Journal of Sustainable Civil Engineering and Technology
e-ISSN: 2948-4294 | Volume 2 Issue 1 (March 2023), 45-60
https://joscetech.uitm.edu.my

The Study of Total Sediment Transport Characteristics at Kanching Forest Waterfall

Siti Nur Khalila Zulkarnain[1], Sharifah Abdullah[1], Shahrul Jainudin[1]

[1]School of Civil Engineering, College of Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

*Corresponding Author: sharifah.abdullah@uitm.edu.my

Received: 28 November 2023 / Accepted: 20 March 2023 / Published online: 28 March 2023

Abstract

Families and environment enthusiasts frequently visit Kanching Rainforest Waterfall, also known as Kanching Recreational Forest. It is located nearby in the Rawang neighbourhood to the north of Kuala Lumpur and has an area of around 47,000 square metres. Due to its proximity to the city, the region has become a popular place for people to enjoy picnics, camping, swimming, and jungle walks during the holidays. The movement or discharge of water flow is closely related with sediment. Since a specific discharge is necessary to propel and carry particles of a particular weight or size along the pathways. In essence, sediment estimates are so crucial because rivers in Malaysia continue to fill reservoirs with river water for daily use. Sedimentation in reservoirs can reduce the amount of accessible water, hence restricting its application. In this study, the Hjulström graph were used to predict the sediments and particles flow distributions, and the correlation between particle size and particle mobility in the flows of rivers was determined at three (3) checkpoints to examine the sediments and particles flow distributions. According to the data obtained, Checkpoint 1 has a particle velocity of around 0.4703 N/s, or 40 grammes per second, whereas Checkpoint 2 has a velocity of roughly 1.534 N/s, or 156 grammes per second. Lastly, Checkpoint 3 lacks a full load transfer. In addition to preserving one of the region's leisure areas, the significance of complete load transit estimation will ensure its maintenance. By using this method, the estimation of the total load that may be eroded along the river by calculating the total transport load can be forecasted hence, provide a maintenance program toward the rehabilitation of the Kanching Recreational Forest.

Keywords: *Total Sediment Transport, Hjulström, Ackers White, Particle Velocity*

1. Introduction

Kanching Rainforest Waterfall, also known as Kanching Recreational Forest, is a popular destination for families and nature enthusiasts to unwind. The plants and wildlife of the Kanching Rainforest are abundant. This woodland appears to be simply another reserve forest from the outside. The surrounding area is magnificent, with towering, green trees making you want to fall in love with nature. One of its distinctive features is that it has roughly seven (7) tiers of cascade so that visitors may appreciate the wonders of nature. The layers commonly resemble other waterfalls in that they each have their own depth and areas (David, 2009).

In our aquatic environment, sediments are crucial to the cycling of several elements. They are in charge of moving a substantial amount of certain pollutants and nutrients along the road. Sediment movement in rivers is related to and truly connected with a wide range of environmental and some engineering challenges depending on the size of the transported material (Bartam, 1999). Sediment not only contributes significantly to water pollution, but also acts as a catalyst, carrier, and storage agent for other types of pollution (Julian, 1998). Water quality for industrial use, recreational activities, or municipal supplies would all suffer from sediment, where it could affect the turbidity and cleanliness of the quality of water itself (Julian, 1998). Additionally, ions exchange between the solutes and the sediment itself may take place as the chemicals and waste are absorbed by the sediment particle. As a result, the sediment acts as a carrier and a storage agent for bacteria, viruses, and pesticide residues as well as for adsorbed phosphorus, nitrogen, and other organic substances.

Aminuddin (2010) conducted research on sediment deposition and movement in Sungai Kulim, Kulim Kedah, to examine the impact of human activity and its nature. The author claimed that human factors affect channel changes both directly through engineering projects like channelization, dredging, snag removal, dam construction, and bridge construction, as well as indirectly through changing the land use of floodplains so that erosion is more likely to occur during flood events. The channel morphology, which includes the cross section, stability, and capacity of the channel, will undergoes physical changes as a result of these modifications to the river's hydrology and sedimentation. Due to current and planned changes, it is imperative to investigate river channel behaviour and assess the stability of the river channel in both its natural form and in reaction to human intervention. By following this research, the aims of this study were to study the characteristics of the total sediment transport flow at Kanching Waterfall and to analyze the significant of the sediment discharge using the Ackers White Equation (1973).

2. Literature Review

A built-up of organic and inorganic elements that can be carried away by water, wind, or ice is referred to as sediment (Shi, Arter, Liu, Keller, & Schulin, 2017). The alternate name, which is usually used to refer for sediment, is soil-based mineral debris, such as clay, silt, and sand, which are produced when organic materials such as nitrate, carbon, amino acids, and more break down (James et al., 2008). When analysing sediment samples, inorganic biogenic components like minerals can also be taken into consideration.

Mineral sediment is mostly created by weathering and erosion, whereas organic sediment is frequently composed of debris or waste from different kinds of gravel, silt, sand, and decomposing substances like algae Nemati et al. (2011).

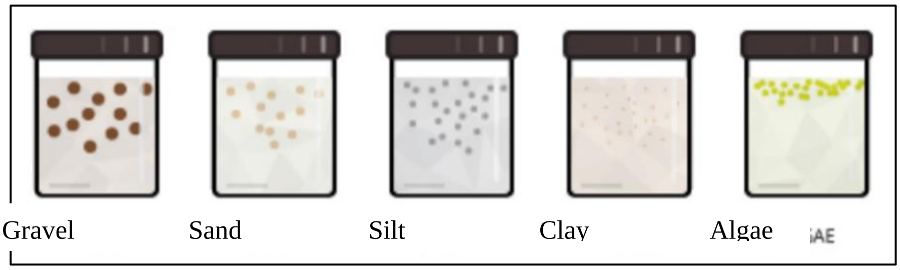

Figure 2.1: Sediment particles in different sizes and substances, (Marshall, 2014)

These sedimentary particles are typically small, with the coarsest sand barely reaching a diameter of 0.00195 mm to 1.5 mm (Shi et al., 2017). A huge boulder, however, may also be categorised as silt during flood events or other high flow occurrences if it is carried downstream by the flow. Sediment is a naturally occurring ingredient in many bodies of water, but it can also be impacted by anthropogenic factors, often known as human influences on the environment, which also includes impacts on biodiversity and the biophysical environment.

