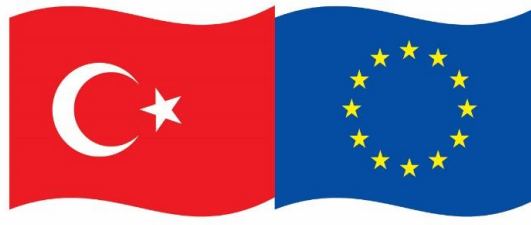




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Identification and Remediation of Contaminated Sites with Persistent Organic Pollutants (POPs)

Kalıcı Organik Kirleticilerle Kirlenmiş Sahaların Tespiti ve İyileştirilmesi Projesi



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Temizleme Teknolojileri, Islah ve İzleme Eğitimi

Training on Remediation Technologies, Remediation and Monitoring

22-23-24 KASIM 2021

Toprak ve Yeraltı Suyu

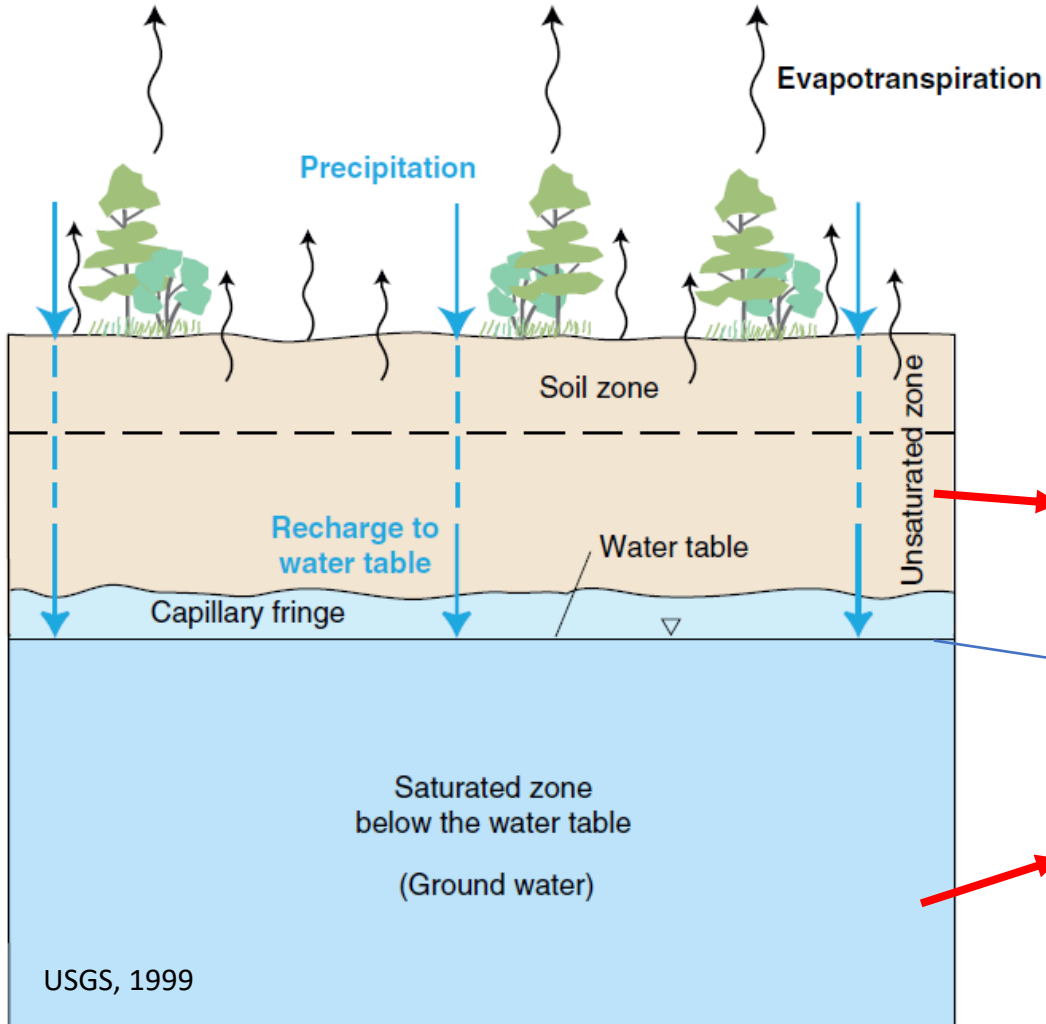
Soil and Groundwater

PROF. DR. AHMET KARAGÜNDÜZ
GEBZE TEKNİK ÜNİVERSİTESİ



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- Doygun Bölge (Yeraltı Suyu)
- Doymamış Bölge (vadoz Bölge)
- Capiler Fringe



Gözenek suyu basıncı < Atmosfer Basıncı

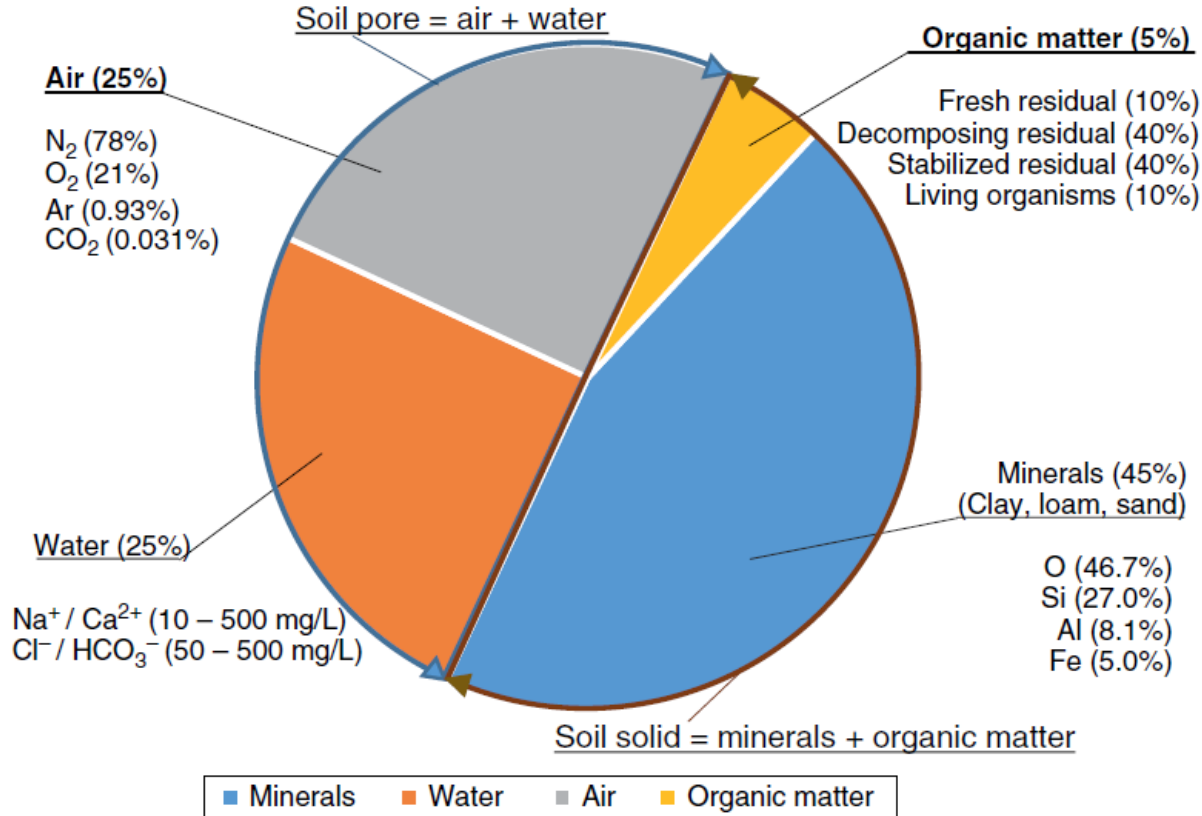
Gözenek suyu basıncı = Atmosfer Basıncı

Gözenek suyu basıncı > Atmosfer Basıncı



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TOPRAK



Zhang, Soil and Groundwater Remediation, 2020

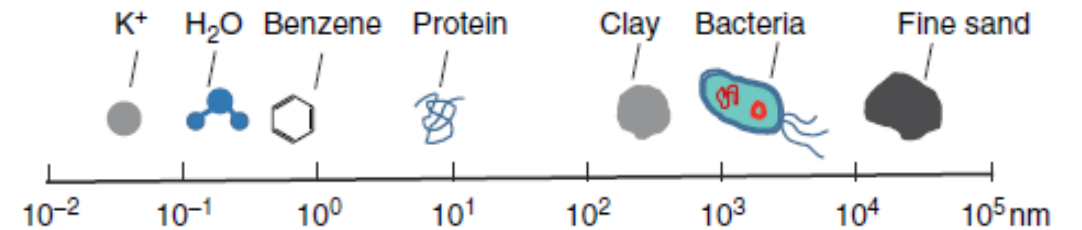
• Organik Madde

• Humus

- Hümin (çözünmeyen)
- Humik Asit(Asitte çöken)
- Fulvik Asit (asidik çözeltide kalan)

