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EVALUATION OF DRAWDOWNS IN WELLS BY MEANS OF A MATHEMATICAL MODEL — THE REZAYEH WATER-SUPPLY SCHEME, IRAN

The evaluation of ground-water reserves of the town of Rezayeh, NW Iran, has been made by means of calculation of maximum drawdowns in the production wells at variable pumping rate.

INTRODUCTION

For Rezayeh, a town in northwestern Iran, a new water-supply scheme has to be developed. Some 1.3 cu. m. per sec. of water are supposed to be necessary to meet the future demand.

The town of Rezayeh is situated 18 km. to the west of the Rezayeh lake and lies on Quaternary sediments the thickness of which is not known accurately.

The sequence of layers is very irregular. There are rambling changes of coarse and fine clastic sediments. The interlayers are subject to lateral changes too. In order to evaluate ground-water reserves the ground-water budget was first made for the whole area (Elektroprojekt Engineering Co., 1971). According to these calculations, it was estimated that there is a surplus of water that could be brought to efficient use. A scheme of production wells was designed and the distribution of drawdowns in the wells at a number of selected points at the required total rate of pumping was simulated by means of a mathematical model. The applied procedure, data and obtained results are presented below.

THE MATHEMATICAL MODEL

For the mathematical model, some simplifications of the hydrogeologic conditions were made. The artesian aquifer was assumed to be a leaky one, with an infinite extension towards the north and south. The eastern and western boundaries are impermeable according to the existing hydrogeologic map, scale 1 : 100 000, although the authors of this paper consider possible some recharge from the west.

The artesian aquifer is overlain by semipervious strata, and by a water-table source bed at the top of the sequence. It is further assumed that the hydraulic head in the source bed remains connstant during the pumping of the artesian aquifer. Under exploitation conditions, the aquifer is recharged by leakage from the source bed. Such a mechanism will be introduced when the initial piezometric pressure is lowered as a result of future pumping. The principal aim of the calculations was to find out the piezometric surface in the vicinity of the wells and at the selected points under steady-state conditions. Twenty-two new wells were assumed to be in continual operation, and the total pumping rate was to be about 95×10^3, 165×10^3, and 173×10^3 cu. m. per day, respectively.

The solution of maximum drawdown (s_m) due to the pumping of the well was derived from the steady-state conditions in a leaky aquifer supposing that the time since pumping began approaches infinity (Jacob, 1946).

$$s_m \left(\frac{Q}{2 \pi T} \right) K_0 (r/B)$$

where

Q = pumping rate
T = transmissibility
K_0 = modified Bessel function of the second kind and zero order
$B = (T b'/K')^{1/2}$ leakage factor
K'/b' = coefficient of leakage

The parameters are in consistent units.

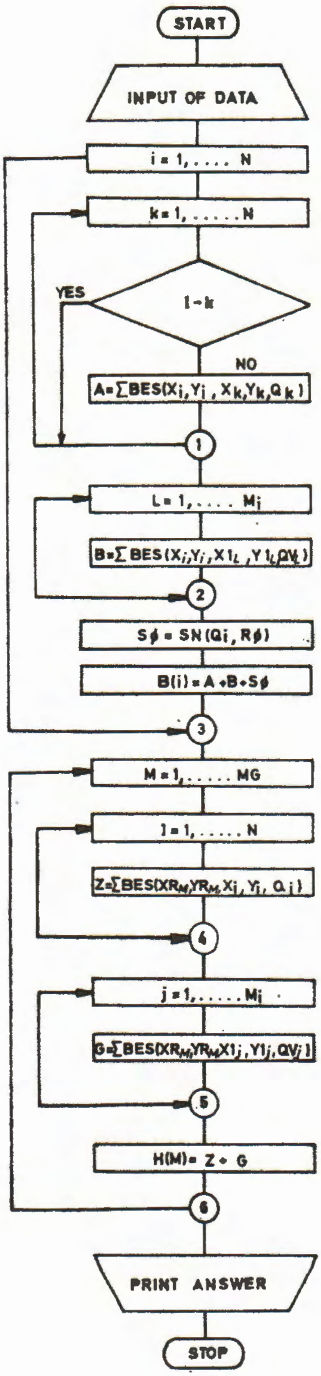
The effect of the impermeable boundary was replaced by image wells situated at the opposite side of each boundary. Only one row of image wells on each side was taken into account because of great distances between the wells. The following values of the hydrogeologic parameters were used:

$$T = 1555 \text{ sq. m. per day}$$

$$K'/b' = 1{,}47 \cdot 10^{-3} \text{ day}^{-1}$$

Computations of drawdowns carried out in total for 22 real wells, 44 image wells, and 22 selected points within the area of study. A program for the use of UNIVAC 1106 electronic calculator was prepared.

The flow diagram is shown in Fig. 1, the mathematical model in Fig. 2 ,and obtained results in Table I.



Text-fig. – Sl. 1

FLOW DIAGRAM
DIJAGRAM TOKA

LEGEND:
LEGENDA:

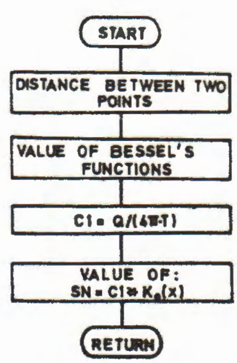
N – NUMBER OF WELLS
BROJ BUNARA

Mi – NUMBER OF IMAGE WELLS
BROJ ZRCALNIH BUNARA

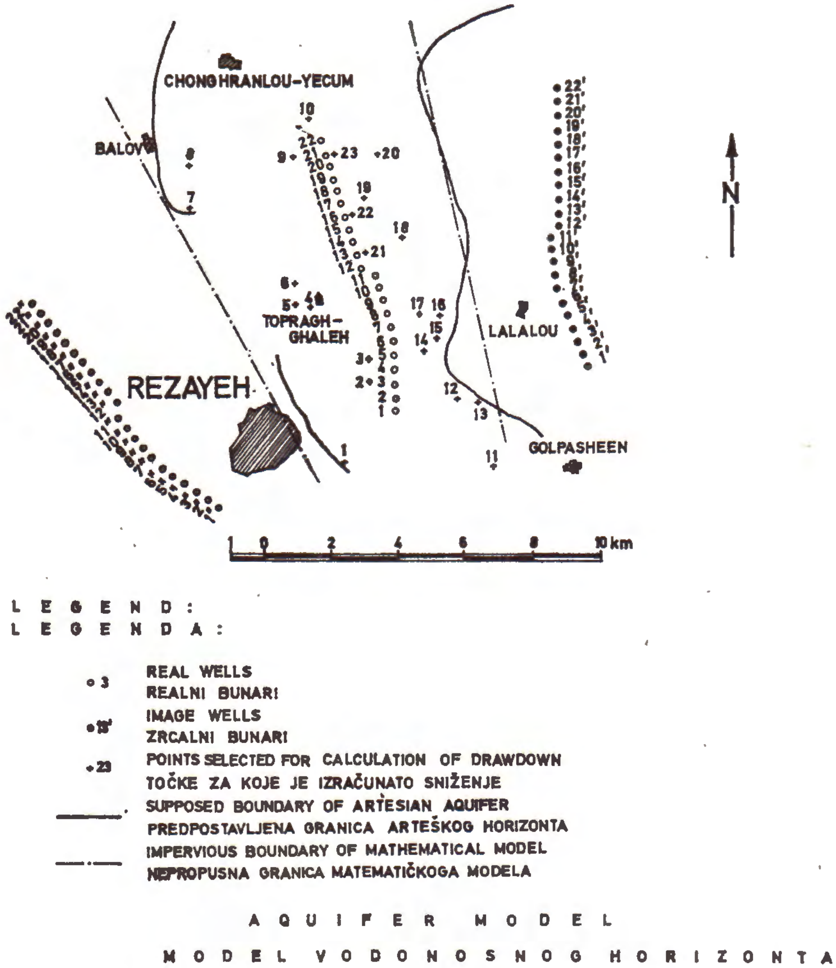
M_G – NUMBER OF SELECTED POINTS
BROJ ODABRANIH TOČAKA

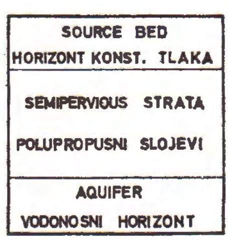
X,Y – COORDINATES OF WELLS AND POINTS
KOORDINATE BUNARA I TOČAKA

SUBROUTINE BES
POTPROGRAM BES



REZAYEH WATER SUPPLY SCHEME
CRPILIŠTE REZAYEH





Text-fig. – Sl. 2

CONCLUSIONS

The evaluation of ground water reserves of the Rezayeh area was made by means of calculations of drawdowns in the production wells at variable pumping rates. For this purpose all data of transmissibility (Elektroprojekt Co., 1971) were averaged, and only one available value of leakage coefficient was assumed to represent the entire Rezayeh area.

The above mentioned assumptions will produce discrepancies between the obtained data and the conditions that will be established during the future exploitation. In spite of this fact, the performed calculations undoubtedly show the possibility that ground water may be withdrawn at the required rate. Furthermore, according to the distribution of drawdowns