The composition of sediment can be measured in terms of the parent rock lithology, mineral composition and also chemical makeup. The topography, geographical features, and past exploitation of the soil in the region all have an impact on the sediment's composition. The physical features of bedrock or older, superficial deposits that are exposed on the earth's surface are described by a rock unit's lithology. The lithology rock's qualities may include a thorough description of its colours, texture, grain size, and possibly even its composition. Typically, rocks are made up of minerals, which are naturally occurring inorganic solids with a crystalline structure and unique chemical compositions. Although clearly not a mineral, rocks are composed of mixtures of different minerals.

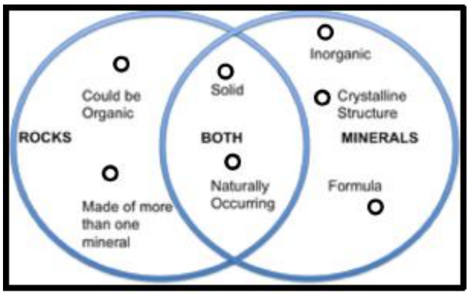

Figure 2.2: Composition of the rocks and minerals, (Marshall, 2014)

Rock can be a solid, inorganic, or organic substance that spontaneously forms and lacks a precise atomic structure, as seen in Figure 2.2. The eroded rocks will influence the types of sediments (Pour & Hashim, 2015). In general, the term "sediment transport" refers to the movement of both biological and inorganic solid particles that are present in flowing water as a result of the fluid's motion and the force of gravity acting on the particles. The greater the flow, the more silt will flow away due to the shear force that is present while the water is being transported (Omidi, Thomas, and Brown, 1996).

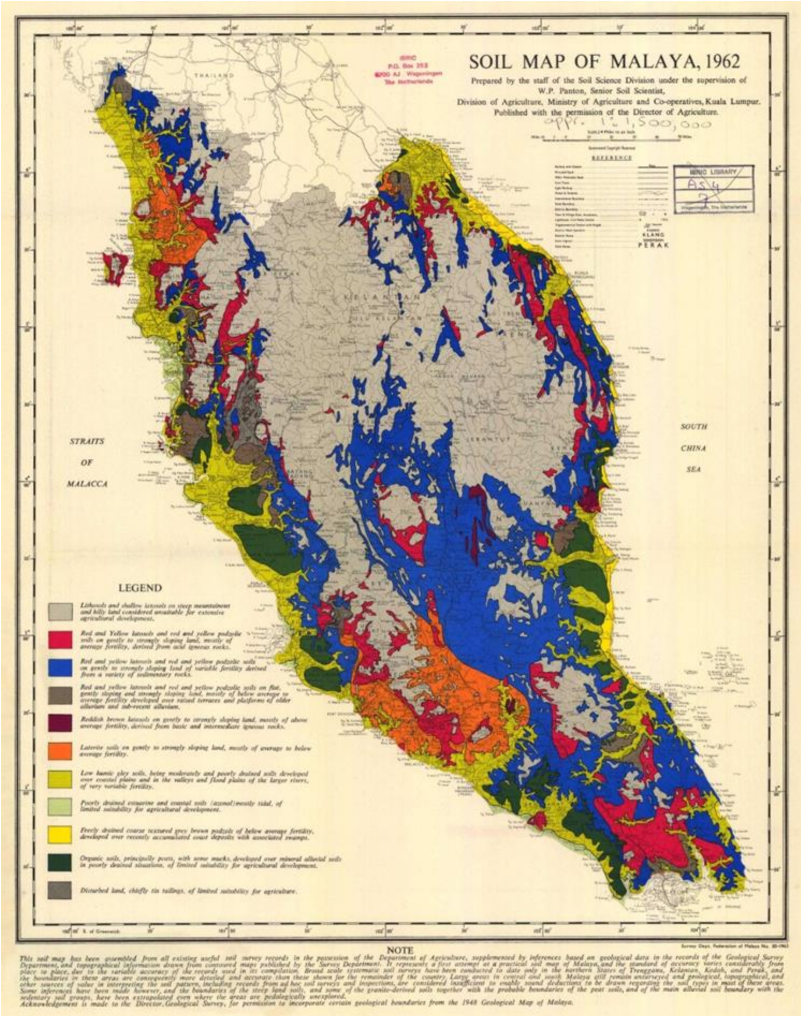

Figure 2.3: Shows the maps of soil distributions in Peninsular Malaysia, (Onyelowe and Agunwamba, 2012)

For instance, as depicted in Soil Map of Malaya, 1962, (Figure 2.3), the study area consists primarily of lithosols and shallow latosols that are unsuitable for considerable agricultural growth due to the steep mountainous and hilly terrain. It may alter the water flow in the form of distribution types and the particle distribution characteristics of sediment transport (Pour and Hashim, 2015).

2.1 Suspended Sediment and Suspended Load

In a naturally occurring river system component, suspended sediment has a special function in shaping the landscape, fostering ecology, and delivering nutrients to different habitats (Robert and Vercruysse, 2016; Dean et al., 2016; Koiter et al., 2013). Fine organic and inorganic materials that have eroded off land surfaces are carried downstream by rivers as silt. Research demonstrates that each stage of this fundamental sediment transport process is becoming more and more chaotic and changeable (Phillips, 2003). Within the vertical flow depth, the concentration of suspended silt also fluctuates.

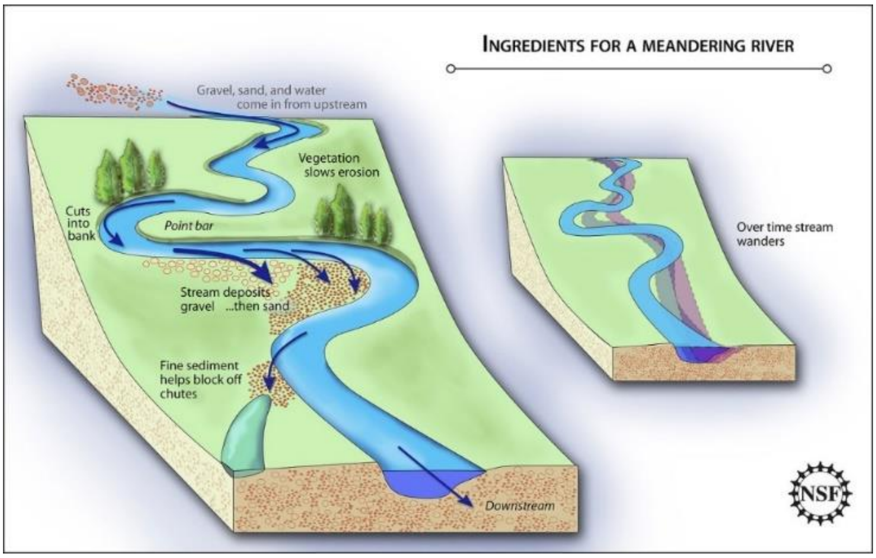

Figure 2.4: The sediment carried downstream by water flow (Sanders, 2009)