• İnorganik Madde

- Karbonat mineralleri
- Silikat mineralleri



Zhang, Soil and Groundwater Remediation, 2020



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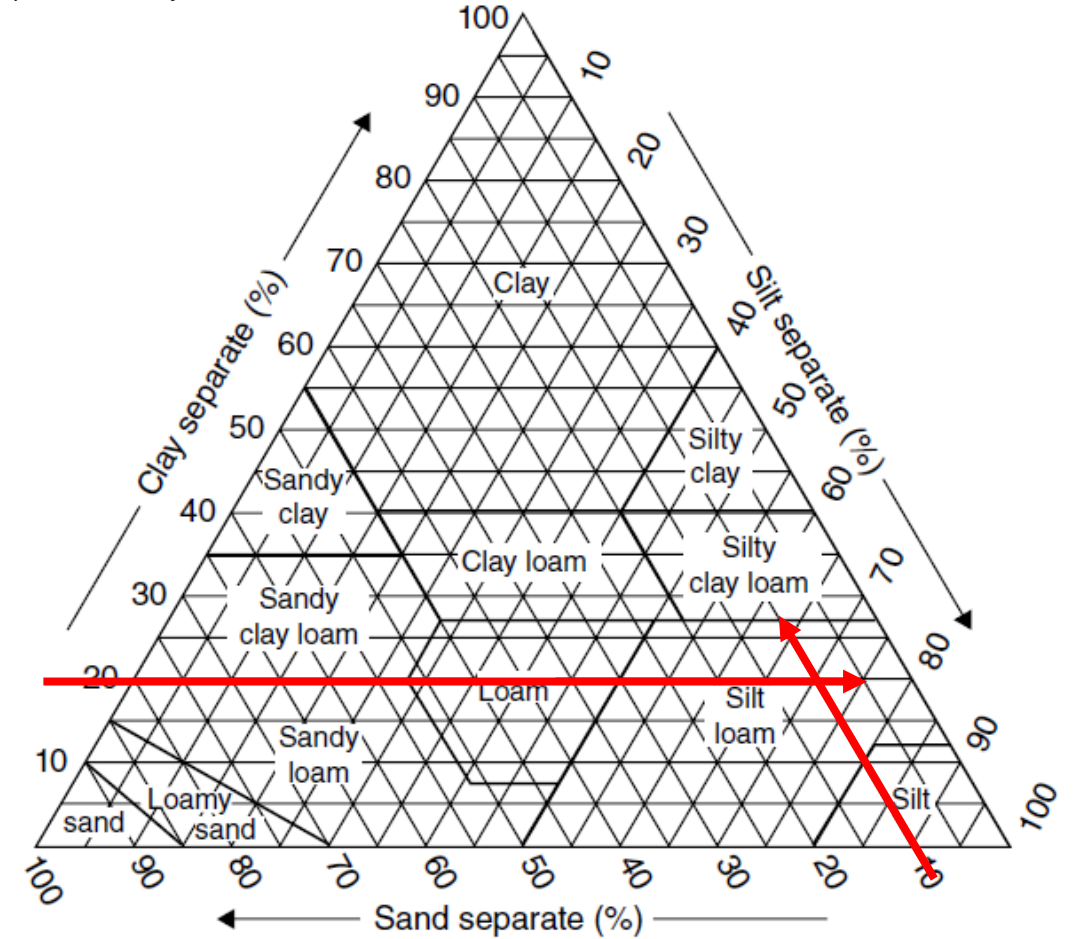
By International Society of Soil
Science

Toprak: 2 mm de daha düşük
partiküllerdir.

- Kil ($<2\ \mu\text{m}$), silt ($2\text{--}20\ \mu\text{m}$), ince kum ($20\text{--}200\ \mu\text{m}$),
ve kalın kum ($200\ \mu\text{m}\text{--}2.0\ \text{mm}$).

USGS Sınıflandırması

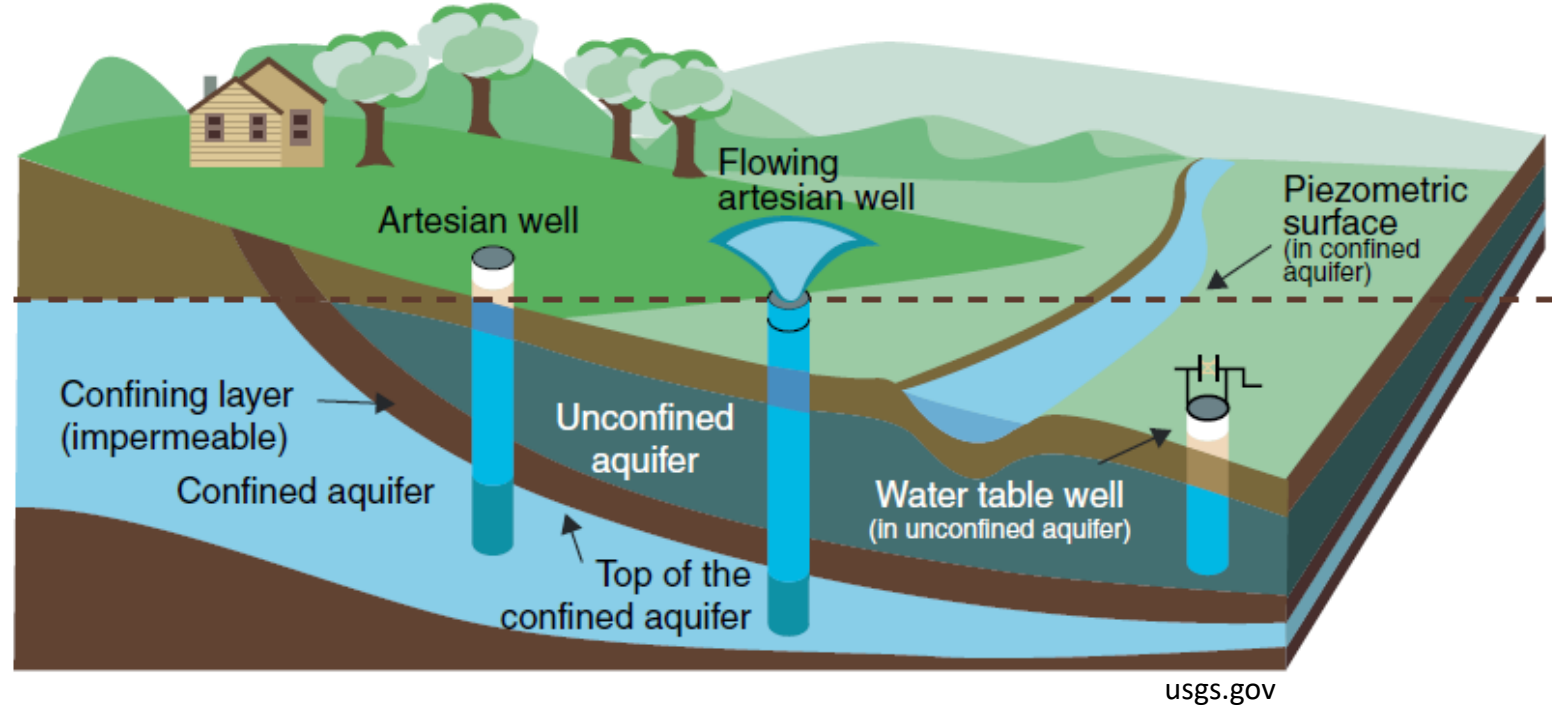
- Örneğin: 20% kil, 70% silt, ve 10% kum
 - **SİLT LOAM**



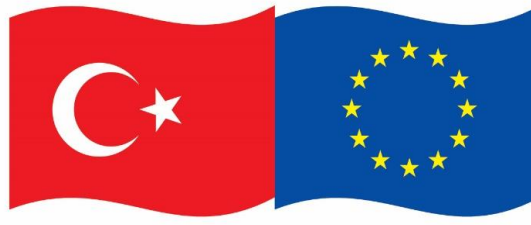


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- **Akifer:** Su bulunduran ve ileten jeolojik birimler
 - Basıncılı
 - Serbest Yüzeyle
- **Akuitard:** Su bulunduran ancak çok düşük hızda bir birimden diğerine su ileten jeolojik birimler
- **Akuifaj:** Su iletmeyen geçirimsiz jeolojik birimler
- **Akuiklud:** Çok düşük iletkenlikte suyu hemen hemen iletmeyen jeolojik birimler

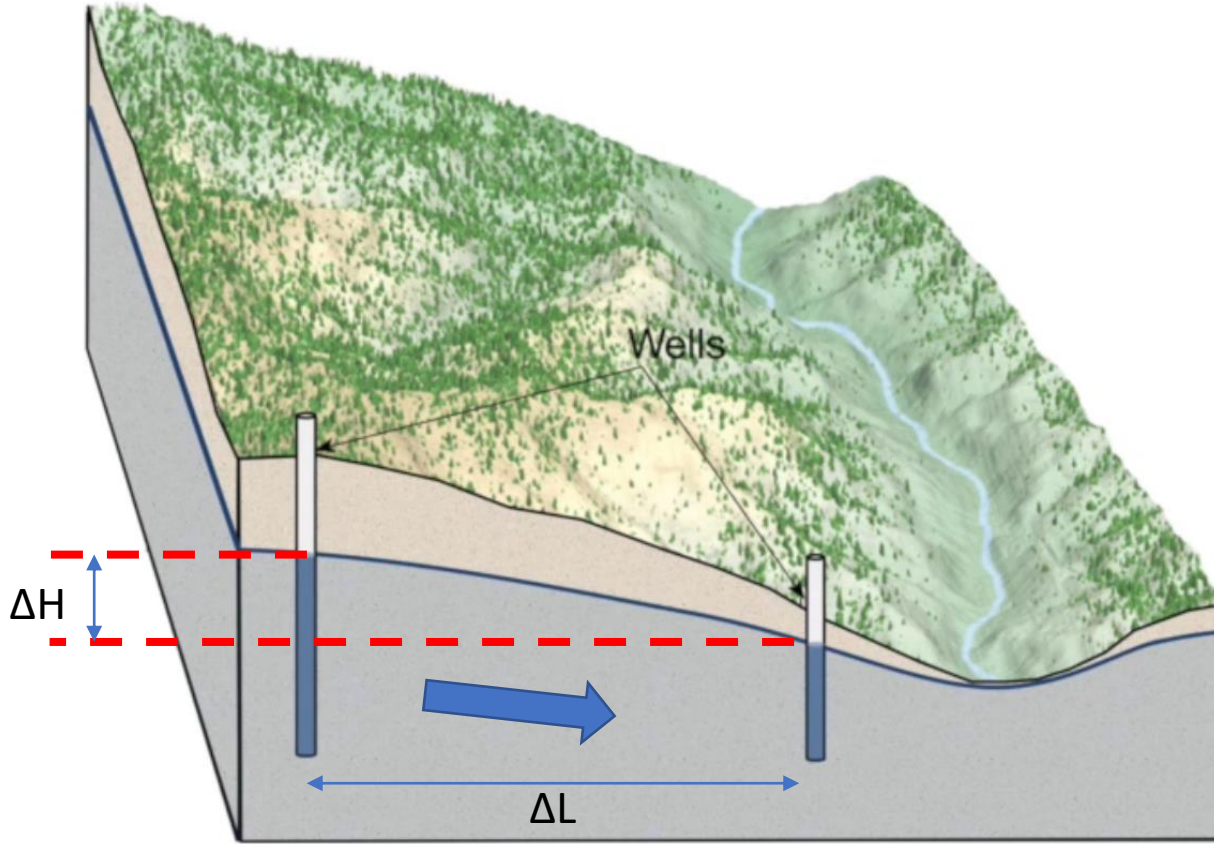


Hidrolik Eğim



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- Hidrolik eğim= Su tablasının eğimi.
- $i = \Delta H / \Delta L$



Geosearch International



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Porosite (n): Boşluk Hacim'in Toplam
Hacim'e oranı

