

Incorporation of the Hydrographical Network into the Digital Map of the Ground Relief

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Abstract – This research is a part of the Project entitled “Creating of hydrogeological model of Latvia to be used for management of groundwater resources and for evaluation of their recovery measures”. It is supported by the European Regional Development Fund. In the hydrogeological model (HM) the ground relief will be used as the boundary condition. In this article, problems and solutions are described of incorporation of hydrographic network (HN) into the digital relief map. The software that automatizes the process of incorporation is described. The algorithm for creating new points of river profile line is described.

Keywords – initial hydrographic data, hydrographic network, shapefile, relief, river.

I. INTRODUCTION

For creating 3D hydrogeological models, the Environment Modelling centre (EMC) team of Riga Technical University is using the ground surface elevation map (relief) as the piezometric boundary condition for the top horizon of HM.

This approach has been used for creating models in Latvia [1], Lithuania [2], Russia [3], Germany [4]. To use the relief for this specific purpose, it's essential to include the hydrographical network (HN) into the relief as exactly as possible.

The topographic maps contain the following initial data:

a) the ground surface elevation marks, river and lake levels at observation points (pointwise data) : (x, y, z) ;

b) isohypses, isobaths, lake shore lines(line or area in a vector form) :

$$\begin{aligned} & (x_i, y_j, z) \\ & (x_{i+1}, y_{j+1}, z) \\ & \dots \\ & (x_n, y_n, z); \end{aligned} \quad (1)$$

c) profiles of rivers (line in a vector form) :

$$\begin{aligned} & (x_k, y_l, z_l) \\ & (x_{k+1}, y_{l+1}, ?) \\ & \dots \\ & (x_{k+i}, y_{k+i}, z_i) \\ & \dots \\ & (x_{k+s}, y_{k+s}, ?) \\ & \dots \\ & (x_n, y_n, z_n) . \end{aligned}$$

The most difficult task is obtaining the (1c) data and their incorporation into the relief, because only a small part of the Z_i values are known at the observation posts on the river.

In Fig. 1 the full HN of Latvia is shown [5], [6]. For regional HM, only the main elements of HN are accounted for.

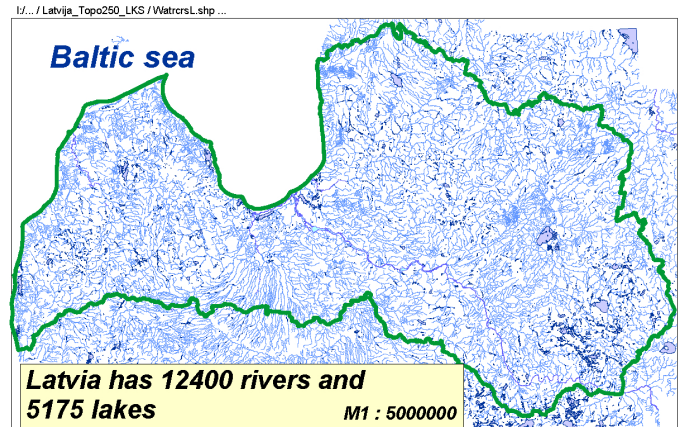


Fig. 1. The full hydrographic network of Latvia

For example, to include a river into HN of HM, a width of the river must exceed 10m.

To automate preparation of data (1), software has been developed for processing and changing data structure according to the standards for input data of the GDI and CRP programs [7], [8].

As the source of data (1), digital relief sets were used [9]. Unfortunately, these digital maps included faulty data. By using the GDI program, one can replace them by the correct data.

II. COHERENCE OF INITIAL DATA

The initial data for long profiles of rivers and levels of lakes are elevation marks of these objects. The minimal data that are needed for a river are the Z-values for the origin and the mouth of a river.

Every river has its drainage basin, which contains a system of connected water streams (tributaries). The connection point of a river with its tributary has the same Z value as the tributary mouth. Any tributary can have tributaries of lower order and so on. Obtaining right long profiles for the drainage basin is possible only iteratively. Firstly, the long profile of the main stem is found, and then for tributaries of the next level and so on. To obtain Z data for each point of the long profile, linear interpolation between two known nearest altitude Z values on the river (the program CRP) was used.

The altitude of the river issue is mostly unknown. To obtain this Z value for a river and the Z value for the lakes, it lacking elevation data, interpolated data from the relief were used and the algorithm described in the article [9] was applied. The long profile of the river can be compared with the digital relief

along the river. The drainage basin of the Krievupe river was used for testing methods of creating long profiles and of their including into the relief map (Fig. 2). In Fig. 3 and Fig. 4, long profiles of the Krievupe river are shown, accordingly, without and with using information obtained from isolines that cross the river.

In Fig. 3, the river long profile somewhere is above the ground level. The long profile of Fig. 4 is much better. However, in some parts, the profile is still above the ground level.

It means that extra measures are necessary, to obtain the right long profiles of rivers.

