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# Determination of Slope Stability using (UAV) Unmanned Aerial Vehicle

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**Abstract**: In this modern era, conventional methods of slope monitoring are not recommended because of their high risk. The goal of this project is to use unmanned aerial vehicles (UAVs) to monitor slope conditions whether safe or not. The following goals were set to achieve that goal by producing orthomass images, Digital Terrain Model (DTM) and Digital Surface Model (DSM) using Pix4d map4 software. In addition, it analyzes drainage system images taken by UAVs and analyzes slope tracks using global mapper software. Drainage on slopes is the subject of this study because it plays an important role in reducing the presence of groundwater and transporting rain that flows from the top to the bottom of the slope surface. This study was conducted in the hillside area behind Pagoh Residential College (3) {KKP3}. Pre-flight planning and preparation, data retrieval using UAV aircraft, image processing using Pix4dmapper software, and slope assessment using Global Mapper software are all included in the process. Thereafter, slope conditions can be determined based on slope drainage monitoring. With images obtained from the UAV, slope surface conditions, such as cracks on the slope structure and excessive crop growth on the slope drainage, can be seen in this research. In addition, the gradient, elevation and flow of water on the surface can be known. Thus, the use of UAV aircraft in slope monitoring and inspection was successful and the purpose of this study was achieved because these devices show excellent propensity and the software supporting our research can be used efficiently with the guidance of our supervisors. Eventually, research studies could be met and slope conditions could be monitored despite the many obstacles that emerged in this pandemic era.

**Keywords**: Unmanned Aerial Vehicle, slope, orthomotic images, drainage

## 1. Introduction

In Malaysia, there are many man -made slopes for infrastructure construction that result in landslides. Collapse of the slope usually occurs when there is a big storm where it can lower the shear strength of the soil and increase the pressure in the soil [1]. These issues will affect the environment such as life and property safety. In this study, slope drainage the focus. Slope stability is influenced by

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slope drainage. The presence of groundwater can break the unity between the grains, and reduce friction. When water replaces air between soil grains, As the dirt on the slope grows heavier, it will most certainly increase the likelihood of downslope mass movement and induce slope failure. [2].

This study was conducted to streamline the work of the inspection surface structure of a slope by using micro UAV technology. This method is to obtain slope inspection and monitoring pictures. In addition, this can also slope safety inspectors will be able to undertake inspections with less danger. as well as save energy and work time.

This problem statement explains that there are man-made slopes that are cut and left for infrastructure construction. Slope construction if not monitored and planned carefully will cause landslides. Therefore, maintenance and improvement work on the slopes should be done by the responsible party. Furthermore, slope damage usually occurs due to environmental factors or natural factors. For example, heavy rainfall will often cause a decrease in shear strength in the soil as well as a decrease in soil pressure. This is because the absorption of water into the soil in large quantities will cause a loose contraction between the sand particles. This will cause slope stability less guaranteed. Therefore, by using Unmanned Aerial Vehicles (UAVs) to observe areas in our territory of choice, this method is more beneficial than the conventional methods. Through this method, our time and energy can be significantly reduced.

The main goal of this study is to investigate the application of unmanned aerial vehicle (UAV) technology and photogrammetry technique for geotechnical data collection. This principal objective is divided into the following secondary objectives which are (1) to produce orthomosaic image, Digital Terrain Model and Digital Surface Model by using pix4d mapper software, (2) to investigate the slope failure by using global mapper software, (3) to determine slope safety factor by using slope/W software, and (4) to simulate the water drop on slope using global mapper software.

### 1.2 Unmanned Aerial Vehicle (UAV)

Unmanned Aerial Vehicle (UAV) is a small and dynamic unmanned aircraft. In Malaysia, the use of UAVs is intended for national defense, mapping, coastal area monitoring and air traffic [3]. UAVs are also equipped with area mapping cameras that are quiker and more flexible than classic aerial photographs [4]. Now UAVs have evolved in the field of civil engineering. Therefore, this UAV is a small aircraft with a high -resolution camera and is very light to take digital photographs from the air [5].

