Limitation of the Distance Between the Group of Wells and Its Effect on the Total Debit

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Abstract

Today, due to several positive indicators of underground water, it is being used in the water supply system. Groundwater wells and their efficient operation ensure the reliability and stability of the entire water supply system. When using wells, their operation individually or in groups causes different calculations, and the justification of this order is a very important factor. The following article is devoted to the calculation of a group of wells and their interaction indicators. The analysis of the problem and the research on its solution shows that the situation is different in wells working individually and in groups. If the decrease in flow rate of individual wells depends only on its indicators, this situation becomes more complicated in a group of wells, that is, they interact depending on their number and location. When calculating water intake structures consisting of a large number of wells, groups of wells interacting with each other are often used by the method called generalized systems. First, let's talk about the impact radius of the well and what factors it depends on.

Keywords: water wells; influence radius; debit; scattering area; well order; rectangular area; circular area; without scattering in the circular area.

1. Introduction

Uzbekistan and other Central Asian regions have big water issues because of both location and surface waters limit. Also, climate condition, agriculture irrigation needs have some challenges related to the water resources sustainable management and environmental safety. Due to several positive indicators of underground water, it is being used in the water supply system. Groundwater wells and their efficient operation ensure the reliability and stability of the entire water supply system. When using wells, their operation individually or in groups causes different calculations, and the justification of this order is a very important factor. Studies related to the efficient operation of a group of wells and the management of their performance are being carried out фt the Samarkand state architectural and civil engineering institute's UZWATER research center. This research is devoted to the calculation of a group of wells and their interaction indicators.

2. Literature Review

A number of scientific and practical-engineering studies have been carried out to investigate water well flow problems and ways to restore them and ensure operational stability. In particular, it was considered in the works of foreign scientists Georg Houben[1], Christoph Treskates[2], A.M.Tugay[3], B.Feizizadeh [4], M.I.Silva [5], J.S.Tukhtabaev[6], S.Lehane[7] and others. B.Khojayorov[8], J.O.Oqilov[9], A.N.Gadaev[10] and other scientists contributed to the development of rehabilitation methods and algorithms for modeling, optimization, and improvement of the declogging process of the water wells. In the analysis of clogging of the water wells in Uzbekistan and stabilization of their operation were determined that not only groundwater quality but also distance between wells is very important factor for stable working of the well. The decrease in the discharge of wells is mainly due to the decrease in the flow rate of ground water, one of the main reasons is the deposition of salt on the surface of the filter and in the zone of the filter. The clogging of

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the filter with salts, corrosion products and small ground particles from the aquifer (GAN). In the scientific language, clogging of salt deposits, particles of the aquifer layer and corrosion products of metal equipment of the filter in the pouros of groundwater movement is called clogging. Since the coagulation process is a multifaceted and complex complex of physico-chemical and hydrogeological processes, determining the main factors that cause it helps to correctly determine the well efficiency, that is, the method of restoring the flow rate. This problem was studied by foreign scientists such as Avila-Garcia[11], J.Malik[12], J.K.Kibi[13], L.S.Pereira[14], M.He[15], J.Baker[16]. D.Kim Verigin[17] modulated the process of reducing well efficiency. During the many years of research in hydrogeological conditions, water management and many foreign scientists are devoted to the study of the solution to this problem following works can be given as an example. Also, in the works were studied the theoretical foundations of the coagulation process and were devoted to solving the problems of recovery of well efficiency. According to the work mentioned above, the methods used to restore the flow rate of the groundwater to the well should help to remove the sediments that are stuck from the outer surface of the filter and the filter zone. First of all we will study an effective distance between wells in the well field with the different location.

3. Methodology

The analysis of the problem and the research on its solution shows that the situation is different in wells working individually and in groups. If the decrease in flow rate of individual wells depends only on its indicators, this situation becomes more complicated in a group of wells, that is, they interact depending on their number and location. When calculating water intake structures consisting of a large number of wells, groups of wells interacting with each other are often used by the method called generalized systems. First, let's talk about the impact radius of the well and what factors it depends on.