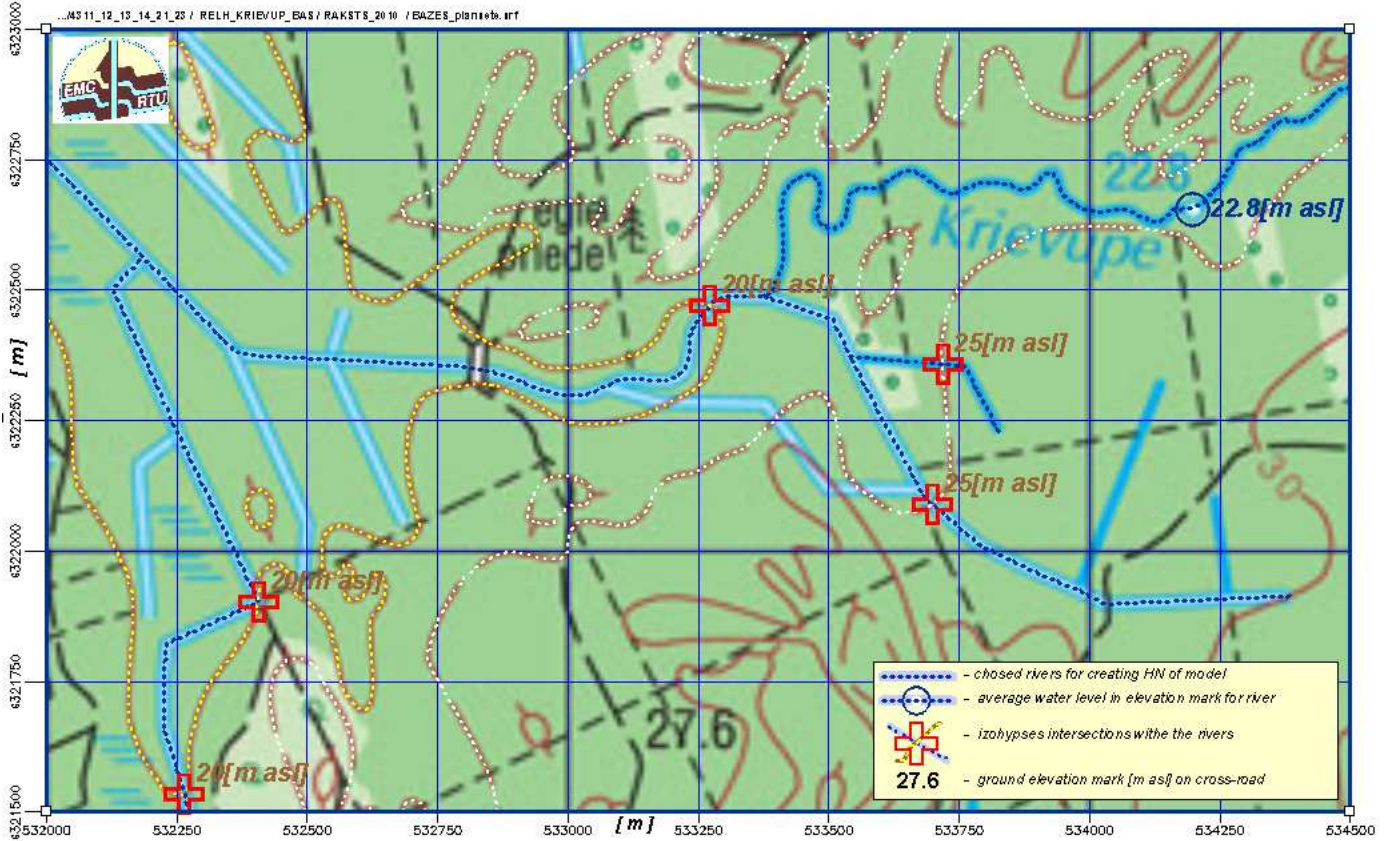


Fig. 2. The fragment of Krievupe drainage basin

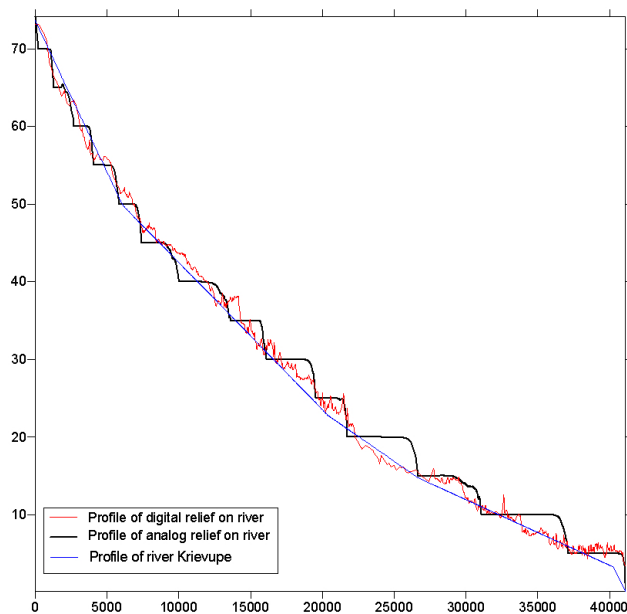


Fig. 3. Long profile of the Krievupe river, elevation marks accounted for

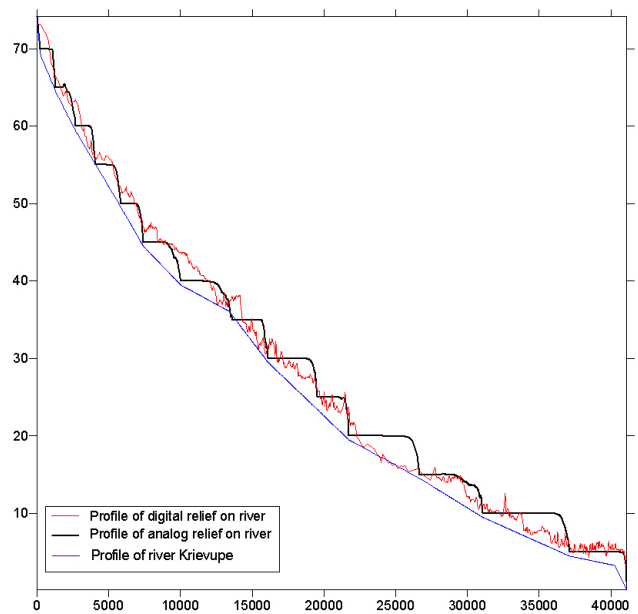


Fig. 4. Long profile of the Krievupe river, updated with isoline data

III. INCORPORATION OF HN INTO THE RELIEF

To explain operations needed for HN incorporation into the relief, the drainage basin of the Krievupe river with all initial data types is shown (Fig. 2). This picture is the hard copy of "the analog relief", defined in a continuous environment.

The full model of the Krievupe drainage basin was attached to the grid $hx=hy=70m$, which included $xn \times yk=428 \times 188 = 80464$ nodes. The grid location was the same as in the digital relief of the Latvian Geospatial Information agency (LGIA) [9], [10].

The initial data package included shapefiles of the Krievupe drainage basin:

- 1) 36 water courses – the river Krievupe and its larger tributaries, 1-3 level (see Fig. 2, marked with the dark blue interrupted line);
- 2) observed water levels with 6 elevation marks (marked with the blue circle);
- 3) additional information was obtained from 65 intersections of the water courses and isohyps (20m – yellow interrupted line, 25m – white interrupted line);
- 4) the model of basin included 122 ground surface elevation marks and 4739 isohyps.

As the first try, "the analog relief" **A_rel1** (see Fig. 5. a) was created, using data which did not contain any HN information. Then HN data of drainage basin was added and the relief **A_rel2** (see Fig. 5. b) was created. The relief **D_rel1** (Fig. 5. c) represents the LGIA digital map. If the HN data are accounted for, the relief **D_rel2** (Fig. 5. d) is obtained.

