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TECHNOLOGICAL FEATURES OF CREATION OF A LARGE-SCALE TOPOGRAPHICAL PLAN OF LVIV CITY LANDFILL USING COMBINED METHOD

Purpose. The compliance with maintenance requirements of a landfill is an important factor that have affects on its functioning. The functioning of Lviv city landfill started in 1959 and continued till 2016. According to evidences from various resolutions, regulations, and scientific publications, it was used and exploited with disabilities and did not meet environmental and sanitary standards. On May 30, 2016 a waste flow slide occurred in consequence of fire and its extinguishing. To update the topographic information about the situation at the landfill, and to correct the remediation project, the following tasks should be performed: to create a topographical plan of scale 1 : 500 with a contour interval of 0.5m, to identify technological features of combined methods using UAV TRIMBLE UX-5 and the electronic total station Leica TCR 405, and to select and take into account the peculiarities of the researched object. **Methodology and results.** When creating large-scale topographic plans for different kinds of objects it should be noted that each object has its own peculiarities that should be considered. In the process of the territory reconnaissance, the boundaries of the surveyed site were determined and the possibility of applying an aerial survey by UAV and remote method of tacheometry survey were considered. According to the purpose, the large-scale topographical plan of Lviv city landfill with the scale of 1 : 500 with 0.5 m relief interval with coordinate system SC-63 and Baltic height system was created using combined methods. Additionally control of created DEM was implemented, the root-mean-square errors of the DEM were calculated before and after the use of technological operations and statistical methods. The results correspond to the requirements specified in the instructions for the topographic survey at an appropriate scale. **Originality and practical significance.** The developed and tested method of creating large-scale plans for the landfill enables designing organizations to solve a number of the following problems: designing new maps for storage place of solid waste, performing calculation of excavation works volume, creating working drawings for strengthening of existing dams and construction of new dams, and developing a plan for the location of the filtrate drainage system.

Key words: large-scale topographical plan, Lviv city landfill, unmanned aerial vehicle (UAV), combined survey.

Introduction

Waste flow slides in landfills are generally a geoecological problem that could potentially lead to loss of life, destruction of property, and cause damage to the environment and infrastructure in the surrounding region [Blight and Fourie, 2005, Dai, 2016].

The engineering properties of the landfill are complex and in the process of its operation, landfills can become unstable under the influence of external factors. Therefore when choosing a place of storage for solid waste a number of hydrogeological and geo-engineering properties should first be considered for the future disposal site [Yılmaz, 2006], and additionally the factors such as the morphometric composition of the waste, physical and geographical location of the site, seismic activity of the territory, rainfall amount, structural features of the landfill body, and human engineering activities are also very important [Huang, 2016, Merry et al, 2005;].

Studies concerning the waste flow slides in landfills can be found in a number of publications. During the period from 1993 to 2015 waste flow slides caused the deaths of more than 600 people and a significant loss of properties [Kocasoy, 1995, Eid et al, 2000; Merry et al, 2005; Blight, 2008, Gandolla et al, 1979, Hendron et al, 1999, Brink et al, 1999, Xu et al, 2016]. The reasons for these phenomena were caused by various factors.

The situation at the Lviv city landfill is new for Ukraine. There is inadequate information related to deformations and processes occurring in landfills. It is especially difficult to study landfills because of their heterogeneity, seasonal changes in the composition of waste, and their morphometric structure. All these factors cause engineering instability in a landfill. Properties of a landfill and processes that it will occur in, directly depend on the term of a landfill functioning and the decomposition process of a solid waste [Blight, 2005].

Stability of the landfill body is the most important engineering problem during the operation of a landfill. The stability among other factors depends on the fulfillment of requirements for operation of any landfill. As for the Lviv landfill, in 2013 the Department of state sanitary epidemiological service in Lviv region noted the following violations: three exploitation periods passed since the start of the landfill functioning; the landfill continues to be operated with violations of sanitary legislation in the terms of waste management; only 40–50 % of the daily waste accumulation is interbedded [Pavliv, For information on solid waste landfill in the village. Velyki Hrybovychi, Zhovkva district, 2013]. In 2003, the Chief sanitary Doctor for the Lviv region issued the resolution №119/01 on 25.11.2003 "About decommissioning of the Lviv landfill maintained by the city municipal enterprise "Zbyranka" belonging to the Department of Housing and Municipal Economy for the Lviv city administration".

