EVALUATION OF RIVER STABILITY BY MORPHOLOGICAL ASSESSMENT

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ABSTRACT

Streams and rivers form an essential link in the hydrological cycle. They are an open channel filled with water and sediments, a continuous processed from geo-morphological by natural reaction. Therefore, numerous hydro-morphological assessment methods have been developed in different countries during recent decades, like in the United States, Australia or German with notable differences in their aims, scales and approaches. Hydro-morphological assessment method is a deep integration between hydrology and geomorphology where inputs from several knowledge area and disciplines are brought together. It is a method that could not exist without invention across many disciplines. Health River Assessment can be used as a tool to make it easier to evaluate and design a stable channel in simple and powerful ways, as well as restoring the morphological appearance of a river to near a state of equilibrium geometry. Two methods have been selected to review the suitability and consistency of river health assessment for Malaysia's river which are OSEPI and CSI methods. Both methods were assessed using Morphological Assessment. Based on the result, it was clearly that there are inconsistencies observed between both indexes. Hence, both methods are not suitable for evaluating the ideal river in Malaysia. Since there is no study have been done for Malaysia's river, further study is important to establish a new Malaysia's River Health Assessment for evaluate the river health. Java programming was successfully created to evaluate river health using CSI and OSEPI method. This programming can be a reference to produce as a new tool for future river health assessment especially for Malaysia's River Health Assessment. River health assessment would be the best solution to alleviate those water related hazards and preserving originality of river landscape for future generation. Furthermore, it is necessary to evaluate the stability of the river before construct a bridge. A stronger foundation and factor of safety need to be increase when designing a bridge at unstable river.

Keywords:
Hydro-morphology, River Stability Index, River Health Assessment Tool, River Stability

INTRODUCTION

Over the years, erosion problems often occur and result in the changes of morphology. Some areas around the rivers encountered floods, frequently due to change of morphology that caused by erosion and sedimentation. Flood occurrence modifies the landforms each year. The modification of river landforms accidently induced the river bank to be instable. The collapse of river bank along the river network will endanger the land profile. The continuous process of this erosion pattern will reduce the capacity of river to contain incoming flow from the upstream. In short, the instability of riverine system has led to various catastrophes in the past such as river bank erosion, sedimentation and degradation of river bed. It has the greatest impact on the environment. Thus, having a tool to assess river stability is crucial to mitigate river related problem and restore riverine system to near equilibrium state. In Malaysia, there are lacking research have been done related to evaluate the river health condition. The established methods for other than Malaysia's river are numerous like in the United States, Australia or German. Thus, main aim of this research is to review the established method for evaluating river health for

Malaysia's river. Selective objectives were highlighted for this research as follows; i) to review the hydro-morphological assessment for river stability; ii) to collect hydro-morphologic database for Malaysia's ideal river; to develop a computer model using JAVA programming for hydro-morphological assessment. The study is significant to the development of River Health Assessment (RHA) as it will help to understand the characteristics and behaviour of the river morphology. Numerous benefits can be achieved from this research works. RHA can be used as a guideline to design natural stable channels and restoring the morphological appearance of a river to near state of equilibrium geometry. The RHA will also provide a relatively simple, easy and direct measurement to identify reaches for evaluating the stability. Moreover, after the data collected and analysed, RHA can store the hydro-morphologic database for a stable river. It is expected that this study should accord a better understanding towards the equilibrium geometry of a stable river and their associated flow structure. The development of channel stability index will provide a good basis towards restoring the Malaysia's river to original river landscape.

METHOD OF RIVER ASSESSMENT

Four main categories of river assessment can be divided such as riparian habitat assessment (RH), physical habitat assessment (PH), hydrological regime alteration assessment (RHA), and morphological assessment (Belletti, 2014). Each assessment has different methodology and procedure to evaluate river stability condition which depends on the aim and target of the result.

PHYSICAL HABITAT ASSESSMENT (PH)

Physical Habitat Assessment includes methods and protocols for the survey, characterization, and classification of physical habitat elements which can be described as river habitat surveys or physical habitat assessments (Platts, 1983; Plafkin, 1989; Raven, 1997; Ladson, 1999; Dunbar, 2009; LAWA 2000, 2002a, b). The assessment focused on in stream habitats or micro-habitats. The aim of PH was to evaluate the overall functioning of the stream by including information on ecology-related features, although they were not strictly habitat survey methods. Seventy-three physical habitat assessment methods were identified, illustrating that this type of assessment remained the most common approach for assessing the hydro morphological state of a river (Belletti, 2014).

