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Photogrammetric and computerized report on site model in feasibility study of navigability channel on Vistula Spit

Abstract

In the report the authors present a course of geodesic and geo-computerized works upon realization of feasibility study of navigability channel on Vistula Spit. A procedure of acquiring verification and modeling of data for requirements of a numeric model of a bottom and site has been presented with construction of original software for 3D visualization of the Vistula Spit area. The activities described in the report can be used for predicting exploitation hazards for objects and marine technical constructions as well as for evaluation of danger and protection of natural environment.

Keywords*:* marine technical constructions, air photogrammetry, geo-computer science, the Vistula Spit

Introduction

Construction of navigability channel across the Vistula Spit is a concept revived in recent years mainly due to the need of restoration of navigability possibility to Polish ports of Vistula Bay – including firstly a port in Elbląg. It results directly from closing of Pilawa Strait to vessels and restricted navigability of navigation track along Szkarpawa river [1], [2]. Also of considerable importance is the development of yacht tourism in the area of the Vistula bay, expected after launching of water route across the Spit. The authors of the report

participated in preparation of Feasibility Study being responsible for geodesic part covering software construction for Digital Terrain Model (DTM) analysis with construction of DTM of the Vistula Spit and the bottom of the Baltic Sea and the Vistula Bay in coastal stripe of the Spit. During works a technology for connection of data from bathymetric measurements for the area of the Baltic Sea and the Vistula Bay and data from air photogrammetry for land area of the Vistula Spit has been developed. Moreover geodesic tools and computer procedures meeting the economic and accuracy requirements for feasibility study of technical investments in coastal area of the sea have been specified.

Among the issues solved by the authors there were:

- Connection of geodesic and bathymetric data acquired in various special reference systems and different formats of computer recording;
- Optimization of geo-computerized procedures enabling for automatic generation of cross-sections and height interpolation on DTM with retaining of accuracy and efficiency of big data groups processing;
- Verification of archival geodesic data with reference to photogrammetric measurements for generating of DTM and orthoimages.

Object characteristics

The work was done following the order of Naval Office in Gdynia in the scope of feasibility study entitled:" Construction of navigability channel across the Vistula Spit". In general a digital model of area of Vistula Spit has been prepared. The operation covered construction, verification and visualization of a numeric model of land area with a digital model of coastal area of the Baltic Sea bed and the VistulaBay bed.

The numeric model of the area of the Vistula Spit has been detailed in the scope necessary for evaluation on investment influence on sea coast condition influence on wildlife and with reference to the operation economy. Initial technical assumptions assumed usage of laser scanning data for land and coastal monitoring data.

In face of laser scanning data unavailability and great costs inadequate to quantity and quality requirements, the task has been performed with usage of coastal monitoring data (profiles made in cycles at every 500 m) and detailed with data acquired by air photogrammetry methods and GPS measurements on part from the Vistula Spit base i.e. Kąty Rybackie to and including Krynica Morska (fig.1).

Fig. 1. Localization of the report area with indicated cross-cut site – white contour in western part of the Vistula Spit – in Google Maps environment

The report area covered the area of western part of the Vistula Spit with towns of Kąty Rybackie and Krynica Morska. In addition, an area of eastern part of the Vistula Spit has been enriched with updated numeric area model being at the disposal of Geodesic Documentation Center; updating and amendments were have been realized based on photogrammetric and satellite measurements (GPS).

Preparation of the report

The report consists of two main stages: stage I: collection already existing materials Or as in case of mostly used photogrammetric reports supported by GPS technology preparation of them in whole from the beginning or once again for verification of previous calculations accompanied by new data from modern measurements.

A list of products under report:

1. Aerotriangulation and numeric model of the area for the area of western part of the Vistula Spit with towns of Kąty Rybackie and Krynica Morska included, realized on the basis of available photogrammetric materials acquired from possible current photogrammetric pictures being at the disposal of Geodesic Documentation Center.
2. Orthopictures from air pictures used for preparation of numeric model of area for western part of the Vistula Spit with towns of Kąty Rybackie and Krynica Morska included.

