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GNSS EQUIPMENT AS A NEW DEVICE FOR FAST MEASURING AND MAPPING OF RIVER SANDBAR MORPHOLOGY

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Introduction

The research of large lowland rivers pose technical problems when conducting surveys of the flowing waters environment. Large dynamics of geomorphologic and hydrologic processes at work render precise localization of the elements in its topography a difficult task. When conducting research, which is usually time and human resources consuming, collecting the ground-truth data tends to be essential.

Using GNSS equipment and GPS RTK technology - a device for obtaining direct geodetic measurements, is a perfect solution for taking fast and inexpensive field measurements in difficult conditions. The precision of the measurement is comparable with the results obtained using the traditional geodetic devices (leveller, theodolite) and it allows to obtain reliable data. GPS RTK method, at the stage of field measurements analysis, requires the use of GIS or geodetic computer software.

The aim, scope and methods of research

Investigated channel sandbar is located at lowland reach of Vistula river (North Poland). River reach resembles a braided-anastomosed river, with partially preserved islands and lateral channels, as well as channel sand mesoforms (bars). Especially during floods, the channel in plan view appears to be multi-branch. In terms of geology and geomorphology, the reach constitutes a transition zone between the gorge fragment of the valley and wide Torun Basin. The channel has nearly constant width (from 500 to 650 m), and the regulatory structures (groynes) occur sporadically in the vicinity of river kilometre 700 and at the reach from km 713 to 719.8. Large islands constitute a major part of the cross-section of river valley floor. The lateral branches behind the existing islands tend to function, albeit partially, even at mean and low flows, unlike at the higher located reach. Channel slopes are diverse – perhaps due to the large quantity and size of accumulated channel mesoforms (bars). Water surface slopes are nearly equal at average and low flows, and do not correlate with channel slope. However, they are influenced by the channel sand mesofroms. Mean hydraulic depths of the channel in its cross-sections are comparable and on average amount to 2.9 m. The maximum channel depths in cross-sections range from 3.7 to 7.0 m. According to the classification proposed by D. Rosgen's (1996), to type C5. W/D ratio amounts to 200, slope is lower than 0.4‰, and the bed is mostly composed of sands. Other variants that may be taken into consideration include type D5 and D_A5.

Presented Vistula’s fragment is typical of a braided river with the channel sand mesoforms. The genesis of the middle-central and longitudinal bars (a group of central bars), which are considered to be the most numerous formations at this reach, is related to river's excessive bed load and its accumulation in the axis of the channel. It should be noted that central bars tend to form during floods. Water flowing around them at low water stages tends to underwash channel banks, which in turn leads to lengthening the bars and widening the two surrounding channels.

The test study was performed on a channel sand-mesoform located on the 713,5 km of Vistula (phot. 1), approximately 40 km below the barrage in Wlocławek (fig. 2). Vistula river bed at times of medium and low water stage was displaying features of a braided channel with the average width of 450-500 m and the lowering of the surface from 0,17 to 0,19 m/km (depending on the amount of water in the river channel). The characteristics of water flow within this section were defined using the water gage in Toruń. In the humid years the average annual water flow ranged from 950 to 1350 m^3/s. In the arid years the value ranged from 577 to 830 m^3/s (Babiński 2002).