RIPARIAN HABITAT ASSESSMENT (RH)

Riparian zones are an integral component of riverine systems, since their lateral and vertical structures depend upon hydro-morphological processes. However, the development of specific methods for assessing riparian conditions is relatively recent. Some indicators of riparian conditions are often included in one of the other types of assessment methods, but this particular category consists of methods that are specifically designed for the characterization of habitats in the riparian zone (Munne´ and Prat 1998), including some assessments of wetland clear distinction should be made between a river audit and a river condition assessment. A river condition assessment is a broader evaluation which places greater emphasis on physical processes, and aims to measure both pressure and response variables such as hydro morphological and biological indicators; as a basis for developing a clearer understanding of the cause–effect relationships that regulate observed changes in system conditions (Munne´ and Prat, 1998)

HYDROLOGICAL REGIME ALTERATION (HRA)

Hydrological Regime Alteration includes a further, independent, group of methods that produce hydrological assessments, particularly the development of specific indicators of hydrologic alteration (Richter, 1998; Poff, 2003), which can support assessments of the alteration of the natural hydrological regime. The output of these assessments is usually an index of the degree of deviation from unaltered conditions.

MORPHOLOGICAL ASSESSMENT (M)

Morphological assessment of a river involves evaluation of geometry of the river basin and how they respond to a number of processes and environmental conditions over period of time (Abdulkader, 2016). The assessment parameters are divided into three main groups, the morphology parameters, the hydraulics flow regime parameter and the sediment carrying capacity parameter. The morphology parameter can be separated into four categories: channel classification, instream features, bank and riparian zone and floodplain parameters. The hydraulics flow regime parameter can be separated into three categories: channel flow, channel geometry and flow resistance. The sediment carrying capacity parameter can be separated into four categories: sediment load, sediment production, sediment transfer, sediment deposition. Fryirs 2005 stated, a river audit permits assessment of river status by generating information on the presence and frequency of physical habitats and their characteristics. The method selection depends on the channel condition and available data collection. Some examples of assessment by morphological assessment methods are Channel Stability Index (CSI), Oklahoma Ozark Streambank Erosion Potential Index (OSEPI), Channel Condition Stability Index (CCSI) and River Hydromorphology Assessment Technique (RHA).

CHANNEL STABILITY INDEX (CSI)

Rapid geomorphic assessments provide a quick method for characterizing stream reaches, defined as lengths or segments of a stream with similar streambank characteristics in terms of bank height and stratigraphy, and their degree of stability (Simon and Downs, 1995). One of the most commonly used is the CSI. CSI was originally designed for areas that are highly sensitive to erosion, such as bridges (Simon and Downs, 1995). CSI required measurements of bed material, bed/bank protection, stage of channel evolution model, percent of channel constriction, number of piers in the channel, percent of blockage, fluvial erosion, meander impact from the bridge, pier skew for each pier, mass wasting evidence, high flow angle of approach, and percent of woody vegetation cover. The theme of data collection using CSI method was bed materials, geometry and morphology, cross section & longitudinal elevation. When streambanks near bridges are not the subject of a study, the CSI can be modified to eliminate the bridge/pier related criteria (Simon and Klimetz, 2008). Scores from each metric are summed to create an aggregate score, with a higher score indicating greater instability. Simon and Klimets, 2008 created the aggregate score is used to categorize each stream reach in a stability category: ≤10 is considered stable, between 10 and 20 is considered moderately unstable, and ≥20 is considered highly unstable.

OKLAHOMA OZARK STREAMBANK EROSION POTENTIAL INDEX (OSEPI)

OSEPI was developed by modifying CSI to produce specifically designed for larger-order streams in the area and to minimize the difficulty in determining some parameters and the quantity of materials needed to gather data. Many of the CSI parameters such as primary bed material, degree of constriction, and stage of the channel evolution model were homogeneous throughout the area and therefore were excluded from OSEPI. According to Healey (2012), metrics equivalent to or similar to those in CSI included the bank angle and the percentage of bank that showed evidence of mass wasting. In addition, the percentage of surface protection such as bank covered in vegetation, roots, large logs, and boulders; and percentage of the bank with established beneficial woody-vegetative cover were included in OSEPI but given additional weight in the RGA. The theme of data collection using OSEPI methods were bed materials, geometry and morphology, cross section & longitudinal elevation. Field and numerical modelling research has also demonstrated that the addition of roots to streambanks improves stability under a range of hydrological conditions (Wynn, 2004; Wynn and Mostaghimi, 2006; Pollen, 2007). Trees straining the bank were not considered beneficial vegetation. It should be noted that there is subjective evaluation included in identifying beneficial vegetation. The definition of beneficial vegetation could depend on root system shape and size as well as lean of a tree therefore, OSEPI users should carefully consider the impacts of these factors.

