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Landslide Rapid Impact Assessment at Hydro Dam via THyCAS and UAS

M.A.A.M. Sharom[1*], M.S. Kamarulzaman[2], M.Z.M. Azmi[1] and A.R. Sipit[1]

[1]*Malaysian Space Agency (MYSA), Ministry of Science, Technology and Innovation (MOSTI), No. 13, Jalan Tun Ismail, 50480 Kuala Lumpur, Malaysia*

[2]*TNB Power Generation Sdn. Bhd. (GenCo), TNB Genco Building, No.129, Jalan Bangsar, 59200 Kuala Lumpur, Malaysia*

The TNB Hydro Catchment Area Surveillance (THyCAS) is a web-based geographic information system (GIS) used to monitor hydropower dam catchment areas in Peninsular Malaysia. It can also be used for landslide rapid impact assessment by monitoring the surrounding landslide area. However, during the rainy season, satellite images are unable to provide the information required by users due to full cloud cover. Therefore, an Unmanned Aircraft System (UAS) is used to provide the data required by THyCAS by mapping the surrounding area affected by landslides and uploading the processed data in THyCAS. Thus, the user can get the required information regarding the landslide incident. Furthermore, with UAS Full Motion Video (FMV) data, the location of the collapsed power transmission towers can be acquired. In addition, any information on land changes that could jeopardise the surrounding dam area is gathered. Therefore, with the information from the rapid impact assessment provided by THyCAS and UAS data, a preliminary risk assessment plan can be established and implemented by the relevant parties. The results obtained from the rapid assessment can also be used as additional information to find out the actual cause of landslides in the area.

Keywords: web-based GIS; rapid assessment; dam monitoring; online monitoring; Full Motion Video (FMV)

I. INTRODUCTION

According to the Malaysian Energy Commission, hydropower produces more than 2,500 MW of installed capacity, which is the third highest in Malaysia (Energy Commission, 2020; Energy Commission, 2021). The major hydropower stations in Peninsular Malaysia are located in Perak, Pahang, Terengganu, and Kelantan. Recently, Hydro Plants in Malaysia have adopted a web-based GIS known as THyCAS to swiftly get the latest information on hydropower dam catchment areas. In addition, THyCAS is also used for any natural disaster rapid impact assessment at the hydro dam by monitoring the surrounding affected areas (post-event). However, satellite images are unable to provide the required information to users clearly due to dense cloud cover at the incident area during the rainy season. To overcome this issue, UAS is deployed to obtain data from the images and videos of the affected area. The acquired images are processed to produce orthophoto and elevation data (Digital Terrain Model - DTM and Digital Surface Model - DSM), and the acquired videos are processed to produce Full Motion Video (FMV) data. FMV data is a video embedded with GPS and aircraft telemetry information, which is complementary for raster data. Usually, FMV data are used for military ISR applications, but nowadays, it has been used in civilian applications, including natural disaster assessment (Mott, 2011; Sharom *et al.*, 2021a; Azmi *et al.*, 2022).

With FMV data, the video footprint shows directly on top of basemaps to give outstanding event fidelity, continuous event progression, and full context regarding the nature of the

*Corresponding author's e-mail: asraf@mysa.gov.my

location and activities being observed on the earth's surface (Sharom *et al.*, 2021b). The processed orthophoto, DTM and FMV data are analysed to obtain information to get a bigger picture of the current situation, and the information is also used for rapid impact assessment. Thus, relevant parties can take early action regarding the natural disaster situation.

Thus, this paper looks at a case study of a landslide incident that occurred surrounding one of the hydroelectric plants in Malaysia, specifically Kenyir Dam. The incident was due to unusually heavy and continuous rain in February 2022. The Kenyir Hydro Plant is operated and maintained by Tenaga Nasional Berhad (TNB), the largest electricity utility in Malaysia. The incident damaged the power station and several high-power transmission towers and severed the power station access route. In this paper, we will describe the use of a web-based system, THyCAS, as a UAS operational planning tool to ensure smooth and safe operations. We will also describe the use of orthophoto images and UAS FMV data in the rapid assessment of landslides.

II. THE OVERVIEW OF THYCAS

THyCAS (Figure 1) is a GIS web-based system developed by MYSA for TNB through a research collaboration. The main purpose of THyCAS is to enable TNB to monitor the water catchment area for TNB's hydropower dam in Peninsular Malaysia.

This system is developed using the ArcGIS web application and is equipped with a geospatial database. This system can be uploaded with raster data such as optical and radar satellite imagery and UAS orthophoto images. Elevation data and other types of data, such as seismic fault data, TNB dam catchment boundaries, and video captured by UAS, can also be uploaded to the system.

THyCAS provides several features for users, such as elevation profile analysis, distance and area measurements, and coordinate point extraction. Also, with high-resolution satellite imagery and very high-resolution UAS orthophoto images, users can do the visual interpretation of the area that is required.

