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Application of UAV in Rip Current Investigations

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***Abstract*— Cases of people dying from being swept away on the beach have been widely published on Bali news; this is because not many people know the dangers of rip currents on the beach. Lack of public knowledge about rip currents is caused by a lack of socialization and warning signs of rip currents on the beach. Rip currents are back currents formed by currents coming perpendicular to the shoreline and meeting the curved shoreline. This current can drag someone who is swimming out to sea. In this study, the existence of rip currents was investigated using aerial photographs or UAVs. The observation location was taken in an area that is often used by the Balinese Hindu community to carry out the Ngaben ceremony process. The UAV device was prepared to observe the rip current and measure its speed. Dye Tracer Test was also conducted to observe the movement of rip currents visually. Rip currents are characterized by calmness between rows of breaking waves. The average rip current speed is 0,29 m/s can also be determined by observing the UAV. The speed of this current is influenced by wave energy that propagates to the beach. The difference in bathymetry causes variations in wave height along the beach, and the rip current causes this. The results of this study can be used as an early warning system for people who carry out activities on the beach.**

***Keywords*— UAV; rip current; Bali; beach.**

I. INTRODUCTION

Bali is a tourist destination that, due to its beauty, natural, and cultural resources, it is visited by many tourists, both international and national. Among Bali's popular tourism sites, visiting the beach in Bali is one of the a-must to-do lists for tourists. The beauty of the sand and waves on the beach make tourists willing to spend a long time at the beach. However, those who prefer to travel on the beach need to accommodate themselves with the knowledge of the potential disasters and threats that may occur while they are on the beach. One of that knowledge is to understand the current potential known as a rip current. A rip current is a narrow, powerful current of water running perpendicular to the beach, and back into the ocean. Sometimes, rip currents are also known as "undercurrent or hidden current". They move along the surface of the water, and able to pull straight out into the ocean. If the current is resisted then the swimmer will run out of energy so that it can result in death.

In fact, the knowledge of rip currents remains unknown to many people. This is because of the lack of public knowledge, socialization, and rejection of the currents' danger. Caldwell [1] also stated the same thing in his research. Particularly, in Bali, the beaches play an important role in the Hindu community in Bali. In Bali, beaches are also used as a place of ritual at the time of *Ngaben* (cremation ceremony). The activity is called *Nganyut* which means to bring the offering to the middle of the sea (Figure 1). On Wednesday, June 12, 2019, there was a Nganyut ritual in Karangasem, Bali. During the ritual procession, a man named Dewa Nyoman Sutama (45), from Manggis Village, was killed by the current, around 12:30 PM. The case of foreign tourists who were swept away by the current were covered the news on social media. The emergence of cases of victims being swept away, remain us to be more careful. Therefore, if the rip currents are known to the public, then the danger of these currents can be reduced.

A rip current is usually characterized by a gap between the breaking waves (Figure 2). There are two things that can form a rip current. First is the shape of the shoreline which causes the direction of the current to reverse from the left and right sides. Second is the existence of large underwater corals approaching the surface creates the water turbulence to form a reverse current. There are some important things need to be acknowledged in order to understand the characteristics of these currents. According to Pethick [2], rip current consists of several parts of the current, such as the feeder, neck, and head as illustrated in Figure 3. The feeder

currents are composed of several coastal recurrent currents resulting from the reflection of several wave faces, then converge, gather, and turn towards the middle of the sea. The neck current is a narrow path, flowing very fast and robust, which also goes to the middle of the sea. This current is so strong that even able to beat the force of the waves that came. This current glides at high speed, reaching speeds of 80 kilometers/hour. The head current is the rip current that its direction starts to widen because its strength begins to weaken; soon after, it disappears in the sea waves. Also, because this rip current movement takes place very quickly and briefly, then people trapped and dragged by these currents are complicated to break away as if dragged into the middle of the sea. Therefore, this current takes many lives. Based on research, rip current is formed at one location but moving following the direction of the coming ocean waves [3]. In some cases, the rip current, even though the seawater is not too deep only to the extent of the knee, a person can make already possible this current attack.

