PRODUCING DIGITAL PHOTOGRAMMETRIC PRODUCTS FROM DATA ACQUIRED USING KINEMATIC GNSS METHODS

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***Abstract**: To determine the volume of material in a quarry and generate photogrammetric products, the DJI Phantom 4 RTK drone was used to capture 146 images, and a UniStrong G970 II GNSS receiver was used to determine the control points. For generating the orthophotoplan, the digital terrain model, and for volume determination, Pix4Dmapper software was used. During processing, interruptions were observed in the point cloud due to the shadow of the conveyor belt above the material and the camera's field of view (FOV), which caused insufficient data collection, leading to underexposed and obstructed areas. Due to these gaps, the volume determination is incorrect, as the software calculates the volume through the break in the point cloud, from the material to the height of the conveyor belt, resulting in a volume of 3211.84 m³ ± 20.12 m³. To compensate for this error, an additional volume of 93.45 ± 0.62 m³ was determined, representing the excess volume. Thus, the final volume, considering the difference between the two volumes, is 3118.39 m³ ± 19.5 m³.*

After introducing the control points (GCPs - Ground Control Points), their optimization was carried out by repositioning them correctly. The correct position is represented by the marks on the ground made with red spray paint. The actual mark is made at the intersection of the two red lines in the point cloud. Seven control points were used, placed near and on the material, whose position was determined with the UniStrong G970 II GNSS receiver. Comparing georeferencing with and without control points, precision decreases when using GCPs, but the position and quality of the products are correct, and the photogrammetric products can be used in other fields as well.

For a detailed visualization of the area where the flight was carried out, contour lines can be generated using additional settings during processing. For the material volume and the surrounding area, contour lines with an interval of 0.5 m were generated, providing a detailed visualization. This can be used to track the behavior of a material volume over time or, in general cases, to monitor areas prone to landslides.

***Keywords:** position; volume determination; Photogrammetry; UAV; GNSS; RTK*

1. Introduction

Photogrammetry is the science concerned with determining the shape, dimensions, and position of objects in the environment based on photographic images of them.[1]

The digital model of an object or phenomenon consists of a systematically stored data collection, describing in a three-dimensional coordinate system, arbitrary or specific, the shape and characteristics of the object or the states of the phenomenon, and allows the deduction of the shape and characteristics through suitable calculation programs. [1]

UAV - Unmanned Aircraft Vehicle is an aircraft without a pilot on board and is a component of UAS (Unmanned Aircraft System). The system refers to a group of equipment necessary for flight and data acquisition. [2]

GNSS - Global Navigation Satellite System - represents essential infrastructure in the field of navigation technology. [3]

Global Navigation Satellite Systems (GNSS) are systems that enable high-precision positioning in a geocentric reference system, at any point located on, near, or above the Earth's surface, using artificial satellites of the Earth.[3]

For this work, real-time kinematic (RTK) positioning was used, meaning that the position is determined during satellite observations.

The working area is located in Gura Vitioarei village, and the studied area is a quarry. The volume of material in a stockpile needs to be determined for future gravel storage and any necessary excavations for various works.

2. Materials and Methods

To capture the photogrammetric images, the DJI Phantom 4 RTK drone, equipped with integrated software dedicated to this field, was used. The flight plan was executed in a double grid on perpendicular directions, with the camera at a 90° angle to the ground, at an altitude of 40 m from the ground. [4]

For large coverage and obtaining a complex point cloud, the horizontal and vertical overlap rate was set at 80%, which densifies the grid.

After the flight, 146 photogrammetric images were captured, with the coordinates of the centres determined by the GNSS RTK method, with a fixed solution and a precision of maximum +/- 2 cm horizontally and +/- 2.5 cm vertically.

In Pix4DMapper, a new project is created, the captured images are imported, and the basic elements for obtaining correct results are set. The Pulkovo42/Stereo 70 reference system (3844 – EPSG code) is introduced. [5] [6] [7]

To transform the B, L, h coordinates of the image centers, we used TransDat to transform the point coordinates in Romania from ETRS89 - Stereo70/Krasovski42 System.