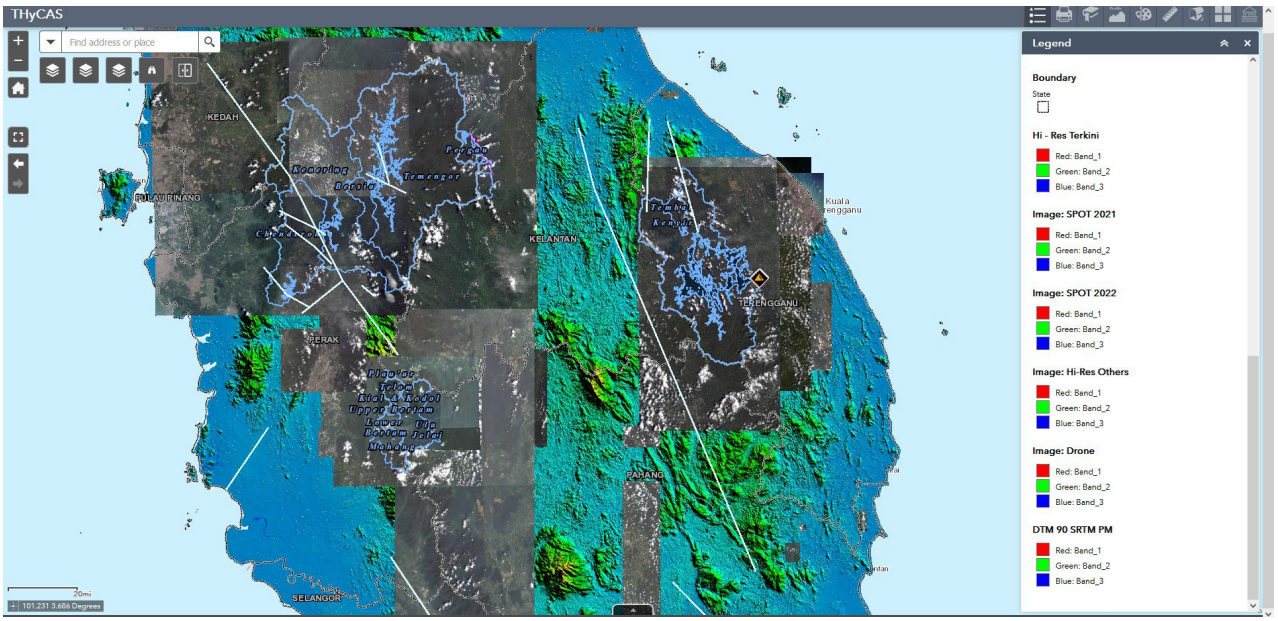

Figure 1. Overview of THyCAS

Even though THyCAS has been developed to monitor the water catchment area for TNB's hydropower dam in Peninsular Malaysia, it can also be used to monitor encroachment at the TNB dam area (Figure 2) and to resolve flood issues with stakeholders by using an elevation profile analysis (Figure 3).

Figure 2. Encroachment at the Kenyir dam

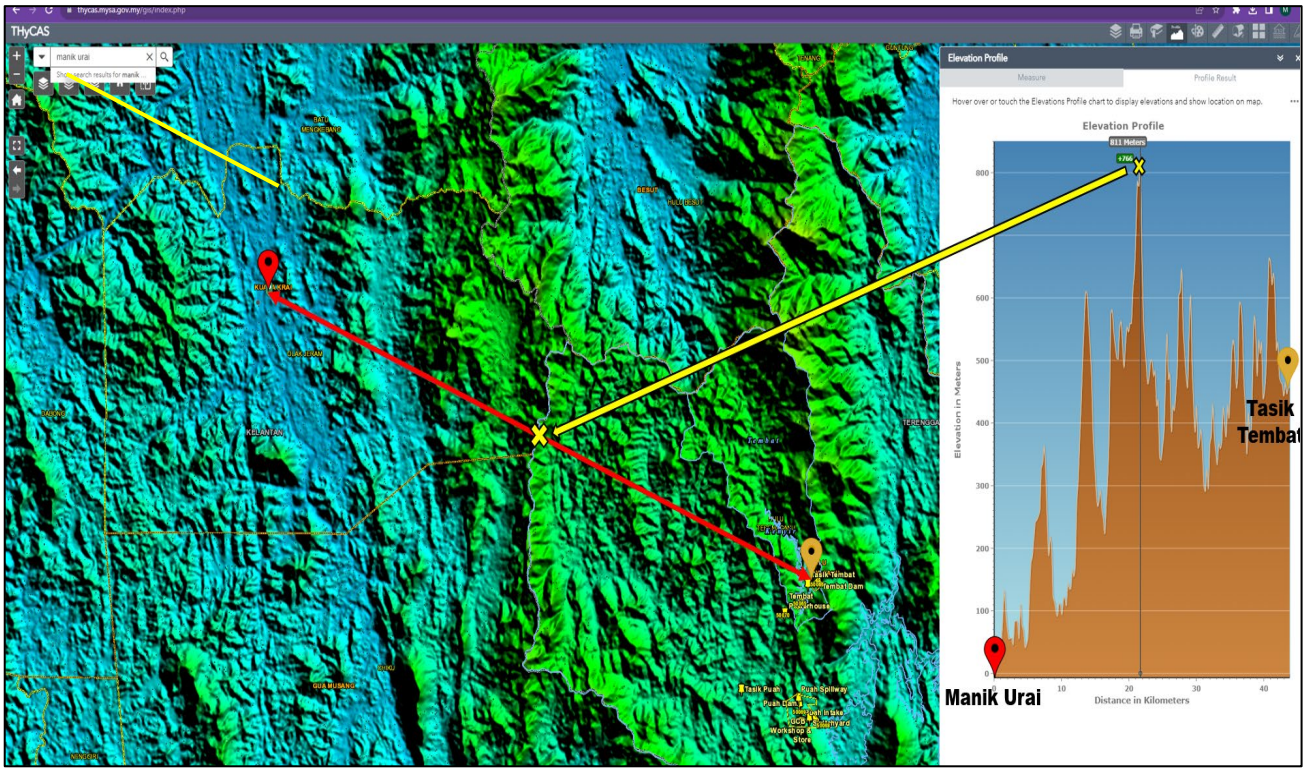

Figure 3. Managing flood issues based on elevation profile

III. METHODOLOGY

A. Overall Process Workflow

During the landslide incident at Kenyir Dam, high-resolution optical images were required by the users to enable them to get current and updated information on the surrounding area. However, during the incident, the optical satellite was unable to acquire high-resolution images due to dense cloud cover because of the rainy season. Therefore, to overcome this issue, UAS was deployed to capture images and videos around the landslide area.

THyCAS is used for operational planning, to plan the take-off area and coverage of UAS operations, and also to identify a UAS-safe altitude for operation. After plans were made, UAS was deployed at the Kenyir Dam to acquire images and video all around the area.

In certain circumstances, the video was acquired because the targeted area could not be covered with UAS photogrammetry and data requirements from a perspective angle of view. The acquired data were processed to produce ortho-photo, DTM, and FMV data. The processed orthophoto and DTM data were then uploaded into THyCAS and analysed. Meanwhile, the FMV data was analysed using FMV software. Therefore, based on all the analysed information from the rapid impact assessment, authorities or related government departments and agencies can establish and implement an early disaster risk assessment plan. The whole workflow is shown in Figure 4.

