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Field Study of Vegetated Channel at UTHM Campus

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Abstract

A vegetated channel refers to a form of infrastructure that aims to mitigate stormwater runoff through the utilization of either natural or constructed systems that replicate the behavior observed in natural environments. The condition of the vegetated channel has the potential to influence the hydraulic behavior of the channel. The regulation of stormwater quantity in the management of drainage systems is influenced by the characteristics of the vegetated channel. Field data was gathered from a channel located in the parking lot of the Faculty of Civil Engineering and Built Environment at the University Tun Hussien Onn Malaysia (UTHM) campus. The purpose of this data collection was to assess the influence of various sectional circumstances on the velocity profile. The measurement of stream flow velocity is conducted by the utilization of current meter equipment during field investigation. The Manning's coefficient for each section was analyzed to assess the impact of variations in this parameter on the flow rate of the channel. In accordance with the results obtained, the coefficient value of Manning's ranged from 0.160 to 0.826. The velocity of flow in the vegetated channel ranged from 0.003 m/s to 0.010 m/s. In the interim, the flow discharge magnitude for the channel exhibits variability within the range of 0.0005 m^3/s to 0.002 m^3/s. This study examines the impact of bed surface condition, channel slope, and Manning's coefficient on flow rate. Therefore, the flow rate and Manning's coefficient were found to be impacted by both the bed condition and the slope of the channel.

1. Introduction

Conventional stormwater management techniques, including concrete discharges in new development zones, fall short of expectations for flow and quality control. This conventional stormwater is the result of quick wastewater treatment or concrete drainage. Rapid disposal requires transporting stormwater discharge as quickly as possible downstream. The current concrete drainage system in the downstream area is rendered ineffective in this case due to the excessive volume of water beyond its capacity. Consequently, the region will see swift inundations, leading to both tangible and intangible harm inflicted upon the people. The flash floods additionally facilitate the transportation of other forms of waste, including trash, rubble, and deceased foliage, to nearby bodies of water. The degradation of water quality and its subsequent influence on the local water supplies is an undeniable consequence. Hence, it is imperative to improve wastewater management and address these three fundamental concerns.

The Department of Irrigation and Drainage of Malaysia (DID) [1] published the first edition of the Urban Stormwater Manual of Malaysia (MSMA) related to stormwater management. In August 2012, the second edition was published. This guide presents a new approach to stormwater management. For the design of the urban drainage system, the integrated approach has been advocated, in which the quantity, quality, and aesthetics of stormwater discharge and the surrounding catchment area are taken into equal account. This integrated method is called Sustainable Urban Drainage System (SUDS) or Best Management practices (BMPs). SUDS replace the conventional concept of rapid disposal with the new paradigm of source control. In SUDS, the number of facilities like vegetated channel/ swales, detention storage, wetland, bio-retention, etc., that can be employed in series is increasing [2].

A vegetated channel or swale refers to an exposed watercourse that is characterized by a covering of vegetation, serving as a conduit for directing the flow of water during periods of intense precipitation. Stormwater management is a specialized management strategy aimed at addressing and reducing the impact of stormwater flow on water quality and volume [3]. The designated function of this structure is to function as a storage facility for stormwater, while also facilitating the removal of suspended debris. Grassed swale presents a viable solution for the transportation of rainwater from impermeable surfaces, its deceleration, and subsequent infiltration into the soil. According to research findings, when a vegetated channel is appropriately built to support a predefined storm event volume, it demonstrates superior performance compared to a traditional drainage ditch in terms of water filtering and stalling [4]. Vegetated channels typically exhibit the capacity to reduce flow velocity, function as facilities for storm discharge detention, and effectively eliminate pollutants.

According to the research conducted by McKain [5], vegetated channels or swales are utilized for the treatment of water quality and quantity control. This approach involves the use of cost-effective and easily obtainable materials such as soil, plant, and microorganisms. The implementation of vegetated channels has the potential to reduce water treatment expenses, offering a more cost-effective alternative to conventional curb and gutter treatment or underground stormwater systems. The maintenance of vegetated channels demands more regular attention, although it is considerably more cost-effective compared to the maintenance of curb and gutter systems.