Also, a number of research sources focus on the highly unsatisfactory environmental conditions of Lviv landfill [Malovanyy, 2011, Haydin, 2013, Holets, 2013]. In the report of OJSC "Geotechnical Institute," the authors noted that the term of the landfill operation exceeded twice the design parameters [Voloshin, 2005]. But despite scientific publications, various kinds of resolutions and regulations, Lviv landfill continued to operate.

As a result of more than fifty years of operation, fire occurred (Fig. 1) on May 28, 2016 at about 23.00 hours, in the Lviv city landfill, located in the village Velyki Hrybovychi five kilometers north from Lviv. A three days later, on May 30 the waste flow slide occurred. Three employees were killeds from emergency services and one employee of the Lviv municipal enterprise "Zbyranka" remained missing.

OJSC "HIRHIMPROM" developed a complex project of remediation of the landfill in the village Velyki Hrybovychi in order to ensure the stage be stage decommissioning and reclamation of the city landfill. This must be carried out during the period from 2014 to 2023, with a cost of 213,155 millions UAH. [The decision of Lviv City Council № 4132, 2014].

As a result, there is a need to update cartographical data about the landfill site (0.35 square kilometers), namely, creating a topographic plan in scale of 1: 500 with a contour interval of 0.5 m. Development of the remediation project is a quite costly process. Additionally it is a complicated the bureaucratic processes that requires all the official procedures and necessary approvals. Therefore it is necessary to clarify the current situation after the waste flow slide.

Fig. 1. Fire in the Lviv landfill in June 2016

Obtaining data to determine geometric parameters of landfills is possible by remote and contact methods [Lozynskyi, 2015]. It should be noted that among the remote methods available, the application of unmanned aerial vehicles (UAVs) becomes more popular and is being used for construction tasks [Siebert, 2014], aerial survey of volcanoes [Nakano, 2014], parks monitoring [Dustin, 2015], detection of illegal draining of sewerage and other waste using infrared range of survey [Lega, 2012], and modeling of archaeological sites [Haala, 2014], etc.

After analysis of recent research and papers related to the creation of topographical plans for landfills it should be noted that they have an advertising character, namely [Nienow, 2014] states that the authors performed geodetic works for 21 ground sites in seven US states. When carrying out the aerial survey with UAV they used a digital 80 megapixel multispectral camera Leica RCD30, and the results are presented with contour lines having an interval of 0.5 m. In the paper [http://www.uavmap.com.au/measuring-landfill-volumes, 2014] the authors generated an orthophoto plan with 350 images, and created digital elevation models. And in 2015 they conducted a repeated survey of the same landfill, and as result they had found differences in the landfill area. It should be noted that the investigated landfill has a small area and uncomplicated configuration. There was practically no vegetation or other objects that did not belong to the relief class. The first experience in using UAVs in the state of Maine for a landfill is shown in [http://www.smemaine.com/ documents/ Website-SMEReceivesFAAApprovalto OperateUAV_007.pdf], and as result of that study the authors created a topographic plan and 3D model of the landfill site.

Aerial surveys used for solutions of the challenges of monitoring and mine surveying is discussed in [Makarov, 2014], and as a result there is created topographical plan in the scale of 1: 2000, with built cross-sections, that implemented the estimation of the control points accuracy.

However, it should be noted that in some cases there is a need to survey territories in which there are objects such as wood or shrubs, and then it is not always possible to use the data from a space and traditional aerial survey. The solution is a combination survey, which includes the application of an aerial survey using UAVs and a tacheometric survey.