3. Numeric model of the area (DTM) for Polish part of the Vistula Spit and sea bed in coastal stripe (to 1800 m towards the Baltic Sea waters) and the Vistula Bay bed (ca. 350 m towards the Vistula Bay waters). Compilation of numeric area model for the area of western part of the Vistula Spit prepared by photogrammetric methods, available numeric area model (coming from LPIS – Land Parcel Identification System) and the results from coastal monitoring conducted by Naval Office in Gdynia.

II stage – connection and optimization of the data verified.

Evaluation of accuracy of the report and aerotriangulation

An important factor which caused acceptance for air photogrammetry as an alternative source for construction and verification of DTM was the evaluation of accuracy of the product manufactured with consideration of economic aspects. The authors' experience influenced attributing a special meaning to methodology of aerotraingulation performance and identification of photo points and characteristic site elements. Setting of coefficients of photo points and verification of the photogrammetric baseline have also been stressed.

Table 1. Results of auxiliary GPS measurements of photo points coefficients

		Coordinate	**Corr**	***Sd***
2007_01	Latitude	54° 20' 19.43135'' N	-0.0004	*0.0022 m*
	Longitude	19 ° 13' 43.79899 E	0.0006	*0.0015 m*
	Height	30.2318 m	0.0010	*0.0036 m*
2007_02	Latitude	54 ° 22' 26.31614'' N	-0.0001	*0.0021 m*
	Longitude	19 ° 25' 21.34683'' E	0.0009	*0.0013 m*
	Height	33.1688 m	0.0016	*0.0040 m*
2007_03	Latitude	54 ° 21' 12.93128'' N	-0.0002	*0.0027 m*
	Longitude	19 ° 21' 04.52288'' E	0.0010	*0.0019 m*
	Height	*28.8919 m*	*0.0018*	*0.0045 m*

In the scope of the report an analysis of accuracy and subsequent equalizing of air pictures aerotriangulation block made in 2004 for Phare LPIS needs has been performed. For testing the accuracy of aerotriangulation control points have been used – field details identified on pictures, measured in field by GPS technique. Archival (acquired with other materials from CODGIK) photo points were used for the report. For equalization middle points of pictures' projection measured by dGPS technique was used; it significantly increases accuracy of aerotriangulation and allow to restrict the number of points of field photogrammetric baseline. Equalization of the pictures' block by the method of independent

beams was made by Photo-T module available in ISDM software with the use of dGPS observation.

In the aerotriangulation process of all blocks 21 pictures in scale 1:26 000, 457 photo points, out of which 9 points measured by GPS method in 2004, 3 points measured by GPS method in 2007 were used. In calculation process atmospheric refraction and curvature of Earth was taken into consideration. As a result of equalization outside pictures orientation elements were achieved.

Table 2. General statistics of the equalization performed (aerotriangulation)

Parameter	**X/Omega**	**Y/Phi**	**Z/Kappa**	**XY**
RMS Control	0.229	0.216	0.144	0.223
RMS Check	0.036	0.125	0.093	0.092
RMS Limits	0.001	0.001	0.001	
Max Ground Residual	0.377	0.321	0.217	
Residual Limits	0.001	0.001	0.001	
Mean Std Dev Object	0.159	0.158	0.236	
RMS Photo Position	0.178	0.219	0.144	
RMS Photo Attitude	0.000	0.000	0.000	
Mean Std Dev Photo Position	0.323	0.570	0.345	
Mean Std Dev Photo Attitude	0.004	0.008	0.003	

Table 3. A list of mean errors of observations before and after equalization for PUWG 1992