By understanding the suspended sediment and load transport principle, it is crucial for issue interpretation and resolution in a wide range of hydraulic, hydrologic, and water resources engineering situations, particularly those involving river and coastal engineering (Lu, Liu, Li, and Dong, 2015; Vo et al., 2017). According to the hydraulic principles that can transport and move the sediments, as seen in Figure 2.4, the sediment will move along the water path until it exits the water ways. The upper portion of the fluvial network is built by mountain streams and their tributary torrents. They play a crucial role in the movement of sediment from upper basins to lower basins. Channels often have a solid bed surface, a wide range of grain sizes, from fine sand to huge stones, and a steep profile. As the term "load" refers to the overall number of particles moving, including bedload, suspended load, dissolved load, and wash load, sediment transport is also referred to as "sediment load" (Eaton and Rosenfeld, 2017). By referring to Figure 2.5 and Table 2.1, the characteristics, and details of each of the type of sediment load is shown.

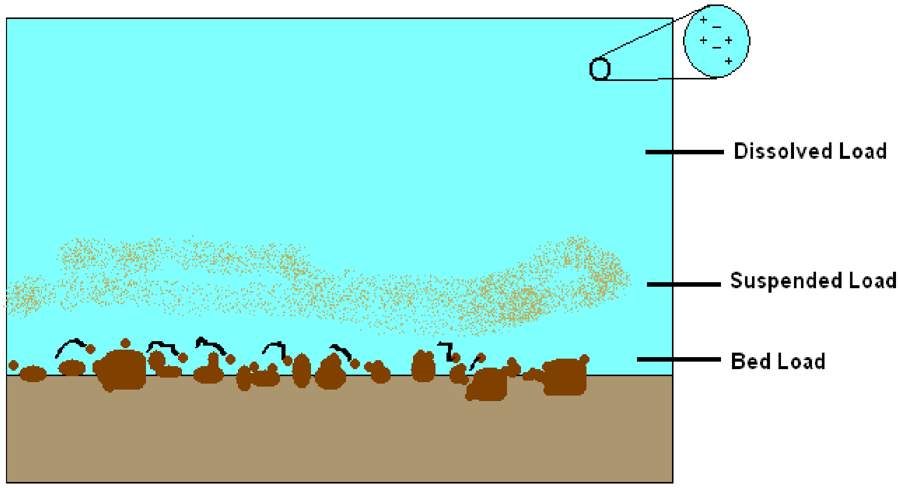

Figure 2.5: The composition of the sediment transport

Table 2.1: The sediment characteristics influencing the rate of the sediment transport, (Onyelowe and Agunwamba, 2012)

Particle size class	Effective Diameter, mm	Specific gravity, g/cm^3	Specific surface area, m^2/g	Fall velocity, mm/s	Time to fall 1 mm/s
Clay	0.002	2.60	20-800	0.003	330
Silt	0.010	2.65	4	0.080	13
Small aggregate	0.030	1.80	35	0.350	2.9
Sand	0.000	2.65	0.05	24	0.04
Large aggregate	0.500	1.60	15	40	0.03
Gravel	1.0	2.65	0	>250	
Organic matter			1000		

As shown in Table 2.1, the typical particles class that found in the sediment has been classified into several criteria as shown in Table 2.1, (Eaton and Rosenfeld, 2017). Basically, the organic matter has the highest value due to the variability of the matters. According to (Fan, Zhang et. al., 2020), Soil Organic Matter (SOM) is affected by altitude, aspect, pH, land use, soil texture. Thus, the higher the organic matter, the higher the fertility value which beneficial for agriculture and carbon capture. Thus, by using a table of particle size classes that the geological engineer has provided, it is possible to identify the size of the data's particles (Rahardjo et.al, 2004).

Table 2.2: The particle size classes that may be use as the indicator for the types of the sample or the particles.

Particle-size class	Size (mm)
Boulders	>200
Very coarse gravel	200-60
Coarse gravel	60-20
Medium gravel	20-6
Fine gravel	6-2
Coarse sand	2.0-0.6
Medium sand	0.6-0.2
Fine sand	0.2-0.06
Silt	0.06-0.002
Clay	<0.002

2.4 Ackers-White Equation

A hypothesis or formula to forecast and compute the transport of non-cohesive sediment was published in 1973 by both Peter Ackers and William Rodney White. These equations are frequently used to determine sediment transport, changes in channel morphology, and they can also be used to create physical models (White W. R., 1973). In an effort to provide frameworks for the analysis of data on sediment transport, many hypotheses have been proposed, some of which are based on the physics of particle motion and others on similarity principles or dimensional reasoning.

According to Ackers and White (1973), only a portion of the shear stress on the channel bed is caused by the sediment's velocity (Julian, Erosion and Sedimentation, 2002). However, in the case of fine sediment, suspended load predominates, and total shear stress is a factor in the particle mobility in the sediment. Additionally, they assert that because the rate of transport is sensitive to the carrying power, inaccurate separation could result in significant mistakes in estimates (White P. A., 1973). In essence, a coarse sediment is considered to be transported mainly as bed process. If the bed features exist, it is assumed that the effective shear stress bears a similar relationship to mean stream velocity as with a plane grain – textured surface at rest. This is given by a development of the rough, turbulent equation:

$$\sqrt{\frac{\tau\ cg}{\rho}} = \frac{v}{\sqrt{32}\log\left(\alpha\frac{d}{D}\right)} \qquad \text{(Eq 2.1)}$$

A fine sediment is also assumed to be conveyed into the flow's body, where it is suspended by stream turbulence, according to the Ackers and White equations. Since the total energy degradation, rather than the net grain resistance, determines the intensity of turbulence for fine-grained materials:

(Eq 2.2)

$$\sqrt{\frac{\tau\, cg}{\rho}} = v. = \sqrt{gdi}$$

Basically, the concentration and sediment movement of fine and extremely fine sands are often overestimated using the Ackers and White technique. The formula's derivations based on grain size have a constraint as well. The equations' equations are as follows:

$$\begin{gathered} for\ D_{gr} > 60\ (coarse\ sediment, D > 2mm) \\ n = 0 \\ A_{gr} = 0.17 \\ m = 1.78 \\ C = 0.025 \\ for\ 1 < D_{gr} < 60 \\ (transitional\ and\ fine\ sediments, 0.06 < D < 2\ mm) \\ n = 1.00 - 0.56 \log D_{gr} \\ A = 0.14 + 0.23 / \sqrt{D_{gr}} \\ m = 1.67 + 6.83/D_{gr} \\ \log C = -3.46 + 2.79 \log D_{gr} \\ -0.98\left(\log D_{gr}\right)^2 \end{gathered} \qquad \text{(Eq 2.3)}$$

Utilizing a software created by San Diego State University named Fluvial-12, the calculations in this study was performed. To use this software, a few changes towards the parameters that will be used in the calculations should be done. Some of the parameters was the hydraulic depth, channel width, mean velocity, bottom slope, and mean diameter. Majority of the parameters simply obtained from the website or from the appendix, which has been derived formulations for the programme listed.

2.5 Hjulström Curve

The Filip Hjulström graph as shown in Figure 2.6 was used by hydrologists and geologists to evaluate erosion, transport, silt deposits condition in a river. The graph only includes sediment particle size and river velocity. Besides that, the graph also able to demonstrates how a river's velocity impacts its efficiency and capacity to dissolve particles of various sizes.

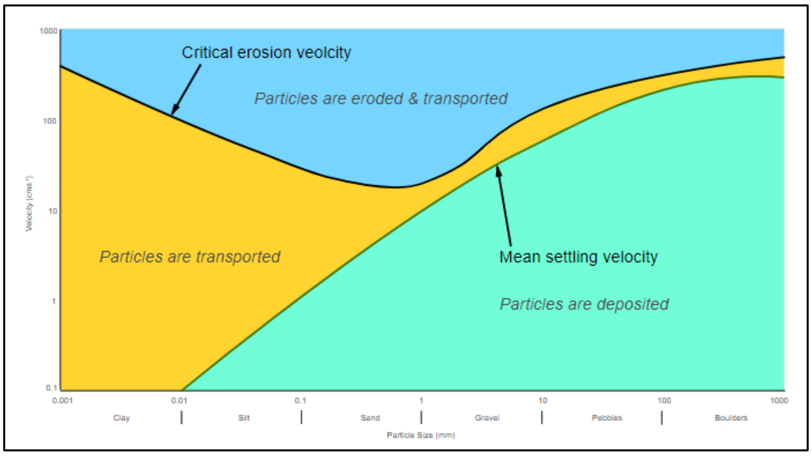

Figure 2.6: The Hjulström curve

Journal of Sustainable Civil Engineering and Technology
e-ISSN: 2948-4294 | Volume 2 Issue 1 (March 2023), 45-60
https://joscetech.uitm.edu.my

3. Methodology

Figure 3.1 shows the methodology chart of the research study.

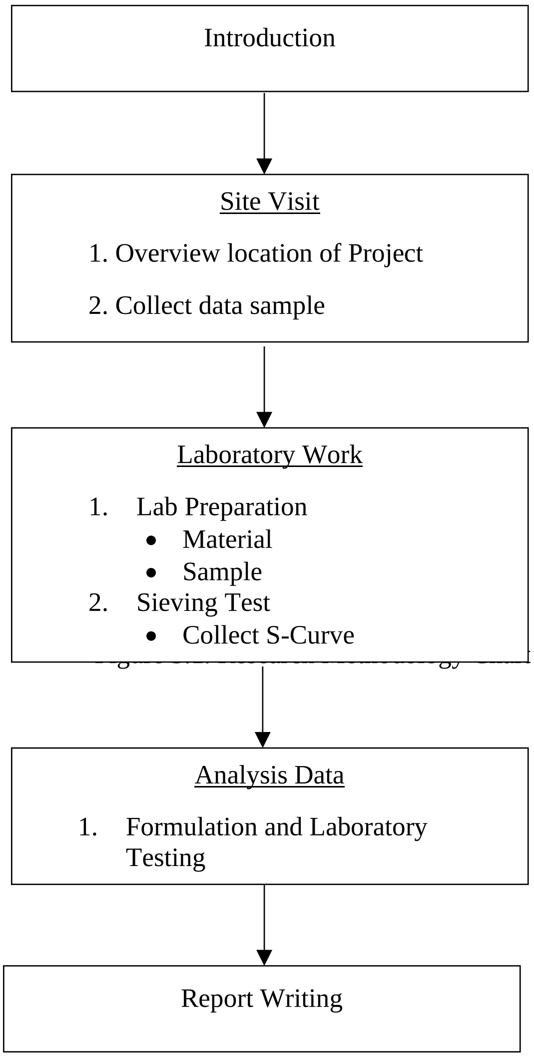

Figure 3.1: Methodology Chart of the Study

3.1 Site Visit

The study's sample was taken at the Kanching Waterfall, where three (3) distinct samples obtained at three (3) different waterfall levels.

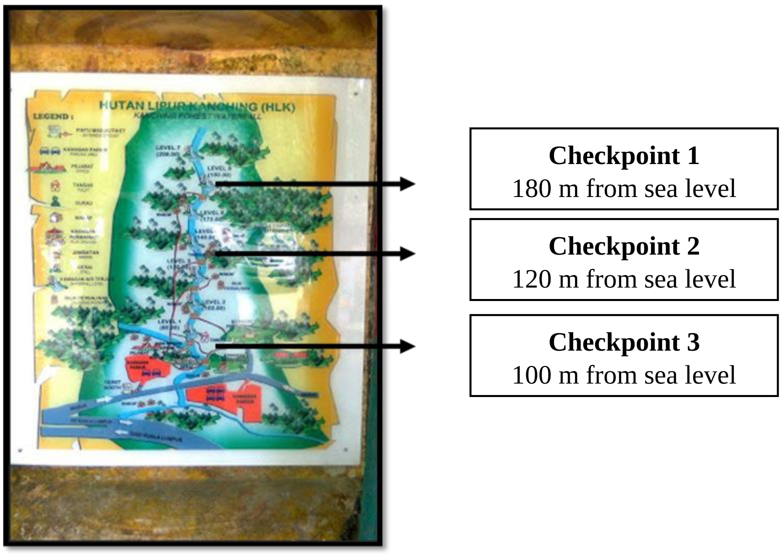

Figure 3.2: Number of checkpoints and the height of the waterfall

Figure 3.3: Checkpoint No. 1

Figure 3.4: Checkpoint No. 2

Figure 3.5: Checkpoint No. 3

3.2.1 Velocity Measurement

Figure 3.6: Current meter equipment to measure the stream velocity.