Purpose

The main purpose is to determine the technological features using a combined method in creating a topographic plan for the Lviv landfill and the surrounding areas using UAVs TRIMBLE UX-5 and Leica TCR 405. Creation of a topographic plan with the scale of 1 : 500 and a contour interval of 0.5 m, taking into account the peculiarities of the investigated object, will enable promptly and with appropriate precision the ability to fulfill the purpose.

Methodology and results

Methods of creating a digital model using the combined survey and various software packages

Creation of a topographic plan consists of two conceptually different methods concerning relief and terrain. The relief on the topographical plan is displayed using contour lines. Contour lines can be obtained in two ways:

- Automated creation of contour lines using a digital terrain model;
- Manual vectorization of contour lines using a stereo model.

In the first case, the modern software, which has a fairly large number of methods and functions, is used. A number of papers are devoted to this theme: in [Burshtynska, 2003] the authors perform terrain modelling, using software Surfer and ArcGIS, and conclude that application of the Kriging method under optimal selection of initial parameters allows one to implement precision modelling. Instead, multiquadrics and multilogarithmic functions give poorer results 1.3–1.4 times compared to the Kriging method. The possibility of modeling contour lines on TIN model in the software environment Digitals is considered in [Burshtynska, 2007]. In the research the authors, after completing the aerial survey and the complex of hydrographic works, proposed the technology for creating the digital elevation model to produce a plan of the river bed. The combined method for creating large-scale plans of hydrotechnical construction is presented in [Hlotov, 2009], where the authors performed a terrestrial digital stereo photogrammetric survey and created the plan of Dnipro HPP at the scale of 1: 500. Development of the technological scheme for creating digital vector maps using aerial survey data of past years and digital terrestrial photo theodolite survey for hilly and mountainous areas is proposed in [Hlotov, 2007]. In the paper a priori and a posteriori accuracy estimations are calculated, which are of the same order, which indicate the possibility of using the method for the creation of large-scale plans.

Relating to the second case, the application of this method is considered for the creation of glacier surface DEM in [Tretiak, 2013], in [Cahyono, 2009] authors implementing modeling of relief using the similar method.

Considering the above sources, it should be noted that each object has its own peculiarities in creating topographical plans, so those features that are specific to the Lviv city landfill should be considered, namely:

- Selection of the method and boundaries of the survey site depending on peculiarities of configuration of the site and surrounding area;
- Single fires of waste (Fig. 1), which could significantly affect the results when creating the orthophotoplan and DEM;

- The danger of reiterated waste flowslides, which stipulate the use of such a method of survey as an application of UAV's.

Technological scheme of creation of large-scale topographic plan of Lviv landfill combined method

Preparation work

Before the work was completed reconnaissance areas, which included defining the boundaries of land removal and application possibilities of contact and remote methods (Fig. 2). Then there was the drafting work in laboratory conditions, making it possible to change both qualitative and quantitative characteristic's expected results depending on the particular area of removal. Configuration of the Lviv city landfill has a complex structure of relief, marked by three terraces with an elevation of more than 80 meters and slopes from 0 to 80 degrees.