TransDat is a coordinate transformation application provided by the National Cartography Center. [8]

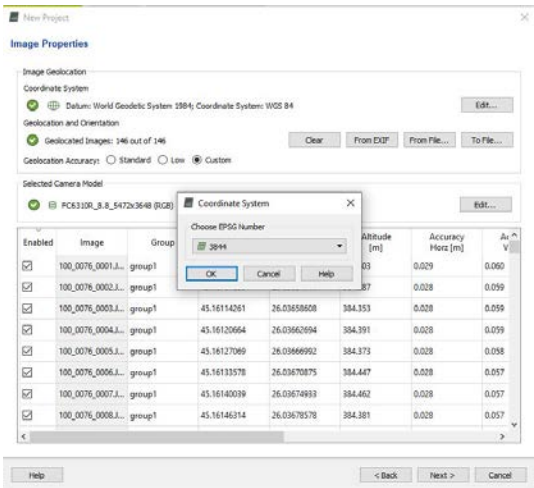


Figure 1 Reference system

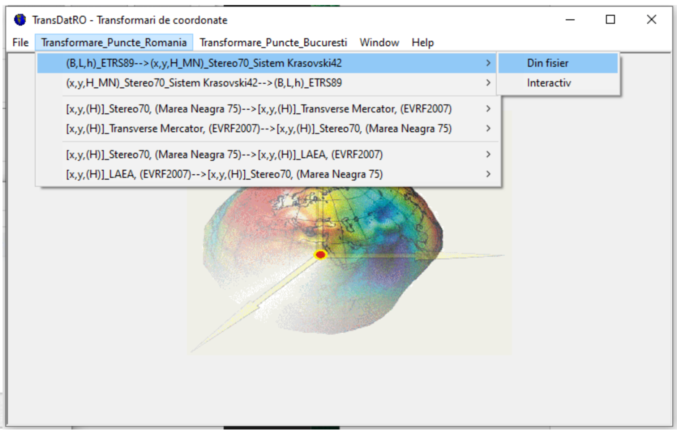


Figure 2 Coordinate transformation in TransDat

After importing the file with the parameters of the image capture centers, the horizontal and vertical accuracy can be verified. Additionally, the orientation parameters can be analyzed in the figure below.

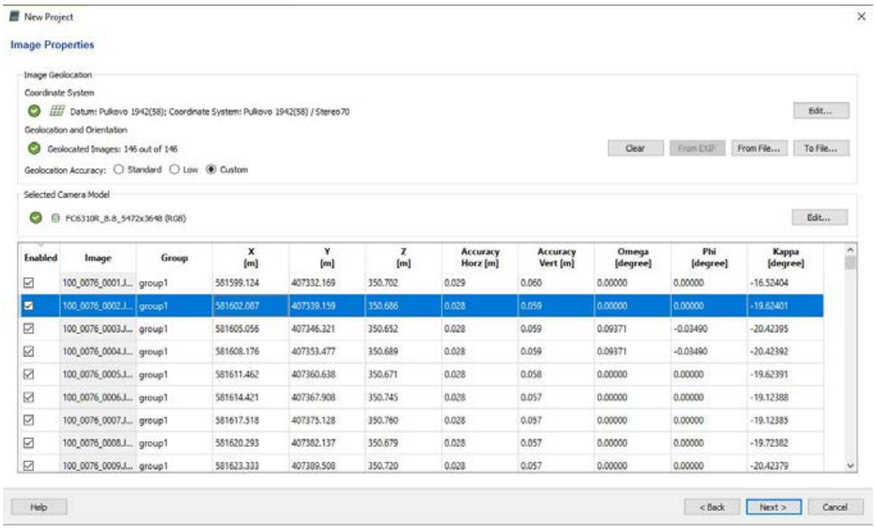


Figure 3 Georeferenced images

To begin the processing, the desired product must be selected from the Predefined Processing Options. The choice of these options varies depending on the method and purpose of the work performed. In this case, the captured images were taken nadirally, for which 3D Maps was chosen. The reliability of these models differs depending on the desired settings.

