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Matching of the ESRI Shapefile Format with the GDI Software

Janis Slangens, *Riga Technical University*, Kaspars Krauklis, *Riga Technical University*, Irina Eglite, *Riga Technical University*, Viesturs Skibelis, *Riga Technical University*, Antons Macans, *Riga Technical University*

***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. Important task of this Project is data preparation for the hydrographical network (HN) that must be incorporated into the ground surface relief. The relief will be used as the boundary condition in hydrogeological model (HM). In this article, problems and their solutions are described for getting and exporting ESRI shapefile data into the GDI BLN format. It is the Golden Software BLN format extended version for obtaining X, Y and Z data for isolines, elevation marks, lakes and rivers that are needed for making of HN.**

***Keywords* – initial hydrographical data, middleware, ArcGIS, shapefile, interpolation.**

I. Introduction

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

This approach was used for creating HM in Latvia [1], Lithuania [2], Russia [3] and Germany [4]. To use the relief for this specific purpose, it is essential to obtain the hydrographical network (HN) (rivers and lakes), as exactly as possible, and to match it with the terrestrial relief.

Up to now, the digital relief map was created by using initial data that were created by manual digitizing. To automate this process, software has been developed for processing and changing data structure according to the standards for input data of the GDI and CRP programs [3]. To evaluate a work that will be needed for automatic initial data preparation, the relief data sources available for purchase were considered. The Latvian Geospatial Information Agency (LGIA) [5] relief map set was obtained, which included three packages: two digital reliefs for the 20m and 70m grids, respectively, as ASCII *.txt data (format <X Y Z>) with identification corresponding to all *.jpg map package for Latvia and "the analog relief". Unfortunately, both digital relief maps do not account for presence of HN. Only "the analog relief" contains data regarding HN. These data are defined in a continuous environment in the *.shp shapefile format. These shapefiles contain information about terrestrial elevation isolines, lakes, rivers, ground elevation marks. Algorithms and software were developed to prepare these data and to change their formats in order to create HN and to incorporate it in the digital relief map.

II. The GDI Program and ESRI

The GDI program is applied for creating digital maps by using pointwise and line data. This is the software developed by the EMC team. For prepare line data for GDI, the program CRP is used. The program CRP is used for interpolating data for line in a vector form. The scheme involving the GDI and CRP programs is shown on Fig. 1. More information about these programs was in [3] and [6].

The ESRI Company is the owner of the Shapefile format and the Company known as the ArcGIS software developer. ArcGIS Desktop performs advanced spatial analysis, model operational processes, and visualizes results on professional-quality maps. ArcGIS Desktop has four main software versions – ArcReader, ArcView, ArcEditor and ArcInfo [7].

For initial data getting and preparing, the ArcGIS program ArcView was used [8].

III. Differences in the Data Formats

Digital topographic maps are presented in the ESRI Shapefile [9] format. The format includes several file types in the binary format:

1. *.shp file stores geometrical data;
2. *.dbf file stores attributes of geometries;
3. *.shx file stores index for both above files.

To create the relief map, the GDI software is used. The GDI program had its specific data format for initial data - points and lines. The point format ASCII file has four columns - X coordinate, Y coordinate, field for additional information and Z value, see Fig. 2.

The line format ASCII file has an extra row (header) containing information about number of nodes in line, line name and line type (see Fig. 3.). The line format was extended from the Golden Software [10] BLN format. It is necessary to match the ESRI Shapefile format with the GDI format.

