INVESTIGATION OF COASTLINE CHANGES AND INSHORE HYDROTECHNICAL OBJECTS LOCATION USING GNSS TECHNOLOGY

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ABSTRACT

Many tasks related to aquatic environment studies and monitoring of phenomena require access to current and reliable information on spatial objects. Hydrotechnical infrastructure located in the coastal zone of the lakes is characterised by relative high dynamics of changes. Considering the shape and size those are hard for taking their inventory using the standard photogrammetric or remote sensing techniques.
The paper presents the results of research work aimed at automation of the gathering, processing and using the data on the course of the coastal line of lakes and the coastal infrastructure objects. The work was conducted using GNSS satellite measurements on test objects located on Lake Dargin and Lake Kisajno.
Additionally, the results of measurements using the ASG-EUPOS system and the prospects for using that system for objects situated in the coastal zone of water reservoirs were presented.

INTRODUCTION

Precise determination of the coastline requires application of the appropriate method for taking the inventory of it. Given the changes in the water level in the reservoir caused by a variety of factors, the course of the coastline may be subject to many changes over time. (Templin et al., 2010).
Both land survey and remote sensing methods are currently used for monitoring the dynamics of changes in the coastline. The incredibly fast development of the measuring equipment causes that increasingly modern equipment is used for traditional land survey measurements. Both electronic total stations combined with complementary sensors such as digital cameras automating the measurement process and precise GNSS receivers prepared for reception of the signal from the ground based augmentation systems GBAS such as the ASG-EUPOS system are used. Thanks to that the measurement can be taken increasingly fast and practically from any place. Remote sensing methods are cheaper than the classic land survey. Methods and the most frequently used technologies here are the photogrammetric measurement of aerial photographs, air or ground based laser scanning and interferometric measurements (Kurczyński, 2006; Burdziej et al., 2006).

Application of one of the above methods provides a set of points with three coordinates. Depending on the intended use and purpose of measurement it defines the spatial location of point, linear and area objects. The fourth component in the form of time thanks to which analyses of the dynamics of changes in not only the coastline but also the coastal area become possible is also considered increasingly often. This is of extreme importance in the maritime environment in particular as the dynamics of changes there is of major importance not only from the perspective of the nature (Michałowska et al., 2007). In the latest scientific publications, both domestic and foreign, the increasingly frequent application of laser scanning techniques in monitoring the changes in the coastal zone can be noticed (Dudzińska-Nowak, 2007). On the base of the measured cloud of points the digital terrain model is generated that currently represents the most common method for recording the information on terrain relief features. With a number of models of the same area available the analysis of changes in the terrain surface relief over time can be conducted (Królewicz et al., 2008).

Use of photogrammetrically processed aerial or satellite photographs as the source of data on the coastline course allows conducting detailed, short- and long-term observations covering a known area (Kim et al., 2008). The situation gets more complicated in case of inland reservoirs that are characterised by dense coastal vegetation and numerous areas difficult for clear identification by means of photogrammetric methods. Additionally, the coastal zone is characterised by presence of numerous coastal infrastructure objects and vegetation that are subject to relative dynamic changes over time.

INVENTORY OF THE COASTAL LINE OF LAKE DARGIN

Verification of the potential for using the DGPS/RTK satellite measurement techniques in the process of updating the coastline course under difficult observation conditions using the: mobile GIS tools, real time services offered within the frameworks of the ASG-EUPOS multifunction precise positioning system and internet spatial data sources including first of all the Geoportal.gov.pl service was the basic goal of the experiment.

On the base of photogrammetric materials the digital (baseline) layers representing the coastline course and coastal vegetation were prepared. The work was conducted by on-screen digitizing using the ESRI ArcGIS 9.2 software package.