In this study, the UAV used was the DJI Phantom 3 Advance. Slope data and information are generated using unmanned aerial vehicles (UAVs). Before running out of power, the UAV is able to return to its original position and land. It is operated by a remote control connected to a smartphone that has DJI Phantom 3 Advance software installed.

Next, Pix4Dcapture is the perfect tool for capturing photo data automatically. After that, all data will be generated using Pix4Dmapper and Global Mapper. Pix4Dmapper is a natural software for creating images retrieved from the air an Unmanned Aerial Vehicle (UAV) micro aircraft. It uses technology that takes pictures so as to be able to create 3D models of the whole subject [6].

Next, Global Mapper is capable of displaying data set vectors, altitudes, and Geographic Information System (GIS) vectors. it can also be used to edit and export data easily [7].

## 2. Methods

Remote sensing techniques were employed to obtain data on terrain morphology and to provide slope geometry for assessing the slope stability. In this study, Remotely Piloted Aircraft System or UAV was used to collect images which were processed by Pix4D mapper to generate a point cloud and mesh. The obtained digital surface model (DSM) was processed and the derived digital terrain model (DTM) allowed cross sections to be drawn and a joint system to be detected [8].

2.1 UAV flight training

To improve the work of data collecting and to ensure that the analysis performs well as precise information is collected. Flight training must be carried out prior any flying operations, this must be done first. The flight training is done by determining the pattern of the fly. The grid mission is used for slopes as a pattern to capture the image. Using Pix4Dcapture, which must be installed on a smartphone, the mission is carried out. This application will help to run the flights smoothly [9].

**Figure 1** show that the example of how the flight will be carried out. The pattern of flight for both slopes is same. Before starting the flight mission, the height needs to be set prior start. Because the height of slopes varies, the height is variable. Automatically operated UAV via the Pix4dcapture application. Ensuring that the UAV Global Positioning System (GPS) is connected to the smartphone via the Pix4dcapture application is the most important thing during the flight mission [9].


**Figure 1: Example of how the flight will be carried out**

2.2 UAV Preparation

Several things should be check before starting the flight mission, this is compulsory to make the flight mission run smoothly without any problem. The utility of a self-contained chipset, radio modem, camera mount to hold a computerised camera, battery capacity, electronic speed controller, and global positioning system are all essential factors to consider. The equipment also needs to be examined, the UAV sensing system such as, lift, rudder and throttle before set in motion.

2.4 Analysis image from UAV wing pix4D mapper software.

For use as a study site, the unmanned aerial vehicle (UAV) will be flown around the hills. When UAV flights are carried out, the height of the UAV and its speed should be maintained so that the image may be captured clearly and with greater quality. The Pix4dcapture software will automatically take the image and the height of drone flight will be set in this software. **Figure 2** show image taken by Pix4dcapture via UAV [9].