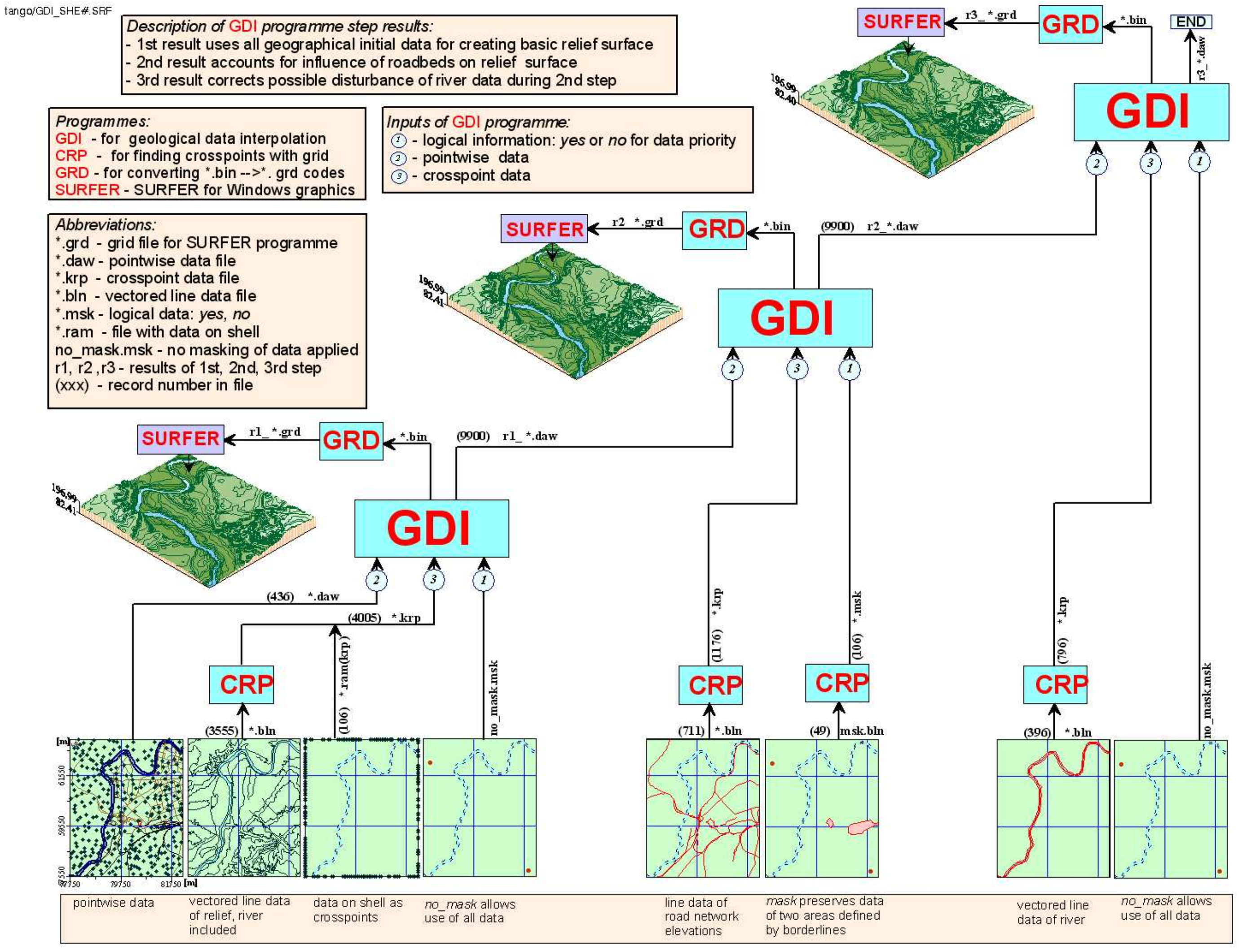
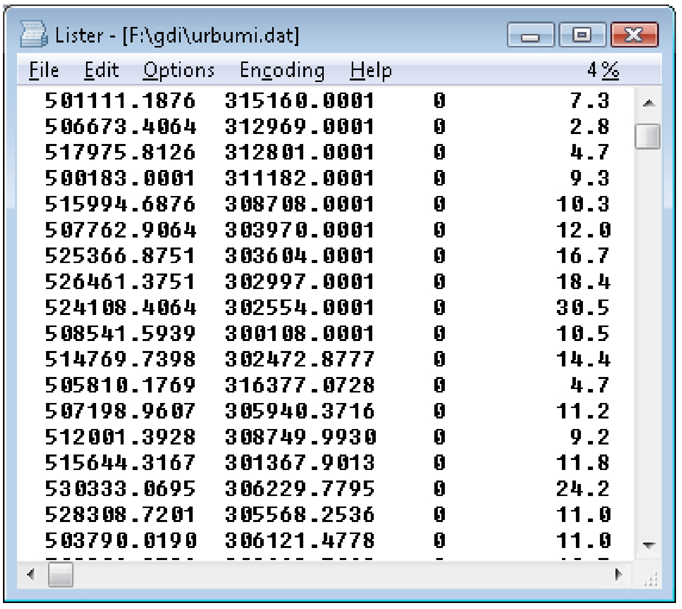


Fig. 1. A scheme for generating the digital relief map by the GDI program

IV. CHANGING SHAPEFILE DATA FORMAT

The Shapefile data format change includes three stages - binary data export to ASCII for geometries, binary export to ASCII for attributes and consolidation of geometry and attribute data into the GDI format. In the first stage of data export, the Golden Software BLN additional programs – Surfer [10] and ArcGIS plug-in TypeConvert [11] are used. Different programs are needed, because the plug-in cannot export big size files. In the second stage, the programming script in the VBScript language is used to open the DBF format file with the MS Excel program and to get the data from target columns. In that way, the GDI post file is created for pointwise data. The third stage depends on the type of the initial data - for rivers, lakes, isolines, elevation marks or for the borderline of Latvia, different algorithms are needed.

For each type of initial data, a distinct program has been developed in the FORTRAN language.