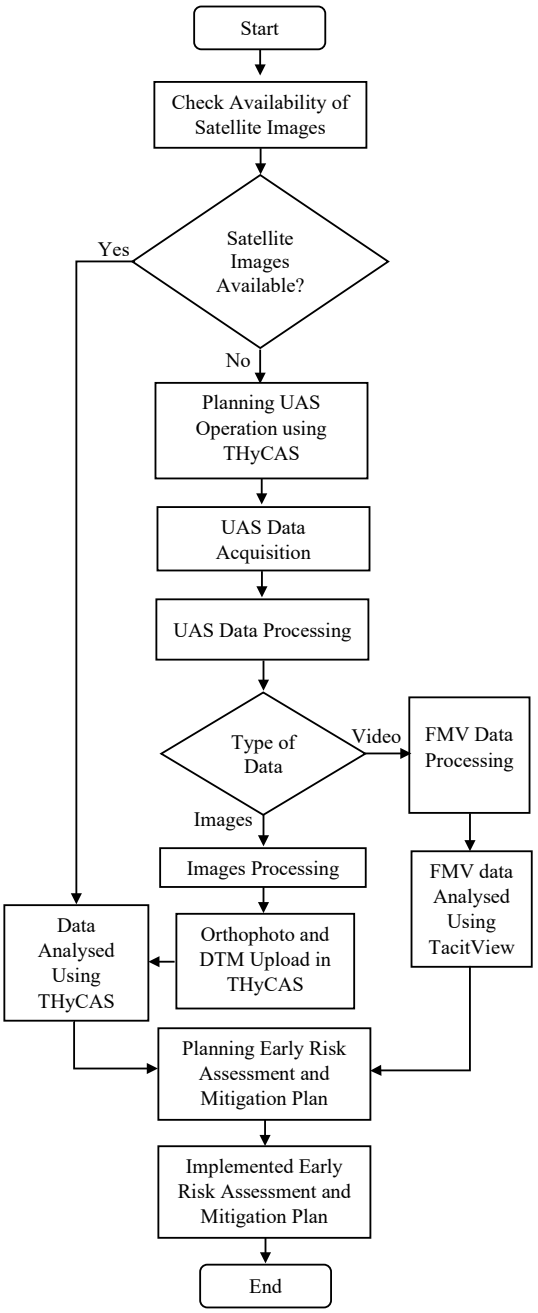

Figure 4. Overall process workflow

B. The Usage of THyCAS for UAS Operational Planning

Before operating UAS at the Kenyir Dam, the UAS team used THyCAS for UAS operational planning and to identify suitable take-off and landing point for the UAS. Furthermore, by using THyCAS the UAS team can plot the estimated area of operation based on the user requirements. Therefore, the area size of the mapping can be estimated, as shown in Figure 5. Moreover, the sectors of operation are made using THyCAS (Figure 6). The sector of operation is determined based on the priority set by the user and the flying endurance of the UAS.

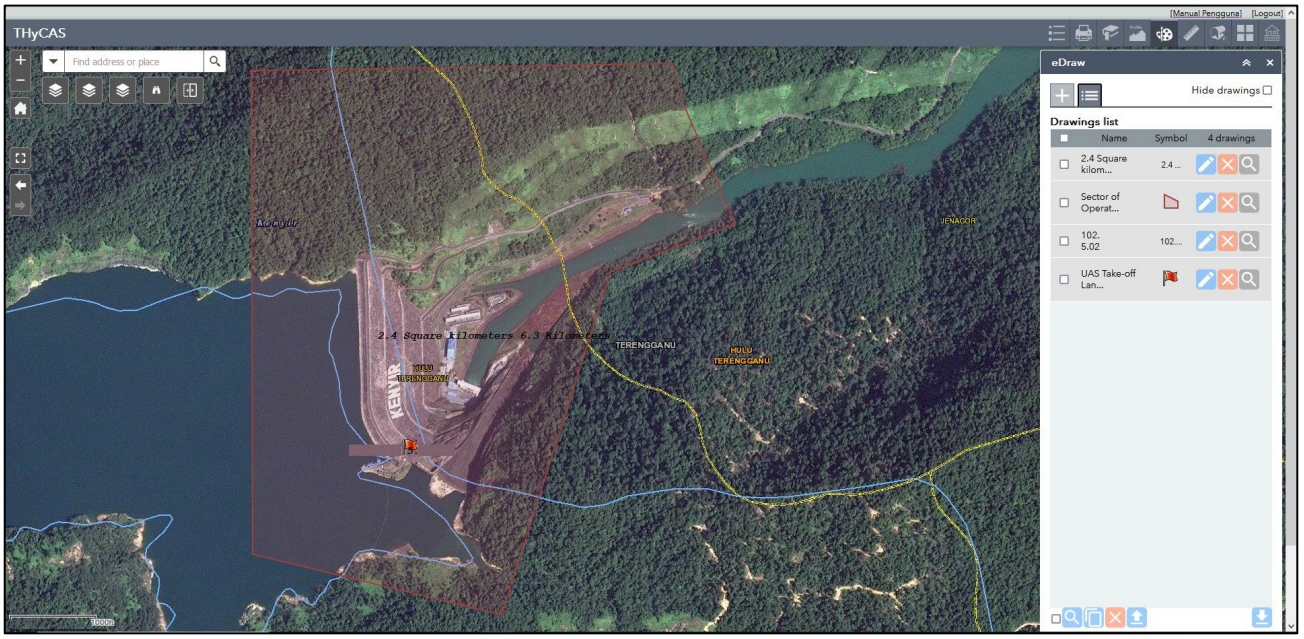

Figure 5. Determination of UAS take-off and landing point and area of operation via THyCAS

