Charvak reservoir modeling based on geoinformation systems

M. Ikramova[1*], *Sh.* Umarova[2], *I.* Ahmedkhodjaeva[3], and *K.* Akhmedkhodjaeva[1]

[1]Scientific Research Institute of Irrigation and Water Problems, Tashkent, Uzbekistan
[2]University of World Economy and Diplomacy, Tashkent, Uzbekistan
[3]"Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Tashkent, Uzbekistan

Abstract. The article describes the Charvak reservoir morphological map development, created using the softs capable of processing, analyzing, and visualizing high-resolution satellite geodata. The study determined the amount of useful volume change during the reservoir's operation. The map was designed to be interactive and processed in real time using GoogleEarth and ArchGIS analytical tools. The study aims to improve effective monitoring of the changes in water reservoir capacity and forecasting the further operational period of the reservoir. The research demonstrates the potential of geoinformation technologies to improve water resources management.

1 Introduction

The Republic of Uzbekistan's economic sectors presently consume 50-55 km^3 of water each year, with approximately 20-22 km^3 managed by 55 large and several small water reservoirs. Effectively managing these reservoirs is crucial in ensuring an adequate water supply for agriculture and energy production. However, during the reservoir operation, morphometric changes occur within the reservoir area, leading to siltation of the upper section and a subsequent reduction in the reservoir capacity, negatively impacting economic efficiency [1-7]. Thus, it is necessary to use GIS technologies to model the operating modes of reservoirs, allowing for the monitoring and prediction of the process of mud accumulation in the reservoirs. The obtained detailed data and based on this, improved reservoirs' operation terms allow to increase the service period of the reservoirs, leading to a greater efficiency in water use [8-9]. The above-described issue is urgent and important for Uzbekistan's water management sector.

The Charvak reservoir in the Tashkent region was constructed on the Chirchik River with a catchment area of 14,240 km^2. The river flow is primarily sourced from the Chatkal and Pskem rivers, with an average long-term water consumption rate of 225 m^3/s. Notably, the maximum water flow entering the reservoir varies between 320-790 m^3/s in June, as observed between 2001 and 2021, whereas the minimum flow occurs in February (see Fig. 1). Analysis of the reservoir's flow control data over the operational period indicates a

* malika.ikramova56@gmail.com

maximum volume range of 1487-1544 million m^3 (observed in 2009 and 1988) and a minimum volume range of 843-900 million m^3 (observed in 2000 and 2008) (Fig. 2).

