On the issue of using AutoCAD to assess flow rates (on the example of the Kama Reservoir)

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Abstract. A method of visualization and further analysis of the flow rate field is proposed. The method is based on using capabilities of the AutoCAD software package, which is currently widely used in research in the geosciences, in particular in hydrological researches. As a result of the work done, the flow rate field on the straight sections of the Kama River could be visualized. Information from speed profiles located close to each other was used. The applied method, which consists in extruding isotachs, turned out to be time-consuming, but representative; it cannot yet be used for section lines located around the turn or remote from each other, and in areas with tributaries. The considered method is planned to be tested on the data of hydrochemical survey in order to analyse the distribution of impurities.

1. Introduction
The AutoCAD software package is one of the most popular and widespread computer-aided design and drawing systems [1], its multifunctionality allows creating drawings, and ensure visualization and animation [2].

In the last decade, AutoCAD has been used more and more frequently in research in the Earth sciences: computer-aided design is widely used in geodesy [3], when creating large-scale topographic plans [4]. AutoCAD provides for the use of data from any thematic maps and is used to create a 2D frame of the model in computer modelling [5]. To obtain the most complete and updated information about the design area, one has to use materials obtained as a result of remote sensing of the Earth.

AutoCAD allows establishing relations between the objects, combining the identified objects into natural-territorial complexes, establishing territorial zones and types of permitted use. It is used for graphical display of research results, for example, modelling of the geofiltration process, changes in temperature and air humidity, lithodynamic analysis and assessment of the dynamics of the beach strip. It is noted that the resulting schemes are convenient for processing and automated digitization of various studied parameters, it is convenient to combine them for comparison, and track the ongoing processes visually.

It is noted that the transition to the technology of dynamic three-dimensional design based on the AutoCAD software package allows improving the entire process of working on the objects, reducing the time and financial costs for performance of engineering surveys and creation of high-quality projects on their basis [6].

For hydrological purposes, AutoCAD can be used, for example (see [7–13]) when performing the following types of works: establishing the length of rivers and other watercourses, defining and
determining the catchment areas of rivers and lakes, working with topographic plans and processing channel surveys, import of depth measurements and tacheometric surveys into a drawing, digital terrain model, construction of longitudinal and cross sections, comparison of digital terrain models, construction of cartograms of channel deformations, dredging volumes, and calculation of flood zones.

The paper [8] shows the possibility of using AutoCAD for compiling a map of predicted flooding of an area when the level of groundwater changes in the event of a rise in the river water level during a flood. AutoCAD allows improving the systems of engineering flood control measures, and calculating the boundaries of flooded areas. It is also used to substantiate environmental protection measures that exclude the negative impact of surface waters on the mines being designed and substantiate the shape and parameters of the technogenic relief of the river valley during quarry operation [14]. AutoCAD acts as an auxiliary tool for preliminary preparation of initial data for the development of a model of the water intake area, when constructing a longitudinal profile of the river channel according to the digital terrain model created in the process of engineering and geodetic surveys [15], which is considered one of the advantages of spatial design.

AutoCAD Civil 3D includes three new extensions that can solving hydrological issues [15]:

1) Hydraflow Storm Sewers Extension – designed mainly for hydraulic and hydrological analysis of simple and complex stormwater drainage networks, and drain analysis.

2) Hydraflow Hydrographs Extension is used for reservoir design and simulating simple and complex catchments. It may be used to create a hydrograph, combine hydrographs, calculate channel sections and drainoutflows through reservoirs, as well as calculate hydrographs of branch channels.

3) Hydraflow Express Extension is used to control drain and water outlet in any flow mode: partial or full depth, with overloads and overflows up to supercritical flow profiles with hydraulic surge.

One can also analyse hydrological data in the comprehensive Autodesk Storm and Sanitary Analysis application, with the help thereof water intakes and catchments, sedimentation tanks and outlets, interconnected bodies of water, flow dividers, standard pipes, pumps and lifting stations, hatches and connections, rivers, streams and ditches, culverts and bridges can be analysed.

AutoCAD Civil 3D may be used, for example, to design a bridge over a riverbed. The software provides for transfer of the field data, processing of aerial photographs and satellite photographs, and importing GIS data.

Based on all the data, real ground elevations can be obtained and used to design a topographic surface, on which, in turn, roads, railways, bridges, etc. can be designed.

The Bridge Model module is used directly for designing of the bridge. And on the basis of the designed three-dimensional model, the scope of earthworks and building materials can be calculated. When designing a bridge, the undercutting of the bridge supports is one of the parameters. To ensure such calculations, the River and Flood Analysis program module is used.

Thus, using AutoCAD, one can achieve fast and high-quality performance of various hydrological tasks.

The purpose of the paper is to expand the practical capabilities of the AutoCAD program for solving hydrometric issuing, namely, assessment of the flow rates of a water body, as in the case of the Kama Reservoir.

