Discharge Calculation in Interfering Wells By Modified Total Drawdown - Discharge Equations

Geliştirilmiş Toplam Düşüm - Debi Denklemleri Yardımı ile Girişim Yapan Kuyuların Debilerinin Hesaplanması

Ahmet Hikmet ÖZYOL [1]

Bu araştırmada, girişim yapan kuyularda, farklı düşüm, farklı yarıçap ve farklı çalışma süresi olması halinde kuyuların debilerinin hesabı için geliştirilmiş toplam düşüm - debi denklemlerinden faydalanılmıştır.

Ayrıca basınçsız akiferdeki kuyular için tam toplam düşüm debi denklemi kullanılmıştır.

***

In this research it was attempted to calculate discharges of interfering wells in the case of different drawdowns, diameters and operating periods by means of modified total drawdown discharge equations.

Also exact total drawdown - discharge equation was used for the wells which are in unconfined aquifers.

INTRODUCTION

Muskat (1) used total drawdown - discharge equations to calculate discharges of interfering wells for steady flows in the case of equal drawns, diameters and operating periods, and furthermore gave some special solutions. However, Hantush (2) used similar equations for unsteady flows and presented some special equations with the same conditions.

---

1 Water Supply Department of the Holy City of Makkah.

DERIVATION OF EQUATIONS

Muskat employed the following equations for discharge calculations in the interfering wells for the case of steady flows as,

$$s_T = H - h_T = \sum_{i=1}^{n} \frac{Q_i}{2 \, . \, \pi k \, . \, b} \cdot \ln (R_i / r_i) \tag{1}$$

$$H^2 - h^2 = \sum_{i=1}^{n} \frac{Q_i}{\pi \, . \, k} \cdot \ln (R_i / r_i) \tag{2}$$

Eqs. (1) and (2) are valid for confined and unconfined aquifers respectively. Eq. (1) was originally derived on the basis of superposition principle as,

$$s_T = \sum_{i=1}^{n} s_i \tag{3}$$

but Eq. (2) is an approximate equation and is valid only for small values of drawdowns ($s_T \ll 2\,H$), where

s_T : Total drawdown in a well, L.
h_T : Height of water in a well which corresponds to total drawdown in the same well, $h_T = H - s_T$, L.
s_i : Individual drawdown in the $i-th$ well, L.
H : Height of piezometric pressure from the base of a confined aquifer or thickness of an unconfined aquifer L.
b : Thickness of a confined aquifer, L.
k : Coefficient of permeability, L/T.
Q_i : Discharge of the $i-th$ well, L^3/T.
r_i : Radius of the $i-th$ well, L.
R_i : Radius of influence in the $i-th$ well, L.

In the solution of Eqs. (1) and (2) Muskat accepted that drawdowns, diameters and operating periods are the same in all the interfering wells. In this research, it was attempted to find solutions for different drawdowns, diameters as well as operating periods for each individual interfering wells. Also, exact total drawdown equation was used, Eq. (3), for wells in unconfined aquifers instead of approximate equation, Eq. (2). First of all Eq. (3) is modified and written in a new form as,

$$S_{Ti} = \sum_{i=1}^{n} s_{ij} \qquad (i=1, 2, \dots n) \tag{4}$$

where

s_{Ti} : Total drawdown in the *i—th* well, *L*.

s_{ij} : Influence (drawdown) in the *i—th* well which is caused by *j—th* well, *L*.

Eq. (4) can be written explicitly as,

$$\left.\begin{array}{l} s_{T1} = s_{11} + s_{12} + \dots + s_{1n} \\ s_{T2} = s_{21} + s_{22} + \dots + s_{2n} \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ s_{Tn} = s_{n1} + s_{n2} + \dots + s_{nn} \end{array}\right\} \tag{5}$$