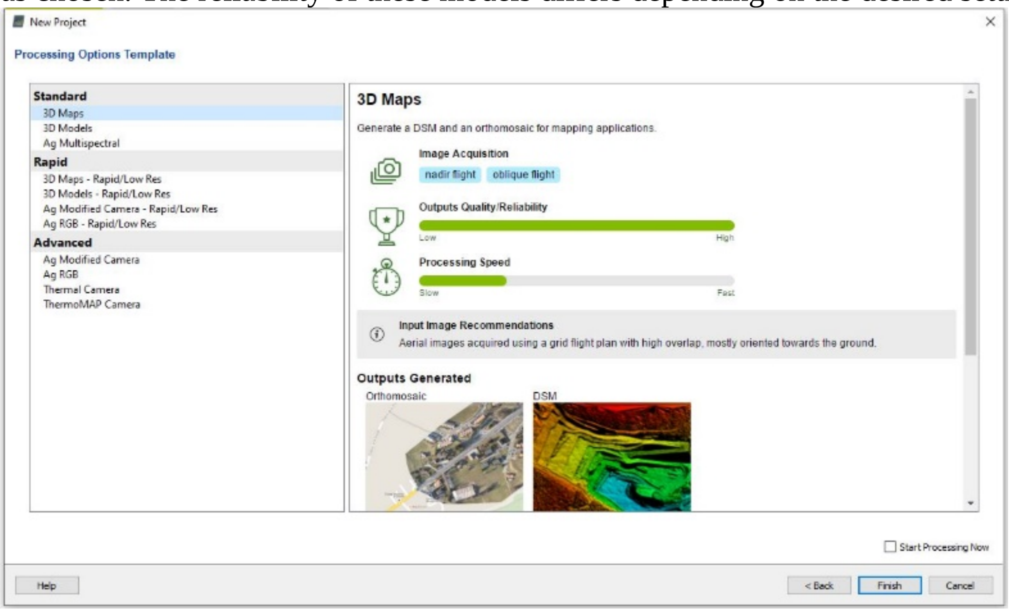
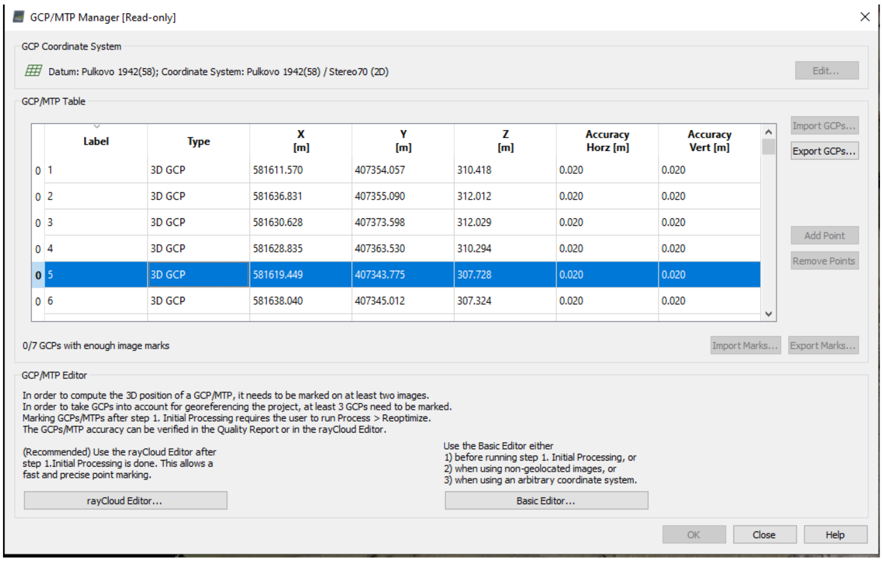


Figure 4 Choosing the photogrammetric data processing method

Post-processing is done following these steps in order: 1. Initial Processing – determines key points in the images, which are used to find matches between images, 2. Point Cloud and Mesh – increases the density of the 3D points of the model generated in the first stage, 3. DSM, Orthomosaic, and Index – creates the digital surface model (DSM).

Before starting the processing, the control points are entered, checked, and then processing can begin.

