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Analysis of Hydrological Characteristics of River Basin Based on Arcgis: A Case Study of Qinhe River Basin

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ABSTRACT: On the basis of understanding the basic principles of hydrological analysis based on DEM data, this paper introduces the method, steps, and process of using 10.8 for hydrogeological analysis. According to the rich topographic and geomorphic information in DEM, the hydrological analysis tool provided by 10.8 is used to simulate and analyze the hydrological characteristics of the Qinhe River basin without depression, extract the real flow direction, Cumulant of confluence, and river network information of the region, simulate the Qinhe River basin, quickly and accurately identify all sub basins, and determine the location of the basin outlet, so as to realize the simulation and analysis of the hydrological characteristics of the region. The research contents and results provide help for hazard prediction, soil quality research, precipitation analysis, and application analysis of Hydrological model.

KEYWORDS: ArcGIS;DEM;Qinhe River Basin;hydrographic features

1. PREFACE

Digital elevation model (DEM) is a mathematical model that approximates the surface elevation information, including a large number of hydrological elements and topographic information. It can extract a large amount of land surface morphological information, including the slope, slope direction and topological relationship between the units of the flow city grid, etc., which is widely used in many disciplines and scientific research fields such as national geographic information foundation, three-dimensional visualization display, topographic and geomorphic micro-features, geological survey and monitoring.

At present, scholars at home and abroad have developed a variety of mature and reliable algorithms and software that can generate digital watershed models. Based on certain algorithm analysis, DEM data is used to simulate surface hydrological characteristics, determine surface flow path, river network and watershed boundary, and form a runoff production and confluence system for hydrological simulation. With its comprehensive spatial analysis function and powerful data processing capability, ArcGIS platform can superposition the information of basin geology and geomorphology, sub-basin classification, vegetation cover and land use on DEM, and obtain some parameters required for hydrological simulation (such as land use type, vegetation interception parameter, groundwater confluence parameter, etc.) through superposition analysis and statistical analysis. Based on the hydrological analysis tool of ArcGIS10.8 and DEM data as the data source, this paper simulated and analyzed the hydrological characteristics of the Qinhe River Basin, which could provide basis for water resources management evaluation, land use and ecological construction planning of the Qinhe River Basin.

2. OVERVIEW OF THE RESEARCH AREA

The Qinhe River basin covers an area of 13,532km2. It originates from Erlangshen Valley at the south foot of Huoshan Mountain, Qinyuan County, Changzhi City, Shanxi Province, flows from northwest to southeast through Anze County, Fen City, Qinshui County, Yangcheng County and Zezhou County, Jincheng City, Shanxi Province, and then enters Henan Province, passes through Jiyuan, Qinyang, Boai, Wen County and other counties, and joins the Yellow River in Wuzhi County.

2.1 Topography and Landform

The elevation of the mountains on the edge of the basin is more than 1500 meters, and the elevation of the central mountain is about 1000 meters. The Shishan forest area is mainly distributed in the upper and middle reaches of the basin, accounting for about 53% of the basin area. This type of area has good vegetation and slight soil erosion. Due to the high slope and dense forest, the topography and vegetation still retain the original natural landscape. The earth and rock hilly area is mainly distributed in and around the Zezhou Basin in the middle of the basin, accounting for about 35% of the basin area, which is the area seriously affected by human activities in the Qinhe River Basin. Compared with other type areas in this basin, the vegetation of this type area is poor, and the soil erosion is slightly heavy, but the soil erosion intensity is not large in general. The alluvial plain area is distributed below Wulongkou, Jiyuan, including river valley flat, gentle slope, fan-front depression and downstream alluvial plain, accounting for about 12% of the basin area. With flat terrain, good water conservancy conditions and developed agricultural production, this type area is the main area for agricultural production and irrigation development in the basin, and is also a high production area for crops.

2.2 Geological Overview

The Qinhe River basin belongs to the southeast corner of the western ancient land of Taishan in the Middle Dynasty. The geotectonic structure belongs to the inner clinal basin between the platform margin and two major anticlines (Huoshan anticline and Taihang anticline). The orogeny affected the horizontal stratification of strata and formed fold structure. There are Pangusi faults in Hekou Village of Qinhe River, and there are also east-west faults from Longmenmen-Houchen of Danhe River, which form the boundary between mountain area and plain.