Lister - [F:\gdi\urbumi.dat]
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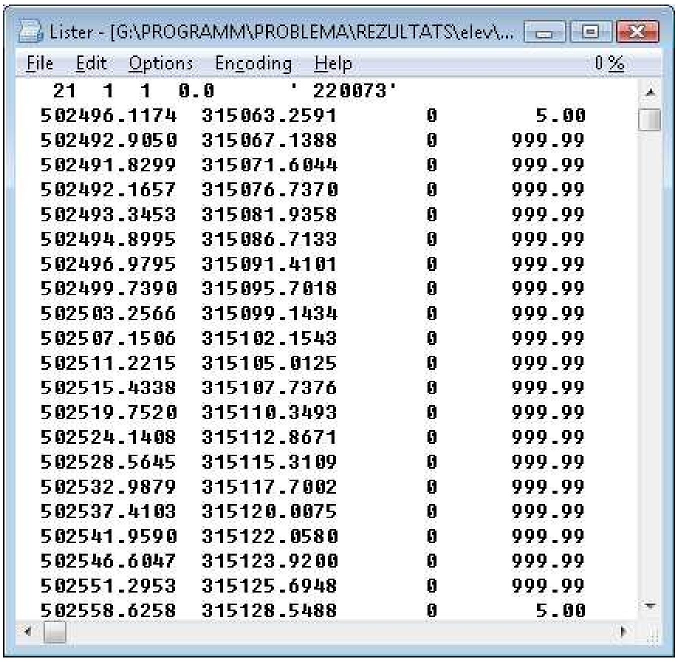
501111.1876	315160.0001	0	7.3
506673.4064	312969.0001	0	2.8
517975.8126	312801.0001	0	4.7
500183.0001	311182.0001	0	9.3
515994.6876	308708.0001	0	10.3
507762.9064	303970.0001	0	12.0
525366.8751	303604.0001	0	16.7
526461.3751	302997.0001	0	18.4
524108.4064	302554.0001	0	30.5
508541.5939	300108.0001	0	10.5
514769.7398	302472.8777	0	14.4
505810.1769	316377.0728	0	4.7
507198.9607	305940.3716	0	11.2
512001.3928	308749.9930	0	9.2
515644.3167	301367.9013	0	11.8
530333.0695	306229.7795	0	24.2
528308.7201	305568.2536	0	11.0
503790.0190	306121.4778	0	11.0

