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CREATING SCHEMATIC MAP OF TOURIST ROUTES AND INFRASTRUCTURE OF AYUSAI GORGE (Ile-Alatau national park)

Today, the number of visitors to national parks grows exponentially every year, hence the anthropogenic load in the mentioned sites increases impacting flora and fauna, as well as other natural resources. To ensure tourism development in all regions, not only popular tourist destinations, creation of maps to ensure development of tourism industry and regulation of tourism activities are important tools, which indicate main tourism resources. User-oriented maps are designed to provide the geospatial information they need primarily for their interests to make geospatial decisions. Well-designed tourist maps may increase the attractiveness of a region and help meeting tourists' needs. This article presents the process of creating schematic map of routes and infrastructure along Ayusai Gorge for the sustainable development of tourist and recreational activities on the territory of Ile-Alatau National Park using GIS technology. Graphic and attributive data, namely digital raster and vector images, semantic information, the principle of layer-by-layer classification and coding of tourist destinations were used. The raster-vector transformation for data digitization was used within the research and thematic map layers were created on the basis of remote sensing (RS) data, point, linear and polygonal localization objects were digitized. The schematic maps of the routes of the Japanese trail, the Ayusai waterfall trail, the Myn Koz trail and the infrastructure map of Ayusai Gorge were created based on RS data. For the first time, when mapping this territory, satellite images were used and a database of tourist objects was created. The results of this work can be useful in the planning and travelling for consumers, as well as for the creation of a geoinformation database of the national park.

Key words: tourist routes, mapping, geographic information systems (GIS), remote sensing (RS).

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Аюсай шатқалы бойынша туристік маршруттар мен инфрақұрылымдардың карта-схемасын жасау (Іле Алатау ұлттық паркі)

Бүгінгі таңда ұлттық саябақтарға келушілердің саны жыл сайын геометриялық прогрессиямен өсуде, сондықтан аталған нысандардағы антропогендік жүктеме артып, флора мен фаунаға, сондай-ақ басқа да табиғи ресурстарға жүктеме әкеледі. Танымал туристік орындардың ғана емес, барлық аймақтарда туризмнің дамуын қамтамасыз ету үшін туризм индустриясының дамуын және туристік қызметті реттеуді қамтамасыз ету үшін карталар жасау негізгі туристік ресурстар көрсетілген маңызды құрал болып табылады. Пайдаланушыға бағытталған карталар геокеңістіктік шешімдер қабылдау үшін бірінші кезекте олардың мүдделері үшін қажет геокеңістіктік ақпаратты беруге арналған. Жақсы жасалған туристік карталар аймақтың тартымдылығын арттырып, туристердің қажеттіліктерін қанағаттандыруға көмектеседі. Мақалада ГАЗ технологияларын қолдана отырып, Іле-Алатау ұлттық паркі аумағында туристік-рекреациялық қызметті тұрақты дамыту үшін Аюсай шатқалы бойынша маршруттар мен инфрақұрылымдардың карта-схемасын жасау процесі қарастырылған. Жұмыста графикалық және атрибуттық мәліметтер, атап айтқанда, сандық растрлық және векторлық кескіндер, семантикалық ақпарат, туристік нысандарды қабаттарға жіктеу және кодтау принципі қолданылады. Зерттеу шеңберінде деректерді цифрлау үшін растрлық-векторлық түрлендіру пайдаланылды және ЖҚЗ деректері

негізінде карталардың тақырыптық қабаттары жасалды, нүктелік, желілік және полигондық локализация нысандары цифрландырылды. ЖҚЗ деректерінің негізінде Жапон соқпағының, Аюсай сарқырамасына апаратын соқпақтың, Мың Көз соқпағының карта-схемасы және Аюсай шатқалының инфрақұрылым картасы жасалды. Алғаш рет осы аумақты картографиялау кезінде ғарыштық түсірілімдер пайдаланылды және туристік нысандардың деректер базасы құрылды. Бұл жұмыстың нәтижелері тұтынушылар үшін саяхатты жоспарлау мен жүзеге асыруда, сондай-ақ ұлттық парктің геоақпараттық мәліметтер базасын құруда пайдалы болуы мүмкін.

Түйін сөздер: туристік маршруттар, картография, географиялық ақпараттық жүйелер (ГАЗ), Жерді қашықтықтан зондау (ЖҚЗ).

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Создание карты-схемы туристских маршрутов и инфраструктуры по ущелью Аюсай (Иле-Алатауский национальный парк)

На сегодняшний день количество посетителей национальных парков с каждым годом растет в геометрической прогрессии, следовательно, увеличивается антропогенная нагрузка в упомянутых объектах, что ведет к нагрузке на флору и фауну, а также на другие природные ресурсы. Создание карт для обеспечения развития индустрии туризма и регулирования туристской деятельности во всех регионах, не только популярных туристских мест, является важным инструментом, где указаны основные туристические ресурсы. Карты, ориентированные на пользователя, предназначены для предоставления геопространственной информации, которая им нужна, в первую очередь, по их интересам для принятия ими геопространственных решений. Хорошо составленные туристские карты могут повысить привлекательность региона и способствовать удовлетворению потребностей туристов. В статье рассматривается процесс создания карты-схемы маршрутов и инфраструктуры по ущелью Аюсай для устойчивого развития туристско-рекреационной деятельности на территории национального парка Иле-Алатау с применением ГИС-технологий. В работе использованы графические и атрибутивные данные, а именно цифровые растровые и векторные изображения, семантическая информация, принцип послонной классификации и кодирования объектов туристского назначения. В рамках исследования было использовано растрово-векторное преобразование для оцифровки данных и созданы тематические слои карт на основе данных ДЗЗ, оцифрованы объекты точечной, линейной и полигональной локализации. На основе данных ДЗЗ были созданы карты-схемы маршрутов Японской тропы, тропы на водопады Аюсай, тропы Мын Коз и карта инфраструктуры ущелья Аюсай. Впервые при картографировании данной территории были использованы космоснимки и создана база данных туристских объектов. Результаты этой работы могут быть полезны при планировании и реализации путешествий для потребителей, а также для создания геоинформационной базы данных национального парка.

Ключевые слова: туристские маршруты, картографирование, геоинформационные системы (ГИС), данные дистанционного зондирования Земли (ДЗЗ).

Introduction

In Kazakhstan, there are various types of specially protected areas: from natural monuments to wildlife sanctuaries etc. (Ob osobo okhraniaemykh prirodnykh territoriiakh, 2013).

