Radial flow, empiric reach of depression, protection zones

Calculation of influence of adjacent pumping wells via Girinskij

Ondrej Nol

Content:

1. ***Case problem – introduction to the hydrogeological problem;***

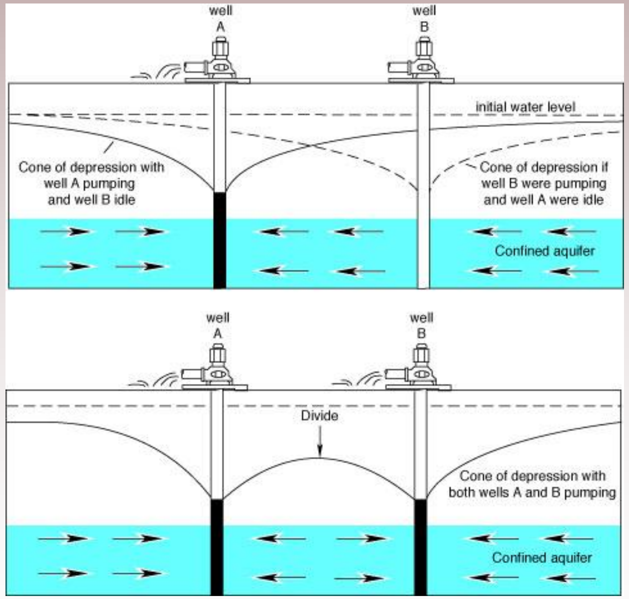
2. ***Derivation of radial flow; cone of depression, radius, empiric equations;***

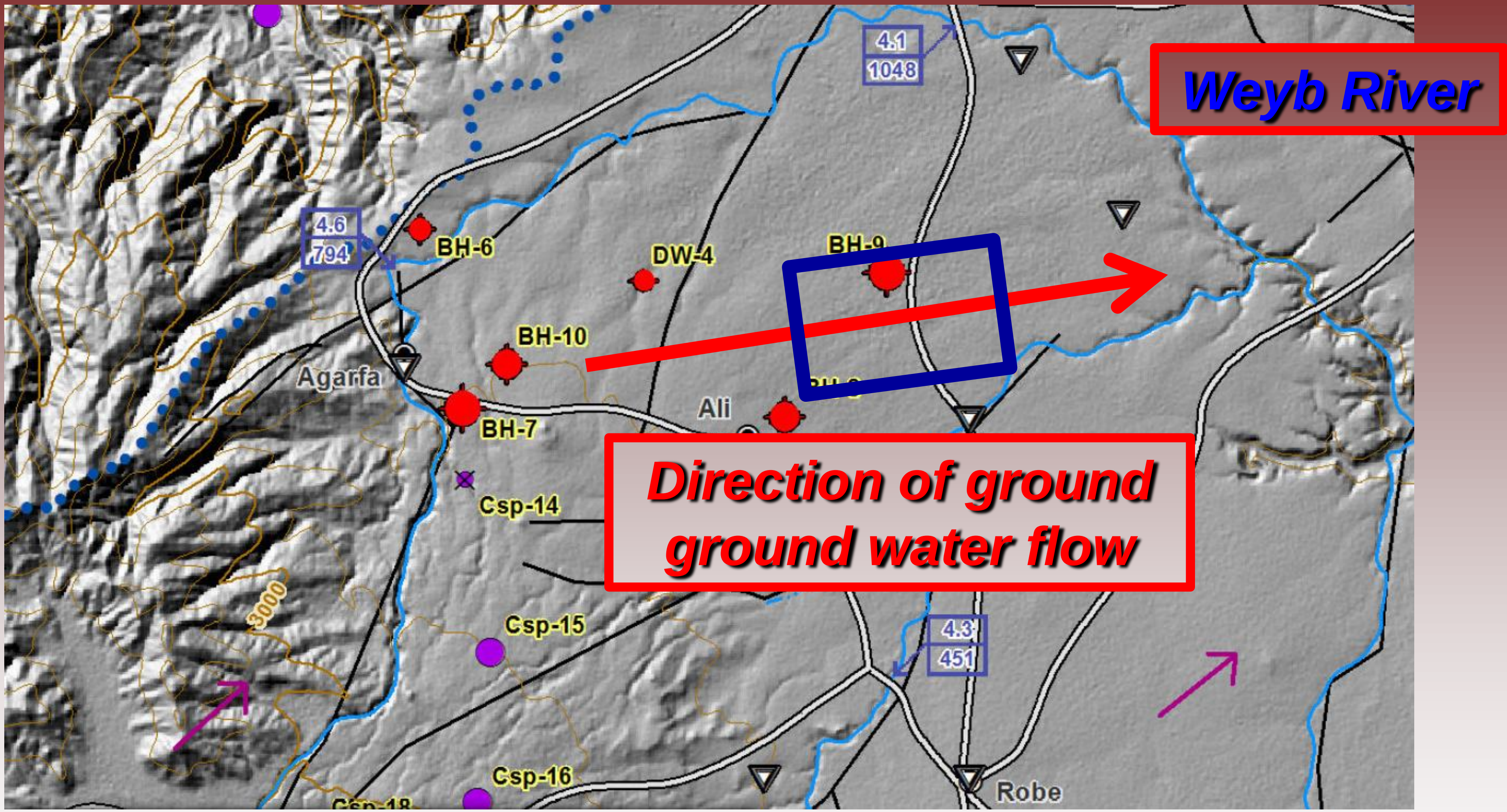
3. ***Radial flow in EXCEL, Interference of wells;***