Fig. 2. GDI post file



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Lister - [G:\PROGRAMM\PROBLEMA\REZULTATS\elev\...
File  Edit  Options  Encoding  Help                 0 %
  21   1   1   0.0        ' 220073'
 502496.1174  315063.2591      0         5.00
 502492.9050  315067.1388      0       999.99
 502491.8299  315071.6044      0       999.99
 502492.1657  315076.7370      0       999.99
 502493.3453  315081.9358      0       999.99
 502494.8995  315086.7133      0       999.99
 502496.9795  315091.4101      0       999.99
 502499.7390  315095.7018      0       999.99
 502503.2566  315099.1434      0       999.99
 502507.1506  315102.1543      0       999.99
 502511.2215  315105.0125      0       999.99
 502515.4338  315107.7376      0       999.99
 502519.7520  315110.3493      0       999.99
 502524.1408  315112.8671      0       999.99
 502528.5645  315115.3109      0       999.99
 502532.9879  315117.7002      0       999.99
 502537.4103  315120.0075      0       999.99
 502541.9590  315122.0580      0       999.99
 502546.6047  315123.9200      0       999.99
 502551.2953  315125.6948      0       999.99
 502558.6258  315128.5488      0         5.00
```

Fig. 3. GDI BLN file with isoline data

The data format change was performed for all initial data types. Special methods and algorithms were used for the further data processing.

V. Isoline Data

Isolines have suitable geometries and attributes for changing them to the GDI BLN format. Processing of the isolines includes export of the geometries and of the attributes and then merging both of them with the middleware program. Isolines were used for the analog relief generation and as extra initial data for the river profile (Z values). Results of relief generation were not good enough when lakes, rivers and unchanged isolines were included. Terrestrial isolines always are above (in intersections of a river with an isoline) the river long profile. To repair this situation, isolines that intersect rivers are interrupted there. The corrected isoline values (value decreased by a difference between the ground and river levels, in the intersection points) are incorporated into the river long profile values. The circular interruption zone has its origin in the intersection point with the river. To interrupt an isoline, it is divided into two segments. Isoline data that are located within the circle of the given radius *r* are deleted. Two new end points of the intersected isoline are obtained (see Fig. 4, Fig. 5).

The isoline nodes were deleted with the condition (1), where $M(x_0,y_0)$- the intersection point, $M(x_1,y_1)$- the current isoline point. The new end point coordinate is calculated by the formulas (2) and (3) where $M(x_1,y_1)$ and $M(x_2,y_2)$ are two points on isoline - one inside the circle, the second one – outside it. $M(x_{new},y_{new})$ – the new end node coordinate, see Fig. 4. The multiplier *direct* changes the expression sign when $x_1>x_2$.

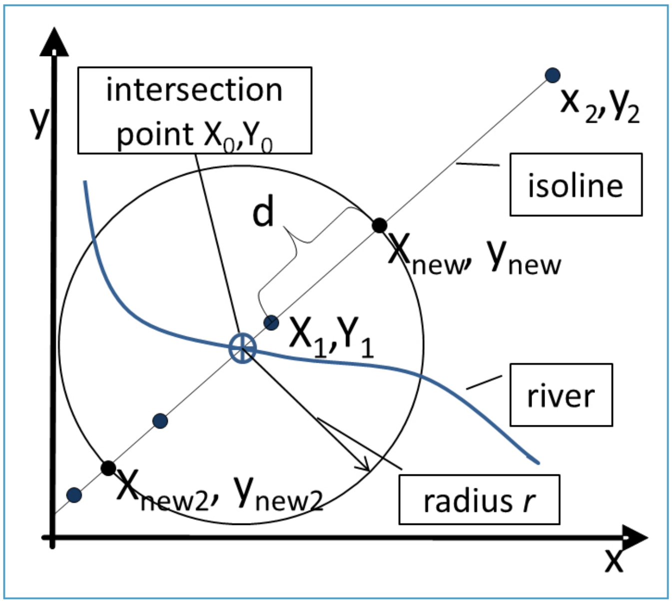

Fig. 4. Endpoints of an interrupted isoline

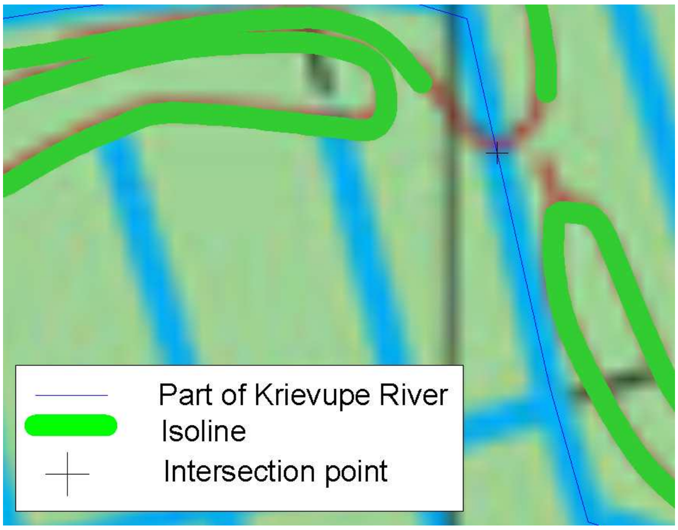

Fig. 5. Interrupted isolines

$$r > \sqrt{(x_0 - x_1)^2 + (y_0 - y_1)^2} \tag{1}$$

$$x_{new} = x_1 + \left(direct \times \frac{d}{\sqrt{1 + \left(\frac{y_2 - y_1}{x_2 - x_1} \right)^2}} \right) \tag{2}$$

$$y_{new} = y_1 + \frac{y_2 - y_1}{x_2 - x_1} \times \left(x_{new} - x_1 \right) \tag{3}$$

The calculations (1), (2), (3) were based on the standard formulas (4), (5).