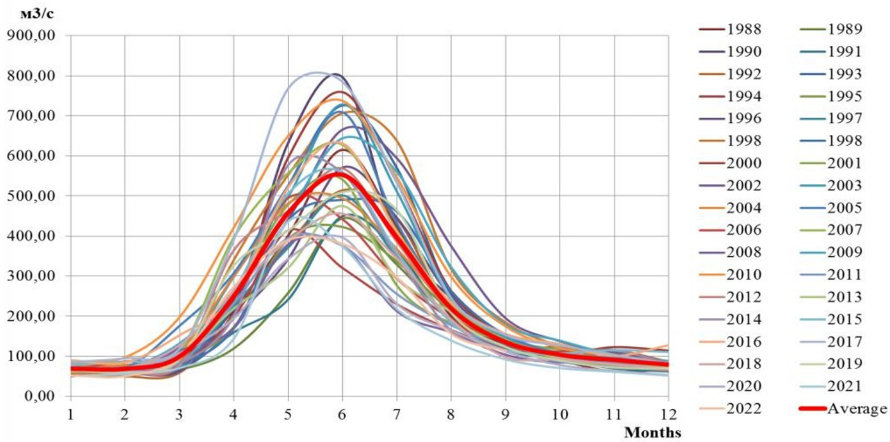

Fig. 1. Regulation of river flow by Charvak reservoir

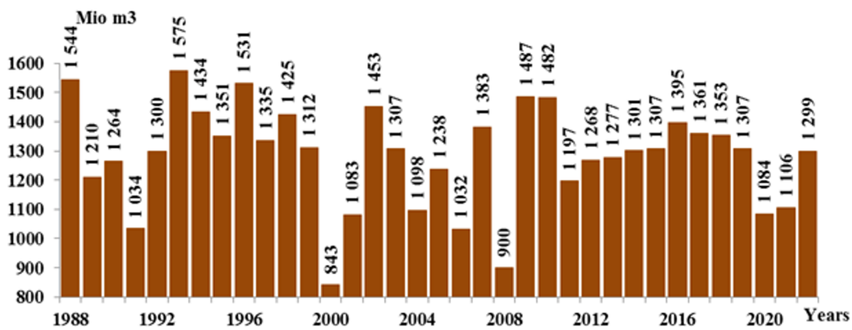

Fig. 2. Reservoir flow control

The Charvak reservoir has a full design capacity of 2,0 billion m^3, with 1.8 billion m^3 useful volume. Upon its initial operation, a bathymetric survey was conducted in 1985, which revealed a total volume of 1.99 km^3 and a useful volume of 1.58 km^3 (A.M. Nikitin). Subsequent measurements in 2011 indicated that the reservoir's total volume had reduced to 1.95 km^3, with a useful volume of 1.526 km^3 (Hydroproekt). Since then, no further reservoir capacity measurements have been conducted.

Various Geographic Information System (GIS) software tools, such as ARC/INFO, ArcView, TerraSoft, IDRISI, MapInfo, AtlasGIS, and MGE, are used for research purposes. Numerous scientific studies have focused on fuzzy methods for reservoirs' storage capacity determination [10-11]. Researchers use modern software models to study the reservoir's operation processes [12-18]. Aerospace methods, including satellite data, are widely used to determine hydrological and morphological changes in reservoirs [19-23]. While satellite data can provide water depth information, it is not always accurate for shallow water areas. These topics have been explored in academic literature, including studies by Sabah et al. (2013), Zhu et al. (2022), Rahuba et al. (2015), Alfredo et al. (2010), Becker et al. (1974), Burnham (2007), Dalabaev et al. (2022), Heydari et al. (2016), Khosronejad et al. (2007), Lee et al. (2007), Zhang (2009), Vlatsky (2010), Kalinin (2010), and Samardak (2005).

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2 Materials and Methods

To assess the morphological changes in the Charvak reservoir, a morphometric map was generated using various software programs such as Google Earth Pro, ArcGIS, and AutoCAD. The Google Earth Pro program was utilized to obtain information about the area as it allows for the processing, analysis, and visualization of geodata based on high-resolution satellite images. The GPS Visualizer was employed to process the geographic information in the created file and create maps and level profiles based on the data. This online utility facilitates the quick visualization of geographic data in either 2D or 3D view and enables the downloaded output file to be converted into gpx format. Finally, ArcGIS was used to continue the work based on the geographic information obtained from the previous steps.

ArcGIS software offers an array of advanced tools for spatial data analysis, geocoding, dynamic segmentation, cartography, raster processing, buffer zone creation, pattern identification, and data management. The downloaded geographic data in gpx format was used to create terrain horizontals in the ArcMap section of the ArcGIS program [22-24]. Spatial data processing was mainly carried out through the commands available in the ArcToolbox window. The conversion of the gpx file from GPS Visualizer to ArcMap was achieved through the command sequence ArcToolbox >> Conversion Tools >> From GPS >> GPX To Features [21-23]. The program window showed a new layer with a set of points on the contour drawn in Google Earth Pro in the Layers section of the Table Of Contents panel. Using the Open Attribute table command from the context menu, the table of all points' parameters, including the elevation of all geographic points in the Elevation column, could be viewed.

3 Results and Discussion

During the analysis of the Charvak reservoir, the terrain horizontals were established, and all geographical points were identified. To draw the desired contour on the area's plane, the Add button can be selected from the tool panel of the software, and a line can be drawn horizontally, vertically, or in any direction. The accuracy of the contour will improve with an increase in the number of points used. The resulting area in the program panel will have a visual appearance (Fig. 3).

Fig. 3. Charvak reservoir area

To generate a raster map that represents the elevation of geographic points, the ArcToolbox >> Spatial Analysis Tools >> Interpolation >> IDW command sequence is employed, and the required parameters are specified. Subsequently, a raster map based on the height of geographic points is produced and displayed in the window (Fig. 4).