CHANNEL CONDITION AND STABILITY INDEX (CCSI)

CCSI presented here is designed to be a fast and cost-effective qualitative screening tool that will be informative to staff involved in condition assessment and Stressor Identification (Nutter, 2004) of biological and chemical impairments. This protocol was developed through consulting existing channel stability assessments (Pfankuch 1975; Simon and Downs 1995; Rosgen 2006; Magner, 2008, & Healey, 2012) and it included modifications that attempt to better characterize physical indicators of channel condition and stability observed in low- to mid-gradient streams in Minnesota. CCSI guidance manual provides a background in channel stability concepts and detailed descriptions of each metric. CCSI metrics rate channel stability indicators as they relate to channel form, function, and sediment continuity. The design of the CCSI worksheet and manual follows the Pfankuch guidance manual (Pfankuch 1975). Metrics from other channel stability assessments were consulted and incorporated into this assessment (Simon and Downs 1995, Arthington, 1998, Nutter, 2004, Rosgen 2006, Magner, 2008). Modifications to the original metrics and the scoring process have been introduced to broadly characterize stream conditions observed in Minnesota. There are 12 metrics. Each metric has five rating categories which were excellent, good, fair, poor, and very poor. The scoring strategy is intended to separate good sites from poor sites while allowing for sites that are in-between to be classified as moderately unstable (not good, not poor).

The morphological approach will be given a special attention for this research. Two existing methods (CSI, and OSEPI) will be used to study the stability of selected rivers. The morphological is direct measurement from the fluvial appearance; hence degree of reliability is higher compared to the other methods.

REVIEW OF CSI AND OSEPI PARAMETER

A review from Healey (2012), the studies were related to rapid geomorphic assessments to assess stream bank stability in Oklahoma Ozark streams. Their objective was to produce OSEPI where requires measuring the physicality of the river such as bank height, bank face length, river stage at base flow, degree of constriction, and average diameter of streambed sediment. Bank height was measured at the thalweg of the stream, while the degree of constriction was the relative decrease in channel width from upstream to downstream. Thalweg is depth of water at the deepest point along the cross section. They also measured the average diameter of streambed sediment (gravel, boulder/cobble, or bed- rock). The degree of incision was calculated from the depth of water at base flow (D) and the bank height (BH). It can be defined as the ratio of the elevation of base flow to the floodplain elevation, i.e., D / (BH + D). Highly incised channels which were low ratio received a high metric score, and stable channels were scored low metric score. Percentage of the bank reinforced by riparian vegetation was estimated for each bank. Both banks were evaluated for evidence of fluvial erosion and mass wasting.

Simon and Down (1995) carried out an approach to evaluation of potential instability in alluvial channels. They started with initial site evaluation where a site evaluation form provided. The site evaluation form contained of information of (i) the site (index variables), (ii) the channel (hydraulic, geomorphic, and vegetative variables) (iii) the bridge, if present, and (iv) stage of reach evolution. Characteristics and conditions of the channel bed, channel banks, accumulation of debris and other causes of flow deflection, and the condition of riparian vegetation can be used to identify the degree of channel instability/stability. All these parameters were groups in 14 variables which are variable (i) bed materials, variable (ii) bed protection, variable (iii) channel evolution, variable (iv) the percentage of stream width constriction, variable (v) piers in the channel, variable (vi) to (viii) local scour and value of channel blockage, variable (ix) bank erosion, variable (x) value of meander impact point, variable (xi) existence of pier skew, variable (xii) mass wasting processes in the vicinity of a pier or abutment which it can lead to failure of the structure , variable (xiii) is the high-flow angle of approach to the site where it is used to indicate the potential for accelerated erosion on a particular side of the channel because maximum shear stresses and flow velocities and the last variable (xiv) the percent woody vegetative cover. All the data were recorded on paper and then entered into GIS database. The procedure used physical data from several disciplines extracted from the GIS database to calculate a channel-instability index (Ii) for each site. The greater value of Ii, the greater the potential instability of the site.

