N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 2, Number 440 (2020), 103 – 113 **https://doi.org/10.32014/2020.2518-170X.37**

UDC 551.49:(556.3)

E. I. Lagutin[1], V. A. Smolyar[2], K. A. Kojobaev [3], A. G. Terekhov[4], M. B. Edigenov[5]

[1]Institute of Water Problems and Ecology, Taraz, Kazakhstan;
[2]Institute of Hydrogeology and Geoecology, Almaty, Kazakhstan;
[3]Kyrgyz-Turkish "Manas" University, Bishkek, Kyrgyz Republic;
[4]Institute of information and computing technologies CS MES RK, Almaty, Kazakhstan;
[5]LLP "Scientific-production firm Geoekos", Kostanai, Kazakhstan.
E-mail: eliktz4065@mail.ru, v_smolyar@mail.ru, kojkanik@gmail.com,
kanatbek.kojobaev@manas.edu.kg, aterekhov1@yandex.ru, edigenov@mail.ru

RK PROBABILISTIC HYDROGEOLOGICAL MAP

Abstract. Hydrogeological maps are currently one of the most important elements of the image of the hydrogeological situation in both regional and local representation. In accordance with the existing instructions, they are compiled on the basis of t opographic, geological and tectonic maps of various scales based on the results of hydrogeological surveys and reflect the boundaries of the distribution of aquifers and complexes, confined, as a rule, to geological-stratigraphic and tectonic formations and their real manifestations on the ground (sources, wells, drilling wells). In addition to the General hydrogeological maps described above, special hydrogeological maps and sections are compiled that reflect the individual sides of the hydrogeological process – maps of the depths of the groundwater level, maps of the filtration properties of the host rocks, maps of the water supply and the level of aquifers, maps of the chemical composition of groundwater and others.

All the above-mentioned hydrogeological maps and sections are static and do not reflect the dynamics of the hydrogeological process in time. They only reflect on the geological and tectonic basis obtained during the hydrogeological survey process one-time field initial hydrogeological parameters (flow rates of individual sources and hydrogeological wells, the chemical composition and physical quality of groundwater, some hydrogeological parameters of aquifers). For these reasons, they can not serve as a benign basis for predicting the further development of the hydrogeological process. Forecast hydrogeological calculations based on such initial data are not characterized by high accuracy and reliability, usually not higher than 15-30%.

In the present article on the basis of our own research we propose new principles and provide specific examples of building a fundamentally different type of hydrogeological maps that reflect the dynamics of the hydrogeological process in time, significantly increasing the accuracy and reliability of predictive hydrogeological calculations and hydrogeological-reclamation forecasts (up to 1-5%). Such maps are built on the basis of long-term monitoring data on the regime of groundwater and its chemical composition, pre-processed using mathematical methods of probability theory and the theory of random functions on the actual material typical for the South of Kazakhstan Tashutkul Irrigation massif. As a result, probabilistic hydrogeological maps of the position of groundwater levels, aquifer capacity, groundwater resources of varying degrees of security (5, 25, 50, etc.,%) were obtained. Received cards of various types of probability distribution and forecasting of hydro-geological process, etc. In such complex probabilistic hydrogeological maps are sufficiently benign basis for prediction of the hydrogeological-reclamation situation on irrigated tracts and can serve as a reliable basis for projecting the resource potential of the groundwater of certain regions and social formations.

Key words: Existing hydrogeologiczny maps, cross sections. Static maps. Insufficient accuracy of existing hydrogeological calculations and forecasts. Probabilistic hydrogeological maps. Monitoring baseline data. Methods of probabilistic data processing. Significantly improved the accuracy of hydrological calculations and drainage-hydrological forecasts.

Introduction. The deterioration of irrigated land in Kazakhstan [2,10,14,17,22,31] requires the search for new, more economical methods and technologies of irrigation, and in addition new, primarily local sources of irrigation water. This category includes groundwater with significant potential resources in Kazakhstan [2,8,9,14,17,19-22,31]. Analysis of the publications known in the scientific literature [3,4,7,6,11,13,17,19,21-23,32,34,39-43] shows that despite the abundance of calculation formulas and methods, a number of important issues arising in the calculation and design of vertical drainage on irrigated areas and in the use of groundwater for irrigation remains to this time insufficiently studied. These include: the need to take into account the regime of irrigation water infiltration at the upper boundary of the flow, the definition of inter-drainage distances, taking into account the boundary hydrogeological conditions, the definition of the reclamation effect of water intake, taking into account changing natural and anthropogenic conditions.

Outlined above specific scientific issues addressed in the process of implementing a special State research program for the study of the state Testconsole array of irrigation, which are typical for arrays of river valleys and rivers of southern Kazakhstan (figure 1). As a result of improper operation of irrigation systems there is a progressive rise of groundwater levels predetermining further salinization of soils and groundwater [5,7,22,17]. Hydrogeological parameters of aquifers and hydrogeological wells were investigated on the site of the existing vertical drainage in the novotroitskiy state farm in the field, water balance observations and studies were carried out. As a result, the discrepancy of hydrogeological parameters was established, obtained from surveys and data exploitation. The material on the regime of groundwater for the entire available observation period (5-25 years) was collected and generalized for a total of 256 observation points.