Fig. 1 In Bali, beaches are also used as a place of ritual of Ngaben

Fig. 2 Rip current occurrence (Munggu Beach)

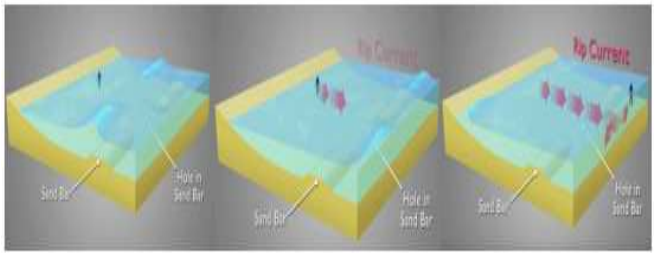


Fig. 3 Rip current process

Rip current are a common occurrence in the coastal areas of Parigi Bay, and often occur in certain parts of Pangandaran beach that have been considered safe [4]. With a period of 6.57 to 8.91 seconds from the Indian Ocean with a direction almost perpendicular to the coastline, the current swell is thought to be the original wave. The results showed six rip currents with speed around 0.8 m/s. The turbidity data records proved the rip currents carry sediment loads from the coast to the middle of the sea. The study site's Bathymetry data showed the undulating seabed morphology forming ridges and valleys extending from the coast towards the open sea. The rip currents' position was not specific in the valley or ridge indicated the absence of seabed morphological control over the occurrence of rip currents. Azhary [5] investigated the rip current using Hydrodynamic Modelling with results that current rip events occur during the spring tide phase when the flow changes from Flood to Ebb. The bathymetry profile in Kerachutis is very steep and dangerous for swimmers because there are 4 meters of waterfall suddenly only a few meters from the coastline.

Ishak [6] conducted a rip current study on the southern coast of Yogyakarta to find out the location of rip current occurrence and the correlation between the type of breaking wave and the morphology of the beach that triggered the rip current. The results of this study indicated the location of rip current occurrence on every sand beach in Yogyakarta. It resulted that in the bay-shaped sand beach, the rip currents occurred at both ends of the bay. Meanwhile, in the straight sand beaches, the rip currents appeared at the beach cusps. The rip current velocity measured at ten measurement points ranges from 0.08 m/s to 1 m/s. Rinto [7] also conducted a study to find out the location of rip current emergence at Pantai Taman (Taman Beach) which has the characteristics of sandy and bay-shaped beaches in Pacitan Regency.

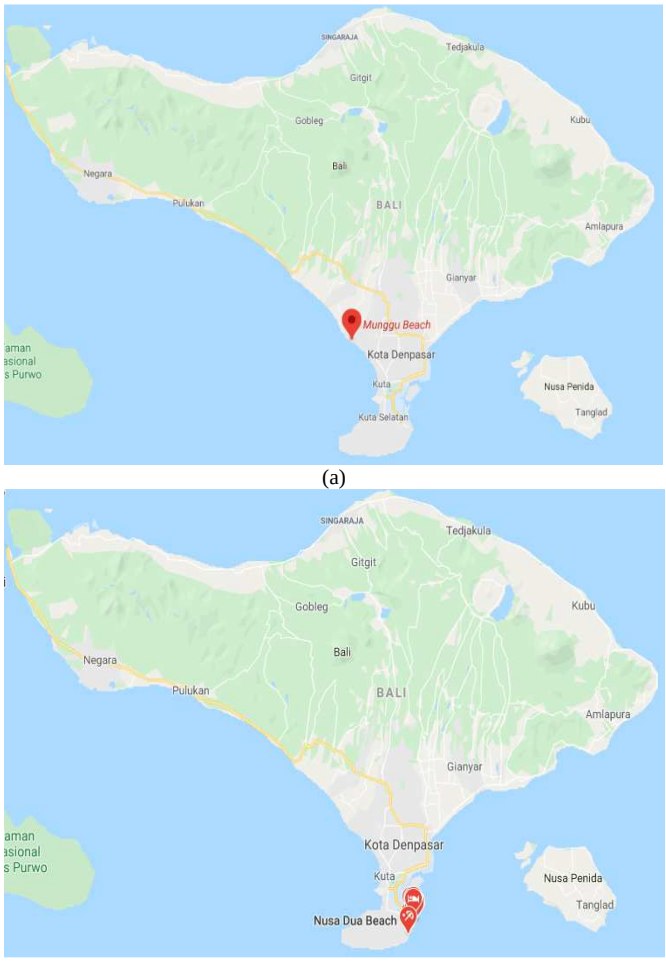
Gadjah Mada University students have developed the Rip Current Identification System at Parangtritis Beach by flying aerial photography in areas prone to reverse flow that they want to monitor. The photos taken will then be processed and combined using the software. Wind is the main obstacle in this system, because minimal wind speeds are often not met with flying kite aerial photography. At present, this weakness can be overcome by using UAV. Benassai in [8] has proven the existence of rip current with hydrodynamic simulations. He used data from the bathymetric survey and UAV observation at Sele river's mouth, in the Gulf of Salerno, southern Italy. While Brouwer [9] describes an exciting potential of UAV for monitoring the surf zone. UAV is unmanned aircraft controlled remotely using a computer or remote control, which can be used to bring a camera to take pictures or record something observed. Besides, Agoston evaluates some of the experiences and describes several initiatives using drones to support disaster management [10]. Use of drones for various types of applications in civil engineering has also been presented [11].

