Proceedings of the 6th International Conference on the Application of Physical Modelling in Coastal and Port Engineering and Science (Coastlab16)

Ottawa, Canada, May 10-13, 2016

USE OF DRONE TECHNOLOGY AND PHOTOGRAMMETRY FOR BEACH MORPHODYNAMICS AND BREAKWATER MONITORING.

GEORGES GOVAERE[1], RONALD VIQUEZ[1], HENRY ALFARO[1]

1 Engineering Research Institute, University of Costa Rica, Costa Rica, georges.govaere@ucr.ac.cr, ronald.viquez@ucr.ac.cr, henry.alfaro@ucr.ac.cr

ABSTRACT

Results from the use of UAV-based photogrammetry for monitoring changes in beaches and breakwaters are presented. Main recommendations are provided on the basis of lessons learned about the collection of reliable results and the detection of the main causes of error in the planning of flights and field work.

Emphasis is made on the quality of the results and the amount of information collected, which cannot be easily obtained by traditional means.

The equipment used herein was an Aibotix X6 V2.0 UAV and a 16Mpixel Nikon Coolpix A camera.

KEWORDS: UAV, Photogrammetry, Survey.

1 INTRODUCTION

Aerial photography and photogrammetry have been very useful tools for surveying large topographical surfaces. However, due to the high cost of the flights, the technology is used in only few projects and specific situations.

In recent years there has been a boom in the use of UAVs, which have become much more stable, have greater flight range, permit the use of airborne cameras and reduce the costs in comparison with other types of flights. Added to this, the improvement and automation of photogrammetric computer programs have allowed these analyzes to be performed without expertise in the field, resulting in a more accessible and attractive technology for monitoring of large surfaces.

The IMARES group at the University of Costa Rica acquired a UAV during 2015 along with the necessary software for coastal monitoring of beaches and breakwaters. During this time, the group of researchers has accumulated considerable experience in the use, limitations and advantages of such technology. The goal of this article is to present these experiences to other colleagues in the field who are interested in the use of the methods explained herein.

2 METHODOLOGY

The type of UAV used was an hexacopter, which has the advantage of performing static flights and can inspect areas of interest in great detail from various angles. The UAV used carried three cameras: the main one for taking photos for photogrammetric analysis, a GoPro video camera that records the flight and an auxiliary camera that transmits video in real time for the use of the pilot. The set of cameras are installed on a support with gyroscopes and servo motors that keep stable the angle of the cameras even if the UAV is moving erratically by wind action.

The first step for the use of UAVs in photogrammetry is planning the flight. This is performed through software programming by creating a flight plan that maximizes photograph overlap to levels greater than 70% with 60% overlap in the flight lines. Such overlap is achieved by the choice of paths, the speed of flight, the flight altitude and the time between shooting photos. The flying height is the primary determinant in the precision obtained at the end of the project. Many of these parameters are very easy to set up due to the visual environment of the software that permits Google Earth integration or the use of personal georeferenced photographs. Figure 1 shows an example of flight planning process.