To evaluate quality of HN incorporation into the relief, the differences **A_rel1 - A_rel2** and **D_rel1 - D_rel2** were found (see Fig. 6. a, b). Blue color indicates that HN was above ground level. To correct the faulty fragments of HN, they must be changed as follows:

$$Z_{x,y}^k = Z_{x,y}^{(k-1)} - \left| \Delta_{x,y} \right| - \lambda, \quad 0 < \lambda \leq 1 \quad (2)$$

where $Z_{x,y}^k$, $Z_{x,y}^{(k-1)}$ are new and old values of the line profile, respectively;

Δ_{xy} - the fault of HN,

λ – parameter that is adjusted experimentally.

In Fig. 7 the digital relief **D_rel2** is shown, where the corrected HN is used. The corrected long profile of the Krievupe river is shown in Fig. 8. The profile is below the ground surface.

IV. EXTRA DATA FOR LINE PROFILE

Extra information from intersection points of rivers and isolines of the digital relief were obtained. However, most of the extra points of long profile values have coordinates, which are different from the coordinates of points of a river (Fig. 9).

The algorithm was created for solving this problem. In Fig. 9, the point $M(x_1, y_1)$ of a river is nearest to the point $M(x_3, y_3)$ which data may be used for adjusting the profile. To find the point, the minimal distance (3) must be found.

$$d = \sqrt{(x_3 - x_1)^2 + (y_3 - y_1)^2} \quad (3)$$

In Fig. 9, the point $M(x_0, y_0)$ is shown where the data from the nearest point $M(x_3, y_3)$ must be obtained.