Figure 1 – Physical and geographical map of southern Kazakhstan. Main irrigation areas:
1-Kyzylkum, 2 - Arys Turkestan, 3 - Talas, 4 - Tashutkul

On the basis of the statistical analysis of the data of regime observations, probabilistic and statistical maps of groundwater levels, evaporation power and resources of different availability were constructed. On the basis of the use of the materials of such maps, a method for calculating the supply at the upper boundary of the groundwater aquifer and the use of this value in the calculations of groundwater intakes [6,17,22] has been developed. Water balance studies have shown that in irrigated areas more than 90% of groundwater supply is lost from irrigation networks and irrigation fields. When using the developed original scheme of water management calculation of vertical drainage on the irrigation massif, irrigation water saving will be up to 20 - 30% with simultaneous improvement of reclamation and hydrogeological conditions. Been zoning Testconsole array of irrigation in terms of application of the developed methods of calculation of underground water intake [17,22,41].

Methods of work. In accordance with the currently existing instructions [24-30,35] hydrogeological maps are compiled on the basis of topographic, geological and tectonic maps of different scales on the results of hydrogeological surveys and reflect the boundaries of the distribution of aquifers and complexes, confined, as a rule, to geological-stratigraphic and tectonic formations and their real manifestations on the ground (sources, wells, boreholes). They are simultaneous, static, to a certain extent random.

In our studies, forecast probabilistic and statistical maps were built on the basis of probabilistic and statistical analysis of monitoring data on the network of observation wells. Generally, a series of observations of at least 10 years in length for each well is recommended. The accuracy and reliability of the maps themselves is determined by the density of the observation network. For maps of scale I:100000 the density of the reference (opened underground water) network is considered sufficient in the presence of an average of one point per 1km^2. with a sparser grid mapping schema. Points with short series of observations in our case resulted in a long representative series of wells with similar hydrogeological conditions. Then, using the research methodology of the statistical population, we obtained the theoretical law of probability distribution corresponding to the essence of the process [15,16,18,22,36,37]. On integral curves of securities calculated the value of the securities of the depths to the water at each observation well.. Under normal and lognormal laws, probabilistic paper (Hazen fiber) was used, on which the curves acquire the character of straightened lines [36,37].

The most important hydrogeological information for the preparation of various water management projects is usually contained in the level maps 1-,5-,50-,75-,95%-of security or repeatability in 1, 5, 20, 50 times per 100 years. Having a corresponding distribution curve for each well, we obtain depths corresponding to the probability of repetition in a given number of years. Thus, groundwater levels of 50 % of availability serve as a source material for mapping the average annual depth of groundwater. Of particular note are forecast maps of the depths of groundwater of rare occurrence (I every 100 years). Such levels are usually not practically observed, but which can be expected with security of 1 and 99 %.

In principle, it is possible and practical to draw up probabilistic and statistical maps of other hydrogeological parameters - amplitudes of fluctuations in levels, resources, supply and evaporation of groundwater to others, some of them are given below. The principles of their construction are similar.

The analysis of the actual predictive probability and statistical cards for example Testconsole array of irrigation. The starting material for predictive probabilistic and statistical maps of hydrogeological parameters for the site Testconsole array of irrigation, based on data from regime observations for 230 wells network Dzhambul hydro-geological expedition of the Kazakh SSR MG (66 SLE.), Chimkent hydrogeological expedition reclamation of Gavrilovskaya Mivh of the USSR (110 SLE.) and Dzhambul of oblselvodkhos of the Kazakh SSR (54 SLE.). The longest series of observations were available for wells DGE (average 10-25 years), slightly lower (up to 5-8 years) on the network CHGME and the least long (up to 3-5 years) on the network Dzhambul regional meliovodkhoz. The latter were used only for data interpolation and boundary refinement (figure 2, table 1).

Table 1 – The depth of groundwater levels of different security in the territory Testconsole array of irrigation (km^2/ %)

Provision, %	Groundwater levels, m			
	0 - 1	1 - 3	3 - 5	>5
1	70 10,1	461 70,2	61 9,2	71 10,3
5	36 5,4	445 67,1	72 10,8	100 15,0
25	25 3,77	434 65,5	94 14,8	110 16,1
50	12 1,8	370 55,8	144 21,8	137 20,6
75	10 1,6	276 41,6	251 38,6	131 19,8
95	8 1,2	224 36,8	270 40,2	141, 21,7
99	–	208 32,5	265 40,0	190 27,5

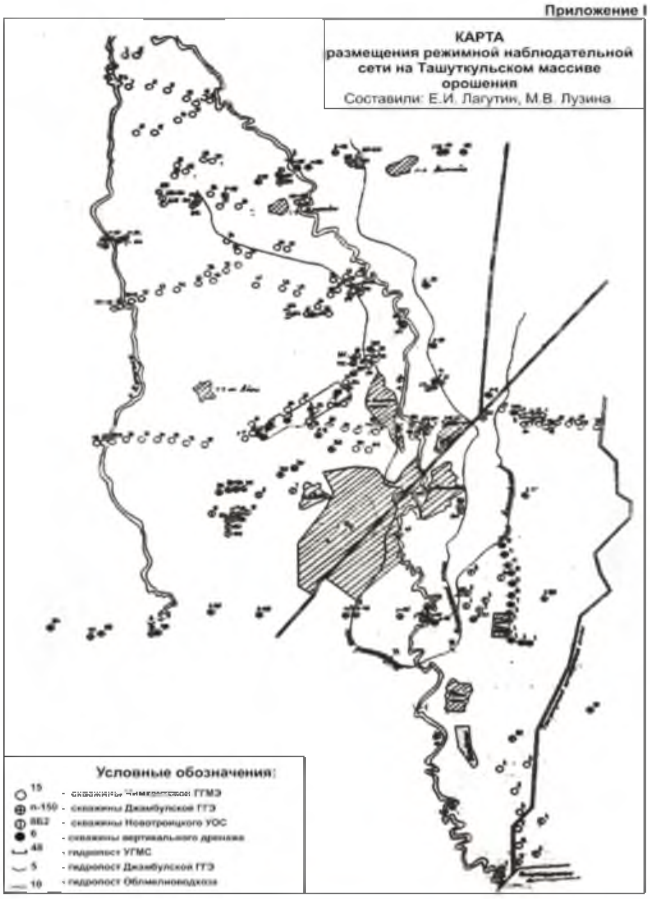

Figure 2 – Map of the location of the monitoring network on the Tashutkul irrigation array. Made: E.I. Lagutin, M.V. Luzina

With the area of the characterized part of the array about 37 thousand hectares (see table 1), the density of the observation network is about 6.1 points per 10 km^2 of array area, including about 1.4 representative points with long-term series of observations. This ensures the reliability of hydrogeological parameters in relation to the scale of about 1:50000.