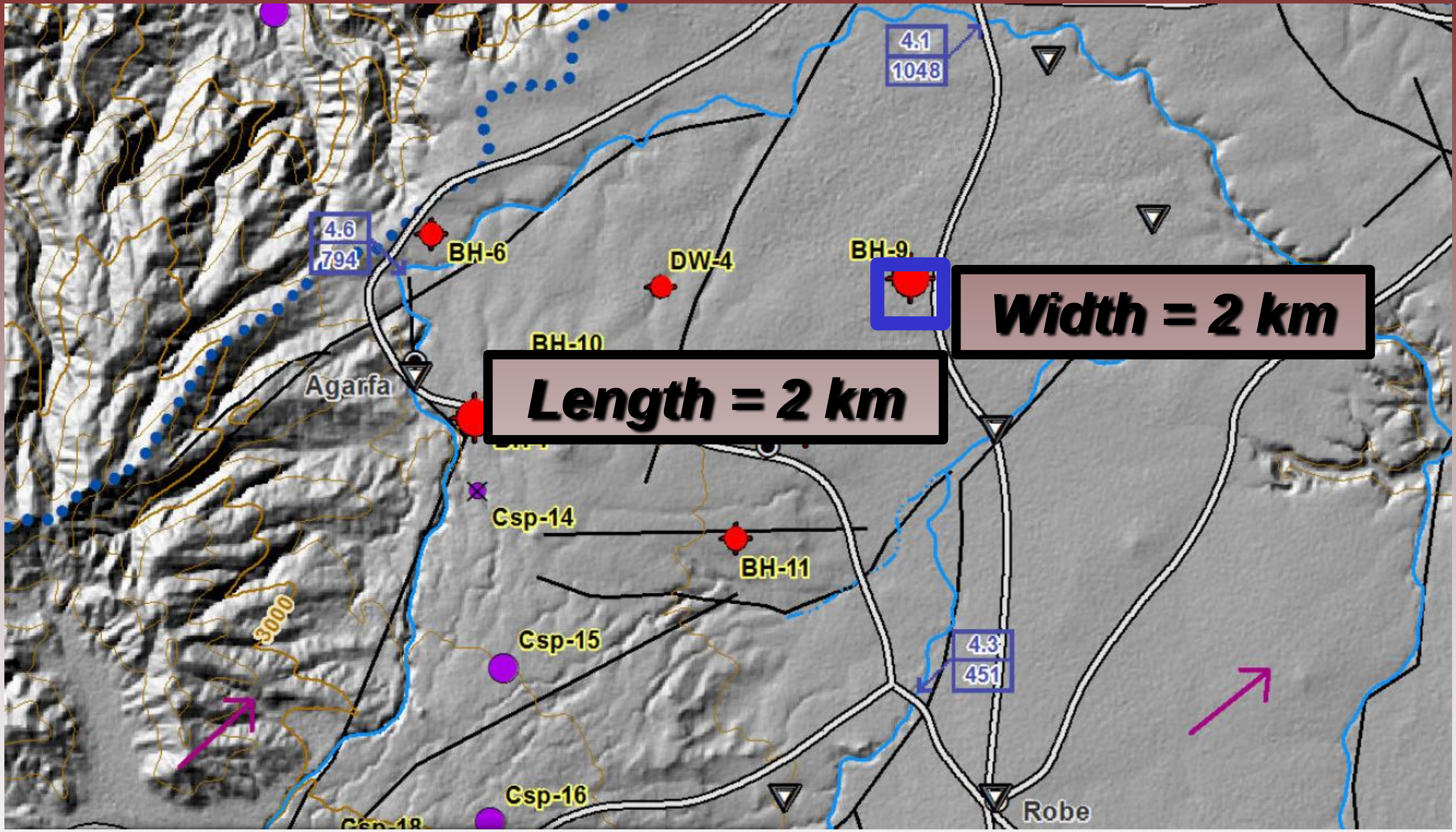
4. ***Protection of zones of ground water sources – with help of 50 day travel time;***