The law of recharge, runoff, discharge, distribution and storage of inland water is affected by topography, landform, lithologic structure and other factors, and there is uneven in horizontal direction and vertical direction. The hydrogeological conditions in the basin are relatively simple. In the middle and lower reaches of the alluvial plain and on both sides of the river course, there are mainly loose rock pore water, which is recharged by atmospheric precipitation and surface water leakage. The water-rich water is good and the water quality is good, which can be used for drinking by residents. In the north of Yangcheng, Qinhe River is mainly clastic rock fracture water, groundwater exists in fracture or weathering zone, the buried depth is relatively shallow, the recharge and discharge conditions are relatively simple, mainly receives the vertical infiltration of atmospheric precipitation, and is discharged in situ through the form of loose spring, the runoff process is short, the adjustment ability is poor, and the water level and discharge vary greatly. In the eastern and southern part of Qinshui Basin, there are mainly clastic rocks with carbonate fissure karst water, the degree of water richness is very uneven, and the salinity is generally low. The Danhe River basin mainly consists of carbonate karst fissure water, which is an important water-bearing type in the basin. From the horizontal direction, the degree of karstification in each karst spring field generally changes from weak to strong from recharge area to runoff discharge area, and from vein to tubular karst cave. In the vertical direction, the karst development is stratified and phased, and there are generally three karst development layers in the basin, and the karst water in each layer has different water richness besides different degree of hydraulic connection. Whether in the horizontal direction or the vertical direction, the degree of karst development shows the characteristics of uneven strength. Generally, in the exposed limestone area, it has the characteristics of strong above and weak below, most of them belong to karst diving, but in the drainage area, because of the uneven development of karst and the reason of multi-layer, it often has the bearing property.

2.3 River System

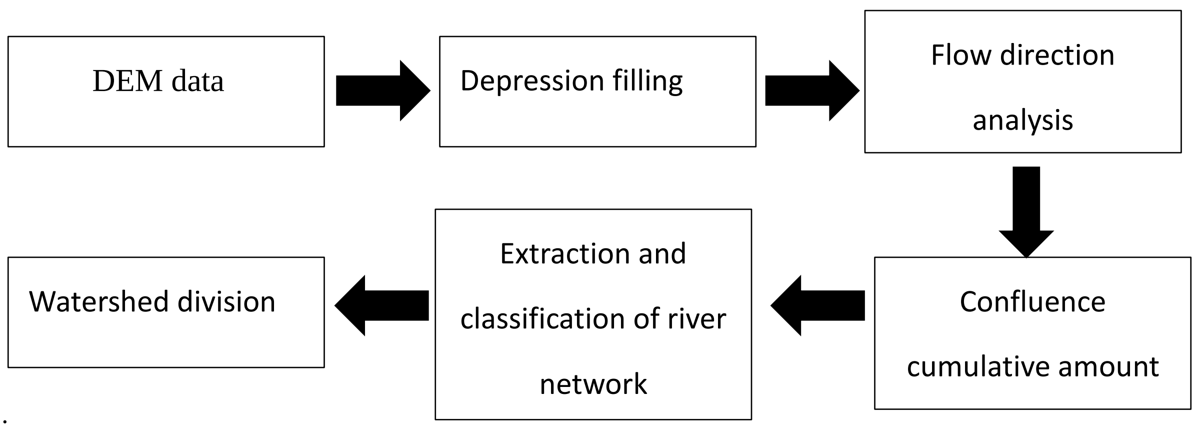
There are many tributaries in the Qinhe River basin, of which 30 are longer than 25km. Danhe River is the largest tributary of Qinhe River, originating in Danzhu Ridge, Gaoping City, Shanxi Province, flowing north to south through the outskirts of Jincheng, entering the Taihang Mountain valley, and then exiting the valley into the alluvial plain, entering the Qinhe River in Beijin Village, Qinyang City, Henan Province. The total length of the Danhe main stream is 169km, with a drainage area of 3152km2, accounting for 23% of the Qinhe River basin area. The runoff of Qin River is mainly formed by rainfall. Part of the rainfall forms surface runoff and flows directly into the river channel, while the other part penetrates into groundwater. Because the terrain of the main stream is high in the north and low in the south, the inland water flow of the basin flows from north to south, and the water supply in the form of spring water in the dry season. Yanhe Spring, Sangu Spring and other large springs in the basin are the main natural drainage centers. Yanhe Spring, located in Yanhe Village, Yangcheng County, is the largest of a series of spring groups within the range of 20km from Bajiakou to Ximotan in the main stream of Qinhe River. In the south of Yanhe Spring there are still spring groups exposed, the larger discharge points are Xiahe spring Zhaoliang spring, Motan spring and Heishui Spring. Sangu Spring is located in Sangu Spring Village on the west bank of Danhe River near the border of Shanxi and Henan. The spring water is concentrated in the form of strands and is the main water source of Qingtian River reservoir. Along the Dan River to the north of Sangu Spring, there are other large outcrops such as Guobi Spring, Tupo Spring, Baiyang Spring, Xiaohui Spring and Taibei Spring.