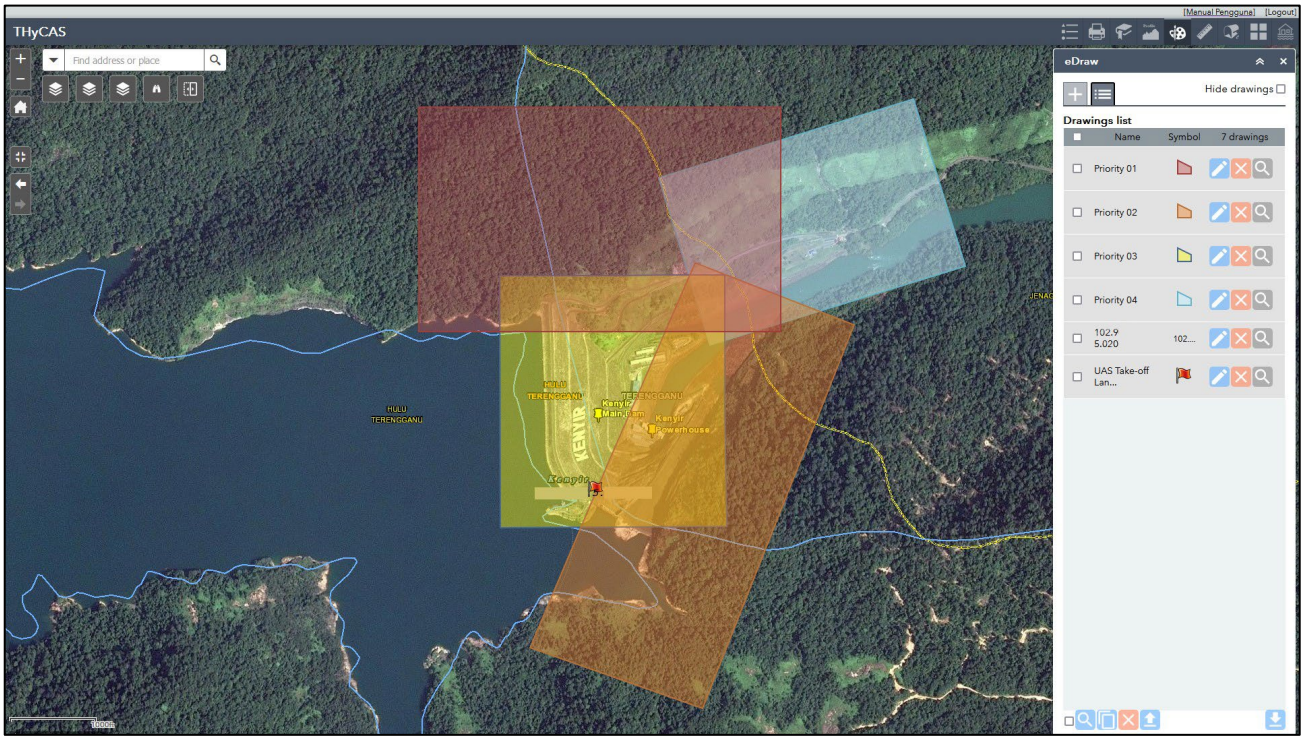

Figure 6. The Sector of operation is based on priority

By using THyCAS, the safe UAS operation altitude can be determined by using the Elevation Profile Analysis (Figure 7). From the obtained information, the UAS team was able to set a safe flying and mapping altitude. Therefore, the average ground sampling distance (GSD) for the orthophoto and the number of sorties for mapping can be obtained.