However, for confined aquifers (in the case of steady flow) mutual drawdown effects can be expressed as,

$$s_{ij} = \frac{\ln (R_i/r_{ij})}{2 . \pi . k . b} \cdot Q_j \tag{6}$$

and for unconfined aquifers this expression turns out to be,

$$s_{ij} = H - \sqrt{H^2 - \frac{\ln (R_i/r_{ij})}{\pi . k} \cdot Q_i} \tag{7}$$

By defining a new variable as,

$$\alpha_{ij} = \frac{\ln (R_j/r_{ij})}{2 . \pi . k . b} \tag{8}$$

and

$$\beta_{ij} = \frac{\ln (R_i/r_{ij})}{\pi . k} \tag{9}$$

Eqs. (6) and (7) can be written implicitly as,

$$s_{ij} = \alpha_{ij} \, . \, Q_j \tag{10}$$

and

$$s_{ij} = H - \sqrt{H^2 - \beta_{ij} \, . \, Q_j} \tag{11}$$

where

r_{ij} : The distance between the $i-th$ and $j-th$ well, L.
R_i : Radius of influence in the $j-th$ well, L.
Q_j : Discharge of the $j-th$ well, L^3/T.
α_{ij}, β_{ij} : Dummy variables.

If Eq. (10) is substituted into Eq. (5), then for confined aquifers one can find,

$$\left.\begin{array}{l} s_{T_1} = \alpha_{11} \, . \, Q_1 + \alpha_{12} \, . \, Q_2 + \ldots + \alpha_{1n} \, . \, Q_n \\ s_{T_2} = \alpha_{21} \, . \, Q_1 + \alpha_{22} \, . \, Q_2 + \ldots + \alpha_{2n} \, . \, Q_n \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ s_{T_n} = \alpha_{n1} \, . \, Q_1 + \alpha_{n2} \, . \, Q_2 + \ldots + \alpha_{nn} \, . \, Q_n \end{array}\right\} \tag{12}$$

or shortly,

$$s_{Ti} = \sum_{j=1}^{n} \alpha_{ij} \; Q_j \quad (i = 1, 2, \ldots, n) \tag{12 a}$$

However, for unconfined aquifers, first, it is useful to define

$$\delta_{ij} = \sqrt{H^2 - \beta_{ij} \, . \, Q_j} \tag{13}$$

and accordingly Eq. (11) becomes,

$$s_{ij} = H - \delta_{ij} \tag{14}$$

On the other hand, if Eq. (14) is substituted into Eq. (5) it leads to,

$$\left.\begin{array}{l} s_{T_1} = n \, . \, H - (\delta_{11} + \delta_{12} + \ldots + \delta_{1n}) \\ s_{T_2} = n \, . \, H - (\delta_{21} + \delta_{22} + \ldots + \delta_{2n}) \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ s_{T_n} = n \, . \, H - (\delta_{n1} + \delta_{n2} + \ldots + \delta_{nn}) \end{array}\right\} \tag{15}$$

or

or

$$\left.\begin{array}{l} n\,.\,H - s_{T_1} = \delta_{11} + \delta_{12} + \ldots + \delta_{1n} \\ n\,.\,H - s_{T_2} = \delta_{21} + \delta_{22} + \ldots + \delta_{2n} \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ n\,.\,H - s_{T_n} = \delta_{n1} + \delta_{n2} + \ldots + \delta_{nn} \end{array}\right| \qquad (16)$$

Furthermore, it can be rewritten shortly as,

$$n\,.\,H - s_{T_i} = \sum_{j=1}^{n} \delta_{ij} \qquad (i = 1, 2, \ldots, n) \qquad (16\text{ a})$$

Since, δ_{ij} is an irrational function, it is necessary to use computer for numerical solutions of Eq. (16).

However, modified approximate equations can be used also for confined aquifers in the case of different drawdowns, diameters, and operation periods provided that drawdowns are small.