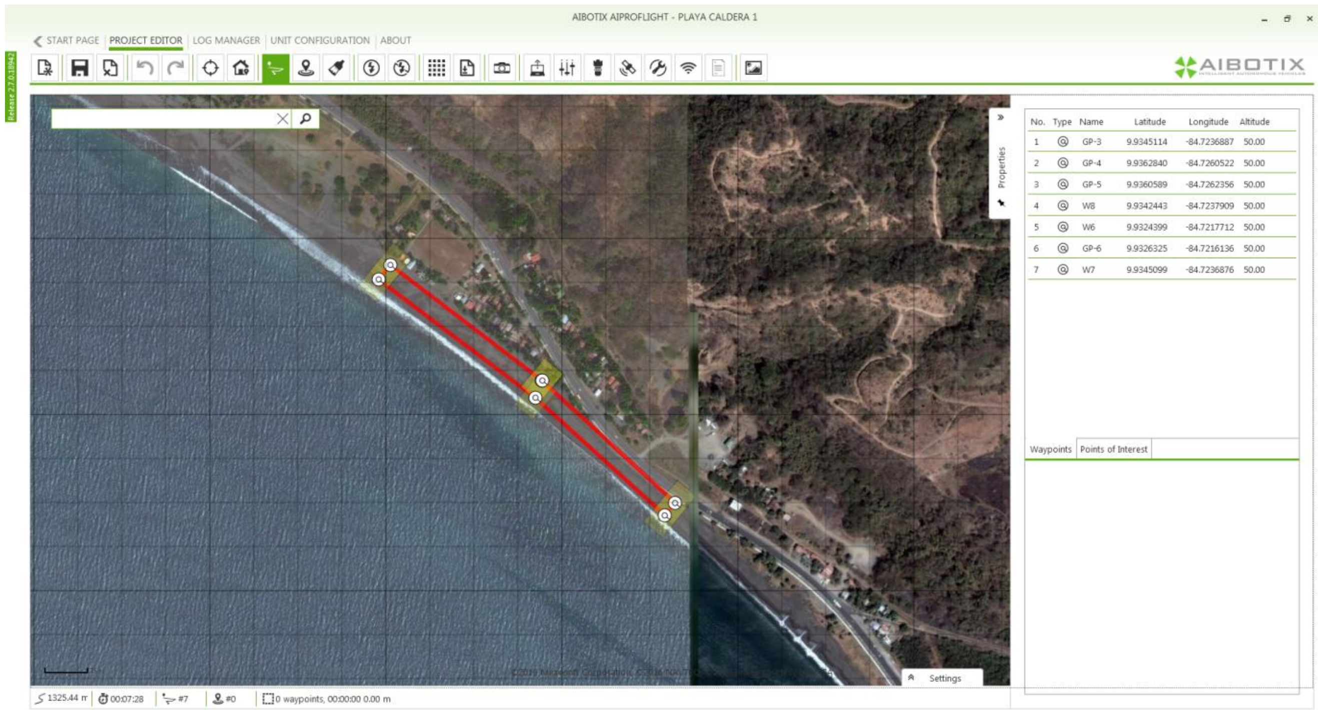

Figure 1. Flight planning in Caldera Beach, Costa Rica

Since the minimum overlap should be around 70% between pictures, the time between successive images has to be decreased to increase such overlap and accuracy. These additional photographs are also useful when some of the photos are blurry and must be eliminated.

The points of takeoff and landing, along the flight plan, must be chosen carefully 1) to minimize the flight time, which it is the main constraint, and 2) in order to meet the appropriate security conditions. Also, the flight plan should consider different points of emergency landing in case the batteries cannot support the scheduled route, most of the time due to bad weather.

In order to achieve optimal resolution in the digital elevation model, it is important to include checkpoints in the flight plan. These are identified in the photographs during post-processing and must be previously placed at preselected locations and georeferenced via a GNSS-RTK system with sub-centimeter precision. These points are either painted directly on concrete or painted metal plates are used.

The rest of the process is performed on a computer, starting with georeferencing photographs using the GPS-based log generated by the UAV, which also includes information about the time and the inclination angles of the camera for each image as shown in figure 2. The Agisoft software is used to automatically perform the necessary processes to generate orthophotos and digital elevation models, which can be exported to different formats such as CAD.

The equipment used in this work is a AIBOTIX X6 V2.0 UAV, the Agisoft processing software, a digital NIKON COOLPIX A 16-megapixel camera and a workstation with 32 cores and 32 GB of RAM.

Examples of digital elevation models and point clouds from the Caldera breakwater are shown in figures 3 and 4. Figures 5 and 6 show the 3D reconstructed surface of the breakwater. In figure 5 we can appreciate and orange checkpoint (bottom left in the figure).