3. CONTENTS AND METHODS OF HYDROLOGICAL ANALYSIS

The basic maps used in hydrological analysis are generated by DEM according to different algorithms and processes. To achieve better results, DEM with high data quality and accuracy must be selected. The basic DEM data selected in this paper comes from the geo-spatial data cloud platform GDEMV2 30M resolution digital elevation data, and the quality of the data meets the requirements of surface hydrological characteristics simulation analysis.

3.1 Contents of hydrological analysis

The main content of surface hydrological analysis based on ArcGIS is to use hydrological analysis tools to fill the DEM depression, extract the flow direction, water flow, extract the river network, analyze the river network, calculate the indicators of the river network, and extract the basin through these indicators, capture the confluence point, finally determine the water outlet of the catchment area, and realize the segmentation of the basin in the study area



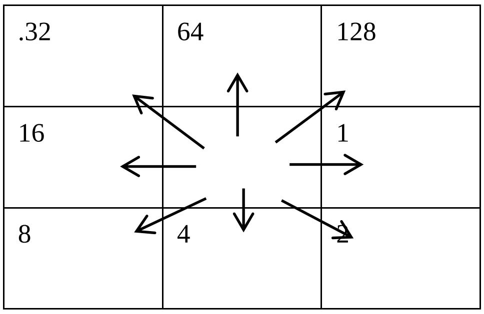
3.2 Hydrologic analysis method

3.2.1DEM pretreatment

DEM is a relatively smooth terrain surface simulation, the quality of which determines the accuracy of water flow direction extraction. Due to the equipment difference, data noise, various interpolation methods and some real terrain (such as karst landform), DEM data often contains some depression information. Depressions may be the real form of the surface, or data errors caused by DEM production. In the surface flow simulation of areas with depressions, due to the existence of low elevation grids, the river flow extracted from DEM will be not smooth, and the flow direction will be deviated or even reversed, which will affect the accurate extraction of hydrological factors. A complete basin river network cannot be formed. Therefore, before calculating the flow direction, depression-free DEM should be obtained by filling in the original DEM data first. The DEM will be smoother after being adjusted by this value, and the generated flow direction matrix can better determine the flow direction and basin boundary to ensure that the correct flow direction can be obtained in subsequent process analysis. In ArcGIS, depression filling can be realized by using the depression filling tool in hydrological analysis.