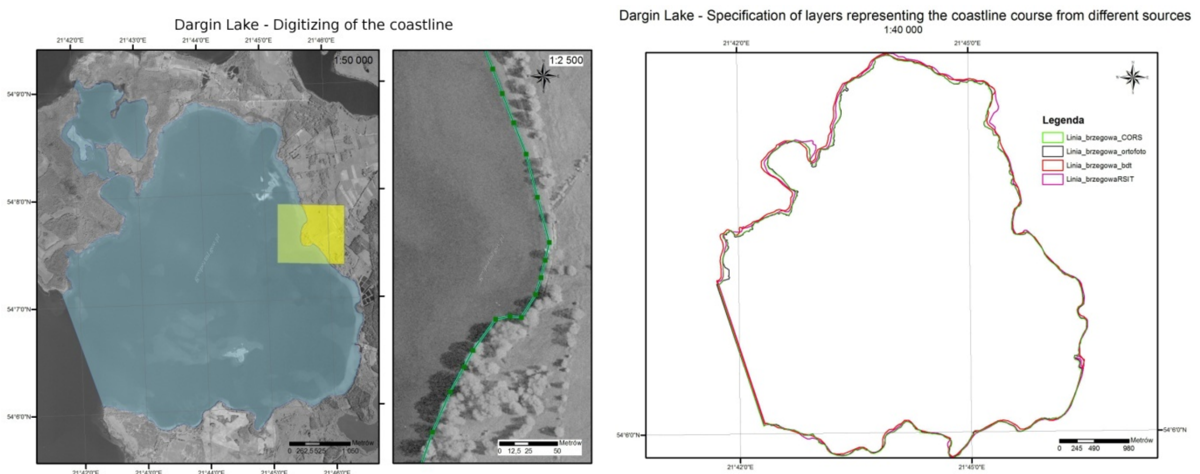

Fig. 1. Digitizing of the coastline on the base of the digital orthophotomap of 2008 (left). Specification of layers representing the coastline course from different sources (right) – Lake Dargin.

On the base of the vectorization conducted the area, perimeter were determined for each identified surface object representing the coastline of Lake Dargin fragment. The specification of the results is presented in table 1.

Table 1. Specification of the results from comparison of the basic parameters of surface objects representing the coastline of Lake Dargin fragment

Orthophotomap source	Area [m^2]	Perimeter [m]
Orthophotomap from satellite photographs	19 650 669,18	21 671,36
Orthophotomap from aerial photographs	19 627 237,31	21 815,48
Topographic Database	19 882 408,16	20 538,03
Regional Land Information System	19 917 162,78	21 292,46

As a result of overlapping layers the areas with the largest differences were determined. Places with the largest changes in the coastline course were identified in the north-eastern and north-western part of the lake. The basic causes of the changes included: different water levels during different years, problems of the interpreters with qualification of unclear areas, and resolution of the individual materials.

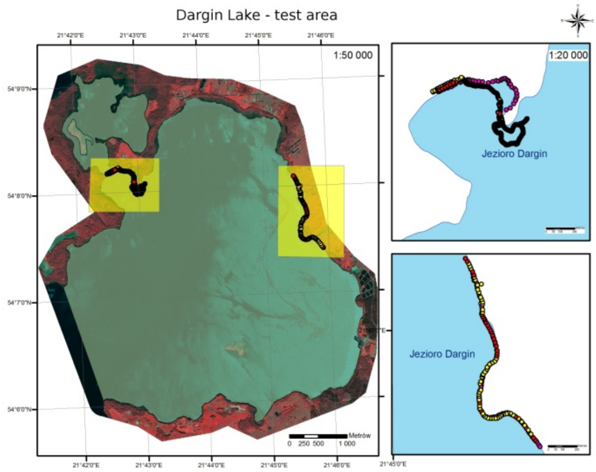

Fig. 2. Choice of test areas for work with GNSS receivers.

The materials developed were used in building the measurement project for the ESRI ArcPad application. The design prepared allowed streamlining the measurement process during the direct taking of the coastline and spatial objects located on the coast or in its direct vicinity inventory.

Fig. 3. Taking the inventory of spatial objects using the ESRI ArcPad software package / Examples of different configurations of the measurement set.