2. Surface Storm Water Control

There exist two major classifications of stormwater drainage systems, namely conventional drainage systems and sustainable drainage systems. In instances of heavy rainfall or storms, conventional drainage systems often prove inadequate in managing the volume of precipitation. The objective of sustainable drainage systems (SuDS) is to mitigate the adverse impacts caused by conventional drainage systems, which often result in flooding events and water contamination [6]. Sustainable drainage systems, as described by the St. Johns River Water Management District [7], aim to replicate natural processes and can manifest in diverse configurations, dimensions, and structures. There exist four primary categories of sustainable drainage systems, including retention basins, vegetated channels/swales, dry detention systems, and wet detention systems. The campus of University Tun Hussein Onn Malaysia (UTHM) employs a range of water management strategies, including the utilization of channels and the implementation of vegetated channels instead of concrete drains. Additionally, the campus incorporates detention basins and engineered waterways as part of its water management infrastructure.

According to the findings of Yu et al. [8], swales were found to significantly mitigate the overall volume and flow levels of stormwater during rainy occurrences with precipitation amounts below 3 centimetres. Based on considerations related to water balance, it is expected that the swales will see a decline in their ability to store water through infiltration, as the maximum rate of infiltration approaches the saturated hydraulic conductivity of the soil. When the amount of precipitation above the maximum infiltration rate, surface flow will occur, leading to storage and subsequent discharge from the swale. A portion of the water that is stored will undergo evapotranspiration, therefore playing a role in the replenishment of groundwater and the maintenance of base flow [9].

The study was carried out at the University Tun Hussein Onn Malaysia (UTHM) campus, with a specific emphasis on the determination of flow velocity within vegetated channels. This study examines the hydraulic characteristics of channel cross-sectional area, flow velocity, flow depth, and flow discharge. The objective of this study is to ascertain the flow velocity of the vegetated channel in UTHM by analyzing the profile of the vegetative channel. Additionally, the study intends to evaluate the effectiveness of the vegetative channel in mitigating the flow discharge of the channel.

3. Materials and Methods

3.1 Study Area

Fig. 1 illustrates the selected site, situated in the parking lot of the Faculty of Civil Engineering and Built Environment (FKAAB) at UTHM. The vegetated channel is employed as a viable alternative for drainage systems. The integration of the swale's shape and placement within the parking lot's landscape design serves the purpose of establishing a versatile drainage system.

(a) **(b)**

Fig. 1 *Location of study area (a) Site area of vegetated channel at FKAAB, UTHM; (b) Selected vegetated channel for research study*

The vegetated channel as shown in Fig.2 was divided into five discrete sections, with an approximate spacing of 10 meters between each section. A site study will be undertaken to collect data related to various factors, such as the state of the vegetated channel, the cross-sectional area, the depth of flow, and the velocity of the flow.

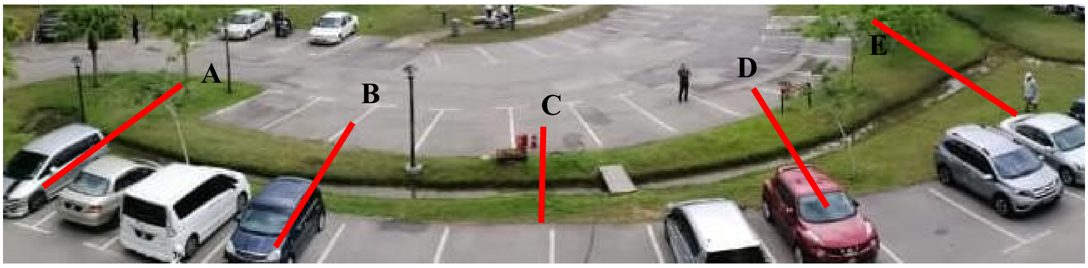

Fig. 2 *Sections of vegetated channel*

3.2 Field Exploration

3.2.1 Levelling Work

The concept of slope refers to the quantification of the variation in height between two specified sites. The determination of Manning's n coefficient involves the consideration of an important variable. To determine the slope, one must divide the discrepancy in elevation by the horizontal distance separating the two sites. Subsequently, the value will be subjected to multiplication by a factor of 100.