In figures 2-6 shows maps of groundwater levels of the Central part of the array Testconsole irrigation of various degrees of security. For the comparative analysis the generally accepted gradations of depth of groundwater levels - up to 1 meter, 1 - 3 m, 3 - 5 m and more than 5 meters were chosen. In table 1 it is shown that with the increase of security (maximum depth) levels vary significantly, so 1 every 2 years (50 % security) groundwater levels up to 3 meters occupy 58 % of the area. Other depths (3-5 m and more than 5 m) occupy about 40 %, 1 time in 20 years close (up to ZM) occurrence is possible by 73 %, and 1 time in 100 years these areas are about 90 %, including depths up to 1 meter are assumed to 0.1 % of the area. On the contrary, with high reliability in 19 years out of 20, depths up to 1 meter occupy about 1%, 1-3 to 38.8% of the area. About 60 % of the area is characterized by a depth of more than 3 meters.

It should be noted that the concept of "security of the process" in refraction to the assessment of groundwater levels is somewhat different from that adopted in hydrology. A wide variety of cutting factors and their combinations determine the diversity of their impact on groundwater levels over time and the corresponding diversity of the distribution of the process security over the area of the massif. for rice.3-4 two maps are presented: a Map of the depth of groundwater levels of Tashutkul massif on a specific date - March 1 and a Map of statistical security (%) of groundwater levels on the same date.

Figure 3 –
Map of groundwater levels in the array
Testcursor irrigation (pre-vegetation period).
Made: E.I. Lagutin, M.V. Luzina

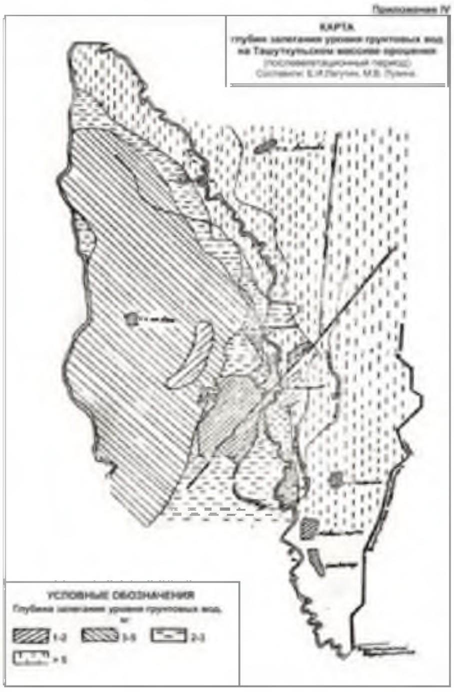

Figure 4 –
Map of probabilities of exceedance levels
of groundwater Testcursor array of irrigation
(after the vegetation period).
Made: E.I. Lagutin, N.G. Vorodgeeva

Of particular interest is the Map of groundwater table (figure 4), the analysis of which shows that with the overall prevalence of levels of 50 - 75 % of security on the array as a whole, there is a significant diversity. Some very large areas of intensively irrigated land are characterized by relatively low security (25-50 =%), in other cases, on the contrary, the security is relatively high, up to 75-95% or more (figure 5, 6).

Figure 5 –
Depth map of groundwater levels (25 % security).
Made: E.I. Lagutin, N.G. Vorodgeeva

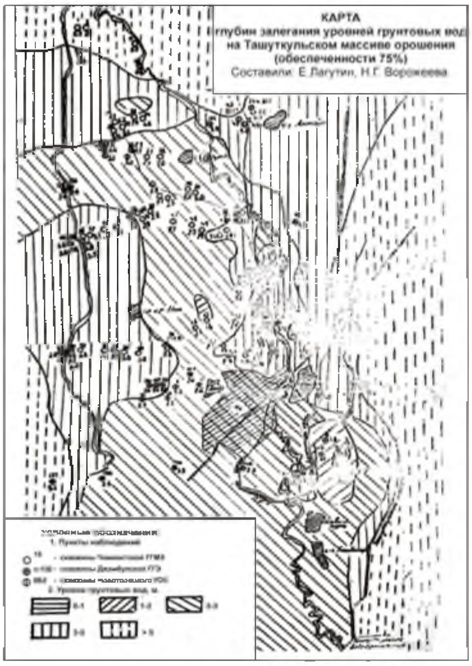

Figure 6 –
Depth map of groundwater levels (75 % security).
Made: E.I. Lagutin, N.G. Vorodgeeva

The importance to ameliorative hydrogeological evaluation to justify the design of drainage measures for the calculation of underground water have special hydrogeological maps obtained from the use of data on fluctuations of groundwater levels. These include, first of all, maps of the amount of evaporation (supply) of groundwater through the aeration zone, maps of "pulsation" of supply, maps of the rates of change of groundwater levels and maps of groundwater resources of different security.

In other words, the amount of feed per time interval (Δt) is proportional to the change in groundwater levels over the same time interval.