To measure the stream's velocity in terms of revolutions per minute, a current meter is used. This technique involves creating several vertical subsections from the cross section of the stream channel. Each subsection's area is calculated by measuring its width and depth, and a current meter is used to measure the water's velocity. By dividing the subsection area by the observed velocity, the discharge in each subsection is calculated. The discharge of each subpart is then added up to determine the overall discharge. Usually, a cable, steel tape, or other comparable piece of equipment is used to measure the breadth of a subsection. A wading rod is used to gauge the depth of the subsection. Figure 3.6 shows the current meter equipment used in this project.

3.3 Laboratory Work

The importance of conducting the particle size distribution for is not only to use it in future computations but also to comprehend its physical and chemical properties. It does have an impact on the sturdy and load-bearing qualities of the rocks and soils themselves. Along with other elements like suspended solid, dissolved solid, and many more, the distribution of particles can also be a sign of the turbidity of rivers.

Thus, the laboratory work was focused solely on sieving analysis; however, this testing is crucial to the success of the entire investigation and was carried out at the UiTM Soil Lab on Level 3 in Shah Alam. Due to the amount of water existed in the sample, it was let dried at for least twenty-four (24) hours.

Figure 3.7: The dried sample after twenty-four (24) hours

Afterwards, the characteristic of flows is determined by using the Hjulström curve such shown in Figure 3.8.

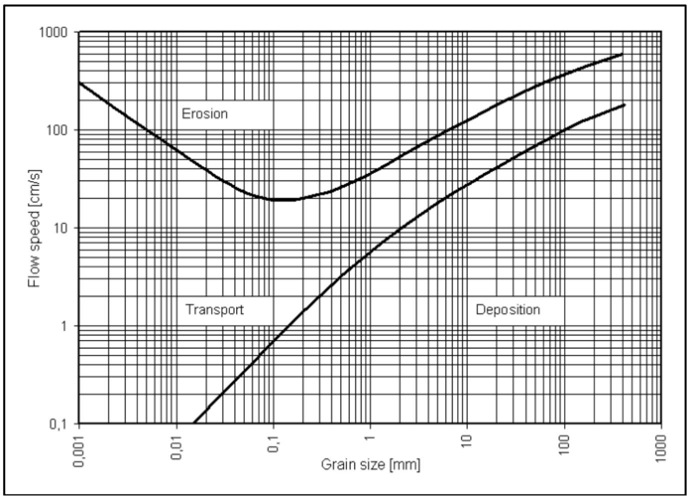

Figure 3.8. The Hjulström Curve to check the characteristics of the flows.

The result of the analysis of the size distribution is used in the calculation of the sediment discharge using the Acker and White equation.

4. Results and Discussion

The sample were collected at three (3) different checkpoints along the river in order to obtain different features in terms of silt size, velocity procedure and total sediment discharge.

Table 4.1: The data obtained for every checkpoints.

No of checkpoint	Velocity (ms-1)	Width, B (m)	Depth, D (m)	d_{50} (mm)
1	0.52	10	1.54	0.52
2	0.42	9	1.20	0.50
3	0.27	4	0.25	0.59

4.1 Sieve Analysis

With the results from the sieve analysis and gradation test, the study's findings are presented. The sample distributions primarily required so that the cumulative 50% point of diameter, d_{50} could be calculated. By obtaining the d_{50}, the sample's median diameter or average particle size could be determined (Jack, 2018).

Checkpoint 1

Total weight of sample: 2385.91 g

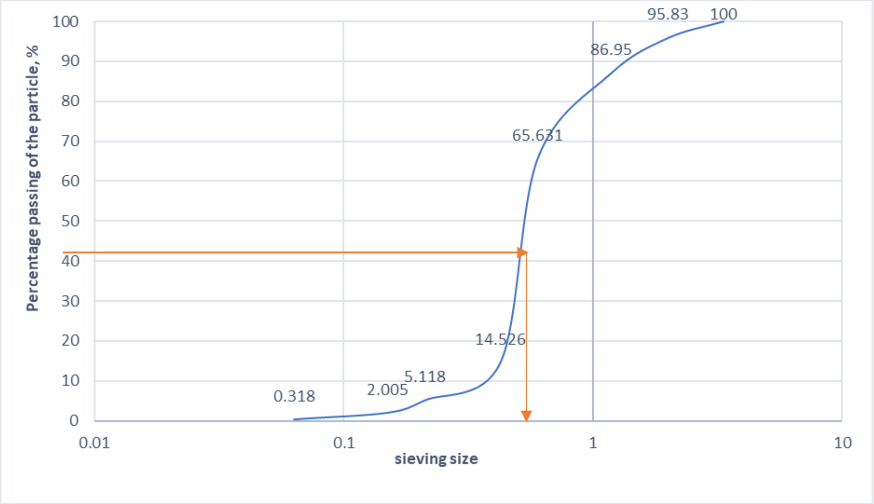

Figure 4.1. S- Curve between the percentage passing of the particle, (%) and the size sieving, (mm) for Checkpoint 1

From Figure 4.1, the d_{50} is 0.52 mm and based on the Table 4.1 the particle is within fine and medium sand. This means at check point 1, the class can be concluded as the mixture of fine and medium sand. As mentioned by (Marshall, 2014), usually at the higher place of a river, the sediments will consist of fine and medium sand. This is due to the less erosion occur in upper streams compared to downstream area.