2. Methods and background information

The 3D rate flow is built in AutoCAD as follows:

1) images of transverse profiles with measurements of velocities and depths are taken and imported to AutoCAD;

2) using the “Polyline” drawing tool, which is located in the “Home – Drawing” tab, horizontals and other lines are outlined;

3) after that background is removed and two profiles are left along the above and below lying sections in the “Polyline” format, which can already be converted into 3D objects;

4) the workspace is changed from “Drawing and Abstracts” to “3D Modeling”;

...
5) “Free Orbit” is activated and with its help the viewing angle of the drawn sections is changed so that they can be viewed from the front and from the side;

6) the section lines are given a volume as follows: the section line is completely selected together with contours and abstracts, then “Squeeze” tool on “Home” is used and the value of the distance to which the polyline object will be squeezed is entered;

7) the section lines are placed one above the other so that it is convenient to connect the isolachts;

8) isolachs of different section lines to visualize the rate flow are connected using “Transition” tool, on “Surface” tab (figure 1).

For the study of the rate flow, the Kama Reservoir was chosen, since the required set of data for it (cross-section maps, measured flow rates and depths) has been provided by “Uralkali” PJSC.

The study of the rate flow was ensured according to the measurements of 2019. In 2019, up to mid-October, the water level of the Kama was relatively high, there was practically no decrease in level marks since the end of the flood, only at the end of October – beginning of November, a more intensive drainage of the Kama Reservoir, which is a reservoir of seasonal regulation, began. Current velocity measurements were performed in July, September and October.

**Table 1. Initial data.**

| Section line on the Kama River | Flow rate measurement date | Water level, m abs. | Water flow rate, m$^3$/s | Current velocity, m/s | River width, m | Depth, m |
|-------------------------------|---------------------------|---------------------|--------------------------|----------------------|---------------|---------|
| above the mouth of the Zyryanka River “White Sea” sludge storage | 20.07.2019 | 108.51 | 1390 | 0.23 | 0.38 | 1096 | 5.47 | 11.62 |
| 07.10.2019 | 108.57 | 1729 | 0.24 | 0.33 | 1328 | 5.43 | 10.36 |
| SKRU-2 port | 25.07.2019 | 108.68 | 1757 | 0.47 | 0.67 | 749 | 5.01 | 8.67 |
| SKRU-2 water intake | 25.07.2019 | 108.68 | 1704 | 0.42 | 0.69 | 757 | 5.34 | 7.07 |
| The Pyskorka River | 27.09.2019 | 108.46 | 825 | 0.17 | 0.25 | 634 | 7.77 | 12.13 |
| Zarazily village | 27.09.2019 | 108.46 | 815 | 0.18 | 0.25 | 572 | 8.15 | 10.53 |

To implement the above described algorithm, the following sections were selected: 1 – section 1: section line XVII (close to the “White Sea” sludge storage) – section line VI (above the mouth of the
Zyryanka River); 2 – section 2: section line I (close to the port of SKRU-2) – section line II (close to the SKRU-2 water intake); 3 – section 3: section line XIV (at the influx of the Pyskorka River) – section line XV (close to Zarazila village). Data on flow rates and calculated water flow rates for the visualized section lines are given in table 1.

3. Results and Discussion

Figure 2 shows some areas where they tried to visualize the flow velocity field. The same figure also shows the obtained high-speed 3D fields for the selected areas.

a) section line XVII (at the White Sea sludge storage) – section line VI (above the mouth of the Zyryanka River)

b) section line I (at SKRU-2 port) – section line II (at SKRU-2 water intake)

section line XIV (at the influx of the Pyskorka River) – section line XV (close to Zarazila village)
Figure 2. An example of visualization of the flow velocity field (b) between section lines (a).

Figure 2 shows a correlation between the distributions of velocities on two adjacent section lines. The velocities are well interpolated, while linear interpolation is not the only thing visible in the first and third section lines. But for the third section, there are no velocity surfaces of small local isoline inherent in the lower section lines. For better interpolation, one needs to have diagrams with the same step of the current velocity change.

Using AutoCad software allows rotating the acquired images for the best analysis of the flow velocity field.

The proposed method for analysing characteristic fields can be used for velocities, and, for example, for mineralization indicator and values of impurity concentrations, which is essential for water bodies where potash production wastes are discharged.

4. Conclusion
The paper proposes a method for analysing flow velocity fields using the example of the Kama Reservoir. In the course of development and testing of this method, the following conclusions can be made: to implement the method, sufficiently complete data on the flow rates at several sections are required, the approach is suitable to visualize the flow velocity field in straight areas, the method turned out to be time-taking, though representative, and it cannot yet be used at the section lines located around a bend or remote from each other, and in areas with tributaries.

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