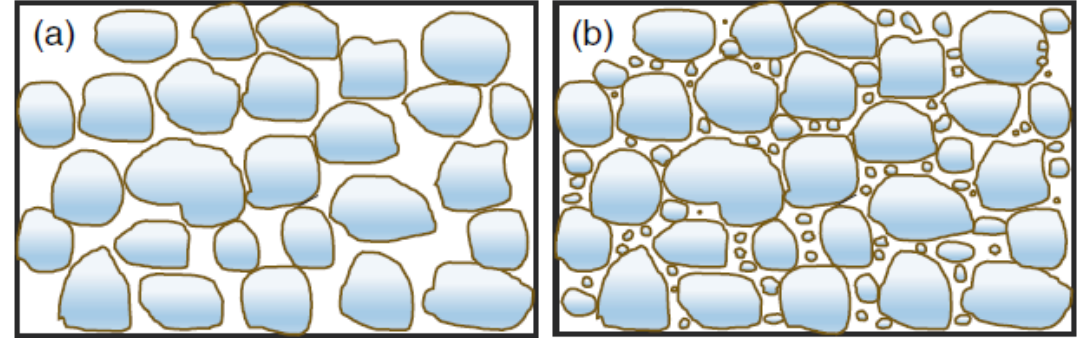
$$n = \frac{\text{Boşluk Hacim}}{\text{Bulk Hacim}} = \frac{V_T - V_p}{V_T} = 1 - \frac{V_p}{V_T}$$

Bulk Yoğunluğu: Toprak ağırlığının toplam
hacime oranı, $\rho_b = W_s/V_T$

Partikül Yoğunluğu: Toprak ağırlığının partikül
hacime oranı, $\rho_s = W_s/V_p = W_s/(V_T - V_v)$

$$n = 1 - \frac{\rho_b}{\rho_s}$$

Etkin (Efektif) Porosite (ne): Porositenin akış
gerçekleşebilen kısmı



Soil type	Porosity (%)	Effective porosity (%)
Clay	45	3
Sand	34	25
Gravel	25	22
Gravel and sand	20	16
Sandstone	15	8
Limestone, shale	5	2
Quartzite, granite	1	0.5



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Hidrojeolojik Tanımlar

- **Özgöl verim (Y):** Yerçekimi ile drene olan suyun hacminin toplam akifer hacimine oranına denir. $Y = V_{w,d} / V_T$
 - Örneğin: Kil %2, Silt: %18, Kum: %27
- **Özgöl Tutma (R):** Yerçekimi ile akiferde kalan su hacminin toplam akifer hacimine oranına denir. $Y = V_{w,r} / V_T$
- $n = Y + R$
- **Doygunluk Oranı (Rs):** Boşlukta bulunan su hacminin toplam boşuk hacmine oranı. $R_s = V_{w,b} / V_{boşluk}$
- **Su içeriği (θ):** Su ağırlığının toplam kuru toprak ağırlığına oranı.

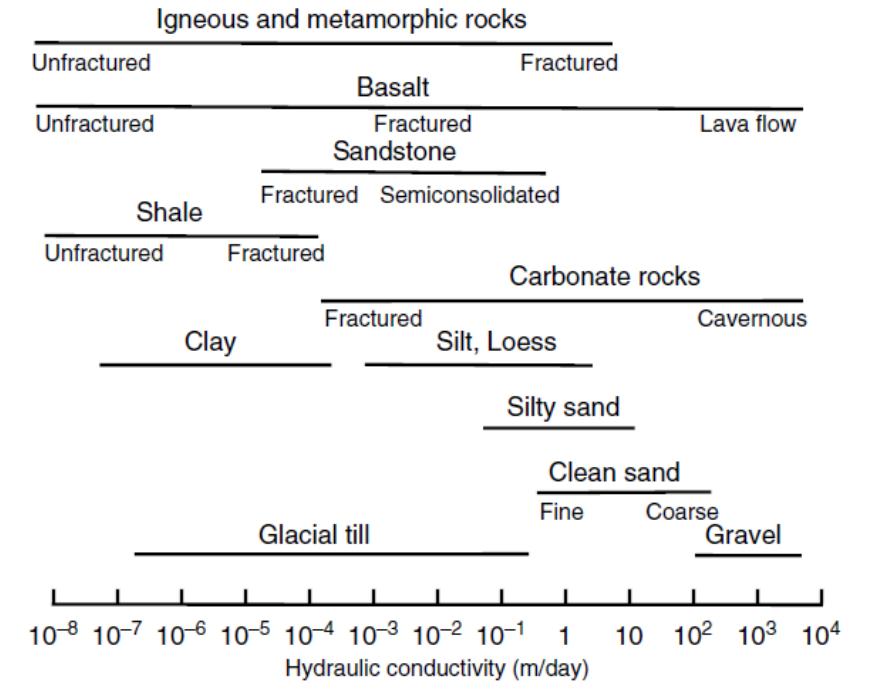


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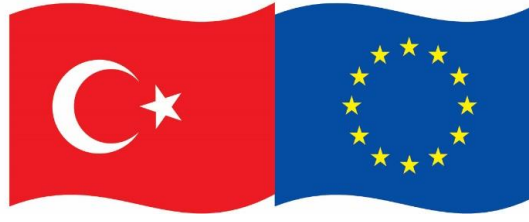
- **Hidrolik İletkenlik (K):** Gözenekli bir ortamda bir akışkanın taşınımının bir ölçüsüdür.
- Akışkanın ve akifer malzemesinin bir fonksiyonudur.

$$K = k(L^2) \frac{\rho \left(\frac{M}{L^3} \right) \times g \left(\frac{L}{T^2} \right)}{\mu \left(\frac{M}{L \times T} \right)} = \frac{L}{T}$$

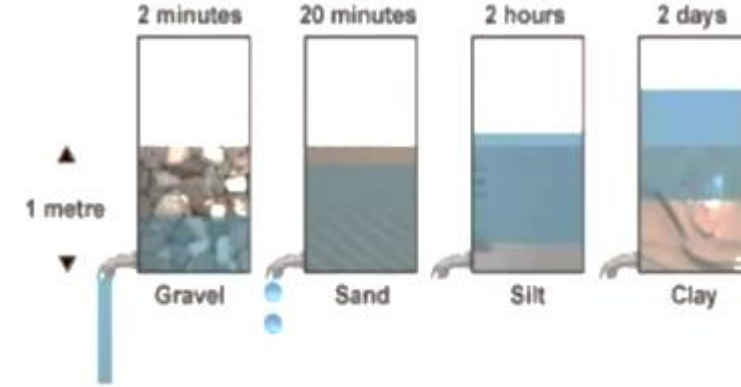
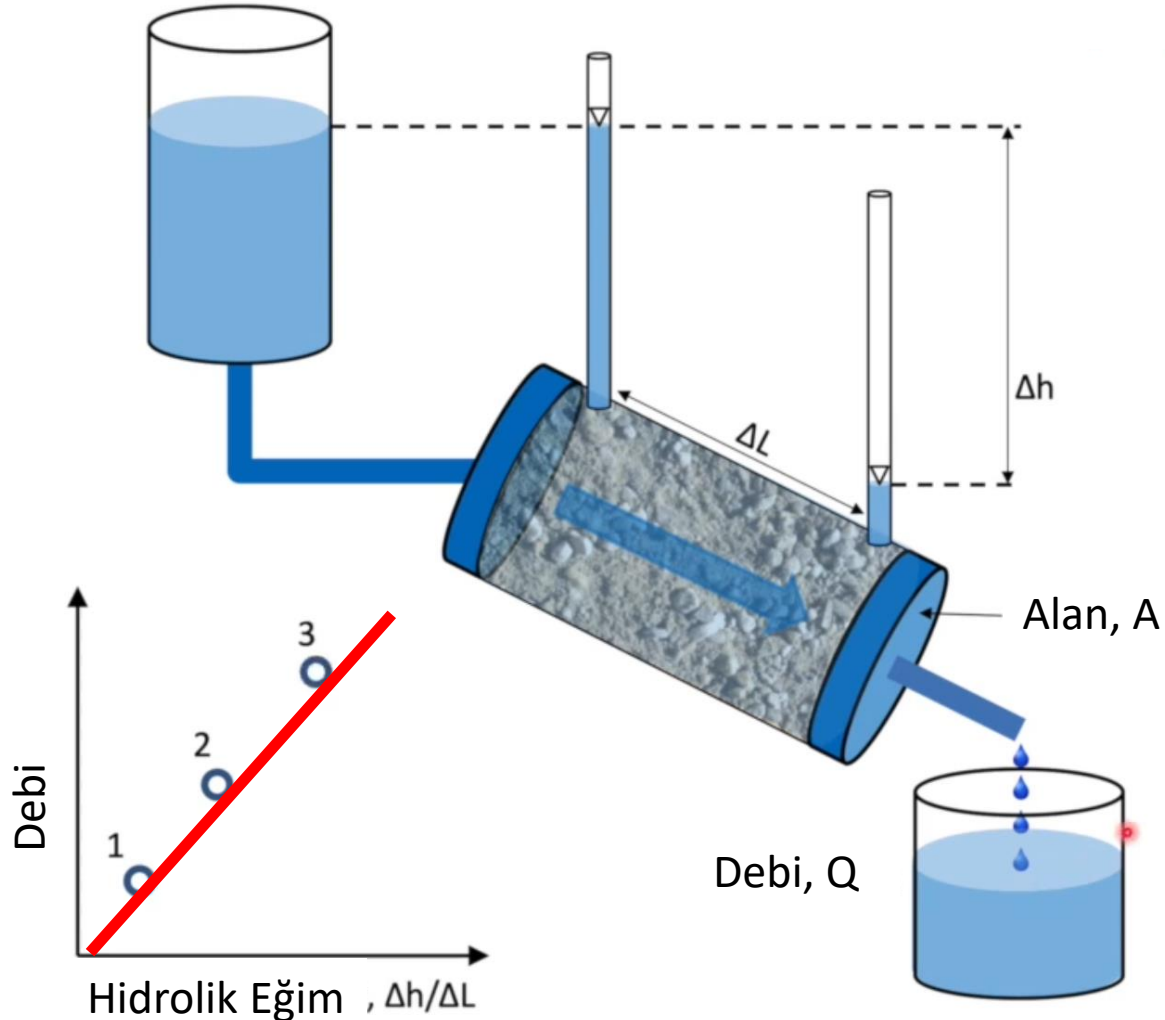
- k: permeabilite, μ : Dinamik viskozite,
 ρ : akışkanın yoğunluğu