Equations of the lines M_1M_2 and M_3M_0 , which are mutually perpendicular ($\vec{s} \perp \vec{n}$) are, as follows:

$$\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1}; \quad (4)$$

$$\frac{x - x_3}{y_2 - y_3} = \frac{y - y_3}{x_1 - x_2}, \quad (5)$$

or rewriting them in the general form:

$$x(y_2 - y_1) + y(x_1 - x_2) + y_1(x_2 - x_1) - x_1(y_2 - y_1) = 0 \quad (6)$$

$$x(x_1 - x_2) + y(y_1 - y_2) + y_3(y_2 - y_1) - x_1(x_1 - x_2) = 0 \quad (7)$$

Coordinates x_0 , y_0 of the point M_0 can be found by solving the system of equations (6)-(7) by using the Cramer's rule:

$$x_0 = \frac{c_1(x_1 - x_2) - c_2(y_1 - y_2)}{(x_1 - x_2)^2 + (y_1 - y_2)^2}, \quad (8)$$

$$y_0 = \frac{c_2(x_1 - x_2) + c_1(y_1 - y_2)}{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (9)$$

where

$$c_1 = x_1x_3 - x_2x_3 - y_2y_3 + y_1y_3, \quad (10)$$

$$c_2 = x_1y_2 - x_1y_1 - x_2y_1 + x_1y_1 \quad (11)$$

V. TECHNICAL SOLUTION

In Fig. 10, the diagram for creating a river long profile is shown. Some of initial data, such as geometry of the river, attributes of the river, elevation marks and intersection points of isolines and the rivers were prepared with the ArcView [15] program. To generate the initial relief, the program GDI was used. Most of the needed functions were realized by different programs, which were written in the FORTRAN language. Their union was realized in a batch file with different parameters for each river basin.