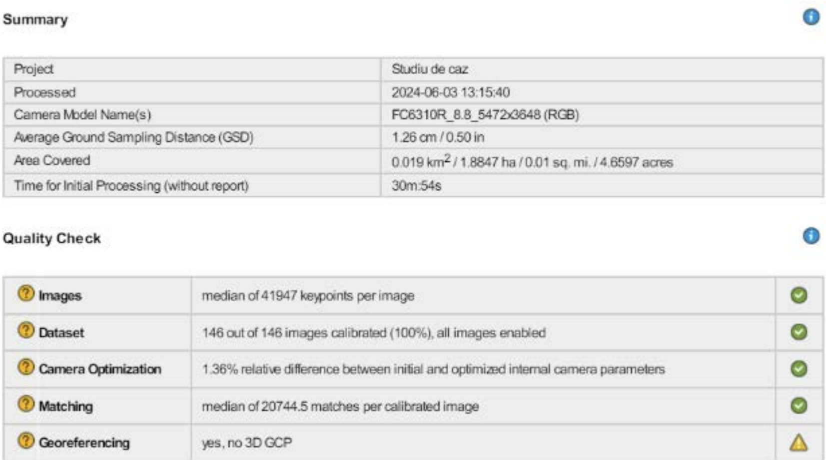


	Label	Type	X [m]	Y [m]	Z [m]	Accuracy Horz [m]	Accuracy Vert [m]
0	1	3D GCP	581611.570	407354.057	310.418	0.020	0.020
0	2	3D GCP	581636.831	407355.090	312.012	0.020	0.020
0	3	3D GCP	581630.628	407373.598	312.029	0.020	0.020
0	4	3D GCP	581628.835	407363.530	310.294	0.020	0.020
0	5	3D GCP	581619.449	407343.775	307.728	0.020	0.020
0	6	3D GCP	581638.040	407345.012	307.324	0.020	0.020

Figure 5 Control Points

After the initial processing, the quality report is automatically generated, displaying information about accuracy, the number of geolocated images, the processing time, and the tie point cloud.

Figure 6 Nor de puncte de legătură generat în prima etapa de procesare



Summary

Project	Studiu de caz
Processed	2024-06-03 13:15:40
Camera Model Name(s)	FC6310R_8.8_5472x3648 (RGB)
Average Ground Sampling Distance (GSD)	1.26 cm / 0.50 in
Area Covered	0.019 km^2 / 1.8847 ha / 0.01 sq. mi. / 4.6597 acres
Time for Initial Processing (without report)	30m:54s

Quality Check

Images	median of 41947 keypoints per image	✓
Dataset	146 out of 146 images calibrated (100%), all images enabled	✓
Camera Optimization	1.36% relative difference between initial and optimized internal camera parameters	✓
Matching	median of 20744.5 matches per calibrated image	✓
Georeferencing	yes, no 3D GCP	⚠

Figure 7 Report

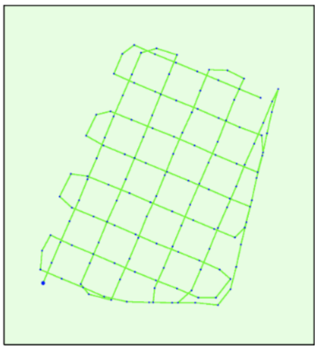


Figure 8 The initial position of the images is represented by green lines, which indicate the flight path of the images. The blue point marks the starting point of the flight.

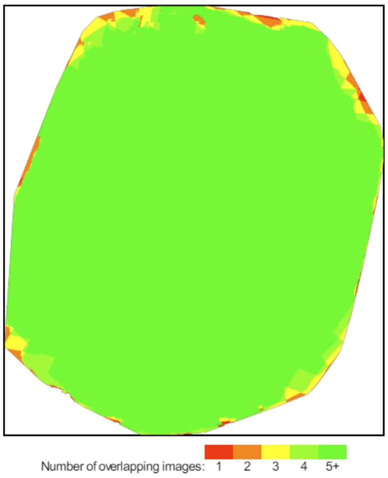


Figure 9 Image Overlap

Red and yellow represent areas with reduced overlap, which results in low-quality outcomes. Green represents the overlap area where at least 5 images overlap for each pixel. The green zone covers the entire area of interest, which will lead to the generation of the desired results for determining the material volume.

Without rechecking the control points in their correct positions, RMS errors of 0.005 m on the X coordinate, 0.007 m on the Y coordinate, and 0.013 m vertically on the Z coordinate were obtained.

To verify and improve the results, an optimization of the control points will be performed by rechecking these points in their correct position using the red spray-marked "x" symbols. This marking must be done at the centre of the intersection of the red lines for each image in which the marked point is visible.

Min Error [m]	Max Error [m]	Geolocation Error X [%]	Geolocation Error Y [%]	Geolocation Error Z [%]
-	-0.09	0.00	0.00	0.00
-0.09	-0.07	0.00	0.00	0.00
-0.07	-0.05	0.00	0.00	0.00
-0.05	-0.04	0.00	0.00	0.00
-0.04	-0.02	0.00	0.68	6.16
-0.02	0.00	47.95	55.48	47.26
0.00	0.02	52.05	41.78	36.99
0.02	0.04	0.00	2.05	9.59
0.04	0.05	0.00	0.00	0.00
0.05	0.07	0.00	0.00	0.00
0.07	0.09	0.00	0.00	0.00
0.09	-	0.00	0.00	0.00
Mean [m]		0.000075	-0.000117	-0.000221
Sigma [m]		0.005649	0.007442	0.013025
RMS Error [m]		0.005650	0.007443	0.013027