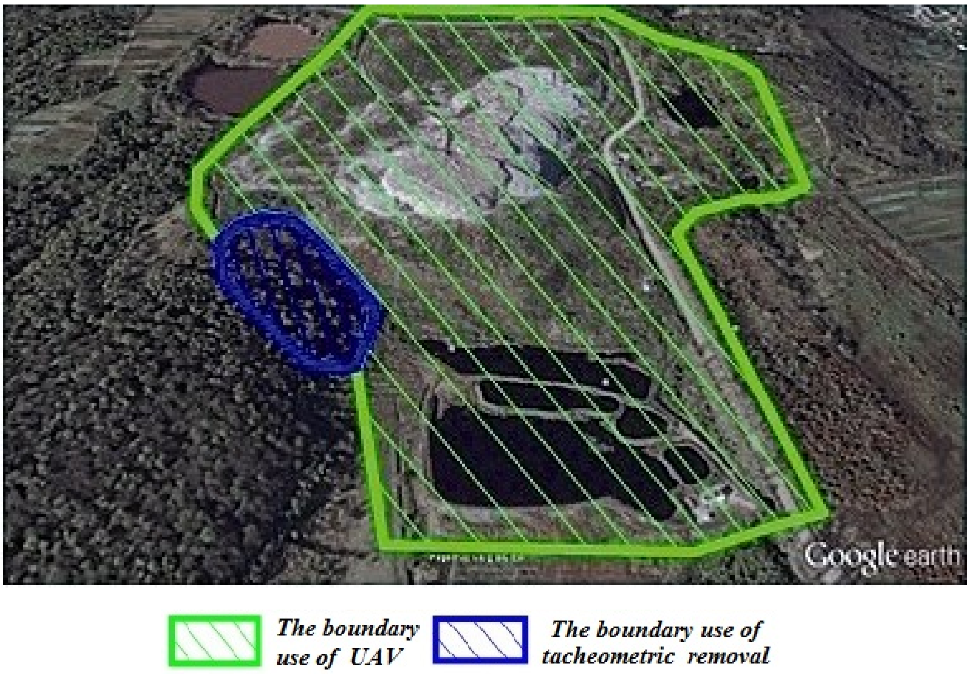

Fig. 2. The boundary use of remote and contact methods on Google Earth

To calculate the mean-square error (MSE) for the three projects that have been implemented at different altitudes the formula that was used was [Lobanov, 1984]:

$$m_x = mx_1\left[\left(\frac{m_{x1}}{x_1}\right)^2+\left(\frac{m_p}{\frac{f}{H}B}\right)^2+\left(\frac{x_1^2}{f\left(\frac{f}{H}B\right)}m_{\Delta\alpha}\right)^2+\left(\frac{x_1y_1}{f\left(\frac{f}{H}B\right)}m_{\Delta\omega}\right)^2+\left(\frac{y_1}{\frac{f}{H}B}m_{\Delta x}\right)^2 m_{\omega}^{2}+\left(\frac{x_1}{f}m_{v'}\right)^2\right]^{1/2}$$

$$m_y = my_1\left[\left(\frac{m_{y1}}{y_1}\right)^2+\left(\frac{m_p}{\frac{f}{H}B}\right)^2+\left(\frac{x_1^2}{f\left(\frac{f}{H}B\right)}m_{\Delta\alpha}\right)^2+\left(\frac{x_1y_1}{f\left(\frac{f}{H}B\right)}m_{\Delta\omega}\right)^2+\left(\frac{y_1}{\frac{f}{H}B}m_{\Delta x}\right)^2+\left(\frac{x_1}{f}m_{v'}\right)^2\right]^{1/2} \quad (1)$$

$$m_z = mz_1\left[\left(\frac{m_p}{\frac{f}{H}B}\right)^2+\left(\frac{x_1^2}{f\left(\frac{f}{H}B\right)}m_{\Delta\alpha}\right)^2+\left(\frac{x_1y_1}{f\left(\frac{f}{H}B\right)}m_{\Delta\omega}\right)^2+\left(\frac{y_1}{\frac{f}{H}B}m_{\Delta x}\right)^2+\left(\frac{x_1}{f}m_{v'}\right)^2\right]^{1/2}$$

where m – the denominator of the scale removal, B – base removal, f – focal length digital terrestrial imaging camera (TSNZK) ($f = 15\,mm$), x_1, y_1 – abscissa and ordinate respectively of personnel frame ($x_1 = 11\,mm$, $y_1 = 7{,}5\,mm$), $\frac{f}{H}$ – scale removal, $m_x, m_y, m_z = 0.005$ UPC determine the coordinates X, Y, Z respectively, $m_p = 0.003\,mm$ – UPC measurement coordinates of the picture according to the technical characteristics of the camera crew, $m_\alpha = m_\omega = m_k = m_{V'} = m_{\Delta\alpha} = m_{\Delta k} = 3''$ – allowed UPC determination of the angular elements of external orientation (after the external orientation of the image).

As a result, data were obtained for UPC photography heights of 110 m, 130 m and 150 m, which is presented in Table 1.