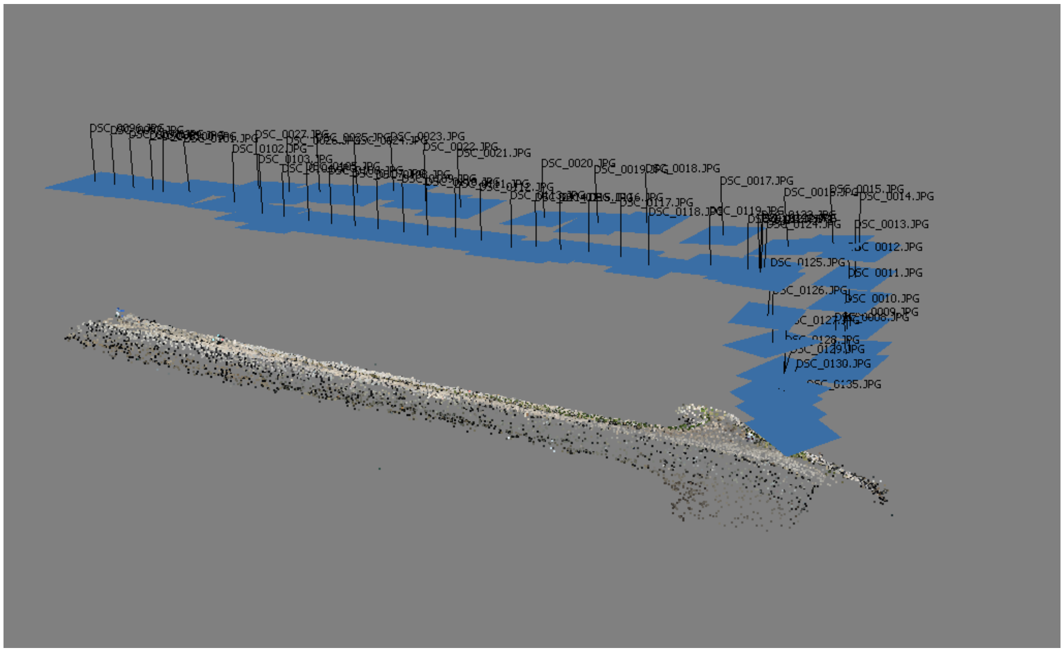

Figure 2. Georeferencing photographs

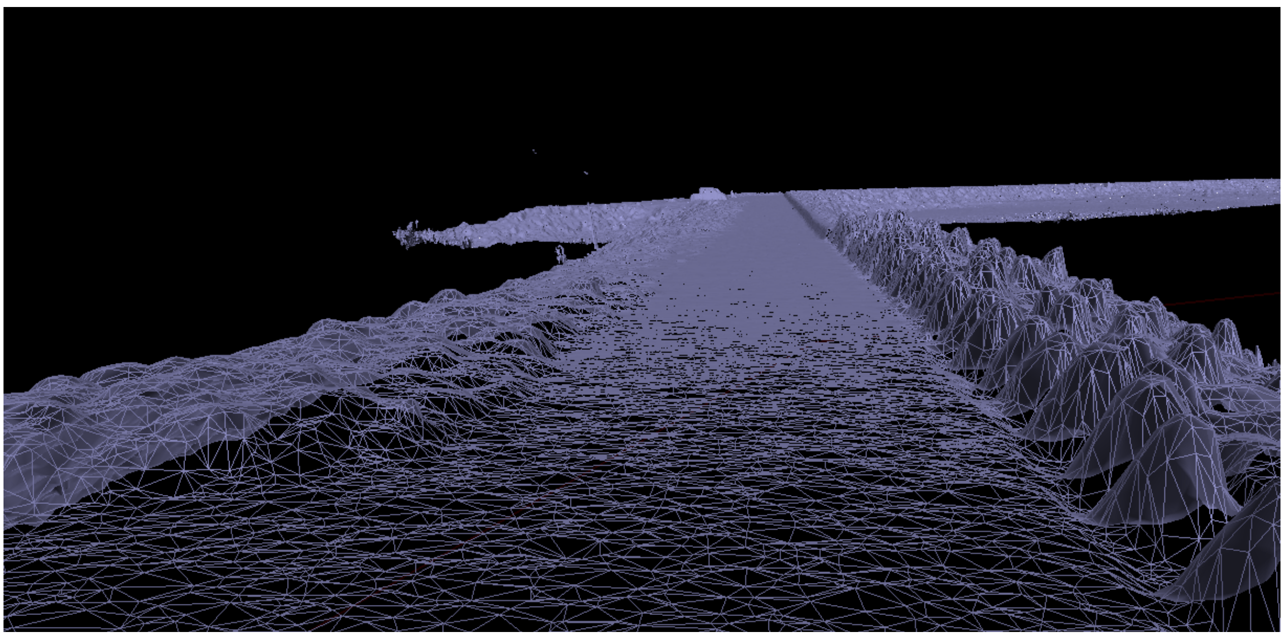

Figure 3. Digital elevation model of Caldera Breakwater, Costa Rica

3 RESULTS

After several approaches to manage the data obtained, we achieved accuracies for the digital elevation model of 1.0 to 1.5 cm in the horizontal and vertical with flights at 50 to 60 meters in altitude, using checkpoints every 300 meters along the travel and separated about 100 meters in width. For flights at 80 to 100 meters of vertical distance from the ground, used to quickly cover much more area, accuracies decreased to 1.5 to 2.0 cm in the horizontal and 3 cm in the vertical. This accuracy refers to the photogrammetry analysis, for the total accuracy the GNSS-RTK error should be added.

The estimation of the accuracy was performed by using additional checkpoints placed randomly (usually about 4 or 5) in the area of the several flight plans. The accuracy is not affected by the location or the type of surface; the same results on a beach or on a breakwater are obtained, equally in high or low areas or in the central areas or the edge of the flying area.

Placing the checkpoints along the route is essential for the precisions described. If only the internal UAV GPS is used, errors, especially in the vertical, can be very large, in the order of several meters. This is observed especially in very lengthy flights as those on beaches where a strip of 3 or 4 km by 100 meters wide is analyzed. In approximately square routes, this phenomenon does not occur and the results may have error within tens of centimeters.

A standard survey in our case requires 4 flights, produce 2,5 to 3.0 GB of data in 650 to 750 photos.

