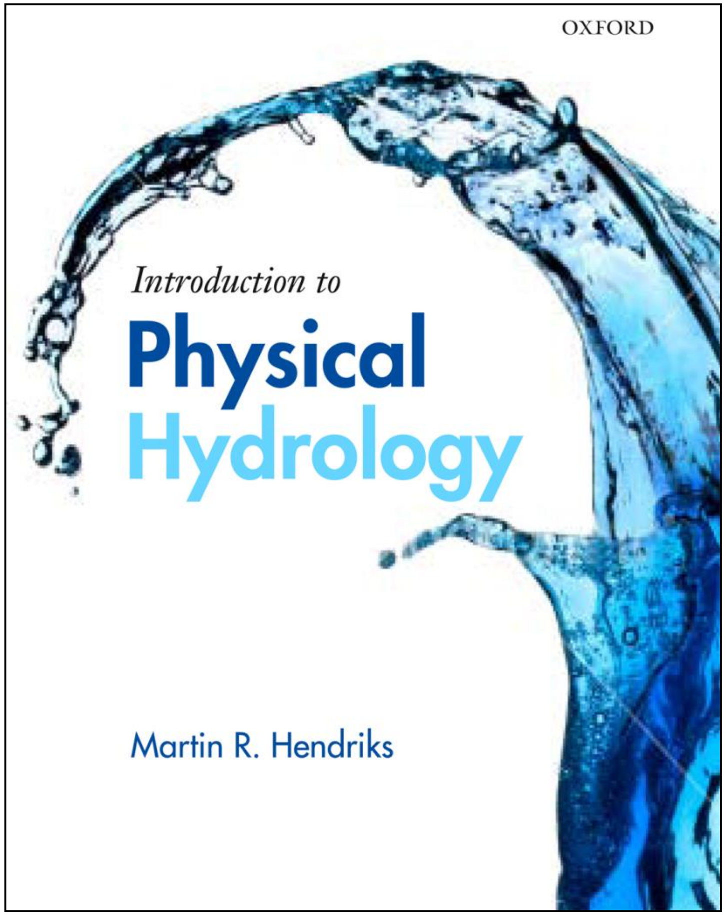
Groundwater hydraulics



Paperback | 351 pages
Follow the book's didactic concept!

- Hydrological cycle
- Drainage basin
- Water balance

- Energy equation
- Flow equation
- Continuity equation

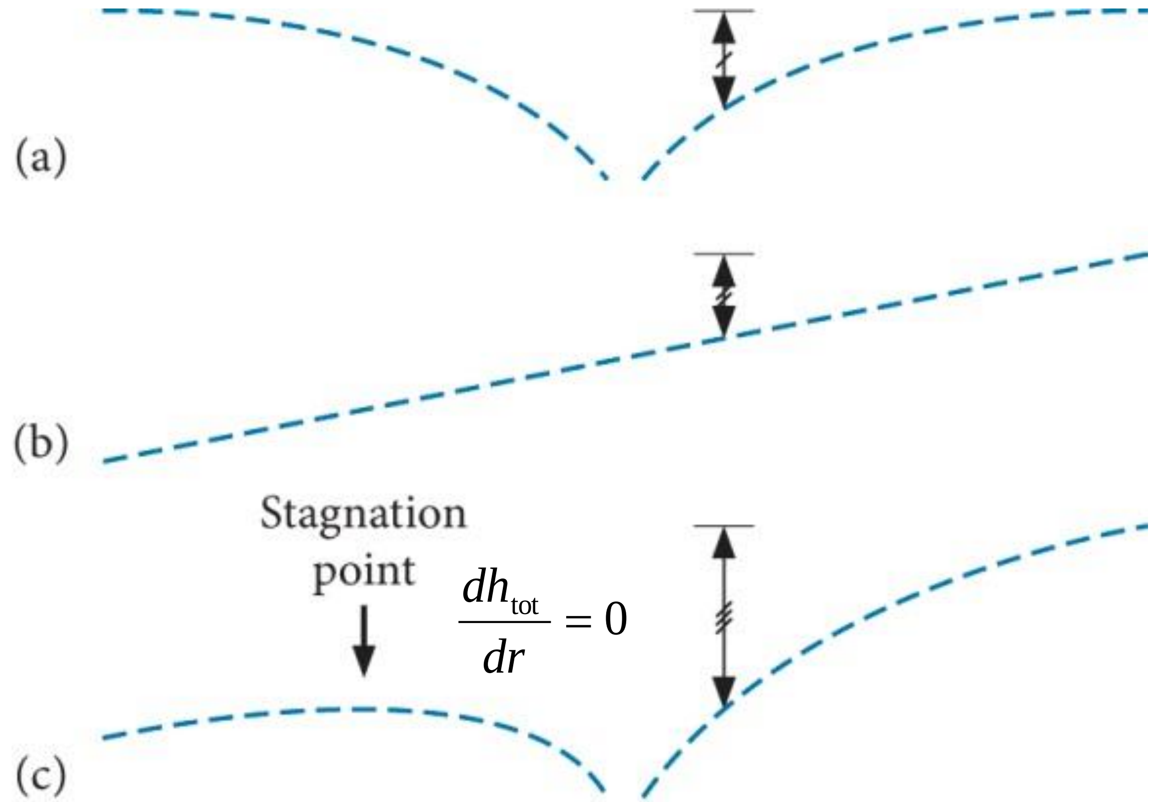
1. Introduction
2. Atmospheric water
3. Groundwater, including **Section 3.15**
4. Soil water
5. Surface water