Table 1

Prior RMS value

№ of project	Height of filming (*m*)	B (*m*)	m_{zn}	m_x (*m*)	m_y (*m*)	m_z (*m*)
1	110	110	1:500	0.05	0.06	0.07
2	130	130	1:500	0.06	0.08	0.09
3	150	150	1:500	0.07	0.09	0.11

Air photography of Lviv landfill (June 2016)

Given the data, the preparatory work for the design was drawn from air photography for 3 projects to perform research object removal at different heights (150, 130, and 110 meters) and calculated parameters for removal of the Lviv landfill for UAV TRIMBLE UX-5 (Table 2) that in future will help ensure the accuracy of the orthophotoplan of 1 : 500.

Table 2

Parameters of the UAV aerial photographic survey

№ of project	Longitudinal and transverse floor,%	Height of filming, *m*	Size of pixel, *sm*	Time of filming, *min*
Project 1	*70*	*150*	*4.80*	*8*
Project 2	*70*	*130*	*4.20*	*9*
Project 3	*70*	*110*	*3.70*	*8*

The project is a planned altitude binding

Obtaining reliable data air photography is an integral part of planning and execution of altitude binding material derived from UAV. Therefore, the coordination of control points used a GPS-receiver Trimble R7. All measurements were carried out in the mode of network RTK base stations GEOTERRACE, which belongs to the Lviv Polytechnic National University. There were 33 coordinate reference points (Fig. 3) and made foto outline for their recognition in the office work. The accuracy of the coordinates of reference points for bindings made: in terms of 3–5 cm, and the altitude component – 10 cm.

Fig. 3. The process of coordinating marking drown mode in RTK

Fig. 4. Orthophotoplan with a marking drown

Fig. 5. Cloud points with imposition of orthophotoplan of Lviv landfill (June 2016)

Processing of air photography

All data obtained from aerial photography were processed in the program PIX4D. For carrying out the orthophotoplan and the digital elevation model the following stages are described:

- ✓ downloading images;
- ✓ internal and external orientation of models using reference points;
- ✓ creating point clouds and their editing.

The process of constructing an orthophotoplan based on the automatic generation of image pixel facilities adjacent images, the resulting orthophotoplan obtained (Fig. 4), the cloud points (Fig. 5) and TIN model for building the digital elevation model in the given area.

Tacheometric removal

As part of the plot it was necessary to perform the removal of the of the dense forest cover (Fig. 2), so the digital terrain model of the UAV can be used. Therefore, to obtain more reliable data on land covered with forest, tacheometric removal was done. These works were performed at the electronic total station Leica TCR 405 according to terrain features bookmarks in the defined area. As a result of the removal, tacheometric received 120 pickets, which then were used to create DTM and contour lines (Fig. 6).

Creating a topographic plan

The resulting cloud of points allows the UAV to be directly used for the construction of contour topographic plan of 1 : 500, as these produce large quantities of small objects, and the main horizontal is not smooth (Fig 7). To address this incorrectness a number of process operations and statistical methods (focal filtering and statistics) were used, which helped to remove high-frequency noise in the digital elevation model. Also for smoothing contours automated and manual methods of editing were used.

An integral part of this process is the decoding of the field, which includes a visit to the area for investigation and recognition of all currently existing facilities to determine their quantitative characteristics. The result of this work is the large-scale topographical plan of scale 1: 500 with 0.5 m section pole relief coordinate system SC-63 and Baltic system of heights (Fig. 8).