With high technology, drones can be used to investigate the existence of rip currents. Techniques for detecting and measuring rip currents are described [12]. The purpose of this study is to examine the existence of rip current using aerial photographs or UAV. The observation location was taken in an area that is often used by the Balinese Hindu

community to carry out the Ngaben ceremony process in Bali.

II. Material and Method

Before this research was carried out, a preliminary survey was investigated by the team in several areas. Observations and interviews with local communities were carried out to obtain information about the area. The research location was finally determined at Munggu Beach and Nusa Dua Beach as shown in Figure 4. We choose this location because there is much Balinese ceremonial activity at Munggu Beach and water sport activity at Nusa Dua Beach.



(a)

(b)

Fig. 4 Location of study (a) Munggu beach and (b) Nusa Dua Beach

A. Research Tools and Materials

To support the implementation of this research, hardware and software are needed as research tools and materials.

- Hardware
  Drone: Dji Phantom 4 and Dji Mavic Pro
  RTK GNSS: CHCNav i50
  Marker for Ground Control Point (GCP): made from white paper which is crossed with a size of 29 x 10 cm
- Materials:
  Food coloring Erythrosine Cl 45430, karmoisin Cl 14720
- Software: Software photogrammetry: Agisoft Metashape 1.6.1; GIS: QGIS 3.12.0 version.

The tools we use are 2 drones with different specifications, both are used to record videos and take photos. We use dyes from food coloring to monitor the movement of currents in the middle of the sea. Some of these tools can be seen in Figure 5. Pictures and Vidios stored in memory and to produce digital surface models (DSM) and orthophoto, Agisoft Metashape software is used. And QGIS used to determine the position of the observation point.

Fig. 5 Research Tools

B. Method

The drone is set before operating; some tests are done before data is taken. Then created several data collection scenarios.

1) Aerial Photos: This stage consists of preparing the equipment needed to build sensors and making flight plan missions. Making flight plans is done using the DJI GS Pro Software. The flight plan is made based on several parameters such as coverage area of the target area, flight height, overlapping rate (front lap and side lap), drone speed, camera position and direction, and obstacles. Drone trajectories in aerial photo-taking missions are shown in Figure 6.

2) Dye Tracer Test: The Dye Tracer test has long been used by scientists and doctors to indicate water movement and a marker of blood flow in the human body. The use of tracer dyes in this study aims as a visual observation to illustrate the current flowing offshore as an indicator of rip current [12]. In this study, the tracer coloring used was a pink food coloring consisting of natural sweetener sorbitol and Erythrosine Cl 45430 so it was an environmentally friendly dye. In this test's first step, the tracking dye is diluted with water to reduce its thickness and concentration. The second stage, the dye, is poured and distributed in an

area indicated as a rip current area (based on interviews with the swim warning flag's life guard and position). The next step is visual observation using drones.