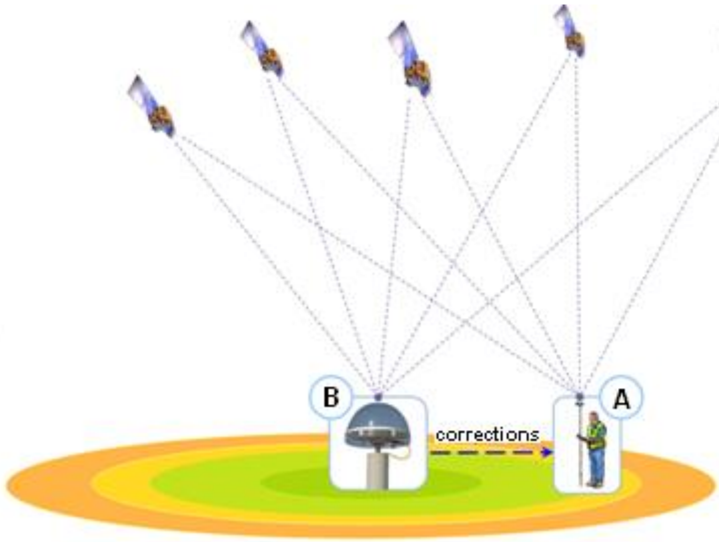

Fig. 1. The scheme depicting the circulation of information during the measurements in the real time in GPS RTK. The receiver (A) is connected with the GNSS satellites that are within its range in the sky and with the reference station/Computer Centre (B) in order to acquire the corrections for the position being measured (http://www.asgeupos.pl).

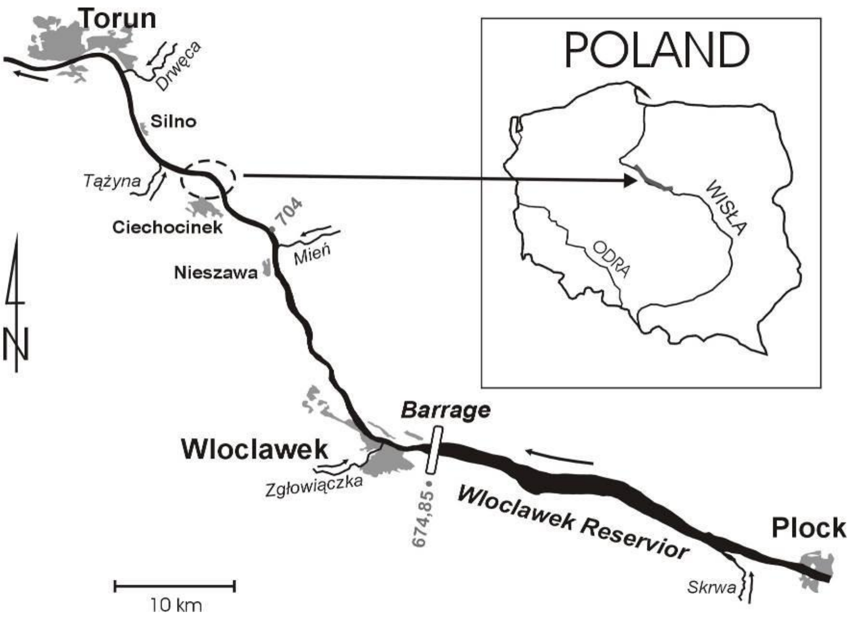

Fig. 2. The localization of the section under study.

The average annual bed-load transport within the section under study in the years between 1971 and 1990 was estimated to approximately 1,3 mln m^3 (this is the highest value obtained within the lower section of Vistula between the barrage and the river mouth) (Babiński 1992).

The partition of the Vistula river bed with Włocławek barrage in 1968 caused drastic changes in both fluvial processes (Babiński, 1992). The deficiency in the transport of material below the barrage is replenished thanks to the deep-water erosion, often lateral. Right below the front of the intense erosion area (at present located 35 km below the barrage) a short accumulative braided channel type section was formed . The research on the dynamics of the fluvial processes in the accumulative area have been conducted since 1984 (Babiński 1992; Babiński, Habel 2009). The study of this section of Vistual is economically significant, since the intensive accumulation of material within the area threatens a river jam and it renders navigation considerably more difficult.

Phot. 1. Investigated channel sand-mesoform under study at the 713,5 km of Vistula river course, the middle part of accumulative area of the lower Vistula, approximately 40 km below the barrage in Włocławek (phot. July 2008).