Modified approximate general equation can be written as follows,

$$H^2 - h^2_{T_i} = \sum_{j=1}^{n} \frac{\ln (R_i / r_{ij})}{\pi\,.\,k} \cdot Q_j \qquad (17)$$

under the light of Eq. (9), Eq. (17) can be rewritten as,

$$H^2 - h^2_{T_i} = \sum_{j=1}^{n} \beta_{ij}\,.\,Q_j \qquad (i = 1, 2, \ldots, n) \qquad (18)$$

or explicitly as,

$$\left.\begin{array}{l} H^2 - h^2_{T_1} = \beta_{11}\,.\,Q_1 + \beta_{12}\,.\,Q_2 + \ldots + \beta_{1n}\,.\,Q_n \\ H^2 - h^2_{T_2} = \beta_{21}\,.\,Q_1 + \beta_{22}\,.\,Q_2 + \ldots + \beta_{2n}\,.\,Q_n \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ H^2 - h^2_{T_n} = \beta_{n1}\,.\,Q_1 + \beta_{n2}\,.\,Q_2 + \ldots + \beta_{nn}\,.\,Q_n \end{array}\right| \qquad (19)$$

Also, Eq. (19) takes the following form of equation system,

$$\left.\begin{array}{l} M_1 = \beta_{11}\,.\,Q_1 + \beta_{12}\,.\,Q_2 + \ldots + \beta_{1n}\,.\,Q_n \\ M_2 = \beta_{21}\,.\,Q_1 + \beta_{22}\,.\,Q_2 + \ldots + \beta_{2n}\,.\,Q_n \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \\ M_n = \beta_{n1}\,.\,Q_1 + \beta_{n2}\,.\,Q_2 + \ldots + \beta_{nn}\,.\,Q_n \end{array}\right| \qquad (20)$$

which can be written briefly as,

$$M_i = \sum_{j=1}^{n} \beta_{ij} \cdot Q_j \qquad (i=1,2,\ldots,n) \tag{21}$$

where in all the above equations

$$M_i = H^2 - h^2_{Ti} \tag{21 a}$$

Eq. (20) is similar to Eq. (12) and can be solved easily.

On the other hand, for unsteady flow in confined aquifers it can be written from Theis (3) equation as,

$$s_{ij} = \frac{W(u_{ij})}{4 \cdot \pi \cdot k \cdot b} \cdot Q_j \tag{22}$$

with the definition of the following new variables,

$$\bar{\alpha}_{ij} = \frac{W(u_{ij})}{4 \cdot \pi \cdot k \cdot b} \tag{23}$$

Eq. (22) can be conciesly written as,

$$s_{ij} = \bar{\alpha}_{ij} \cdot Q_j \tag{24}$$

And for unsteady flow in confined aquifers from modified Theis equation one can write,

$$H^2 - h^2 = \frac{Q}{2 \cdot \pi \cdot k} \cdot W(u)$$

It can be written that,

$$s = H - \sqrt{H^2 - \frac{W(u_{ij})}{2 \cdot \pi \cdot k} \cdot Q}$$

due to $h = H - s$, or

$$s_{ij} = H - \sqrt{H^2 - \frac{W(u_{ij})}{2 \cdot \pi \cdot k} \cdot Q_j} \tag{25}$$