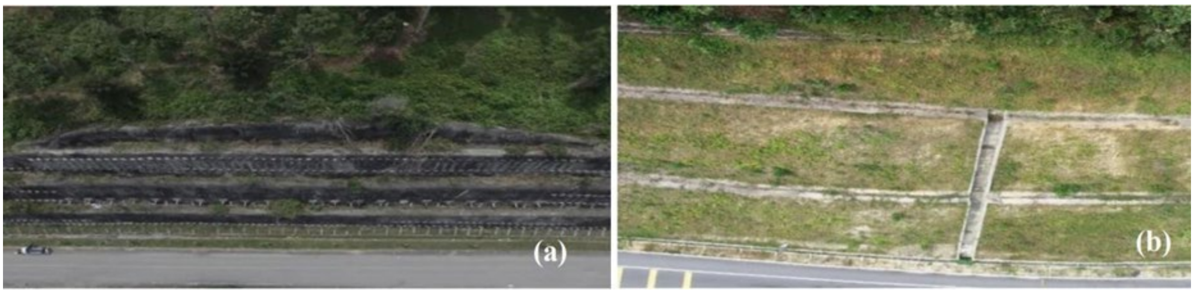



**Figure 2: Image taken using UAV**

The visual examination of slopes is done using Pix4Dmapper to analyse the picture. Pix4Dmapper generate an orthomosaic picture, as well as a Digital Terrain model and a Digital Surface model. All of this information is utilised to create contour and watershed analyses. This program is focused on finding thousands of common points in between images automatically. A key point is called every characteristic point found in an image. When 2 key points are found to be the same on 2 different photos, the key points are balanced. Each group of key points properly matched will generate one 3D point [9]

## 3. Results and Discussion

The slope image behind the UTHM student residential college was processed using Pix4Dmapper software. Once the image processing is complete, the file analyzed. By using this software, users can perform water flow analysis on the field data loaded to find the flow path as well as describe the river flow area that flows to a particular part of the flow.

### 3.1 Pix4Dmapper

Using the Pix4Dcapture application, slope images were taken using a UAV and processed to produce Orthomosaic, Digital Photos Terrain Model (DTM) and Digital Surface Model (DSM). Pix4Dmapper software is used to combine all the photos taken by the UAV.

Based on figure, an orthomosaic image is an aerial photograph geometrically where the scale is uniform and the photo has the same lack of distortion as a map. Unlike uncorrected aerial photographs, orthomotic photo can be used to measure actual distance, as it is an accurate representation of the Earth surface, has been adjusted for topographic clearance, lens distortion, and camera tilt.

The Digital Surface Model (DSM) is an elevation model that captures natural and artificial features from the environment. This includes the top of buildings, trees, electrical outlets, and other objects. Typically, this is seen as a canopy model and just a 'runway' where there is nothing else on it. This is shown in **Figure 3** of the Digital Surface Model (DSM) drawing.

In addition, the Digital Surface Model was generated using overhead images for the slopes. Colors represent different heights. Slopes and flat surfaces of easily recognizable land. Unlike the DTM, the DSM shows all surface and path of the crop. The picture shows that the blue color represents the lowest altitude and the almost red-orange color represents the highest altitude.

Next, figure shows four cross -sections on the slope having different slope geometries for each was generated from Global Mapper Software.