Checkpoint 2

Total weight of sample: 1875.66 g

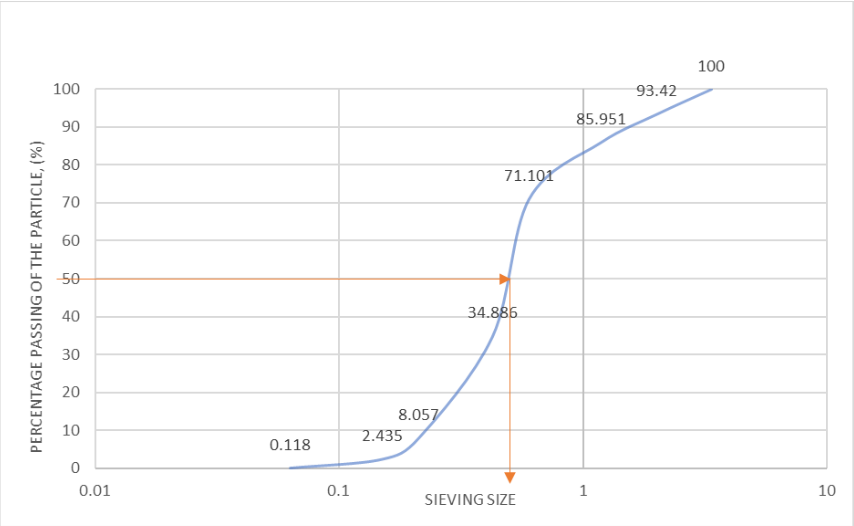

Figure 4.2: S- Curve between the percentage passing of the particle, (%) and the size sieving, (mm) for Checkpoint 2

From Figure 4.2, the d_{50} value obtained was 0.50 mm. By referring to Table 4.1, this part of the river was identified as the fine sand. According to (Marshall, 2014), the downstream area in a river will most likely consist of fine sand. This is due to the travelled length of the sediment itself, where they are experiencing erosion and abrasion along the way.

Checkpoint 3

Total weight of sample: 2801.74 g

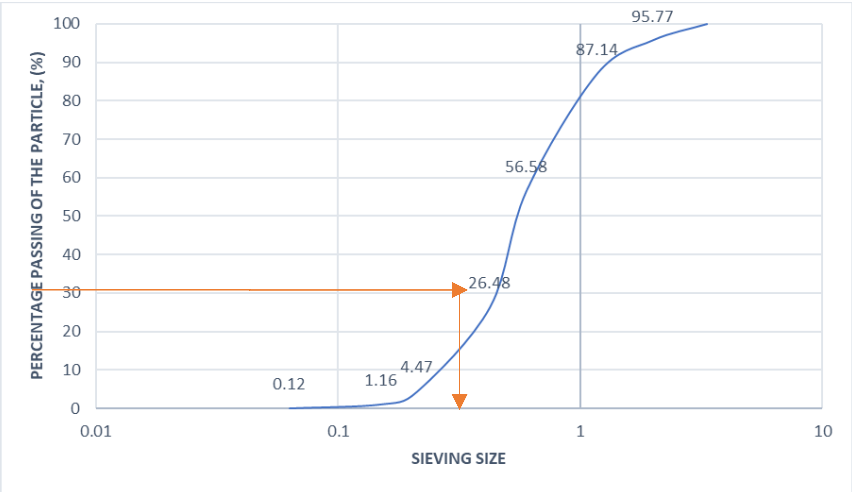

Figure 4.3: S- Curve between the percentage passing of the particle, (%) and the size sieving, (mm) for Checkpoint 3

From Figure 4.3, the d_{50} value identified was 0.59 mm. Based on the Table 4.1 that has been provided before, the class of the particle within the medium sand.

From the results obtained, it can be concluded that the sediments in Kanching Forest Waterfall primarily consist of fine and medium sands. According to Liton Biswas, river sand often has spherical grains that are also well-graded (Biswas, 2017). By comparing the previous findings with (Marshall, 2014), it can be concluded that Kanching River is suitable and safe for public usage and could be used for recreational activities.

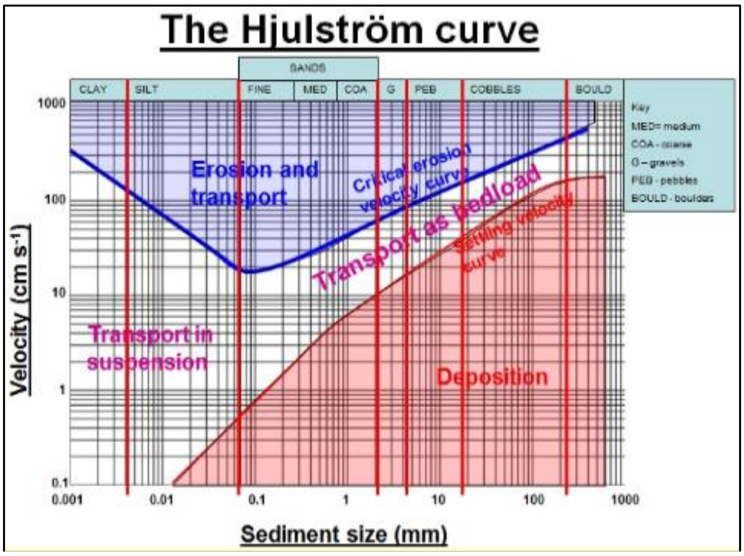

Figure 4.4: Hjulström curve of sediment transport.

Using the graph of the Hjulström curve in Figure 4.4, a broad understanding of the velocity and sediment size of the data were collected as shown in Table 4.1, thus proceeded with the Ackers and White formulas. There is a correlation between the particle size and the particle mobility in the rivers' flows. As the purpose of the study is to examine the characteristics of the sediment, the curve was used to describe what types of flow characteristics may occur at Kanching Forest Waterfall depending on the particle's velocity, this silt can occupy a range of positions within the flow.

At Checkpoint 1, the d_{50} value is around 0.52mm and the velocity obtained from the site is approximately 0.52 m/s. However, At the beginning of this study, it is assumed that chechpoint 1 will experience bedload transportation. However, based on Hjulstrom curve and the obtained velocity of 0.52m/s, the particle is experiencing erosion and transported instead.