with the definition of the following new variable

$$\bar{\beta}_{ij} = \frac{W(u_{ij})}{2 \cdot \pi \cdot k} \tag{26}$$

Eq. (25) can be written briefly as,

$$s_{ij} = H - \sqrt{H^2 - \bar{\beta}_{ij} \cdot Q_j} \tag{27}$$

And also if it is defined that,

$$\bar{\delta}_{ij} = \sqrt{H^2 - \bar{\beta}_{ij} \cdot Q_j} \tag{28}$$

Eq. (27) becomes as,

$$s_{ij} = H - \bar{\delta}_{ij} \tag{29}$$

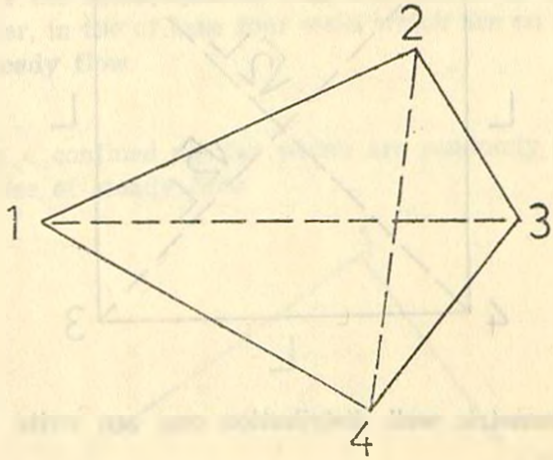
In this case Eqs. (12), (16) and (20) can be used for unsteady flows by replacing $\bar{\alpha}_{ij}$, $\bar{\beta}_{ij}$, $\bar{\delta}_{ij}$ instead of $\alpha_{ij}, \beta_{ij}, \delta_{ij}$. The meanings of some parameters in the above derivations are as follows,

$W(u_{ij})$	:	Well function.
u_{ij}	:	$S \cdot r^2_{ij} / 4 \cdot T \cdot t_0$.
r_{ij}	:	Distance between the $i-th$ and $j-th$ wells, L.
S	:	Storage coefficient.
T	:	Transmissibility. L^2/T.
$\bar{\alpha}_{ij}$, $\bar{\beta}_{ij}$, $\bar{\delta}_{ij}$	:	Dummy variables.
t_0	:	operation time, T.

APPLICATIONS

Problem I :

4 wells in a confined aquifer which are randomly scattered in the field in the case of steady flow.



Solution :

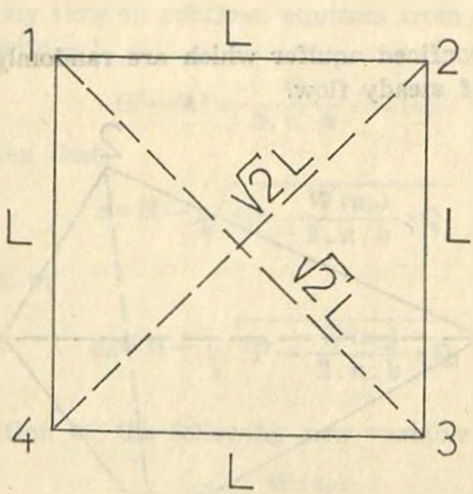
First, Eq. (12) is written

$$\left.\begin{aligned} s_{T1} &= \alpha_{11} \cdot Q_1 + \alpha_{12} \cdot Q_2 + \alpha_{13} \cdot Q_3 + \alpha_{14} \cdot Q_4 \\ s_{T2} &= \alpha_{21} \cdot Q_1 + \alpha_{22} \cdot Q_2 + \alpha_{23} \cdot Q_3 + \alpha_{24} \cdot Q_4 \\ s_{T3} &= \alpha_{31} \cdot Q_1 + \alpha_{32} \cdot Q_2 + \alpha_{33} \cdot Q_3 + \alpha_{34} \cdot Q_4 \\ s_{T4} &= \alpha_{41} \cdot Q_1 + \alpha_{42} \cdot Q_2 + \alpha_{43} \cdot Q_3 + \alpha_{44} \cdot Q_4 \end{aligned}\right| \quad \text{(I-1)}$$

Then according to Eq. (8) the values of α_{ij} are calculated as follows.

$$\alpha_{11} = \ln (R_1/r_{11})/2 \cdot \pi \cdot k \cdot b$$
$$\alpha_{12} = \ln (R_2/r_{12})/2 \cdot \pi \cdot k \cdot b$$
$$\cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot$$
$$\alpha_{43} = \ln (R_3/r_{13})/2 \cdot \pi \cdot k \cdot b$$
$$\alpha_{44} = \ln (R_4/r_{44})/2 \cdot \pi \cdot k \cdot b$$

The values s_{T1}, s_{T2}, s_{T3}, s_{T4} are given in the beginning as data. For a special case, if it is assumed that four wells are on the corners of a square, and drawdowns, diameters and operation periods are equal to each other in the well group as shown in the following sketch, the calculations can be achieved as follows



Due to the symmetric well distribution one can write the following points :

