

## 3-D Modeling of Angara River Bed

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**Abstract.** This work is devoted to development of hybrid geoinformation system for making forecasts of possible flooded areas in the downstream water of the Irkutsk hydroelectric station with damages evaluation in conditions of extreme water content for lake Baikal and for effluents of the Angara river. For 3D model construction of the Angaras bed they used Atlas Map of the Angara River in Irkutsk hydroelectric power station up to 142 km on scale of 1: 10000 General plan of Waterways of the East Siberian basin ", Irkutsk, 1994. Due to lack of a digital model (map), a paper-based map was digitized using vectorizer program Easy Trace 7.99. Depth contours, marks and bank lines were also digitized. To combine the data about land and underwater terrain a specific software was developed using Delaunay triangulation method. The role of data layers in the construction of triangulation is specified. The layers contain information about: land relief, standing water levels, shore lines, underwater topography. Auxiliary triangulation is made according to the data whereof further information is revealed regarding heights levels to which shore contours are attached and in reference to which depths are measured. Hybrid geographic information system allows to simulate different scenarios of flooding and to determine the flood zones with account for underwater and land relief.

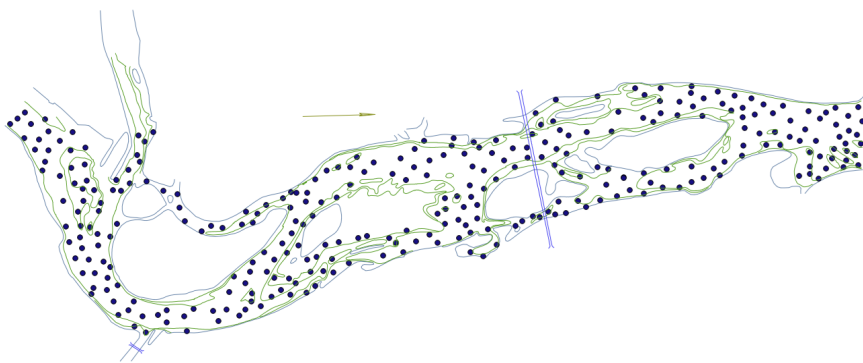
**Keywords:** GIS, flooding, lake Baikal, river Angara, surface.

In the course of the project execution on calculation of flooding areas in the downstream of the Irkutsk hydraulic power station it was necessary to get a terrain model that takes into account the shape of the river bottom. The land relief with different mipmapping levels is shown on topographical vector electronic maps of different scales but the information on underwater terrain of the Angara River in soft copies wasn't found. Existing data of some navigation systems on the depths are fragmented and experts' comments are not precise. The only reliable source is an atlas that is distributed in paper form. In this regard the need of presented maps digitizing and its combining with the existing topographic base has arisen. Digitizing of paper Atlas of the Angara river maps was performed with the help of freeware Easy Trace 7.99 Vectorizer of cartographic representations. The following data were digitized: depths curves, marks of depth points, the coastline.

The Atlas sheets are randomly oriented aiming to the most close-together arrangements of the river sections on the pages. To use it further, we made rotation and shift to the maps reference system containing a terrain model. To select the rotation parameters we compared characteristic points of coastlines contours (capess, bays, islands tips, etc.) of two maps. Utility program was implemented, that calculates the transformation parameters for the given list of coordinates pairs of points and performs maps transformation. To find the transformation parameters they use the least square method. To use the method it is sufficient to specify two pairs of corresponding points, but the use of a larger number of them allows you to get a more exact result, as well as to evaluate the accuracy under the mean square deviation. The mean square deviation of the given examples in this case was 25-70 m. The deviation is due to the presence of significant divergence of contours, because these differences may affect also on characteristic points used for setting of maps conformance.

Attempts to combine contours of vectorized coastline to coastline of topographic base showed that the used atlas was prepared schematically without reference to any map (Figure 2). The atlas reflects the characteristic curves of the shoreline, but it is impossible to combine this line with a more precise contour by turning and shifting. User experience of the calculated under matched characteristics points of rotation and shift showed that the obtained result can not be significantly improved by clarifying the transformation settings. In order to make possible use of not enough precise data for terrain modeling software for electronic cards morphing have been made. To perform morphing it is necessary to find a continuous transformation of the plate area that can combine inexact contours of coastlines with more accurate ones. Layers of coastlines are used to align the maps because they exist on both cards. After that, the same transformation is applied to the other layers of the underwater contours maps (isobathic lines and depth marks). The resulting data are better consistent with the information about land relief, at least, transformed isobathic lines and depth marks are not beyond the shoreline. The transformed coastlines contours are not used as there are more exact coastlines available, so their deviation from the target lines is admissible, for example, by adding alignment interdiction. Principal is that the zones of contours deviation do not contain data of used layers of an inaccurate map. To perform a map morphing two separate software modules are implemented: for semi-automatic alignment parameter setting and for transformation performing.