$$\frac{x_{new} - x_1}{x_2 - x_1} = \frac{y_{new} - y_1}{y_2 - y_1} \qquad (4)$$

Every isoline that cross a river was interrupted, see Fig. 5. These interrupted isolines take part in creating the relief map.

Several software components were used for processing isolines, as shown in Fig. 6. They were included in the batch file.

In the first stage, attributes were derived from the shapefile. For this operation, the VBScript program with the MS Excel program call, to operate with DBF file columns, was used. To derive geometry from the shapefile, the ArcGIS extension TypeConvert was used. In the second stage, for making intersection points, the ArcGIS extension HawthsTools [12] procedure "Intersect Lines" was used. The program of interrupting isolines using algorithm, was written in FORTRAN.

VI. Lake Data

Some lakes had islands that are represented in the shapefile geometrically, as the compound polygon - the lake polygon included the island polygon. In the BLN file, it is not possible. For this reason, a compounded area was manually deleted in the Arcview program. The GDI BLN format requests data about the lake altitude. Large lakes have altitude data, but the smaller ones don't. For this reason, these data was derived from the digital relief. Every lake node has the one nearest digital terrestrial relief node. Each nearest node has its altitude h_i. A lowest value from all nearest nodes of terrestrial relief with the fall (distance between ground and lake levels) was assigned as the lake altitude. The nearest relief node was found by formula (5), where $M(x_1, y_1)$ – the lake node, $M(x_2, y_2)$ - the relief node, d - the distance.

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \qquad (5)$$

Calculations involving each lake node and relief nodes outside the lake are rather time consuming. Optimization was accomplished that performed calculations along rows and columns, until the distance *d* started to grow. The first direction was the relief first row. The second direction was the relief column that had smallest *d* with the first row. In the example (see Fig.7, 8), the relief has 81 nodes and a part of the masked lake area included.

Initially, 69 calculations must be done to find the nearest relief node for the lake node. After optimization, only 10 calculations are necessary. The components that are used for processing lakes are depicted in Fig. 9. The programs are included in the batch file.

The first stage of the lake processing is described in the section "Changing data format". In the second stage, the program written in FORTRAN gets all elevation marks from the model area. Then the node nearest to the current elevation mark for every lake is found. If a node closest to the elevation mark had the distance that is below the given limit, then this elevation mark was used as the altitude (Z value) for a current lake. All the other lakes obtained their altitude from the relief, as described above.

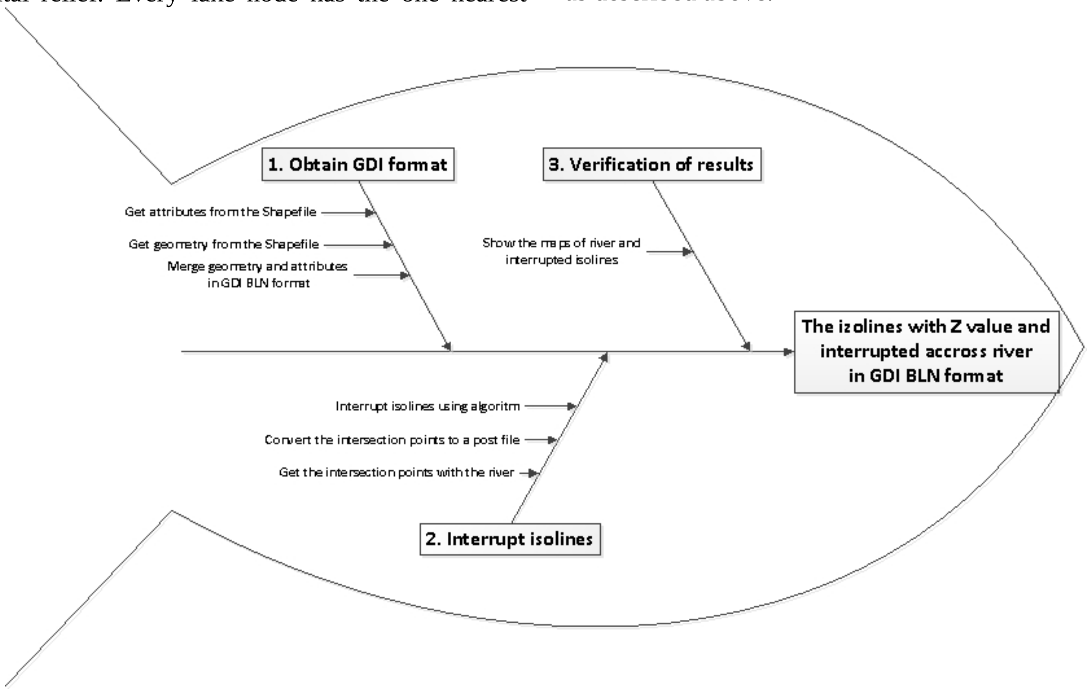

Fig. 6. Scheme for processing isolines

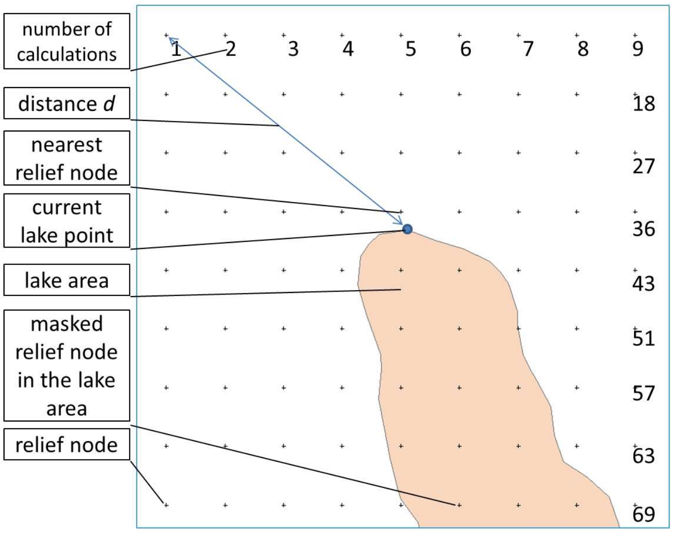

Fig. 7. Calculation cycle for one lake node without optimization

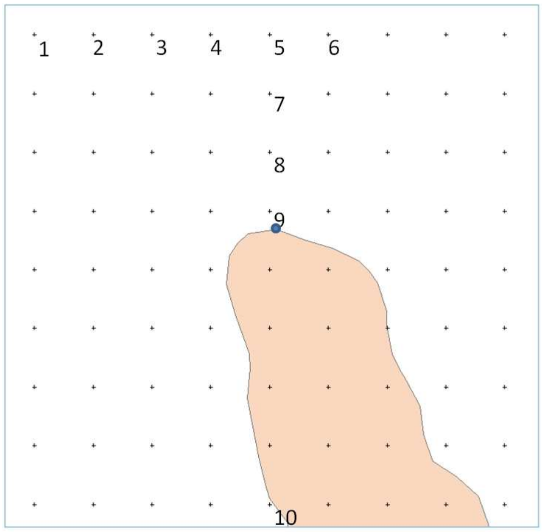

Fig. 8. Calculation cycle for one lake node with optimization

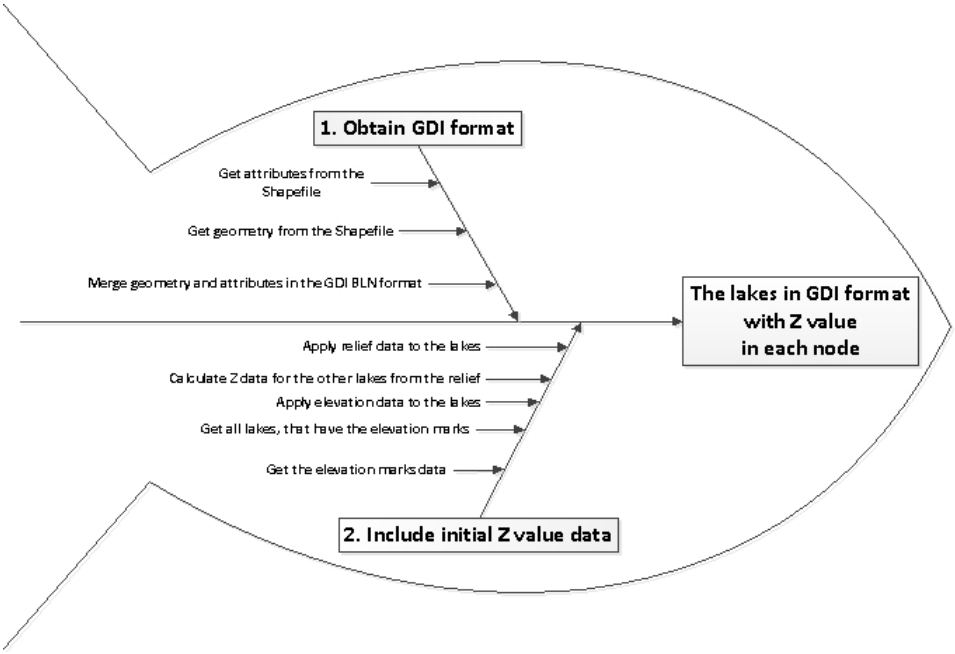

Fig. 9. Scheme for processing lakes

VII. Relief Data