Maps of evaporation and groundwater supply are obtained from the analysis of the General equation of groundwater supply.

$$\mu\ (\partial H/\partial t) = T\ (\partial 2H/\partial x2) + T\ (\partial 2H/\partial y2) + \partial W/\partial t \qquad (1)$$

For point conditions, where the left side characterizes the change in moisture, the right - the distribution of pressure and power, the equation takes the form:

$$\mu\Delta N/\Delta t = \Delta H/\Delta t \qquad (2)$$

In our calculations $\Delta x = 1$ month., a $\Delta H=NT+1-Ht$, that is. changes in groundwater levels for 1 month were analyzed, then the data were recalculated in another series (m3/day per 1 ha of area), after which they were subjected to statistical processing. According to the results of statistical processing maps of groundwater evaporation were constructed (figure 7, 8).

Figure 7 –
Map evaporation of groundwater Testcursor array of irrigation (75 % security). Made: E.I. Lagutin, N.G. Vorodgeeva

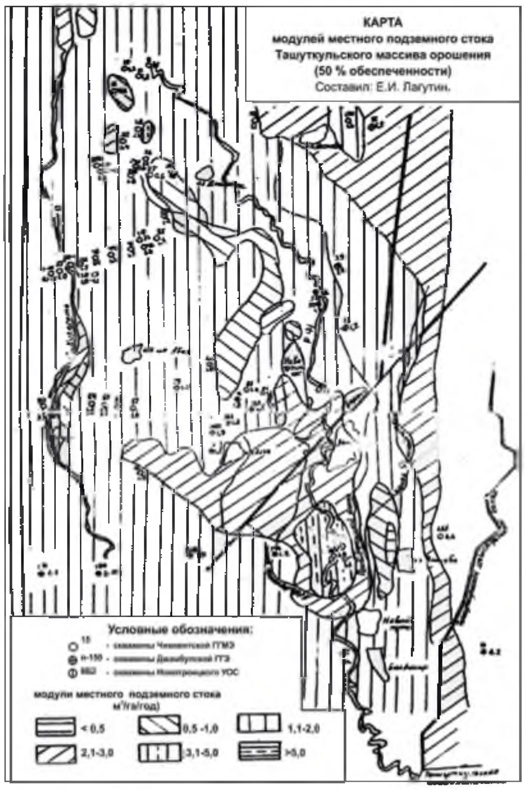

Figure 8 –
Map of local modules groundwater Testconsole array of irrigation. Made: E.I. Lagutin, N.G. Vorodgeeva

Analysis of such maps of different security for Tashutkul massif shows that in the year of 50 % security or in every second calendar month evaporation of groundwater occurs only in the Central part of the massif in small areas. On the overwhelming area of the massif there is the presence of groundwater supply in sizes up to 5 - 10 m^3/day per 1 ha, which indicates the rise of groundwater levels at a rate of up to 0.01 - 0.1 m per month. The distribution of these values over the area of the array is very variegated. However, there is reason to believe that higher rates of level fluctuations are due to artificial reasons, i.e. intensively irrigated areas. Conditionally it is possible to allocate zones with speeds more than

0,1 m/month and less than 0,1 m/month and the first to carry to conditions of intensive irrigation and irrigation losses and the second – to conditions of weak irrigation losses. This situation, however, requires further study and is not the subject of this study. In periods 5% probability of the process, i.e. 1 time in 20 months the evaporation is negative, ie groundwater is fed in the sizes of 25 - 50 m^3/day per 1 ha on the predominant areas of the Central part of the massif, 10 - 25 m^3/day per 1 ha on the southern part, 50-75 m^3/day per 1 ha - in the Northern and North-Eastern parts of the massif.

At 95 % of the provision of the process, that is, 1 time in 20 months, evaporation from the surface of groundwater occurs, and on the vast majority of the array (up to 90%) it is up to 25 m^3/day per 1 ha. At 99% of the provision, i.e. 1 time in 100 months. (1 time in 7.5 years) the process is characterized by increased evaporation. While in the Central and southern parts it is 25-50 m3/day/ha, in the Northern part of the massif it is mainly 50 - 100 m^3/day/ha and more than 100 (see figure 8) so of interest is the forecast Map of mathematical expectations of the values of evaporation (power) of groundwater. On this map, which contains essentially the average annual situation, separate zones are clearly distinguished, characterizing the tendency to the total consumption of groundwater and to reduce their levels in sufficiently large sizes (up to 0.1 m^3/day/ha) and zones characterized by some average annual nutrition (also in sizes up to 0.1 m^3 /day/ha). The first are arranged in two horizontal bands at latitude G. Chu - S. Novotroitskoe in the Northern part of the massif, also in irrigated areas of removal cones in the foothills of HR. Khantau in the Eastern part of the massif (see figure 1B9.). In the rest of the territory there is a supply of groundwater. These are primarily irrigated areas in the head parts of the left-Bank and right-Bank main canals, in the Central part of the left Bank and in the Northern part of the district. The long-term trend towards rising groundwater levels in these areas requires active intervention to prevent salinization of soils and groundwater. The map of annual amplitudes of groundwater levels is made on the basis of statistical data processing of annual changes in the amplitude of the wells of the regime network. The most common annual amplitude in the range of 1-2 meters. On the Eastern edge of the massif with the approach to the middle parts of the removal cones amplitudes increase to 2-3 and more meters. Amplitudes on actively irrigated areas adjacent to the head of the left-Bank and right-Bank channels are also high.