4. Results And Analysis

It should be noted that the rate of flow reduction as a result of the interaction of a group of wells directly depends on the details of the location of the group as a catchment area. As a note, the analysis is performed on a group of wells that receive water in one layer. Therefore, a group of wells is scattered in a certain area (this area can be circular, rectangular, or surfaces with a curved border) (Fig. 1). That is, the distance between them is different, and there is no repetition of a certain cycle.

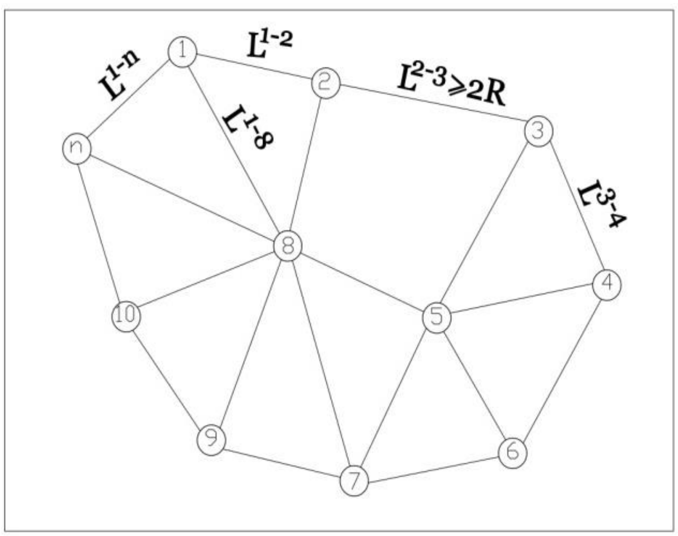

Figure 1: Schemes for calculating systems of a group of wells without scattering in a rectangular area.

The second case is when a group of wells repeats the distances between the wells in such an area in order and according to a certain t cycle, that is, the rowsandthe distances between rows are also in a certain order (Fig. 2). In this case, the calculation of a group of wells is made much easier, because the laws of groundwater movement are fulfilled in them. Stability is observed in influencing factors.

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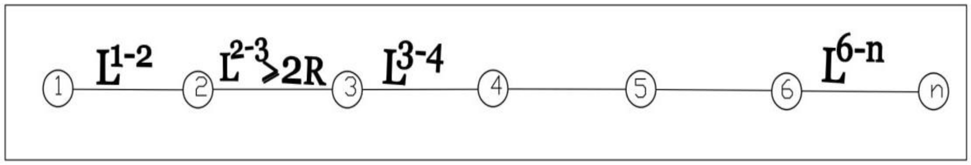

Figure 2: Schemes for calculating the systems of a group of wells with a layout in such an area.

In the next case, a group of wells is exactly repeated in a rectangular area in an orderly manner and a certain t cycle, that is, the rows andthe distances between rows are also in a certain order (Fig. 2). Even, in this case, the interaction of a group of wells occurs, and the calculation is made much easier because the laws of underground water movement are fulfilled in them (Fig. 3).