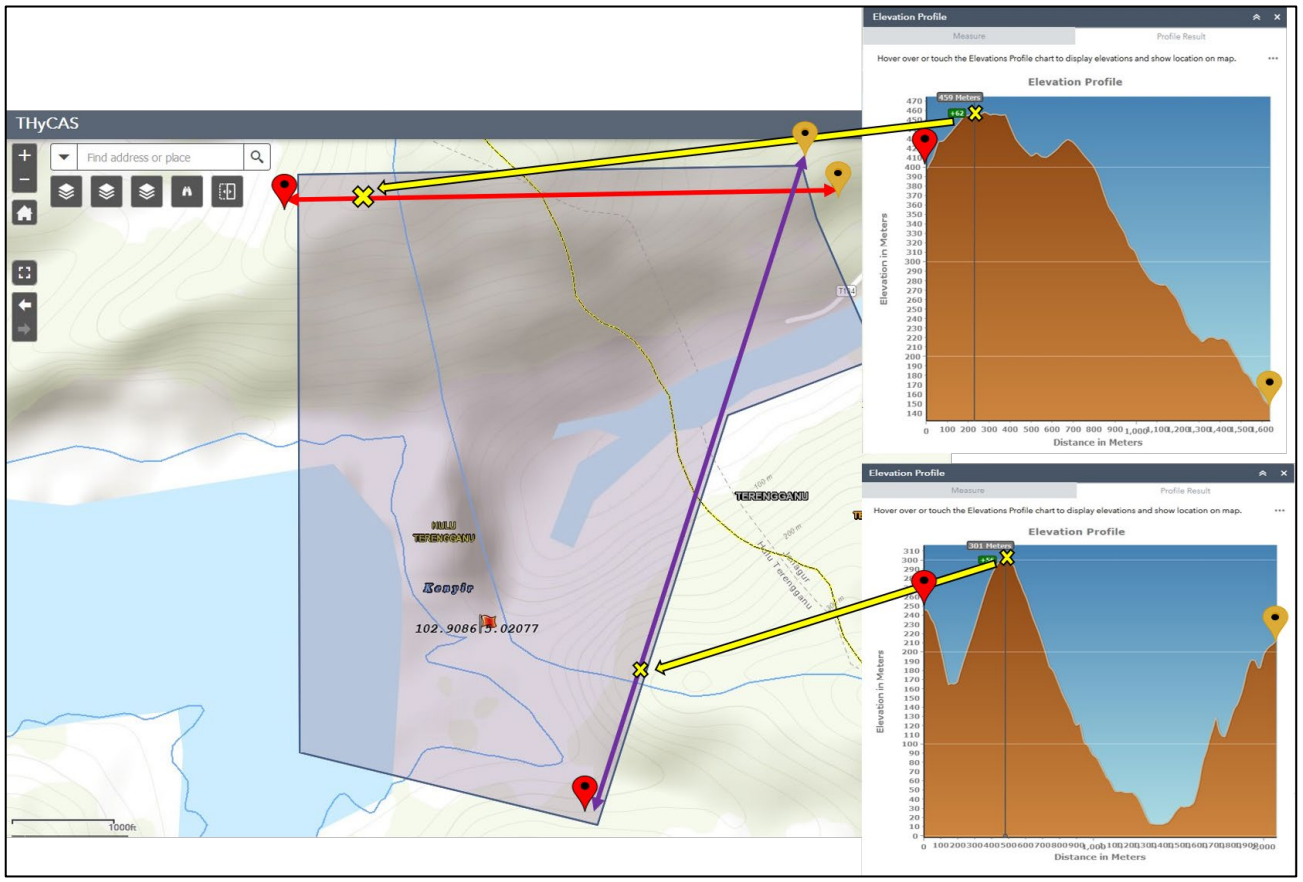

Figure 7. Determination of UAS safe flight altitude

C. UAS Data Acquisition and Processing

During natural disasters, the UAS with vertical take-off and landing (VTOL) capability, such as a quadrotor, is suitable to deploy because of the limited area for take-off and landing and the limited ground vehicle access to the take-off and landing area at the disaster area. Therefore, during the landslide incident at the Kenyir Dam area, the UAS that was used to acquire data was a DJI Mavic 2 Enterprise Dual (Mavic2ED). Mavic2ED is a small quadrotor UAS equipped with an optical and thermal camera that can be easily deployed.

Due to the UAS mapping activities being carried out in the rainy season, the UAS image acquisition needs to be carried out in a short and limited time. Careful planning needs to be done to ensure that all data in the operational sectors can be acquired.

In addition, the drone detection system, DJI Aeroscope, is also used during operations to facilitate the coordination and safety of drone flights. This is because, usually during disaster situations, government departments and agencies, as well as private companies, will also fly drones around disaster areas.

The images acquired by Mavic2ED were processed to produce orthophotos and DTM using Pix4Dmapper software. For this operation, the ground control point (GCP) was not collected and used in image processing. It is because, the data accuracy direct from the UAS inertial navigation system (INS) and Global Navigation Satellite System (GNSS) would suffice for time-critical events or fast-response situations (Zhou, 2009; Remondino *et al.*, 2011; Nex & Remondino, 2014; Sun *et al.*, 2016). The comparison between the UAS emergency and normal mapping is shown in Table 1.

To ensure that UAS-captured video provides detailed information to the users, the video is processed into FMV data using the ArcGIS FMV multiplexer geoprocessing tool based on the FMV processing workflow, which is compatible with any DJI UAS model (Sharom *et al.*, 2021b). With FMV data, the geolocation and measurement information of the objects can be obtained through video.

Table 1. Comparison between emergency mapping and normal mapping (Mashfiq, 2017)

Items	Emergency Mapping	Normal Mapping
Planning scope	No proper flight plan, ad-hoc	Require proper flight plan to capture the information
Results production time	Real-time or near real-time (within hours)	Possibility to process the results, and come up with results in days
Required location accuracy	Low (acceptable)	High
Possibility of complementary mission	No	Yes
Bandwidth constraints	Preferable online upload	Offline upload acceptable
Availability of risk assessment experts in the field	Scarce	Often available
Focus	Damage zones	Whole regions

D. Data Analysis Using THyCAS and TacitView

The processed UAS data were analysed using THyCAS and TacitView software. The produced orthophoto image and DTM of the landslide incident at the Kenyir Dam area were uploaded in THyCAS where the visual interpretation and measurement are implemented.

The estimated affected area was measured using THyCAS based on an uploaded orthophoto image, and the processed UAS orthophoto image was compared with the satellite image before the landslide incident to determine which area of the dam was affected by the landslide. Furthermore, by using visual interpretation, any object or thing that could risk the condition of the dam can be identified. The same technique of visual interpretation is applied to FMV data, where the data are opened and analysed using the TacitView software. By using the FMV data, captured video can be analysed based on the perspective angle of view. Thus, damage caused by the landslide was identified, and the position of objects and features that had been damaged was extracted through the FMV data. To achieve precise results, FMV data must be analysed together with other geospatial information, such as geo-corrected raster images (satellite or airborne), elevation data, and digital cartographic maps. The accuracy of FMV data, on the other hand, is solely dependent on the accuracy and precision of the aircraft or UAS navigation system (latitude, longitude, altitude, etc.) (Taylor & Settergren, 2012; Coffman, 2015; ESRI, 2018; Patel & Butler, 2020) and the sensor or camera orientation information (Inside Unmanned Systems, 2020; Patel & Butler, 2020).

Based on the information extracted from the analysed orthophoto and FMV data from the rapid impact assessment, early landslide risk assessment plans are prepared by the relevant parties for further action based on the provided information. The information extracted from the analysed orthophoto and FMV data was also used as preliminary information to identify the cause of the landslide at the Kenyir Dam.

IV. RESULTS AND FINDINGS

The estimated area covered by UAS mapping for the Kenyir Dam (Figure 8) was around 2.31 km² (230.6 Hectares). According to the uploaded orthophoto image in THyCAS, the area affected by the landslide was identified by comparing the UAS orthophoto with the satellite image before the landslide incident. The primary access route to the power station (Figure 9) was affected by the landslide based on a visual interpretation of the surrounding dam area. For instance, landslides have rendered the major access road that leads to the power station impassable and completely submerged. Therefore, this information was provided to the relevant authorities to aid in the repair of the dam's main entrance.

