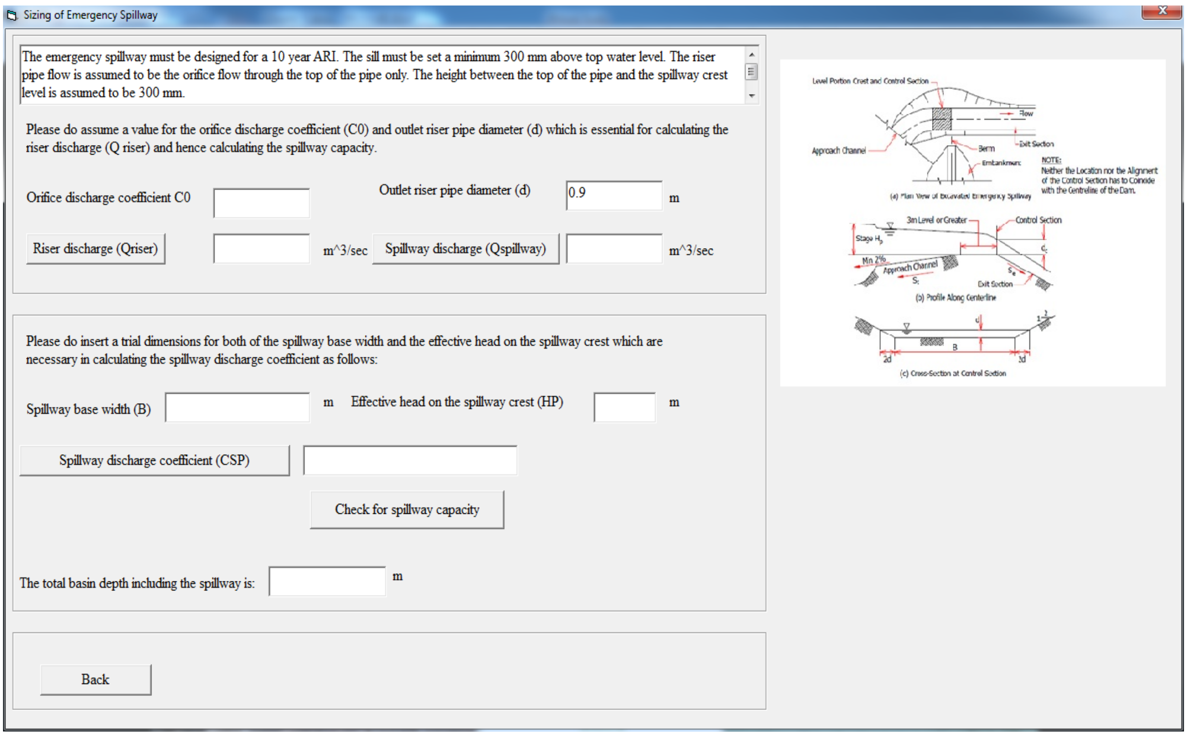


(a)

Figure 5. Continued.



(b)



(c)

Figure 5. (a) Dry sediment basin design main interface, (b) Sizing of the dry sediment basin main interface, (c) Sizing the emergency spillway main interface.

4. Sediment basin design system verification and validation

The developed system is verified to remove uncertainty from the various sources like ambiguity and incompleteness. Besides, the system is validated using preliminary validation and refined validation. The preliminary validation is performed to quantitatively measure system performance against the satisfaction and acceptability of evaluators. For the refined validation, it is composed of two main parts, the Turing test and field test. The following paragraphs clarify each of the validation techniques in more details.

4.1 Preliminary validation

In preliminary validation, the evaluators are people from different departments and organisations like Urban Drainage Division, Department of Irrigation and Drainage, private consultors, engineers, and university academics. A combination of open ended and closed ended questions were provided to the evaluators to judge the satisfaction and acceptability of each feature of the system. The T-Test was performed using the Statistical Product and Service Solutions. Results from the SPSS software are presented in Table 4.

As shown in Table 4, it is clear the feature "presentation of the results" is not accepted. Based on that, the system modified and presented again to the experts until get their satisfaction.

Table 4. Results of preliminary validation.