3.2.2 Determination of water flow direction

In order to divide the watershed boundary accurately, it is necessary to determine the flow direction in each grid unit. The direction of water flow refers to the direction of water flow as it leaves each grid cell. Flow direction calculation is an important part of hydrological analysis, which is used to further determine the catchment area, flow length, catchment basin and other important hydrological parameters. There are many algorithms to determine the direction of water flow. In this paper, D8 single flow direction algorithm is adopted, and the flow direction of water flow is determined by calculating the maximum distance weight drop between the central grid and the neighboring grid. According to the flow law of water flow dependent terrain from high to low, it is considered that the runoff generated by a grid flows to a neighboring cell with the lowest elevation, and the maximum value between it and the neighboring grid is adopted. That is, the maximum elevation difference is taken as the direction of water flow, and the result calculated from this is called the cell flow grid diagram, which shows the direction of water flow when it leaves this cell, and judges the direction of water flow according to the elevation of the grid. There are 8 directions in the flow direction, which are 2 to the n power respectively. The meaning expressed by the attribute value of each cell represents the 8 directions of E, S, W, N, NE, NW, SE and SW from 20-27 respectively. Distance weight drop refers to the elevation difference between the center grid and the neighborhood grid divided by the distance between the two grids. The distance between the grids is related to the direction. If the direction value of the neighborhood grid to the center grid is 2, 8, 32, 128, then the distance between the grids is SQRT(2)=1.414. Otherwise the distance is 1. If the elevation difference is positive, it is outflow; If the value is negative, it is inflow. Surface runoff always flows from high to low in the basin space, and finally drains the basin through the basin outlet. In order to accurately delineate watershed boundaries, it is first necessary to determine the direction in which water flows within each grid cell. The direction direction is determined by calculating the distance weight difference between the DEM center grid and the neighboring grid. The so-called distance weight drop refers to the elevation difference between the center grid and the neighboring grid divided by the distance between the two grids, and the distance between the grids is related to the direction. By specifying the hydrologic flow direction, the direction value of the neighborhood grid to the center grid can be obtained, and the direction of the maximum distance weight drop can be found. If the elevation difference is positive in this direction, it is outflow. If the elevation difference is negative, it is inflow. In ArcGIS, flow direction can be determined by using flow direction tools in hydrological analysis



3.2.3 Calculation of confluence cumulant

In the process of surface runoff simulation, runoff is obtained according to the confluence cumulant, which is calculated based on the flow direction data. The amount of runoff cumulant indicates the number of upstream grids of water that eventually confluence through the grid unit. The larger the confluence cumulant value, the easier it is to form surface runoff in the area. Based on the calculation of the flow direction of the no-depression DEM, the DEM data used is the established and filled no-depression DEM. After the flow direction is obtained, the flow direction data can be used to calculate the confluence cumulant. In ArcGIS, the flow tool in hydrological analysis can be used to determine the cumulative number of upstream cells that flow into this cell to generate a catchment capacity grid. Start from each grid cell and scan the flow direction matrix successively, tracing along the flow direction to the DEM boundary. When the whole flow direction matrix is scanned, the grid distribution map of the catchment capacity can be obtained. The value of each cell on the bus gate represents the total number of upstream grid cells (NIP) flowing into that cell within the upstream bus. If the NIP value is large, it is regarded as a valley. If the NIP value is zero, it indicates that the NIP is higher and may be the watershed of the basin.

3.2.4 Extraction and classification of river network

When the sink flow reaches a certain value, surface water will be generated, and all those grids with sink flow greater than that critical value are potential flow paths, and the network of these flow paths is the river network. In ArcGIS, the con command of grid calculator in map algebra tool or setnull command can be used to calculate and generate river network information. When setting the threshold value, the research area and research object should be fully analyzed, and the appropriate threshold value that can meet the research needs and conform to the topographic and geomorphological conditions of the research area should be determined through continuous experiments and the auxiliary testing method using existing topographic maps and other data. With the increase of threshold value, the total length of river decreases, while the number of river segments extracted gradually decreases, and the minimum and maximum of river length also gradually increase. The number of river segments extracted under different flow thresholds is different, and the number and distribution of the extracted river network will also be different. With the increase of the flow value, the river with small grade will be excluded, making the accuracy of the extracted river network become lower. However, the accuracy of the extracted river network is mainly in the river channel and the river with high grade will not be greatly affected by the threshold value. Then the starting point and ending point of each river network arc are obtained by using the river connection tool in hydrological analysis. The classification of a linear river network is called the classification of river network. In the hydrological analysis of ArcGIS, two commonly used river network classification methods are provided: Strahler classification and Shreve classification, Stahler classification is to divide all the river network arcs without tributaries into the first level, and the river network arcs formed by the confluence of two first-level river network arcs into the second level, followed by the third and fourth levels, all the way to the water outlet of the river network.

The definition of the first-level river network on Shreve scale is the same as that on Stahler scale, but the difference is that in the future, the river network arc formed by the confluence of two first-level river network arcs is the second-level river network arc segment. Then, for the future higher-level river network arc segment, its level is defined as the sum of levels that it merges into the river network arc segment. In this analysis, Strahler's classification method was adopted to obtain the graded river network.