Zhang, Soil and Groundwater Remediation, 2020



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- Bernoli Denklemi

$$H = z + \frac{P}{\rho g} + \frac{V^2}{2g} = \text{Sabit}$$

$$Q = Ki = K \Delta H / \Delta L$$



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Yeraltı Suyu Akımı

- Bernoli Denklemi

$$H = z + \frac{P}{\rho g} + \frac{V^2}{2g} = \text{Sabit}$$

- Darcy Yasası

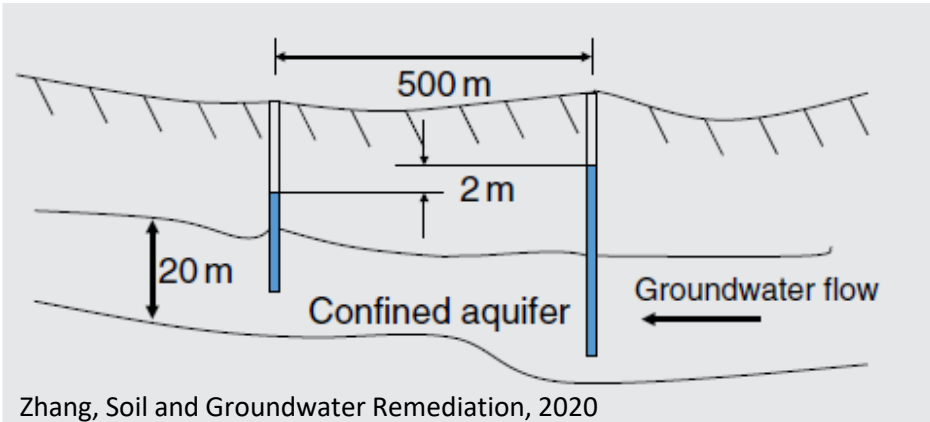
$$q = -K \frac{dH}{dx} = -Ki$$

- Yeraltısuyu Hızı

$$v = \frac{q}{n} = -\frac{K}{n} \frac{dH}{dx} = -\frac{K}{n} i$$

- Kirletici Taşınım Hızı

$$v_c = \frac{v}{R} = \frac{v}{1 + K_D \frac{\rho}{n}}$$



$$\frac{dH}{dx} = \frac{2}{500} = 0.004 \text{ m/m}$$



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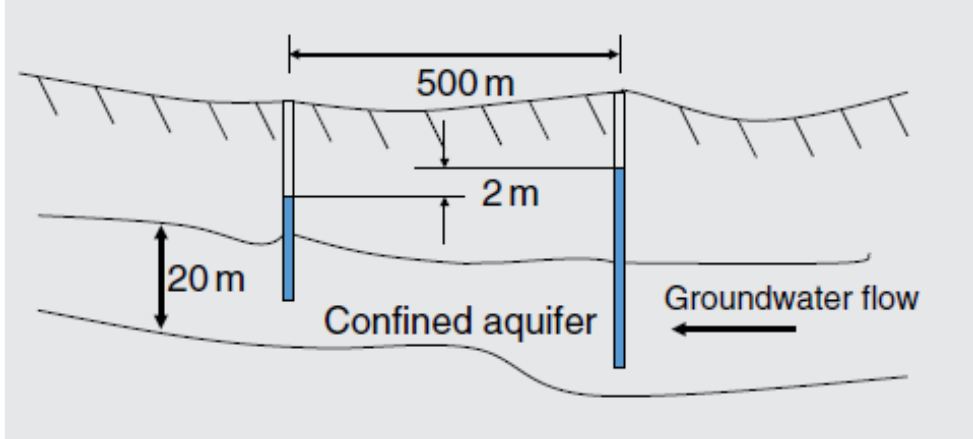


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Zhang, Soil and Groundwater Remediation, 2020

$$\frac{dH}{dx} = \frac{2}{500} = 0.004 \text{ m/m}$$

$K=50 \text{ m/gün}$, $n=0.35$ ve $\rho_b=1.8 \text{ g/cm}^3$

Darcy Hızı nedir?

YAS Gerçek Hızı Nedir?

Adsorplanmayan bir kirletici bu akiferde 500 m mesafeyi ne kadar zamanda gider?

$KD=5.2 \text{ L/kg}$ olan bir kirletici aynı mesafeyi hangi ürede alır?

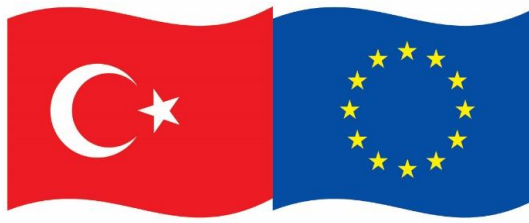
$$q = -K \frac{dH}{dx} = -50 \times (-0.004) = 0.2 \text{ m/gün}$$

$$v = \frac{q}{n} = \frac{0.2}{0.35} = 0.57 \frac{\text{m}}{\text{gün}}$$

$$t = \frac{500 \text{ (m)}}{0.57 \left(\frac{\text{m}}{\text{gün}}\right)} = 877 \text{ gün}$$

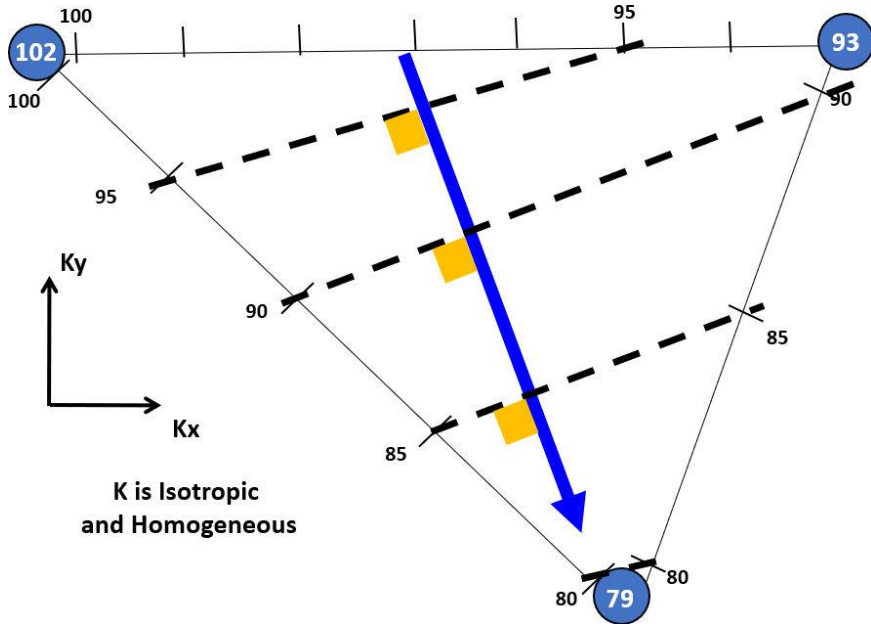
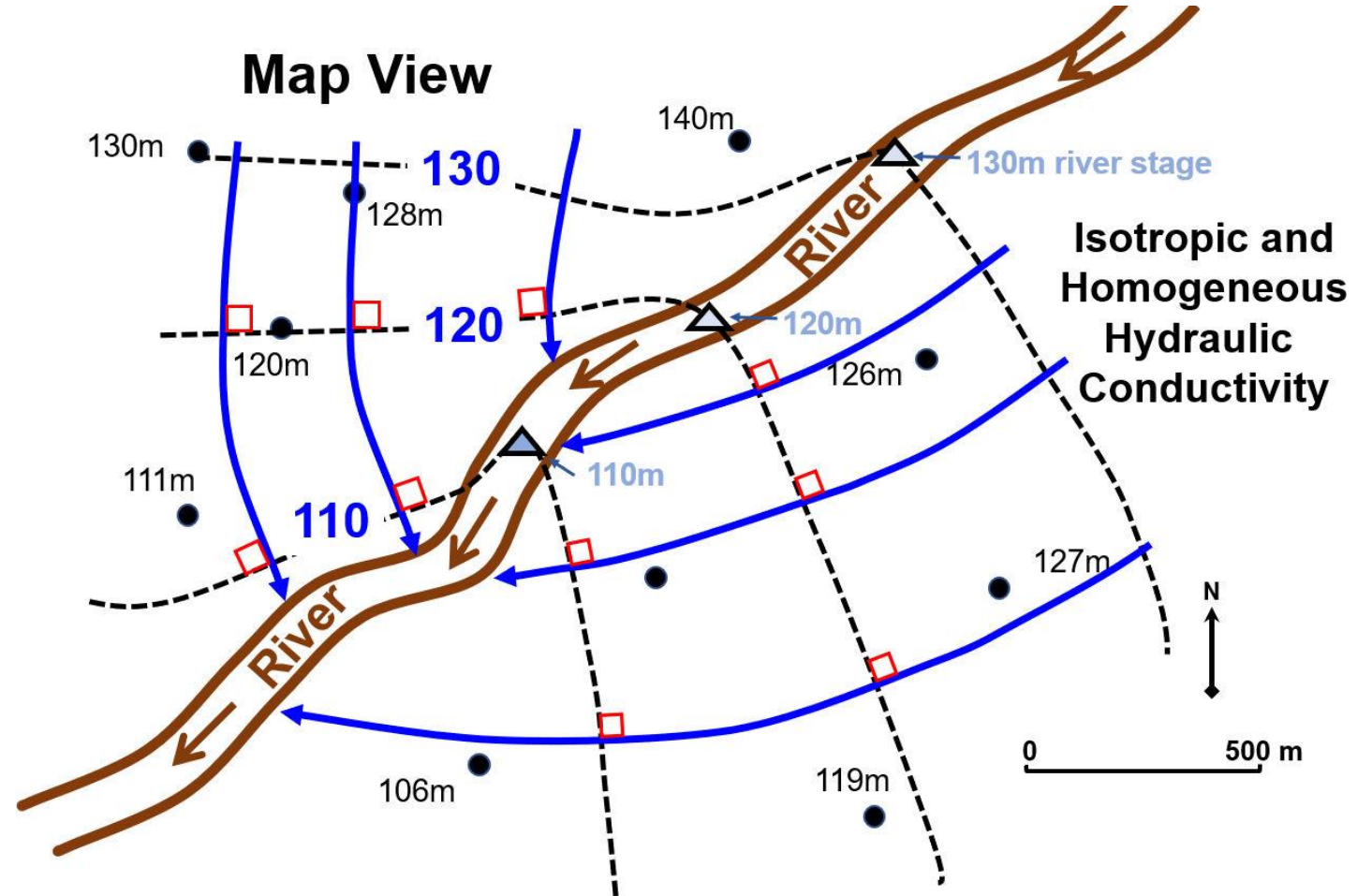
$$v_c = \frac{v}{R} = \frac{v}{1 + K_D \frac{\rho}{n}} = \frac{0.57}{1 + 5.2 \frac{1.8}{0.35}} = 0.0206 \frac{\text{m}}{\text{gün}}$$

$$t = \frac{500 \text{ (m)}}{0.0206 \left(\frac{\text{m}}{\text{gün}}\right)} = 24272 \text{ gün}$$