Based on the Map of annual amplitudes of groundwater level fluctuations (figure 7) a Map of groundwater resource modules (figure 8). The module of groundwater reserves is the value of natural reserves formed per unit area. Following this definition, annual groundwater volumes per 1 ha per year were calculated in cubic metres. From the analysis of the map it follows that annually about 1.5-3.0 thousand m^3/ha of ground water is formed on the overwhelming area of the massif. In some significant areas in the Eastern part of the array modules reach values of 3.0-4.5 thousand m3/ha. Even higher modules of 4.5-7.5 thousand m3/ ha are observed in the head part of the left-Bank and right-Bank channels on the areas of intensive irrigation

It should be noted that due to the rather good conditions of internal outflow in these areas, the groundwater reserves indicated on the Map are drained, mainly in the autumn-winter period and replenish the main drainage of the district - the Shu river.

Conclusion. The probabilistic hydrogeological maps of groundwater levels presented in this article and the special hydrogeological maps obtained on their basis described above can and should be widely used in the practice of design of reclamation measures in the development of the irrigated massif, including the calculations of groundwater withdrawals and vertical drainage. In meliorative-hydrogeological constructions, in particular, specific figures and areas of 5 and 25% of security are important, which corresponds to a minimum of 75 % and 95 % of security. This means that these minimum levels are possible once every 4 years (75 %) and once every 20 years (95 %). Can be used as input data in the design of reclamation drainage, including vertical, appropriate level of security. Security is 1 %, i.e. 1 every 100 years is very important in the design of foundations of critical structures, in order to assess their possible subsidence. Maps of 75 % and above (maximum) can be used in the design of groundwater intakes, and in accordance with the necessary design security, that is, the depth of groundwater levels should not be below 75 % of the security specified in 15 cases out of 20. In addition, such maps will be very useful in urban studies, predictive micro-seismic zoning, military engineering surveys, airfield construction, etc.

We recommend you to authorized organizations (GKZ) to produce the estimated acceptance of the protected categories of groundwater for deposits of underground water, drawing it on offer in this article a probabilistic methodology for hydrogeological maps, which certainly enhance the objectivity and scientific conclusiveness protected final numbers and results.

Gratitudes. Deep gratitude to colleagues and companions in work in expeditions and further processing of initial monitoring information – G.G. Loshkov, I.Zh. Kadyrova, M.V. Luzina, N.G. Vorozheeva, E.A. Koytunenko.

Е. И. Лагутин[1], В. А. Смоляр[2], К. А. Кожобаев[3], А. Г. Терехов[4], М. Б. Едігенов[5]

[1]Су мәселелері және экология институты, Тараз, Қазақстан;
[2]Гидрогеология және геоэкология институты, Алматы, Қазақстан;
[3]«Манас» қыргыз-түрік университеті, Бішкек, Қыргыз Республикасы;
[4]Ақпараттық және есептеу технологиялары институты,
Қазақстан Республикасы Орталық гылыми-практикалық қогамы, Алматы, Қазақстан;
[5]«Геоэкос» ғылыми-өндірістік фирмасы «ЖШС, Қостанай, Қазақстан

МАҢЫЗДЫ ГИДРОГЕОЛОГИЯЛЫҚ КАРТАЛАР

Аннотация. Гидрогеологиялық карталар қазіргі уақытта өңірлік және жергілікті көріністегі гидрогеологиялық жагдайды бейнелеудің маңызды элементтерінің бірі болып табылады. Қолданыстагы нұсқаулықтарга сәйкес олар гидрогеологиялық түсірілім нәтижелері бойынша әр түрлі масштабтағы топографиялық, геологиялық және тектоникалық карталар негізінде жасалады және әдетте геологиялық-стратиграфиялық және тектоникалық түзілімдерге ұштастырылган су тұтқыш деңгейжиектер мен кешендер-дің таралу шекарасын және олардың жергілікті жердегі нақты көріністерін (көздер, құдықтар, бұргылау ұңгымалары) көрсетеді. Жогарыда сипатталған жалпы гидрогеологиялық карталардан басқа гидрогеологиялық процестің жекелеген жақтарын көрсететін арнайы гидрогеологиялық карталар мен тіліктер – жер асты сулары деңгейінің жату тереңдігінің карталары, сыйысымды жыныстардың сүзу қасиеттерінің карталары, су өткізгіштігінің және су тұтқыш қабаттардың деңгей өткізгіштігінің карталары, жер асты суларының химиялық құрамынын карталары және басқалар жасалады.

Жогарыда белгіленген барлық гидрогеологиялық карталар мен тіліктер статикалық және гидрогеологиялық процестің уақыт динамикасын көрсетпейді. Олар тек гидрогеологиялық-түсіру процесі барысында алынган геологиялық-тектоникалық негізде бірмементті далалық бастапқы гидрогеологиялық параметрлерді (жекелеген көздер мен гидрогеологиялық ұңғымалардың дебиті, жер асты суының химиялық құрамы мен физикалық сапасы, су тұтқыш қабаттардың кейбір гидрогеологиялық параметрлері) көрсетеді. Көрсетілген себептер бойынша олар гидрогеологиялық процестің одан әрі дамуын болжаудың сапасыз негізі бола алмайды. Мұндай бастапқы деректерге негізделген болжамды Гидрогеологиялық есептеулер, әдетте 15-30%-дан жогары емес дәлдікпен және сенімділікпен ерекшеленбейді.