The aim of the research is to verify the effectiveness of the new research technique, which is helpful at specifying the dynamics of the accumulative area, its parameters, as well as at calculating the amount of bed-load transport. Methods used so far included:

- taking geodetic measurements of the dynamics of the sandbar fronts – vertical and horizontal angels are measured (with theodolite) from a high escarpment located at a river bank at times of low and medium water stage.
- taking bathometric measurements of the river bottom within the section under study, at least once a year, at times of high water stage – average depth of the channel and the amount of bed-load can be estimated.
- conducting aerial reconnaissance over the river section under study and analysis of the purchased aerial photography.

The newly proposed research method consists in taking direct morphometric measurements of the channel sand-mesoforms above the surface of water using GPS RTK technology. Older research methods were limited to the observation of the changes of range of the bar fronts and edges, which was restricted to places, where it was possible to install an observation station at an exposed and sufficiently high river bank.

The new method is based on the application of advance GPS RTK (Real Time Kinematic) measurements. The device conducting the field measurements collects the data on its location in reference to GNSS satellites, as well as it keeps communicating with the Computer Centre (reference stations) in order to obtain corrections for the measurements (fig. 1). The entire process of data exchange is conducted in the real time thanks to the GPRS internet connection, which is why the user obtains data directly while conducting field work.

The horizontal and vertical position of the device is estimated with approximately 1-2 cm error margin. Such devices are gradually replacing the traditional equipment used by the geodesists (Pająk, Ciećko, Oszczak 2006). Polish Goverment lunched in 2008 a system of reference stations ASG-EUPOS. The national reference stations (in the number of 120) are mainly situated on top of the buildings of public administration. An average distance between them is 70 km and the coordinates of the stations are included in the ETRS89 system (European Terrestrial Reference System 1989), as well as in the national coordinates systems (http://www.asgeupos.pl).