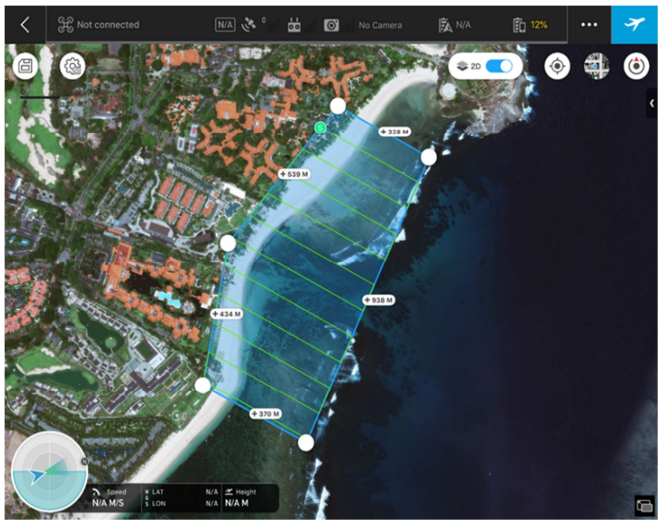


Fig. 6 Drone trajectory using the DJI GS Pro Software

3) RTK-GNSS survey: Ground Control Point (GCP) made of white paper and crossed, placed on the surface of the sand. Furthermore, GCP is distributed in the research area. The GCP midpoint coordinates are then measured by the Real Time Kinematic Global Navigation Satellite System (RTK-GNSS) with an accuracy of ± 3cm (Figure 7). These coordinates are then used for georeferenced aerial photographs and optimization of 3-dimensional models generated in photogrammetric analysis, where aerial photographs with pixel coordinates will be converted to actual coordinates (World Coordinate), so they can be used for further processing.

Fig. 7 Measurement of GCP coordinates

4) Video data collection: In this study, a drone with quad-copter (4 propler) type Dji Mavic 2 Pro (Figure 8) was used. Drones are flown over the research area (rip current area) with a height of 150 m above the home point. The direction of the recording camera goes downward. The direction and pattern of the dye distribution are then recorded using a drone camera and video data is generated. Visual observations using drones are carried out until the tracking dye disappears from the surface of the water.

Fig. 8 DJI Mavic 2 Pro drone flight

5) Aerial photo data collection: Aerial photographs were taken using camera stock (4K / ultra-high-definition camera; FOV: 940; resolution: 3840 x 2160 pixels; frame rate: 29.97 frames / s; color depth: 24 bits) on the DJI Phantom 4 drone (small, lightweight quad-copter UAV) (Figure 5). The camera's direction and position are set to the lowest position, where the angle of shooting is 90^0 (vertical aerial photo) at each waypoint. Drone flying height is set 150 m above ground level (drone home point), resulting in an aerial photo resolution of 6.5 cm/pixel. To produce a 3D model, the resulting aerial photographs must overlap one another, the higher the overlapping area the better the resulting model, so that in this mission the overlapping rate is set at 75% for the front lap and 70% for the side lap.

6) Calculation of Current Speed Based on Interpretation of Color Movement in Video Drone: The resulting aerial video is a video with MOV (Quick time file format) format. This video is then converted into several photos in JPG format using Photoshop CS.6 software to generate a photo frame every second. Visual interpretation in determining the direction and pattern of rip currents can be made by observing photos with frames t = 0 to t = n. Current velocity can be analyzed by determining the time of the tracker's coloring when moving in rip current relative to GCP. Rip current speed can be calculated by the following formula:

$$\text{Current speed} = (S1\text{-}S2)/(t2\text{-}t1) \quad (1)$$

where S1 and S2 are distance of coloring at t1 and t2 and t1 and t2 are the time taken by the dye to reach point 1 and 2.