Error name		**before equating**	**after equating**
Mean error of background coefficient		5.0 μm	4.2 μm
Mean errors of photo point coefficients	X	0.30 m	0.23 m
	Y	0.30 m	0.22 m
	Z	0.20 m	0.14 m
Mean errors of projection centers	X	0.10 m	0.18 m
	Y	0.10 m	0.22 m
	Z	0.20 m	0.14 m

It was a priori assumed a mean error of coefficient measurement on pictures to be 5 μm mean identification error of photo point on the pictures with reference to field values was set at the level of 0,30 m for component X, 0,30 m for Y, and 0,20 m for Z, considering the accuracy of photogrammetric projection and accuracy of identification of the point on the picture measured. The accuracy of localization of centers of projections measured by GPS, used in equalization was assumed to be at the level of 0,1 m for component X and Y and 0,20 m for Z.

Considering the above mean errors the accuracy of DTM performance has been evaluated at the level of mXYZ = 0,5 m [3].

Digital Terrain Model

The numeric area model has been prepared in whole on digital IS SKK station with the usage of Image Station Stereo Display software by Intergraph company in the setting of PUWG 1992 (polish national geodetic co-ordinate system).

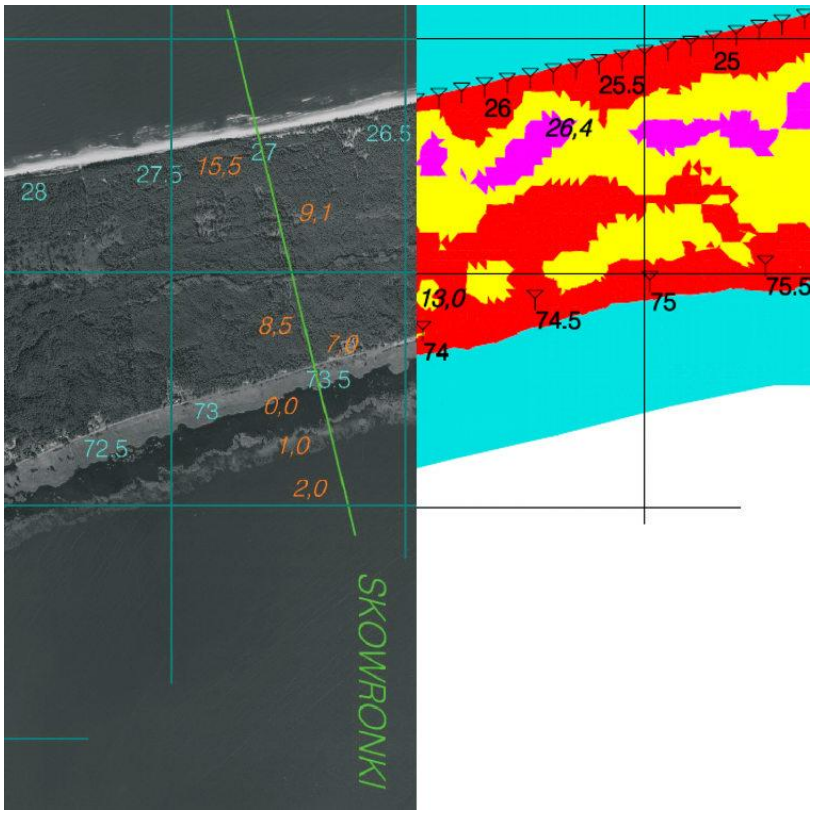

Fig . 2. Illustrative list of two products of the report: orthomap and DTM

Acquiring of data for numeric area model by photogrammetric method was initiated by measurement of a regular points grid of 40 m eye. In addition the following elements underwent stereodigitailization:

- Structural lines (area discontinuity lines; skeleton lines);
- Field points from manual measurement;
- Planar surfaces (bays lakes);
- Continuous slope surfaces (channels);

The range of areas excluded and of diminished accuracy on which acquiring of height data by photogrammetric method was not possible to enforce or is loaded with greater error than the one specified in technical conditions (forests), were visualized in the area of the model by layers of 1 m interval and were subject to visual testing on stereoscope models. Layers visualization allowed for additional elimination of possible errors occurring in DTM.