5. ***Discussions, uncertainty.***

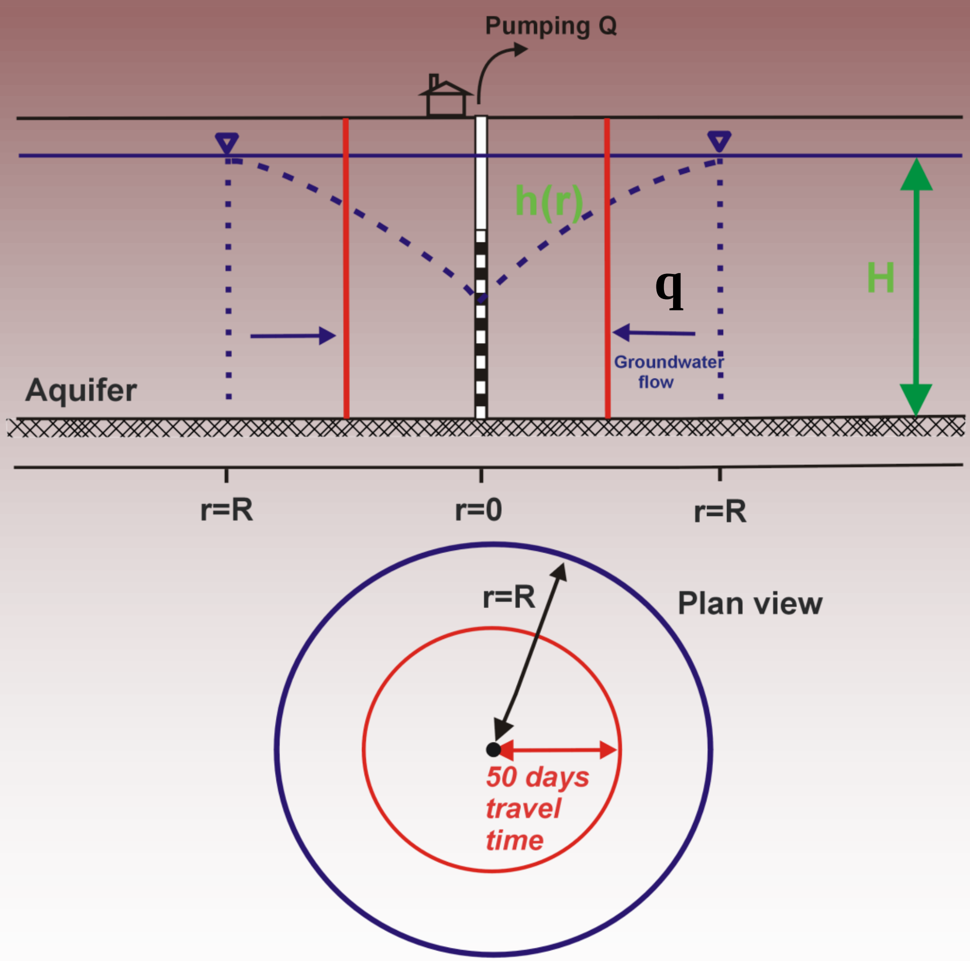
$$h(r)^2 = H^2 - \frac{Q}{2\pi k}\ln\frac{r}{R}$$




Weyb River
4.1
1048
4.6
794
BH-6
DW-4
BH-9
BH-10
Agarfa
BH-7
Ali
Direction of ground
ground water flow
Csp-14
3000
Csp-15
4.3
451
Csp-16
Robe


4.1
1048
4.6
794
BH-6
DW-4
BH-9
Width = 2 km
BH-10
Agarfa
Length = 2 km
Csp-14
BH-11
3000
Csp-15
4.3
451
Csp-16
Robe

Let's consider, the cylinder around pumping well. The flow through the cylinder surface is given:



$$Q = 2\pi * r * q$$

and

$$q = -k\frac{dh}{dr}h(r)$$

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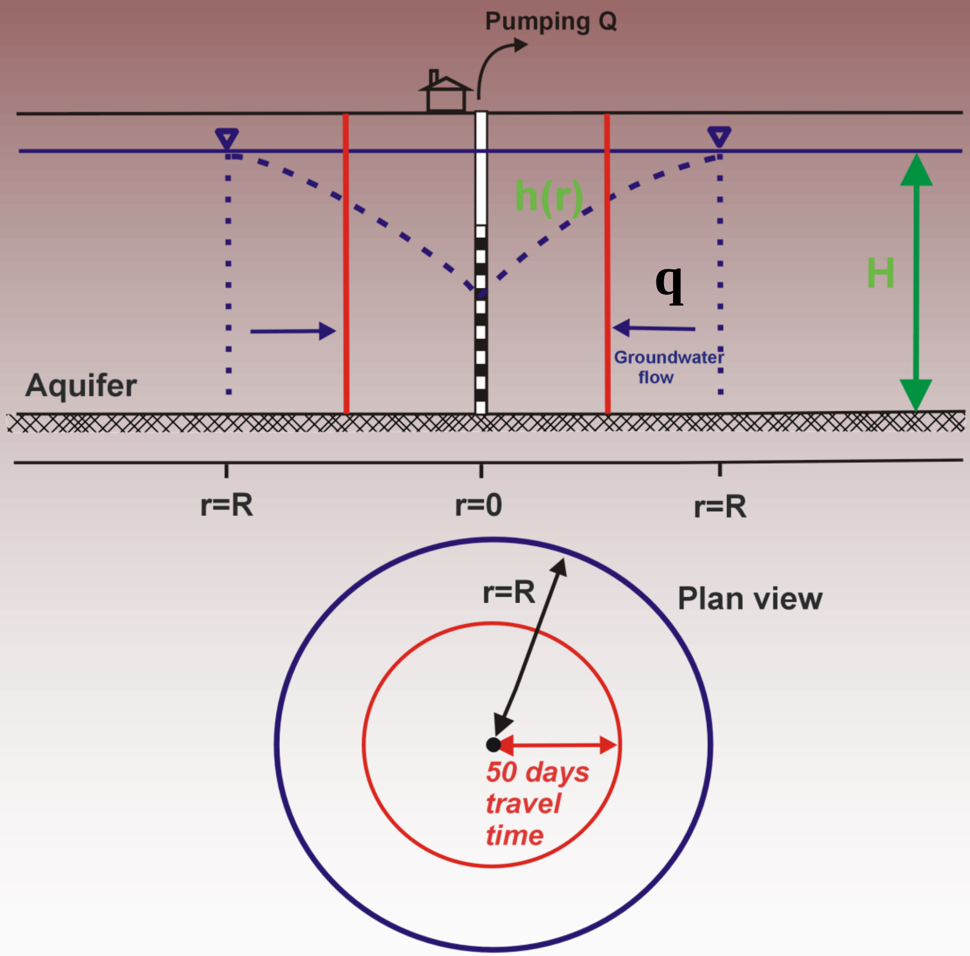