RESEARCH METHODOLOGY

This part presents the research works. The research started with the selection of an ideal river which located in Ayer Hitam Forest Reserve, Puchong, Selangor. The river name was Rasau River. Ayer Hitam Forest Reserve still contain untouched river basin as the remaining water catchment was enclosed by the surrounding hills and had not suffered great disturbance. Figure 1 shows the location of Rasau River. The field sampling involved three main themes which were river surveys, hydraulic geometry and hydraulic data. River survey was done by the measurement of the channel size at cross section and longitudinal section, such as the width, depth and slope. Depth of the river was measured at every 1.0m interval and the measurements were from the left bank to the right bank. The equipment used like auto level and tripod, measuring tape and staff of levelling. All the data then was transferred in HEC-RAS to get the river profile. About eight cross sections were selected based on different morphological appearance such as riffle pool, pool, cascade and step pool. Current velocity meter was used to measure the velocity at each 1.0m interval of the river cross section. All the velocity data then was analysed to get the discharge of each cross section. Bed materials data was measured using Wolman Pebble Count for range of material size between 4 mm to 180 mm. For larger size of materials, measuring tape was used to get the size of the materials, while for smaller size; about 500g of the samples were collected and done on dry sieving analysis at laboratory. For this study, two methods of Morphological Assessment were choosing which were OSEPI and CSI method. The parameter needed by the OSEPI and CSI was programmed using JAVA Programming. JAVA programming is a secure, fast and simple programming that can easily produce a result of the river evaluation.

Figure 1: Location of Rasau River

RESULT AND DISCUSSION

This part explains the details assessment of Rasau River reach using Channel Stability Index (CSI), and Ozark Stream Erosion Potential Index (OSEPI). CSI and OSEPI were selected to review the established method for evaluating Malaysia's river. OSEPI and CSI indexes used different set of rating score to categorize the rating score. Rating for CSI was classified into three classes i.e. stable, moderately unstable and highly unstable, while rating for OSEPI was categorised into six classes i.e. highly stable, moderately stable, stable, unstable, moderately unstable and highly unstable. These two indexes used different parameters to categorize the level; hence it was quite difficult to find uniformity amongst them.

Evaluation of Rasau River using CSI and OSEPI method was successful. The evaluation is projected in Table 1. The rating scale for CSI was: Score values range 0 – 10 as the channel was stable, 10 – 20 as the channel was moderately unstable and > 20 as the channel was highly unstable (Simon and Downs, 1995). The results of CSI Index evaluation were Stable for cross section 1 until 3, cross section 4 until cross section 8 are in moderately unstable. While the rating scale for OSEPI was between 0 – 25 were highly stable; 26 – 35 were moderately stable; 36 – 45 are stable; 46 – 55 were unstable; 56 – 65 were moderately unstable and 66 – 85 were highly unstable (Healey, 2012).

	CSI Methods		OSEPI Method (Left Bank)		OSEPI Method (Right Bank)	
Cross section	Index Score	Index Class	Index Score	Index Class	Index Score	Index Class
CS 1	10	Stable	10	Highly Stable	10	Highly Stable
CS 2	7	Stable	10	Highly Stable	10	Highly Stable
CS 3	6	Stable	10	Highly Stable	10	Highly Stable
CS 4	10	Moderately Unstable	12.5	Highly Stable	12.5	Highly Stable
CS 5	12	Moderately Unstable	15	Highly Stable	15	Highly Stable
CS6	16	Moderately Unstable	17.5	Highly Stable	17.5	Highly Stable
CS 7	17	Moderately Unstable	20	Highly Stable	22,5	Highly Stable
CS 8	14	Moderately Unstable	27.5	Moderately stable	27.5	Moderately stable

JAVA programming was created to produce a simple, secure and fast result of the river health evaluation. Figure 2 shows the River Health Assessment interface. First, user needed to choose the method of assessment. Then, the user clicked 'Go' button. Figure 3 shows the interface of CSI method. Here, user needed to key in the required data based on the parameter required. Then, the user clicked 'Result' button to generate the result of river health assessment as shown in Figure 4. This programming could store or save the data so it would be easier to locate the history data when needed at any time.