Finally DTM in the form of triangles grid was constructed (TTN format Intergraph). triangulation was performed for the whole area of report in PUWG 1992.

Orthoimages

Orthoimages and orthomap resulting from them were used in digital technique based on Image Station OrthoPro software package.

Orthoimages and orthomap were an additional element – not considered in the agreement by the orderer however they enriched informative part of the report and were handed over free of charge. They refer to the area of four analyzed localizations of navigation channel across the Vistula Spit.

For orthomap preparation the following have been used:

- Scanned monochromatic air pictures in scale 1:26000;
- Previously calculated photogrammetric project in ISPM format prepared in PUWG 1992 setting (full data of pictures orientation elements);
- Numeric area model of irregular structure of triangles grid base on measurement points – TTN format – PUWG1992 setting.

Visualization software

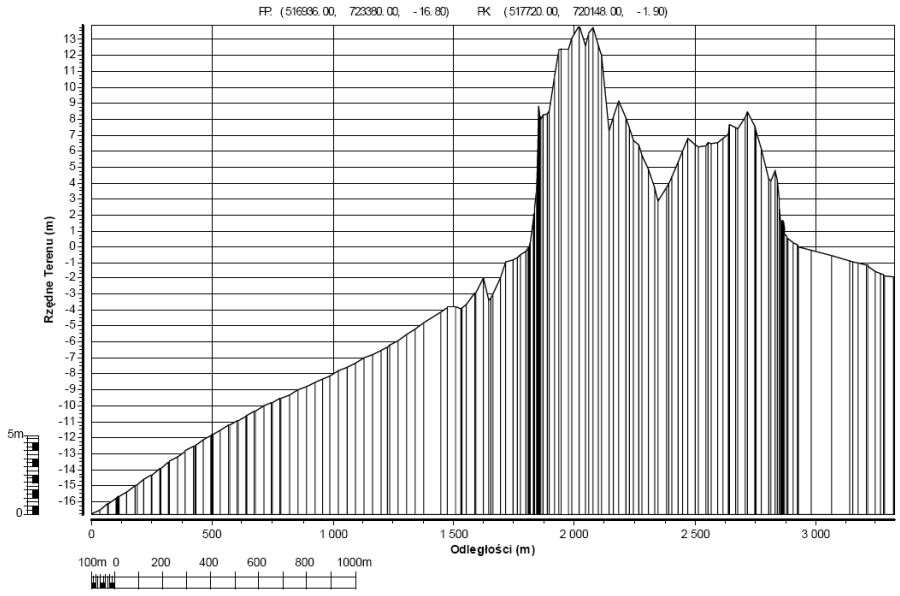

Fig . 3. Vertical cross-section of the preferred localization SKOWRONKI

PROFILER software visualizes in the form of triangles grid (TTN format – Intergraph) recorded in files data.inet. PROFILER enables visualization on DTM and generation of profiles made during the "cutting" of TIN surface by regular surface crossing two points specified by the operator on DTM (fig 3).

Conclusion

Realization of works connected with preparation of numeric model of coastal area of the Baltic Sea bed and the Vistula Bay bed and the land on the Vistula Spit allowed to specify usability of geodesic and cartographic materials available in the resources of Geodesic Documentation Center for sufficiently accurate preparation of 3D model for the needs of the feasibility study. The report's authors in the scope of the task performed specified that accurate performance of photogrammetric works allows to gain calculation accuracy and preparation of a proper computer algorithm enables efficient and dynamic visualization of 3D model on units of PC class.

As a result of works products and software were prepared which allow for realization of analyses suitable for economic and safe designing of engineering structures in the coastal area of the sea with consideration of specification of hydrotechnical constructions in particular with respect to possible exploitation danger to objects and marine technical constructions.

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