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Characteristics of groundwater and urban emergency water sources optimazation in Luoyang, China

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Abstract: The construction of emergency water sources is the material basis for ensuring urban water safety, and it is also an inherent requirement for maintaining social stability and development. The hydrogeological characteristics of groundwater in Luoyang City from the aspects of the division of groundwater aquifer groups, water yield property and groundwater dynamics were described in this paper. Two emergency water sources were selected on basis of comprehensively considering groundwater resources and ecological environmental effects, groundwater quality and exploitation technology, *etc*. Then it further analysed the aquifer types, water yield properties and groundwater recharge, runoff and discharge conditions of the two emergency water sources, and evaluate the groundwater resources quantity of the water sources. The results are that the shallow underground aquifer in Luoyang City is thick, coarse, and stable in lithology and thickness. The two water sources enjoy good exploitation potential and can be used as backup water sources to supply water in the event of a water source crisis.

Keywords: Groundwater characteristics; Emergency water sources; Exploitation potentiality; Urban water supply risk; Luoyang City

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Introduction

The urban emergency water source refers to the strategic reserve water source for residents' domestic water usage in the case of continuous drought or water safety emergencies caused by a large amount of water shortage. It is an unconventional temporary water source (JIANG Long *et al*. 2014; Mitja Janža, 2014).

Luoyang is an emerging industrial city located in the Luoyang Basin. The Luo River, the Yi River and the Jian River are included in the area. There are two large reservoirs in the upper reaches, *i.e.* Luhun and Guxian. The surface water resources are relatively abundant. The underground aquifer has coarse particles, heavy thickness, strong water yield property, and sufficient recharge sources. However, with the acceleration of urbanization, urban water consumption has increased sharply, and the quality of surface water has deteriorated year by year, and quality-induced water scarcity has become increasingly serious (PEI Li-xin *et al*. 2016; YE Yong *et al*. 2010). The water source crisis caused by extreme conditions such as sudden pollution of urban water sources and extreme low water periods has gradually emerged, and urban water supply security is extremely vulnerable (YANG Xin *et al*. 2018; Craig and Jeffrey, 2011). In order to deal with these sudden water shortages, it is imperative to establish emergency water sources.

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1 Study area

Luoyang City is the political, economic and cultural center of western Henan Province and the sub-central city of the Central Plains urban cluster (Fig. 1). It has a total area of 15 208 km^2 and an urban area of about 900 km^2. It belongs to a warm temperate continental semi-humid and semi-arid monsoon climate zone with an average annual temperature of 14.7°C and an annual average precipitation of 606.9 mm. The rivers in the area belong to the Yellow River system, including the Yellow River and its tributaries such as the Yiluo River. The landform mainly includes mountains, hills, and plains. Except for the Proterozoic Erathem, Cambrian, Ordovician, Carboniferous, Permian, Triassic, and Jurassic, the Paleogene, Neogene and Quaternary are mainly distributed in the plains and loess plateaus.

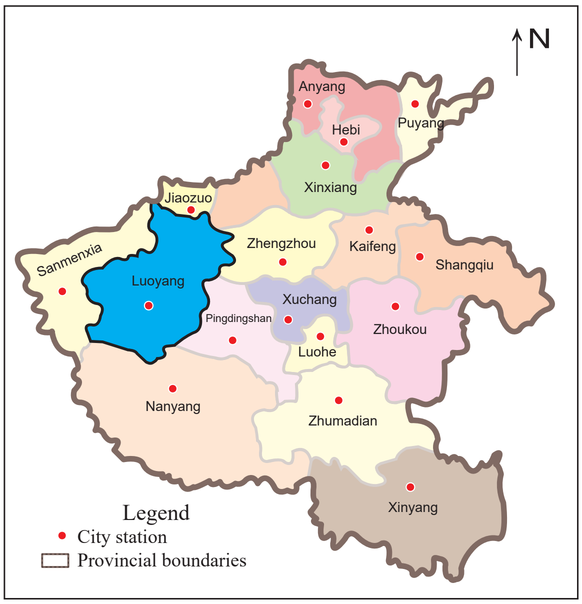

Fig. 1 Location of Luoyang City

2 Characteristics of groundwater

2.1 Occurrence conditions and distribution of groundwater

The landform types in this area mainly include bedrock mountains, loess hills, loess plateaus, alluvial fans, floodplains and valley terraces, *etc*.

In the bedrock mountains of carbonate rock, fissure caves are developed, and fissure cave water is present. In clastic rock distribution areas, there is pore fissure water, and groundwater is relatively scarce in this area.