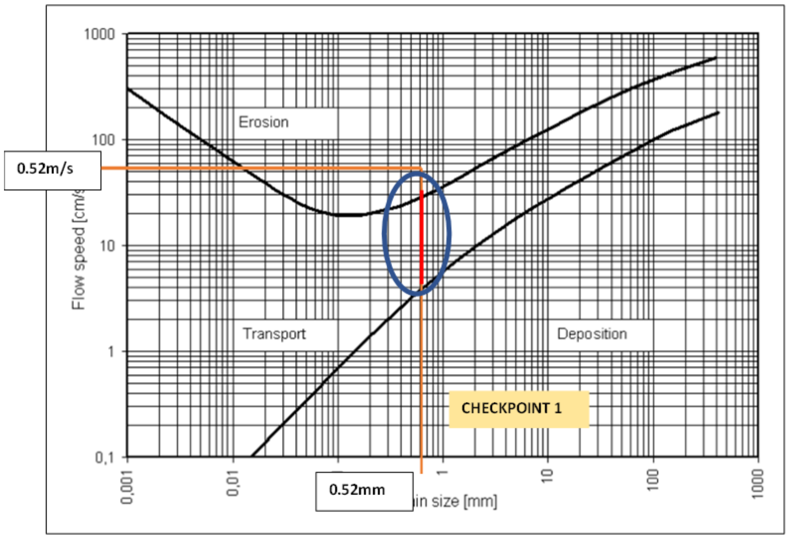

Figure 4.5: The Hjulström curve Checkpoint 1.

At Checkpoint 2, the obtained d_{50} is 0.50 mm and velocity that obtained is 0.42 m/s which means the particles are eroded and transported rather than transported as bedload towards other waterfall sections.

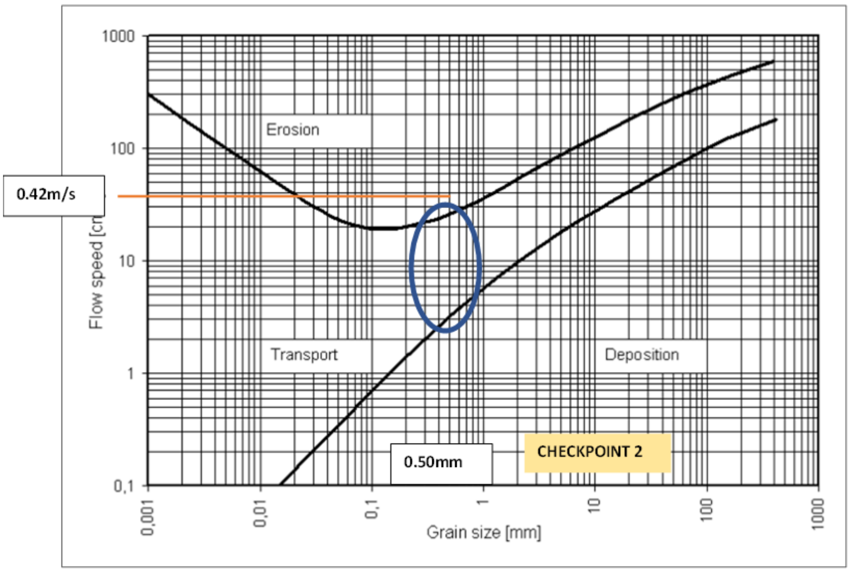

Figure 4.6: The Hjulström curve Checkpoint 2

In contrast, at Checkpoint 3, the particle size determined by sieve analysis is around 0.59 mm. It is within the range of the sieve analysis, but the velocity in this checkpoint is 0.27 m/s which is lower than the other checkpoints. By comparing the samples and particles to the Hjulström curve, it is determined that the silt delivered by a river consists of particles that are too dense to be in suspension.

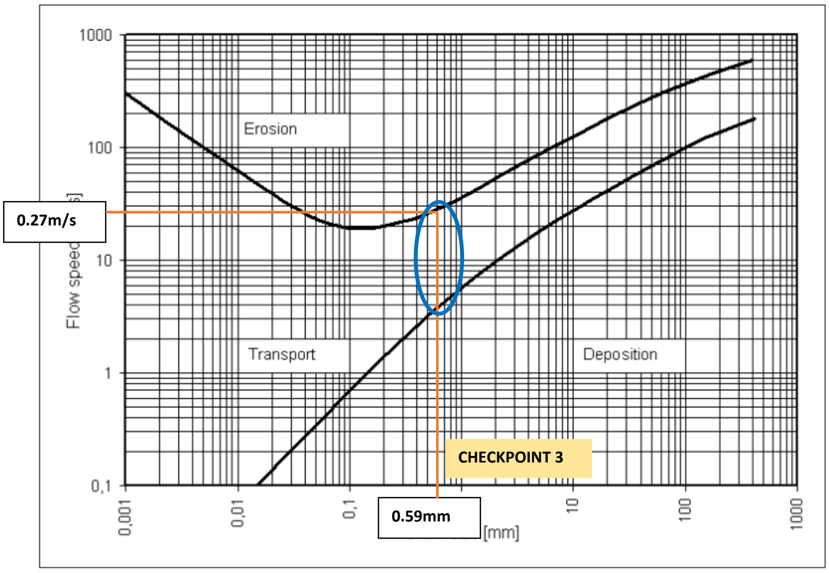

Figure 4.7: The Hjulström curve Checkpoint 3

As mentioned earlier, the aim of this study is to compare the data between the Hjulström curve and the Ackers White in order to comprehend the flow characteristics of particles. By utilizing the graph of Ackers White in Figure 4.5 only the velocity and grain size will be displayed to calculate sediment movement. By using this form of graph experiences of the particle that has already occurred can be expected.

4.2 Total Sediment Discharge

<u>(Akers White Formula)</u>
Bed slope for every checkpoint: 1/1000
1kg = 9.81 Newton

Table 4.2: Total Load Transport for each of the Checkpoints.

No of checkpoint	Total Load Transport (Newtons/s)
1	0.4703
2	1.5343
3	-

The carrying capacity of a stream depends on two factors: water velocity and stream discharge. With an estimated velocity of 0.52 m/s at checkpoint 1 and a particle diameter of 0.55 millimetres, the 0.55 mm particle will be transported without difficulty. Along the streams, particles can move with a velocity of 0.4703 N/s or within 40 gram/sec due to the strength of the flows.

At checkpoint 2, where the velocity of the water is around 0.42 metres per second and the particle size distribution is about 0.5 millimetres, the total load transit is approximately 1.534 N/s, or 156 grammes per second. The size of the overall load discharge is extremely large, but it may be acceptable because Checkpoint 2 is where people crowded in, as its depth is only 1.4 metres. Within this depth, it is ideal for people to enjoy themselves. As they continue to swim around and aid in the transportation of the particles, the density of these individuals may influence the outcome.