Altitude data for the river outset (the first river node) can be derived only from the relief. It is interpolated from the four nearest relief nodes by the following calculations (6), (7), (8), (9), (10), where $M(x, y, z)$ is x, y, z of the first river node, $M(x_{1\text{-}4}, y_{1\text{-}4}, z_{1\text{-}4})$ are x, y, z of the nearest four nodes, h - the plane approximation step, see Fig. 10. The calculation of the altitudes z_{12} (7) and z_{34} (8) was based on the ratio (6) of line segments between (x_1, x) and (x, x_2). Proportion (9) of line segments was calculated between (y_1, y) and (y, y_2). This proportion was used to obtain the z value (10). The same algorithm was applied to get the relief profile along a river.

$$A_1 = \left|\frac{(x - x_1)}{h}\right| \tag{6}$$

$$z_{12} = A_1 \times z_2 + (1 - A_1) \times z_1 \tag{7}$$

$$z_{34} = A_1 \times z_3 + (1 - A_1) \times z_4 \tag{8}$$

$$A_2 = \left|\frac{(y - y_1)}{h}\right| \tag{9}$$

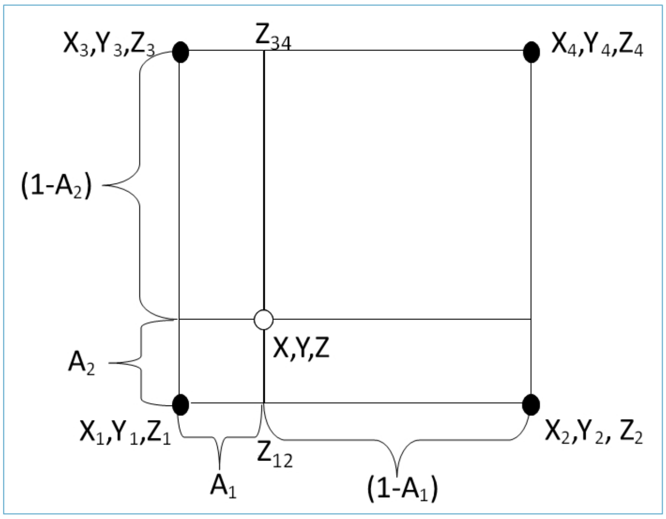

Fig. 10. Node of river on relief grid cell

$$z = A_2 \times z_{12} + (1 - A_2) \times z_{34} \tag{10}$$

VIII. Borderline of Latvia

The initial shapefile data didn't have the closed borderline of Latvia. The data included only the terrestrial borderline part. Latvia has the borderline with the Baltic Sea too. In the initial data for the borderline there were many parts of the terrestrial borderline as polylines and several parts of the Baltic Sea as polygons, see Fig. 11.

To derive the closed borderline of Latvia (see Fig. 12), sequential steps were made by using the ArcView software:

1. Join geometry of all Baltic Sea parts into one polygon.
2. Use TypeConvert to convert polygon from step one to polyline.

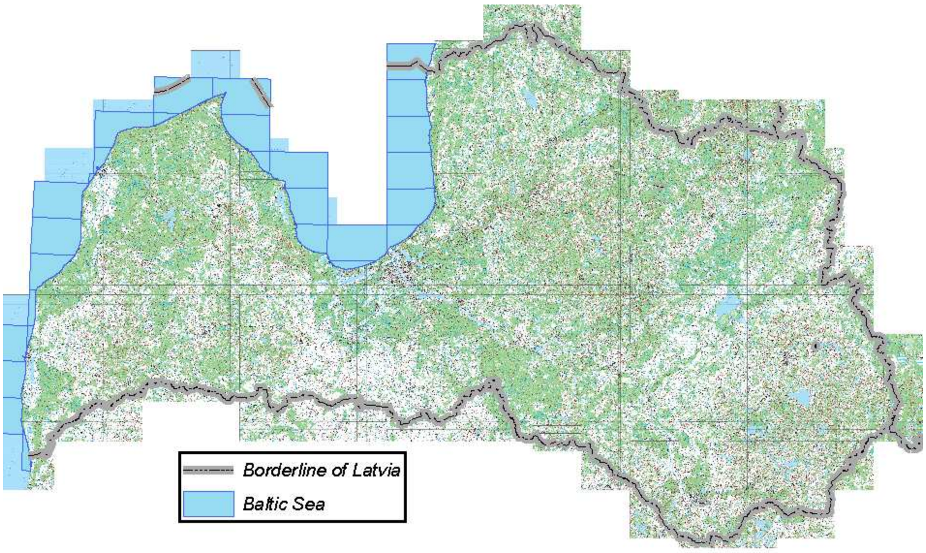

Fig. 11. Initial borderline of Latvia

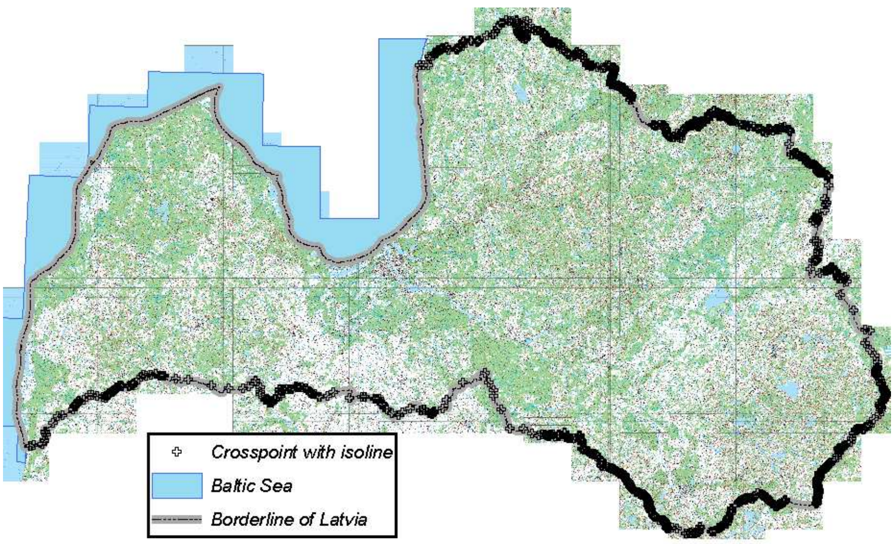

Fig. 12. Full borderline of Latvia

3. Change column types and data for the Baltic Sea shapefile attributes file to make them compatible with the borderline attributes data.
4. Merge shapefiles of the Baltic Sea polyline and the borderline polyline with the "Merge" subroutine from the Toolbox Management.
5. Merge needed geometry parts for the whole borderline.

The borderline is used with the Z data in each node. To get borderline data, borderline intersection points with isolines are found. The intersection points are incorporated into the borderline by the interpolation [6]. In the borderline, all z values from terrestrial isolines and zero value, when the boundary is the sea coastline, are used. In Fig. 12, the full borderlie is shown.

IX. Conclusions

Technical solution that prepares initial data for the GDI software has been obtained. The algorithms and methods for exporting initial data for creating digital relief maps are described. Different types of initial data have problems that must to be solved before their exporting to the GDI program is possible.

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Janis Slangens was born 1940, Latvia. In 1969, he graduated Riga Polytechnical institute (since 1990, the Riga Technical university) as computer science engineer. In 1985, J. Slangens received degree of science candidate confirmed by thesis entitled "*Hybrid computers for solving boundary field problems* ". In 1994, this degree was transferred to the one of the doctor of engineering sciences.
Janis Slangens has been with the university science 1965 (as a student) until now. Since 1969 he was assistant, senior lecturer of Department of Computer Engineering of Faculty of Computer Science and Information Technology. Since 1993 he is senior researcher of Environment Modelling Centre.