Loess with a thickness of tens of meters is accumulated in the loess hills, with vertical joints and large pores developed and strong vertical permeability, which creates favorable conditions for the vertical infiltration of groundwater. Therefore, loess pores and fissure water are common in the loess plateau and hilly areas, and groundwater resources in this area are extremely scarce.

Loose rock pore water occurs in alluvial fans, floodplain areas of the Luo River and the Yi River, and first and second terraces. The loose deposits in floodplains and terraces are Quaternary and Neogene alluvium, alluvial lacustrine deposits and lacustrine deposits. They are generally a two-layer structure of interbedded silty clay, silt, sand and pebble. The surface layer is mostly silt and silt clay. The terrain slope is small, and groundwater is shallow, so these areas have abundant or very rich groundwater (YUAN Xi-tai *et al*. 2012).

2.2 Division of aquifer groups and water yield property

2.2.1 Loose rock pore water-bearing rock group

(1) Shallow groundwater

Shallow groundwater is mainly distributed in floodplains and terrace areas on both banks of the Yellow River from Baihe toJili, the Yiluo River block below Guanlin-Weitun, the riverside area on the north bank of the Luo River, Zhuge North-Gaoya on the south bank of the Yi River, Xiguo Village on the north bank of the Yellow River, the old Town of Mengjin on the south bank of the Yellow River, and the floodplain area on both banks of the Luo River from Zhangzhuang Bridge to Anle, Mengjin Town-Songzhuang Town and Chaoyang Town-Pingle Town in the central, and Koudian Town-Dakouji Town in the southeast and other first and second terrace areas. The water-bearing type is mainly pore fissure water and pore water, and the aquifer is composed of coarse particles, mainly sand, gravel, and medium-coarse sand. The depth of the aquifer floor is 60~90 m, and the thickness of the aquifer is 30~50 m. There is no stable water barrier. The amount of groundwater belongs to the rich to medium area. The depth of shallow groundwater in the area is less than 30 meters, and the water inflow of a single well is 100~1 000 m^3/d, and the amount of groundwater is abundant (Fig. 2).

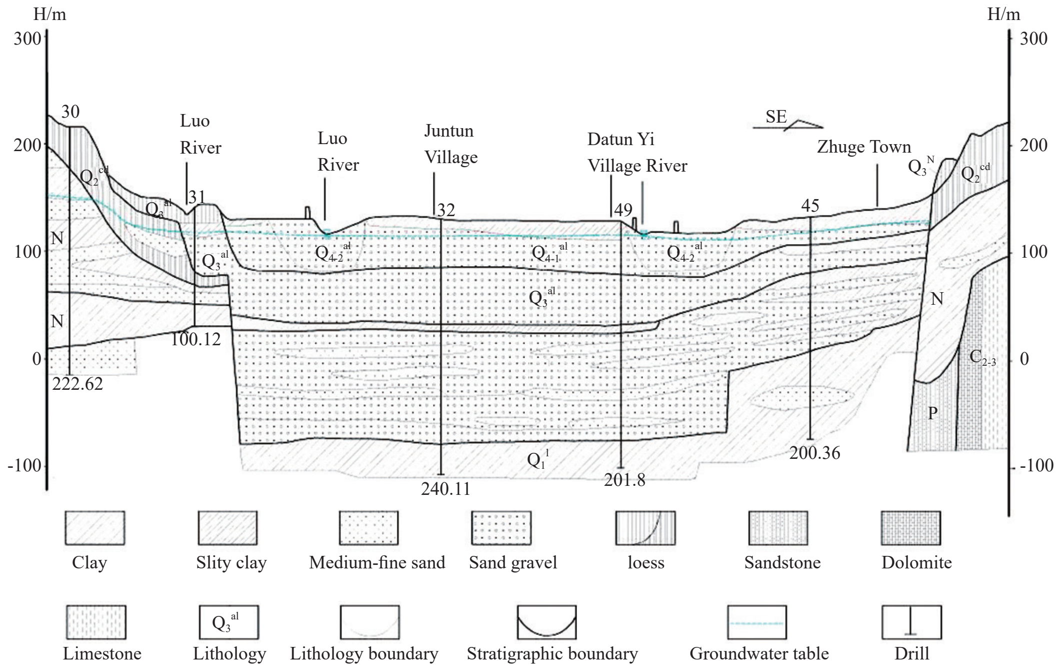

Fig. 2 Luoyang-Zhuge hydrogeological profile

In the Zhaohe Town-Youfangtou area north of the Yellow River, Changdai Town-Yangling area, Cijian Town-Sunqitun Town–the west of Yanqiujie, and the loess hills and loess plateau areas south of Fengli Town-Litun Town, the aquifer is mainly composed of argillaceous sand and gravel, with a thickness of less than 15 m and a groundwater depth of 10~30 m. The water inflow of a single well is less than 100 m^3/d, and the amount of groundwater is scarce.