3.2.5 Watershed Division

With the intensification of human activities, the basin has become a very sensitive and complex geographical unit of regional human-land relationship. With water as the hub, the natural geographical elements in the basin, such as the basin area, are classified. Terrain, temperature, humidity, rainfall, vegetation, soil and other natural geographical elements are connected into an inseparable whole, which directly affects the land use status in the basin, and then interacts with human activities.

The core of a basin is the catchment area and the outlet. Firstly, the flow direction is analyzed and calculated, the catchment area is extracted, and then the position of the outlet at the edge of the same basin is determined. That is, in the division of basin basins, the outlet of all basin basins is at the edge of the same drainage area. After the location of the water outlet is determined, the locations of all the upstream grids that flow into the water outlet are also found. Through the analysis and calculation of the flow direction data, all the grids that are connected, have a common water outlet and are in the same basin are extracted, which are the basin basins in the study area. Water outlet is the end point of water flow in each basin, that is, the lowest point in a whole unit, which is obtained by automatic extraction through hydrological analysis and combined with manual screening. During the calculation of flow direction data and confluence cumulative data, the structure information of the river network can be obtained, which records the connection information between nodes of the river network. These node information represent that each arc is connected with two nodes serving as outlet points or catchment points, or is connected with the node serving as outlet points and the beginning point of the river network. The end of the arc is the position of the outlet of the catchment area. Therefore, the outlet vector file is superimposed with the basin basin to obtain the outlet location of the basin at each level.

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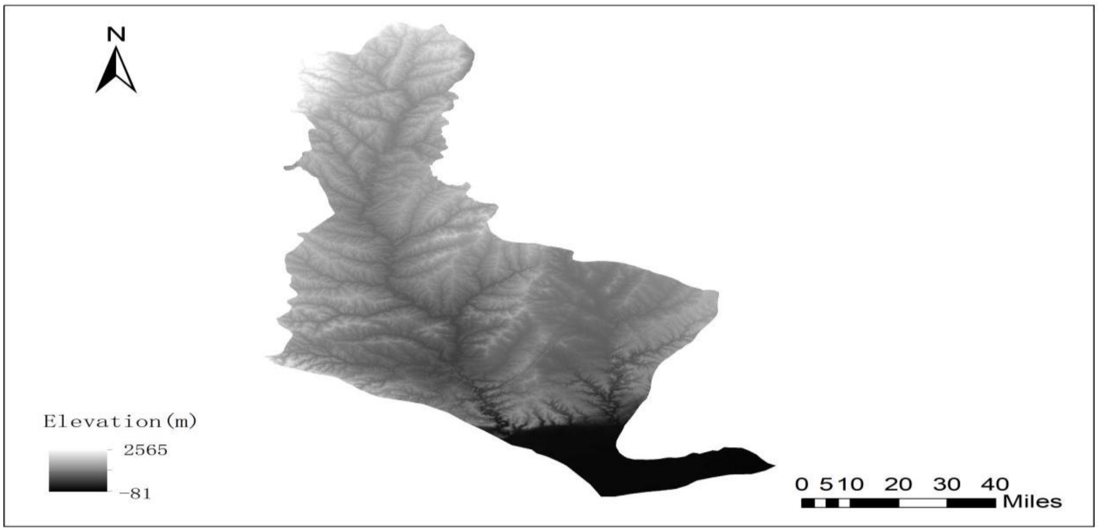
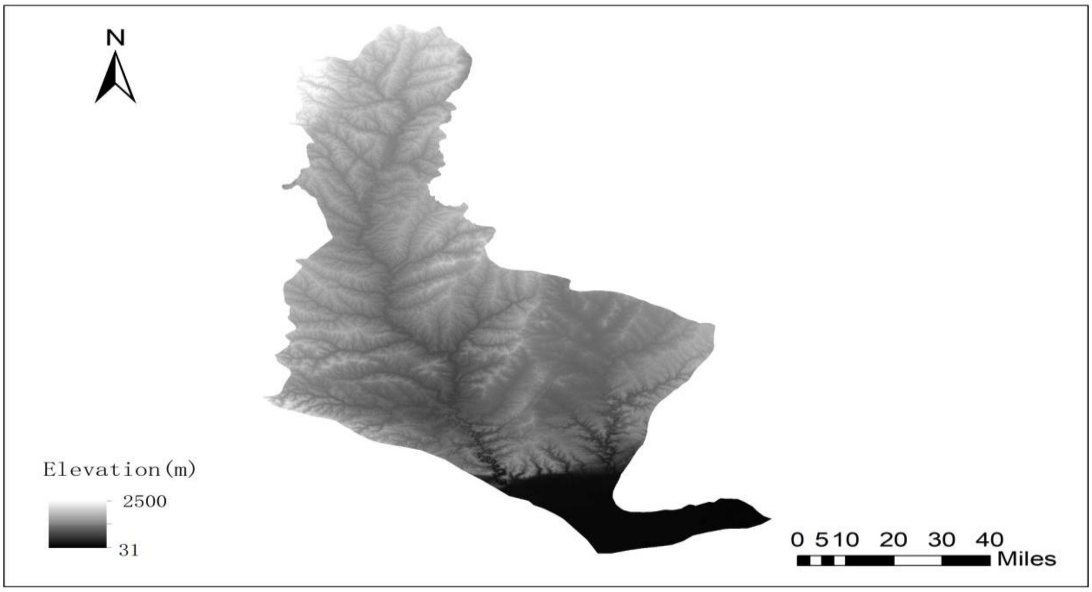
Use vectorization commands in the hydrology tool and catchment tool to divide the watershed, determine the watershed boundaries and the location of the watershed. Firstly, river networks of different scales are obtained according to different thresholds, and then the results of watershed division are obtained by combining watershed analysis tools. In this paper, the thresholds of river network extraction are set as 500, 1000 and 2000, and the basins with the above thresholds are superimposed and compared with the existing actual topographic maps to select a reasonable threshold for watershed division.