ANALYSIS OF THE COASTLINE COURSE

The following stage of the works allowed determining the dependence between the coastline course determined by digitazing of the satellite orthophotomap and the results obtained during the direct inventory taking.
During the measurements several configurations of the measurement sets as well as DGPS and RTK receivers by different manufacturers. Measurements were conducted in two test areas located in the northern and north-eastern part of Lake Dargin. The characteristics of measurement methods applied and the number of points measured are presented in table 2.

Table 2. Statistical distribution of the RTK results obtained

	Whole		Area 1		Area 2	
Solution type	**Number of points**	**Percent share**	**Number of points**	**Percent share**	**Number of points**	**Percent share**
float	141	27%	84	19%	57	70%
fixed	377	73%	352	81%	25	30%
	518	**100%**	**436**	**100%**	**82**	**100%**

The distances of measurement points from vectorization of the lake coastline were computed to verify the differences between the course of the coastline determined by photogrammetric methods and the points measured by the direct DGPS and RTK methods.

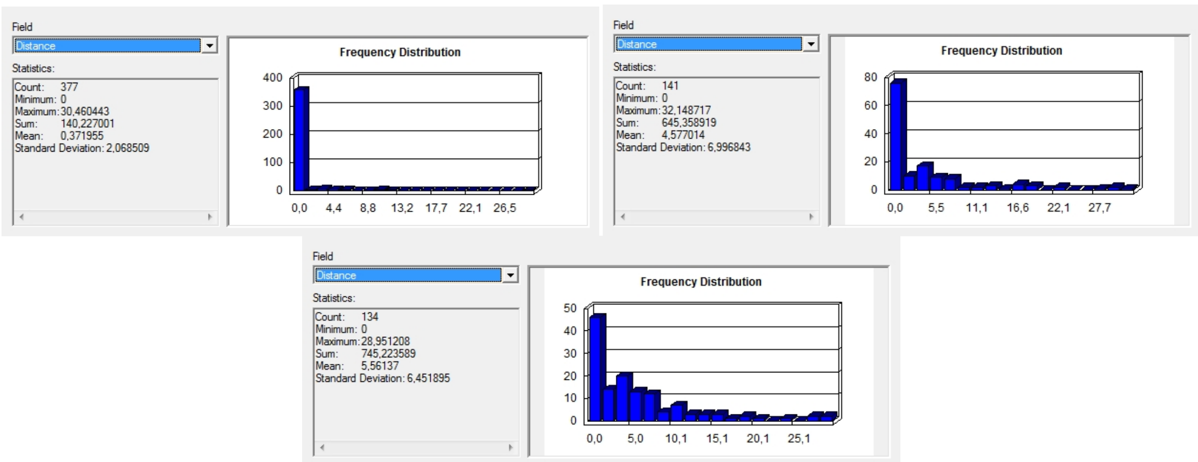

Fig. 4. Statistical distribution of the distance of measurement points determined by the DGPS method, RTK – float solution, RTK – fixed solution, from the coastline determined from the orthophotomap (of 2008).

For DGPS measurements the minimum difference is 0 m (point on the coastline), the maximum is 28.95 m and the mean value is 5.56 m while the standard deviation is 6.45 m. Points measured using the RTK technique were divided into two sets (fixed and float) and then subjected to analysis. In case of the RTK float measurements the minimum difference was 0 m, maximum 32.15 m with the mean value of 4.57 m and standard deviation of 6.99 m. For the RTK fixed measurements the minimum difference was 0 m, maximum 30.46 m with the mean value of 0.37 m and standard deviation of 2.07 m.

The largest differences result from the higher water level in 2009 and classification of a fragment situated under water as land. The distances reach almost 20 metres. The scope of changes is presented in the figure below.