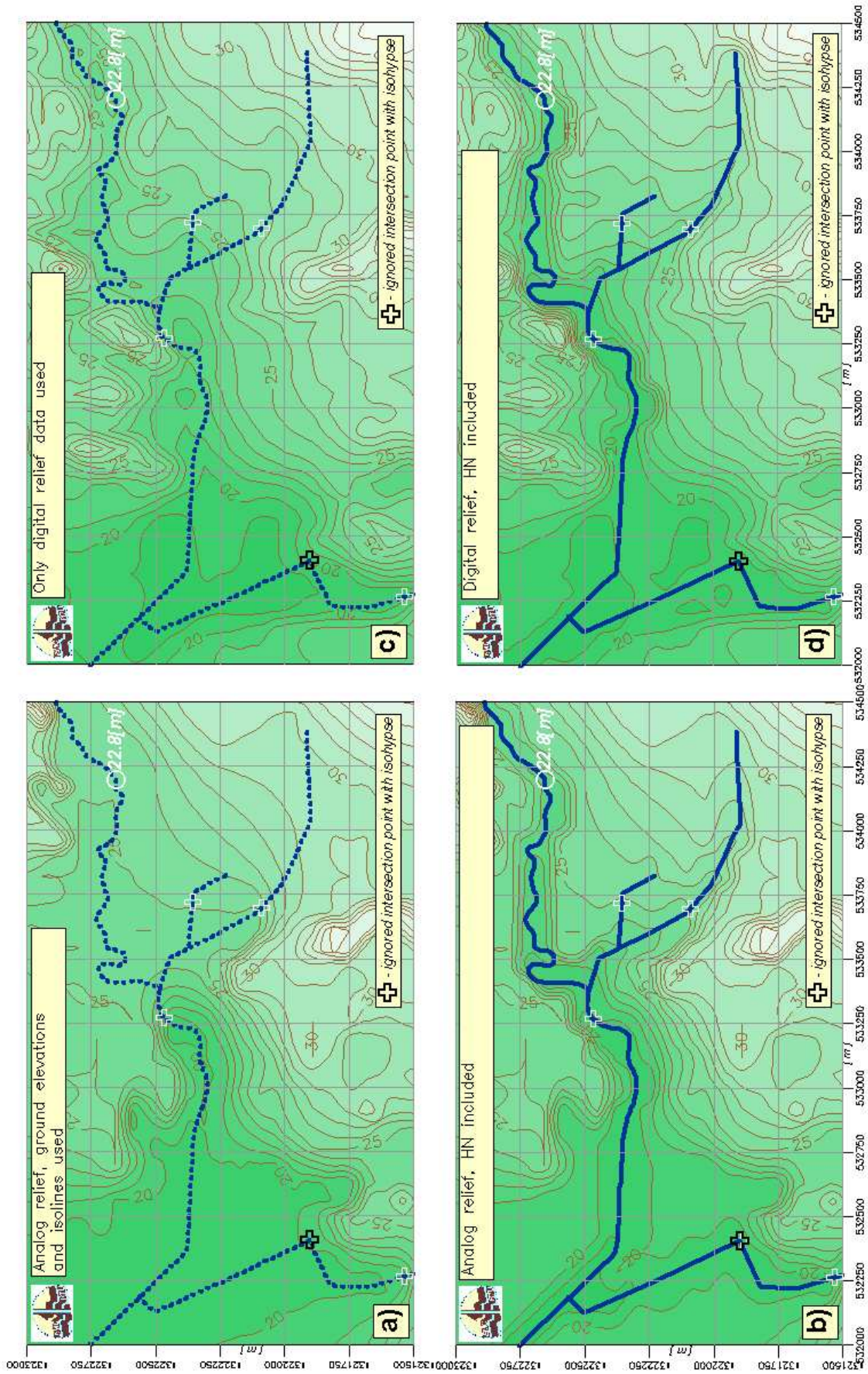


Fig. 5. Relief models of the Krievupe drainage basin

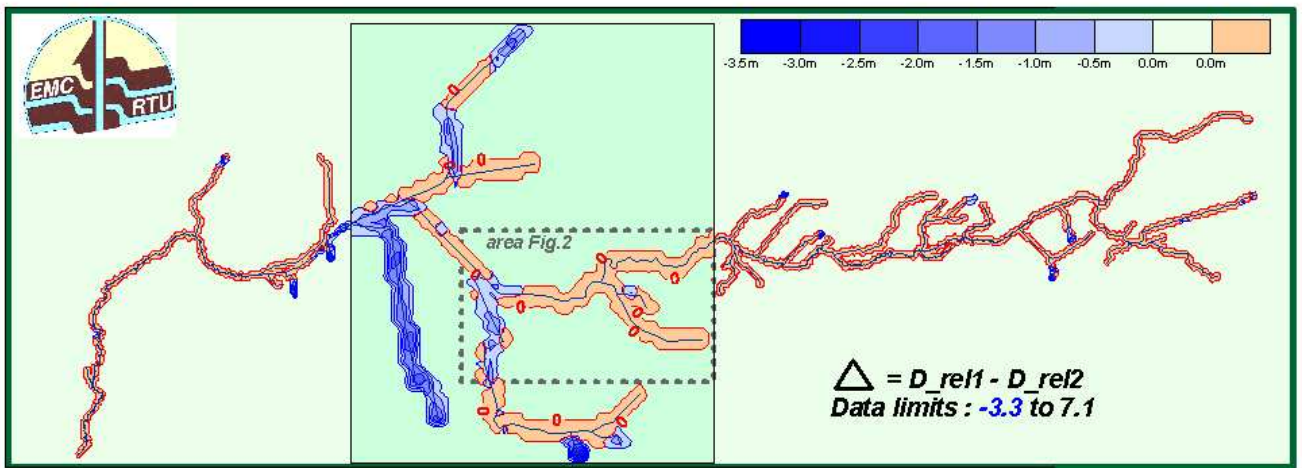
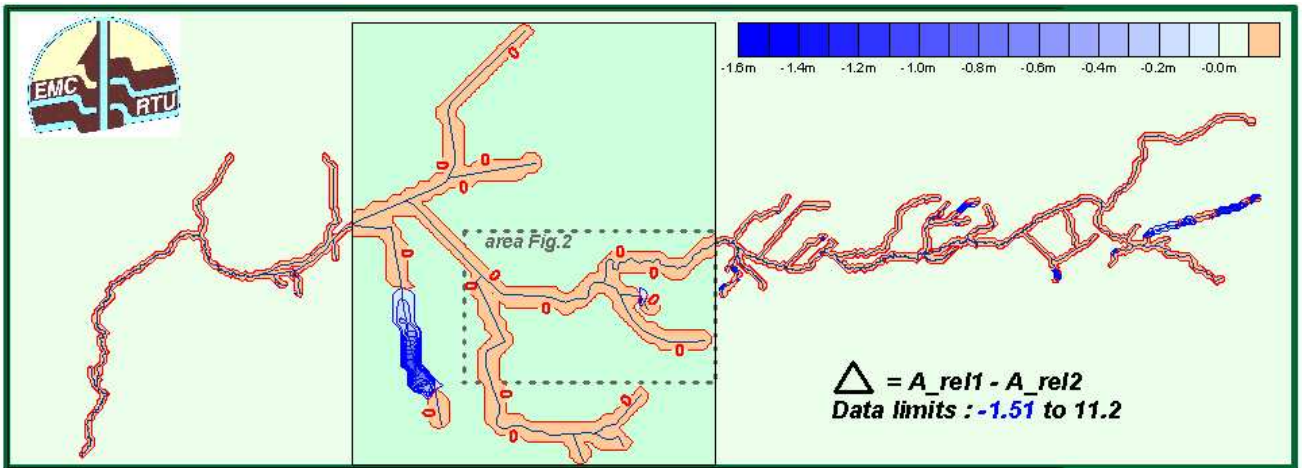