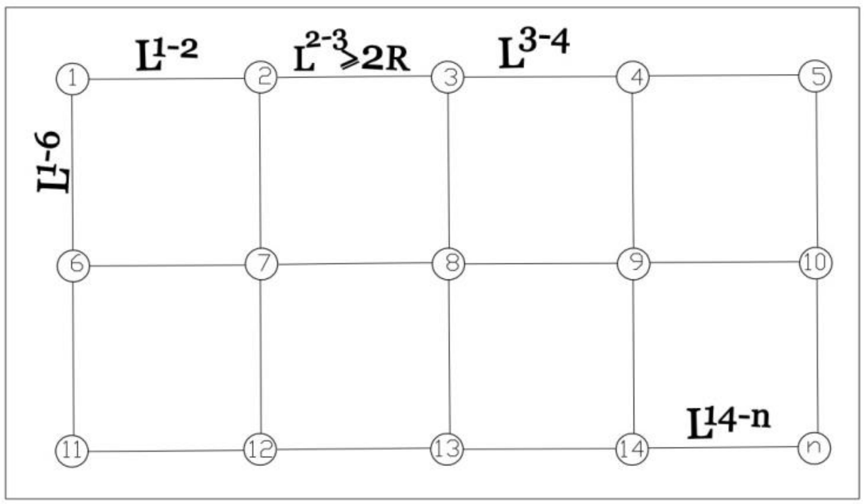

Figure 3: Schemes for calculating systems of a group of wells in a rectangular area with an arrangement.

In the next case, in the area of the circular view of the group of wells, the exact repetition of the distances between the rows of circular order and for a certain t cycle, that is, the rowsandthe distances between rows are also stored. Even in this case, a certain impact occurs and the calculation is made much easier (Fig. 4).

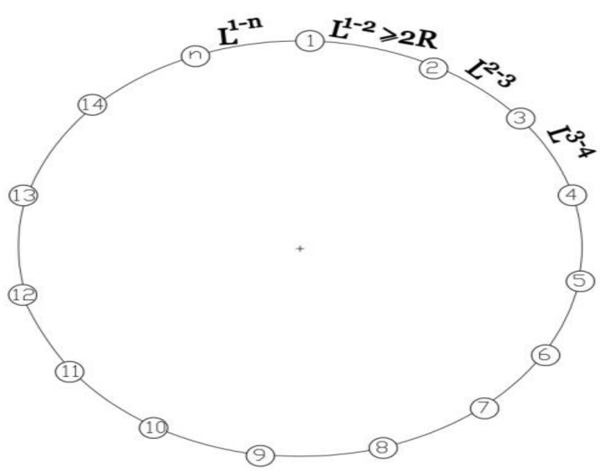

Figure 4: Schemes for calculating the systems of a group of wells with a circular array in the area of a circular view.

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In the last case, the group of wells is arranged in a circular pattern in the field, which does not repeat for a certain t cycle, the distances between them are not exactly equal, that is, the rowsandthe distances between rows are also different. Even in this case, a certain level of interaction of wells occurs, and its calculation becomes more complicated. Because in them the movement of underground water is carried out based on certain laws, but the factors are constantly changing (Fig. 5).

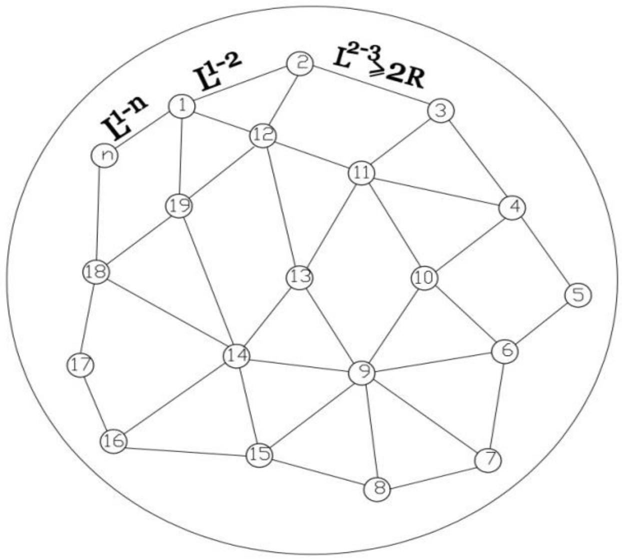

Figure 5: Schemes for calculating the territorial system of a group of wells scattered in a circular area.

In this article, we will consider the restrictions for the calculation of groups of wells depending on the order of their location on the fields.