1. *Unconfined aquifer;*
2. *No recharge;*
3. *Homogeneous environment; zero hydraulic gradient at the beginning of calculation*

Let's consider, the cylinder around pumping well. The flow through the cylinder surface is given:

$$Q = 2\pi * r * q \quad \text{and} \quad q = -k\frac{dh}{dr}h(r)$$

$$q = \frac{Q}{2\pi r} = -k\frac{dh}{dr}h(r)$$

$$\frac{Q}{2\pi k r}dr = -h(r)dh$$

$$\frac{Q}{2\pi k}\ln r = -\frac{h(r)^2}{2} + C$$

h(R)=H

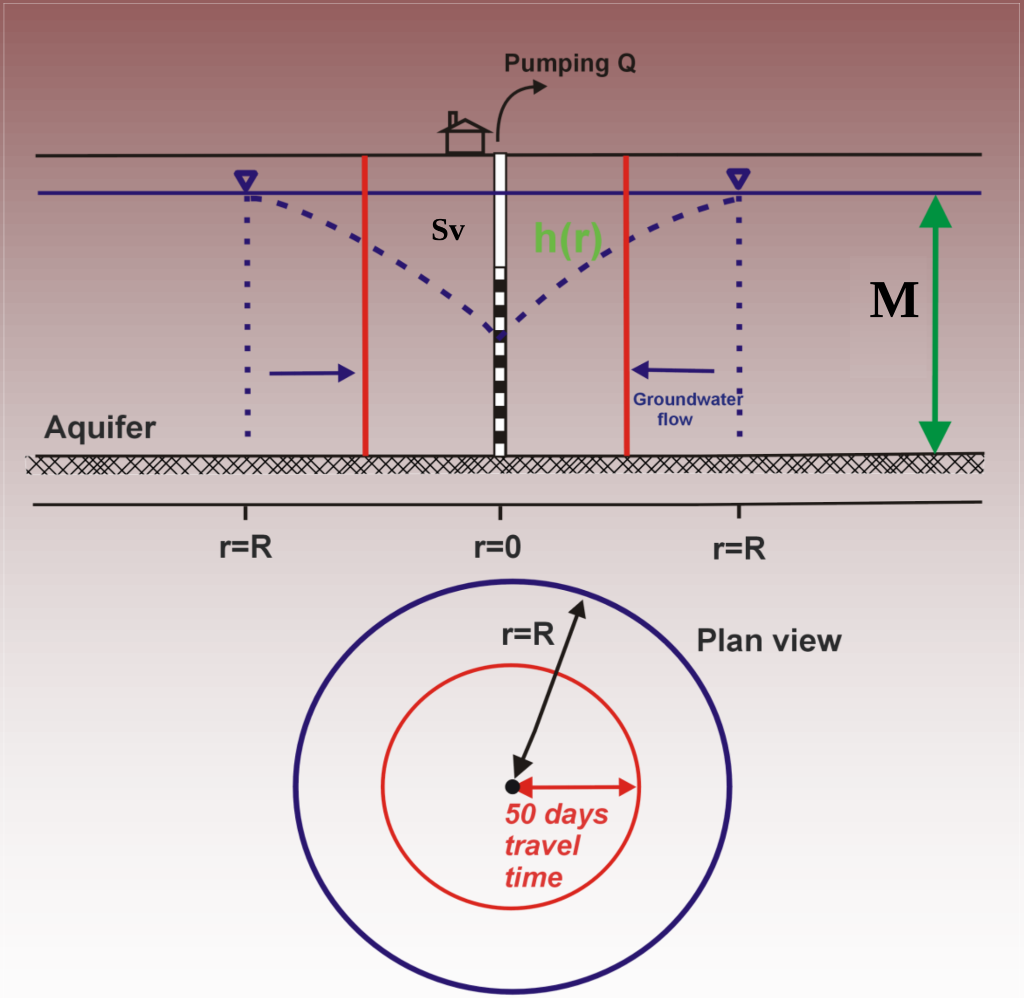
$$\frac{Q}{2\pi k}\ln R = -\frac{H^2}{2} + C \qquad \frac{Q}{2\pi k}\ln R + \frac{H^2}{2} = C$$

$$\frac{Q}{2\pi k}\ln r = -\frac{h(r)^2}{2} + \frac{Q}{2\pi k}\ln R + \frac{H^2}{2}$$

$$h(r)^2 = H^2 - \frac{Q}{2\pi k}\ln\frac{r}{R}$$

For unconfined aquifer

Radius of depression is given by empiric relation e.g. Kusakin:



$$R = 575 s_v \sqrt{M * k}$$

Cone of depression – when water is pumped from a well, the water table (in the case of an unconfined aquifer) or piezometric surface (in the case of a confined aquifer) near the well is lowered.

Groundwater Protection

- **Sustainable Groundwater Development - the objective is that Groundwater resources are properly considered and sustainably used for developing drinking water supply sources.**

Groundwater Protection

- Protection against contamination

(qualitative aspects)

- the groundwater may be temporarily or forever degraded for use as drinking water and even for other needs

- Protection of reserves and resources

(quantitative aspects)

- excessive takings out of the aquifers by increasing exploitation may cause their degradation as groundwater resources.