Exercises

A well in a regional groundwater flow field

$$h_r = h_R + \frac{Q_0}{2\pi T}\ln\frac{r}{R}$$

$$h_x = ix + C = ir + C$$

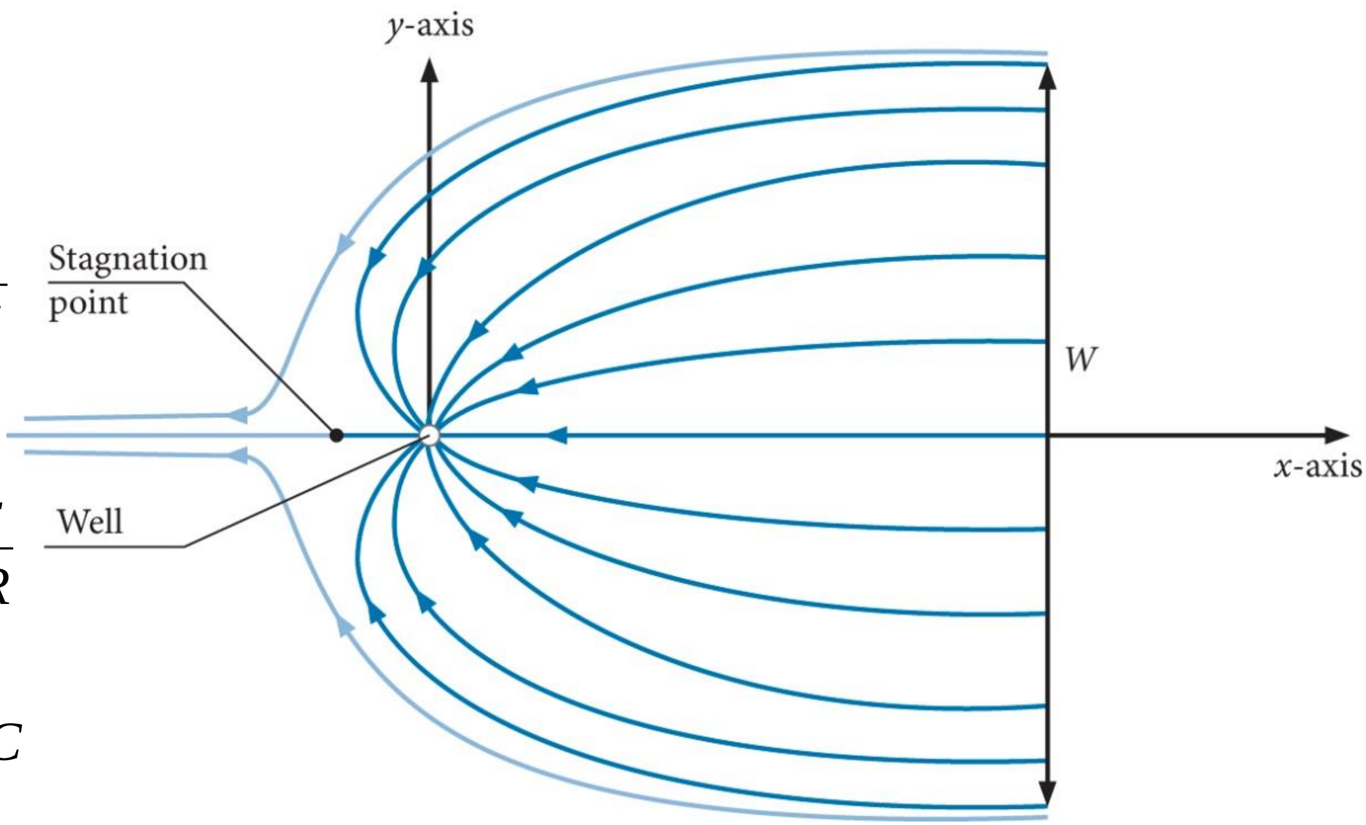


$$h_{tot} = h_r + h_x = h_R + \frac{Q_0}{2\pi T}\ln\frac{r}{R} + ir + C = h_R + \frac{Q_0}{2\pi T}(\ln r) - \frac{Q_0}{2\pi T}(\ln R) + ir + C$$

$$\frac{Q_0}{2\pi T}\left(\frac{1}{r}\right) + i = 0 \Rightarrow \frac{Q_0}{2\pi T r} + i = 0 \Rightarrow \frac{Q_0}{2\pi T r} = -i \Rightarrow 2\pi T r = \frac{-Q_0}{i} \Rightarrow r = \frac{-Q_0}{2\pi T i}$$