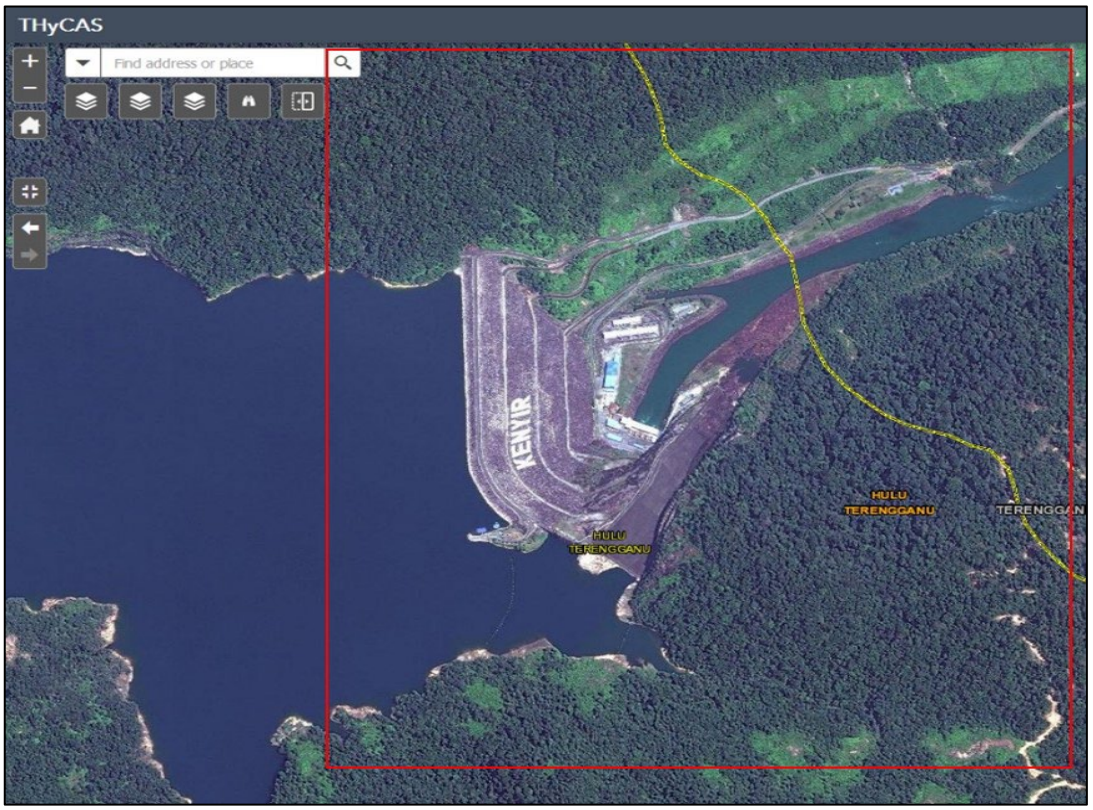

Figure 8. The total area covered by UAS mapping

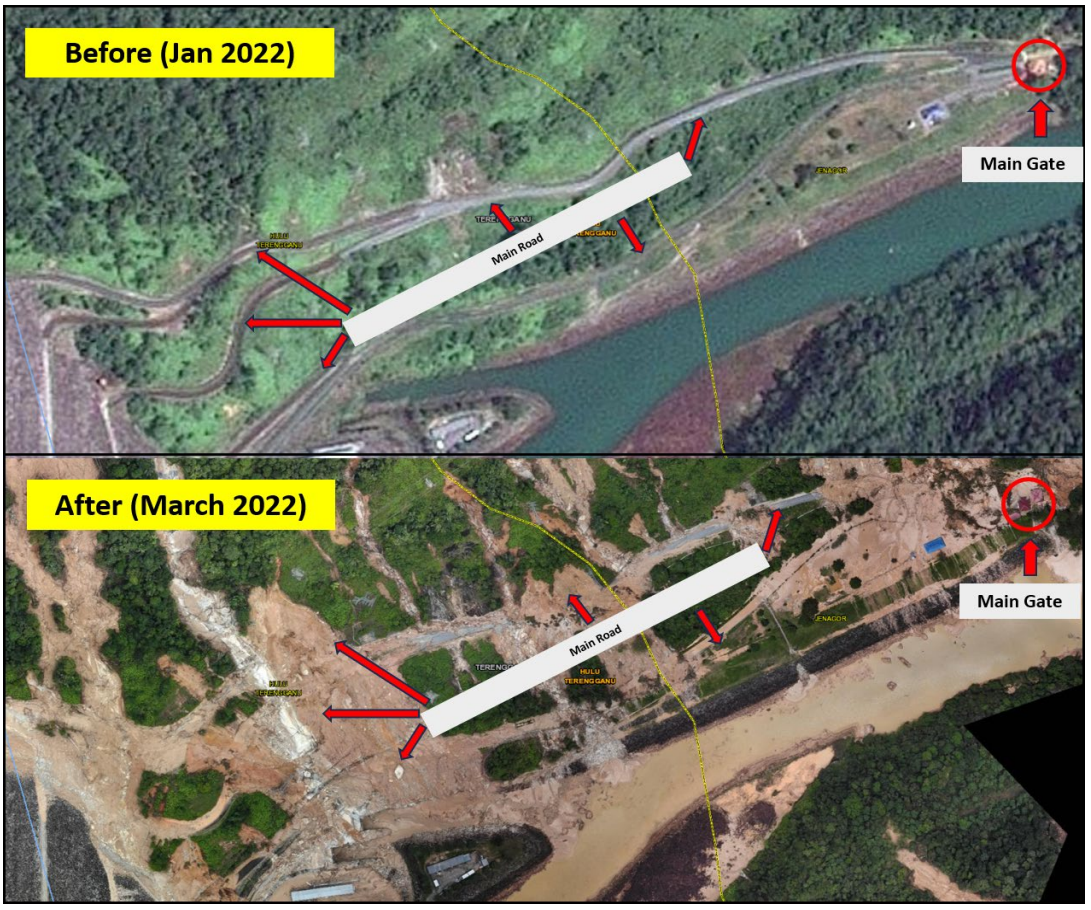

Figure 9. Kenyir dam's main access route before (top: satellite image) and after (bottom: UAS image) the landslide incident

The sediment and driftwood were identified near the dam embankment and spillway, where the measured area of sediment and driftwood was 0.021km² (2.1 Hectares) near the embankment area and 0.028km² (2.8 Hectares) near the dam's spillway area, as shown in Figure 10. Meanwhile, the measured distance between the driftwood and the dam spillway was about 132.2 metres, which had a high probability of the driftwood blocking the spillway. This will cause overtopping if the dam reservoir is full and the spillway cannot flow the excess water. This information was provided to the dam maintenance team for them to act by removing the driftwood and sediment near the dam embankment and the spillway.