The system of specially protected natural areas as a whole is a large, highly complex and delicate structure. Purpose of national parks, along with their conservation function, is to establish of conditions for recreation and regulated tourism in a natural environment. (Perspektivy razvitiia ekoturizma v Kazakhstane, 2010).

Tourists need to use equipment, including tourist maps, among other things. Despite supposed popular use of general maps, tourists most often use trail maps. These are mainly maps (Uvarova 2012:1) at a scale greater than 1: 100,000, but also maps at a smaller scale covering lowland or less popular tourist areas. A separate subgroup of general maps intended for hikers can be identified. Such maps are complemented by smaller-scale inset maps that show hiking trail layouts and additional information related to selected hiking trail sections.

Maps for hiking in mountainous areas and lowlands constitute a separate category of maps (Jance-

wicz 2017:7). On maps for hiking in mountainous areas and lowlands, the general geographical basis should be worked out in sufficient detail, as well as natural features (lakes, waterfalls, caves, etc.) should be clearly localized. Terrain visualization is great significance not only for mountainous areas, but also for general recognition of any terrain, for estimating the difficulty of routes. The presence of relief increases the precision and attractiveness of the image, greatly facilitates the perception of the map. The icon method remains one of the main ways of displaying images on tourism maps. To demonstrate architectural, historical, archaeological sights, as well as sites and objects that merit the attention of tourists and excursionists, a variety of icons are being developed – geometric, letter, visual pictograms.

Thus, the main task of the tourism industry is to provide information with high-quality cartographic products, both traditional (tourist maps, map-charts, booklets) and modern (3D-digital models, audio and video materials, virtual tours, web-resources). Geographic information systems (GIS) are among such advanced technologies, containing a large amount of information and fully providing cartographic tourist requests (Kuzyk Z., Rutska L. 2019:92).

The promising possibilities of tourist GIS are:

1. Analysis and assessment of the resource potential for the development of different types of tourism.
2. Monitoring and forecasting of recreational needs and demand for tourism services.
3. Development of programs for the collection of information data on socio-economic indicators in the field of tourism, creation of a unified information network.
4. Development of schemes for the development and placement of tourist centers for different types of tourism.
5. Development of schemes for new effective forms of tourism, tours and routes.
6. Forecasting the development of the situation in the tourism market by region, depending on changes in the recreational needs of the population in the short and medium term.
7. Development of an algorithm for the formation of regional (municipal) tourism policy.
8. Assessment of the impact of tourism on the development of other sectors of the economy.
9. Determination of the territorial boundaries of tourism development, based on the real conditions of the ecological, socio-cultural and infrastructural state of the territories.
10. Coordination of activities for the development of regional tourism.

11. Providing users with tool search and view of the placement of tourist sites on an electronic map.

12. Providing tools for entering or correcting information on tourism objects.

13. Providing the ability to analyze the generalized characteristics or concentration of individual objects within selected fragment of an electronic map.

14. Visualization and printing of map fragments, as well as geodatabase “tourist and recreational potential of the territory” (Panin A.N., Makhmudov R.K., Prikhod’ko R.A., Umerenko A.A. 2014:572).

The use of GIS technology provides an opportunity for better analysis of the current situation, spatial representation of results, planning and management of tourist and recreational activities, which will allow obtaining benefits by optimising the management structure and tourist and excursion flows in the study areas.

Given the above, aim of creating a series of route and infrastructure maps of Ayusai Gorge in Ile-Alatau National Park based on GIS technology implies solving the following tasks:

- analysis of the experience of creating multi-tasking maps using RS data;
- creating of an interactive database in digital format;
- creating a schematic map based on RS data along three trails: Japanese, Ayusai waterfall, Myn Koz;
- introduction of attributive and geometric data with reference to the coordinates of routes of tourist trails, resting places, points of passage through water bodies, gazebos, tables, benches and other objects in the geobase;
- performing verification of objects along the trails, i.e. introduction of objects on the vector schematic map of the considered areas, taking into account the coordinate referencing;
- creation of a three-dimensional digital elevation model (DEM); and
- ultimately, to ensure sustainable development of tourist and recreational activities on the territory of the national park.

Thus, in order to promote and improve the services offered by the national parks, the results in the form of geographical maps will help to attract and discover new tourist destinations.

Object of study

Ayusay Gorge is the left branch of the Big Almaty Gorge (BAU), about 6-7 km long, starting slightly east of the summit of the Big Almaty Peak

(Akulov 2017). There is Ayusai river in Ayusai gorge with a length about 7 km long (Kantarbaev S.S., Mynbaeva B.N. 2015:71).

The Japanese trail. Trail length: 10.2 km, trail of medium difficulty. The elevation difference is 597 metres. The current mountain serpentine is the remnants of a working road that was built during the construction of HPP-1. The tunnels through the mountains were driven by Japanese prisoners of war, who were in Camp 40, stationed in Almaty from 1939 to 1956 (Guzeva A, Aubaikirov I. 2019). The mountain serpentine is gentle and easy. The ascent along does not require much physical effort, and if you come from the side of Ayusai Gorge rather than the Kokshoky settlement, there is bicycle trail for tourists (Guzeeva A, Spivak N. 2019).

The Myn Koz trail. Volunteers are currently developing new walking tours. One of them is the Myn Koz trail. The length of the trail: 2.5 km, the level of difficulty of the trail is easy. The elevation difference is 92 m. It is suitable for parents with children and older people. The second trail will be specially equipped for disabled visitors. In the future, issue of acquiring cross-country wheelchairs is being considered (Today.kz 2020).

The Ayusai waterfall trail. The length of the trail: 1.9 km, the difficulty level of the trail is medium. The height difference is 415 m. Ayusai Gorge is famous for its many mountain waterfalls, of which there are more than five along the river. On the right of the waterfall there is a steep talus, and if climb up, you may go further along the path to the interior of Ayusay, sometimes losing sight of the familiar river. Soon the path will lead to a narrow rocky canyon where a second waterfall falls from a height of three metres (Turanga.group 2020). One of the tallest is the third waterfall, which falls steeply from a height of 12 metres.