at selected points, it seems that a considerable decline of the water table in the source bed will not occur. Further investigations, especially concerning the definition of the western boundary and the amount of lateral recharge from this side, are recommended. The change of vertical leakage from the artesian aquifer and the loss of water due to evapotranspiration and subsurface outflow towards Lake Rezayeh will have to be studied too.

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REFERENCES

Jacob, C. E. (1946): Radial Flow in a Leaky Artesian Aquifer — Trans. Amer. Geophysical Union 27/2.

Elektroprojekt Engineering Co. (1971): Rezayeh Project, Feasibility Report, Teheran (unpublished report).

Table — tabela I

Rezayeh water supply scheme

Prognoses of the drawdowns

Transmissibility T=1555.0 met²/day
Diameter of well R_0 = 0.20 met.
Leaky factor B = 1026.0 met.
Capacity of well variable Q (m³/day)

Drawdovns in the wells

B (1) = 4,96	Q (1) = 4320,00
B (2) = 5,45	Q (2) = 4320,00
B (3) = 5,70	Q (3) = 4320,00
B (4) = 5,85	Q (4) = 4320,00
B (5) = 5,97	Q (5) = 4320,00
B (6) = 6,06	Q (6) = 4320,00
B (7) = 6,17	Q (7) = 4320,00
B (8) = 6,25	Q (8) = 4320,00
B (9) = 6.33	Q (9) = 4320,00
B (10) = 6,35	Q (10) = 4320,00
B (11) = 6,27	Q (11) = 4320,00
B (12) = 6,27	Q (12) = 4320,00
B (13) = 6,35	Q (13) = 4320,00
B (14) = 6,29	Q (14) = 4320,00
B (15) = 6,19	Q (15) = 4320,00
B (16) = 6,13	Q (16) = 4320,00
B (17) = 6,08	Q (17) = 4320,00
B (18) = 6,01	Q (18) = 4320,00
B (19) = 5,91	Q (19) = 4320,00
B (20) = 5,76	Q (20) = 4320,00
B (21) = 5,50	Q (21) = 4320,00
B (22) = 5,00	Q (22) = 4320,00