A well in a regional groundwater flow field

$$\frac{dh_{tot}}{dr} = 0 \quad r = \frac{-Q_0}{2\pi Ti}$$

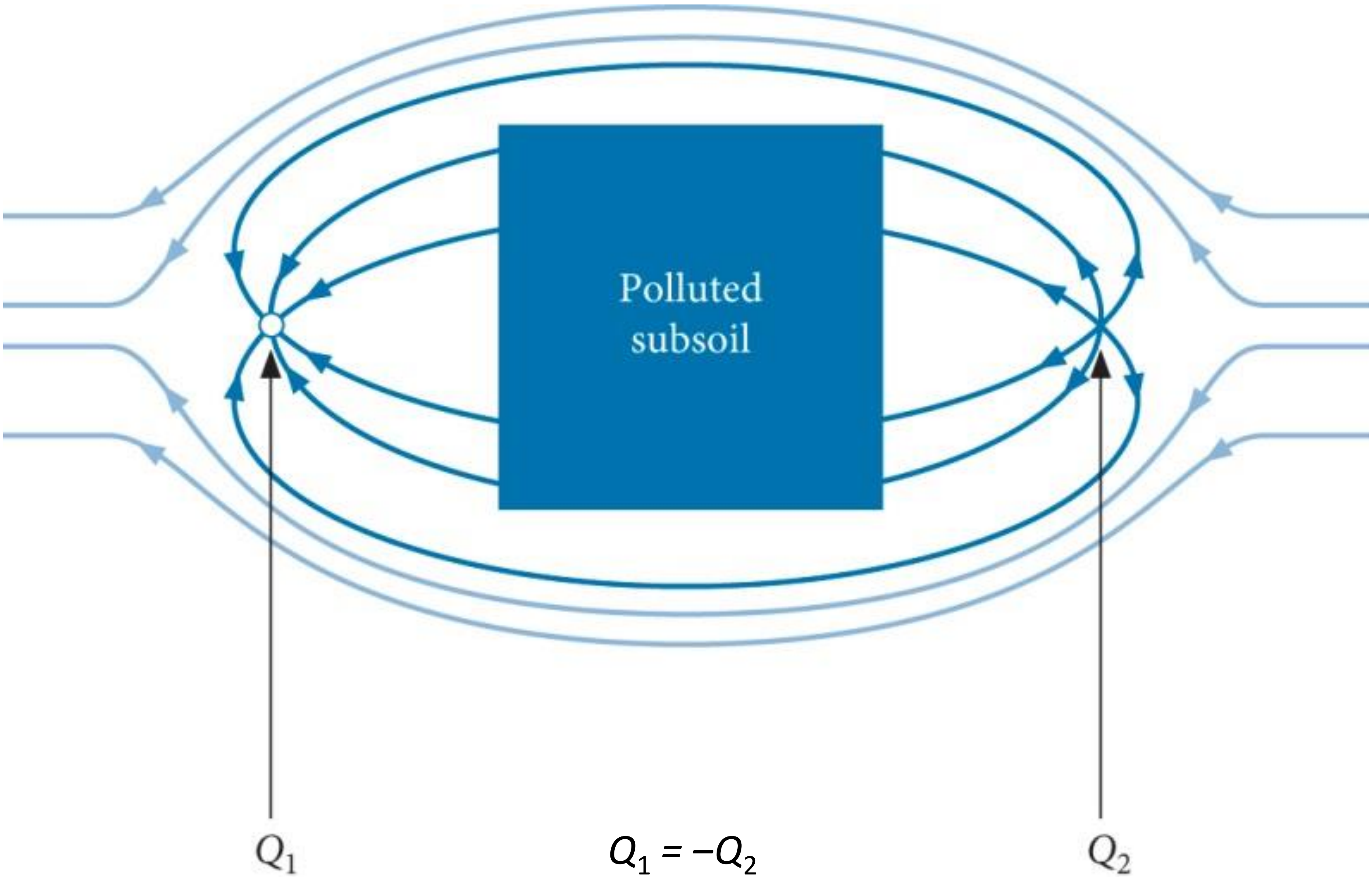


$$h_r = h_R + \frac{Q_0}{2\pi T} \ln \frac{r}{R}$$

$$h_x = ix + C = ir + C$$

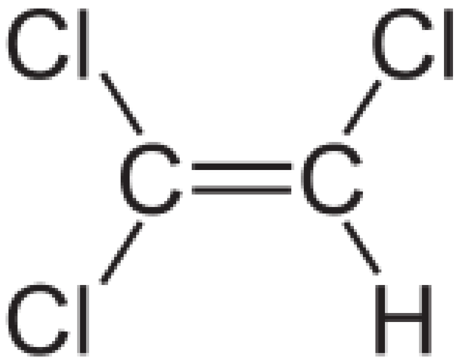
$$h_{tot} = h_r + h_x = h_R + \frac{Q_0}{2\pi T} \ln \frac{r}{R} + ir + C = h_R + \frac{Q_0}{2\pi T}(\ln r) - \frac{Q_0}{2\pi T}(\ln R) + ir + C$$