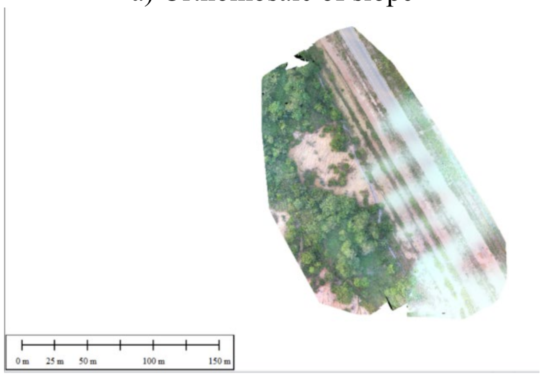
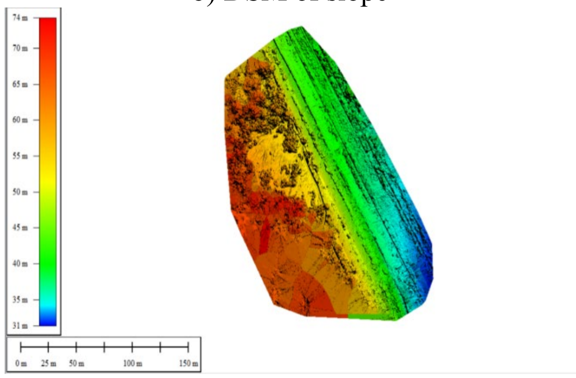
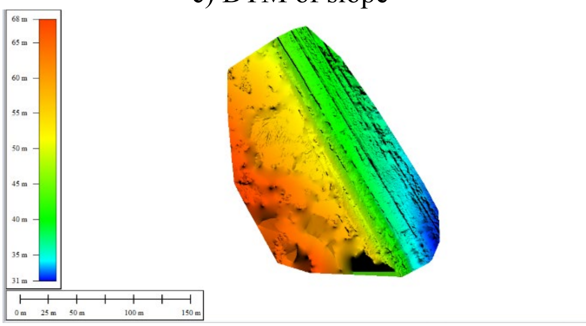
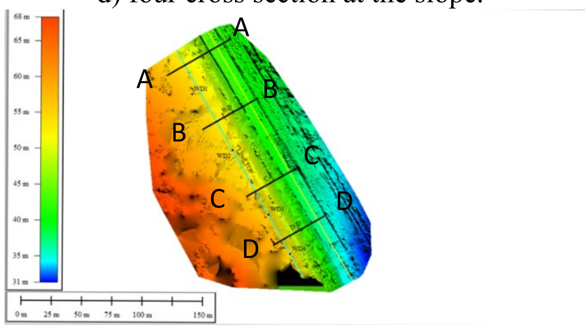
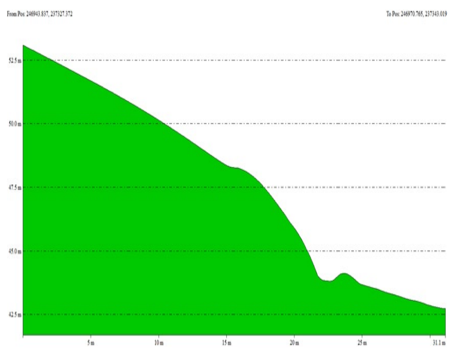
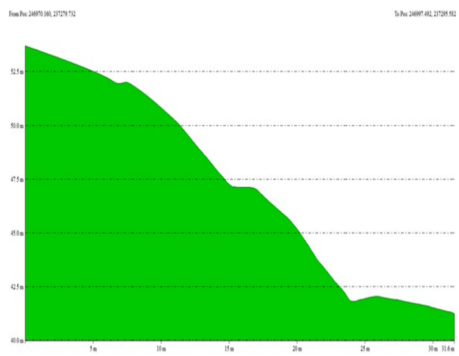
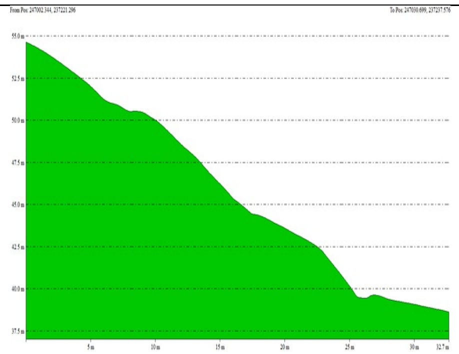
| a) Orthomosaic of slope | b) DSM of slope |
|---|---|
|  |  |
| c) DTM of slope | d) four cross section at the slope. |
|  |  |

**Figure 3: The slope image processed using Pix4Dmapper**

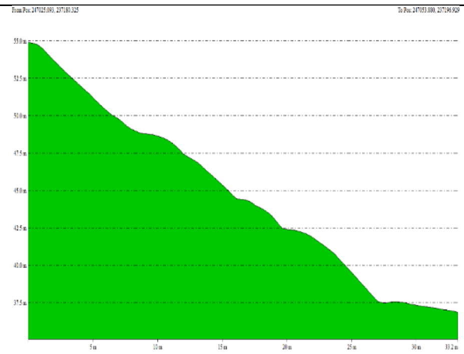
3.2 Cross -section profiles

In this research, **Figure 4** shows the height and distance of the slope can be determined from the Global Mapper software. The slope is cut into four cross-sections namely A-A cross-section, B-B cross-section, C-C cross-section and D-D cross-section. Using a global mapper, cross -sectional profiles can be identified using loaded elevation data. Each cross -section has different shape, height and distance values based on the diagram.

| a) cross section A-A | b) cross section B-B |
|---|---|
|  |  |
| Line A: the slope height obtained from the cross-sectional line A-A is 10m and the slope distance is 22.5m. | Line B: the slope height obtained from the cross-sectional line B-B is 12.5m and the slope distance is 24m. |
| c) cross section C-C | d) cross section D-D |



Line C: the slope height obtained from the cross-sectional line C-C is 17.5 m and the slope distance is 27 m.