His present scientific interests are computer modeling of groundwater flows and migration of contaminants. He is author of about 200 scientific papers.
Address: 1/4 Meza str., Riga, LV-1007, Latvia
Phone: +371 67089511
E-mail: emc@cs.rtu.lv

Kaspars Krauklis holds MSc degree of engineering science in computer systems from Riga Technical University (2007) and the certificate in Teaching of Engineering Sciences from RTU Institute of Humanities (2005). Since 2007 he is a PhD student in RTU, in the Faculty of Computer Science and Information Technology. Currently he works as the researcher in the Environment Modelling Centre which is the part of the Faculty of Computer Science and Information Technology of the Riga Technical University and as a lecturer in the Division of Applied Systems Software of RTU. His main scientific interests are - groundwater modelling and technologies of e-learning. He is an author or co-author of 17 publications in both above fields. Since 2005 he participated in several projects of ESF, ERDF and Latvian council of science.
Address: 1/4 Meza str., Riga, LV-1007, Latvia
E-mail: emc@cs.rtu.lv

Irina Eglite was born in Latvia. She received the diploma in mathematics from the Latvian University in 1974. In 1995, I. Eglite received degree of M.sc. (applied computer science). She is a PhD student of the Department of Engineering Mathematics, Riga Technical University, from 2009. Since 1974 she is researcher of Environment Modelling Centre, Riga Technical University. Since 1991, she took part in projects of Latvian Science Council on informatics for hydrogeology and other projects. Since 2002, she is lecturer of the Department of Engineering Mathematics. Her current research interests are computer modelling of groundwater flow and migration of contaminants, and mathematical pedagogical problems. She is author and co-author of about 50 scientific papers. She is a member of the Latvian mathematical society.
Address: 1/4 Meza str., Riga, LV-1007, Latvia
E-mail: Irina.Eglite@rtu.lv

Viesturs Skibelis was born 1945, Germany. In 1967, he graduated Riga Polytechnical institute (since 1990, the Riga Technical university) as computer science engineer. In 2001, V. Skibelis received degree of M.sc. (applied computer science). Viesturs Skibelis has been with the university science 1965 (as a student) until now. Since 1971, he is researcher of Environment Modelling Centre, Faculty of Computer Science and Information Technology, Riga Technical University. . Since 1991, she took part in projects of Latvian Science Council on informatics for hydrogeology and other projects. His present scientific interests are computer modeling of groundwater flows and diagnostic of electrical circuits. He is author and co-author of about 30 scientific papers.
Address: 1/4 Meza str., Riga, LV-1007, Latvia
E-mail: Viesturs.Skibelis@cs.rtu.lv

Antons Macans was born in 1938, Latvia. In 1963, he graduated Riga Polytechnic institute (since 1990, the Riga Technical university) as computer science engineer. Antons Macans has been with the university science 1965 (as a student) until now. Since 1960 he took part in research and technical service of hybrid computing systems for boundary field problems. Since 1991 he is assistant of Environment Modelling Centre, Faculty of Computer Science and Information Technology, Riga Technical University be took part in projects of Latvian Science Council on informatics for hydrogeology and other projects.