Осы бапта өз зерттеулерінің негізінде біз жаңа қағидаттарды ұсынамыз және гидрогеологиялық карталардың принципті басқа түрін құрудың нақты мысалдарын келтіреміз, ол уақыт бойынша гидрогеологиялық процестің динамикасын көрсетеді, болжамдық Гидрогеологиялық есептеулер мен гидрогеологиялық-мелиоративтік болжамдардың дәлдігі мен дұрыстыгын айтарлықтай арттырады (1-5%-га дейін). Мұндай карталарды біз жер асты суларының режимі және олардың химиялық құрамы туралы көп жылдық мониторингтік мәліметтер базасында, Қазақстанның оңтүстігіне тән Ташуткул суару алқабының нақты материалында Ықтималдықтар теориясының математикалық әдістерін және кездейсоқ функциялар теориясын пайдалана отырып алдын ала өңделген. Нәтижесінде жер асты сулары деңгейінің, су тұтқыш қабаттың қуаттылыгының, қамтамасыз етілу деңгейі әртүрлі Жер асты сулары ресурстарының (5, 25, 50 және т.б., %) жагдайының ықтимал гидрогеологиялық карталары алынды. Коплексте мұндай ықтимал гидрогеологиялық карталар суармалы алқаптардағы гидрогеологиялық-мелиоративтік жағдайды болжау үшін жеткілікті сапалы негіз болып табылады және жекелеген өңірлер мен әлеуметтік түзілімдердің жер асты суларының ресурстық әлеуетін болжау үшін сенімді негіз бола алады.

Түйін сөздер: Қазіргі гидрогеологиялық карталар, тіліктер. Карталардың статикалылыгы. Қолданыстағы гидрогеологиялық есептер мен болжамдардың дәлдігі жеткіліксіз. Ықтимал гидрогеологиялық карталар. Мониторингтік бастапқы деректер. Деректерді ықтималдық өңдеу әдістері. Гидрогеологиялық есептеулер мен мелиоративтік-гидрогеологиялық болжамдардың едәуір жогары дәлдігі.

Е. И. Лагутин[1], В. А. Смоляр[2], К. А. Кожобаев[3], А. Г. Терехов[4], М. Б. Едигенов[5]

[1]Институт водных проблем и экологии, Тараз, Казахстан;
[2]Институт гидрогеологии и геоэкологии, Алматы, Казахстан;
[3]Кыргызско-Турецкий университет "Манас", Бишкек, Кыргызская Республика;
[4]Институт информационных и вычислительных технологий цо МОН РК, Алматы, Казахстан;
[5]ТОО "Научно-производственная фирма Геоэкос", Костанай, Казахстан

ВЕРОЯТНОСТНЫЕ ГИДРОГЕОЛОГИЧЕСКИЕ КАРТЫ

Аннотация. Гидрогеологические карты являются в настоящее время одним из важнейших элементов изображения гидрогеологической ситуации как в региональном, так и в локальном представлении. В соответствии с существующими инструкциями они составляются на основе топографических, геологических и тектонических карт различного масштаба по результатам гидрогеологической съемки и отражают границы распространения водоносных горизонтов и комплексов, приуроченных, как правило, к геолого-стратиграфическим и тектоническим образованиям, и их реальные проявления на местности (источники, колодцы, буровые скважины). Кроме описанных выше общих гидрогеологических карт, составляются специальные гидрогеологические карты и разрезы, отражающие отдельные стороны гидрогеологического процесса – карты глубин залегания уровня подземных вод, карты фильтрационных свойств вмещающих пород, карты водопроводимости и уровнепроводности водоносных горизонтов, карты химического состава подземных вод и другие.

Все обозначенные выше гидрогеологические карты и разрезы единомоментны и не отражают динамику гидрогеологического процесса во времени. Они лишь отражают на геолого-тектонической основе полученные в ходе гидрогеолого-съемочного процесса полевые исходные гидрогеологические параметры (дебиты отдельных источников и гидрогеологических скважин, химический состав и физические качества подземной воды, некоторые гидрогеологические параметры водоносных горизонтов). По указанным причинам они не могут служить доброкачественной основой прогнозирования дальнейшего развития гидрогеологического процесса. Прогнозные гидрогеологические расчеты, основанные на таких исходных данных, не отличаются высокой точностью и достоверностью, обычно не выше 15-30%.

В настоящей статье на основании собственных исследований нами предлагаются новые принципы и приводятся конкретные примеры построения принципиально другого типа гидрогеологических карт, отражающих динамику гидрогеологического процесса во времени, существенно повышающие точность и достоверность прогнозных гидрогеологических расчетов и гидрогеолого-мелиоративных прогнозов (до 1-5%). Такие карты построены нами на базе многолетних мониторинговых данных о режиме подземных вод и их химическом составе, обработанных предварительно с использованием математических методов теории вероятностей и теории случайных функций на фактическом материале типичного для юга Казахстана Ташуткульского массива орошения. В результате были получены вероятностные гидрогеологические карты положения уровней грунтовых вод, мощностей водоносного горизонта, ресурсов подземных вод различной степени обеспеченности (5, 25, 50 и т.д. %). Были получены карты различных типов распределения вероятностей и прогнозирования гидрогеологического процесса. В комплексе такие вероятностные гидрогеологические карты служат достаточно доброкачественной основой для прогнозирования гидрогеолого-мелиоративной ситуации на орошаемых массивах и могут служить надежной основой для прогнозирования ресурсного потенциала подземных вод отдельных регионов и социальных образований.

Ключевые слова: *Существующие гидрогеологические карты, разрезы*. Статичность карт. Недостаточная точность основанных на них существующих гидрогеологических расчетов и прогнозов. *Вероятностные гидрогеологические карты*. Мониторинговые исходные данные. Вероятностная обработка.