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Map View



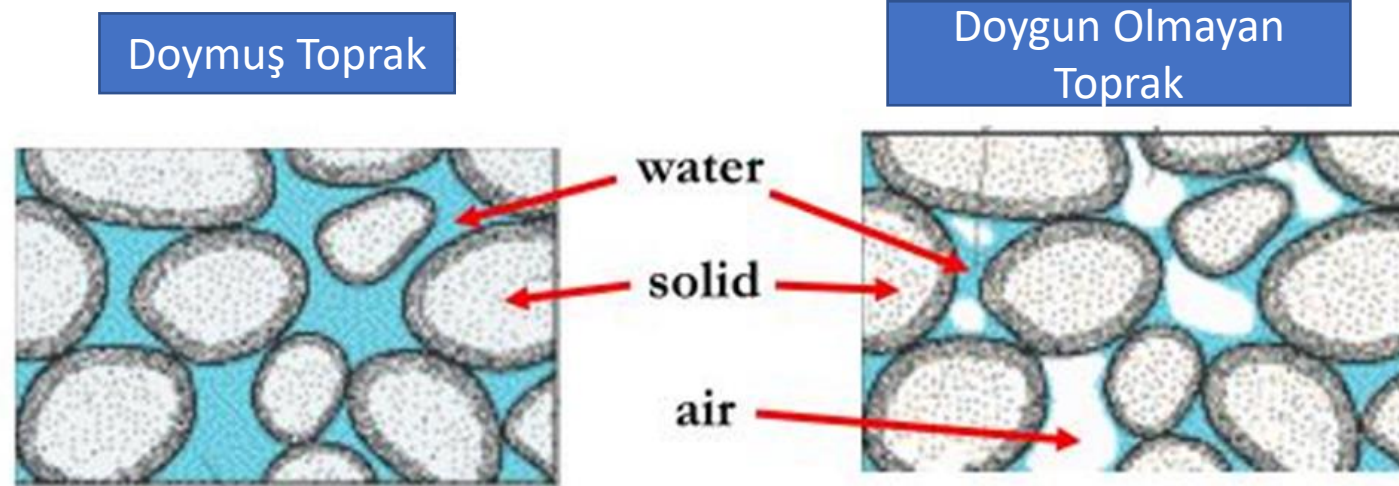
gw-project.org



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Doygun Olmayan Toprakta Akış

- Boşluklarda, hem hava hem de su mevcut
- Genellikle havanın hareketsiz olduğu Kabul edilir.

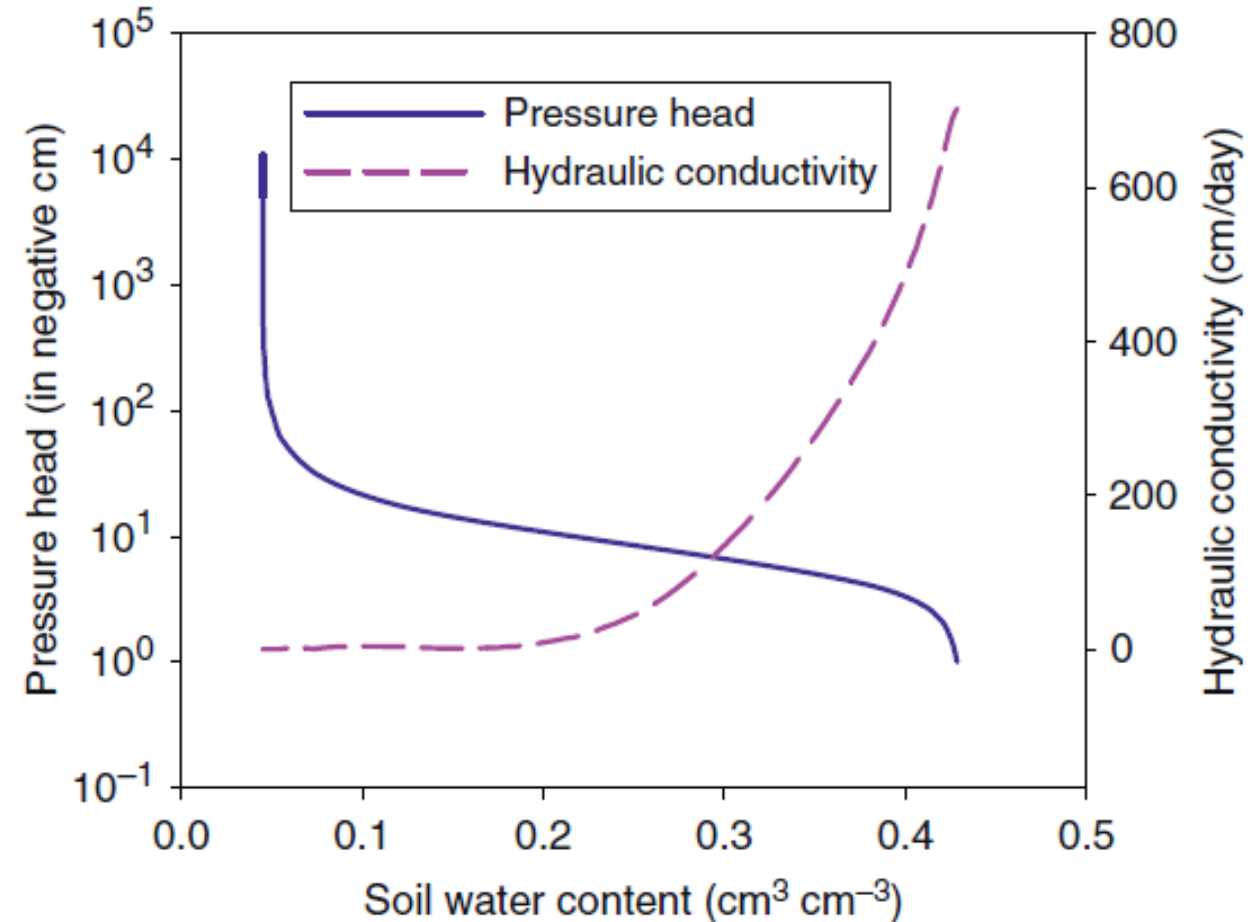
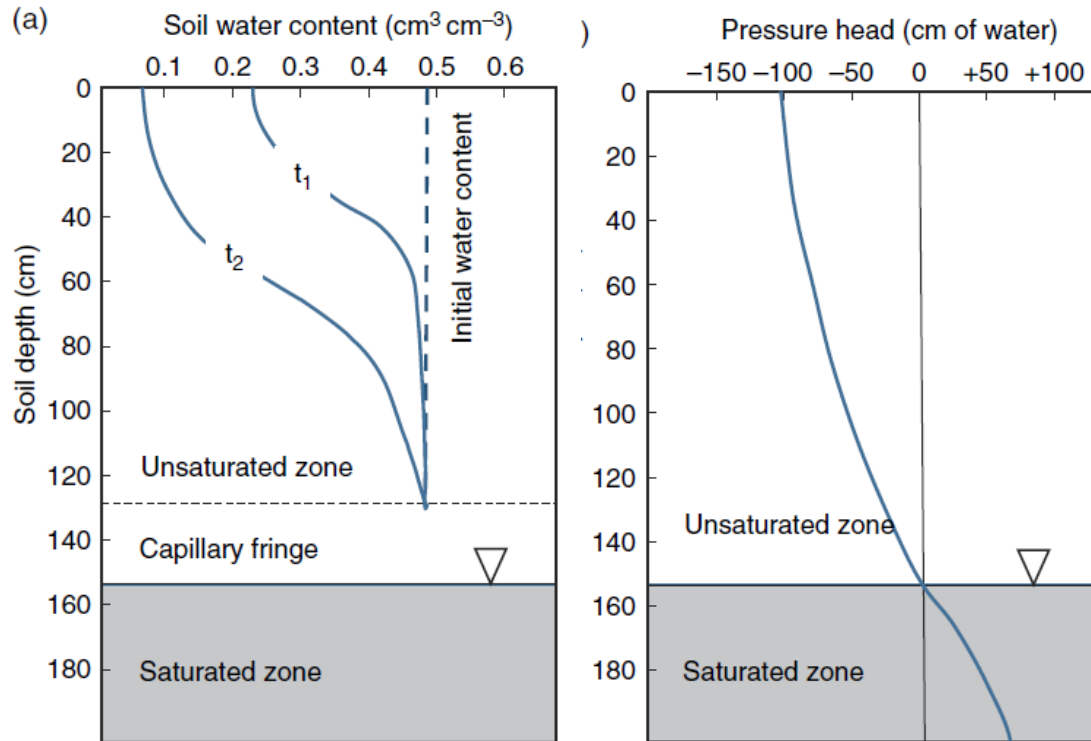