Quantitative aspect

- Groundwater is best viewed in the context of the **three-dimensional hydrogeologic system** that constitutes a **groundwater basin**.

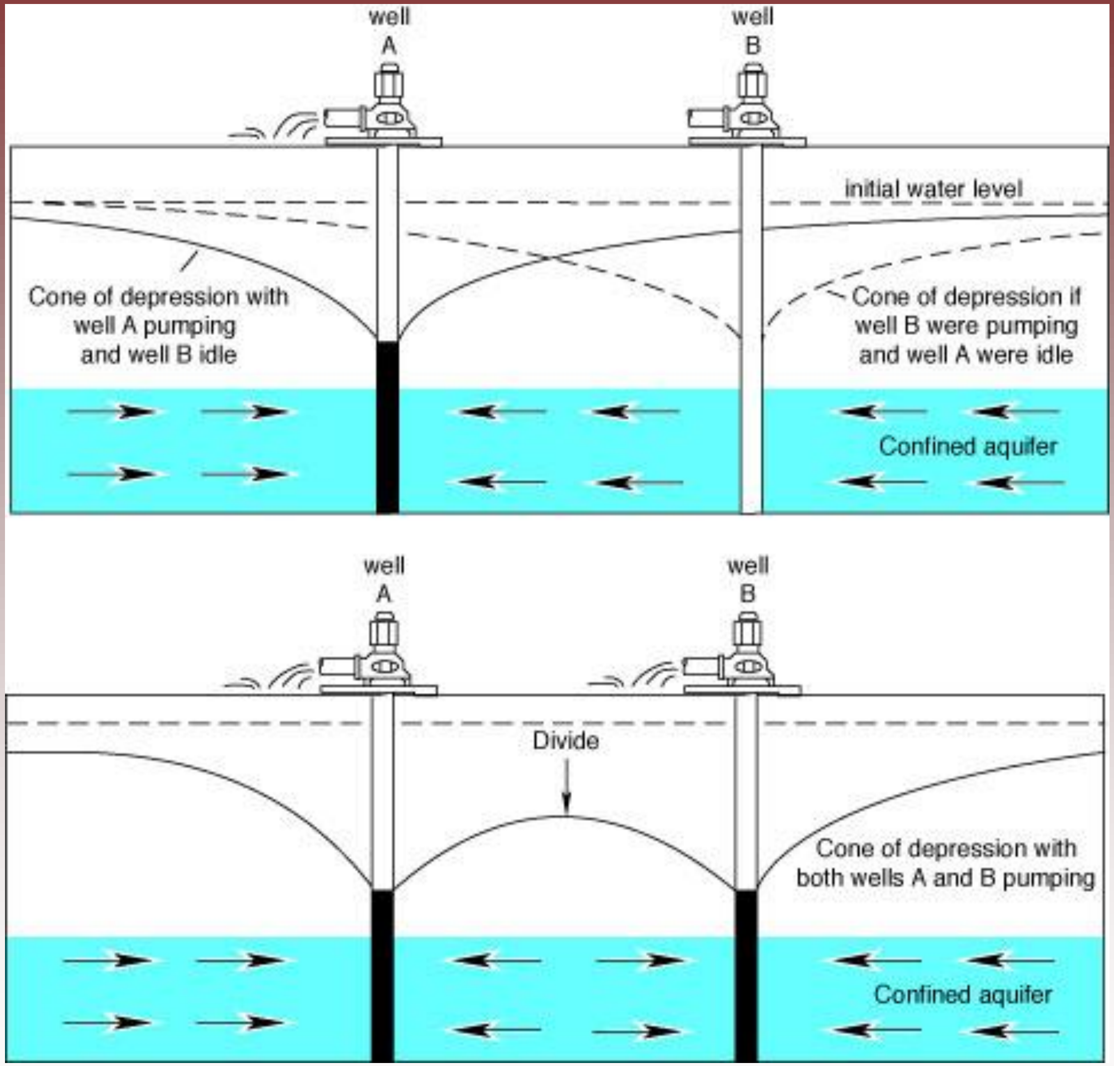
- **Safe yield** of a groundwater basin should be the amount of water that can be withdrawn from it annualy without producing an undesired result. Any withdrawal in excess of safe yield is **overdraft**.