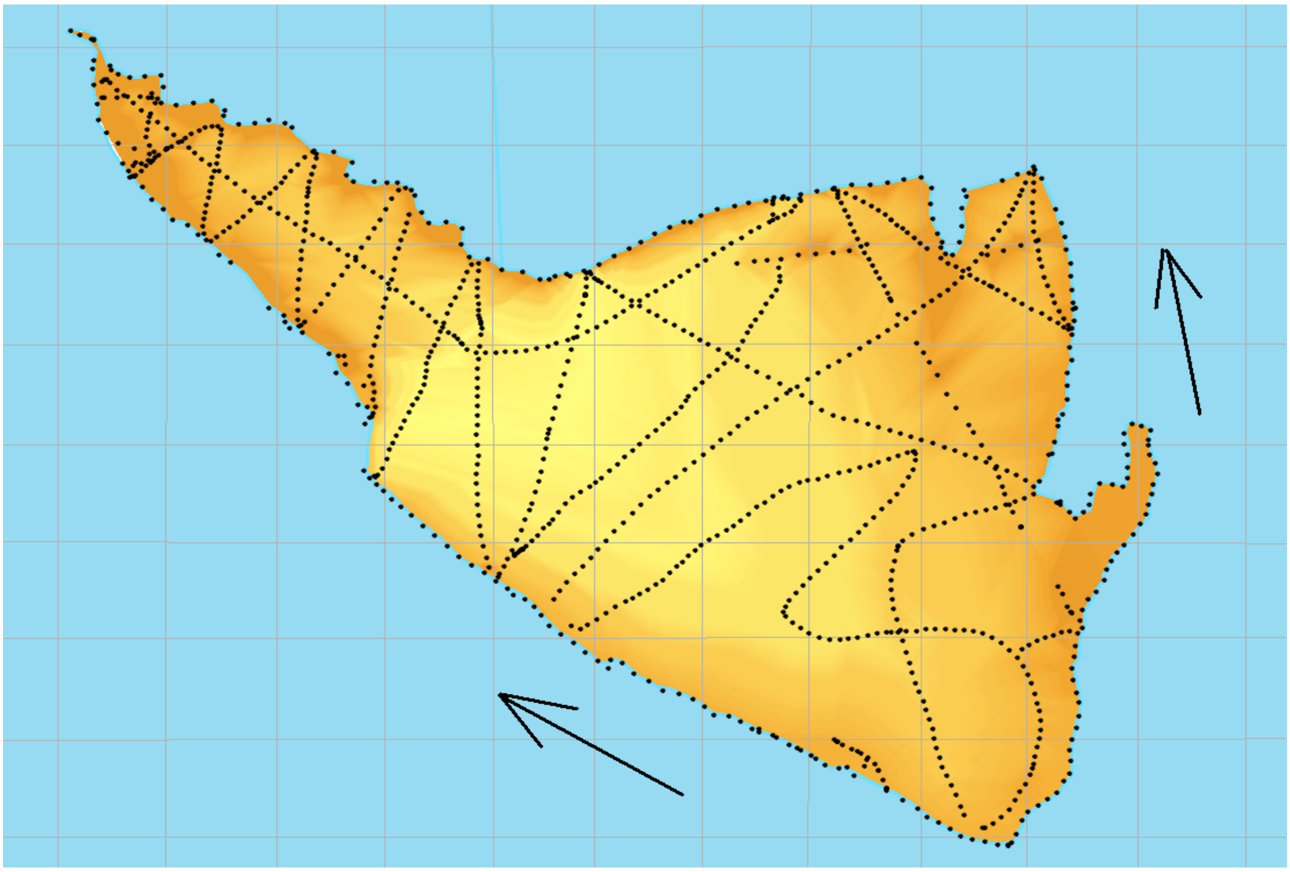

Fig. 3. The measurement profiles and the arrangement of points (station poles) that served to generate the Digital Terrain Model (DTM) of the channel form above the surface. The dimensions of the grid are 20 by 20m. The arrows indicate the river flow direction.

The morphology measurements of the channel sand-mesoform were taken on 28 September 2009, at the time of low water stage and water flow amounting to approximately 380 m^3/s. The GPS RTK 5800 Trimble device was installed not on a pole (as it is usually done with the classic measurements of station poles) but on a low base reminding a dustpan. Then the device was started and slowly pulled over the channel sand-mesoform surface using a string. The measurement profiles as well as the arrangement of the survey points (station poles) are illustrated in figure 3. Every two seconds the device registered its geographical position as well as its altitude. Surveying 1084 points took approximately 60 min. During the measurements The GPS device applied the corrections obtained from the GPRS data transmission executed via the built-in GSM modem. It connected to the reference station in Toruń, 20 km away from the device. The high quality of measurements (the error in establishing the horizontal and vertical position ranged from 1-2 cm) was achieved thanks to good visibility of the satellites orbiting on the horizon. During the measurements the availability of the satellites ranged from 7 to 9. After the measuring was complete, software provided by the producer of the device was used to prepare a report of the measurement precision. The report indicated, among other things, at which points the measurements were less precise (fig. 4). The most popular indicator of the measurement precision is so called Position Dilution of Precision (PDOP). The said indicator specifies the ratio between the error in positioning the user and the error in positioning the satellite. It says when the arrangement of the satellites allowed to obtaine the most accurate result (Śliwiński 2005). In the case of measurements conducted on the channel mesoform the anticipated PDOP value was to be lower than 3. Points that did not achieve the expected precision were excluded from the further analysis. 17 points were excluded because did not meet the anticipated precision - PDOP value was increase than 3 (fig 4).

The results of measurements and analysis

The results obtained – 1067 elevation points were used to generate so called Digital Terrain Model (DTM) in ArcGIS 9.0. programme developed by ESRI company. 17 elevation points had been excluded. Apart from creating a three-dimensional visualisation of a big channel sand-form (fig. 5) it was also possible to calculate its basic morphometric characteristics.

