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Research Article

Sources of Useful Fresh Groundwater Storage of The Molodezhnoye Deposit of the Tyumen Region

Rimma ABDRASHITOVA[1, a *], Evgeniya NEELOVA[1, b], Valentin PANIKOROVSKIJ[1, c], Denis DRUGOV[1, d]

[1]Industrial University of Tyumen, Tyumen, Russia
[a]ritte@mail.ru, [b]neelovaeu@tyuiu.ru,[c]panikarovskijvv@tyuiu.ru, [d]drugovda@tyuiu.ru

ABSTRACT.

The exploration data set for fresh groundwater at the Molodezhnoye deposit of the Tyumen Region of the Russian Federation (drilling of wells, aquifer testing, geophysical data) made it possible to substantiate that the water-saturated stratum is a multiple-bedded system for which overflowing is a typical response. The authors calculated and justified reserves in the amount of 1200 m^3/day. To determine the seepage parameters, cluster pumping tests and single tests were performed.The target horizon at the deposit is the Rupelian-Chattian field. It is a part of the Oligocene-Quaternary hydrogeological complex of the West Siberian megabasin. The target horizon is covered by the Quaternary polygenetic aquifer and is underlain by the Turonian-Priabonian (Tavda) impermeable horizon. The main sources of formation of the useful fresh groundwater storage are the natural (dynamic) resources of the Rupeliana quifer sub-horizon, as well as attracted reserves due to the evacuation of rock water-absorbing capacity of the upper quaternary strata.

Keywords: Useful fresh groundwater storage, Fresh water aquifer, Groundwater mining, Overflowing, Groundwater resources, Drinking water aquifer.

INTRODUCTION

The creation of useful fresh groundwater storage (UFGS) is a multifactorial process of water inflow to the water intake facilities. As part of the shared water resources, the groundwater of various aquifers interrelates with each other, with open water and the atmosphere. According to the classical concepts of hydrogeology [1-4], the formation of UFGS occurs under the influence of geological, hydrogeological, orohydrographic, climatic and other natural factors, as well as man-made factors associated with changes in water-related activities.

The combination of these factors determines the space-time hydrodynamic structure of the seepage flow (size, surface shape, and depth of depression pit), possible changes in water quality, as well as the effect of exploitation on various environmental components. Depending on the conditions of formation, various types of reserves (resources) will play a pivotal role. The purpose of the study was to determine the sources of formation of the resources of the Molodezhnoye deposit of fresh groundwater. This further allowed for a quantitative assessment of UFGS in the amount of 1200 m^3/day.

According to the generally accepted hydrogeological zoning [1], the territory of the Molodezhnoye deposit is located in the southwestern part of the West Siberian megabasin, near Tyumen. By condition of formation of chemical composition, water exchange, dynamics, and groundwater resources, the basin is divided into two hydrogeological stages, the Mesozoic-Cenozoic and Mesozoic ones. The determination of stages was made according to the regional Turonian-Priabonian impermeable horizon.

METHODS

At the field stage of the study, the following tasks were solved:

- study of the geological structure of the estimated area;
- justification and selection of sites that are promising for the formulation of valuation works;
- determination of conditions for occurrence and distribution of aquifers;
- study of the conditions of formation and discharge of groundwater;
- determination of the main hydrogeological parameters of the prospective aquifer.

For this, core drilling of 12 wells was performed; 5 prospecting holes and 1 exploratory well were drilled. Geophysical surveys were performed in all wells. Cluster pumping tests and the single test were performed to determine the seepage parameters of horizons. In addition, from all the studied horizons, groundwater samples were taken for complete chemical analysis. The resulting materials were analyzed and processed. The analysis of published scientific literature was also carried out.

RESULTS

Within the studied area, the water-saturated stratum is a multiple-bedded system, which represents a constant replacement of lithological facies (pervious, low-permeable and impervious rock) with each other.

The processes of overflowing in the formation of UFGS are typical of such deposits. In the course of the study, the authors have qualitatively determined the sources of the formation of reserves of the future water intake. These are natural (dynamic) resources of the Rupelianaquifer sub-horizon and attracted reserves due to the evacuation of rock water-absorbing capacity of the upper quaternary strata.

DISCUSSION

For the purpose of the water supply of the field, groundwater from the upper hydrogeological stage can be used. It is characterized by the pressureless and forced mode of seepage, as well as the coincidence of recharge areas. The upper hydrogeological stage is represented by the Quaternary polygenetic aquifer, the water-bearing Rupelian-Chattianformation, and theTuronian-Priabonianimpermeablehorizon.

Fig. 1 shows one of the sections of the work site, which allows tracing the hydrogeological parameters and the lithological composition of the sediments. At the site of works, the Quaternary polygenetic aquifer lies first on the surface.

Quaternary polygenetic aquifer (nQ). The horizon is distributed throughout. Aquiferous rocks are represented by fine-grained sands with a capacity of 2-3 m. The depth of the groundwater level varies from 1.8 to 3.3 m. The water horizon is pressureless. The seepage properties of water-bearing sediments are low. Well flow rates do not exceed 0.09 dm^3/s with a decrease in level by 2.2 m.