Materials and methods

Geographic information systems can be used in the study of large areas as well as local tourism sites (Vishnevskaya E.V., Bogomazova I.V., Litvinova M.I. 2012:179). A geodatabase is used for storing spatial and attributive data. In the geodatabase, objects and related attributes are structured as an integrated system with the help of rules, relations and topological relations. In addition to the tourism map, *databases of specialised digital maps* characterising recreational objects can be placed in the GIS:

- recreational facilities and tourism infrastructure;

- schemes of existing and prospective tourist routes;
- schemes of transport routes;
- natural monuments;
- architectural, historical and cultural monuments, etc.

Graphic and attributive data, namely digital raster and vector images, semantic information, the principle of layer-by-layer classification and coding tourist destinations, raster-vector transformation for data digitization and creation of thematic map layers using the space image were used in the work. Objects of different localization - point, linear, polygonal - have been digitized.

These types of work include georeferencing space images to a single coordinate system, vectorizing contours, creating shapefiles and updating the database. A vector layer of contour lines was created according to ALOS PALSAR DEM, three hiking trails and objects along Ayusai gorge were digitized.

The ability to identify and characterize features in an image depends on both the spatial and radiometric resolution of the image. When planning the creation of a cartographic output product, it is necessary to remember that the requirements determined by the map scale affect not only the accuracy of the contour positions, but also the detail of the situation representation, so it is necessary to make sure that all classes of objects can be interpreted (Adrov V.N., Karionov Iu.I., Titarev P.S., Chekurin A.D. 2005:4). Also, when selecting RS data for mapping, spatial resolution and image price are usually the main criteria.

Satellite images are interpreted using visual and automated methods. The technology of visual analysis is based on comparing available information array and the qualifications of a specialist.

Vectorization of interpreted objects by raster implies using raster image as a basemap for the creation of vector objects (Lur'e 2008). All three methods of vectorization were used in this work: manual vectorization in dialogue mode; interactive (automated) vectorization; automatic vectorization (About preparing raster data for vectorization 2019).

In this case, vectorization is performed in special software packages ArcGIS, QGIS for RS data processing and the software program forms a vector map, arcs in which repeat image pixels. As a result, a vector map is formed, in which the objects have a characteristic "serrated" boundary.

Satellite images obtained from the BirdsEye Satellite Imagery Garmin satellite, with a resolution of 2 m in GeoTiff format, were used to create digital maps as a source material, respectively, and Alos

Palsar matrix to create a digital elevation model (Oskorbin N.M., Sukhanov S.I. 2013:87).

Creation of geographic and semantic database.

A geographic information system is distinguished from other information systems by its spatial analysis function. Spatial analysis helps to identify trends in the data, create new relations from the data, view complex relations between data sets and make more informed decisions. Although data entry tends to take the longest time, GIS is used specifically for data analysis. To answer questions about the real world, analysis functions use spatial and nonspatial attributes in the database. Geographic analysis helps research of real-world processes through the development and application of models. Such models illuminate major trends in geographical data and thus make new information available.

Before embarking on a geographic analysis, it is necessary to assess the problem and set a goal. Analysis requires stage by stage processes to arrive

at conclusions. The series of geographic analysis procedures can be divided into the following categories: database query, network analysis, overlap, digital terrain model, proximity analysis, statistical and tabular analyzes.

The procedure for creating the database includes the following:

- acquisition of graphic maps of the region;
- converting paper maps into digital maps by vectorization (digitization);
- creating a topology to establish relationships between map objects;
- conversion to real world coordinates.

To create tourist maps, it is necessary to integrate vector graphic shapes (for example, paths consisting of straight and curved lines), text information and images. A thematic layer is assigned to each type of object. Each layer brings together related features such as roads, buildings, or waterways. A traditional multi-layer model is used to integrate tourism data (Figure 1).

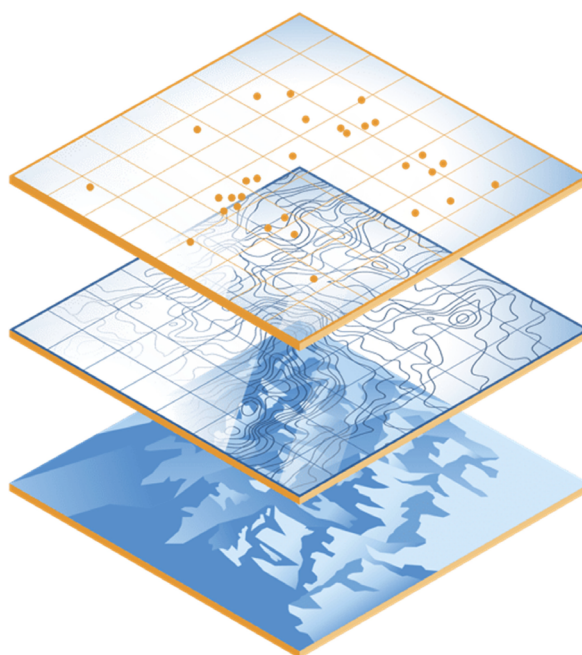


Figure 1 – Extended layer model
(Access Maps, Layers, and Data 2021)

Analyzing the above, GIS is presented as a set of methods and tools for managing and analysing spatial and related attributive (thematic) data and thus differs from mapping and computer-aided design systems, as well as other information systems.

Results and discussion

For a more accurate transfer of field data to a cartographic base, satellite images were *selected and interpreted*, assuming visibility, frequency and

regularity of acquisition, high spatial and radiometric resolution.

The next crucial point for the optimal selection of RS data is to define the requirements for the output products, i.e. their composition (orthophotomaps, digital maps, DEMs, etc.), accuracy and detail (determined by the scale of the output products).

The main characteristics of RS materials are the scale or spatial resolution of the imagery, its type (black and white, colour, multispectral, visible, infrared or radio bands of the electromagnetic wave spectrum), season and time of acquisition. The choice of images (Figure 2) with certain characteristics depends crucially on the purpose of the survey and the properties of the area to be covered.