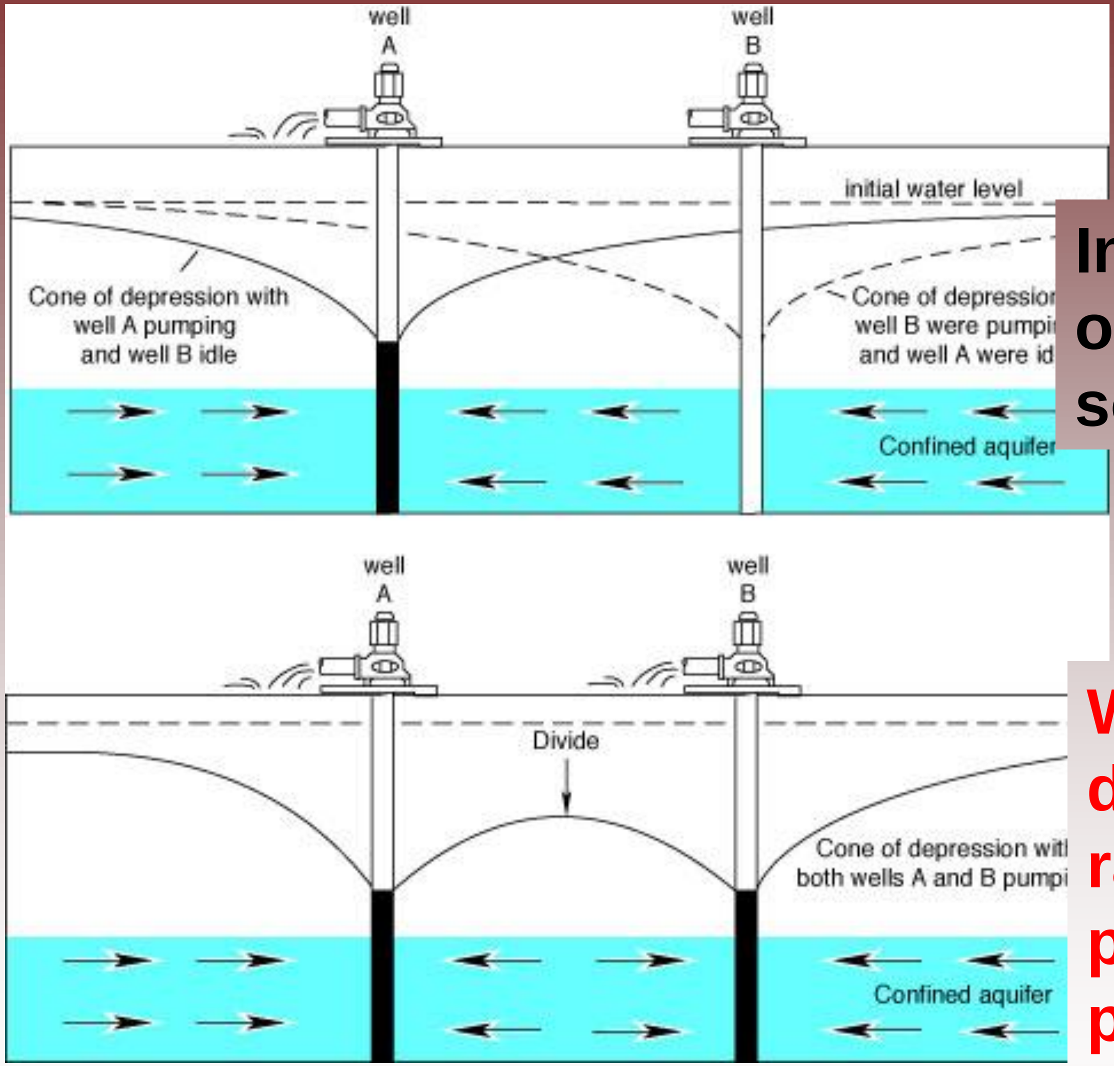
- It is necessary to respect safe yield and not to exceed natural resources of groundwater.

Quantitative aspect

- **Well interaction: If there is higher water demand it is necessary to obtain evaluation of ground water resources by authorized hydrogeologist who estimate availability of groundwater and predict interference between existing and new boreholes.**

- **Otherwise increasing of pumping rate and number of boreholes in use will lead to greater pumping (energy) costs, reduced yields and at last pump failure (if the water level drop bellow its level).**