1) $r_{12}=r_{23}=r_{34}=r_{41}$, $r_{13}=r_{24}$

2) $r_{11}=r_{22}=r_{33}=r_{44}=r$

3) $s_{T1}=s_{T2}=s_{T3}=s_{T4}=s_T$

4) $t_1=t_2=t_3=t_4=t$ or
$R_1=R_2=R_3=R_4=R$

From the above mentioned knowledge the following results are found,

$$\alpha_{11}=\alpha_{22}=\alpha_{33}=\alpha_{44}=\frac{1}{2.\pi.k.b}.\ln(R/r)$$

and

$$\left.\begin{array}{l}\alpha_{12}=\alpha_{23}=\alpha_{34}=\alpha_{41}\\ \alpha_{21}=\alpha_{32}=\alpha_{43}=\alpha_{14}\end{array}\right\}=\frac{1}{2.\pi.k.b}.\ln(R/L)$$

and

$$\alpha_{13}=\alpha_{31}=\alpha_{24}=\alpha_{42}=\frac{1}{2.\pi.k.b}.\ln(R/\sqrt{2}.L)$$

After these procedures all α_{ij} values are substituted in Eqs. (I - 1) together with $s_{T1}=s_{T2}=s_{T3}=s_{T4}=s_T$, and because of the symmetry, it can be written $Q_1=Q_2=Q_3=Q_4=Q$. Hence, it is found that

$$s_T=\frac{Q}{2.\pi.k.b}[\ln(R/r)+\ln(R/L)+\ln(R/\sqrt{2}.L)+\ln(R/L)]$$

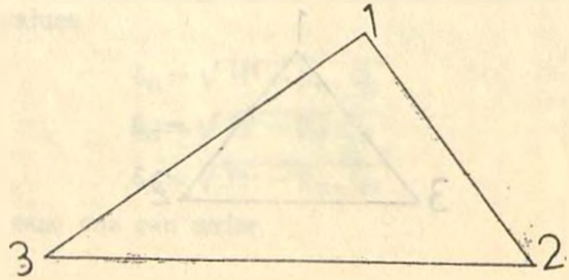
where in Eq. (I - 1) each of the four equations become the same. Hence, it is found that,

$$Q=\frac{2.\pi.k.b.s_T}{\ln(R^4/\sqrt{2}\cdot L^3.r)} \qquad \text{(I-2)}$$

In fact, this is the same equation that was found by Muskat (1) in a confined aquifer, in the of case four wells which are on the corners of a square, for steady flow.

Problem II :

3 wells in a confined aquifer which are randomly scattered in the field in the case of steady flow



Solution :

First, Eq. (16) is written

$$\left.\begin{aligned} 3\,.\,H - s_{T1} &= \delta_{11} + \delta_{12} + \delta_{13} \\ 3\,.\,H - s_{T2} &= \delta_{21} + \delta_{22} + \delta_{23} \\ 3\,.\,H - s_{T3} &= \delta_{31} + \delta_{32} + \delta_{33} \end{aligned}\right\} \qquad \text{(II-1)}$$

where from Eq. (13)

$$\delta_{ij} = \sqrt{H^2 - \beta_{ij}\,.\,Q_j} \qquad \text{(II-2)}$$

and from Eq. (9)

$$\beta_{ij} = (1/\pi\,.\,k)\,.\,\ln(R_j/r_{ij}) \qquad \text{(II-3)}$$

From Eq. (II - 3) it can be seen that :

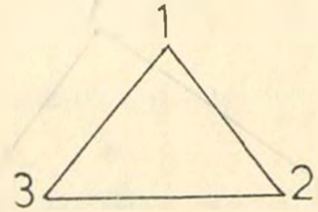
$$\begin{aligned} \beta_{11} &= (1/\pi\,.\,k)\,.\,\ln(R_1/r_{11}) \\ \beta_{12} &= (1/\pi\,.\,k)\,.\,\ln(R_2/r_{12}) \\ \beta_{13} &= (1/\pi\,.\,k)\,.\,\ln(R_3/r_{13}) \\ &\ldots\ldots\ldots \\ \beta_{33} &= (1/\pi\,.\,k)\,.\,\ln(R_3/r_{33}) \end{aligned}$$