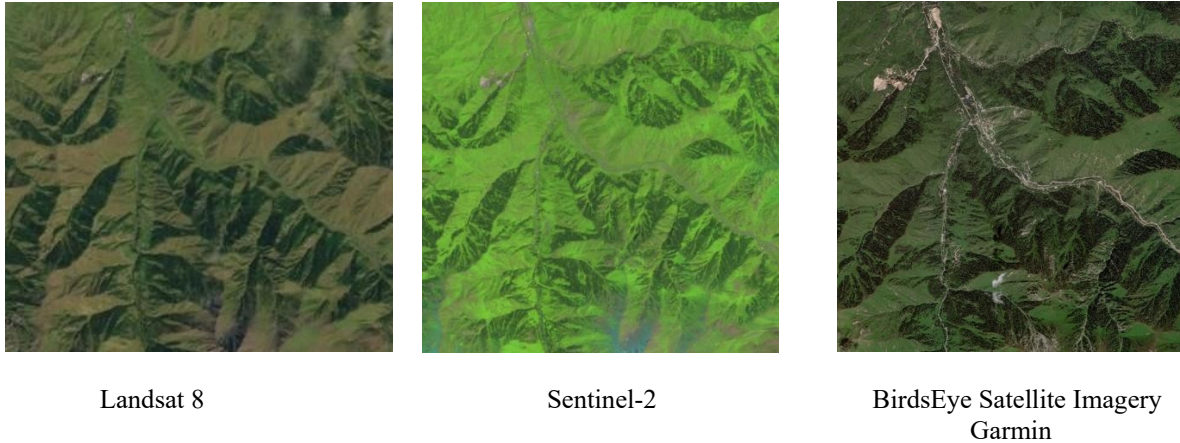


Figure 2 – Selecting satellite images

In the course of our work, we carried out an interpretation of an area with a high degree of fragmentation of dense vegetation cover using an expert classification method on images taken in summertime.

The integration of the interpreted fragments into the final map was carried out using raster algebra techniques. It should be pointed out that the interpretation of vegetation with high-resolution imagery is subject to generalization problems. Detailed processing of high-resolution images (spatial resolution of 1-2 m) is redundant for the interpretation of vegetation classes. At the first stage information on initial images was generalized by filtering, at the final stage of the interpretation all segments with the insignificant area were deleted. The final result of the interpretation was converted from raster data to vector data (Figure 3).

Figure 4 shows object attributes, which is a special type of data file that stores information on each spatial object on the digital map (point, arc, or polygon). The figure shows that an “attribute layer table” includes a given set of fields (columns) and records (rows), the number of which is equal to the number of spatial objects in the digital map. Thus,

one digital map object corresponds to one record in the attribute table.

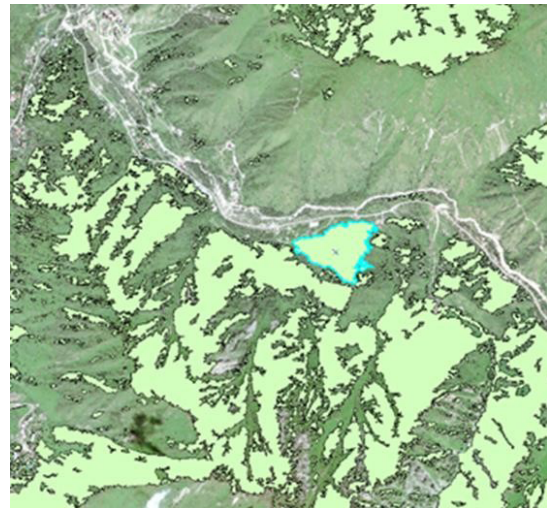


Figure 3 – Land cover interpretation

The size of the object attribute must be sufficient for the longest stored value and is up to 254 for character type and up to 16 for numeric type, including number sign and decimal point.

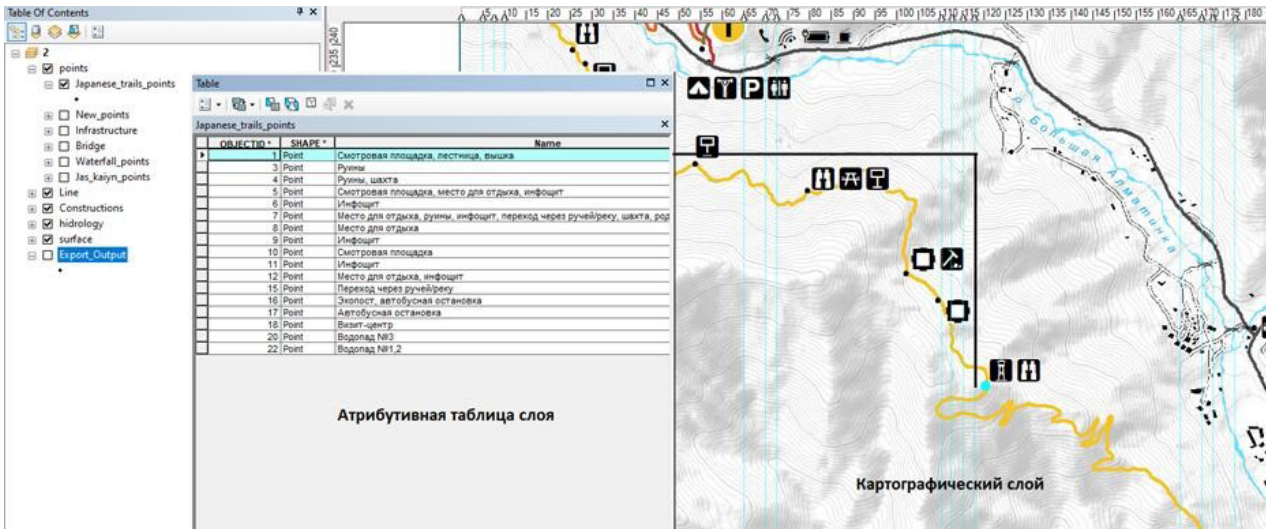


Figure 4 – Vector layer attribute table

The next step is map vectorization, which involves the process of converting a raster image into a vector graphic. A raster image is put together from pixels like a mosaic. Vector graphics are more precise because every line in the drawing is the result of mathematical modelling. Therefore, professionally performed vectorization of maps is necessary to display engineering schemes, relief,

buildings and structures as correctly as possible (D’iakonov V.V., Zhorzh N.V. 2008:38).

For further work in the program on the georeferenced map base we have formed the working layers: water bodies, forest plantations, roads, symbols of tourist objects (NPS Map Symbols, 2018). Figure 5 shows the stages of the object vectorization process.