Drawdowns at selected points

T (1) = ,18	T (12) = ,35
T (2) = 1,71	T (13) = 1,43
T (3) = 1,89	T (14) = 1,04
T (4) = ,64	T (15) = ,87
T (5) = ,45	T (16) = 1,38
T (6) = ,54	T (17) = 1,08
T (7) = ,00	T (18) = 1,57
T (8) = ,07	T (19) = ,70
T (9) = ,93	T (20) = 2,78
T (10) = ,62	T (21) = 2,65
T (11) = ,51	T (22) = 2,55

Table — tabela II

Rezayeh water supply scheme

Prognoses of the drawdowns

Transmissibility T = 1555.0 met²/day
Diameter of well R_0 = 0.20 met.
Leaky factor B = 1026.0 met.
Capacity of well variable Q (m³/day)

Drawdovns in the wells

B (1) = 8,62	Q (1) = 7515,00
B (2) = 9,48	Q (2) = 7515,00
B (3) = 9,92	Q (3) = 7515,00
B (4) = 10,18	Q (4) = 7515.00
B (5) = 10,39	Q (5) = 7515,00
B (6) = 10,55	Q (6) = 7515,00
B (7) = 10,73	Q (7) = 7515,00
B (8) = 10,88	Q (8) = 7515,00
B (9) = 11,01	Q (9) = 7515,00
B (10) = 11,04	Q (10) = 7515,00
B (11) = 10,91	Q (11) = 7515,00
B (12) = 10,91	Q (12) = 7515,00
B (13) = 11,05	Q (13) = 7515,00
B (14) = 10,95	Q (14) = 7515,00
B (15) = 10,77	Q (15) = 7515,00
B (16) = 10,67	Q (16) = 7515,00
B (17) = 10,57	Q (17) = 7515,00
B (18) = 10,45	Q (18) = 7515,00
B (19) = 10,29	Q (19) = 7515,00
B (20) = 10,02	Q (20) = 7515,00
B (21) = 9,57	Q (21) = 7515,00
B (22) = 8,69	Q (22) = 7515,00

Drawdowns at selected points

T (1) = ,32	T (12) = ,60
T (2) = 2,97	T (13) = 2,40
T (3) = 3,29	T (14) = 1,81
T (4) = 1,11	T (15) = 1,51
T (5) = ,79	T (16) = 2,40
T (6) = ,94	T (17) = 1,87
T (7) = ,00	T (18) = 2,73
T (8) = ,12	T (19) = 1,35
T (9) = 1,62	T (20) = 4,84
T (10) = 1,09	T (21) = 4,61
T (11) = ,88	T (22) = 4,43

Table — tabela III

Rezayeh water supply scheme

Prognoses of the drawdowns

Transmissibility T=1555.0 met²/day
Diameter of well R_o = 0.20 met.
Leaky factor B = 1026.0 met.
Capacity of well variable Q (m³/day)

Drawdovns in the wells

B (1) = 9.02	Q (1) = 7862,00
B (2) = 9,92	Q (2) = 7862,00
B (3) = 10,38	Q (3) = 7862,00
B (4) = 10,65	Q (4) = 7862,00
B (5) = 10,87	Q (5) = 7862,00
B (6) = 11,04	Q (6) = 7862,00
B (7) = 11,23	Q (7) = 7862,00
B (8) = 11,38	Q (8) = 7862,00
B (9) = 11,51	Q (9) = 7862,00
B (10) = 11,55	Q (10) = 7862,00
B (11) = 11,41	Q (11) = 7862,00
B (12) = 11,42	Q (12) = 7862,00
B (13) = 11,56	Q (13) = 7862,00
B (14) = 11,46	Q (14) = 7862,00
B (15) = 11,27	Q (15) = 7862,00
B (16) = 11,16	Q (16) = 7862,00
B (17) = 11,06	Q (17) = 7862,00
B (18) = 10,94	Q (18) = 7862,00
B (19) = 10,76	Q (19) = 7862,00
B (20) = 10,49	Q (20) = 7862,00
B (21) = 10,01	Q (21) = 7862,00
B (22) = 9,10	Q (22) = 7862,00