7) The making of Orthophoto and DSM uses photogrammetric techniques: Aerial photo processing is done with Agisoft Metashape Professional Software. This software can process aerial photography into 2D (orthophoto) and 3D (dense point cloud and DSM) models using photogrammetric techniques with Structure from Motion (SfM) and Multi View Stereo (MVS) algorithms. In this technique, firstly a selection of aerial photography is carried out, photos with low quality will not be included in further processing. Aerial photo processing is continued using photogrammetric techniques. At this stage, the SfM algorithm will first estimate the camera's intrinsic and extrinsic parameters, and produce a sparse point cloud. Furthermore, GCP coordinates are used to convert the apparent coordinates on the model to actual coordinates and optimize the camera's intrinsic and extrinsic parameters. The

MVS algorithm is then used to generate dense point clouds. To produce DSM, then 3D point interpolation is performed on the dense point cloud using linear interpolation techniques. An orthophoto is produced by combining all aerial photographs that overlap into one unit (mosaic). Overall, the workflow for making orthophoto and DSM is shown in Figure 9.

8) Making Bathymetry Map: In the initial stage, digitization is done using QGIS software version 3.10 on the orthophoto model generated in the above step to get *the ocean area.shp* file. This area is then used to extract DSM in the ocean area to generate the ocean DSM. Ocean DSM is used as a basic material in making bathymetry maps. The bathymetry map is obtained by reducing the average elevation value on the coastline with ocean DSM. The bathymetry map produced is still influenced by the refraction effect (water-water interface refraction effect), so it needs to be corrected using the following formula:

Real water depth = apparent water depth x correction factor (CF) where CF = refractive index of water is equal to 1.34 [13].

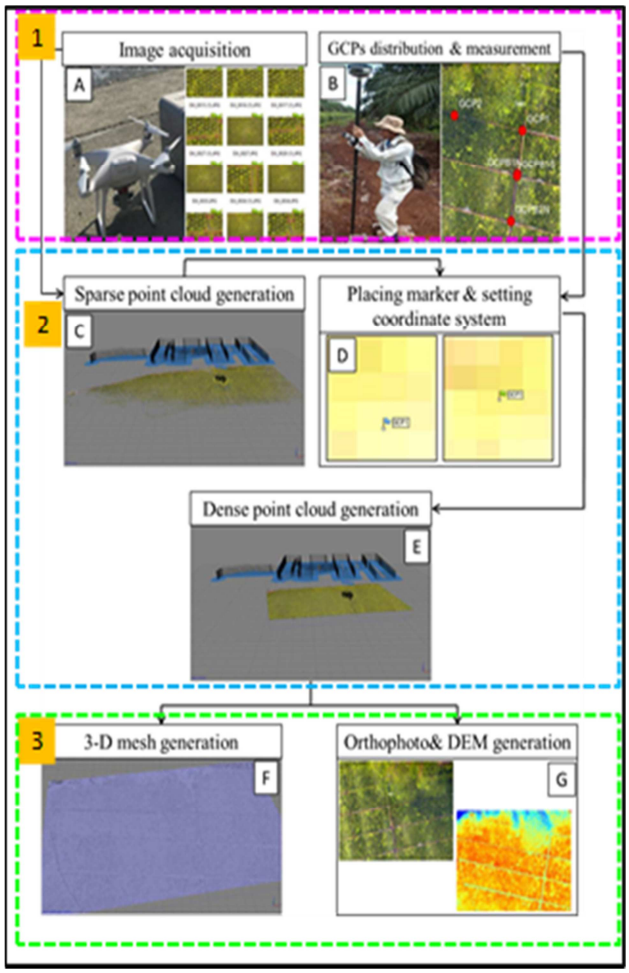


Fig. 9 Workflow of making orthophoto and DSM

III. Result and Discussion

The results on UAV and controller in the form of image file, UAV flight location, the position sensor value used by the UAV, UAV flight configuration structure, UAV hardware and software conditions, video files, UAV, and controller ID. All data is compiled and analyzed to get comprehensive data.

A. Rip Current

As explained earlier in the introduction, that rip current is marked by the gap between the breaking waves. Figure 2 is the observation result of the rip current case in Munggu Beach. Kusmanto [4] also mention that turbidity proved rip currents carrying sediment loads from the coast to the middle of the sea. Based on this information, we got a picture, as shown in Figure 10. The picture shows that rip current occurs in the prohibited area to swim right in front of the danger flag. After zooming out, it appears that there is an area experiencing turbidity, as explained by Kusmanto. The picture results prove that the coast guard has placed the danger flag properly and can also prove that the drone can be applied to investigate the area where this rip current occurs.