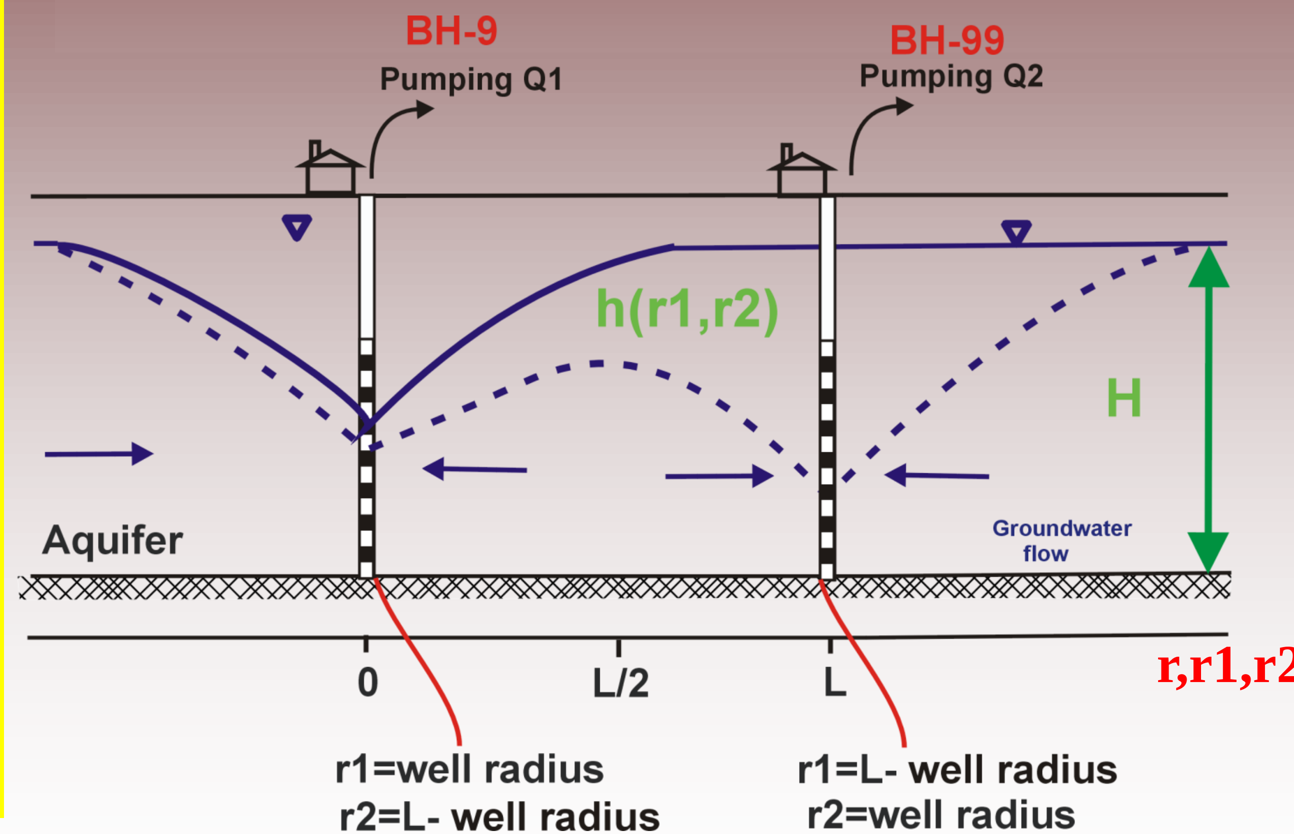

well
A
well
B
initial water level
Cone of depression with
well A pumping
and well B idle
Cone of depression if
well B were pumping
and well A were idle
Confined aquifer
well
A
well
B
Divide
Cone of depression with
both wells A and B pumping
Confined aquifer



Interference with other groundwater sources and uses.

Water level declines. This can raise problem for position of the pump

In case of two interacting well, we need to capture influence of two or more wells in one governing equation. Sum of 1D flows per unit width (CAUSED BY EACH WELL) is not possible, but we can sum their potentials – Girinskij potential which is given:



$$q = \frac{dG}{dr}$$

$$q = \frac{dG}{dr} \qquad q = \frac{Q}{2\pi r}$$

$$dG = \frac{Q}{2\pi r} dr$$

$$G(r) = \frac{Q}{2\pi} \ln r + C$$

G(r)=G(R)

$$G(R) = \frac{Q}{2\pi} \ln R + C$$

$$C = G(R) - \frac{Q}{2\pi} \ln R$$

$$G(r) = G(R) - \frac{Q}{2\pi} \ln \frac{r}{R}$$

$$G(r) = \int_0^h (z-h) k\,dz = -\frac{1}{2} kh^2$$

$$G(R) = -\frac{1}{2} kH^2$$

Principle of superposition

-To calculate G we can sum potential of each well

$$G(r) = G_1(r_1) + G_2(r_2)$$

$$G(r_1) = G(R) + \frac{Q_1}{2\pi} \ln \frac{r_1}{R} \qquad G(r_2) = G(R) + \frac{Q_2}{2\pi} \ln \frac{r_2}{R}$$

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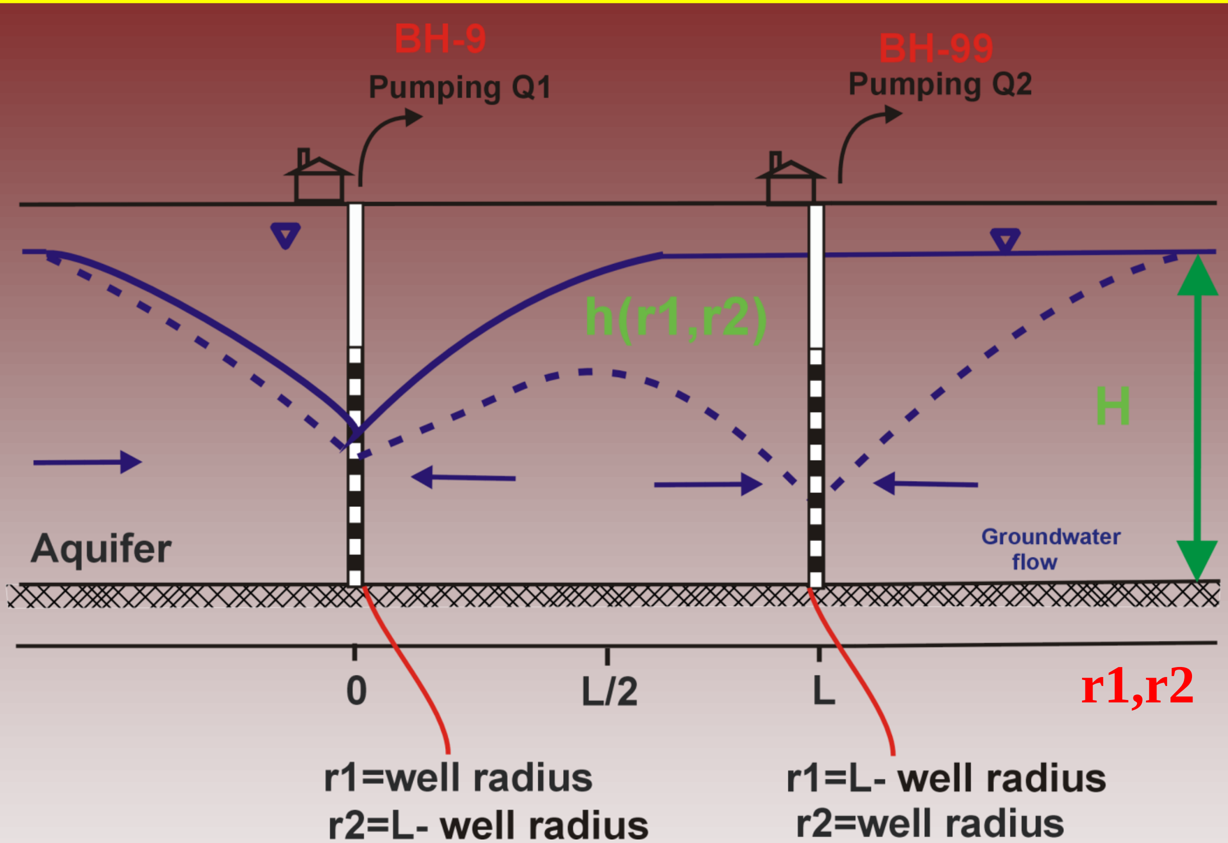
$$G(r_2) = G(R) + \frac{Q_2}{2\pi}\ln\frac{r_2}{R}$$