Fig. 6. Faults of HN, used for creating reliefs A_{rel2} , D_{rel2}

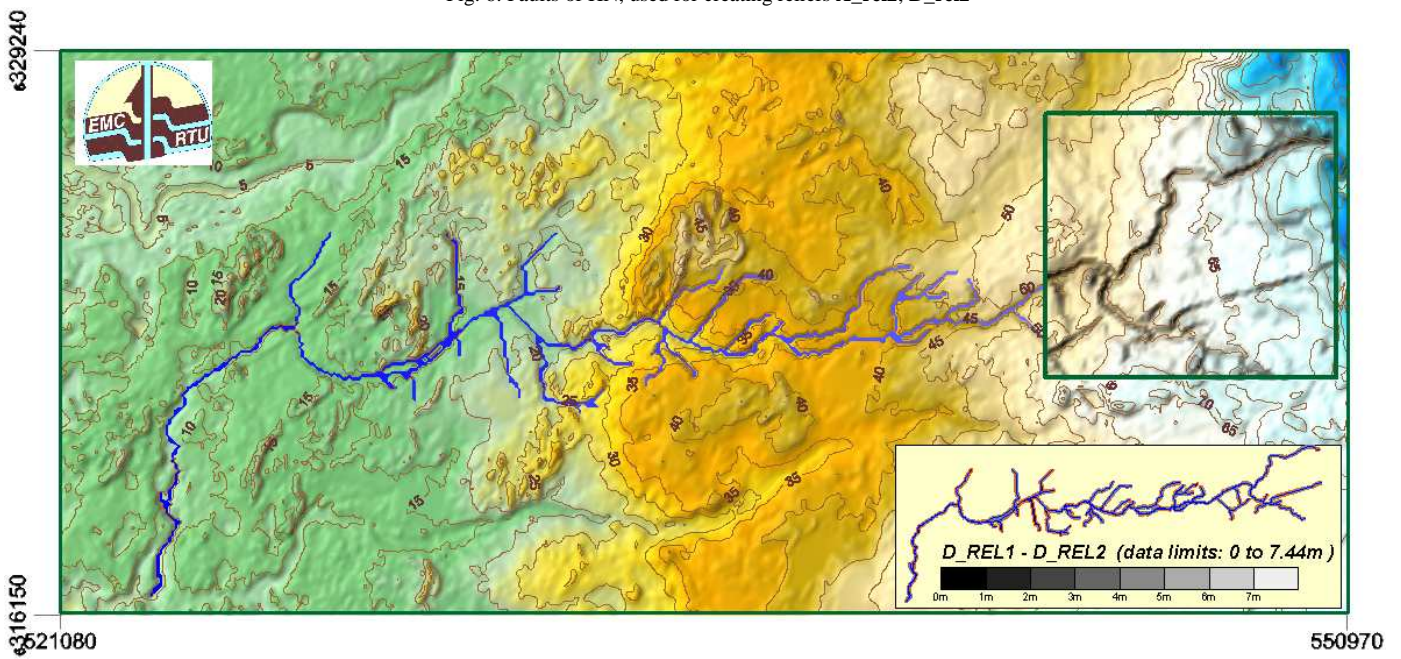


Fig. 7. The relief of Krievupe river drainage basin D_{rel2} with corrected HN data