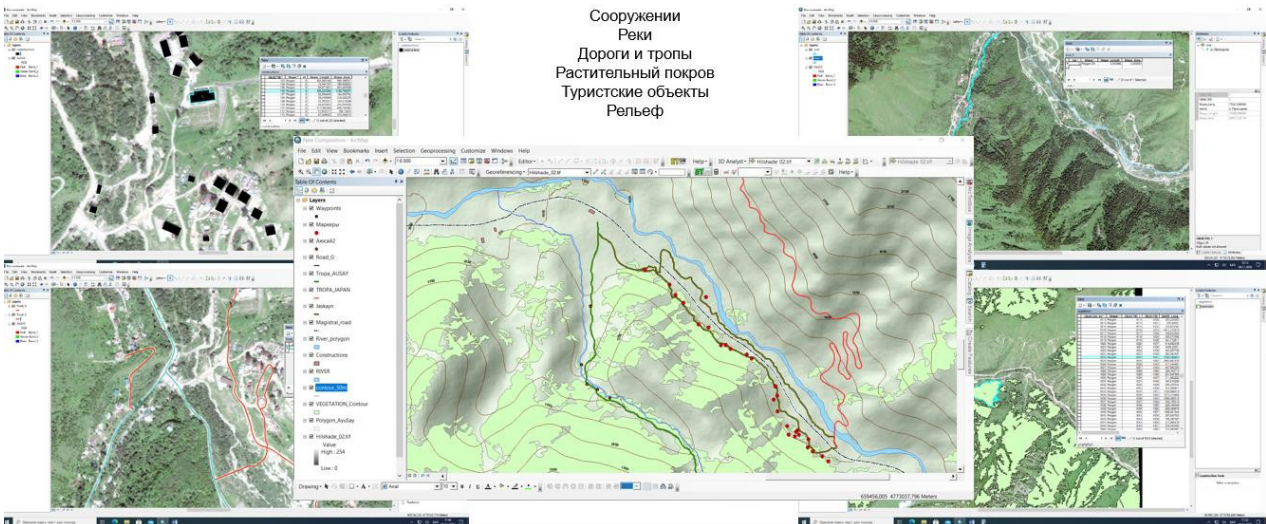


Figure 5 – Vectorization of objects

Before creating the surface, it is necessary to understand how accurate the model is in interpolating the values at the unknown points. Cross-validation and routine checks help to make an informed decision

regarding the choice of model that will provide the best interpolation. Computational statistics serve as a diagnostic tool that shows whether the model and/or the values of the associated parameters are

acceptable. The checks are based on the following principle - removing one or more data locations and interpolating the associated values using the data in the remaining locations (Figure 6, 7) (Performing cross-validation and validation 2016).

Within the framework of the project «Creating a schematic map of tourist routes and

infrastructure of Ayusai Gorge (Ile-Alatau National Park)» the staff of Remote Sensing Centre together with the Department of Recreational Geography and Tourism organized a hike along each trail to verify the location of markers (tourist objects) on the map using a GPS device (Figure 8).

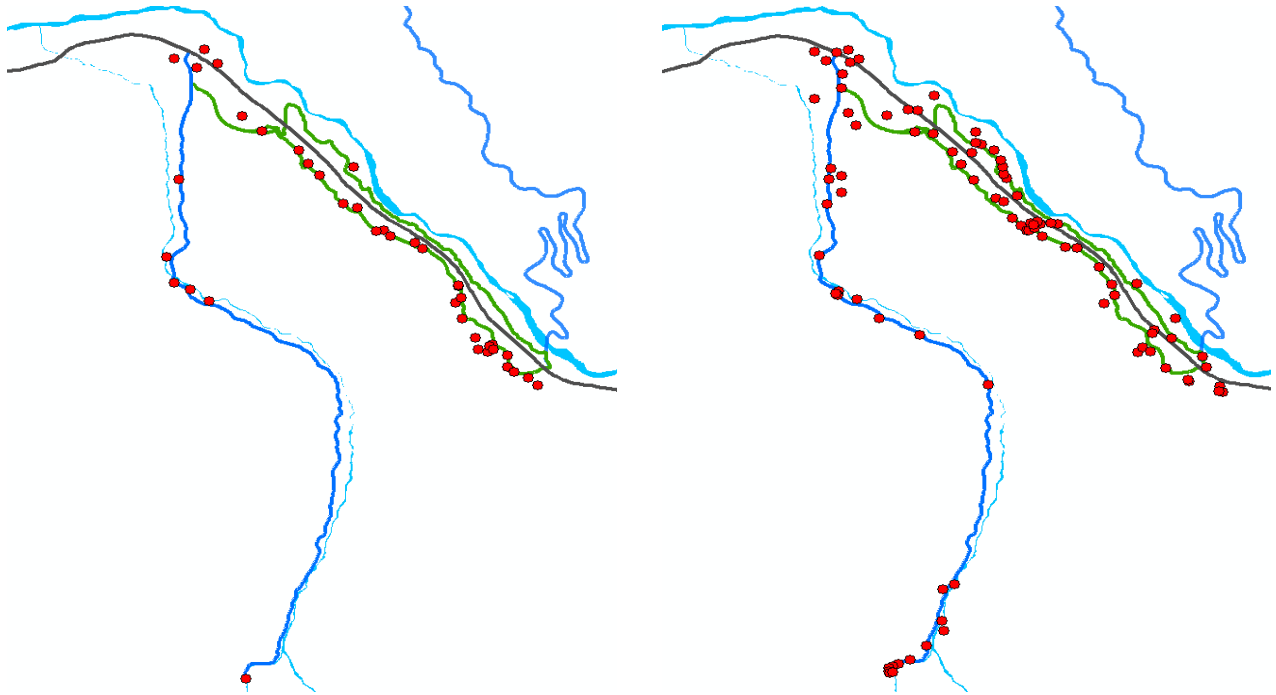


Figure 6 – Markers before and after verification (Myn Koz trail and Ayusai waterfall trail)

Modern GPS receivers are extremely accurate due to their parallel multi-channel signal processing design. Garmin GPS receivers provide location accuracy of up to 15 metres 95% of the time. Users can typically observe accuracies in the range of 5 to 10 metres (16 to 33 feet) under normal conditions (Garmin Russia, 2021).

As a result of the work performed, a map of terrain elevations and vector objects of hydrography, roads, forests, settlements spread over layers was obtained (Figure 9). The created geodatabase also serves as a basis for other applications, as the created maps can be exported to a specific GIS.

After vectorization we move on to map design and layout - placement of the map image itself, title of map, legend, and another data inner the frame and on the fields of the map. If all the elements of the map are arranged appropriately, it is compact enough, i.e. the space of the map is organized rationally, and the image is visually balanced, then the layout of the map is considered successful.