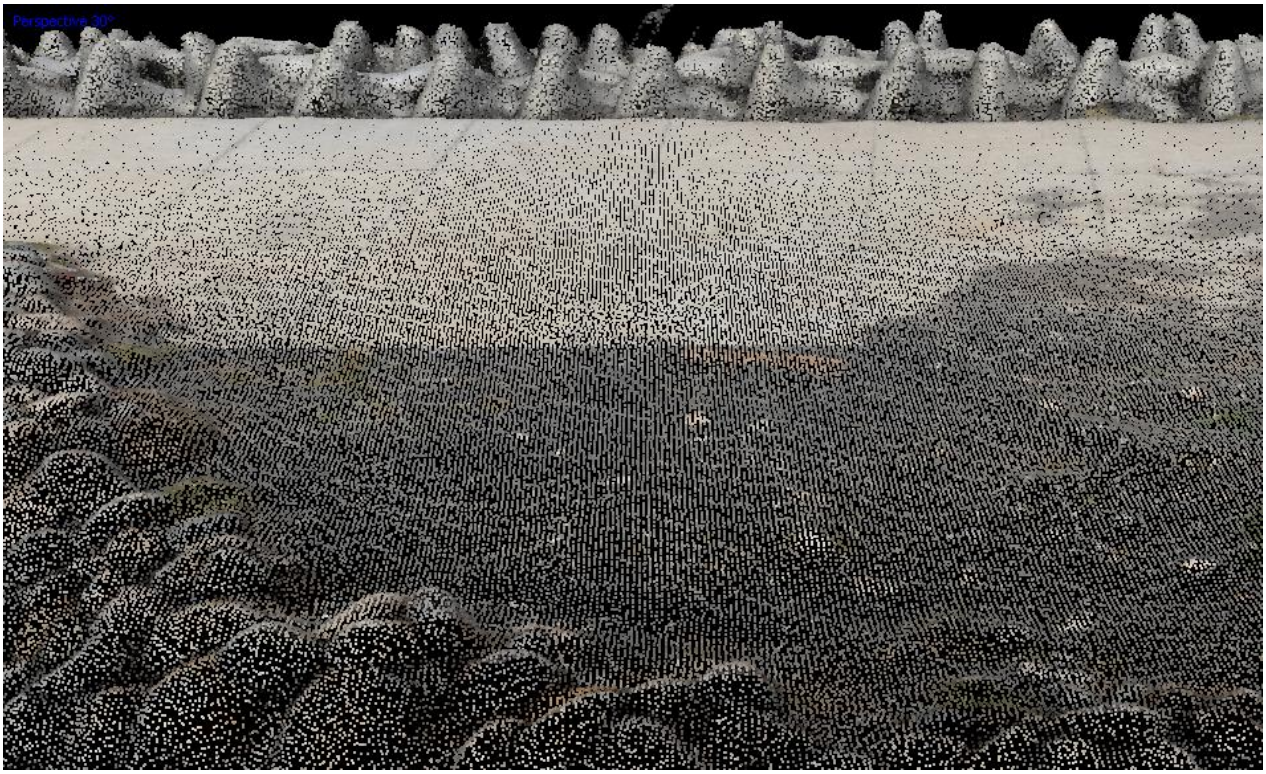

Figure 4. Point cloud from the Caldera breakwater, Costa Rica

Figure 5. 3D reconstruction of the Caldera breakwater, Costa Rica

The positioning and georeferencing of checkpoints is a task that takes longer in the fieldwork. For the latter we used painted steel plates with black background and an orange cross, easily identifiable from the aerial photographs. It is preferable to place these points on fixed locations (roadside curb, gutter or any other place known not to move) but in our case, they have to be located at the beach.

The actual flight times are much lower than those announced by the manufacturer. In theory, the flight autonomy is 30 min, however in ideal conditions (no wind) we only achieved 15 min, and actual flight conditions on beaches (where we always have a moderate wind) the flight range drops to 9-10 min in flight plans planned for 12 min. The overall survey time takes about 4 to 6 hours including installing and GNSS-RTK georeferencing the checkpoints, packing and unpacking the equipments, UAV pre checks and flight 4 to 6 times.

Figure 6. 3D reconstruction of Caldera breakwater, Costa Rica

Figure 7 presents the location of two profiles of the breakwater and Figure 8 shows the breakwater profiles obtained from the point cloud.