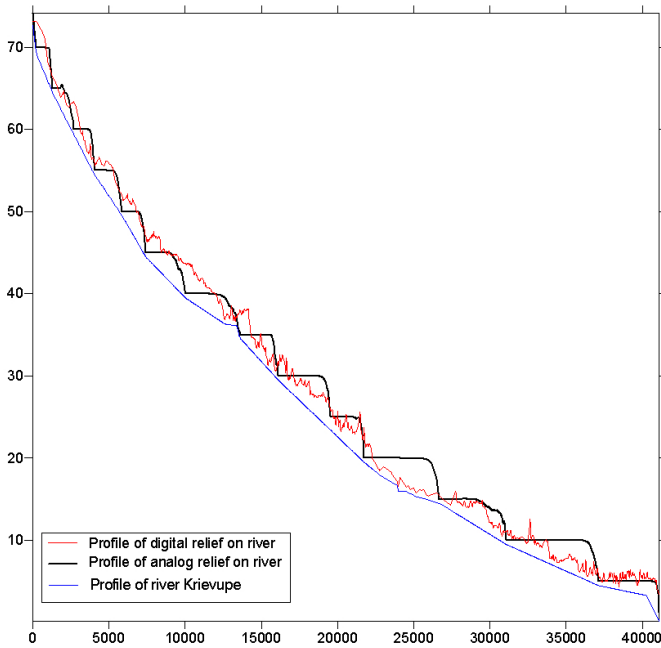


Fig. 8. Long profile of the Krievupe river, correction values included

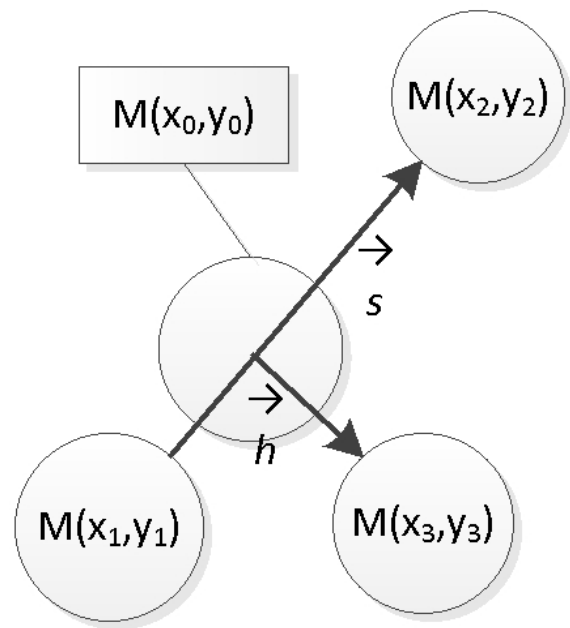


Fig. 9. Place for incorporated point into the river

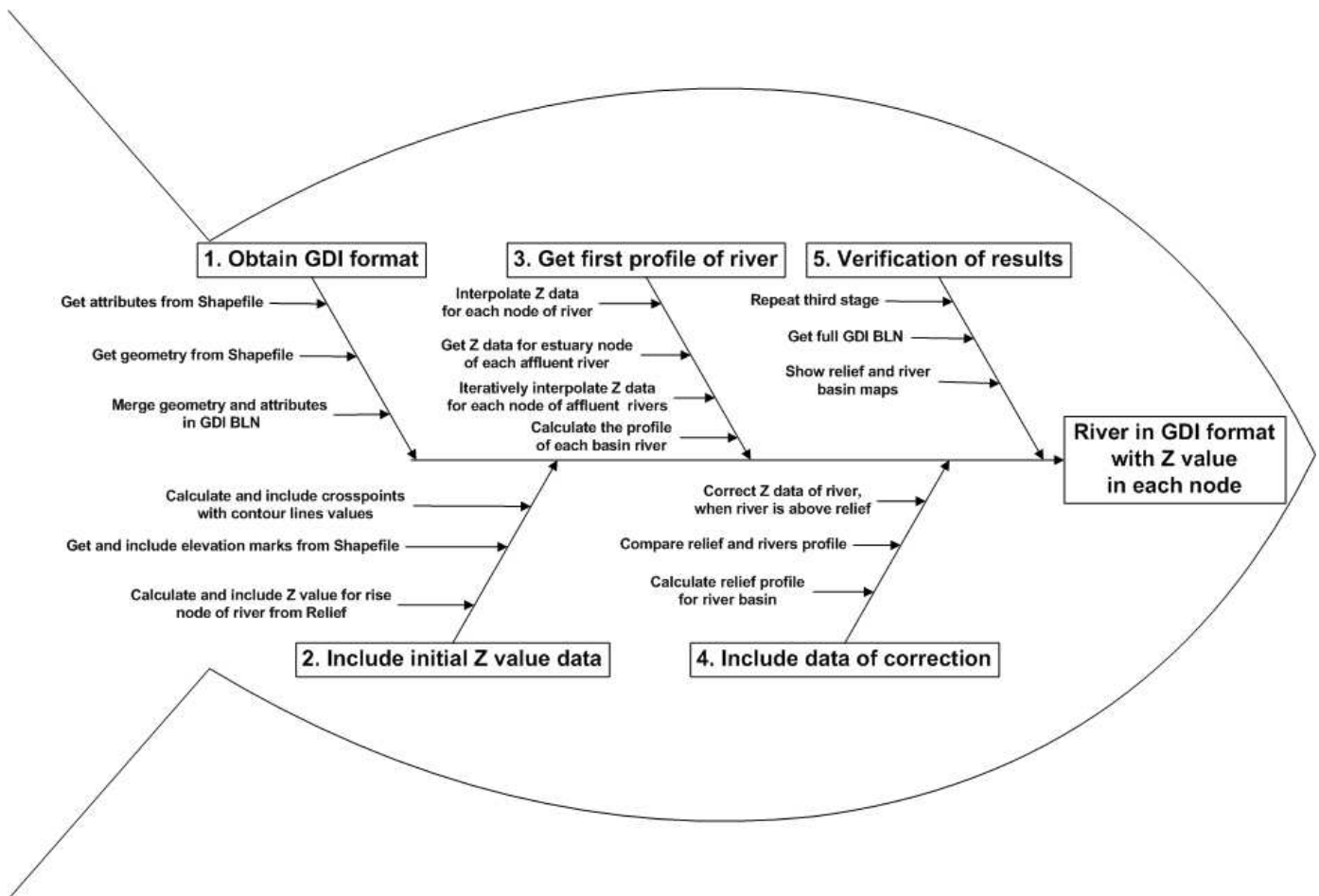


Fig. 10. Diagram for creating long profile of a river

The first stage included getting attribute data of the river basin from the shapefile, such as identifier of the river. For this operation, the VBScript script was used, in which was call to the program MS Excel, in order to operate with the target columns from the shapefile of attributes. The ArcGIS [13] extension TypeConvert [12] was used for getting geometry from shapefile. For getting intersection points the extension HawthTools [14] is used, procedure "Intersect Lines". Additional attributes, as the intersection point x and y coordinates were added. Data from the shapefile attribute file – x -coordinate, y -coordinate and the elevation value was exported to the GDI post file [9]. Altitudes of the river were interpolated using the program CRP. The Z-value of the river basin was interpolated iteratively. The long profiles of the river basin were created by the program CRP. In the stage 4, the relief data were interpolated to each river point by using algorithm, which was described in [9]. The data for correction of line profile were obtained. In the stage 5, the stage 3 was repeated and river basin long profiles were obtained. For visual verification of results in the last stage, the program Surfer [11] can be used.