Information about authors:

Lagutin Evgeny Ivanovich, Director. Doctor of geological-mineralogical Sciences, academician of International Academy of Ecological Safety (St.-Petersburg, section of ecology), LLP "Institute of water problems and ecology" of the Republic of Kazakhstan, Taraz, Kazakhstan; eliktz4065@mail.ru; https://orcid.org/0000-0002-7897-5620

Smolyar Vladimir Alexandrovich, Chief specialist. Doctor of geological-mineralogical Sciences, academician of International Academy of Ecological Safety (St.Petersburg, section of ecology), LLP "Kazecoproject" Republic of Kazakhstan, Almaty, Kazakhstan; v_smolyar@mail.ru. https://orcid.org/0000-0003-4790-339X

Kojobaev Kanatbek Asekovich, Doctor of technical Sciences, Professor, Academician of Engineering Academy of KR, Kyrgyz-Turkish Manas University, Bishkek, Kyrgyz Republic; kojkanik@gmail.com; kanatbek.kojobaev@manas.edu.kg; https://orcid.org/0000-0001-6719-5015

Terekhov Alexey Gennadievich, leading researcher, Candidate of technical Sciences, RSE "Kazhydromet" Republic of Kazakhstan, Almaty, Kazakhstan; aterekhov1@yandex.ru; https://orcid.org/0000-0003-3209-1333

Edigenov Michael Bekkyzhievich, Director. Candidate of geological-mineralogical Sciences, LLP "Scientific-production firm Geoekos" Republic of Kazakhstan, Kostanai, Kazakhstan; edigenov@mail.ru; https://orcid.org/0000-0002-2915-7023

REFERENCES

[1] Averyanov S.F. (1978) Fight against salinization of irrigated lands. M., "Kolos" (in Russ.).

[2] Akhmedsafin U.M. (1982) et al. Formation and groundwater resources of southern Kazakhstan. Alma-ATA, "Science". 920 p. (in Russ.).

[3] Baron B. A., Serov V. N. (1971) Methodological recommendations on the prediction mode, the level of groundwater irrigated areas to subaerial deltas. M., "VSEGINGEO". 68 p. (in Russ.).

[4] The Bindeman N.N., Yazvin L.S. (1970). Estimation of operational stocks of underground waters M., "Nedra" (in Russ.).

[5] Bogomolov Y.G. Zhabin S.V., Khachaturyan V. H. (1980). The Change of the hydrogeological conditions under the impact of reclamation. M., "Science" (in Russ.).

[6] Bochever F.M., Garmonov M.V., Lebedev D.V. (1969). the basis of the hydrogeological calculations. M. "Nedra" (in Russ.).

[7] Gulaev A.J. Panasenko I.M., Lagutin E.I. (1979). Ecological-economic assessment of integrated development of water resources of closed basins. Theses of reports at the IV all-Union interuniversity scientific conference "Economic problems of improving the efficiency of capital investments in land reclamation in the light of the decisions of the July (1978) Plenum of the Central Committee." Tashkent (in Russ.).

[8] Zapariy M.P. (1975). Assessment of prospects of the territory of the USSR in the use of groundwater for irrigation. In The Security Council. "Questions of meliorative hydrogeology". Issue 100. M. "Nedra" (in Russ.).

[9] Kamenskii G.N. Tolstikhina M.M., Tolstikhin N.I. (1960). Hydrogeology of the USSR. M., "Gosgeoltekhizdat" (in Russ.).

[10] Katz D.M., Bogomolov Yu.G., Zhelobov A.A. (1976). And others the Role of groundwater in the development of reclamation and drainage in the USSR. In the book. Problems of hydrogeology of arid regions. International geological Congress, XXV session. Reports of Soviet geologists. M. "Science" (in Russ.).

[11] Lagutin E.I. (2019). Forecast of the meliorative-hydrogeological situation on the irrigated massif using the Monte Carlo method. Geology and subsoil protection N 4 (73). P. 45-52 (in Russ.).

[12] Lagutin E.I. (2019). Water resources of Central Asia at the present stage (problems and prospects) Science, new technologies and innovations of Kyrgyzstan. N 4. P. 230-232 (in Russ.).

[13] Lagutin E.I., Smallar V.A., Kozhobayev K.A., Tereshov A.G., Edigenov M.B., Atykenova E.E. (2019). Use of mathematical methods in genetic research of underground hydrosphere (on the example of Tien-Shan) Science, new technologies and innovations of Kyrgyzstan. N 4. P. 233-239 (in Russ.).

[14] Lagutin E.I. (2018). Modelling of geohydrology of underground runoff of Central Asia 's landlocked orogens. Science, new technologies and innovations of Kyrgyzstan. N 3. P. 141-145 (in Russ.).

[15] Lagutin E.I., Mambetaliyeva Sh.M. Hydrogeochemical zones of the hydraulic sphere of Kyrgyzstan Science, new technologies and innovations of Kyrgyzstan. 2018. N 3. P. 192-196 (in Russ.).

[16] Usupayev Sh.E., Valiev Sh.F., Lagutin E.I., Sadybakasov I.S., Atykenova E.E., Sharifov G.V., Dudashvili A.S., Andamov R.S. (2017). The "xv - ignon" methodology in geoid theory and practice. Science and Innovation. N 1. P. 184-192 (in Russ.).

[17] Lagutin E.I., Usupayev S.E. (2014). Management of georisk grazing water intakes of underground runoff on the example of Central Kazakhstan News of the Kyrgyz State Technical University named after I. Razzakov. N 33. P. 409-413 (in Russ.).

[18] Lagutin E.I., Usupayev S.E. (2014). Anthropogenic geohazards and georics in Kazakhstan. News of the Kyrgyz State Technical University named after I. Razzakov. N 33. P. 422-425 (in Russ.).