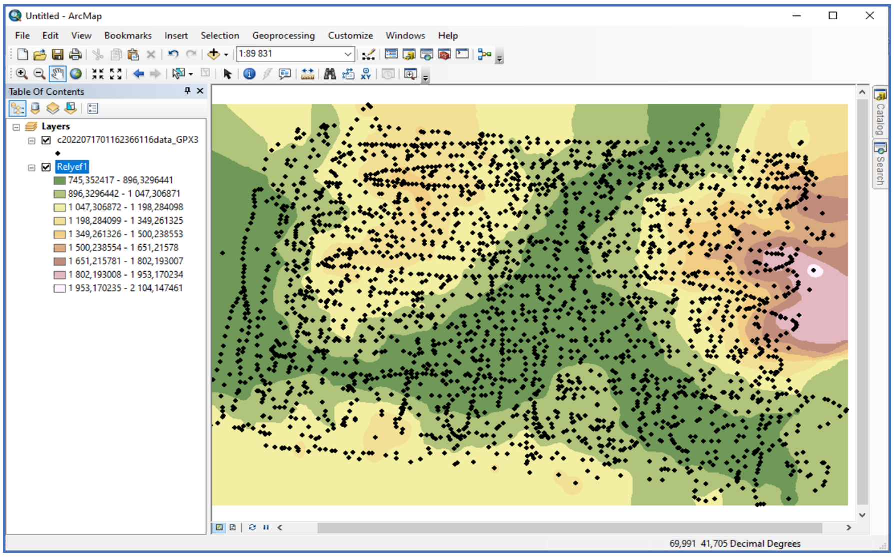

Fig. 4. Raster map of area.

To explain each color on the map, the Table Of Contents panel can be referred to, for example, dark green on the map signifies an elevation between 745-896 meters. To add projections of horizontal terrain sections to the map, the ArcToolbox >> Spatial Analyst Tools >> Surface >> Contour command sequence can be utilized. This requires selecting the appropriate file for the Input field and choosing the distance between horizontals from the Contour Interval field. The height indicator of the horizontals on the map can be modified by accessing the Labels section of the Properties window via the context menu above the relevant layer in the Table Of Contents panel. The resulting horizons can then be exported to a shape file (vector format) using the Data >> Export Data… command sequence from the context menu (Fig. 5).

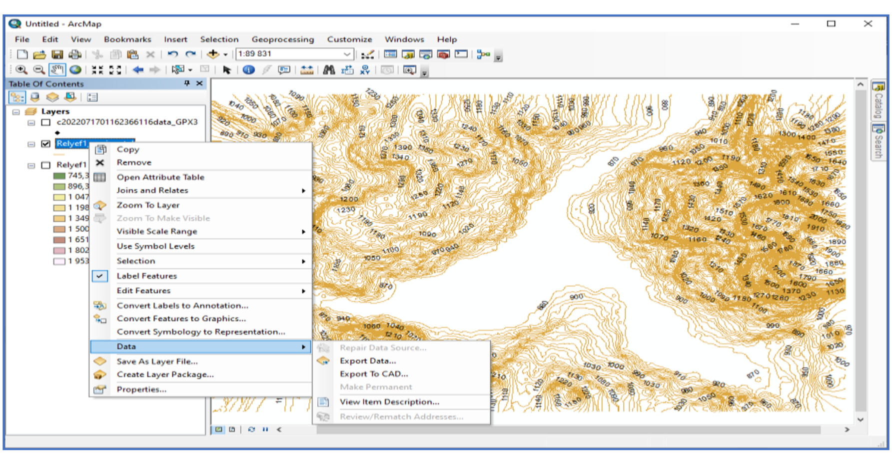

Fig. 5. Data export

To process the data created in ArcGIS in AutoCAD, the ArcToolbox was used with the command sequence ArcToolbox >> Conversion Tools >> To CAD >> Export to CAD. In the dialog box that appears, the appropriate file was selected for the Input field, and the format of the corresponding version of the AutoCAD program was selected in the Type field for Output (Fig. 6).