VI. CONCLUSIONS

1. Digital ground relief maps must be corrected before they are used.
2. Some information about HN can be obtained from „the analog relief”. For obtaining and using extra information, special software and algorithms must be created.
3. The software package, based on the GDI program, that automates incorporation of HN into „the analog relief” and into the digital relief, was created.
4. The algorithm for obtaining coordinates for adding extra data points to the line profile of the river was described.
5. Iterative approach of incorporating of HN into the ground relief map gives better results in comparison with the direct method that has been used before.

This research is a part of the Project entitled “Creating of hydrogeological model of Latvia to be used for management of groundwater resources and for evaluation of their recovery measures”. It is supported by the European Regional Development Fund.

This work has been supported by the European Social Fund within the project «Support for the implementation of doctoral studies at Riga Technical University».

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Jānis Šlangens, Kaspars Krauklis, Irina Eglite. Hidrogrāfiskā tīkla iestrāde reljefa digitālajā kartē

Apskatītās problēmas un to risinājumi ir tieši saistīti ar ERAF un Rīgas Tehniskās universitātes projekta „Hidrogeoloģiskā modeļa izveidošana Latvijas pazemes ūdeņu apsaimniekošanai un vides atveseļošanai” izstrādi Vides Modelēšanas centrā. Apskatīta hidrogrāfiskā tīkla iestrādes problēma zemes virsmas digitālā reljefā, kas kalpos kā pjezometriskie robežnotekumi hidrogeoloģiskā modeļa augšējam horizontam. Ir aprakstītas problēmas un to risinājumi saistībā ar upju un ezera līmeņu iegūšanu, korekciju no pieejamiem datiem, kā arī iekļaušanu upju un ezeru līmeņu datos. Ir piedāvāts iteratīvs risinājums hidrogrāfiskā tīkla iestrādei, kurā, lai iegūtu saskaņotus upes līmeņus ar reljefa augstumu, tiek veikta upes līmeņu korekcija tajos upes punktos, kas atrodas virs reljefa, kurā nav iekļauts hidrogrāfiskais tīkls. Pēc šādas upes līmeņu saskaņošanas ir iespējams iecirst hidrogrāfisko tīklu reljefā, saglabājot tā drenējošās īpašības attiecībā pret zemes virsmas reljefu. Ir aprakstīta programmatūras arhitektūra, kas nepieciešama augšminētā procesa automatizācijai. Pamatā tika izmantotas sekojošas programmas: ArcView, ArcView paplašinājuma programmas TypeConvert un HawthTools, Surfer 8, VMC izstrādātā programmatūra - CRP, GDI un vairākas papildus programmas, kas realizē nepieciešamos algoritmus valodās VBScript, Fortran, kā arī *.bat vadības programmas. Ir aprakstīts upes līmeņa vērtību iekļaušanas algoritms jauna punkta veidā upes līnijā, kas ļauj aprēķināt ievietošanas koordinātes punktam uz upes līnijas, gadījumā, kad iekļaujamās vērtības koordināte ir ārpus upes līnijas.

Янис Шланген, Каспар Крауклис, Ирина Эглите. Врезка гидрографической сети в цифровую карту рельефа земли

Рассмотренные проблемы и их решения прямо связаны с выполнением проекта Европейского фонда регионального развития и Рижского Технического университета „Создание гидрогеологической модели Латвии для управления грунтовыми водами и оздоровления окружающей среды” в Центре Моделирования Окружающей среды (EMC). Рассмотрена проблема врезки гидрографической сети в цифровую карту рельефа земли, которая в гидрогеологической модели будет использоваться как пьезометрическое граничное условие для верхнего горизонта. Описаны проблемы и их решения, связанные с выборкой, коррекцией уровней рек и озёр на основе доступных данных, а также занесение значений в уровни рек и озёр. Предложено итеративное решение для врезки гидрографической сети, в котором, для того, чтобы получить согласованные уровни рек по отношению к рельефу, используется коррекция значений в тех точках линии реки, которые выше цифровой карты рельефа земли, где не учитывалась гидрографическая сеть. После такого согласования значений, становится возможной врезка гидрографической сети в цифровую карту рельефа земли, с сохранением дренажных свойств. Описана архитектура программного обеспечения, необходимого для автоматизации вышеупомянутых процессов, а также алгоритм для включения значения уровня реки в виде новой точки на линии реки. В основе использовались следующие программы: ArcView, плагины ArcView - TypeConvert и HawthTools, Surfer 8, программное обеспечение, разработанное в EMC - CRP, GDI и несколько дополнительных программ, которые реализуют необходимые алгоритмы на языках VBScript, Fortran и командные файлы *.bat. Описан алгоритм вычисления новых точек на линии реки, который используется для включения в линию реки дополнительных значений уровня реки, изначально координаты которых не находятся на линии реки.