$$G(r) = G(R) + \frac{Q_1}{2\pi}\ln\frac{r_1}{R} + \frac{Q_2}{2\pi}\ln\frac{r_2}{R}$$

$$-\frac{1}{2}kh(r)^2 = -\frac{1}{2}kH^2 + \frac{Q_1}{2\pi}\ln\frac{r_1}{R} + \frac{Q_2}{2\pi}\ln\frac{r_2}{R}$$

$$h(r)^2 = H^2 - \frac{Q_1}{\pi k}\ln\frac{r_1}{R} - \frac{Q_2}{\pi k}\ln\frac{r_2}{R}$$



Remarks:

If r1,r2>L then r1,r2=R.
For simplifications both wells have same well radius and radius of depression cone.

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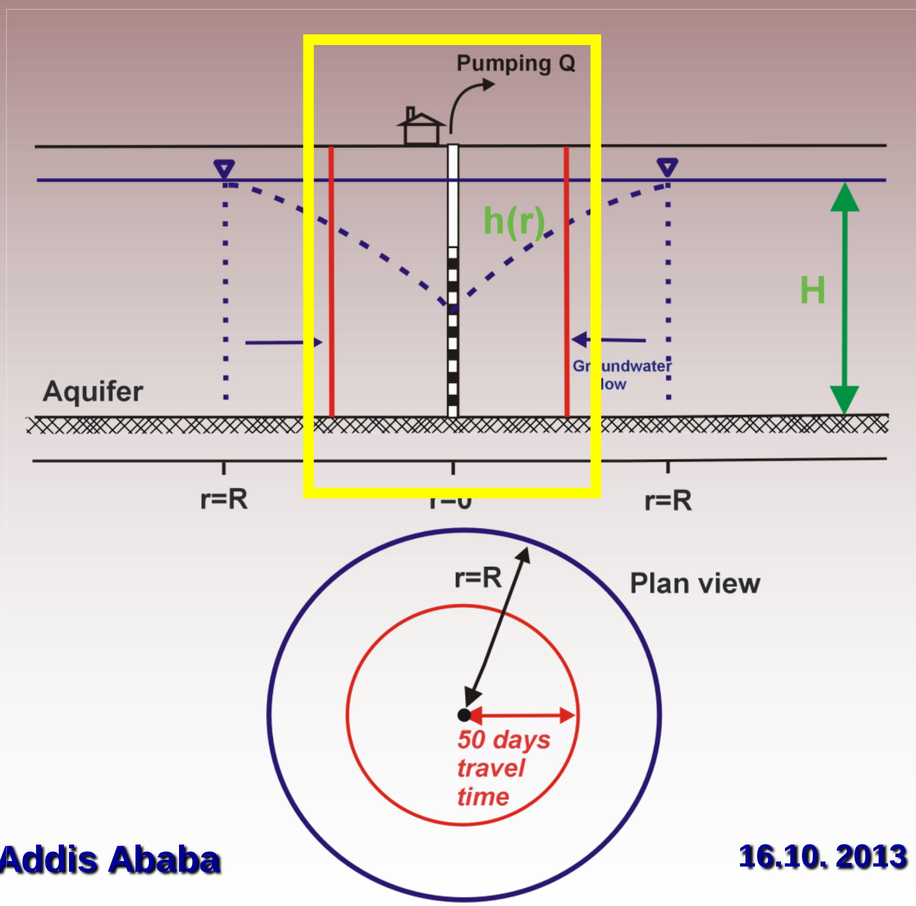
Potential Sources of Contamination

- Land disposal of solid wastes
- Sewage disposal on land
- Agricultural activities
- Urbanization
- Petroleum leakage and spills
- Activities of mining industry
- Seepage from industrial waste lagoons

Type of contaminants

- Long-term persistent contaminants – heavy metal, hydrocarbons, pesticides, nitrogen…
- Fastly degradable contaminant - disease pathogens, microorganism, fecal bacteria

Protection of zones of ground water sources – with help of 50 day travel time = distance (or pathway), which particle of ground water (or microbial contamination) covers in 50 day. It is assumed, that the most resistant micro-organism should not survive;



Avoidance of potential sources of contamination. It is essential to avoid point contamination sources such as pit latrines, septic tanks, livestock pens, burial grounds and solid waste dumps.