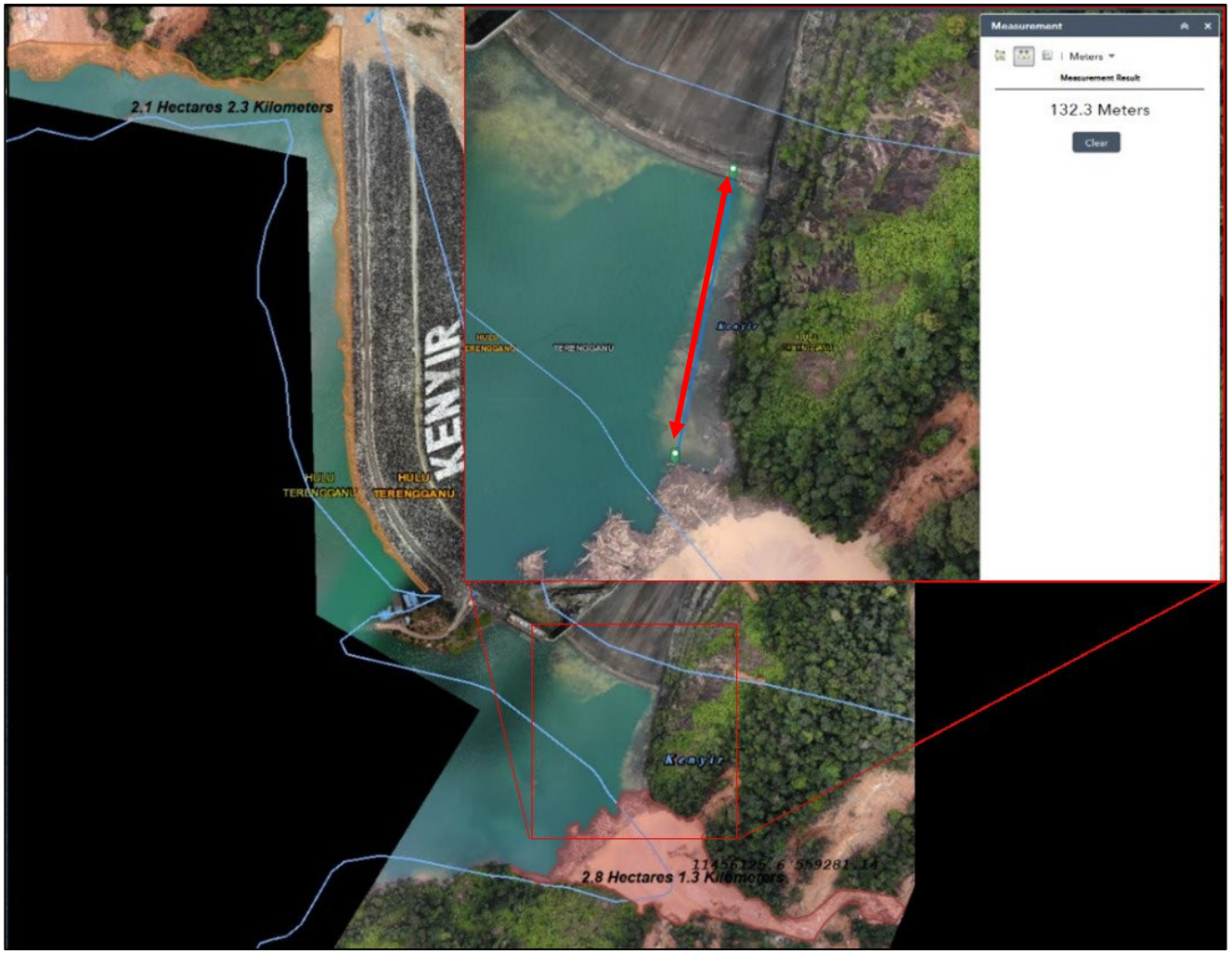

Figure 10. Sediment and driftwood near the dam embankment and spillway

The floating driftwood near the dam embankment needed to be removed to ensure the driftwood did not block the dam spillway and compromise the integrity of the dam embankment structure, which could cause dam failure. Furthermore, the sediment needed to be cleared before it fell to the bottom of the reservoir, reducing the total volume of the dam reservoir.

Meanwhile, for areas that were not covered by the UAS mapping, this area information is acquired by using FMV data. From the FMV data, it was found that the effect of the unusual and continuous heavy rains that had caused the landslide was identified on the other side of the hill.

Moreover, further details regarding the landslide area were obtained with a perspective view of the video and spatial information through FMV data. With FMV data, the location of the collapsed high-power transmission towers was

identified (Figure 12), which could not be identified using two-dimensional data. There were about five collapsed high-power transmission towers identified and located using FMV data. However, the resulting coordinates of the collapsed high-power transmission towers obtained from FMV data were dependent on the UAS internal GNSS accuracy, which was sufficient during emergency situations.

Thus, together with the information collected from the rapid impact assessment using THyCAS and UAS FMV data, the information was provided to the relevant parties for the preparation of an early landslide risk assessment plan, and further action could be taken.