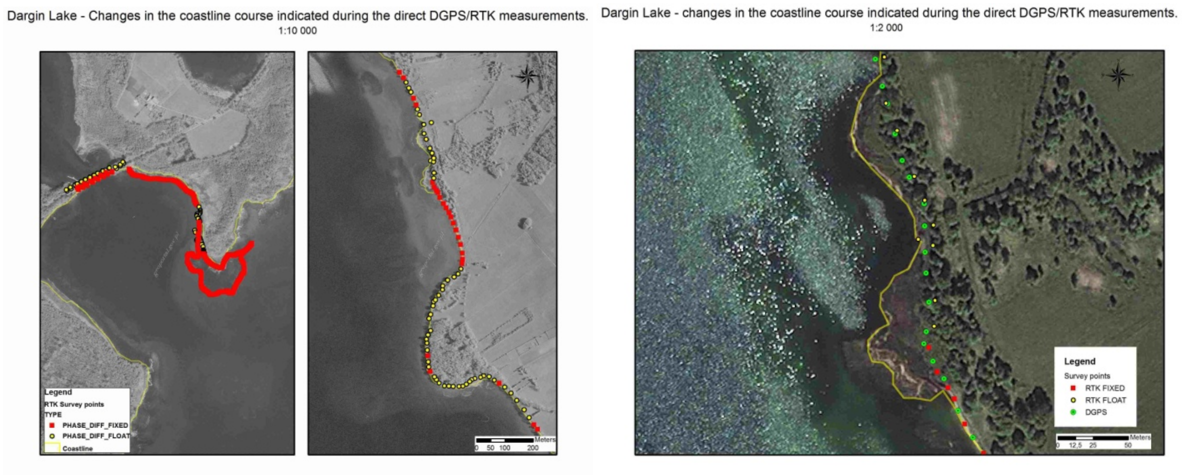

Fig. 5. Changes in the coastline course indicated during the direct DGPS/RTK measurements.

INVENTORY OF THE HYDROTECHNICAL INFRASTRUCTURE OBJECTS AND COASTLINE OF LAKE KISAJNO

Experiments on Lake Kisajno represented the direct extension of the experiments and measurement works conducted on Lake Dargin. They aimed at verification of the selected technical solutions on the second reservoir under different observation conditions (autumn). Indicating solutions allowing acceleration of preparatory works necessary for efficient conducting the direct hydroacoustic sounding of the inland reservoir bottom as well as development of maps taking into account the current status of coastal infrastructure was the basic aim of those works.

The planned works covered: measurement of the coastline course and taking the inventory of coastal infrastructure of Lake Kisajno using the precise RTK method. The experiments were planned and conducted on the selected part of Lake Kisajno in the bay connecting Lake Kisajno with Łuczyński Canal.

Fig. 6. Test area on Lake Kisajno. Pontoon with combustion engine facilitating access to closed fragments of the coastline.

The measurement works were conducted in two stages during three measurement days – stage one on 29 October 2009 and part two in 14 and 15 November 2009. As a result of the RTK measurements 438 measurement points were determined. They defined the coastline course and the coastal infrastructure objects within the chosen test area. Analysing the results obtained it was concluded that 39 out of 438 points representing less than 9% of measured points possess the Float solution. The graphic analysis of the results obtained showed that problems with obtaining the fixed type solutions were encountered mainly among trees and at the edge of the densely wooded area.

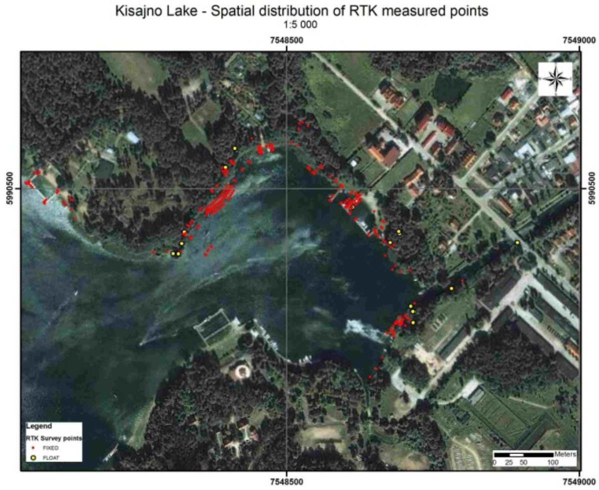

Fig. 7. Spatial distribution of RTK measured points with the division into the Fixed and Float solutions.