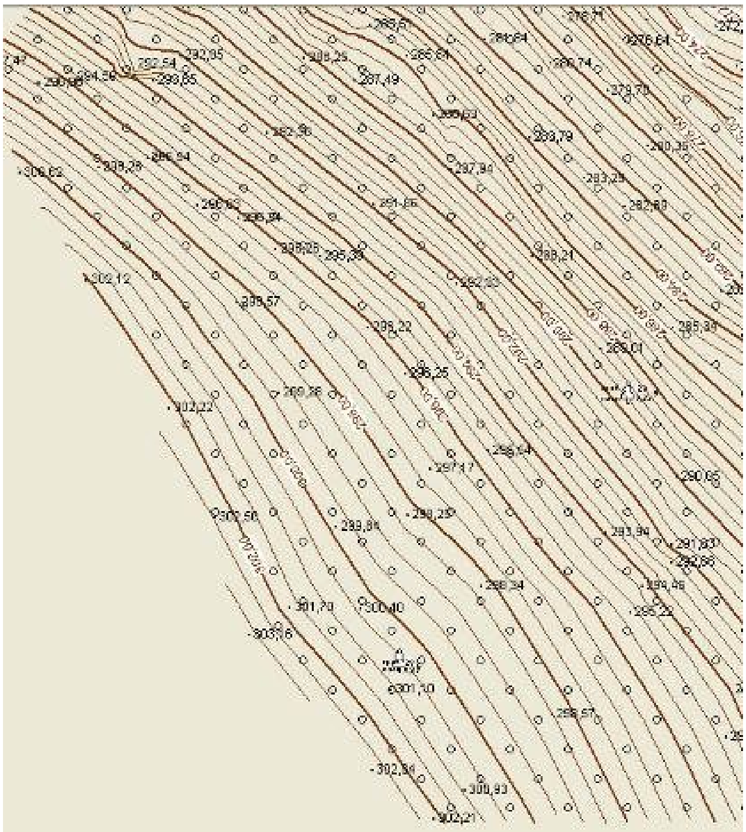

Fig. 6. Digital surface models as contours for the results tacheometric surveying