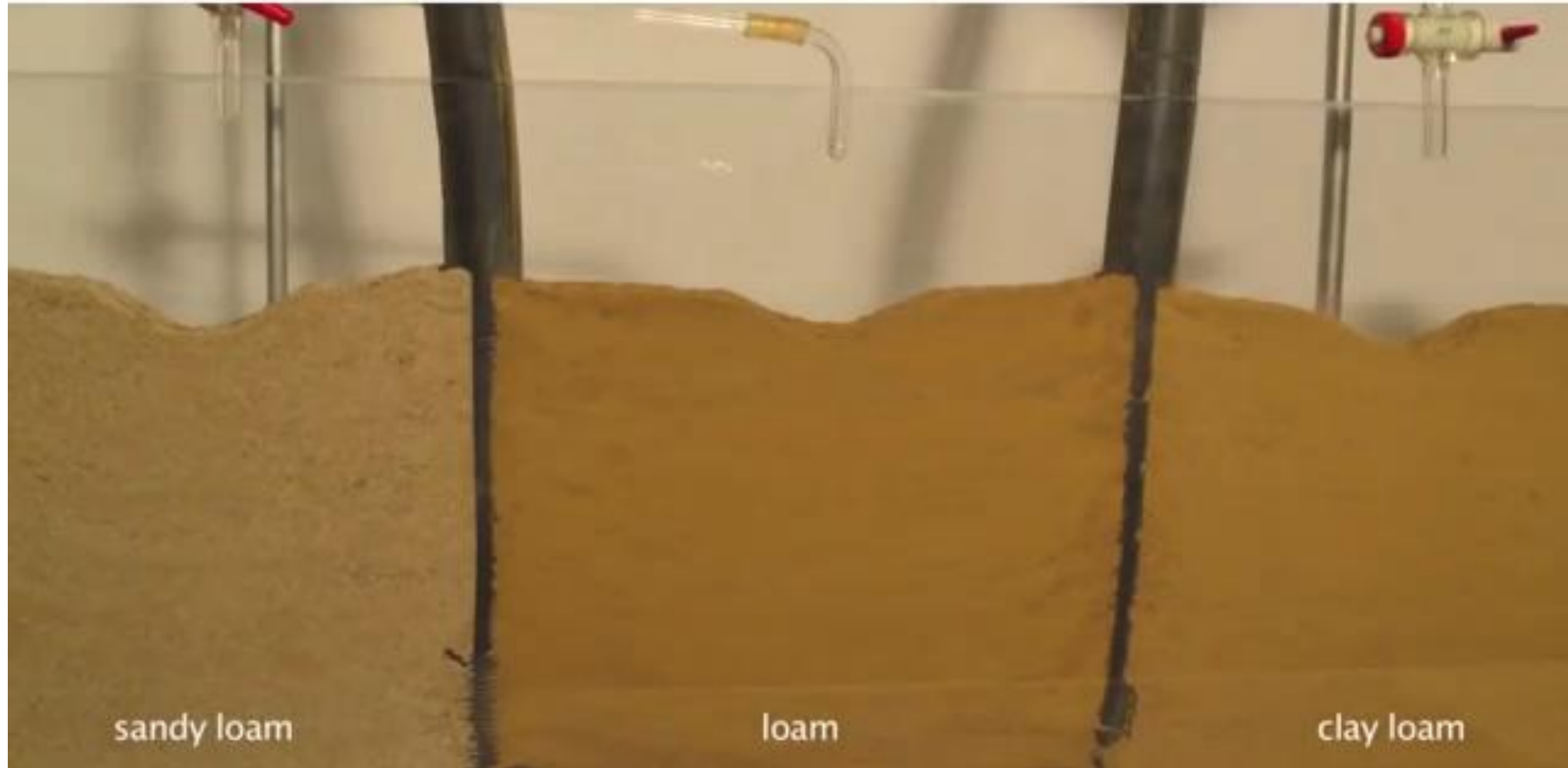
Doygun olmayan toprakta akış



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$$q = -K(\theta) \frac{dH}{dx}$$

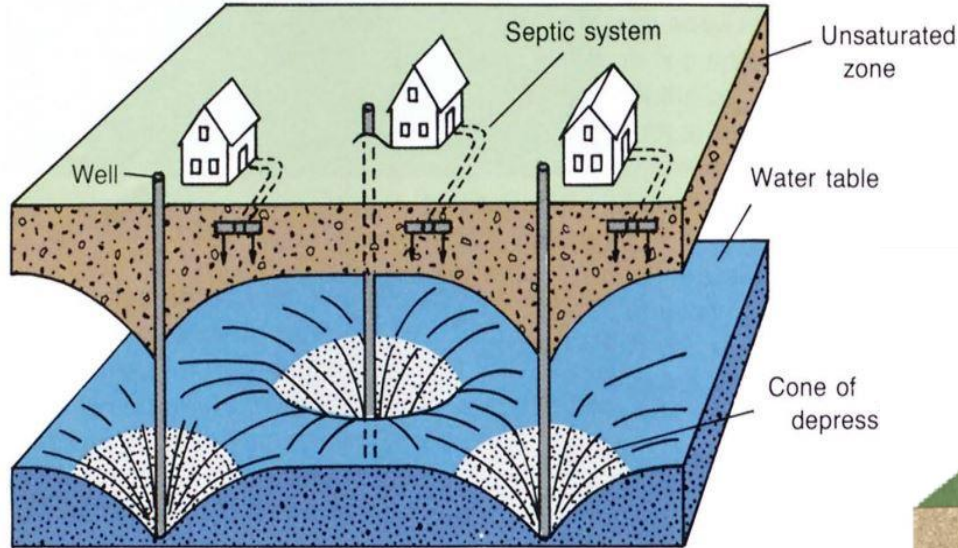




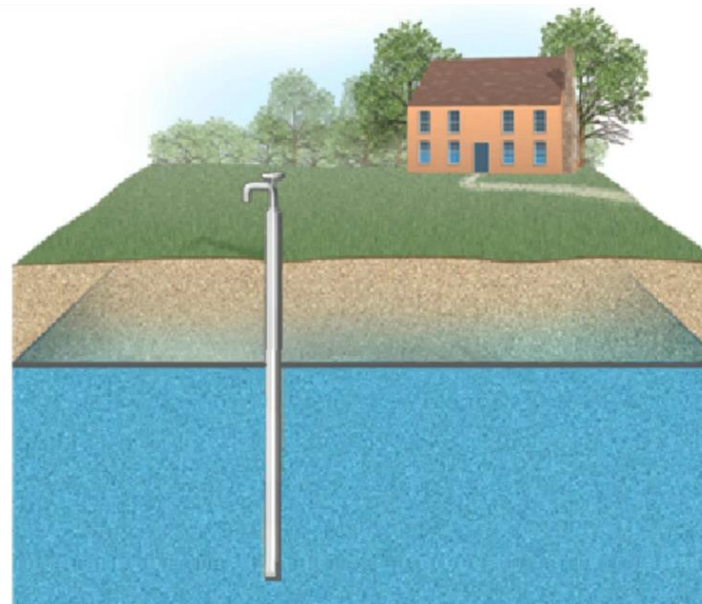
Radyal Akış



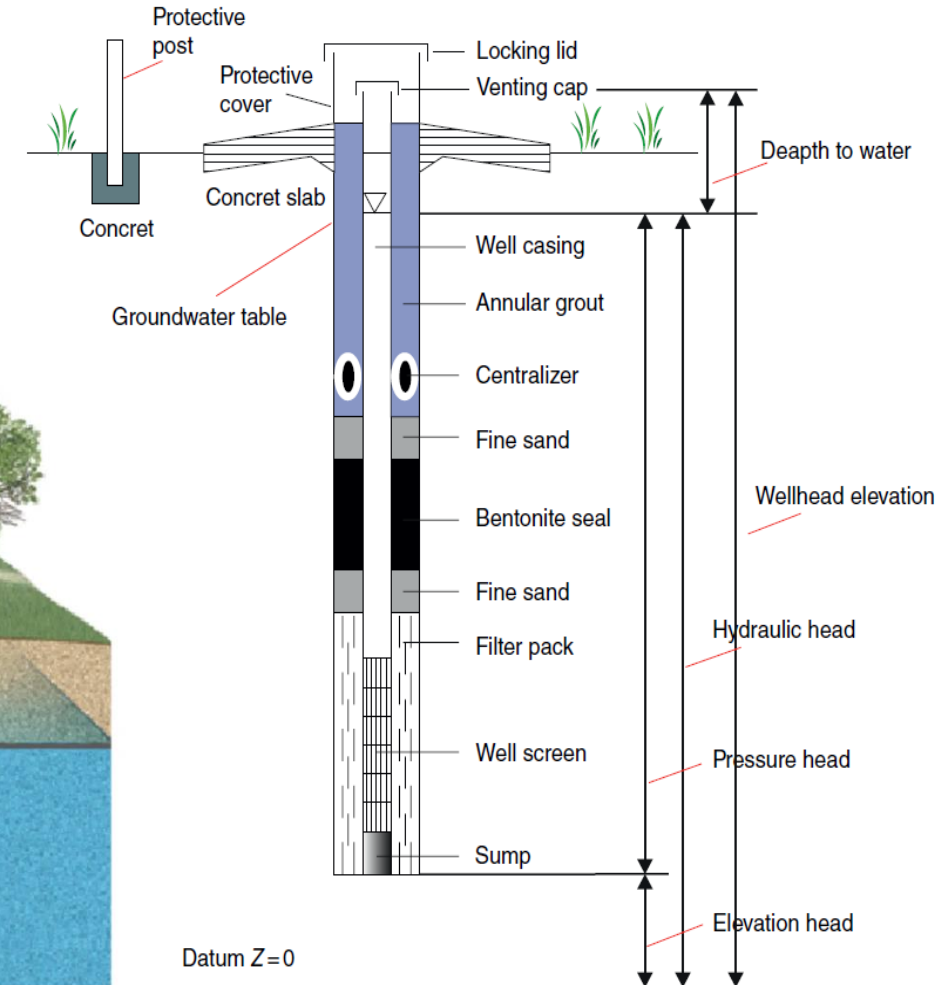
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USGS, 2019