Line D: the slope height obtained from the cross-sectional line D-D is 17.5 m and the slope distance is 27.5 m.

**Figure 4*: The cross section for slope***

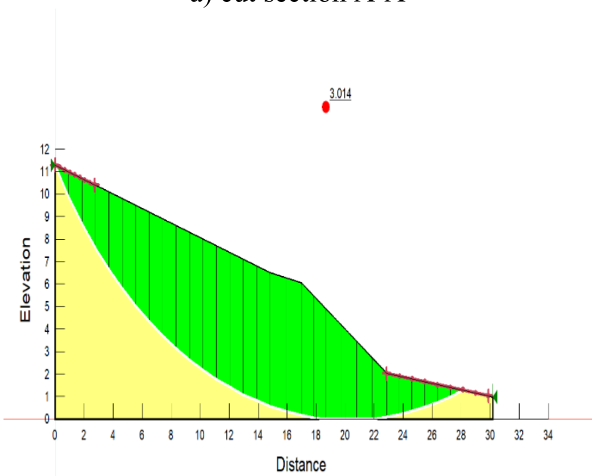
3.3 Safety factors of slope

Next, by using Slope / w software to analyze the slope, to determine the safety factor of slope stability using the data that has been collected. **Table 1** shown the cohesion, friction angle and unit weight calculated at four difference cross section. **Figure 5** shows the slope safety factors at four different cross -sections after being analyzed by the Slope / W section. From this analysis, it is shown that the slopes exceed the minimum requirements of the safety factors and are in a stable state. Once the slopes are analyzed, it can be concluded that all four slopes of the cutting section are in a safe condition. Safety factors were compared using different methods such as morgenstern, janbu, and bishop. The data generated from the three methods are different based on **Table 2**.

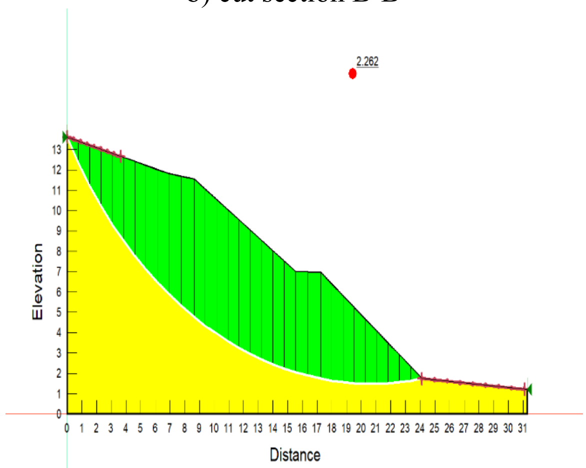
**Table 1: Laterite soil properties**

| Properties | Value |
|---|---|
| Cohesion | 31kPa |
| Friction angle | 23.54° |
| Unit weight | 18.17kN/m$^3$ |