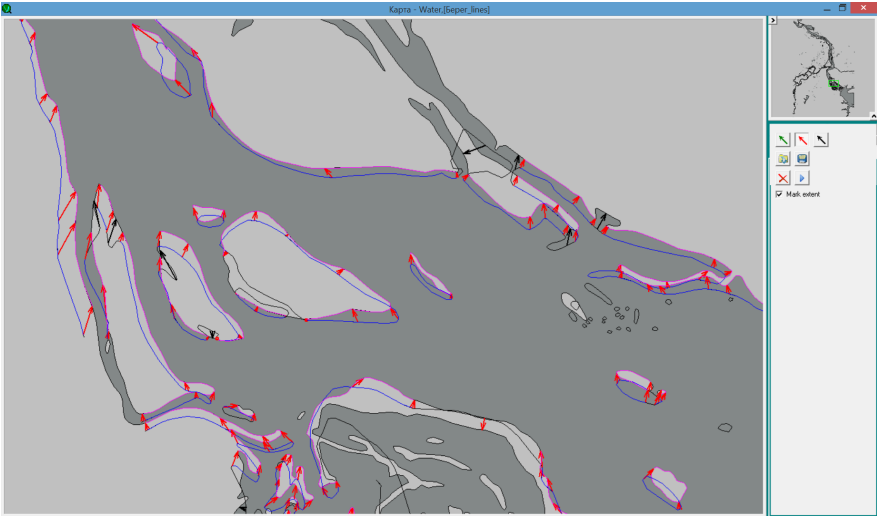
The contours combination is implemented in the form of a special task in the program of electronic maps viewing IrkGV (Figure 3). While the task is performing the operator sets the directions, combining the maps of starting (inaccurate) and target (exact) maps. Then the contours combining starting and ending points of drawn by the user arrows are imaged on the closest to them contours points of relevant maps. Further they make a reflection of every contour line of the object of original map to the specified contour area of target map for each pair of arrows, that are adjacent to both contours. Thus, if, for example, to add an arrow combining this point to the third contour between the points of one



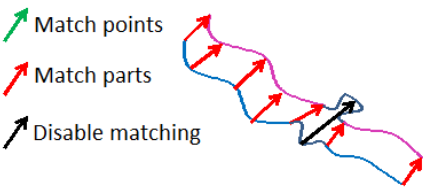
**Fig. 1.** Digitization result.



**Fig. 2.** Maps comparison.



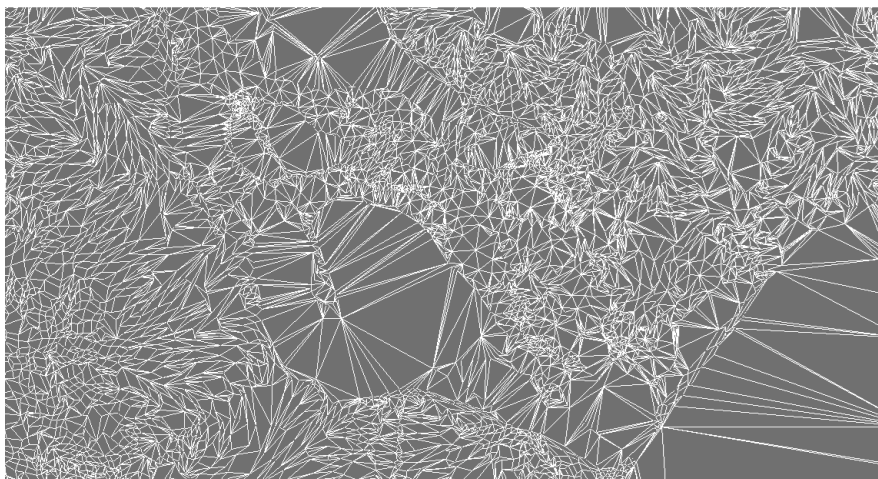
**Fig. 3.** Contours alignment parameter setting. Accurate map is displayed with filling, movable as boundary representation.