The differential height is determined by employing the levelling method, which enables the measurement of the relative height between several sites. In situations involving small distances, the determination of the vertical difference between two points can be easily achieved by employing the method of placing a staff in a vertical position at each respective point. Next, proceed to create a horizontal line by utilizing either an optical or digital level. The dissimilarities in the positions at which the horizontal line intersects with each staff result in the variation in elevation between these ground sites. The method is commonly referred to as conventional levelling [10].

3.2.2 Current Meter

The utilization of a current meter is primarily for the purpose of quantifying the velocity of water at different vertical positions inside a transverse segment of a watercourse. Additionally, the corresponding area associated with each measurement is ascertained. The average watercourse discharge in the specified segment is determined by multiplying the flow velocity by the corresponding area for each part and summing these products.

The International Standardizations Organization [11] lays out the requirements for the accurate measurement of the mean velocity for various vertical locations, the calculation of the discharge using various graphical or arithmetic methods, and the selection of the fewest possible vertical locations. In each instance, some flexibility is required to adapt these requirements to the various conditions that are encountered at each site throughout time.

3.3 Data Collection

After the rainfall event, data collection was carried out in the vegetated channels of the University Tun Hussein Onn Malaysia (UTHM) campus. The study was carried out in the field to obtain channel hydraulic characteristics such as flow depth, cross sectional area, velocity, discharges, and Manning's roughness coefficient.

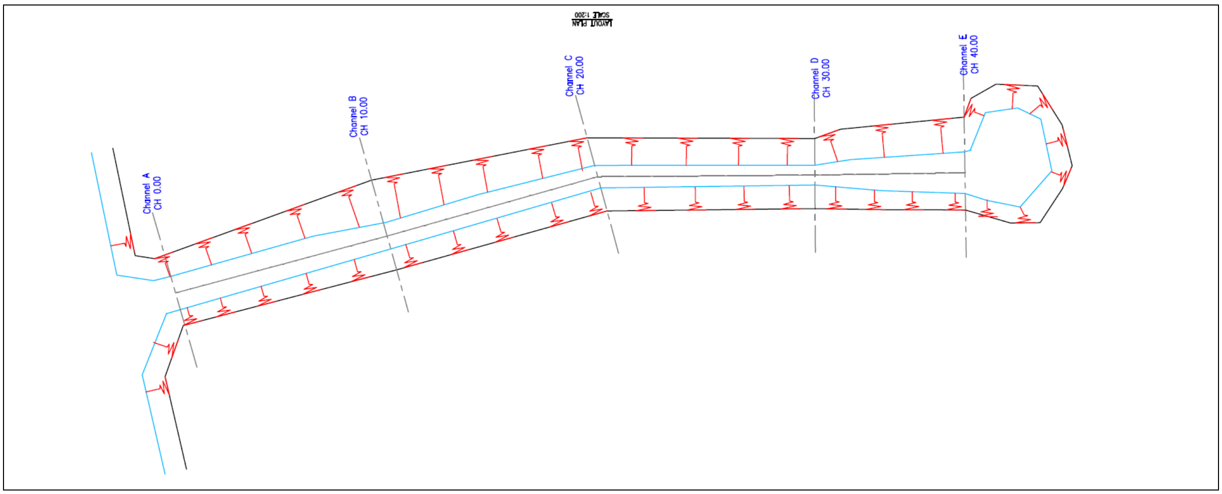

Fig. 3 *Schematic diagram of vegetated channel by section A, B, C, D and E*

Fig.3 illustrates a vegetated channel that spans a length of 40 meters and is partitioned into five distinct portions, namely section A, Section B, Section C, Section D, and Section E. Every section is approximately 10 meters apart from one another. The data collected from the vegetated channels includes measurements of flow depth (Y), velocity (V), and the top width of the vegetated channel (T). The data holds significance in assessing the efficacy of the channel with respect to its hydraulic parameters, specifically the cross-sectional area (A) and flow discharge (Q) of the swale.