Drawdowns at selected points

T (1) = ,33	T (12) = ,63
T (2) = 3,11	T (13) = 2,60
T (3) = 3,45	T (14) = 1,89
T (4) = 1,17	T (15) = 1,50
T (5) = ,82	T (16) = 2,51
T (6) = ,99	T (17) = 1,96
T (7) = ,00	T (18) = 2,85
T (8) = ,12	T (19) = 1,41
T (9) = 1,70	T (20) = 5,06
T (10) = 1,14	T (21) = 4,82
T (11) = ,92	T (22) = 4,64

P. MILETIĆ, M. HEINRICH i B. ŠVEL

ODREĐIVANJE SNIŽENJA NIVOA VODE U BUNARIMA UZ POMOĆ MATEMATIČKOG MODELA ZA VODOOPSKRBU GRADA REZAYEHA, IRAN

Za Rezayeh, grad u sjeverozapadnom Iranu, potrebno je osigurati 1300 l/sek. vode za vodoopskrbu.

U tu svrhu izrađen je bilans voda koji pokazuje mogućnost pridobivanja tražene količine vode (Elektroprojekt, 1971). Zbog općenito nesigurnih hidrogeoloških podataka odlučeno je da se eksploatacione rezerve provjere pomoću matematičkog modela.

Opća hidrogeološka situacija je slijedeća:

Zapadno od jezera Rezayeh leže kvartarni (a moguće i stariji) arteški vodonosni horizonti čiji kontinuitet nije u prostoru stalan. U krovini se nalazi horizont slobodne površine. U području crpilišta arteški horizonti ograničeni su prema zapadu i istoku dok se u smjeru sjever—jug nastavljaju izvan područja crpilišta. Za horizonte postoji više vrijednosti koeficijenta transmisibiliteta, ali je iz podataka moguće izračunati samo jednu vrijednost za koeficijent vertikalnog procjeđivanja.

Za konstrukciju matematičkog modela bilo je potrebno provesti izvjesna pojednostavljenja hidrogeološke situacije. Ona se sastoje u slijedećem: vrijednost koeficijenta vertikalnog procjeđivanja uzeta je kao karakteristična za čitavo crpilište, a tlak u najgornjem, freatskom horizontu stalan. Prihranjivanje arteškog horizonta pretpostavljeno je isključivo procjeđivanjem kroz krovinske slabo propusne naslage. Utjecaj zapadne i istočne nepropusne granice nadomješten je nizom zrcalnih bunara (sl. 2). Veći broj zrcalnih nizova nije uzet u obzir zbog malih međusobnih utjecaja.

Za određivanje eksploatacionih rezervi u gornjim uvjetima korišten je izraz C. E. Jacob-a (1946) za maksimalno sniženje u bunaru u slučaju vertikalnog procjeđivanja i stacionarnog stanja toka. U datim uvjetima izračunata su sniženja za 22 realna bunara, 44 zrcalna bunara (za ukupne kapacitete od 95040 m³/dan, 165330 m³/dan, 172964 m³/dan), te 22 točke na području crpilišta.

Za simulaciju priređen je program za elektroničko računalo UNIVAC 1106, čiji je dijagram toka prikazan na sl. 1. Rezultati proračuna vide se na prilogu br. 1. Oni pokazuju da na obrađenom crpilištu možemo sa sigurnošću računati s traženim rezervama vode. To vrijedi unatoč toga što se očekuju izvjesna odstupanja od izračunatih vrijednosti zbog pretpostavki s kojima se ušlo u račun.

Rezultati nam također nameću potrebu detaljnijeg određivanja zapadne granice vodonosnog kompleksa i prihranjivanja koje se s te strane može očekivati. Također treba proučiti promjene vertikalnog procjeđivanja iz arteškog horizonta, kao i gubitak vode putem evapotranspiracije i podzemnog toka prema jezeru.

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