Due to the fact that δ_{ij} is irrational function of Q_j, it is necessary to use computer for numerical solutions. If it is desired to use approximate equation for small drawdowns, Eq. (19) can then be written as,

$$\left.\begin{aligned} H^2 - h^2_{T1} &= \beta_{11}\,.\,Q_1 + \beta_{12}\,.\,Q_2 + \beta_{13}\,.\,Q_3 \\ H^2 - h^2_{T2} &= \beta_{21}\,.\,Q_1 + \beta_{22}\,.\,Q_2 + \beta_{23}\,.\,Q_3 \\ H^2 - h^2_{T3} &= \beta_{31}\,.\,Q_1 + \beta_{32}\,.\,Q_2 + \beta_{33}\,.\,Q_3 \end{aligned}\right\} \qquad \text{(II-4)}$$

The values of β_{ij} are the same as before.

For a special case, where three wells are on the corners of an equi lateral triangle and drawdowns, diameters and operation periods are equal then it is possible to write the following points.



1) $r_{12}=r_{23}=r_{31}=L$
2) $r_{11}=r_{22}=r_{33}=r$
3) $h_{T1}=h_{T2}=h_{T3}=h_T$
4) $t_1=t_2=t_3=t$ or
$R_1=R_2=R_3=R$

From the above mentioned knowledge the following results are found

$$\beta_{11}=\beta_{22}=\beta_{33}=\frac{1}{\pi . k}\cdot \ln (R/r)$$

$$\left.\begin{array}{l}\beta_{12}=\beta_{23}=\beta_{31}\\ \beta_{21}=\beta_{32}=\beta_{13}\end{array}\right\}=\frac{1}{\pi . k}\cdot \ln (R/L)$$

After these calculations all β_{ij} values are substituted into Eq. (II - 4) together with

$$h_{T1}=h_{T2}=h_{T3}=h_T$$

Also, it is a fact that $Q_1=Q_2=Q_3=Q$ which are due to symmetry. These considerations leads us to,

$$H^2-h^2{}_T=\frac{Q}{\pi . k}\cdot[\ln(R/r)+\ln (R/L)+\ln (R/L)]$$

where, in Eq. (II - 4) system, each of the three equations become the same. Hence, it is found,

$$Q=\frac{\pi . k . (H^2-h^2{}_T)}{\ln (R^3/L^2 . r)} \qquad \text{(II-5)}$$

This is the same equation that was earlier found by Muskat in an unconfined aquifer, for three wells which are located on the corners of an equilateral triangle, in the case of steady flow.

However, for this special case exact equations, Eqs. (II - 1) and (II - 2) can be solved without going to computer. First of all it is better to write δ_{ij} values

$$\delta_{11}=\sqrt{H^2-\beta_{11} . Q_1}$$

$$\delta_{22}=\sqrt{H^2-\beta_{22}\, Q_2}$$

$$\delta_{33}=\sqrt{H^2-\beta_{33} . Q_3}$$

For this special case one can write,

$$\beta_{11}=\beta_{22}=\beta_{33}=\frac{1}{\pi . k}\cdot \ln (R/r)=\beta_r$$

and also because $Q_1=Q_2=Q_3=Q$, due to symmetry,

$$\delta_{11}=\delta_{22}=\delta_{33}=\sqrt{H^2-\beta_r . Q}=\delta_r$$

Furthermore,

$$\left.\begin{array}{l}\beta_{12}=\beta_{23}=\beta_{31}\\ \beta_{21}=\beta_{32}=\beta_{13}\end{array}\right\}=\frac{1}{\pi . k}\cdot \ln(R/L)=\beta_L$$

and therefore

$$\left.\begin{array}{l}\delta_{12}=\delta_{23}=\delta_{31}\\ \delta_{21}=\delta_{32}=\delta_{13}\end{array}\right\}=\sqrt{H^2-\beta_L . Q}=\delta_L$$