The chemical composition of water is predominantly chloride-hydrocarbonate magnesium-calcium, sodium-magnesium. The prevailing mineralization values are 0.6-0.8 g/dm^3.

According to the degree of protection, the aquifer is characterized as unprotected. Thus, this horizon cannot be used as a source of water supply due to a low abundance of water and easily accessible possibility of pollution.

Rupelian-Chattian aquifer (₽$_3$ r-h). This horizon is widespread throughout the study area and is related to the deposits of the Kurtamyshskaya and Turtasskaya suites. It is capped with sandy-clayey sediments of the Quaternary Period. The horizon is underlain by seat clay of the Tavdinskaya suite. Its top lies at a depth of 6.5-16 m, the bottom – from 41.8 to 78.8 m. The absolute depth mark of the top is 83.9-94.1 m, bottom – 21.1-59.48 m.

The aquifer is a single water-bearing stratum composed of unevenly interbedded sands of various grains and clay, aleurites, clays of varying degrees of sandiness. In some areas, clays are replaced by sandy rocks forming lithological “windows”. It is almost impossible to identify any pattern in the distribution of sand

and clay material due to the frequent lithological interchangeability of sediments.

Throughout the water-saturated stratum, it is conditionally possible to distinguish three productive formations, which are replaced in certain areas by aleurites of various degrees of clay content.

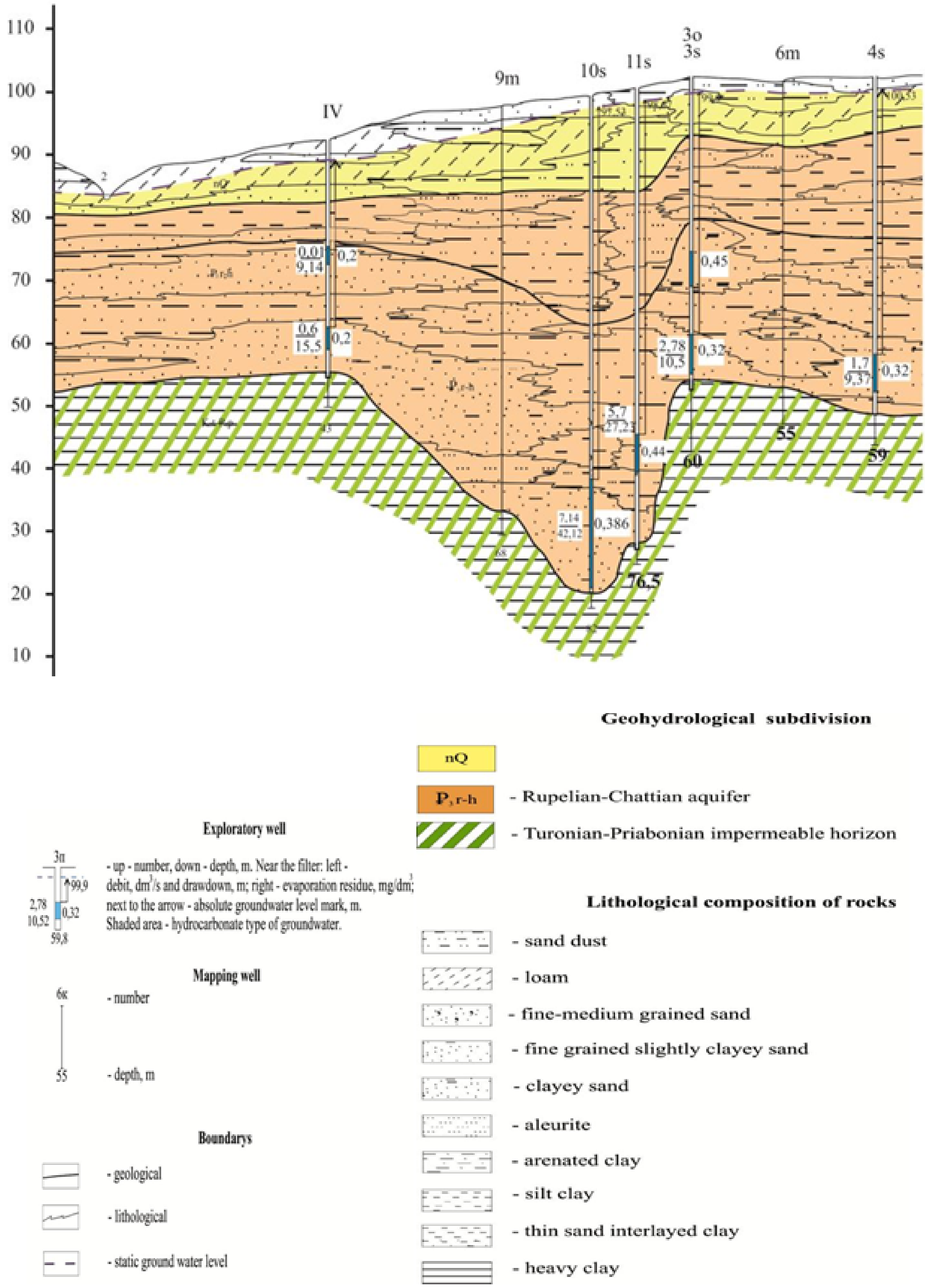

Fig. 1 Hydrogeological section of the Molodezhnoye deposit.