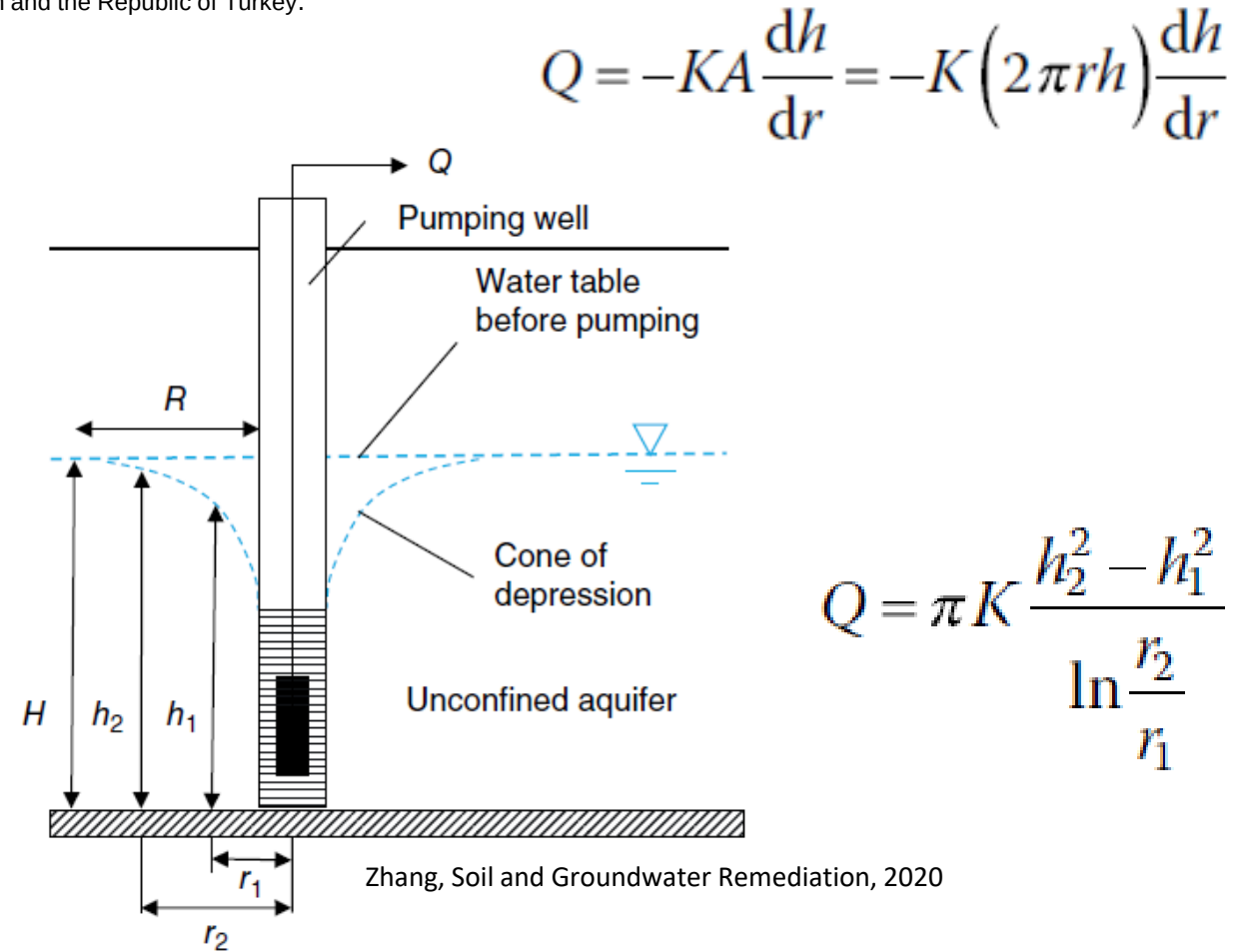
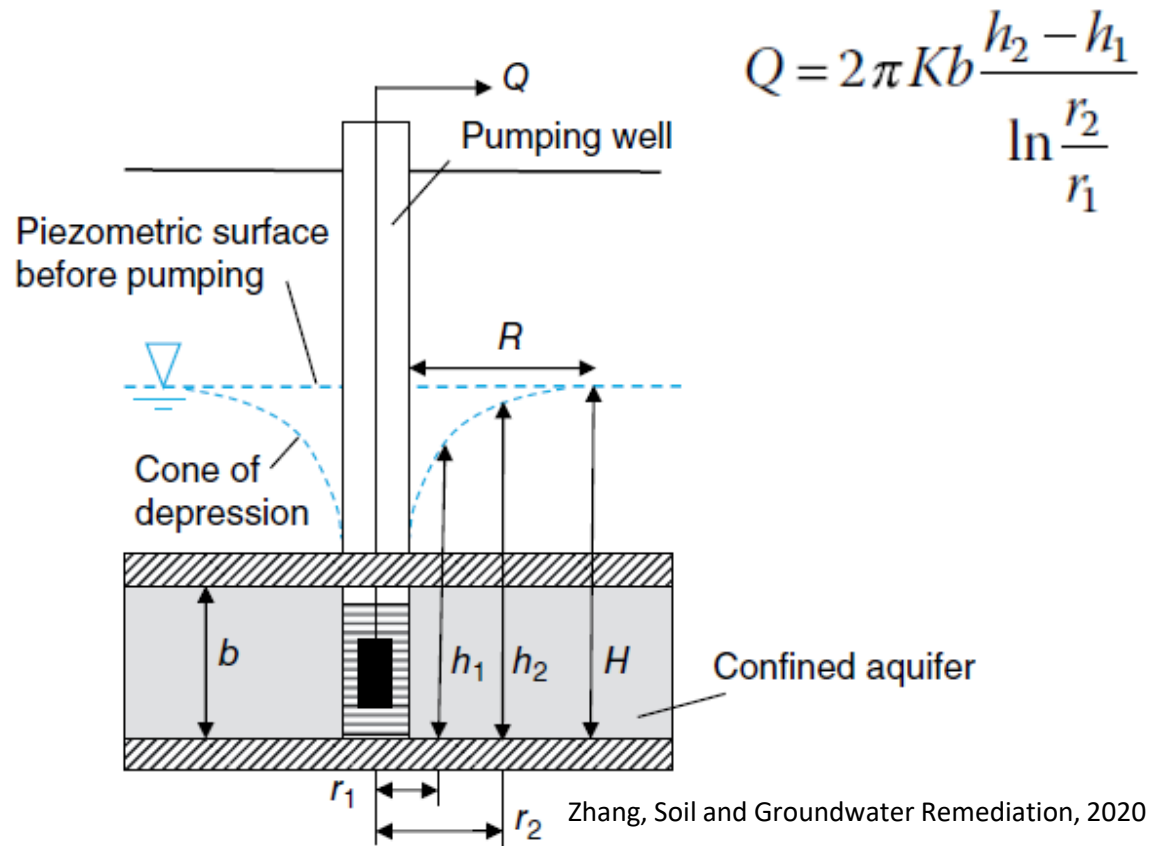
<https://www.youtube.com/watch?v=mRqrCtC4u88>



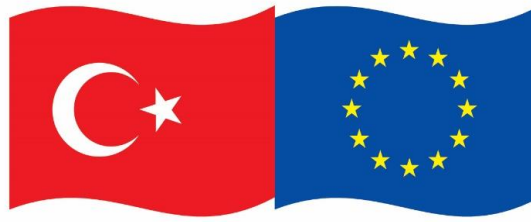
Zhang, Soil and Groundwater Remediation, 2020



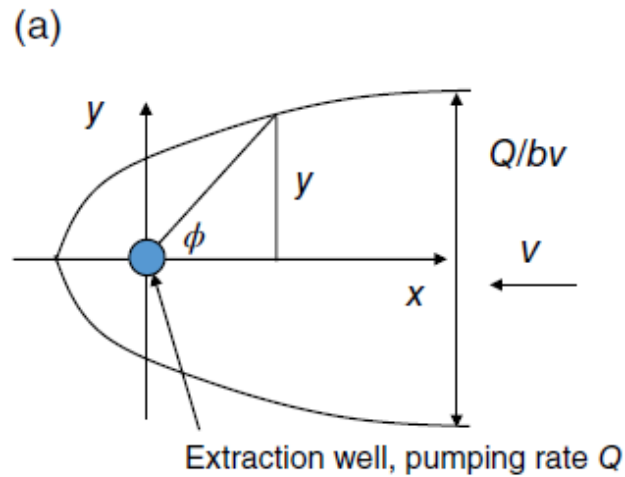
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Capture Zone

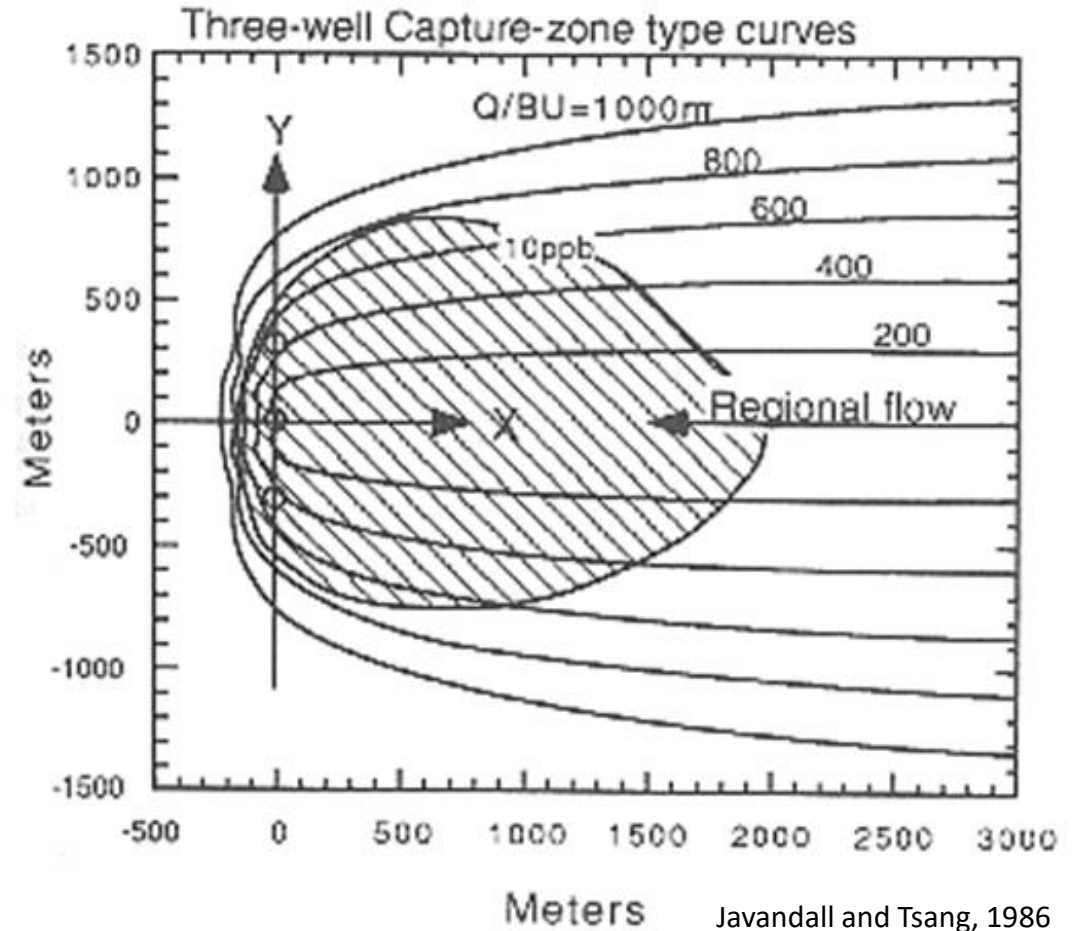


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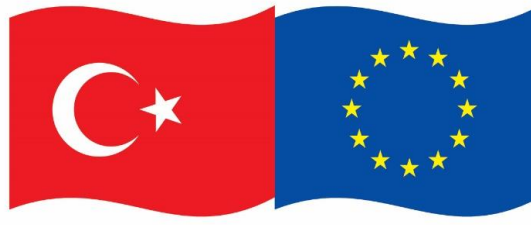


$$y = \frac{Q}{(bv)}$$

Çoklu Kuyu için: $y = n Q/(b v)$.