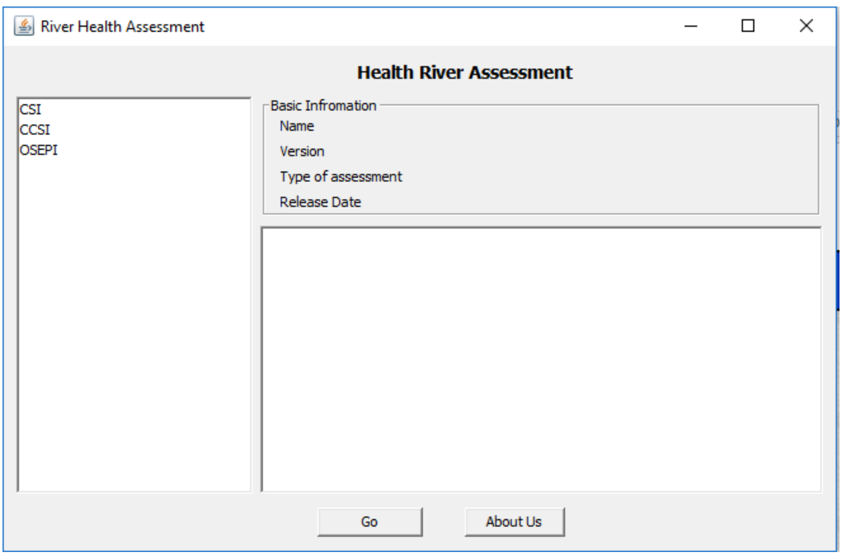

Figure 2 : Interface of River Health Assessment

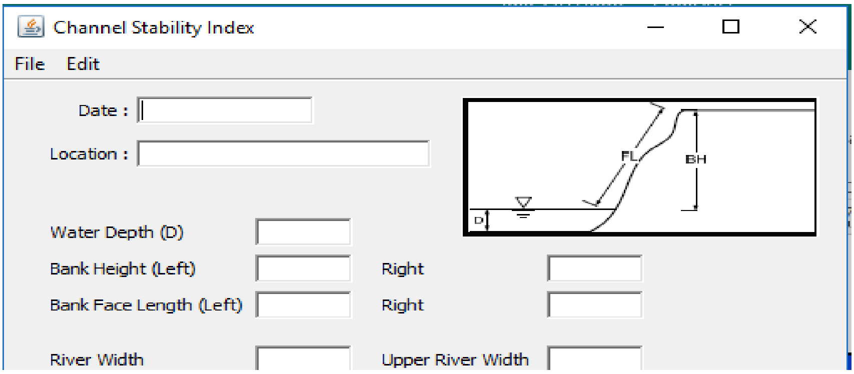

Figure 3 : Interface of CSI method

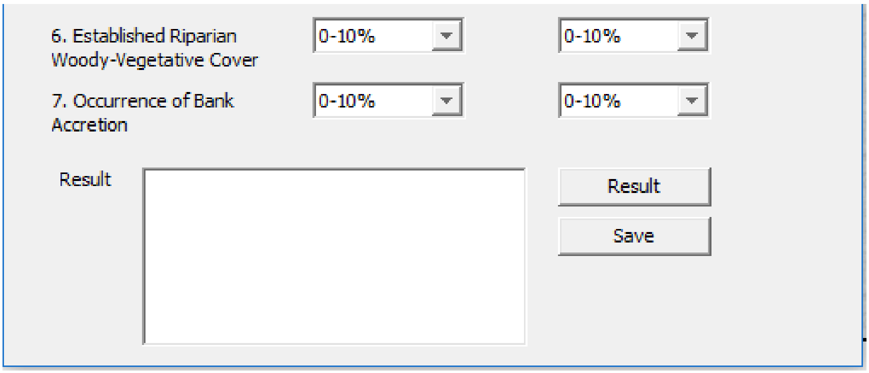

Figure 4: Button for Result of the River Health Assessment

CONCLUSION AND RECOMMENDATION

The research focused on collecting geometry and morphological data of Rasau river to evaluate the river stability using OSEPI and CSI method. The use of CSI and OSEPI index successfully evaluated the level of channel stability at Sungai Rasau, Selangor. CSI evaluated that cross section 1 until 3 were in a stable condition, and cross section 4 until 8 were in moderately unstable. Meanwhile for OSEPI index, 7 cross sections were highly stable and at cross section 8 only moderately stable. From this result, it was evidently found that inconsistencies observed between both indexes such as:

a) Both indexes were using different weightage for each parameter;
b) Both indexes were using different set of rating score to categorize the level;
c) Both indexes were using different parameters to categorize the level; hence it was quite difficult to find uniformity amongst them.

Based on the review and result of both methods, the researchers concluded that CSI and OSEPI methods were not suitable to evaluate the health of river in Malaysia. Since there was no river health evaluation had been done for Malaysia’s river, further study is important to establish a new Malaysia’s River Health Assessment for evaluate the river health.

Java programming was successfully created to evaluate river health using CSI and OSEPI method. This programming could be amended for future river health assessment especially for Malaysia's River Health Assessment.

In the future, authorities or policy makers may use this research as reference to evaluate the river health for any cross section before initiate any rehabilitation or restoration work at specific cross section.

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