Fig. 10 Rip Current at Munggu Beach.

B. Speed Current Measurement

To investigate the speed of the rip current, Dye Tracer Test was used. After discussed with the lifeguard in Nusa Dua Beach, the dye is poured and distributed in an area indicated as a rip current area. Measurements are made at spring tide where the flow changes from flood to ebb. The yellow dye is poured in a few minutes using a canoe while the drone records the dye's movement, as shown in Figure 11. The average of the rip current speed is 0,29 m/s as shown in Table 1.

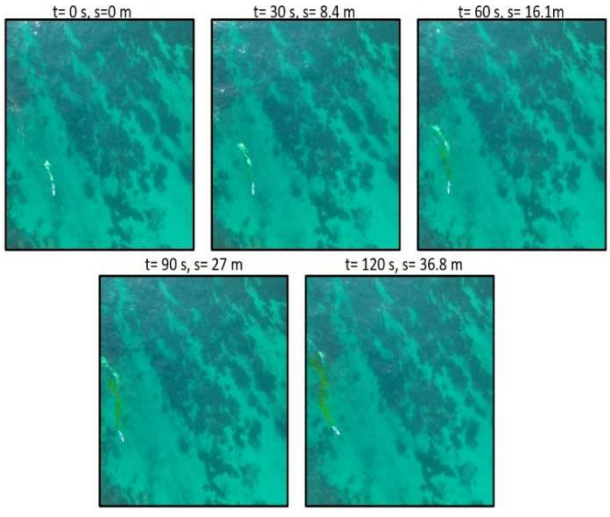


Fig. 11 Visualization of the rip current speed at Nusa Dua Beach.

TABLE I
SPEED CURRENT MEASUREMENT

Current Speed							
Time (s)	X (pix)	Y (pix)	Distance (pix)	Img Res (m/pix)	Distance (m)	speed current (m/s)	Average speed (m/s)
0	680.4583	604.4583					0.28838634
30	630.5417	531.4583	88.434535	0.0949	8.392437	0.279747912	
60	585.4375	464.375	169.26985	0.0949	16.06371	0.267728485	
90	516.5417	372.4167	284.0985	0.0949	26.96095	0.299566082	
120	457.4167	287.5	387.5695	0.0949	36.78035	0.306502882	

C. *Rip current channel*

The results of aerial photo processing with Agisoft Metashape Professional Software into 2D (orthophoto) and 3D (dense point cloud and DSM) models are shown in Figures 12 and 13. Photogrammetric techniques with Structure from Motion (SfM) and Multi View Stereo (MVS) algorithms are used. Figure 12 indicated the map of the surfzone at study area on Nusa Dua Beach. From this picture clearly visible the channel oft rip current, it was clear that there was sediment carried towards the channel. Thus, the area is unsafe area.