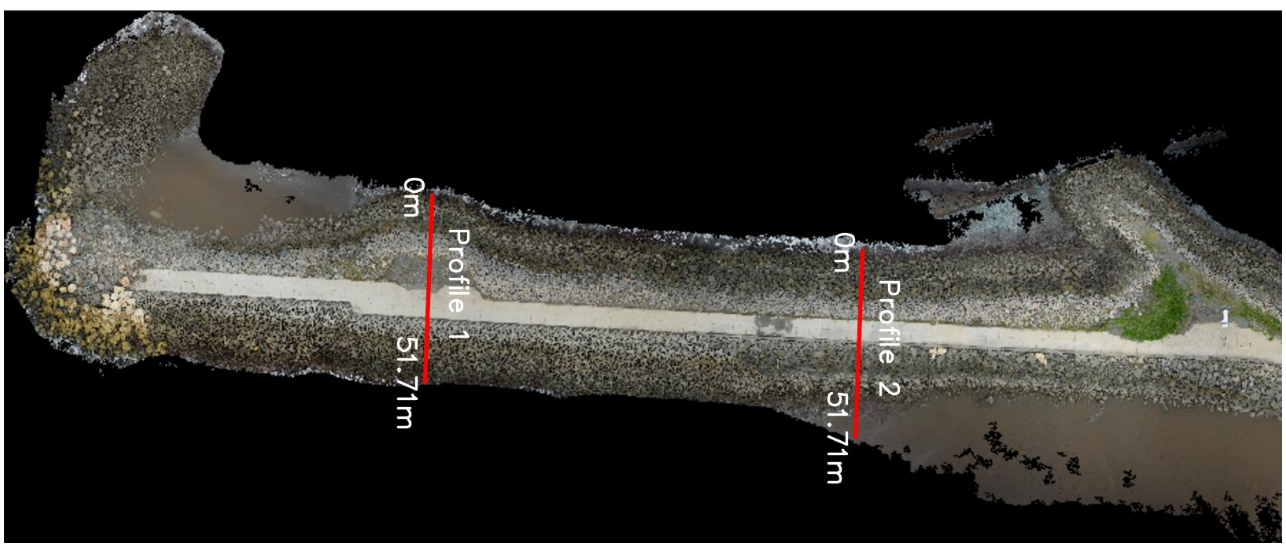

Figure 7. Location of profiles for Caldera breakwater, Costa Rica

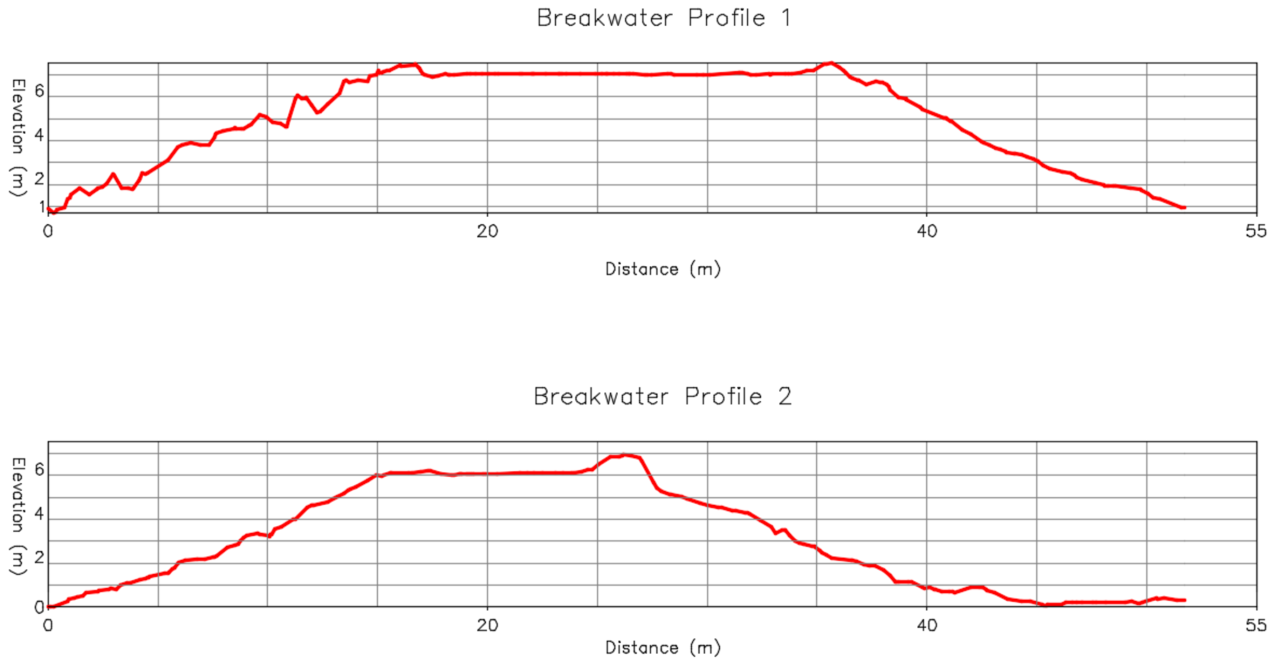

Figure 8. Caldera breakwater profiles

Figures 9 and 10 show the 3D surface model of two sections of Caldera beach. Figure 11 presents the change in the contour level in a temporal gap of 1 month.