The methodology employed in this analysis bears resemblance to a prior work [12], wherein the velocity of the flow was recorded at three distinct sites along each cross-section. The velocity of each point has been recorded on three occasions, and the average of these measurements is considered to represent the true velocity at that specific site. The discharge was calculated by implementing the continuity equation, which states that Q = AV.

4. Results and Discussion

Table 1 shows the geometrical properties of each section of the swale channel. For section A until section D, the surface condition is the existing condition with a vegetation bed surface; meanwhile, section E has a crusher run and vegetation bed surface of the swale channel.

Table 1 *Geometrical properties of each section*

Geometrical Properties	**Dimension of Station Channel (m)**				
	Section A	**Section B**	**Section C**	**Section D**	**Section E**
Channel	0.00	10.00	20.00	30.00	37.00
Top Width, T (m)	1.68	1.32	1.17	1.00	2.00
Bottom Width, B(m)	1.58	1.24	1.07	0.90	1.90
Bed Slope, So	1:300	1:300	1:300	1:300	1:300
Surface condition	vegetation	vegetation	vegetation	vegetation	vegetation & crusher run

4.1 Flow Rate Against Flow Depth

Fig.4 depicts the graphical representation of the relationship between discharge and flow depth for the rain event that occurred on October 22nd and October 26th, 2019, as derived from the data presented in Table 2. The chart displays the relationship between flow depth and discharge across sections A through E.

Table 2 *Data analysis of sections on 22nd October 2019*

Section A		**Section B**		**Section C**		**Section D**		**Section E**	
Flow Depth,y (m)	**Discharge , Q (m^3/s)**	**Flow Depth,y (m)**	**Discharge , Q (m^3/s)**	**Flow Depth,y (m)**	**Discharge , Q (m^3/s)**	**Flow Depth,y (m)**	**Discharge , Q (m^3/s)**	**Flow Depth,y (m)**	**Discharge , Q (m^3/s)**
0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000
0.32	0.0001	0.30	0.0000	0.26	0.0000	0.27	0.0000	0.27	0.0000
0.33	0.0016	0.32	0.0017	0.26	0.0013	0.27	0.0009	0.27	0.0014
0.32	0.0001	0.30	0.0001	0.26	0.0001	0.27	0.0001	0.27	0.0000
0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000