Figure 10 Errors (RMS) Without GCP Repointing

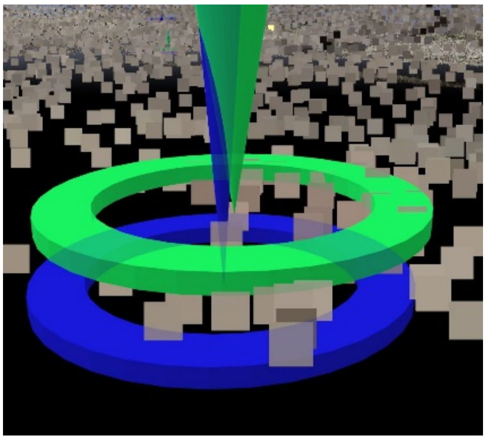


Figure 11 Green – Correct Position - Blue – Initial Position

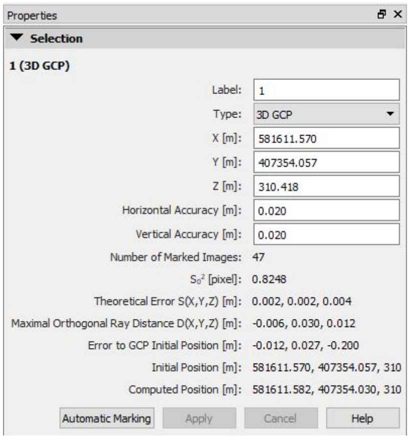


Figure 12 Coordinate Differences After GCP Repointing

After completing this step, the initial processing is re-optimized.

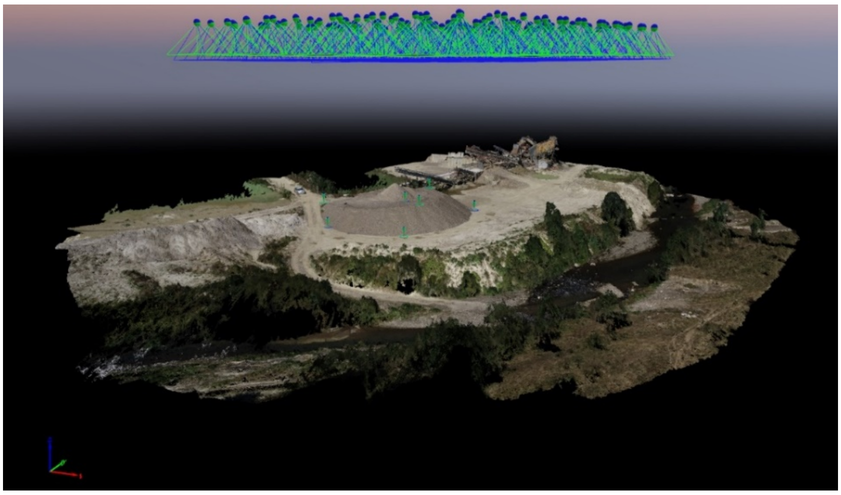


Figure 13 Dense point cloud

To determine the volume of the ballast stockpile, Pix4DMapper provides a "Volume" feature that, based on manual delineation, will automatically calculate the volume.