Javandall and Tsang, 1986



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- **Suda çözünmeyen sıvılar (Non-aqueous phase liquids-NAPLs)**
- Bu sıvılar su içinde çözünmez
- Su dışında ikinci bir faz gözlenir
- Eğer sıvının yoğunluğu suyun yoğunluğundan düşük ise
→ Hafif suda çözünmeyen sıvılar
(Light non-aqueous phase liquid-LNAPL)
- Eğer sıvının yoğunluğu suyun yoğunluğundan yüksek ise
→ Yoğun suda çözünmeyen sıvılar
(Dense non-aqueous phase liquid -DNAPL)



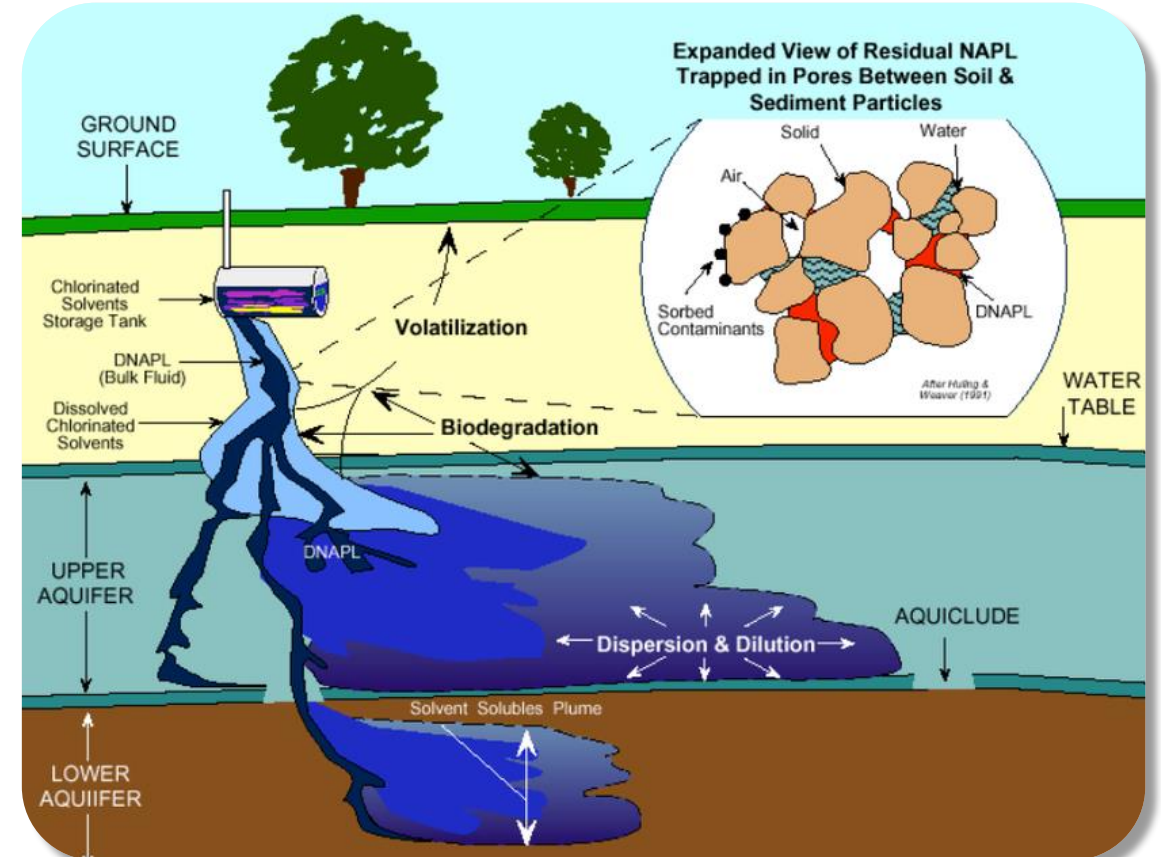
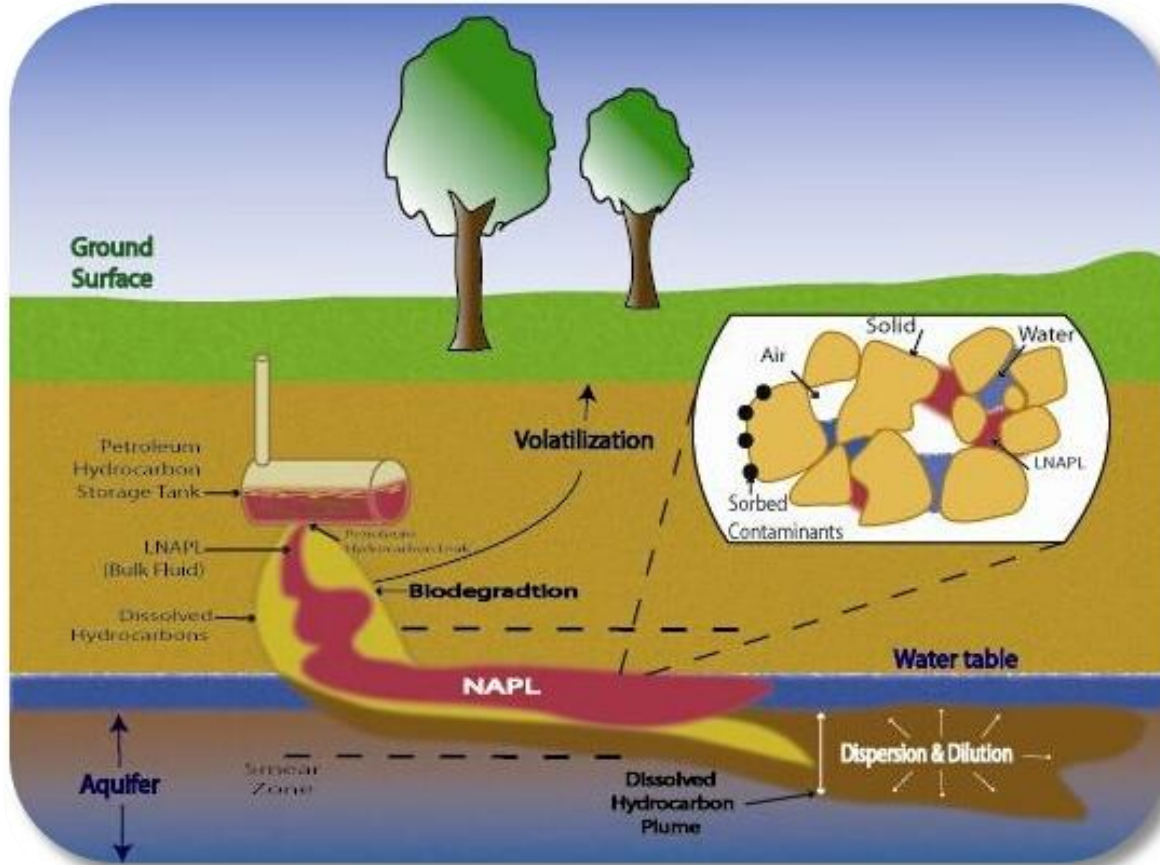
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DNAPLs	
PCE	1.62
Carbon tetrachloride	1.59
Chloroform	1.48
TCE	1.46
1,1,1-TCA	1.34
Methylene chloride	1.33
Coal tar	1.01-1.05

LNAPLs	
Xylene	0.86
Toluene	0.87
Benzene	0.88
Gasoline	0.72-0.76
Jet fuel	0.76
Diesel fuel	0.84-0.85
Fuel oil	0.87-0.95



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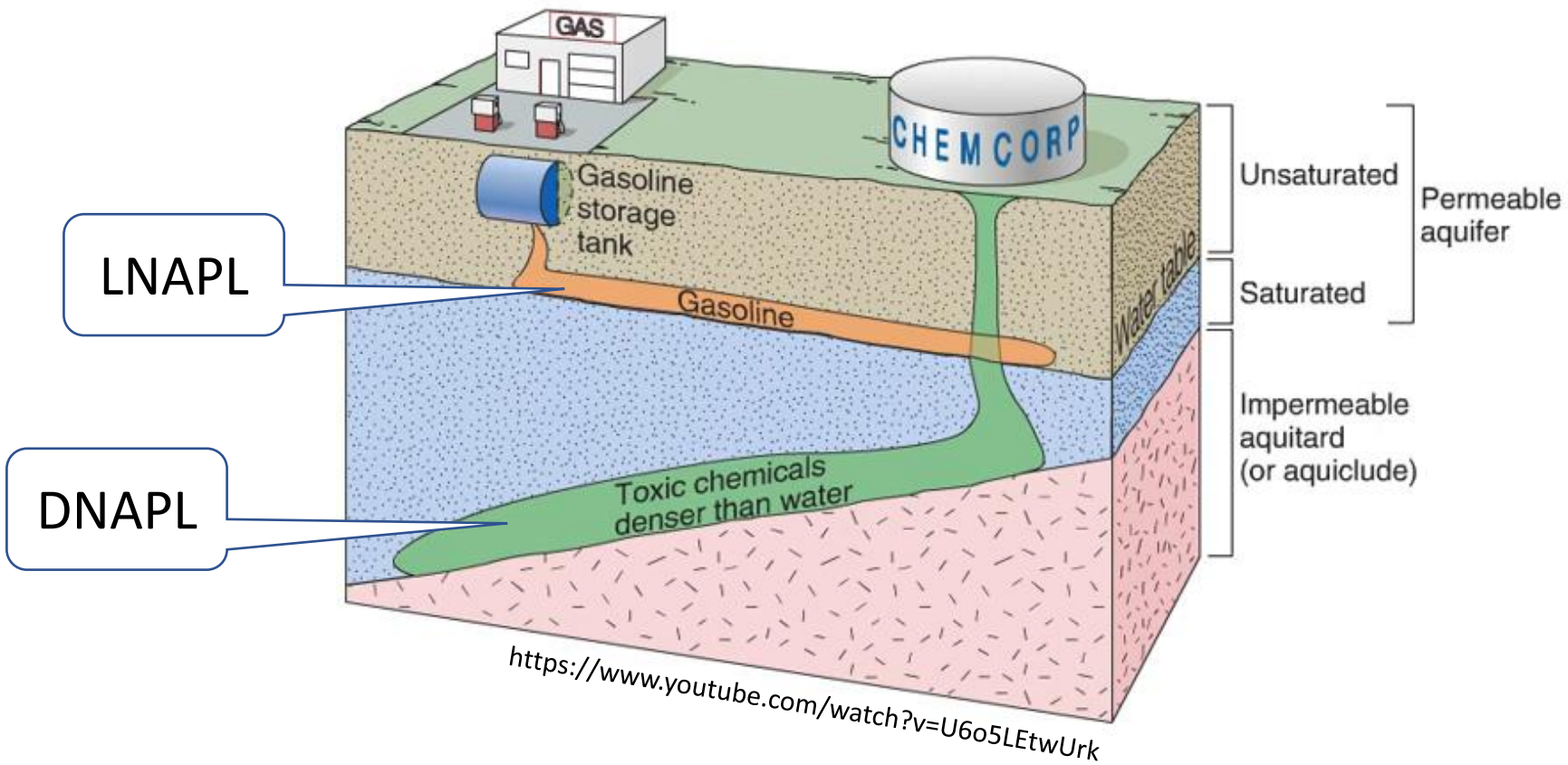


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- NAPLların çözünürlükleri düşüktür.
- Ancak içme suyu standartlarında bunların değerleri çok daha düşüktür.
- Çok düşük hacimde NAPL bile yeraltı suyunu kirletir;
- Doğal koşullarda, DNAPLların giderimi için yüzyıllar binyıllar gereklidir.

Compound	Solubility (mg/L)	MCL (µg//L)
Trichloroethylene	Approx. 1000	5
Tetrachloroethylene	Approx. 150	5
Benzene	Approx. 1800	5



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THANK YOU...