(2) Medium and deep groundwater

The medium-deep groundwater is distributed in the alluvial plains and loess hilly areas of the Yellow River. The lithology of alluvial plains is coarse-grained sand and pebbles, medium-fine sand, pebbles, semi-cemented sand and gravel, *etc*. The groundwater depth is 60~90 m. The groundwater is abundant, and the specific yield is generally 1 000~3 000 m^3/d. In the floodplains and terraces of the Yellow River, the medium-deep aquifer is a confined aquifer, and the lithology is composed of medium sand, medium-fine sand, gravel, and local fine sand. The total thickness of the aquifer is generally 20~50 m, and the groundwater is abundant. The lithology of the aquifer in the loess hilly area is medium-fine sand, semi-cemented sand and gravel, *etc*., with a thickness of 10~20 m. The water inflow of a single well is less than 100 m^3/d, and the amount of groundwater is scarce.

2.2.2 Carbonate karst fractured water-bearing rock group

It is mainly distributed in the Longmen area in the south, and occurs in the Cambrian, Ordovician and Carboniferous limestones. The water level varies greatly. In some sections, the groundwater is directly exposed to the surface in the form of spring water, but in some sections, the burial depth can reach more than 100 m, and the water yield property is also extremely uneven.

2.2.3 Pore and fracture water of clastic rocks

It is mainly distributed in the base rock mountainous area in the south of the Longmen-Dakou junction and the northwestern part of Yexu Town. The water occurs in the Permian and Triassic sandstones, mudstones and shale. The bedrock mountains are undulating, valleys are developed, and the groundwater formed by the infiltration of atmospheric precipitation always flows quickly, leading to poor groundwater. The bedrock mountains in the south are located in favorable topography and geological structure. Water in this area is mostly the spring water, and the spring flow is mostly less than 1.0 L/s. Seasonal changes are obvious, and most of the water dries up during the dry season.

2.3 Dynamic characteristics of groundwater

The dynamics of shallow groundwater are mainly restricted by meteorological and hydrological factors under natural conditions, and its replenishment is mainly provided by the Yellow River, the Luo River, the Yi River, the lateral infiltration of the Yiluo River and the infiltration of atmospheric precipitation. The dynamic changes of shallow groundwater levels are related to changes in atmospheric precipitation. The rainy season is from May to June every year, and the groundwater level begins to rise and reaches its highest in September. After the rainy season, the groundwater level drops and reaches its lowest from March to April. The downtown area of Luoyang and concentrated mining areas of water source are also affected by artificial mining. The groundwater level is also closely related to river water level. The annual variation of groundwater level in the far river section is large, while the annual variation of phreatic water level in the area near the river is small.

2.4 Quantity of groundwater resources

According to the calculation results of natural resources and exploitable resources of groundwater in Luoyang City, the multi-year average exploitable amount of shallow groundwater in Luoyang City is 128 341.67×10^4 m^3/a. The main source of recharge for medium-deep groundwater in Luoyang City is lateral runoff, and the discharge is mainly lateral runoff. As shallow groundwater resources are abundant, the exploitation and utilization of medium-deep groundwater in the area is low. The elastic release of the medium-deep groundwater in the area is 9 560.84×10^4 m^3/a, and the medium-deep groundwater can be exploited for 20 years. The calculation shows that the annual recoverable resources are 478.04×10^4 m^3/a.

3 Priority choices of emergency water source

According to the hydrogeological conditions of Luoyang City, this paper comprehensively considers groundwater resources and ecological environment effects, groundwater replenishment resources, storage resources, groundwater quality, exploitation technology and other factors, and determines two urban reserve water sources, *i.e.* Mengjin Old Town-Kouma Water Source and Baima Temple water source.

3.1 Mengjin old Town-Kouma water source

The water source is located in Mengjin old Town-Kouma on the south bank of the Luo River. The landform is the floodplain and first terraces on the south bank of the Yellow River, with an area of 85.20 km^2.