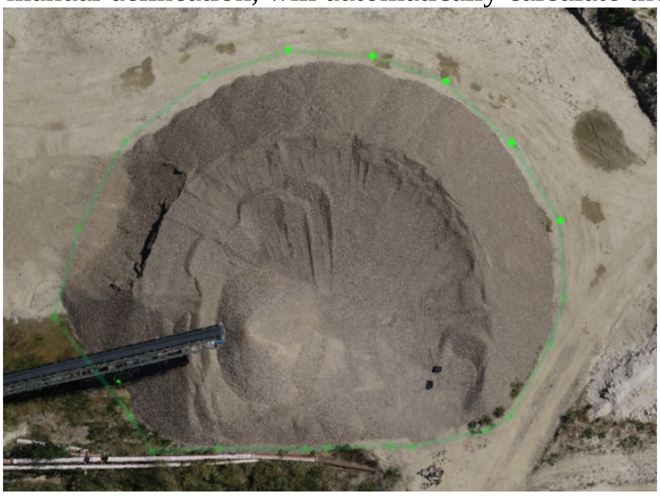


Figure 14 Contour created for volume determination

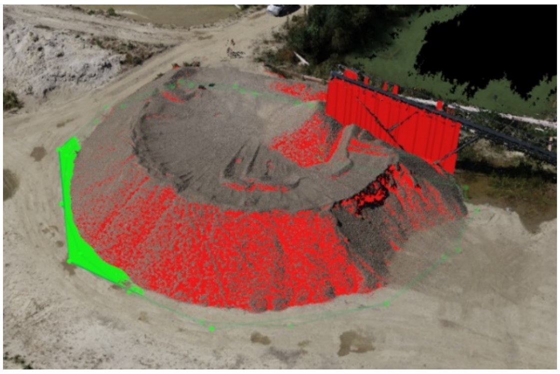


Figure 15 Incorrectly determined volume

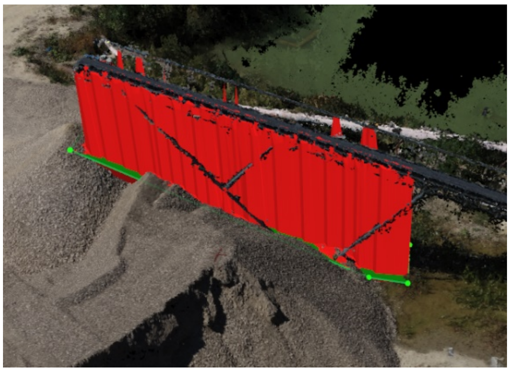


Figure 16 Volume for error correction

Errors in photogrammetry can arise from multiple causes, which cannot be avoided in the field. In this case, the shadow of the conveyor belt transporting material causes incomplete processing of the point cloud due to missing data in the shadowed area, resulting in a "perforated" material. The present gaps lead to incorrect volume determination, with Pix4Dmapper detecting the conveyor belt in the area without details as the highest point and calculating the volume up to this point, thus resulting in an erroneous volume.

Figure 17 Gaps in the point cloud

3. Results and Discussion

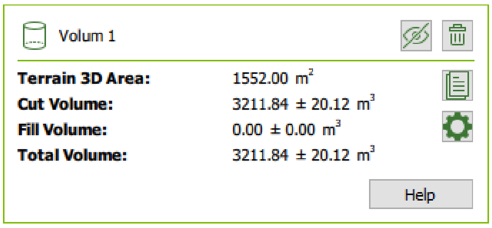


Figure 18 Incorrect volume

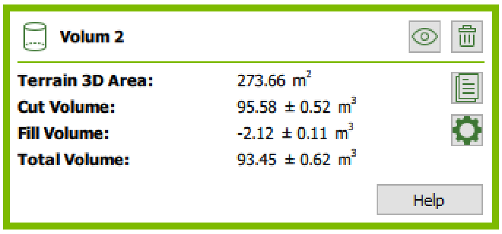


Figure 19 Volume for excess removal

To eliminate the error in the determined volume, a second measurement above the material stockpile was carried out, thus obtaining the excess, with the final result being obtained by calculating the difference between *Volume 1* and *Volume 2 = 3118.39 ± 19.5 m³*.

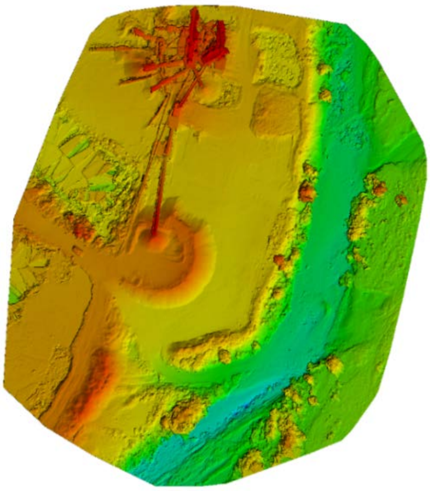


Figure 20 Digital Terrain Model (DTM)

4. Conclusions

Following the study on volume determination, it was found that in spite of a well-executed flight plan, certain environmental conditions can induce various errors that could lead to incorrect determinations.

Ground control points improve the accuracy and quality of the photogrammetric data, providing the desired results.

Following the study and analysis of the photogrammetric products, it was concluded that the photogrammetry field has developed in recent years, and future technologies will further streamline operations by improving accuracy, data volume, and the ability to obtain photogrammetric products in real-time on-site.

5. Acknowledgments

The authors wish to express their gratitude to all the faculty members of the Faculty of Geodesy at the Technical University of Civil Engineering Bucharest and the Union of Surveyors of Romania for the scholarship granted, which made the publication of this article possible.

6. References

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