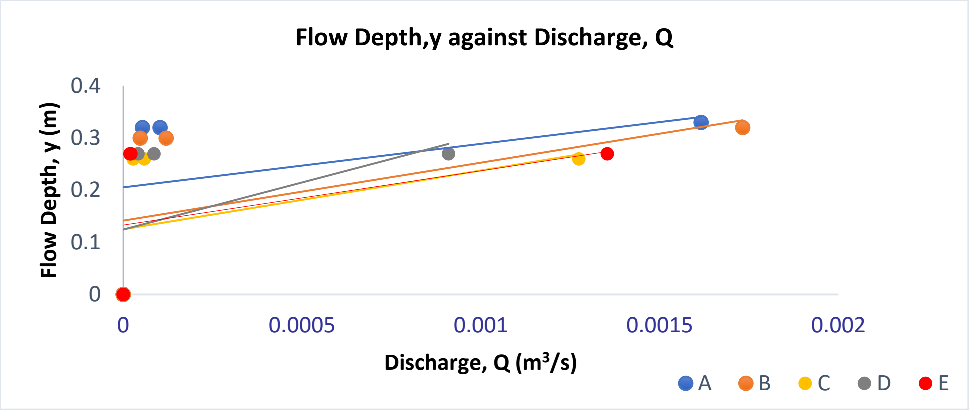

Fig. 4 *Graph between flow depth, and discharge on 22 October 2019*

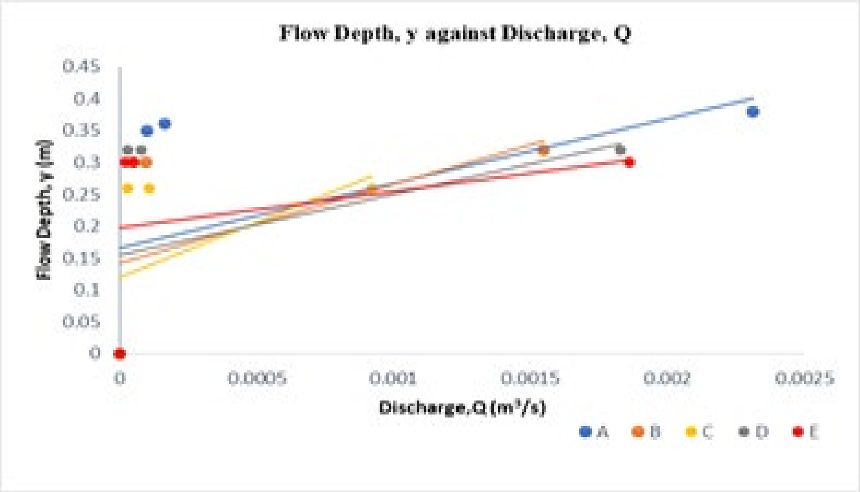

Fig. 5 *Graph between flow depth and discharge on 26 October 2019*

The graph presented in Fig 4 demonstrates a positive correlation between the depth of the channel and the discharge. Section A exhibited the highest discharge with value of 0.00231 m3/s at 0.38 m of flow depth on 26 October 2019 than 0.0016 m3/s and 0.33 m on 22 October 2019. Section C is expected to have the lowest discharge of 0.00003 m3/s at flow depth 0.26 m on 26 October 2019, due to its more elevated position in comparison to the other sections. Sections B, D, and E share a same average depth of flow and demonstrate a consistent correlation between discharge and depth of flow. This relationship suggests that the presence of aggregates on the surface of section E does not impact the decrease in flow discharge. This pattern of events can likely be attributed to the occurrence of intense rainfall on that day.

4.2 Velocity Against Flow Depth

Fig. 6 and Fig. 7 illustrate the correlation between velocity and flow depth observed during a rainfall event occurring on two separate dates, namely 22 October 2019 and 26 October 2019. The graph illustrates the correlation between the depth of flow and the velocity of water as it progresses from section A to section E. On 22 October 2019, it was observed that the velocity of section C reached its maximum value among the various depths, measuring 0.01 m/s at a depth of 0.26 m. The realism of the graph can be attributed to the fact that the velocity dispersion inside a channel is influenced by its average velocity. Typically, the area exhibiting the highest velocity is frequently observed near the core region and beneath the surface. In Section E, the velocity is observed to be at its minimum, measuring 0.0047 m/s, while the flow depth is recorded at 0.27 m. The observed phenomenon can be attributed to the presence of aggregates located on the surfaces of the sections. The wind direction may also have an impact on the velocity of the segment.