3.1.1 Shallow groundwater aquifer and water yield property

It is mainly distributed in the south bank of the Yellow River flood plain and terrace area and Mengjin old Town area. The shallow groundwater aquifer group is composed of sand and pebbles, coarse sand and gravel, coarse-grained stratum dominated by medium-coarse sand, and loess-like silt, sand and gravel, and sand pebbles. The main water-bearing types are pore fissure water and pore water. The thickness of the aquifer is 30~50 m, and the groundwater depth in the extremely rich and abundant area is less than 30 m, and the water inflow of a single well is 1 000~3 000 m^3/d. In some areas, it is greater than 3 000 m^3/d.

3.1.2 Dynamic characteristics and water quality of groundwater

The dynamic changes of the shallow groundwater level are related to changes in atmospheric precipitation, human activities and river water levels. The main types of groundwater dynamics are: Hydrology-exploitation type, precipitation infiltration-exploitation type. The hydrochemical type of shallow groundwater in the source area is HCO_3-Ca·Mg, and the water quality is good.

3.1.3 Exploitable amount

The evaluation range of Menjin old Town-kouma water source is north to the Yellow River, south to the Yellow River secondary terrace and loess tableland junction, west to the Yellow River bend, east to the map boundary. According to the calculation results of shallow groundwater resources, the above-mentioned recharge and discharge amounts are substituted into the equilibrium equation. Under the mining conditions, the average shallow groundwater exploration for years is 9 470.76×10^4 m^3/a, which is 25.95×10^4 m^3/d (Table 1). The groundwater is closely linked with the Yellow River water. Under the mining conditions, the Yellow River water can be stimulated to replenish the groundwater, and the mining potential is great.

Table 1 Annual average shallow groundwater availability Unit: 10^4 m^3/a

Natural recharge					Invincible			Available resources
Precipitation infiltration	Irrigation infiltration	Riever recharge	Lateral runoff	Total	River discharge	Lateral runoff discharge	Total	
1 358.29	226.68	7 782.08	103.7	9 470.76	0	0	0	9 470.76

3.2 Baima Temple water source

The water source is located in the Baima Temple area on the north bank of the Luo River. The landform is in the floodplain and first terraces, with an area of 35.43 km^2. It is planned to mine shallow groundwater. It is a river-side water source with large aquifer thickness, coarse particles and good water conductivity. The shallow groundwater is closely related to the water power of Luohe River, coastal well exploitation can effectively stimulate the recharge of groundwater in Luohe River.

3.2.1 Division of shallow groundwater aquifer groups and water yield property

The water source of Baima Temple is located on the north bank of the Luo River. The landforms are floodplains and terraces. The lithology of shallow aquifer is dominated by sandy gravel layer. The aquifer is coarse, thick, loose in structure and porous. Its sorting and roundness are good, and the groundwater is extremely abundant. The thickness of the aquifer is less than 30 m. The water output of a single well is generally greater than 3 000 m^3/d, and the maximum can reach more than 5 000 m^3/d (Fig. 3).

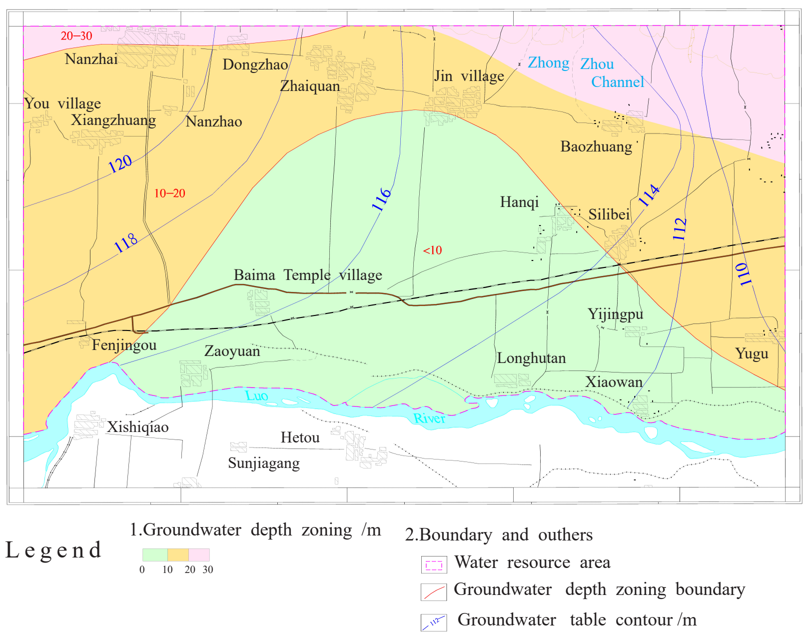

Fig. 3 Water table contour of Baima Temple water resource

3.2.2 Dynamic characteristics and water quality of groundwater

The dynamic changes of the shallow groundwater level are related to changes in atmospheric precipitation, human activities and river water levels. The groundwater dynamic types mainly include: Hydrological type, meteorological hydrological type and precipitation infiltration-runoff type. The hydrochemical type of shallow groundwater in the source area is HCO_3-Ca·Mg, and the water quality is good.