Several factors were taken into account in the map layout: map projection; the shape of the depicted area (water area); its orientation within the frame; the need to show neighbouring areas; the size of the legend; the placement of inset maps; additional graphs, diagrams, etc.

Especially many problems arise when mapping territories with a complex non-compact configuration. Then the remote part of the territory can be given in the inset. In other cases, the protruding parts of the mapped area are displayed in the frame breaks. Sometimes the inset repeats the same area, but on a smaller scale. Sometimes several territories (or one territory several times) are freely placed on one sheet without frames, they are called “floating” layouts. Depending on the configuration of the territory, a place is chosen to place the name of the map, legend, scale inside or outside the frame - the design options are very diverse.

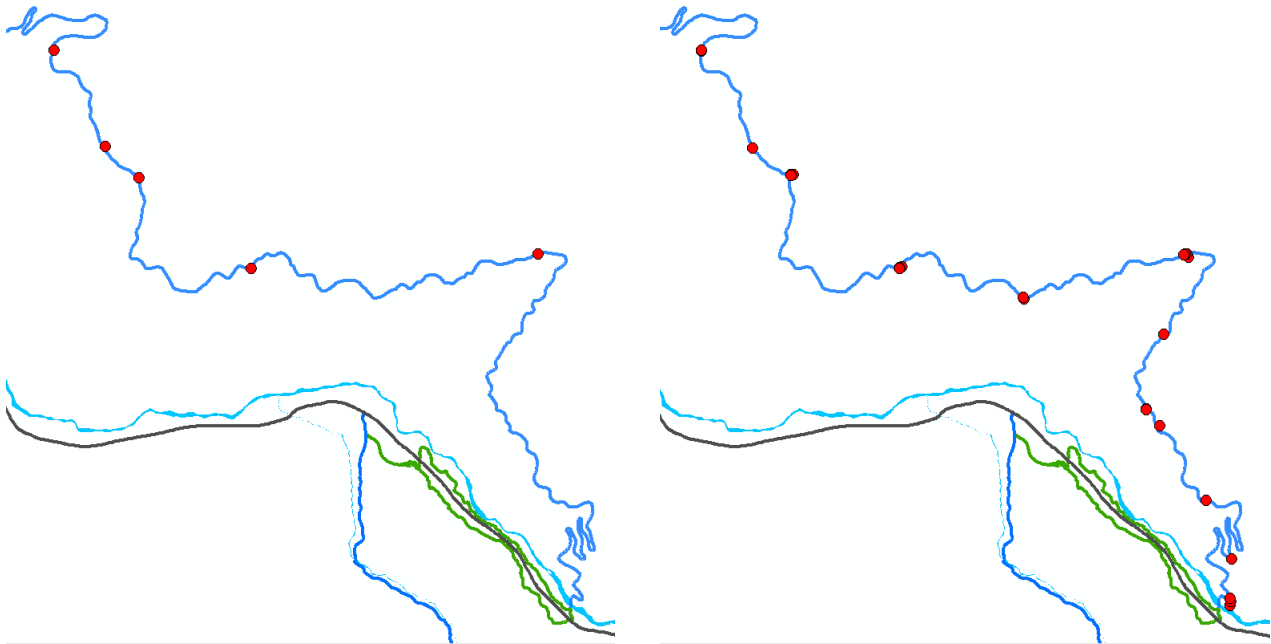


Figure 7 – Markers before and after verification (Japanese trail)



Figure 8 – Hike for verification along the Myn Koz trail, the trail to Ayusai waterfall trail and the Japanese trail

A map representation is constructed on a mathematical basis, the elements of which in a map are the map projection, the coordinate grids, the scale and the base. The choice of projection is influenced by many factors, which can be grouped as follows:

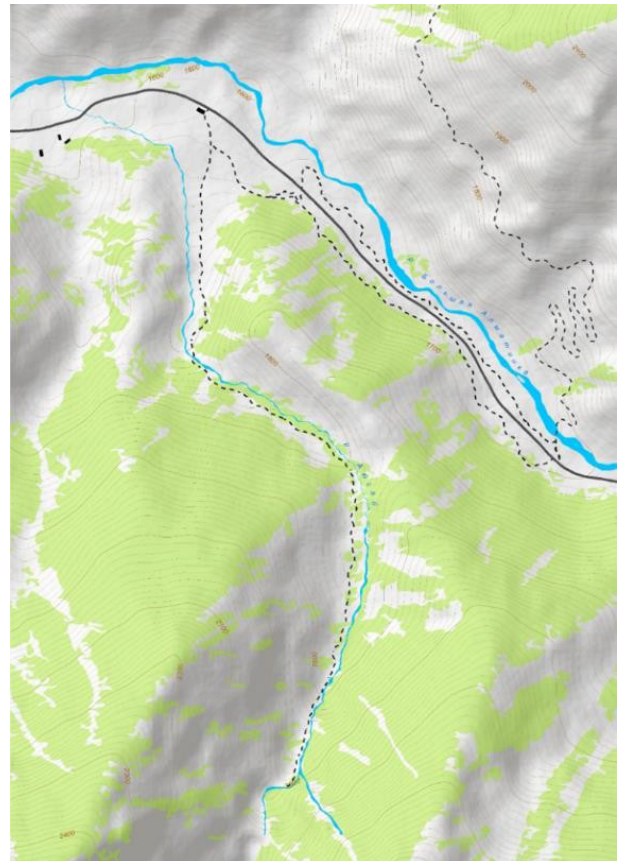
- the geographical features of the area to be mapped, its position on the globe, size and configuration;
- the purpose, scale and theme of the map, the intended audience;

- the conditions and uses of the map, the tasks to be performed on it, and the requirements for the accuracy of the measurements.

Using RS data, trail maps and infrastructure were created for three trails: Japanese Trail, Ayusai waterfall trail, and Min Koz Trail. The total length of the trails is 14.6 km, of which the Japanese Trail is 10.2 km, Ayusai waterfall trail 1.9 km, and Min Koz Trail 2.5 km (Figure 10).



Basemap of OpenStreetMap (OSM)



Digitized basemap with hillshade

Figure 9 – Comparative result of vectorization (digitization)

Creating a digital elevation and terrain model. Digital elevation models (DEM) are one of the important modelling functions of geographic information systems, comprising two groups of operations. The first of these serves the task of creating a terrain model, while the second serves the task of using it.