Pump and treat

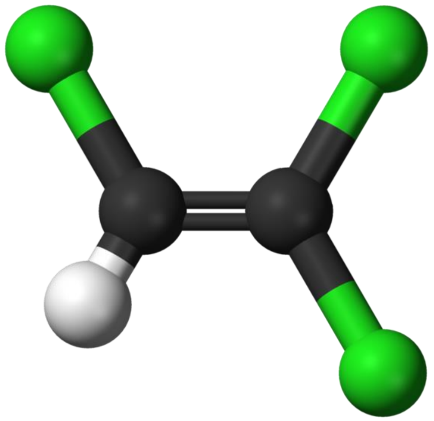


$Q_1 = -Q_2$

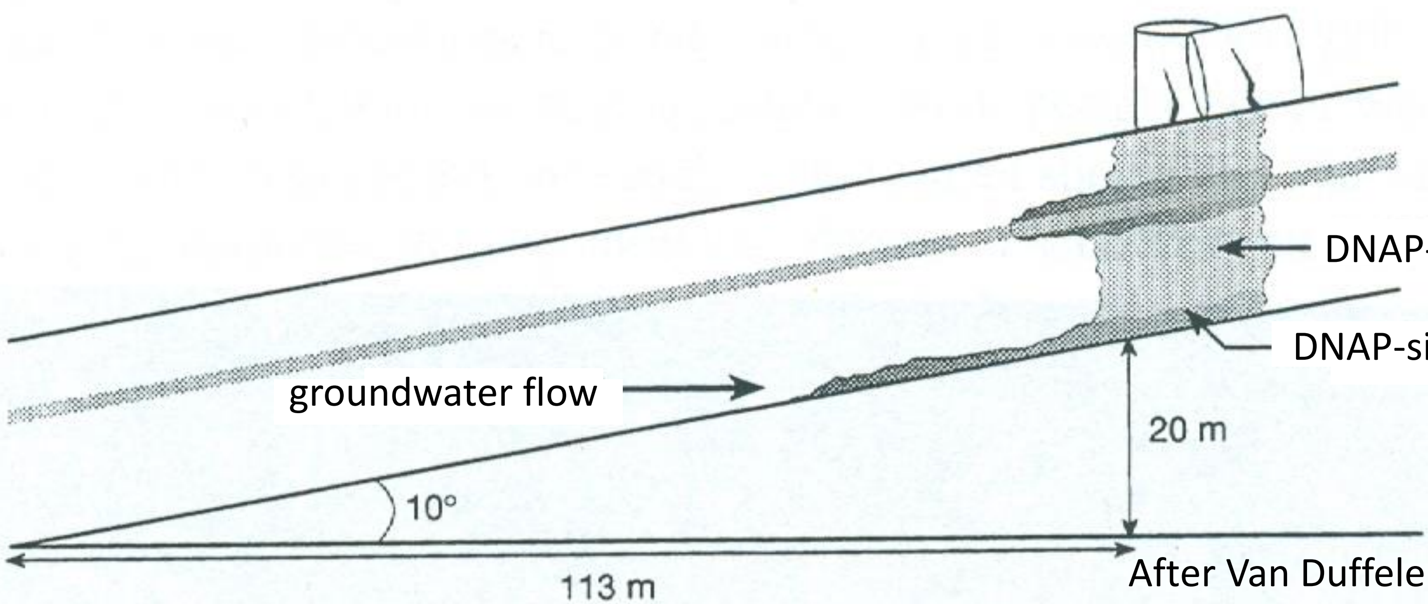
Trichloroethylene (TCE)