Arrangement of a group of wells in a single line. In this case, we replace the complex of 2 L long wells arranged in a line with the consumption volume of each well Q (Fig. 1) with distributed resources Q_{all} equal to the total consumption of real wells. In this case, the level decrease that occurs under its influence is as follows:

$$S_{ch} = \frac{Q_{all}}{4\pi km} k_{ch}. \tag{1}$$

where it is the dimensionless hydraulic resistance during the action of a linear system of wells. The above-mentioned analysis and results show that it becomes possible to predict changes in the flow of underground water to the well in the efficiency of the group of wells and their stable operation.

$$K_{ch} = \frac{1+\bar{x}}{2} I_{ch}(\alpha_{0+}, \beta_{+}) + \frac{1-\bar{x}}{2} I_{ch}(\alpha_{0-}, \beta_{-}) \tag{2}$$

The dependences of the above-mentioned approximate calculations for filtration [18] show that during the extraction of water from a well, the water level in one type of layer first rises very quickly (in the well in the initial state - one rise and one fall), and then gradually decreases (Fig. 7). At this time, the level decreases according to the logarithmic law (dependencies S-ln, *t*-straight lines). Such regularity is characteristic of a period of constant debit (withdrawal) and the change of debit according to linear and parabolic dependences concerning time.

In this case, taking into account the filtration rate, according to the formula, for a constant discharge condition, it is equal to:

$$v_f = \frac{Q}{2\pi mr} \tag{3}$$

the actual rate of change in the depression curve is:

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$$v_d = \frac{Q}{4\pi kmt} \quad (4)$$

Thus, after a relatively short period, the depression curve in the well and the adjacent area is the same as during the period of steady (fixed value) movement.

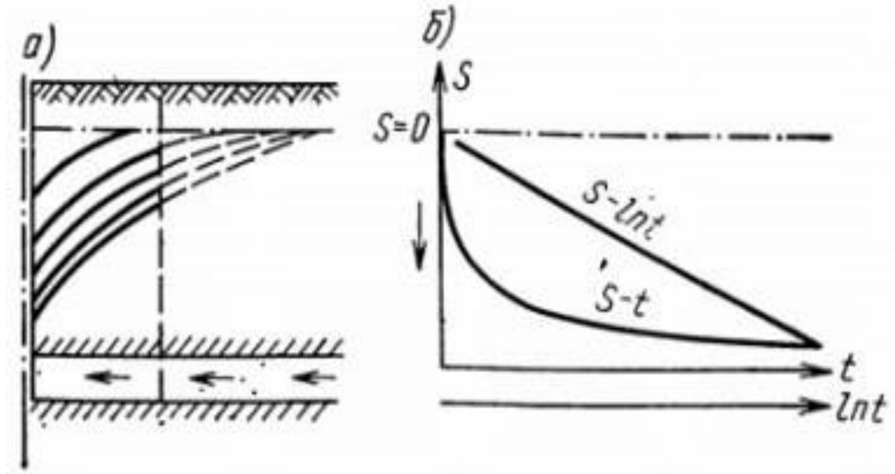

Figure 6: Level drop graphs (b) and depression curves (a) when drawing water from a well with a constant flow rate.

According to the formula (4), the velocity υ_d does not depend on the coordinates *x* and *y* in the discharge process, that is, the depression curve moves parallel to itself in the vertical section (see the continuous curve in Fig. 6 a).
These regularities are characterized by a regular or quasi-steady value mode of filtering. The area in which such a regime of groundwater movement occurs expands over time and can reach significant dimensions during periods of increased pressure transfer capacity of the formation medium. In the case of long-term water extraction during the use of water extraction facilities, this area covers the entire area affected by the water extraction.
It should be noted that in the conditions of an unconfined layer, at $t\rightarrow \infty$, the hydraulic resistance, which means the level drop, moves to infinity, which is not true. The value of lowering the level is usually limited because when drawing water from the well into the area of its influence, large areas are added to the process, and the depression curve reaches the limits closest to it, which ensures the saturation of the formation. It is not possible to use the corresponding formulas given in the unbounded layer scheme for this time interval.
However, in cases where additional sources and limits of layer saturation have little or no effect, the calculated level drop may exceed the capacity of the layer when *t* is large (or Q is large). In such conditions, a different mode of water extraction is used: the drop in the level inside the well remains unchanged, and the discharge decreases over time. The formulas presented here are intended to be used during the period when the level drop value is below the permissible value.
From the given solutions, another conclusion is drawn that when groundwater is extracted from a well in an unbounded layer, its influence can spread to the "infinite area". But the redistribution of the pressure and level drop in the formation occurs gradually over time, covering all areas far from the well. Therefore, even in individual layers, the real or, according to the term of V. N. Shelkachev, the conditional radius of the influence of the well (radius of influence) r^*_t can be distinguished, where the effect of water withdrawal from the well at the same time is not felt in the area outside it. In this case, the efficiency of water extraction can be evaluated according to the level of drop.
Noting the specified level of the level decrease (for example, under the influence of meteorological factors, equal to or not exceeding the value of the level change that occurs under natural conditions), the conditional radius of the effect r^*_t can be determined based on (5) and another formula.
From this formula, it can be concluded that at the time when the level of S_t decreases to a specified (acceptable) level within a certain amount of debit and within the range of influence the ratio must remain, which results in an expression (value) for the conditional radius of the sphere of influence:

$$\frac{4\pi kmS_t}{Q} = -E_i\left(-\frac{r_t^{*2}}{4at}\right) \quad (5)$$

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$$r_t^* = \varphi_s \sqrt{at}, \qquad (6)$$

Here in

$$\varphi_s = \varphi_s(\frac{kmS_t}{Q})$$

According to this formula, with continuous extraction of water, we obtain the following result:

$$\varphi_s = 1{,}5e - \frac{2\pi kmS_t}{Q}$$

φ_s values, other things being equal, increase with an increase in good consumption, and decrease with a decrease in consumption. For accurate calculations, the change values of this coefficient can be obtained from[19]. However, it should be noted that the value of r^*_t is not used in the calculations to determine the performance of water intake facilities. Calculated dependences include the magnitude determined by direct comparison of the formula $r_t = 1{,}5\sqrt{at}$ for a well in an unbounded layer under conditions of unsteady motion based on Dupuy's formula for a circular layer with radius r^*_t during steady motion.

The radius of action of the water intake facility (wells) and the mode of filtration will significantly depend on the rate of additional saturation of the layer.

For example, in the case of $t=0$, as soon as the water extraction process begins, additional saturation of the moisture-retaining layer, estimated by the ε_{inf} modulus occurs.

In this case, the expression for determining the drop in water level when withdrawing water from one well (or one enlarged water outlet) for a non-territorial moisture-retaining layer has the following form:

$$S = \frac{Q}{4\pi km}\left[-Ei(-\alpha) - \frac{A}{\alpha}\right] \qquad (7)$$

Here in

$$A = \frac{\pi r^2 \varepsilon_{\inf}}{Q}; \alpha = \frac{r^2}{4at}$$

It follows from this formula that when ε_{inf} = const, the level of decay over time reaches a certain high value and then starts to decrease. The maximum time of the level decrease is determined by the following ratio:

$$t_{maks} = \frac{r^2}{4a\alpha}; \alpha e^{-\alpha} = A \qquad (8)$$

Therefore, it is known from the formula (8) that in certain ratios of Q and ε_{inf}, the level decrease can have a negative value. But since the additional infiltration factor caused by the operation of the water outlet is assumed with the magnitude of ε_{inf}, the current (dynamic) level of groundwater is higher than the initial (static) level, that is, $H(t)<H_e$ and, as a result, the effect of the water outlet is S>0 should be lower at every point of the layer. As a result of such reasons, when the dynamic level increases and, accordingly, when S_{mak} is determined by the ratio of (8), the increase should not decrease

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after reaching the expression t_{mak}, that is, it should always be $S \geq S_{mak}$ Otherwise, an impossible expression $A = \frac{\pi r^2 \varepsilon_{\inf}}{Q} > 1$ should be accepted. Thus, when ε_{ifn} = constand A→1, the groundwater level tends to a steady state.