A DEM is a quantitative representation of Earth's surface data and spatial information, which has become a vital source of elevation, slope and terrain information for scientific research and researchers. It replaces traditional paper topographic data sources and formats. It also takes over data structures for storing, displaying, and analyzing topographic information.

DEM can be derived from a variety of sources: interpolation of contour lines, existing topographic maps, field surveys and photogrammetry, with field surveys being the most accurate compared to other sources.

The Alos Palsar satellite image data was used to create DEM and altitude contours of the study

area, as well as to obtain the markings of the hiking trails' benches. All the images were atmospherically, geometrically and radiometrically corrected in ENVI 5.0 SP3, ArcGIS 10.7 and ArcGIS Pro 2.7 software.

Thus, the source data for the digital elevation model (DEM) was the ALOS PALSAR survey with 12.5 m resolution (Figure 11).

After the standard correction of the input data, DEM of the project area was recreated taking into account the correction of abnormal heights using the GPS coordinates of the terrain points. The resulting DEM was used to create a 3D terrain model and elevation isolines on the ArcGIS Pro platform.

The main stages of the technology for creating a digital terrain model based on satellite imagery using available cartographic materials include:

- collecting available cartographic materials, ordering satellite images;
- control of the correspondence of the coordinates of the points of the image and the terrain;
- recalculation of coordinates, frame transformation, accuracy check;

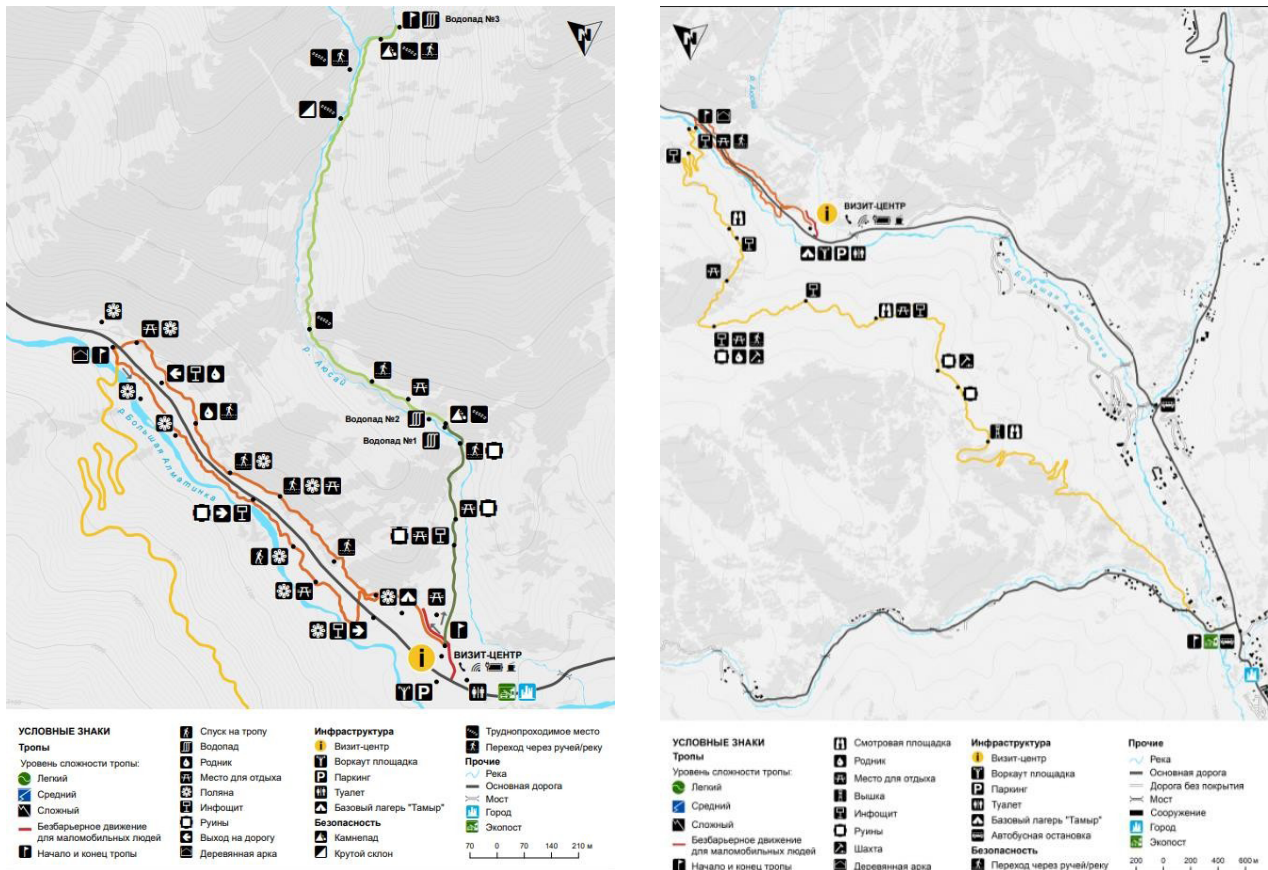


Figure 10 – The final version of the schematic map approved by Turanga Group LLP

- interpretation and creating layers of a vector map;
- creating the digital terrain model and verification of its accuracy;
- producing a hard copy of the map.

The first stage is the ordering satellite images and collection of existing cartographic materials. They can be used to estimate the geo-referencing error of the satellite image, as well as to create a digital terrain model.

It is also required to check the position of the image in the study area. An additional request to the image archive (catalog) is generated when “uncovered” areas are detected. If the contrast of the selected objects is disrupted, this operation is also performed. When it is necessary to correct the spectral brightness of the processed fragments, processed from several satellite images acquired at different times from different satellite orbits, then the initial information about the study area can be done in the ENVI program. The problem of ortho-rectification of an image arises after obtaining high-quality fragments.

A set of reference points and a digital elevation model with sufficient accuracy in elevation and in the plan are required for orthorectification. The determination of coordinates of reference points is commonly uncomplicated, but the situation with acquiring a digital terrain model is deadlocked. Highly accurate digital terrain models are the domain of the military. The American Alos Palsar terrain model with a spatial resolution of 5 m is the only thing that the ordinary user can rely on.

A survey base has been created in the form of a network of reference points, which are specially installed geodetic signs for photogrammetric processing of digital data received from Turanga Group LLP. The survey network became the basis for subsequent photogrammetric processing of the digital images. Satellite-based determinations have been completed in two steps in the research:

- acquisition of a large amount of satellite measurements;
- continue statistical processing with the determination of surveying points’ coordinates.