The first one is in the deposits of the Turtasskaya suite and can be conventionally attributed to the *Chattian sub-horizon.* Aquiferous rocks represented by fine-grained sands of various degrees of clay content occur in the form of layers and lenses. Their thickness is 2-4.5 m. The water abundance of water-bearing rocks directly at the site of work has not been studied. According to the degree of natural protection, the Chattian sub-horizon is considered to be conditionally protected.

The second and third interbeds are related to the deposits of the Kurtamyshskaya suite and can be conditionally attributed to the *Rupelianaquifer sub-horizon*. The subhorizon is a wet stratum composed of uneven interbedded mudstone, sands, and siltstones, which is characterized by sharp facies variability. Aquiferous rocks are represented by fine-grained and medium-fine-grained or clayey sands. In some areas, there is a complete replacement of sand with aleurite sands. The thickness of the sandy beds varies from 2.5 m to 18 m.

In general, the total effective thickness of sands of the Rupelian-Chattian aquifer varies from 4.5 to 24 meters in terms of the area of prospecting and evaluation work. Low permeable rock differences are represented by sand and aleuritic clays, sometimes with thin layers of sand and aleurite.

Groundwater horizon water has its pressure. Levels are set at depths from 1.4 m to 2.79 m. Absolute marks are 97.14-101.24 m. Aquifer testing at the field was carried out from June to September 2018. A one-time measurement of groundwater levels was made for all wells on September 28, 2018. The results of these measurements are shown in Table 1.

Seepage properties of water-bearing rocks are different. Well flow rates vary from 0.08 to 7.14 dm^3/s with a decrease in the level of 9.37-42.12 m. The specific flow rates are 0.14-0.26 $dm^3/s \cdot m$.

The water conductivity of the productive Rupelian-Chattian sub-horizon within the entire study area varies from 0.9 to 70 m^2/day. According to the coefficient of transmissibility, the studied area can be divided into three parts: Eastern, Central, and Western ones.

Number of a well	3n	3p	10p	11p	2p	4r	4p
Cover thickness of static level, [m]	2.59	2.7	2.37	2.39	3.1	1.92	2.09
Absolute depth mark of static level, [m]	100.05	99.87	97.53	98.67	98.18	100.56	100.53

Table 1: Static levels by wells as of September 28, 2018

The lowest values (0.9 m^2/day) are noted in the center and high values in the west (70 m^2/day) of the studied area. Water-transmitting capability in the west varies from 32 to 70 m^2 /day, in the east – from 9 to 39 m^2/day. The values of water-transmitting capability while calculating using the Dupuis formula were the following ones: in the west of the site 20-34 and in the east – 17-32 m^2/day. The pressure conductivity factor according to calculations was $8 \cdot 10^3$ to $1.4 \cdot 10^7$ m^2/day.

According to the chemical composition, horizon water is bicarbonate sodium or magnesium-calcium. Groundwater is fresh with a dry residue of 0.3-0.45 g/dm^3.

CONCLUSION

The authors have found that replenishment of the groundwater reserves of the horizon is mainly due to influent seepage of precipitation and downward seepage from the uppermost quaternary polygenetic aquifer. Discharge is carried out by descending seepage from the Chattiansub-horizon into the Rupeliansub-horizon and along the slope of the underground flow in the direction of the river valleys. The natural slope of the groundwater flow in the northern part of the area is slightly lower, and there is a slight thickening of hydroisobath southward, especially in areas of small water streams. Directly at the site of prospecting and evaluation works, the surface of the levels of the Rupelian-Chattian horizon is calm; there is a slight slope ($i = 0.003$-0.004) southward.

This horizon is considered to be the main source of drinking water supply of settlements in the district.

On the basis of the combination of factors that determine the principal features of the formation of UFGS and their common factors in various natural hydrogeological conditions, several types of drinking water aquifers (DWA) have been formed.

In the practice of exploration in Russia, the typification developed by Yazvin and Borevsky (1976) became widely used. The improved typification of DWA by these authors is based on the totality of natural physiographic, geological, and hydrogeological factors. Anthropogenous factors are considered to be secondary ones [2]. Under the conditions of this typification, the studied territory in the hydrogeological respect is a “groundwater deposit in the artesian basins of platforms”. Deposits of this type are characterized by relative sustainability of the distribution of the main aquifers and low-permeable formations, small slopes of the natural flow.

The deposit is characterized by the process of overflowing as well. The main sources of UFGS are natural (dynamic) resources of the Rupelianaquifer sub-horizon and attracted reserves [5-9] due to the evacuation of rock water-absorbing capacity of the upper quaternary strata. An additional source of nourishment should be considered precipitation: The amount is 470 mm/year. At the same time, it can be assumed that up to 20% of precipitation accounts for the seepage nourishment of groundwater (depending on the season).

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