[19] Usupayev S.E., Edigenov M.B., Lagutin E.I. (2014). Georisk hydrospheres of land in sub-parts of Central Asia. Journal of the Institute of Seismology of the National Academy of Sciences of the Kyrgyz Republic. N 1 (3). P. 121-128. (in Russ.).

[20] Lagutin E.I. (2011). Exploration and calculation of groundwater for irrigation; Mezhdunar. Foundation of Akad K. I. Satpayev, Ministry of Education of Republic. Kazakhstan, U. M. Ahmedsafin in hydrogeology and geoecology. Taraz. Prod. Format-plus. 239 p. (in Russ.).

[21] Lagutin E.I. (2010). Chemical composition of groundwater Tian Shania Northwest part, Kyrgyzstan / Mezhdunar. S. I. Satpayev Foundation of Hydrogeology and Geoecology named after W. M. Ahmedsafin. Taraz. Prod. Format-plus. 310 p. (in Russ.).

[22] Lagutin E.I., Mambetaliyeva Sh.M. (2009). Underground reservoirs on pastures of Central Kazakhstan (exploration, design, construction and operation)/; In-t of hydrogeology and geoecology named after W. M. Ahmedsafin. Taraz. Prod. Format-plus. 179 p. (in Russ.).

[23] Lagutin E.I., Sychev K.I., Fomenko V.I., Khordikainen M.A. (1979). Creation of artificial groundwater resources during grazing Forestry and forestry. N 1. 55 p. (in Russ.).

[24] Lagutin E.I., (2010). "Rational use of low-power aquifers of the exogenous fracture zone for restoration and watering of pastures in Central Kazakhstan". Izvestiya NAS RK. A series of geological. N 5. P. 50-58 (in Russ.).

[25] Lebedev A.V. (1957). Forecast of changes in groundwater level in irrigated areas. M., "Gosgeoltekhizdat". 187 p. (in Russ.).

[26] Methodological guidance on hydrogeological and engineering-geological studies for reclamation construction on irrigated lands. Issue 3. M. 1972 (in Russ.).

[27] Methodical guidance on the choice of the type of water intake facilities for vertical drainage on irrigated lands. "Soyuzvodproekt". Approved. Soyuzvodproekt from 24.12 75 (in Russ.).

[28] Methodological guidelines for the calculation of groundwater intakes for irrigation. "Soyuzvodproekt". Approved. Minvodkhoz. Of the USSR from 10.11.75 (in Russ.).

[29] Guidelines for the production of hydrogeological survey at a scale of 1:50000 and 1:200000. M., "Gosgeoltekhizdat" 1962 (in Russ.).

[30] Guidelines for the production of hydrogeological survey at a scale of 1:1000000 and 1:500000. and 1:200000-1:100000. M., "Gosgeoltekhizdat" 1962 (in Russ.).

[31] Methodological guidance on the justification and integration of research methods in hydrogeological and engineering-geological survey for land reclamation. Issue. IV. M., "Nedra" 1979 (in Russ.).

[32] Mirzaev S.S., Valiev H.V. (1977). Exploration and evaluation of groundwater reserves for irrigation. Tashkent. "Fan" (in Russ.).

[33] Mirzaev S.Sh. Plotnikov N. (1977). So. Hydrogeological forecasts and groundwater use for irrigation. In the collection "Materials of the interdepartmental meeting on forecasting of hydrogeological, engineering-geological and soil-reclamation conditions". Issue. M. (in Russ.).

[34] Pashkovsky I.S. (1973).Methods of determination of infiltration power according to the calculations of moisture transfer in the aeration Zone. Moscow state University Publishing house (in Russ.).

[35] Reshetkina N.M., Yakubov R.A., (1978). Vertical drainage. Publishing house of UzSSR (in Russ.).

[36] Guidelines for the design mode of operation of vertical drainage systems for the conditions of Central Asia (VTR-P-II-76). Composed of SANIIRI. Minvodkhoz of the USSR from 08.12.76 (in Russ.).

[37] Fahrenholz E.D., Kolyada M.N. (1969). Experience of application of methods of mathematical statistics to study the laws of distribution of hydrogeological parameters. In the book.: Evaluation of groundwater resources. M., "Nedra". Vol. 171 (in Russ.).

[38] Hald. A. (1965). Mathematical statistics with technical applications. "Publishing house of foreign literature". 326 p. (in Russ.).

[39] Kharchenko S. I. (1975). Hydrogeology of irrigated lands. L., "Gidrometeoizdat".

[40] Yazvin L.S. (1972). The Reliability of hydrogeological forecasts in the assessment of operational reserves of groundwater. M., "Nedra" 1972 (in Russ.).

[41] Lagutin E.I. (2019). Geohydrodynamic systems of the continental sub-part of the planet Earth as the basis of hydrogeological stratification (On the example of Central Asia). American Sceinces Journal. N 32 /(2019). Vol.2. P. 4-13. (in Eng).

[42] Lagutin E.I. (2019). Modern design solutions for watering summer pastures using groundwater (Central Kazakhstan). Eurasian Union of scientists (ECU). Monthly scientific journal. N 12 (69)/2019). Vol.4. P. 11-17. ISSN 2411-4467.(Print). https://doi.org/10.31618/2019.4-69. (in Eng).

[43] Mukhamedzhanov M.A., Sagin Jay, Kazanbaeva L. M., Nurgazieva A.A. (2019). Challenging issues of fresh water within the territory of East Kazakhstan and adjacent areas of Central Kazakhstan// Bulletin of national academy of sciences of the Republic of Kazakhstan. 2019. Vol. 2, N 434. P. 15-20. ISSN 2518-170X (Online), ISSN 2224-5278 (Print). https://doi.org/10.32014/2019.2518-170X.33 (in Eng).