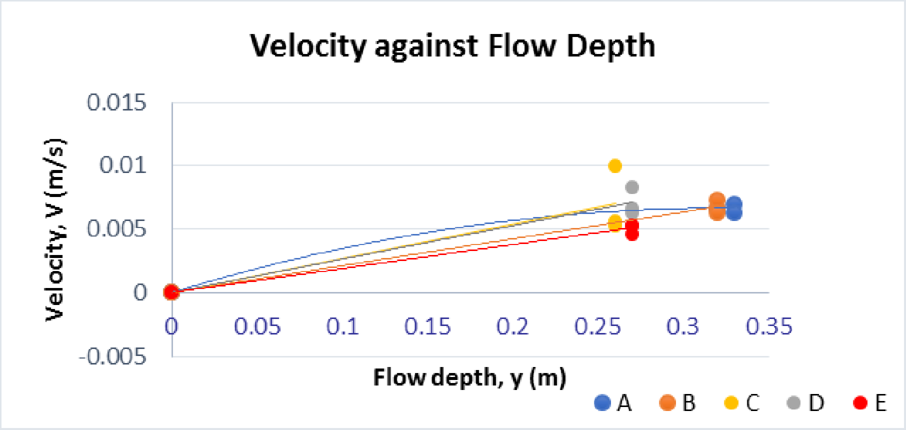

Fig. 6 *Graph between velocity and flow depth, on 22 October 2019*

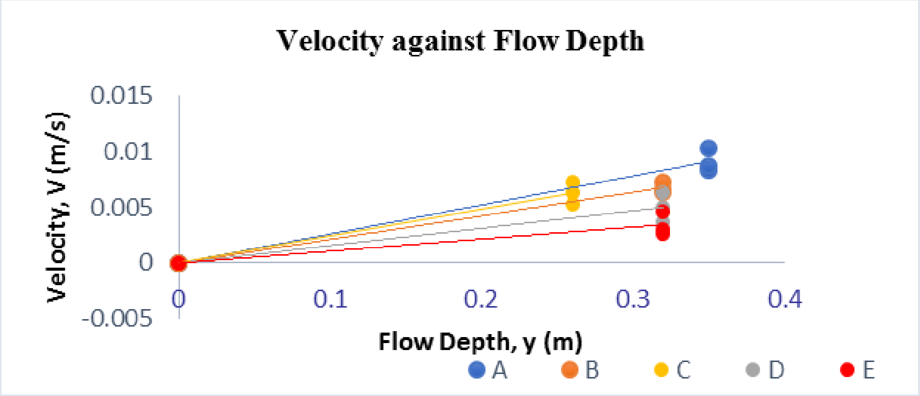

Fig. 7 *Graph between velocity and flow depth, on 26 October 2019*

The graph depicted in Fig. 6 shows a similarity to the precipitation patterns observed on October 22, as depicted in Fig. 7. On 26 October 2019, Section A exhibited the greatest velocity of 0.0103 m/s at a flow depth of 0.35 m, whereas Section E displayed the lowest velocity of 0.0027 m/s at a flow depth of 0.32 m. The graph illustrates the positive relationship between flow depth and channel velocity, suggesting that a rise in flow depth is related to a correlated increase in channel velocity.

5. Conclusions

The channel cross-section influences the flow velocity in a vegetated channel, as determined by this study. The results indicate that if the vegetated channel is designed appropriately with the appropriate hydraulic parameters, then the channel will function as an effective drainage system. A productive vegetated channel would transport stormwater runoff to the detention reservoir. Alternatively, the river inhibits the occurrence of flooding. Vegetated channels must be capable of carrying their intended flow without erosion or overtopping. If the flow velocity is too high for vegetation cover in the channel and the slope and cross-section cannot be altered, the channel can be strengthened with riprap or turf reinforcement matting, which can withstand a higher flow velocity. Vegetation also plays a significant role in the efficacy of the vegetated channel, which functions as an agent to reduce flow discharge by slowing the flow velocity. Maintaining a vegetated channel is necessary to accomplish the intended purposes of the channel, which are controlling the volume of stormwater runoff and preventing flooding.

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Conflict of Interest

There is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to the paper as follows: ***study conception and design:*** *Noor Aliza Ahmad, Nabila Daud;* ***data collection:*** *Noor Aliza Ahmad, Nabila Daud;* ***analysis and interpretation of results:*** *Noor Aliza Ahmad, Hartini Kasmin, Nabila Daud;* ***draft manuscript preparation:*** *Noor Aliza Ahmad, Hartini Kasmin, Nabila Daud. All authors reviewed the results and approved the final version of the manuscript.*

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