The static level of underground water can vary significantly during the seasonal and annual periods under the influence of natural hydrometeorological factors. However, this should not affect the level drop that occurs as a result of water withdrawal from the water outlet, as it is calculated relative to the static level for each current period.

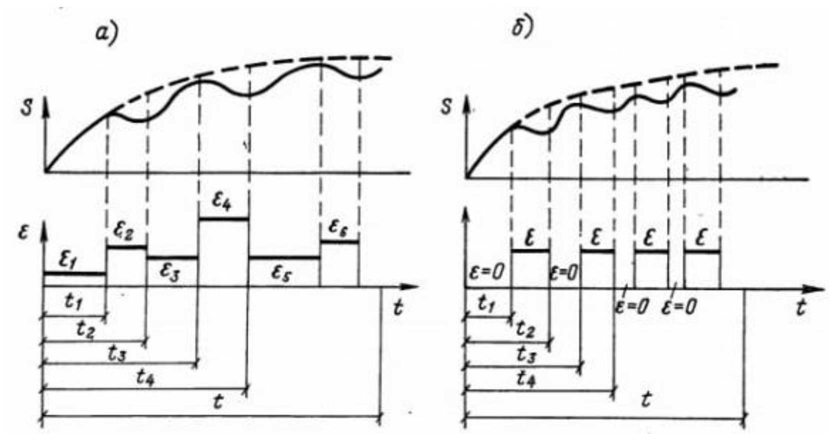

Figure 7: Graphs of periodic infiltration unequal (a) and equal (b) saturation.

When periodic infiltration saturation occurring during periods of increased water volume (for example, snowmelt or periods of heavy precipitation) is observed, the level drop during the operation of a water discharge facility in an unbounded layer of influence is expressed as follows (Fig. 7 a):

$$S = \frac{Q}{4\pi km}\left[-Ei(-\alpha) - \sum_{j=1}^{k}(A_j - A_{j-1})\frac{f(t-t_{j-1})}{\alpha(t-t_{j-1})}\right] \quad (9)$$

where, j=1, 2, ..., k; k - total calculation of infiltration saturation cycles;

$$\alpha(t-t_{j-1}) = \frac{r^2}{4at}; \frac{r^2}{4a(t-t_1)}; \frac{r^2}{4a(t-t_2)}$$

When j=1, ε_1=0, ε_{1-j-1}=0, ε_3= ε_5=0, i.e. periods without infiltration are counted in the formula in the same way as periods with infiltration, but with the opposite sign

$$f(t-t_{j-1}) = \begin{cases} 0 \; in & t<t_{j-1}; \\ 1 \; in & t>t_{j-1}, \end{cases}$$

where tj is the period during which the decrease in the level of *S* is determined.

In the case of equal distribution and the same magnitude of infiltration periods, the formula (10) is expressed as follows (Fig. 7 (b)):

$$S = \frac{Q}{4\pi km}\left[-E_i(-\alpha) - \varepsilon_{\inf}\sum_{j=1}^{k}\frac{f(t-t_{t-1})}{\alpha(t-t_{j-1})}\right] \quad (10)$$

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Thus, when evaluating the effects of uniform infiltration, it is usually necessary to take into account the total length of the period of its effect, which is usually much shorter than the service life of the discharge facility. For example, if the main infiltration saturation layer occurs before the flood, as well as during the period of floods when the loss of flows on the surface of the ground in the area of influence of the drainage facility reaches its maximum, its duration is 8-10% of the total usage time.

5. Conclusion

In conclusion, it can be said that the distances of the group of wells are linearly repeated in any area in order and according to a certain *t* cycle, that is, therowsanddistances between them also have a certain order, and their interaction glaze occurs. The given analysis and results show that the efficiency of the group of wells and their stable operation make it possible to predict the changes in the flow of underground water to the well, and the stability of the influencing factors makes it possible to predict the debit changes in them in advance.

Predicting the decrease in debit due to interaction in a group of wells makes it possible to provide consumers with a continuous and reliable water supply and prevents interruptions in the water supply.

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