Figure 9. Caldera beach 3D model (central section)

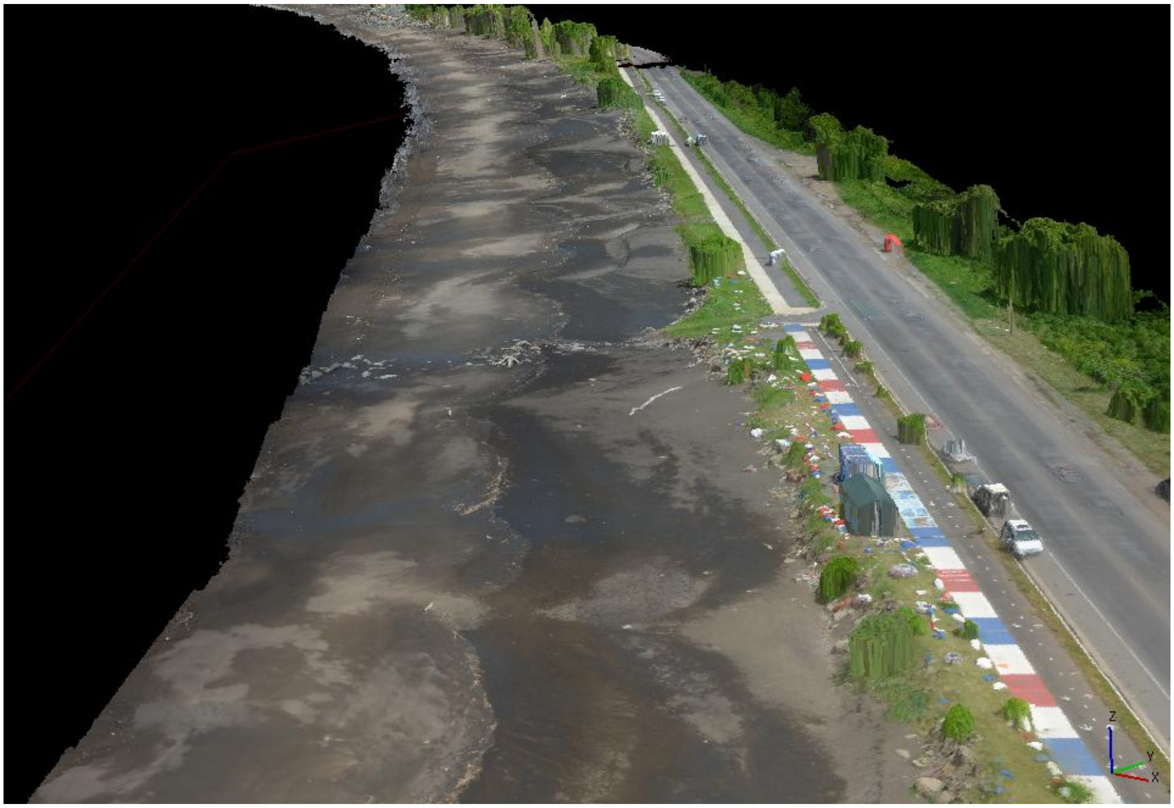

Figure 10. Caldera beach 3D model (south section)