3.2.3 Exploitable amount

The evaluation range of Baima Temple water source is south to the Luohe River, north to the junction of Luohe secondary terrace and loess plateau, west to the bend of the Luohe River and east to Yugu Village. According to the calculation results of shallow groundwater resources, the above-mentioned recharge and discharge amounts are substituted into the equilibrium equation. Under the mining conditions, the average shallow groundwater exploration for years is 3 274.67×10^4 m^3/a, which is 8.97×10^4 m^3/d, and the exploitation potential is large.

4 Conclusions

(1) By analyzing the lithology and hydraulic characteristics of the aquifer, the groundwater in Luoyang is divided into loose rock pore water, carbonate karst fractured water and bedrock fissure water.

(2) Mengjin Old Town-Kouma water source and Baima Temple Reserve water source are both pore water type, riverside water sources. The shallow groundwater aquifer has a large thickness, and the aquifer has coarse particles, loose structure, good sorting, roundness and the permeability. The groundwater is extremely rich, with high quality, and the mining conditions are good. It is suitable as an emergency reserve water source for Luoyang City.

(3) On the basis of the work, further demonstration of the guarantee for long-term mining of the water sources, prediction of the change trend of groundwater during the mining period, and analysis of the possible impact on the emergency water sources after mining and possible environmental geological problems are expected.

(4) Emergency water supply plan is needed. According to different levels and categories of emergencies, emergency water supply plans should be formulated to respond to the needs of different groundwater emergency water supply, so as to strengthen the urban water supply system's ability to respond to emergencies.

(5) The construction of urban emergency water sources should be lifted to the height of ensuring urban safety, and all tasks from construction to management should be effectively done. Groundwater dynamics and environmental monitoring systems should be gradually established for water sources, and dynamic research on water levels, water quality, and water volume should be conducted. The pollution of the surrounding environment should be monitored and forecast, and the water sources should be well protected

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Acknowledgements

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References

Craig L Patterson, Jeffrey Q Adams. 2011. Emergency response planning to reduce the impact of contaminated drinking water during natural disasters. Frontiers of Earth Science, 5: 341-349.

FANG Rong-jie, FU Jian-gen. 2013. Characteristics of groundwater and optimal selection of emergency groundwater sources in Haikou City. Water Resources Protection, 29(1): 61-64.

JIANG Long, FAN Chang-jie, QIAN Li-li, *et al.* 2014. Study on the emergency and back-up groundwater source in Ningyang County. Groundwater, 36(3): 37-39.

LONG Yan, XU Guo-bin, MA Chao, *et al*. 2016. Emergency control system based on the analytical hierarchy process and coordinated development degree model for sudden water pollution accidents in the Middle Route of the South-to-North Water Transfer Project in China. Environmental Science and Pollution Research , 23: 12332-12342.

Mitja Janža. 2015. A decision support system for emergency response to groundwater resource pollution in an urban area (Ljubljana, Slovenia). Environmental Earth Sciences, 73: 3763-3774.

PEI Li-xin, YANG Liu, LIU Chang-li, *et al*. 2016. Investigation and analysis of emergency water supply sources. Sourth-to-North Water Transfer and Water Science & Technology, 14(02): 1-5.

SHI Zheng-tao, LIU Xin-you. 2008. Urban water security and emergency water source construction–Taking Kunming City as an Example. Urban Problems, 2: 24-28.

WANG Shuai, WANG Wu-tao, LV Xiao-fan. 2015. Analysis of exploitation potential and investigation of the current situation of groundwater resources in Zhengdong district, Zhengzhou, China. Groundwater, 37(3): 22-23.

YANG Xin, NING Li-bo, JIA Hao-ran. 2018. Discussion about connotation and resources evaluation of urban emergency water source. Journal of Hunan Industry Polytechenic, 18(3): 26-31.

YE Yong, XIE Xin-min, CHAI Fu-xin, *et al*. 2010. Research on groundwater emergency water source field of city. Water Resources and Power, 28(1): 47-49,82.

YUAN Xi-tai, GONG Xiao-jie, YU Chang-he. 2012. Experimental study on development and utilization of shallow geothermal energy in Luoyang, China. Groundwater, 34(4): 48-63.