Analysing the Position Dilution of Precision (PDOP) coefficient it was determined that over 90% of points were measured with the PDOP value below 3. The values higher than allowed were recorded in 7 points only. The minimum value was 1.00 the maximum value was 3.70, and the mean value was 1.27, while the standard deviation was 0.28.

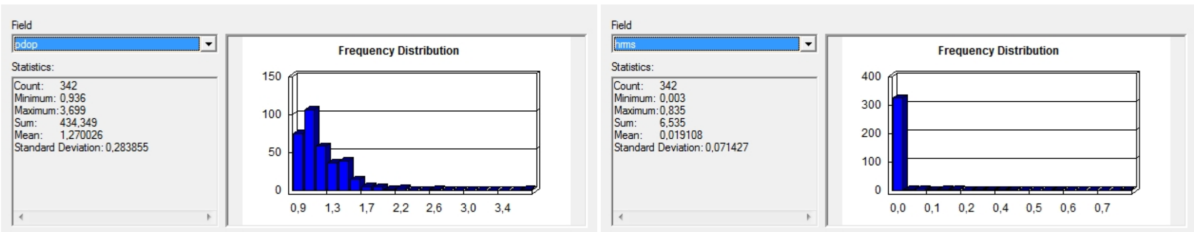

Fig. 8. Statistical distribution of the Position Dilution of Precision (PDOP) coefficient and the Horizontal Root Mean Square (RMS).

Analysing the statistical distribution of the HRMS error we may conclude that the RTK solutions obtained the values within the range of from 0.03 m to 0.84 m, with the mean value of 0.02 m and the standard deviation at the level of 0.07 m. On the base of the results obtained it can be concluded that the RTK solutions obtained guaranty reliability of the solution and high accuracy of the results obtained. He largest error values were recorded for 7 measurements with the float type solution.

ANALYSIS OF DATA OBTAINED IN THE POST-PROCESSING

The computations were made in the AOSS 2.0 (*Ashtech Office Suite for Survey*) software on the base of the "raw" data recorded in the receiver during the RTK measurements. Data from the ASG-EUPOS system reference station located in Giżycko was used for computations. During the computations 19 032 points measured with 1 second interval were determined.
Ten test points were selected for further analyses. Those were characteristic points easy to identify, located mainly at the corners of landings. Seven out of ten points had the fixed type solutions while the remaining three the float type solutions. The positioning of the selected points is presented in figure 9.

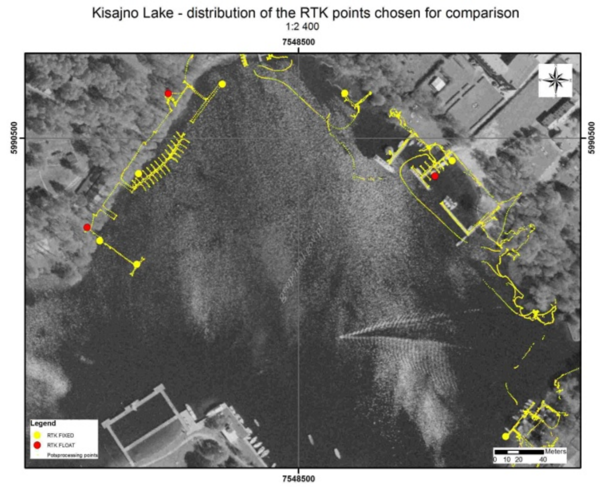

Fig. 9. Spatial distribution of the RTK points chosen for comparison.

The correlation of points from the post-processing method and RTK points was performed on the base of the recording time. During the performance of measurement works using the RTK technique the rover making the measurement performed the measurement for 10 seconds. That is why for each RTK point 10 points were found from the "raw" data.
On the base of the coordinates the distance in centimetres between the RTK point and each of the points from post-processing was determined. The computed distances ranged from 0.6 to 75.98 cm. Such big differences result from the presence of points with the „float" solution that clearly increase the upper values.