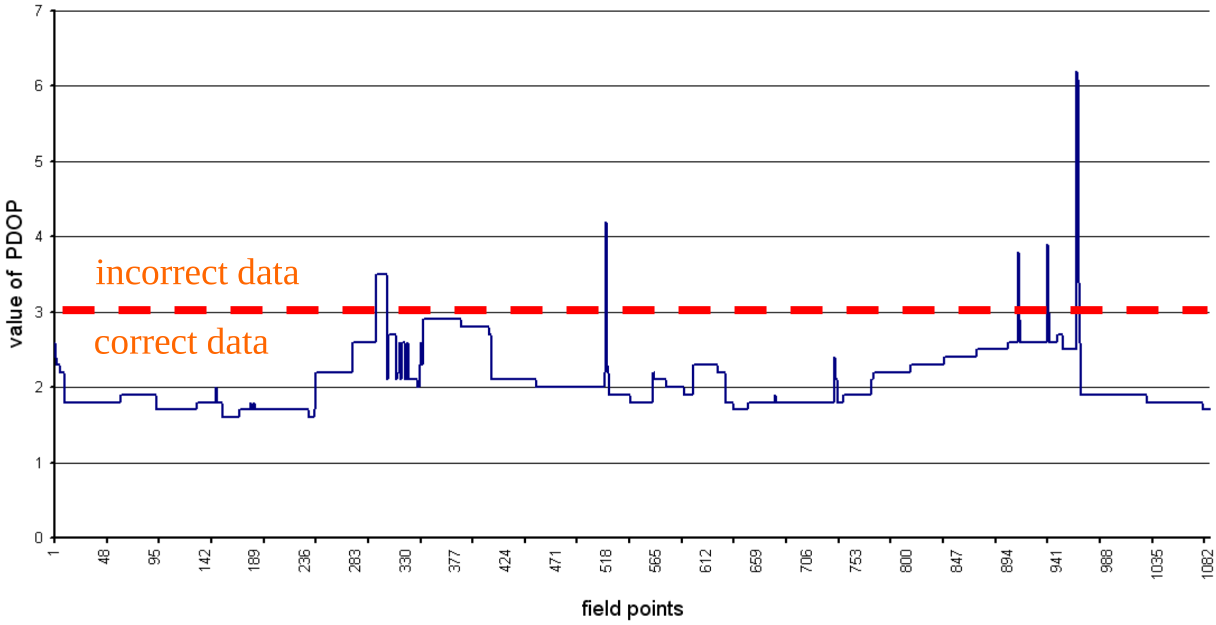

Fig. 4. The chart (the raport) illustrates the PDOP (Position Dilution of Precision) value, which indicates the precision of measurements achieved with GPS RTK. For the 1084 elevation points surveyed on the surface of the channel sand-mesoform only 17 did not meet the anticipated precision.

The channel form is composed of a central bar and a “horn” formed at its front (from the side of lower water). The positioning of the front of the bar is crosswise to the course of the river. At the time the measurements were taken the surface area of the form amounted to 18 808,4 m^2. On the 3D model the diverse morphology of the bar is indicated. The microforms on its surface clearly visible as ripples, especially from the side of lower water, on the “horn” before the front. Denivelation of the central bar amounts to 0,95 m with the culmination point in the front part (38,44 m a.s.l. from the lower water side) and the lowest fragment indicated at the side of upper water (37,49 m a.s.l.), the maximum width amounts to 131 m, and its legth is 144 m. The horn-like form is narrow – approximately 30 m width, with denivelation reaching 0,38 m and length of 95 m. From the Digital Terrain Model a longitudinal and crosswise profile of the bar was generated. In the ArcGIS 9.0 programme, there is an option to quickly create a hypsometric profile of the visualised form. (fig. 6 and 7). A longitudinal drop of the central bar was calculated at 6,59 m/km. The angle of inclination is opposite to the direction of the river bed fall. The direction of fall of the “horn” is in line with the river course and it amounts to 4,54 m/km. There was also an option to automatically estimate the volume of the material that forms the part of the bar above the surface and it amounts to 4924,39 m^3.