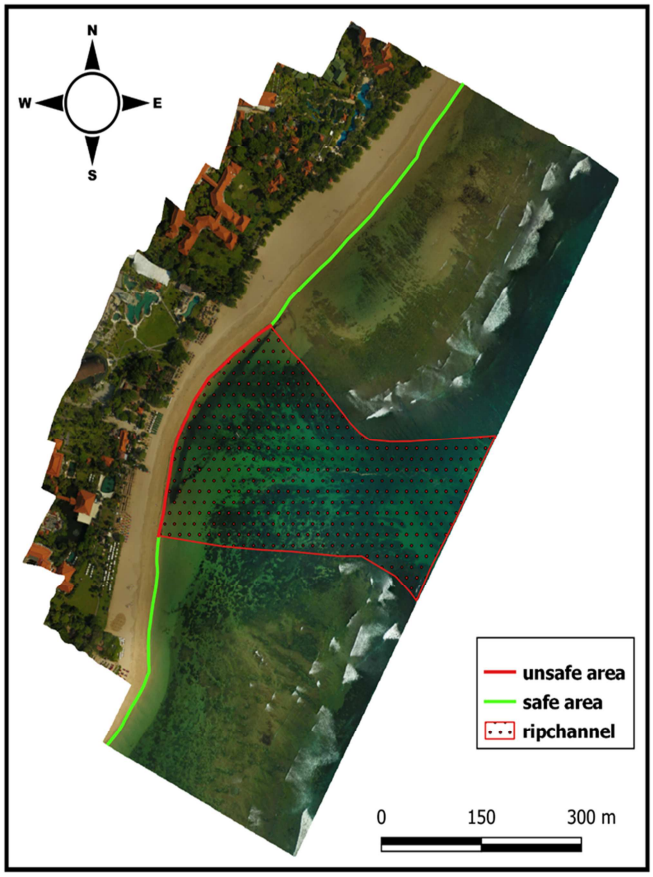


Fig. 12 Surf zone mapping from UAV-orthophoto.

Waves will bring mass, energy, and momentum towards the beach. When the waves travel towards the beach, the water depth decreases which causes the wave height increases. Beaches that have bathymetry differences will have shoaling and refraction processes that can cause variations in wave height along the coast. The difference in wave height along the beach can cause a rip current [3]. Figure 13 shows the bathymetry at the study area in Nusa Dua Beach where the blue color indicates a depth of more than 7 m. The water depth profile is presented in Figure 14, where there is a clear difference in bathymetry at the rip current location. The steep bathymetry causes waves to break near the shore. The energy due to these waves can then cause a pressure gradient along the beach and become one of the generating factors of rip current. When the wave height increases, the higher energy generated. This will have an impact on the rip current intensity at the beach. The higher the waves can cause the intensity of rip current will be even greater.

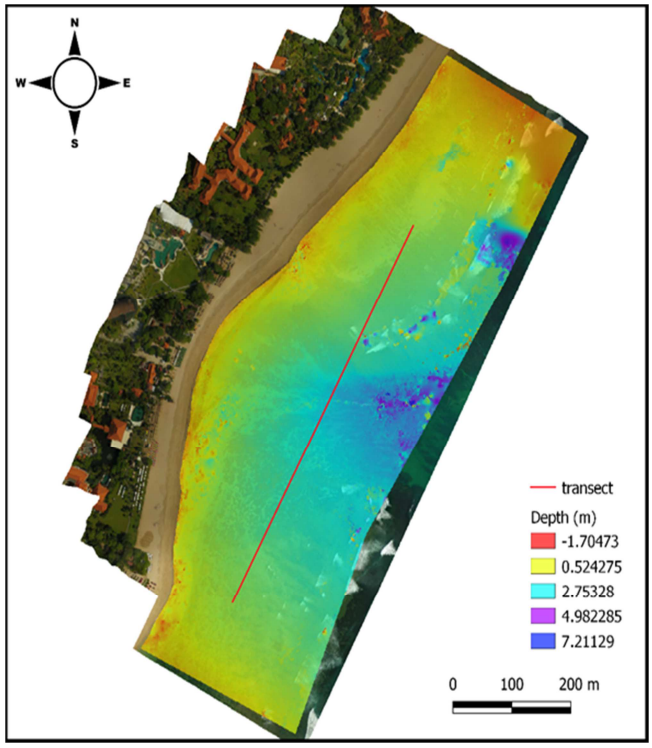


Fig. 13 Bathymetry.

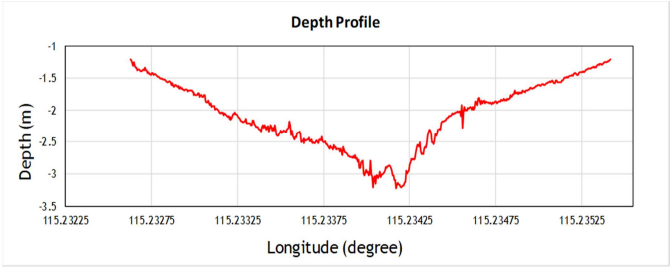


Fig. 14 Depth profile of bathymetry.

IV. CONCLUSIONS

The results of this study indicate that UAVs can be used to examine the existence of rip current. The difference in bathymetry causes variations in wave height along the beach and this is caused the rip current. The speed of this current is influenced by wave energy that propagates to the beach. Strengthening knowledge about the dangers of rip current can be done by socializing people who have activities on the beach. Research needs to be developed to get a map of rip current areas as an early warning for the community.

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