Table 3. Mean error of RTK points positioning in relation to points from post processing

	RTK fixed							RTK float		
Point	**1112**	**1190**	**1256**	**1306**	**1339**	**1404**	**1410**	**1208**	**1313**	**1398**
Distance [cm]	**0,74**	**0,62**	**2,21**	**0,73**	**0,93**	**0,70**	**1,12**	**34,35**	**74,07**	**22,48**

Conducting the analysis for the „fixed" type points it was determined that the maximum distance was 3.02 cm. For the individual points the averaged value of the distance to the corresponding points from post-processing is presented in table 3. The largest mean value is 2.21 cm while the arithmetic average of those values was 1 cm.

The figure 10 presents the mutual positions determined in the post-processing mode in relation to the RTK point number 1306 and 1208. To the left the general view is presented and to the right the magnification in which the distance of the furthest point is 1.22 cm and to the nearest point 0.32 cm. Similar distributions of points from "raw" data almost evenly spread around the RTK measurement point was the most frequent situation in case of individual RTK points. It is worth realising that the delicate movement of the receiver with the antenna on a pole the height of which during the measurements was 2 m might be the cause for those differences. It seems that blocking such movements could improve the results obtained even further. The points with the "float" solution obtain much worse accuracies of the determined position and possess a different characteristic. The distribution of points is characterised by high precision but low accuracy.

Fig. 10. Spatial distribution of points in different scales - „fixed" point number 1306 (left) and "float" point number 1208 (right).

CONCLUSIONS

The comparative analysis of date measured by means of direct methods (using the RTK method) with the data obtained on the base of photogrammetric materials allowed finding high compatibility of the results obtained. The works conducted confirmed occurrence of the largest differences in the coastline course on shallow sections with the diversified coastline, frequently overgrown with coastal vegetation and trees. In case of such areas the largest difficulties in interpretation of the coastline course in the base of photogrammetric studies are encountered. The indicated course remains closely correlated with the water surface level at the time of taking the aerial or satellite photograph. For the areas with regulated or hardened coastline course very high correspondence with the direct measurements can be noticed. The conducted studies confirmed that digitalisation of coastline on the base of photogrammetric materials allows obtaining information on the coastline course fast.

The results of direct RTK measurements compared to the existing photogrammetric materials allow fast verification of currency of the images. This is particularly well-visible on the example of the dynamically changing coastal infrastructure located by the lakeshores where absence of the newly built or rebuilt landings as well as growth of reeds can be noticed.

On the base of the analysis of the results obtained we may conclude that problems with maintaining vertical position of the GPS antenna on the measurement pole 2 m high above the point measured is one of the main components influencing errors in the determined point coordinates measured in centimetres. On the other hand, poor geometry of the distribution of satellites caused by natural obstructions during measurements is the main cause of differences expressed in decimetres. That poor distribution of satellites caused impossibility of obtaining the fixed type solution and as a consequence lower reliability and accuracy of the results obtained.

Choice of the RTK technique guaranties high accuracy and possibility of conducting the measurements under difficult measurement conditions. However, there are situations where RTK technique application does not allow obtaining satisfactory results. Those situations could be, e.g. measurement of the point in the terrain that is hard to access possessing numerous obstructions in the form of trees or high buildings as well as closeness of the water surface reflecting the signal. In difficult conditions when positioning accuracies expressed in centimetres must be obtained, total stations and classic land survey techniques are applicable. The combination of both techniques and application of the devices integrating both measurement techniques in one device increasingly common in the market represents the ideal solution.
The measurement application interface is an element of importance in the process of spatial data gathering. During the measurements the ArcPad software by ESRI was used in the process of data gathering. Preparation of the project including the photogrammetric base map and additional subject layers facilitates current verification of attachment of the point measured to a given class. Additionally, appropriate adjustment of the measurement application interface allowed significant automation of the process of data gathering and update of the existing data accelerating significantly the operations that must be performed at the place of measurement. This simplifies the procedures related to processing the results obtained and their later analysis using the GIS tools significantly.

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