a) cut section A-A




b) cut section B-B



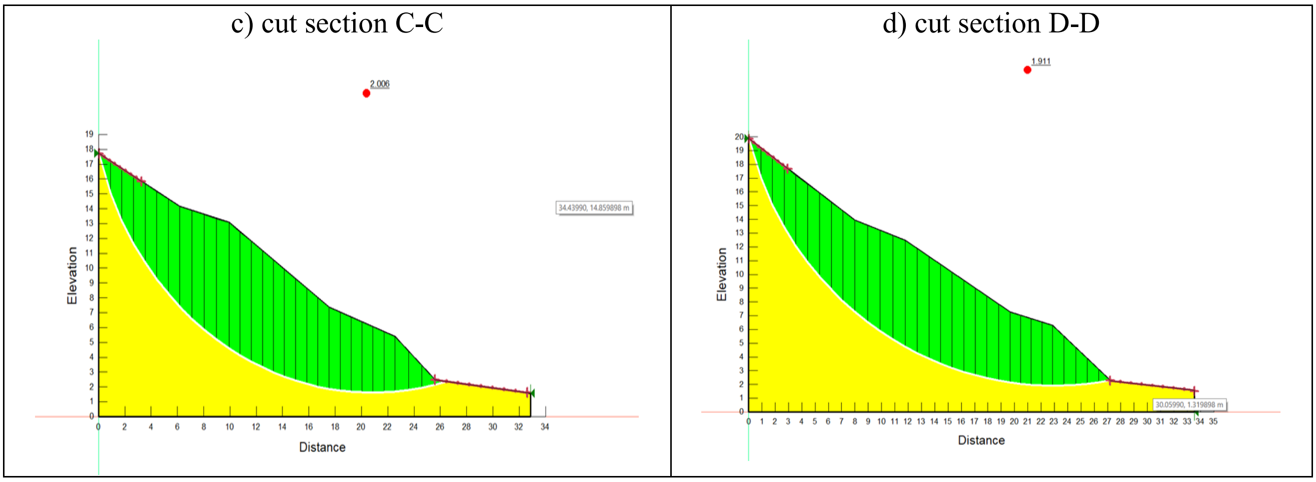



**Figure 5: Safety factors of the slope**

**Table 2: Comparison safety factor using different method**

| Cross-Section | Morgenstern | Janbu | Bishop |
|---|---|---|---|
| A | 3.014 | 2.839 | 3.018 |
| B | 2.262 | 2.117 | 2.266 |
| C | 2.006 | 1.875 | 2.011 |
| D | 1.911 | 1.801 | 1.916 |

### 3.4 Water droplets on the slope

In addition, by using global mapper software to simulate water droplets on slopes. **Figure 6** shows water droplets on the slope at four different cross -sections after analysis. Water drop analysis is an analysis to simulate the water by putting a point on the area to analyze the movement of water whether the water flow on the right path and channel. The analysis is to discover whether the drainage system is function properly. Figure show 4 location have been put to simulate where the water to flow from the point. The red arrows are indicated as the path of water flow along the slope. For waterdrop 1 and 2 the water stream path does not follow the drainage system contrast to waterdrop 3 and 4, the water stream path is clearly following the drainage system. The cause why the water path not following the channel will be discuss on the next part of this chapter.