System features	Evaluators satisfaction											$\bar{X}$	SD	t-test (2 tails) with DF=10	acceptability
		Poor 1		Weak 2		Average 3		Good 4		Excellent 5					
	1	2	3	4	5	6	7	8	9	10	11				
Ease of use															
Starting the system	5	5	5	4	4	5	4	4	5	4	4	4.454	0.522	9.238	Acceptable
Obtaining explanations	5	4	4	4	5	5	4	5	4	5	5	4.545	0.522	9.815	Acceptable
Help facilities	4	5	4	5	3	3	3	4	4	4	5	4.00	0.774	4.282	Acceptable
Interface techniques	4	4	5	5	4	5	4	5	4	4	5	4.454	0.522	9.238	Acceptable
Exiting the system	5	5	4	4	4	4	4	4	4	4	3	4.090	0.539	6.708	Acceptable
Nature of questions															
Clarity of terms	3	5	5	5	4	4	3	4	4	4	5	4.181	0.7507	5.221	Acceptable
Answers complete	4	5	5	4	5	5	4	5	5	5	5	4.723	0.467	12.264	Acceptable
Clarity of questions	4	4	4	5	4	5	4	4	5	4	5	4.363	0.504	8.964	Acceptable
Nature of explanations	4	4	5	4	5	3	5	4	4	4	4	4.181	0.603	6.500	Acceptable
WHY explanations	5	4	4	3	4	5	4	4	5	4	3	4.090	0.700	5.164	Acceptable
HOW explanations	3	5	4	4	4	4	3	4	5	4	5	4.090	0.7006	5.164	Acceptable
Presentation of results															
Easy to follow	5	4	4	4	5	4	5	4	4	5	4	4.363	0.504	8.964	Acceptable
Complete	4	2	3	4	4	3	4	3	3	4	4	3.454	0.687	2.193	Not acceptable
System utilities															
Easy to access	4	5	5	4	5	5	5	4	4	5	4	4.545	0.522	9.815	Acceptable
Knowledge usability	4	5	4	5	4	5	4	5	4	4	4	4.363	0.504	8.964	Acceptable
Complete	4	4	5	4	4	4	5	4	4	4	5	4.272	0.467	9.037	Acceptable
General considerations															
Speed of system	4	4	5	4	5	5	5	4	3	4	5	4.363	0.674	6.708	Acceptable
System usefulness	5	4	5	4	5	5	4	5	5	5	5	4.727	0.467	12.264	Acceptable

4.2 Field validation

In field validation, date used are collected from construction site located in the north parts of Kuala Lumpur and more specifically in Kelantan. Results of the field validation are presented in Table 5 in which they show very high matching between the field results and the system's results.

4.3 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:

H_o: There exists no distinguishable difference between system and experts.

H_1: 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 6 presents the results obtained from the Turing Test

As shown in Table 6, 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 developed system is able to function/perform as good as human experts.

Table 5. System's results and field results for the design of five dry sediment basins.

	Observed (Field study)									Predicted (System)									
	Overall basin dimensions									Overall basin dimensions									
Sediment basin no.	W_{TWL} (m)	L_{TWL} (m)	W_B (m)	L_B (m)	**Settling zone depth (m)**	**Sediment storage depth (m)**	**Riser discharge (m^3/s)**	**Spillway discharge_m(m^3) Q10**	**Total basin depth (m)**	W_{TWL} (m)	L_{TWL} (m)	W_B (m)	L_B (m)	**Settling zone depth (m)**	**Sediment storage depth (m)**	**Riser discharge (m^3/s)**	**Spillway discharge (m^3) Q10**	**Total basin depth (m)**
1	55	110	50	108	0.6	0.7	0.93	3.555	2.2	45.62	118.199	41.5	115.39	0.6	0.7	0.93	2.496	2.2
2	82	120	78	120	0.6	0.7	0.93	6.320	2.2	77.62	118.589	73.5	115.78	0.6	0.7	0.93	4.924	2.2
3	57	117	51	114	0.6	0.65	0.96	4.294	2.2	54.12	118.067	50	115.26	0.6	0.7	0.93	3.1265	2.2
4	63	113	58	111	0.6	0.65	0.96	4.601	2.2	58.12	118.675	54	115.87	0.6	0.7	0.93	3.449	2.2
5	122	102	117	100	0.6	0.65	0.96	1.429	1.9	117.12	104.049	113	101.24	0.6	0.7	0.93	6.8225	2.2

Table 6. 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

5. Conclusions

The system developed 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 fresh engineers to guide them in designing the 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 be web based to expand the capability of the software in the universe of internet accessible information. Finally knowledge from other sources and information from other countries need to be collected and embodied into the system.

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