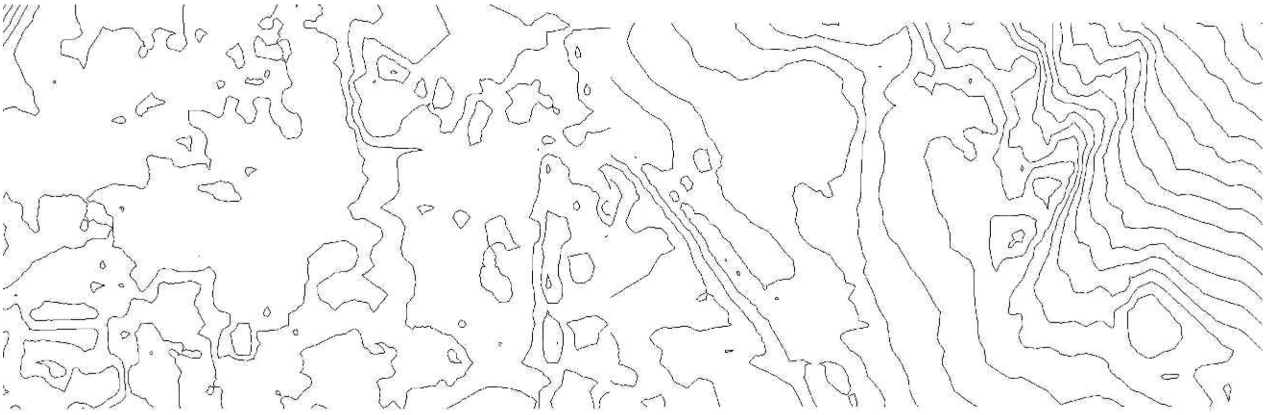

Fig. 7. Contours line generated automatically from the matrix of heights

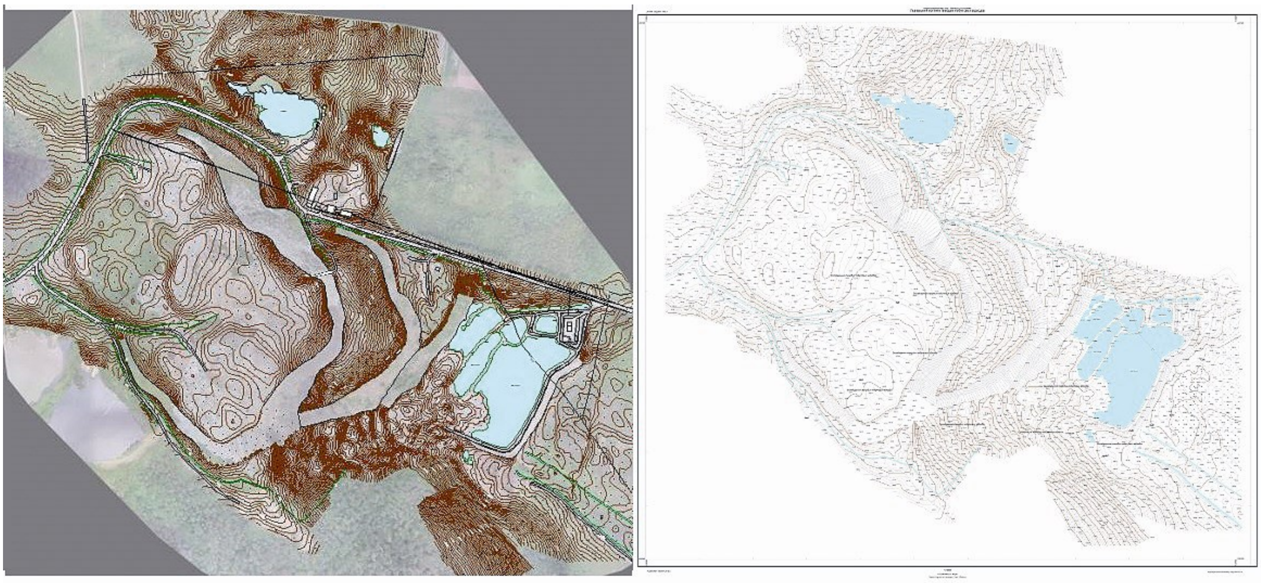

Fig. 8. Topographic plan of Lviv landfills in June 2016

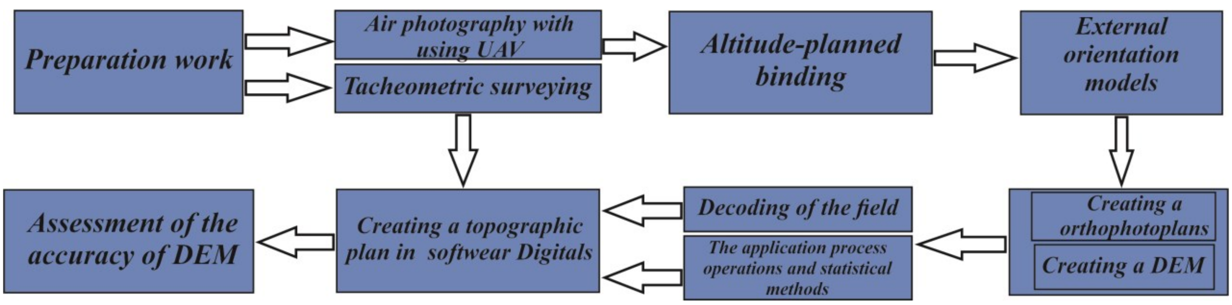

Fig. 9. Flowsheet creation of large-scale topographic plan of Lviv municipal landfill

Table 3

The value of mean square error before and after the application process operations and statistical methods

Number of control points, (p.)	Mean square error to the application of technological operations and statistical methods, *m*	Mean square error after the application process operations and statistical methods, *m*
55	0.063	0.095

To control the DEM built before and after the application process operations and statistical methods using a GPS receiver with a defined height of 55 points. According to the formula (2) calculated mean-DEM error, the results are presented in Table 3.

$$m_{ЦМР} = \sqrt{\frac{\sum_{i=1}^{n}\left(H_i - h_i\right)^2}{n-1}} \quad (2)$$

де n – number of control points; H_i – the height of the control point on the DTM; h_i – the height of the reference point, determined using GPS receiver.

Based on the results of UPC is worth noting that the quality of construction contours to fully meet the requirements specified in the [Instructions, 1998].

Technological scheme of creation of large-scale topographic plans scale 1 : 500 is presented in Fig. 9.