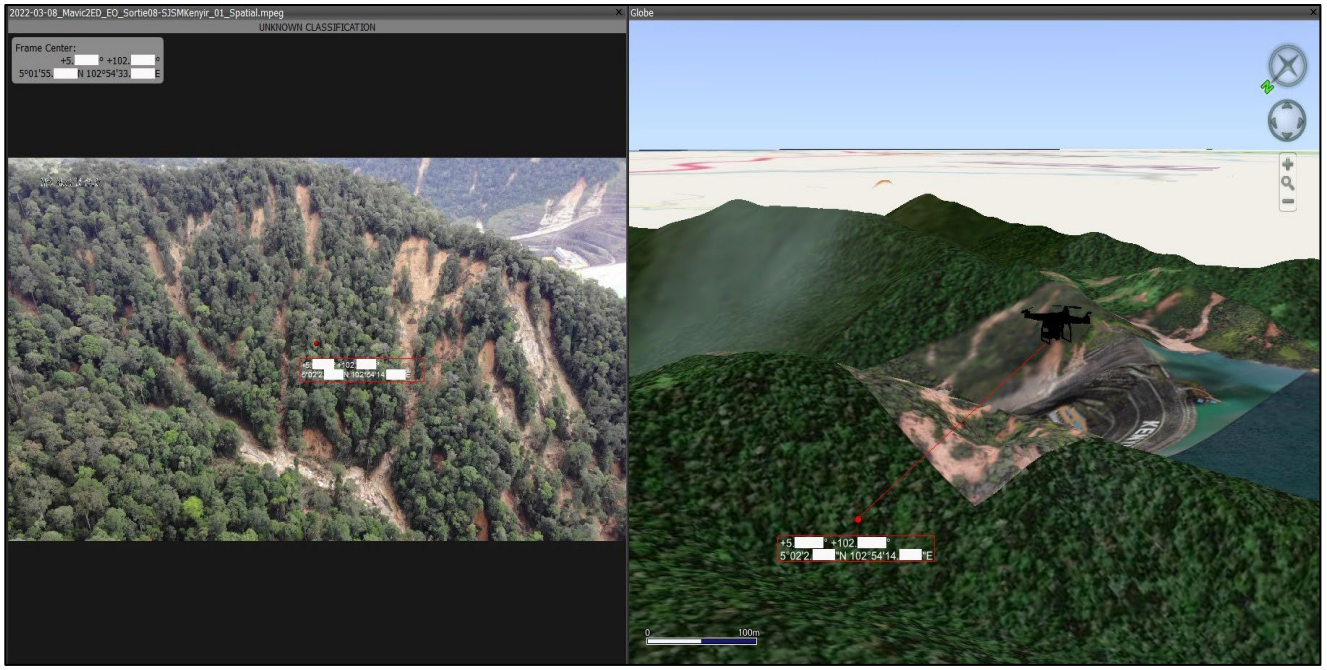

Figure 11. Landslide at the other side of the hill near kenyir dam

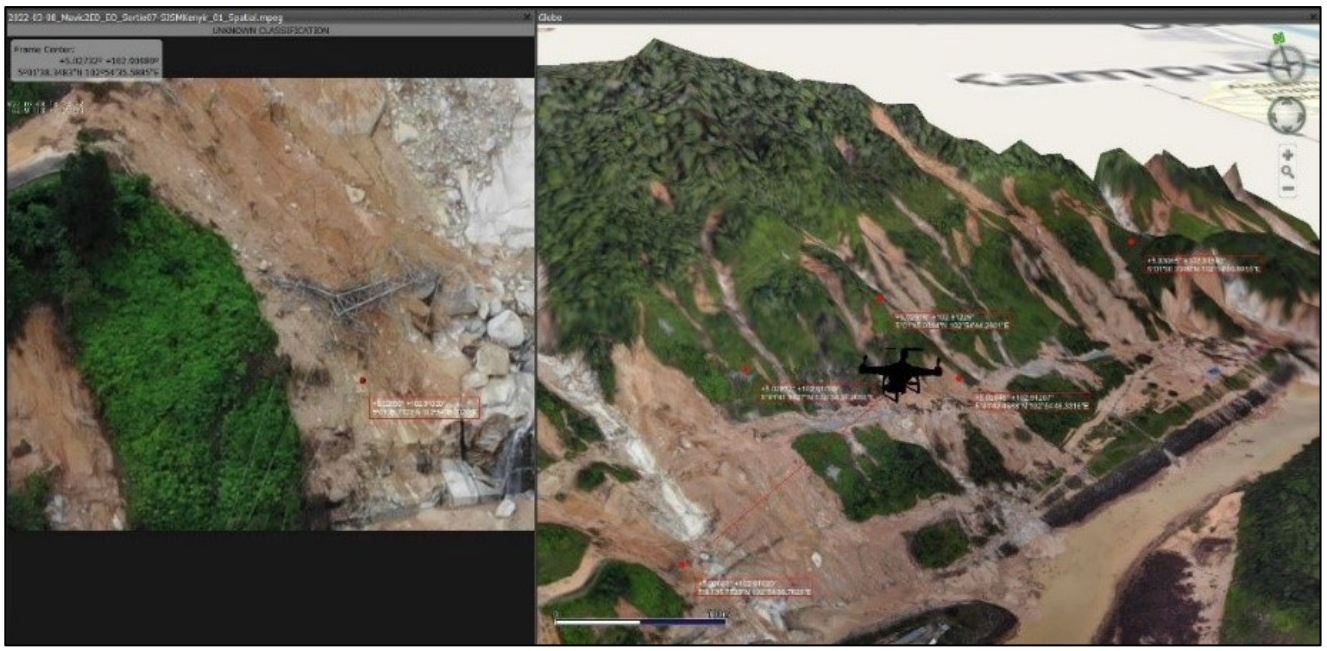

Figure 12. Extracting location of collapsed high power transmission tower through FMV data

Therefore, information obtained from UAS data can support preliminary information about the cause of landslides. According to the Terengganu Forestry Department, the flood that caused the landslide at the Kenyir Dam was not caused by logging activities, as was spread by certain parties on social media (Bernama, 2022).

V. CONCLUSION AND WAY FORWARD

This paper has shown that both THyCAS and UAS can be used for a rapid impact assessment, and the provided information can be used for early landslide risk assessment plans. The UAS data are used as a supplement to the high-resolution optical satellite images, especially in areas with dense cloud cover. With THyCAS, users can visualise and measure the processed UAS data.

Furthermore, along with raster data and elevation data, UAS FMV data can provide information of actual situation on the ground, where the video footprint can be viewed directly on the basemap, which provides excellent event fidelity, seamless event progression, and full context regarding the nature of the location and activities being viewed on the earth's surface.

Therefore, the information provided by THyCAS and UAS FMV data can be used as preliminary information to identify the damage and cause of the landslide at any hydro dam. The provided information can also be used by relevant parties to plan an early disaster risk assessment and mitigation.

VI. ACKNOWLEDGEMENT

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