His present scientific interests are computer modeling of groundwater flows and migration of contaminants. He is author and co-author of about 20 scientific papers on software problems of solving boundary field problems.
Address: 1/4 Meza str., Riga, LV-1007, Latvia
E-mail: Antons.Macans@cs.rtu.lv

Jānis Šlangens, Kaspars Krauklis, Irīna Eglīte, Viesturs Šķibelis, Antons Mačāns. ESRI Shapefile formāta saskaņošana ar GDI programmatūru
Apskatītās problēmas un to risinājumi ir tieši saistīti ar ERAF un Rīgas Tehniskās universitātes projekta „Hidroģeoloģiskā modeļa izveidošana Latvijas pazemes ūdeņu apsaimniekošanai un vides atveseļošanai" izstrādi Vides Modelēšanas centrā. Apskatīta automatizēta ieejas datu sagatavošanas problēma digitālā reljefā ar tajā iekļautu hidrogrāfisko tīklu izveidei, kas kalpos kā pjezometriskie robežnotekumi modeļa augšējam horizontam. Daļa no reljefam nepieciešamo datu glabāti ESRI Shapefile formātā, tādi kā izolīnijas, upju novērošanas posteņi u. c. Citi dati – divi digitālie reljefi ASCII formātā. No šiem datiem bija jāiegūst nepieciešamo informāciju GDI BLN un GDI punktveida datu failu izveidei. Bija nepieciešams rast risinājumu diviem uzdevumiem – datu konvertācija no shapefile binārā formāta uz uzdota veida ASCII formātu, nepieciešamo vērtību izgūšana interpolējot pieejamos datus. Ir aprakstīts veids kā iegūti attiecīgie dati, kā arī aprakstīti vairāki algoritmi un metodes: izolīniju pārtraukumu izveides algoritms, reljefa interpolācijas algoritms, metode aprēķinu samazināšanai režģī, metode Latvijas robežas līnijas iegūšanai. Izolīniju pārtraukums tiek realizēts tās krustpunktā ar upes līniju, likvidējot izolīniju punktus uzdotā rādiusā un izveidojot jaunus beigu punktus izolīnijai uz apļa ar uzdoto rādiusu malām. Reljefa interpolācijas algoritms lineāri izskaitļo vērtību no četriem reljefa mezgliem. Metode aprēķinu samazināšanai režģī samazina aprēķinu skaitu tuvākā mezgla atrašanai uzdotam punktam. Metode Latvijas robežas līnijas iegūšanai izmanto vairākus secīgus soļus ArcView programmā.

Янис Шланген, Каспар Крауклис, Ирина Эглите, Виеступ Шкибелис, Антон Мачанс. Согласование формата ESRI Shapefile с программным обеспечением GDI
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 Моделироваия Окружающей среды. Рассмотрена проблема автоматизации подготовки изначальных данных для создания цифрового рельефа с включённой в него гидрографической сетью, который в модели будет использоваться как пьезометрическое граничное условие для верхнего горизонта. Часть необходимых данных находилось в формате ESRI Shapefile, такие как: изолинии, отметки высоты и др. Также доступны два цифровых рельефа в формате ASCII. Из этих данных было необходимо получить необходимую информацию для построения файлов формата GDI BLN и GDI для точечных данных. Рассмотрены архитектуры решений связанных с экспортом данных, а также: алгоритм создания прерываний изолиний, алгоритм интерполяции рельефа, метод уменьшения расчетов в сетке, метод получения линии границы Латвии. Алгоритм создания прерываний изолиний реализуется на пересечении с линией реки, все точки изолинии в указанном радиусе удаляются, на пересечении круга с указанным радиусом и изолинии создаются новые точки изолинии. В основе алгоритма интерполяции рельефа линейное вычисление значения в указанной точке с исспользованием значений 4 узлов рельефа. Метод уменьшения расчетов в сетке уменьшает количество вычислений для нахождения ближайшего узла рельефа по отношению к заданной точке. В методе получения линии границы Латвии исспользуются пошаговые действия в программе ArcView.