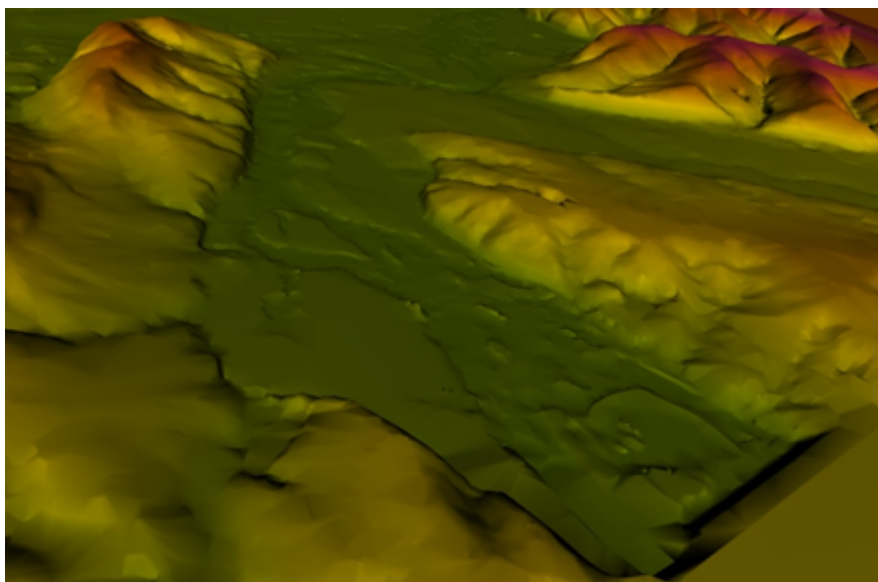
**Fig. 4.** Maps overlap procedure.

contour the comparison of contours areas stops. Comparison of two closed loops is performed separately. Without regard to this case it would be necessary to set at least three pairs of corresponding points to connect contours lines totally. While selecting lines for comparison on less number of corresponding points it is needed to be taken into account direction of tracing: they compare contours areas that have the same direction of tracing. This allows to set correlation between contours using only one pair of points. Displaying of compared contour plots points is performed using a linear transformation of parametric coordinates of curves. In case if the obtained result is not satisfied, in order to ensure combination of some characteristic contour points it is necessary to match explicitly these points together. After entering the information on the maps alignment they form a displacement file that in addition to the explicit shifts contains displacements calculated for the intermediate contour points. Blockage of overlapping circuit plots is required when they compare plots represented with different refining degree. For example, there is a specified precise contour of bay, that is absent in

the less precise. In this case it is better to avoid comparison of corresponding bay plot with a straight line of a transformable contour. The corresponding operation is implemented in the program of triangulations construction to transform morphing. At that triangulation with constraints is formed according to the original points from the file of displacements. Hard edges are added for the nearly located



**Fig. 5.** Segment of formed triangulation, containing information on land and under-water terrain.



**Fig. 6.** Combined terrain (altitude is increased for clarity).

points of the same contour. Shift vector to the target point is stored additionally at every point of triangulation. After that, layers processing is performed in Shape format: each point is moved to the vector obtained by linear interpolation from the points of triangulation. For matching data on above and underwater terrains they modify form of a triangulation construction by maps layers. Now the role at construction of the triangulation is indicated. A layer can contain the following data: land relief, water edge mark, contours of coastlines, underwater terrain. To work with underwater terrain it is required to provide information about water edge marks. According to the data we construct auxiliary triangulation from which further information is extracted regarding altitude marks, to which coastline contours are attached and with regard to which depths are measured. To calculate flooded areas they use contour lines construction according to triangulation, that points altitude are determined by the difference in altitudes of points on the original terrain and are calculated with level of water in case of flooding. This approach allows to get more accurate results and to cover larger area than construction of contour lines according to terrain model for the altitude equal to the level of water at any point increased for the height of water rise at this point that is often used in such cases.

Formed terrain model is stored in a triangulation file (the files extension is .trg) and can be used to perform further analysis using dynamic library TrigLib.dll, designed to work with this data. This library allows to obtain the height of the terrain from triangulation at any point and to perform line tracing, i.e. to receive terrain section along any segment or a broken line. In addition to the basic triangulation, containing information about the terrain, auxiliary triangulation built according to water edge marks is also formed. It contains information about the water level surface used for the construction of a generalized terrain model. The program of triangulation construction includes morphopro file generation algorithms under the specified in the file coordinates, terrain contouring under the given triangulation, and subtraction of altitudes given by one triangulation from the heights of the other points of triangulation. Thus, for the construction of flood zones they make triangulation that takes into account the calculated water level. On the basis of dynamic library TrigLib.dll use we developed the program for altitude marks forming according to a randomly given sort of the Angara section.

**Conclusion.** As a result of the performed works on evaluation of extreme floods under different scenarios of extreme water availability in the basin of the Angara river and lake Baikal, they created hybrid geoinformation system, which allows to simulate different scenarios of floods and to identify flooded areas considering underwater and land relief.

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