And also it is given that, $s_{T1}=s_{T2}=s_{T3}=s_T$, hence it can be written that,

$$3 . H - s_T=\delta_r+2 . \delta_L \qquad \text{(II-6)}$$

or explicitly

$$3 . H - s_T=\sqrt{H^2-\beta_r . Q}+2 . \sqrt{H^2-\beta_L . Q} \qquad \text{(II-7)}$$

where, in Eq. (II - 1) system, each of the three equations become the same. After solution Eq. (II - 7) it is found that,

$$Q=(-B_3\pm\sqrt{B_3^2-4A_3 . C_3})/2 . A_3 \qquad \text{(II-8)}$$

where

$$A_3=\beta_r . \beta_L - E_2^2$$

$$B_3=-(H^2 . \beta_r+H^2 . \beta_L+2 . E_1 . E_2)$$

$$C_3=H^4-E_1^2$$

and

$$E_1=[(3 . H-s_T)^2-5 . H^2]/4$$

$$E_2=(\beta_r-4 . \beta_L)/4$$

The problem of two interfering wells with equal drawdowns can be solved in the same way,

$$\left.\begin{array}{l}2 . H - s_{T1}=\delta_{11}+\delta_{12}\\ 2 . H - s_{T2}=\delta_{21}+\delta_{22}\end{array}\right\} \qquad \text{(II-9)}$$

where

$$\delta_{11} = \delta_{22} = \delta_r$$

$$\delta_{12} = \delta_{21} = \delta_L$$

$$s_{T1} = s_{T2} = s_T$$

Hence, it is found

$$2 . H - s_T = \delta_r + \delta_L \tag{II-10}$$

since

$$\delta_r = \sqrt{H^2 - \beta_r . Q}$$

$$\delta_L = \sqrt{H^2 - \beta_L . Q}$$

it can be written

$$2 . H - s_T = \sqrt{H^2 - \beta_r . Q} + \sqrt{H^2 - \beta_L . Q} \tag{II-11}$$

After solution Eq. (II - 11) system it is found that

$$Q = (-B \pm \sqrt{B_2^2 - 4 . A_2 . C_2}\,)/2 . A_2$$

where

$$A_2 = \beta_r . \beta_L - F_2^2$$

$$B_2 = -(H^2 . \beta_r + H^2 . \beta_L + 2 . F_1 . F_2)$$

$$C_2 = H^4 - F_1^2$$

and

$$F_1 = [(2 . H - s_T)^2 - 2 . H^2] / 2$$

$$F_2 = (\beta_r + \beta_L)/2$$

REFERENCES

1. Muskat, M., The Flow of Homogeneous Fluids through Porous Media, McGraw-Hill Book Company, New York, 1937.
2. Hantush, M. S., Hydraulics of Wells, in V.T. Chow (ed.), Advances in Hydroscience, Vol. 1, Academic Press, New York, pp. 281 - 432, 1964.
3. Theis, C. V., The Relation between the lowering of the Piezometric surface and the rate and duration of discharge of a well using groundwater storage, Trans. Amer. Geophys. Union, Vol. 2, pp. 519 - 524, 1935.

EDITORIAL POLICY
and
SCOPE

The aim of the Bulletin is to allow rapid dissemination of interesting results in the field of Engineering and Science of the Staff of The State Academy of Engineering and Architecture of Sakarya.

The Executive Editor has authorized to publish the papers of the authors who do not belong to the Academy.

GUIDE FOR AUTHORS

Bulletin of The School of Engineering and Architecture of Sakarya is published with issues appearing in July, October, January and April. The Executive Editor has authorized to publish extra issues.

Papers for publication should be submitted with two copies to Editorial Secretary of Bulletin of The State Academy of Engineering and Architecture of Sakarya, Adapazarı/TURKEY.

Papers should be written in English, French and German and contain an abstract of about 150 words.

Further details are included in the booklet «Information for Authors and Manuscript Preparation Requirements» avaible from Editorial Secratary of Bulletin

MATBAA TEKNİSYENLERİ KOLL. ŞTİ. — İSTANBUL 1981