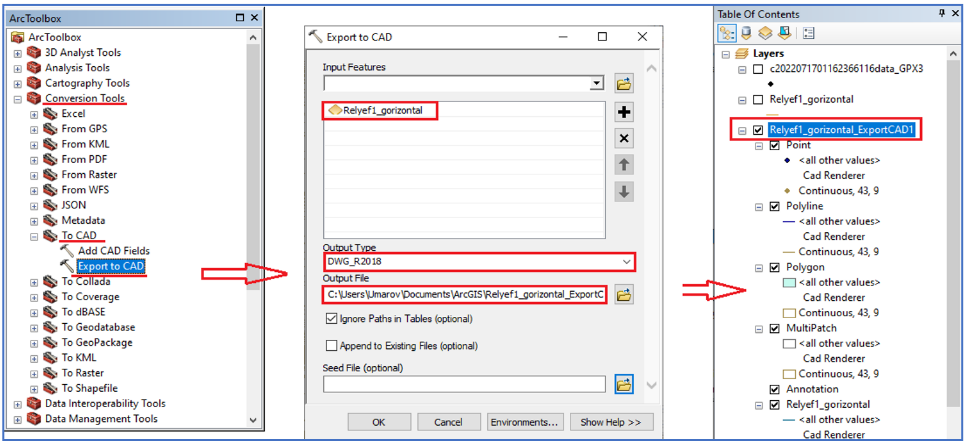

Fig. 6. Saving data in CAD format

The map's visual display was altered, and multiple appropriate layers were generated in the layers panel (refer to Figure 7). Employing the Google Earth Engine program, a technique was developed for analyzing alterations in the water surface area over the years, utilizing the information within the .csv format file that was stored. By utilizing the acquired data, it was determined that the capacity of the Charvak reservoir is predicted to decrease to 1475.26 million m^3 by 2022, with 325 million m^3 of volume being covered by mud.

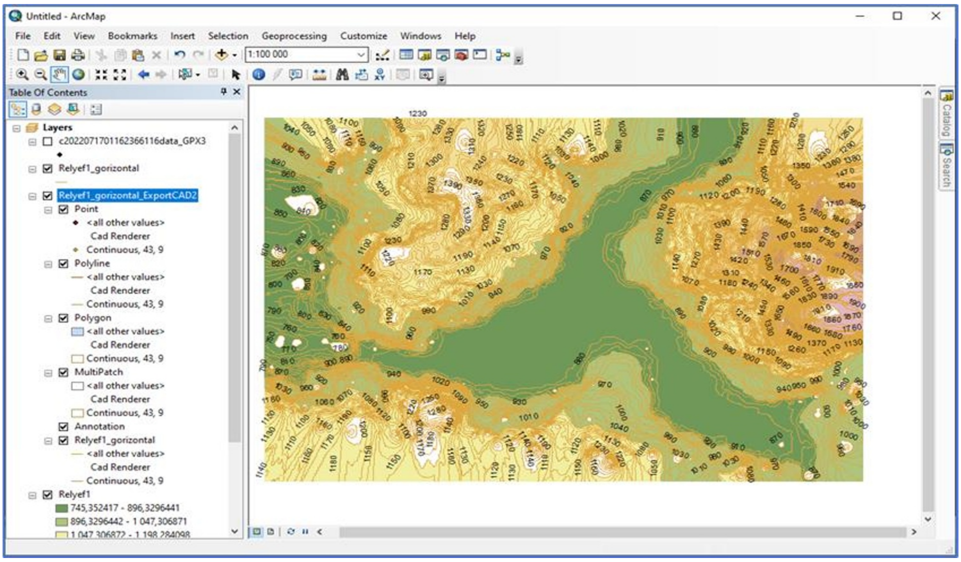

Fig. 7. View of Chervok reservoir in CAD format

4 Conclusions

As part of the research, a digital elevation model of the Chervok reservoir was created using cartographic materials, and morphometric characteristics were calculated using GIS tools. The analysis of the results revealed that the reservoir's capacity has decreased to 1475 million m^3, and the volume of sedimentation has increased to 324.74 million m^3, indicating a 19% reduction in capacity during its operational period. These findings provide valuable insights into the hydrological regime of the reservoir and enable the forecasting of future changes in the hydrological process, thereby facilitating timely and rational decision-making.

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