In contrast, at Checkpoint 3, there is either no total load transfer or the number of transports is insufficient for us to disregard the worth of the loads. This is because, as we can see, the flow velocity in that area is approximately 0.27 metres per second. As the weight of the grains grows, the capacity of the flows to transport grains of 0.58mm size may become more challenging.

From the graphic, we can see that Checkpoint 1 is elevated above the other checkpoints, therefore it makes sense if the velocity in those places is quite high in comparison to the other checkpoints. While Checkpoint 3 is located downstream of the river, these areas are essentially covered with huge particles or grains.

According to research conducted by Ab. Ghani (2012) at Sungai Kulim, Kulim Kedah, the significance of sediment conveyance is to prevent flooding caused by sediment concerns If the silt in the river is not controlled, the similar consequence may occur in the Kanching River residential neighbourhood. The significance of the study will also provide some basic insights on the conditions under which the river remains shallow or deep. We are all aware that one of the functions of the river is to act as a catchment area within the locations; however, if there is no catchment area or if the river remains shallow due to the effect of sediment, the water that may result from heavy rain will overflow, affecting the people who live in the vicinity.

5. Conclusion

Sediment is closely associated with the movement or discharge of water flow. This is because, to transport the given weight or size of the particles, a certain discharge is required to propel and transport the particles down the routes. In essence, sediment estimations are so important because certain rivers in Malaysia still use river water to fill reservoirs for daily use. Sedimentation in reservoirs can restrict the volume of available water, hence limiting its use. Depending on the location chosen, river water could be used as one of the water supply sources for facilities such as toilet flushes. To do this, the appropriate pipe size and filtration must be designed depending on the collected and analysed grain particles.

According to the data, particles at Checkpoint 1 can move with a velocity of 0.4703 N/s or within 40 grammes per second. Next, the total load transit at Checkpoint 2 is roughly 1.534 N/s, or 156 grammes per second. Due to a growth in the number of people who participate in outdoor water activities in this region, the overall load discharge is incredibly large. At Checkpoint 3, there is either no complete load transfer or an inadequate number of transports due to the low strength of the flow to transport grains of 0.58mm size.

The significance of complete load transit also ensures the preservation of one of the region's recreational places. By calculating the entire transport load, the total load that may be eroded along the river can be estimated. Therefore, estimation and maintaining the river's depth so that people can use it (Ab. Ghani, 2012) could be done efficiently. As everyone knows, Kanching Forest Waterfall is the most popular spot for residents of Kuala Lumpur to enjoy a scenic vista where it can be reached in less than an hour. Lastly, by conducting this research it may also be possible to collect data for future use.

Acknowledgement

No acknowledgement

Declaration of Conflicting Interests

All authors declare that they have no conflicts of interest.

References

Ackers P and White Wr. (1973) *Sediment Transport in Channels: New Approach and Analysis*, Proc ASCE, JHD 99 HY11

Aminuddin Ab. Ghani, C. H. (2012). Sediment size and deposition characteristics in Malaysian at Sungai Kerian . *Urban Water Journal*.

Bartam, J. &. (1999). Water Quality Monitoring. *A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Prog.*

Biswas, L. (7 5, 2017). *Types of Sand*. Retrieved from A Civil Engineer: http://www.acivilengineer.com/2017/05/Sand-Types.html

David. (15 January, 2009). Malaysia Traveller.

Drainage and Irrigation Department (2000). Urban Stormwater Management Manual for Malaysia – Manual Saliran Mesra Alam Malaysia. Malaysia

Eaton, B., & Rosenfeld, J. (2017). Mechanisms of Flow and Sediment Transport in Fluvial Ecosystems : Physical and Ecological Consequences. Jack, H. (27 March , 2018). *What is Particle Size Distribution D50, D50 Particle Size Distribution*. Retrieved from http://www.isizer.com/what-is-d50/

Fan, M., Lal, R., Zhang, H., Margenot, A. J., Wu, J., Wu, P., Zhang, L., Yao, J., Chen, F., & Gao, C. (2020). Variability and determinants of soil organic matter under different land uses and soil types in eastern China. Soil and Tillage Research, 198, [104544]. https://doi.org/10.1016/j.still.2019.104544

James, S. C., Grace, M. D., Ahlmann, M., Jones, C. a., & Roberts, J. D. (2008). Recent Advances in Sediment Transport Modeling. World Environmental and Water Resources Congress 2008: Ahupua'a, 88220, 361–361. https://doi.org/10.1061/40976(316)361

Julian, P. Y. (1998). *Erosion and Sedimentation (First Edition).* United Kingdom: The Press Sydicate of The University of Cambridge.

Lu, H., Liu, J., Li, Y., & Dong, Y. (2015). Heat Transport and Water Permeability during Cracking of the Landfill Compacted Clay Cover. Journal of Chemistry, 2015. https://doi.org/10.1155/2015/685871

Marshall, S. T. (2014). Soils, Sediment, Weathering, and Sedimentary Rocks.

Omidi, G. H., Thomas, J. C., & Brown, K. W. (1996). Effect of desiccation cracking on the hydraulic conductivity of a compacted clay liner. Water, Air, and Pollution, 89(1–2), 91–103. https://doi.org/10.1007/BF00300424

Onyelowe, K. C., & Agunwamba, J. C. (2012). Technical Note : GEOTECHNICAL EXAMINATION OF THE GEOPHYSICAL PROPERTIES OF OLOKORO BORROW SITE LATERITIC SOIL, 31(3), 397–400.

Pour, A. B., & Hashim, M. (2015). Structural mapping using PALSAR data in the Central Gold Belt, Peninsular Malaysia. Ore Geology Reviews, 64(1), 13–22. https://doi.org/10.1016/j.oregeorev.2014.06.011

Rahardjo, H., Aung, K. K., Leong, E. C., & Rezaur, R. B. (2004). Characteristics of residual soils in Singapore as formed by weathering. Engineering Geology, 73(1–2), 157–169. https://doi.org/10.1016/j.enggeo.2004.01.002

Shi, P., Arter, C., Liu, X., Keller, M., & Schulin, R. (2017). Soil aggregate stability and size-selective sediment transport with surface runoff as affected by organic residue amendment. Science of the Total Environment, 607–608, 95–102. https://doi.org/10.1016/j.scitotenv.2017.07.008

Sinnakaudan, Shanker & Sulaiman, Mohd & Teoh, S.. (2010). Total bed material load equation for high gradient rivers. Journal of Hydro-environment Research. 4. 243-251. 10.1016/j.jher.2010.04.018