Conclusion

The authors of this paper believe that the research conducted on improving the research methods in fluvial geomorphology brought about the anticipated results:

- The measurements with GPS RTK device allowed us to collect large amount of information in a very short time and without involving many people in field research.

- It appears that within the river bed the conditions are conducive to work with methods described in the present study due to clear sky horizon, which allowed us to receive, through the GPS device, signals from a number of satellites and obtain highly precise data.

- The processing of the GPS data in GIS computer programme provides the means to conduct extensive analysis of morphology and channel forms development, as well as calculation of the intensity of bed-load transport.

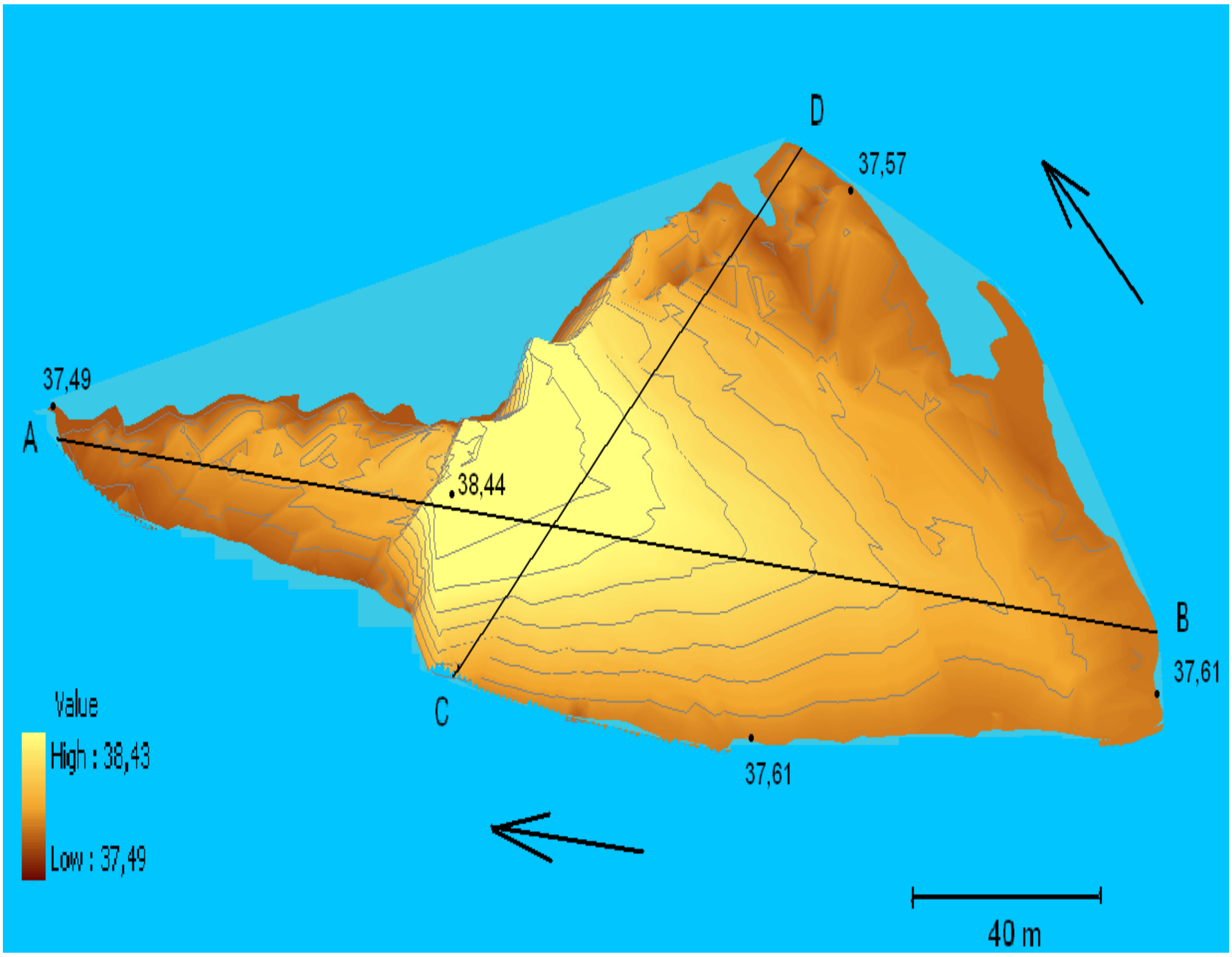

Fig. 5. the DTM visualisation of the channel sand-mesoform – the central bar with its front directed oppositely to the river flow and the “horn” indicated at the side of lower water. The arrows indicate the river flow direction. Isolines are indicated at 0,1 m (Habel, 2013).