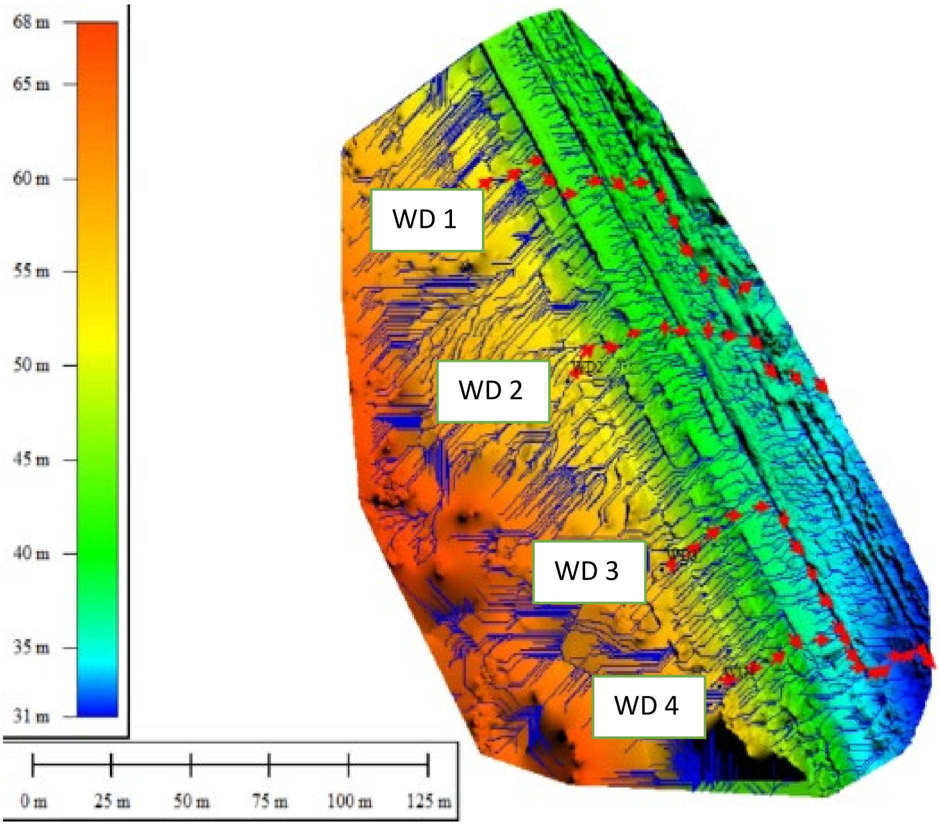
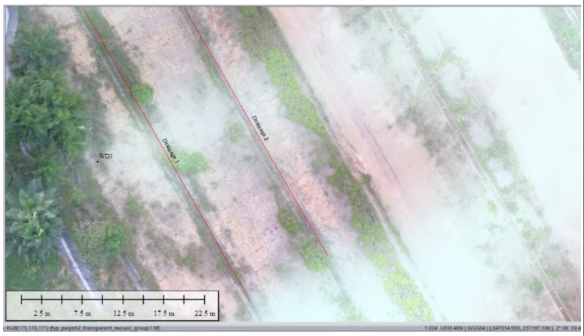



**Figure 6: Water droplets on the slope at four different cross –sections**

3.5 Slope investigation

From the picture taken from UAV a monitoring and investigate have been did to this slope. Although the slope passes the slope safety factor it is uncertain the slope will be last longer than expected thus by investigate this failure, the problem can be found. **Figure 7** shown some over growth vegetation on the slope drainage structure have been detected along the drainage. It can cause the drainage to be block by the vegetation causing overflowing of water. The water that overflows can resulting the slope to lose it strength. The plants had covered 2 drainage structure 113.6m long for drainage 1 and 167.89m long drainage 2. Additionally, cracking have been detected on some part of the slope. Water can enter the cracking cavity making the slope structure lose it shear strength. Cracks were found along 55.411m of perimeter Last figure show that the landslide was occurs on this slope structure. The main reason the landslide was cause by the overflowing water from the blocked drainage.

a) drainage system on slope infected with overgrowth vegetation



b) cracking on surface of the slope with 55.411m perimeter


c) landslide on the slope


**Figure 7: Slope investigation**

## 4. Conclusion

In this modern age, technology has paved the way for more multifunctional modern technology. Manual slope inspections can be monitored through the use of a much easier and safer UAV. However, this study suggests that UAVs can be used as an alternative method. Throughout this research it has been proven that through UAVs, orthomass images, Digital Terrain Model (DTM) captures and Digital Surface Model (DSM) captures can be generated through software. Therefore, it can be concluded that slope inspection data can be collected in a more efficient manner. Not only that, the inspection used by Unmanned Aerial Vehicle (UAV) can obtain a clearer and more accurate visual image. In addition, by using slope / W software to obtain slope geometry test data, Slope / W was also used to determine the slope safety factor as a solution path to complete this research process. Furthermore, through visual images of the slope taken by the UAV, water droplets on the slope can be simulated using global mapper software. Next, from the photos taken by the UAV, monitoring and investigation were carried out to this slope. As a result of the study, there was some damage to the slopes. In conclusion, from the analysis and results of the study, the average slope safety factor in the back area of UTHM student residential college is **2,298**. This indicates that the slopes in the study area are in a safe and stable condition where the slope safety factor is more than one.

**Acknowledgement**

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