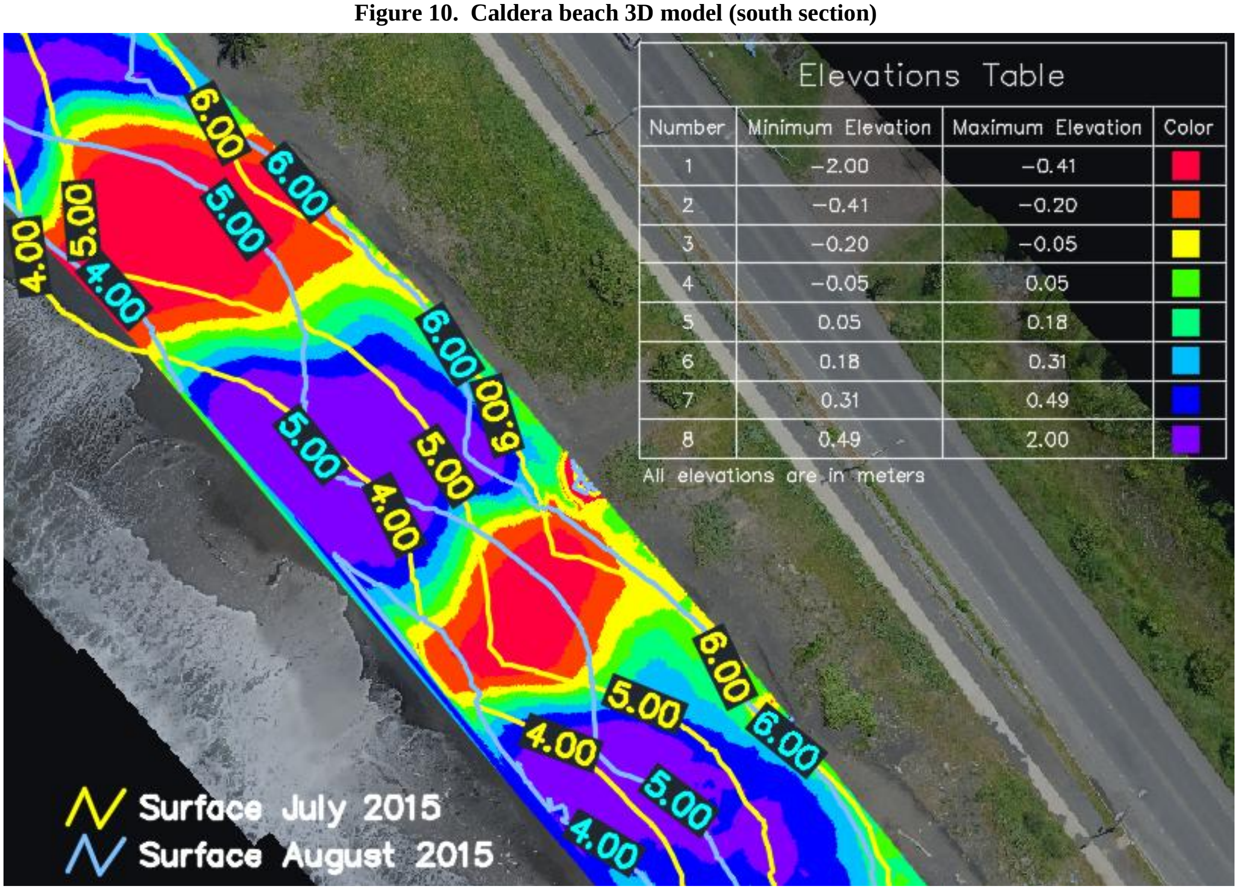

Figure 11. Changes in contour levels in Caldera beach (south section)

The projects currently being monitored in Costa Rica with this technology are: the progress and impact on the beach by the construction of TCM-Moín port by APM-Terminals (Caribbean coast), the rehabilitation and expansion of the main breakwater of the port of Caldera and subsequent changes in the morphology of Caldera beach (Pacific coast).

4 CONCLUSIONS

We have use successfully UAV and photogrammetric technology for studies of beach dynamics and the general changes in coasts, showing great advantages over conventional methodologies.

The main advantages found with the system used herein are:

- A large amount of high precision data can be acquired in a short time. This is not limited to just beach profiles, but the entire surface so the number of profiles required are easy to get.
- The time of completion of the field work is very fast for the amount of information obtained.
- The resolution obtained is very accurate, with greater accuracy than conventional methods.
- The analysis of complex surfaces such as a breakwater dolos, which are very difficult to perform by standard survey methods, is possible at a minimum cost.
- The work can be done without exposing personnel to hazards such as high-traffic areas of heavy machinery, or without disrupting the normal processes of construction or operation.

The main disadvantages found with the system used herein are:

- It is essential to place checkpoints via RTK-GNSS for good ground resolution.
- The flight time can be quite short, just 9-10 min in actual flight conditions.
- There is high dependence on weather conditions for the flight, rain and wind can make flights difficult or impossible and battery life is significantly compromised.
- The equipment is very sensitive to dust and sand, conditions normally encountered in our workplace.
- The current cost of the equipment is high, but this will probably decline over time.