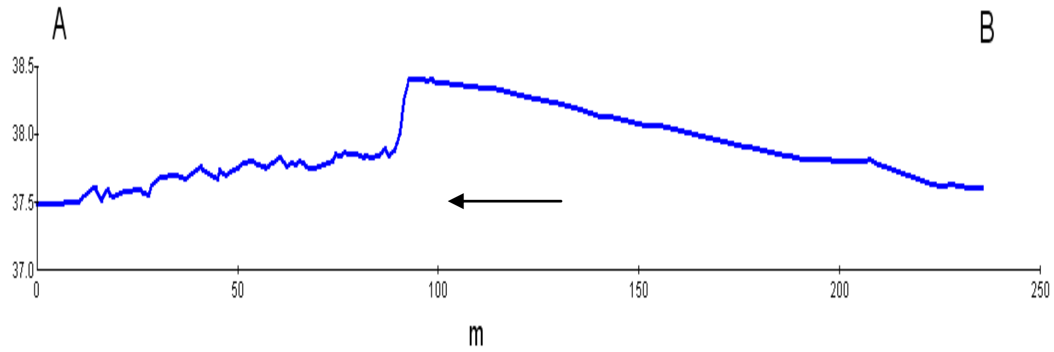

Fig. 6. Longitudinal profile of the channel sand-form generated from the Digital Terrain Model in ArcGIS 9.0. programme. The direction of the line course indicated in figure 5.

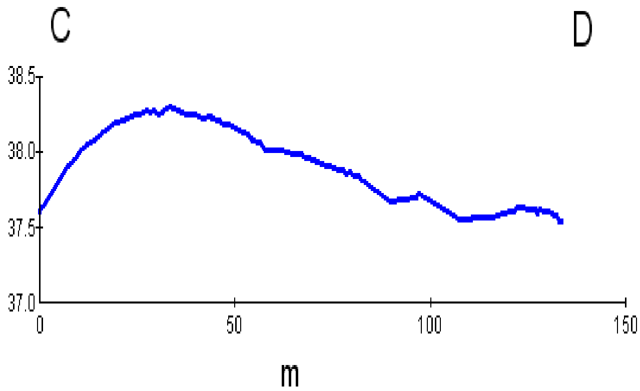

Fig.7. Crosswise profile of the channel sand-form generated from the Digital Terrain Model in ArcGIS 9.0. programme. The direction of the line course indicated in figure 5 (Habel, 2013).

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Abstract
This paper presents the results obtained from the topographic surveys of the surface of one of the positive channel forms (sandbars) of the Vistula river. The new data collection technology, a GPS RTK device, was used to take the geodetic measurements. The results obtained were processed in GIS computer programme and represented in the form of a Digital Terrain Model (DTM). The results of the morphometric measurements of the channel are also presented.

Keywords: channel morphology, river sandbar, GNSS equipment, geodetic measurement, Vistula river.