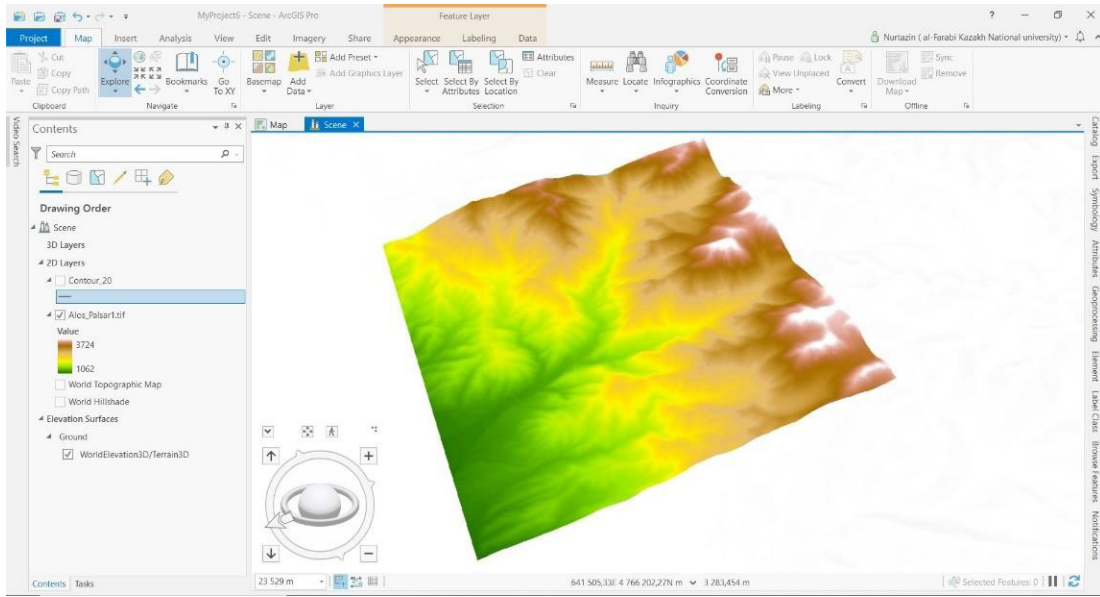


Figure 11 – Creating a digital elevation model of the Ayusai Gorge in ArcGIS Pro

Tasks of transferring points on a digital image in a pixel coordinate system to a terrain coordinate system, building on them digital irregular (TIN, Triangulated Irregular Network) and regular (DEM, Digital Elevation Model) surface models and textured terrain models (TMM, Textured Terrain Model) based on them and orthophotomaps were solved in the process of photogrammetric processing of the results of aerial photography of

the UAV. At an altitude of 170-200 m with 60% overlap of images, an aerial survey of the UAV was carried out. The coordinates of a large number of points on digital images, as well as a 3D model of the textured surface were obtained during photogrammetric processing (Figure 12). Large-scale orthophotomaps of the study area (M 1:1000) and a DEM were created as a result of the digital processing of the aerial photos.

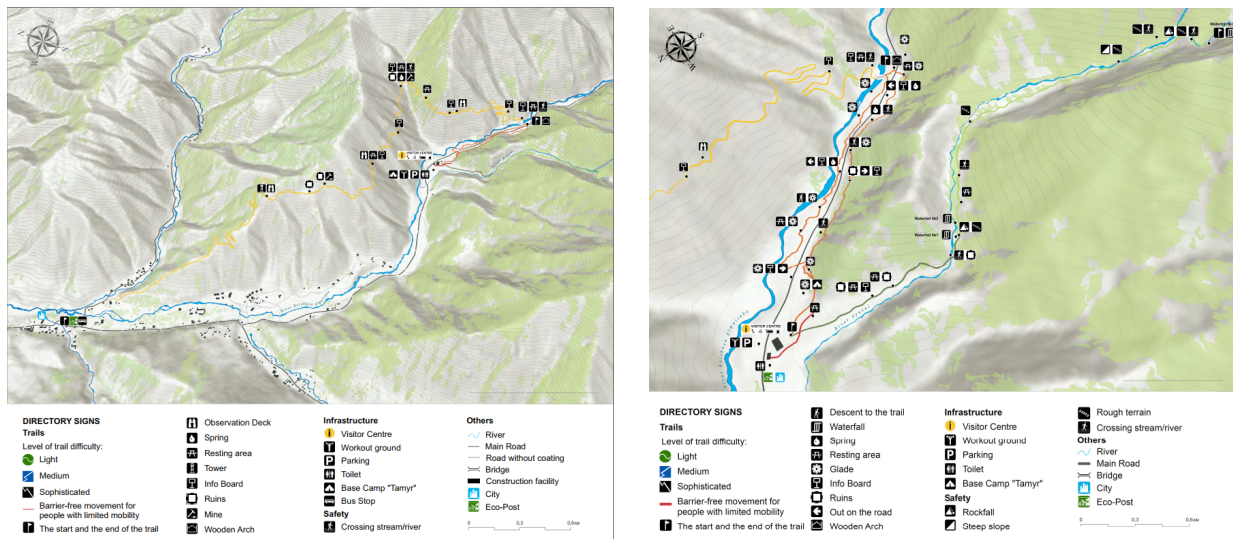


Figure 12 – Final version of 3D schematic map approved by Turanga Group LLP

Three-dimensional terrain modelling in the planning and development of tourist routes allows to clearly show the area, the features of the terrain.

Conclusion

Taking into account the above, the set goal of creating a schematic map of routes and infrastructure along Ayusai gorge of the Ile-Alatau National Park based on GIS technologies involves solving the following tasks:

- analysis of experience in the creation of multi-tasking maps using RS data was carried out;
- an interactive digital database was created;
- using RS data, maps were created for routes and infrastructure along the Ayusai gorge (Japanese trail, Ayusai waterfall trail, Min Koz trail);
- attributive and geometric data were entered into the geodatabase with reference to the coordinates of the routes of tourist trails, resting places, points of passage through water bodies, gazebos, benches and other objects;
- verification of objects along the trails, indicated on the vector schematic map of the given area, was carried out;

– a three-dimensional digital elevation model (DEM) was created.

Thus, in order to promote and improve the services offered by the national parks, our geographical maps will help to attract and discover new tourist destinations.

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