4. ANALYSIS OF HYDROLOGICAL CHARACTERISTICS OF QINHE RIVER BASIN

After data acquisition, ArcGIS10.8 was used to Mosaic, projection transformation and tailoring DEM data to generate DEM in Qinhe River Basin. The clipped DEM was preprocessed by using the hole filling tool in hydrologic analysis. The DEM original image after cropping and DEM image after filling are shown in the following figure

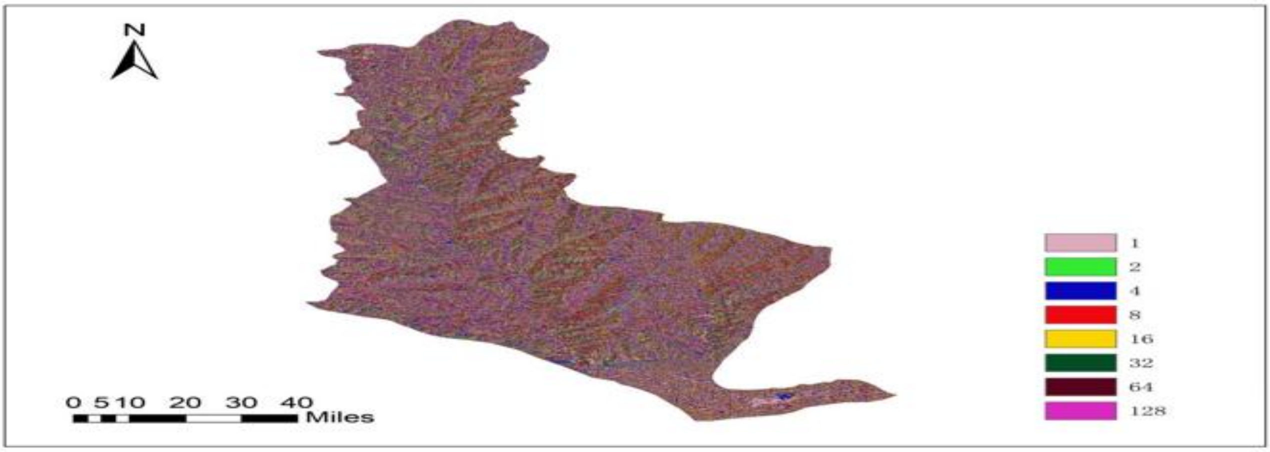


（a）DEM before depression filling

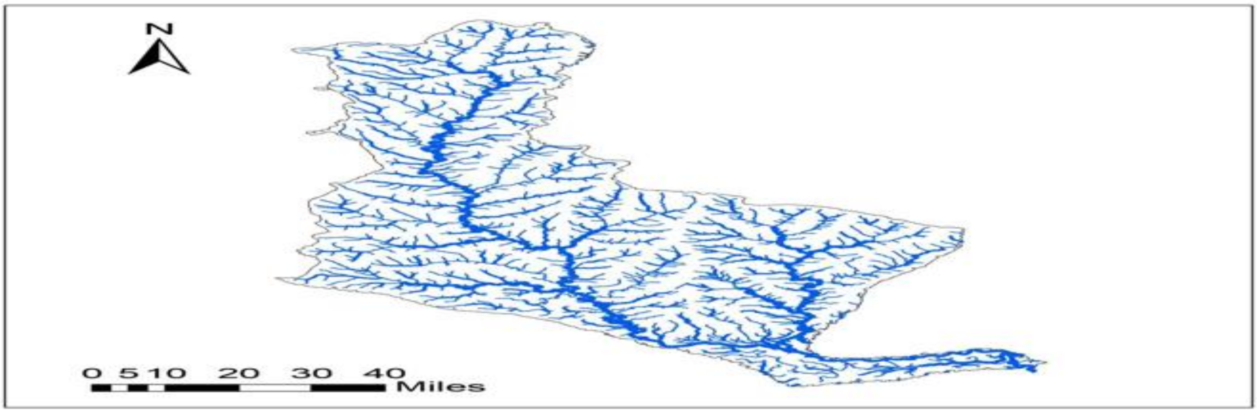


（b）DEM after depression filling

Eight flow directions are generated for DEM in no-depression area of Qinhe River Basin by using flow direction tool in hydrological analysis. The cumulative amount of flow in this area is calculated. The minimum value of the cumulative amount of flow is 0, while the maximum cumulative amount of flow is 14979007. The calculation formula is con(" Flow "> threshold, 1), the river network is divided into two categories, and the appropriate threshold is set. The data less than the threshold is classified as 0, and the data greater than the threshold is classified as 1. In this paper, the threshold of river network extraction is set as 500, 1000 and 2000, and the final threshold is selected as 1000. After extracting the river network, the classification method of Strahler was adopted to obtain the graded river network, and the vectorization command in the hydrological tool was used to vectorize the graded river network. The flow direction diagram and river network diagram of Qinhe River Basin are shown in the following figure:

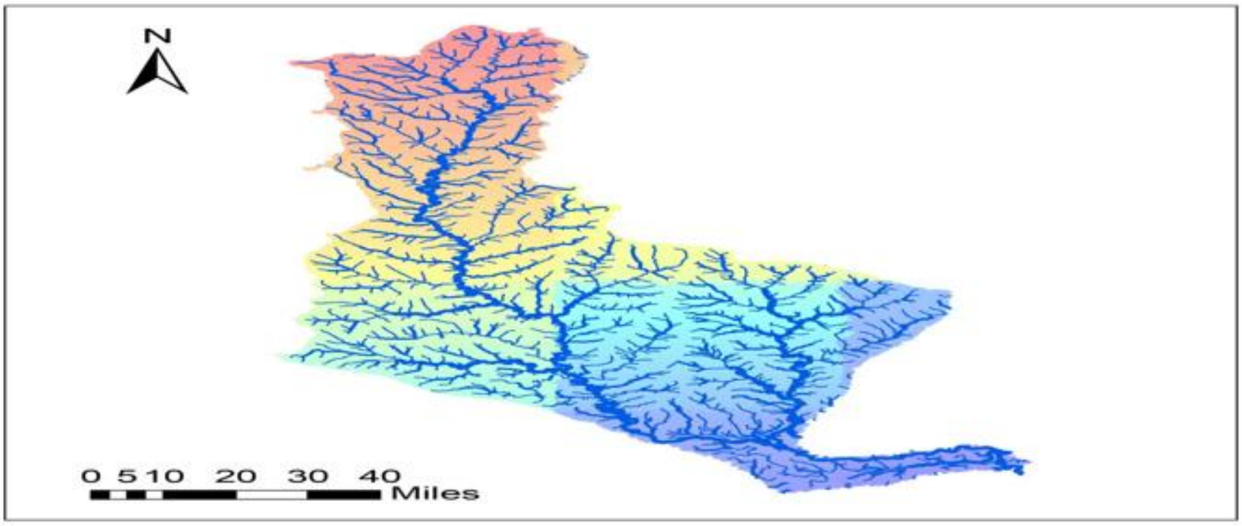


Flow direction map of Qinhe River basin



River network map of Qinhe River basin

Finally, the watershed is divided by the catchment tool in the hydrological tool.



Qinhe River basin zoning map

5. CONCLUSION

In this paper, the ArcGIS10.8 software is used to analyze the steps and methods of hydrogeological analysis based on DEM data in Qinhe River Basin, simulate and analyze the surface hydrological characteristics of Qinhe River Basin, and extract the characteristic factors such as surface flow direction, confluence accumulation and river network in the DEM data of the study area. By dividing the river basin, the scope of Qinhe

River basin is simulated and the catchment area of the river basin is determined.

The use of ArcGIS hydrological analysis technology to extract hydrological information from DEM data has important practical significance for China, digital watershed management and water conservancy construction projects with frequent flood disasters. DEM data resolution, the selection of flow threshold and the topographic characteristics of the study area will affect the segmentation effect of the basin. Using DEM data to extract basin information, the larger the distance of DEM grid, the flatter the landform, which will lead to a large error in extraction results. The optimal river network can be simulated by setting the appropriate threshold value according to the water density of the study area and the need of the study. For the division of large basins, ArcGIS hydrological analysis module can be directly used for extraction. For the extraction of small basin information, it is recommended to use self-designed extraction algorithm or extraction of river network classification conditions based on map algebra, which will achieve better results.

REFERENCE

1. Wang Min. Application of ArcGIS and DEM in hydrological basin simulation [J]. Groundwater, 2011,33 (04):159-161.
2. Cheng Zheng, Li Yongsheng, Gao Weiwei. Basin division by DEM based on ArcGIS [J]. Groundwater Science, 2011,33 (06):128-130. (in Chinese)
3. Li Junchao, Ma Qian, Tao Jun. Analysis and application of hydrological basin based on ArcGIS [J]. Geospatial Information, 2012, 10(06):121-123+2+1.
4. Xia Jide, Zhang Yangan, Zhou Bo, et al. Preliminary study on hydrogeological analysis method based on ArcGIS and DEM [J]. Journal of Yangling Vocational and Technical College, 2016, 15(03):11-14+20.
5. Wang L. Study on surface groundwater conversion rule in Qinhe River Basin based on distributed model [D]. Tsinghua University, 2006.
6. Hu Y J. Research on analysis method of hydrological characteristics of river basin based on ArcGIS [J]. Surveying, Mapping and Spatial Geographic Information, 2018,41 (01):167-171.
7. River basin segmentation based on ArcGIS. Jingwei World, 2020, No.196(05):68-72.]
8. LIU Fengmei, Li Yiyong, Xiao Pan et al. Simulation and analysis of hydrological characteristics in the Pearl River Delta based on DEM [J]. Modern Surveying and Mapping, 2021,44 (01):31-34.
9. Zheng Zhong, Xiao Jun, Wang Jun. Application research of engineering hydrological information extraction based on DEM in ARCGIS: A case study of hydrological analysis and calculation of some rivers in Xinjiang [J]. China Rural Water Resources and Hydropower, 2010, No.330(04):20-22.
10. Liu Chunyu, Zhao Yan, Li Qiang. Based on ArcGIS watershed hydrological analysis and regional flood study [J]. Electric power survey design, 2019, No. 128 (S1) : 81-85. The DOI: 10.13500 / j. LKCSJ. Issn1671-9913.2019. S1.023.
11. Li Jing, Zhang Zheng, Zhu Jiangang et al. Hydrological characteristics extraction of Taihu Basin based on DEM [J]. Environmental Science and Management,2009,34(05):138-142.