Originality and practical significance

Because of the need to update information on the situation at the Lviv city landfill, there was the need to create a topographic plan which will be used in refining the draft remediation of the facility.

Developed and tested method of assembling large-scale plans for landfill design enables organizations to address a number of these problems, namely designing new cards for storage of solid waste, perform calculation of volume of excavation, prepare working drawings for reinforcement and construction of new dams, and the development of a plan location for a leachate drainage system.

Conclusions

Based on theoretical developments, experimental studies and the results of the Lviv city landfill formulated the following conclusions and results:

1. The possibility of use of modern UAV to design and build topographical plans landfills.
2. The analysis of scientific sources revealed that when creating topographical plans they should be tailored to suit different types of objects.
3. The technological scheme of large scale topographic plans used combined methods using UAVs and electronic total station in Lviv municipal landfill.
4. Calculated priori assessment of the accuracy that meets the requirements for taking large-scale topographic plans.
5. A topographical plan to scale 1 : 500 with 0.5 meters of relief SECTION POLE coordinate system SC-63 and Baltic system heights.
6. Calculated posteriori estimation precision built a digital elevation model (mtsmr = 0,095 m) that meets the requirements of 1 : 500, confirming the effectiveness of this technique.
7. The resulting orthophotoplan and DEM landfill in the future will enable further research to assess the impact of anthropogenic impact in the Lviv city landfill and determine the area and volume of garbage collapsed.

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ТЕХНОЛОГІЧНІ ОСОБЛИВОСТІ СТВОРЕННЯ ВЕЛИКОМАСШТАБНОГО ТОПОГРАФІЧНОГО ПЛАНУ ЛЬВІВСЬКОГО МІСЬКОГО ПОЛІГОНУ ТВЕРДИХ ПОБУТОВИХ ВІДХОДІВ КОМБІНОВАНИМ МЕТОДОМ

Мета. Під час функціонування полігону ТПВ важливим факторам, який впливає на його роботу, є дотримання вимог щодо експлуатації. З початку роботи Львівського міського полігону ТПВ, а саме з 1959 р. і до 2016 р., як свідчать різні постанови, приписи та наукові публікації, він експлуатувався з порушеннями та не відповідав екологічним та санітарно-гігієнічним нормам. Внаслідок пожежі та результатів її гасіння 30 травня 2016 р. стався зсув сміття. Для оновлення топографічної інформації про ситуацію на полігоні ТПВ, та для внесення коректив у проект рекультивації, слід виконати такі завдання: створити топографічний план у масштабі 1:500 з перерізом рельєфу через 0,5 м, а також визначити технологічні особливості комбінованого методу з використанням БПЛА TRIMBLE UX-5 та електронного тахеометра Leica TCR 405, виділити та врахувати особливості досліджуваного об'єкта. **Методика та результати роботи**. Під час створення великомасштабних топографічних планів різних об'єктів слід зазначити, що кожен має свої особливості, які слід врахувати під час розроблення планів. Під час виконання рекогностування місцевості вибрано межі ділянки знімання та можливості застосування аерознімання з використанням БПЛА та дистанційного методу тахеометричного знімання. Відповідно до поставленої мети створено великомасштабний топографічний план Львівського міського полігону ТПВ у масштабі 1:500 з січенням рельєфу 0,5 м у системі координат СК-63 та Балтійській системі висот комбінованим методом, виконано контроль побудованої ЦМР, обчислені СКП ЦМР до та після застосування технологічних операцій та статистичних методів. Отримані результати відповідають вимогам, зазначеним в інструкції з топографічного знімання відповідного масштабу. **Наукова новизна та практична значущість**. Розроблена та апробована методика складання великомасштабних планів для полігону ТПВ дає змогу для проектних організацій виконати низку таких завдань, а саме: проектування нових карт для складування ТПВ, виконання розрахунку об'єму земляних робіт, складання робочих креслень для укріплення та побудови нової дамби, розроблення плану розташування дренажної системи фільтрату.

Ключові слова: великомасштабний топографічний план, Львівський міський полігон твердих побутових відходів, безпілотний літальний апарат, комбіноване знімання.

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