Source: Wikipedia

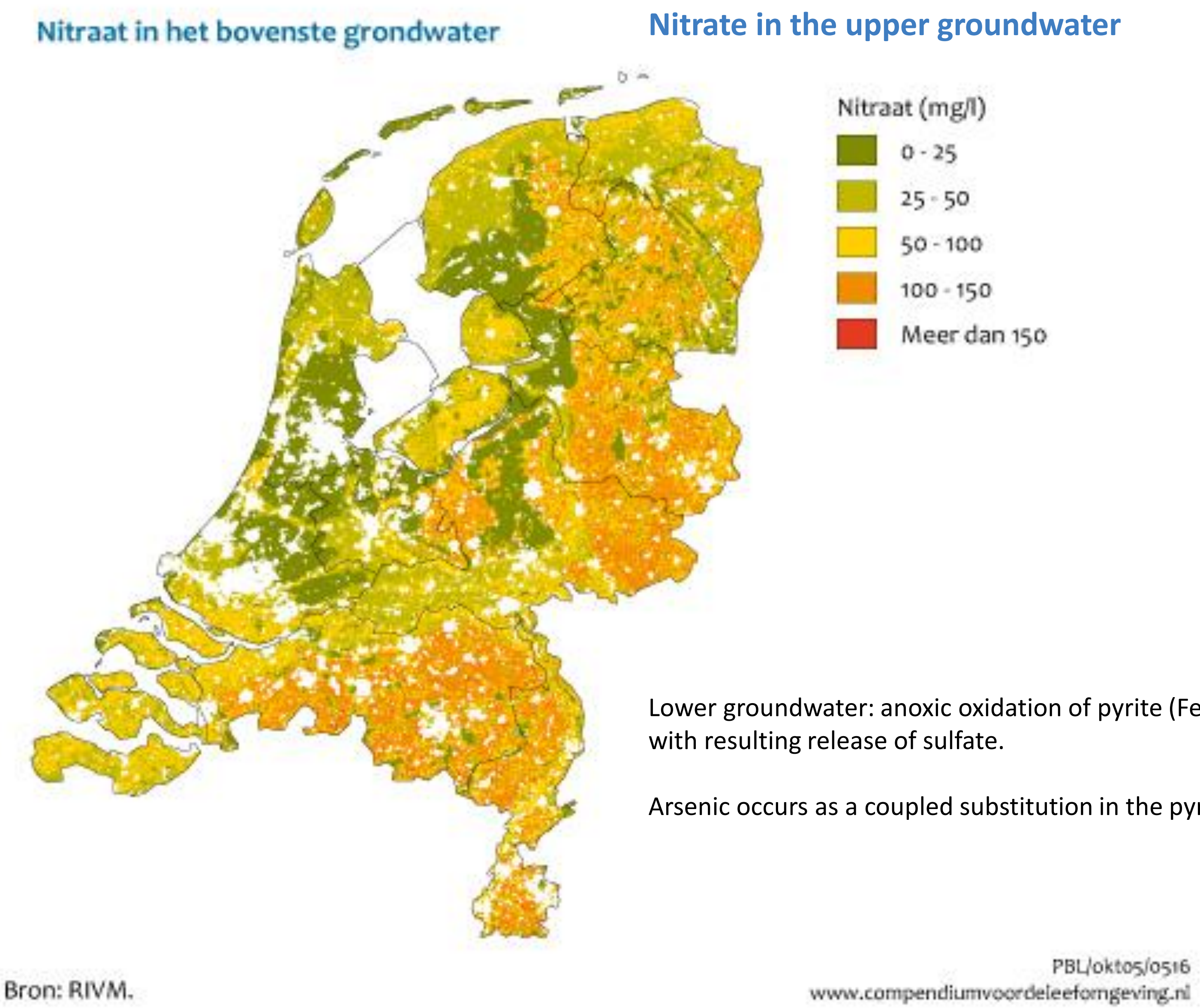


Source: Wikiwand



After Van Duffelen (1996)

Nitrate in The Netherlands in 2000

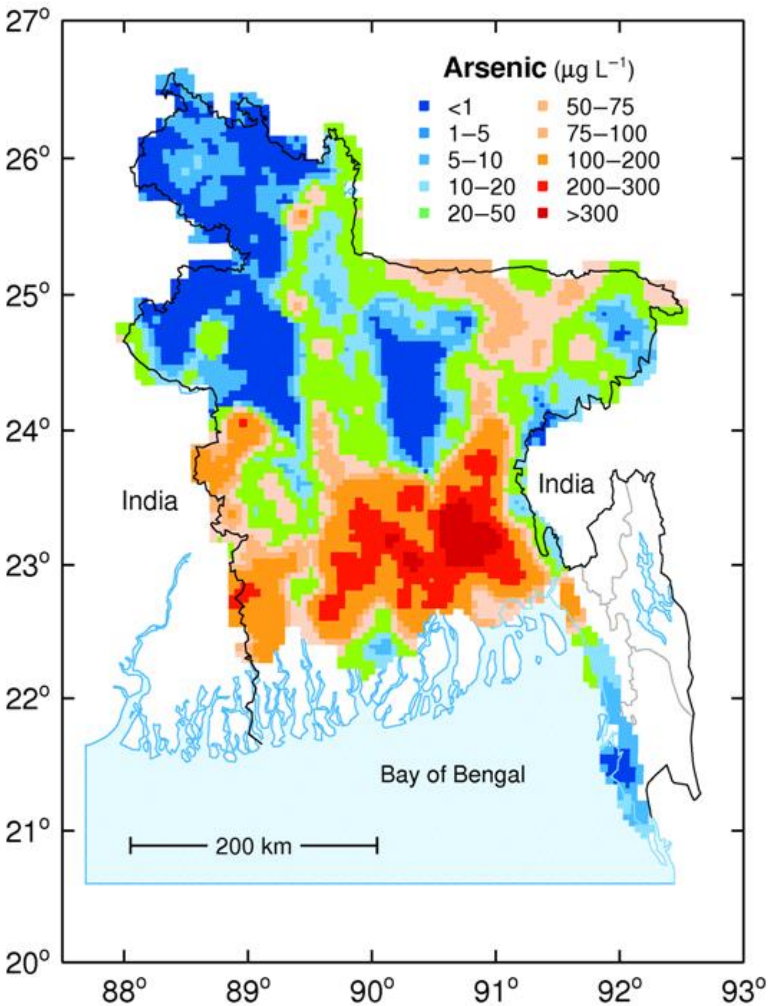


Nitrate in the upper groundwater

Lower groundwater: anoxic oxidation of pyrite (FeS_2) by nitrate with resulting release of sulfate.

Arsenic occurs as a coupled substitution in the pyrite structure.

Arsenic contaminated groundwater



Source: Bangladesh Arsenic Poisoning

Faculty of Geosciences

Universiteit Utrecht

autumn **FEST**

Friday Earth Sciences Talk

drinks afterwards

Dr. Case v. Genuchten

Researcher

Geochemestry

12.10.2018, 16h-17h,

VJ Koningsberger - Pangea

Sustainable treatment of arsenic contaminated groundwater

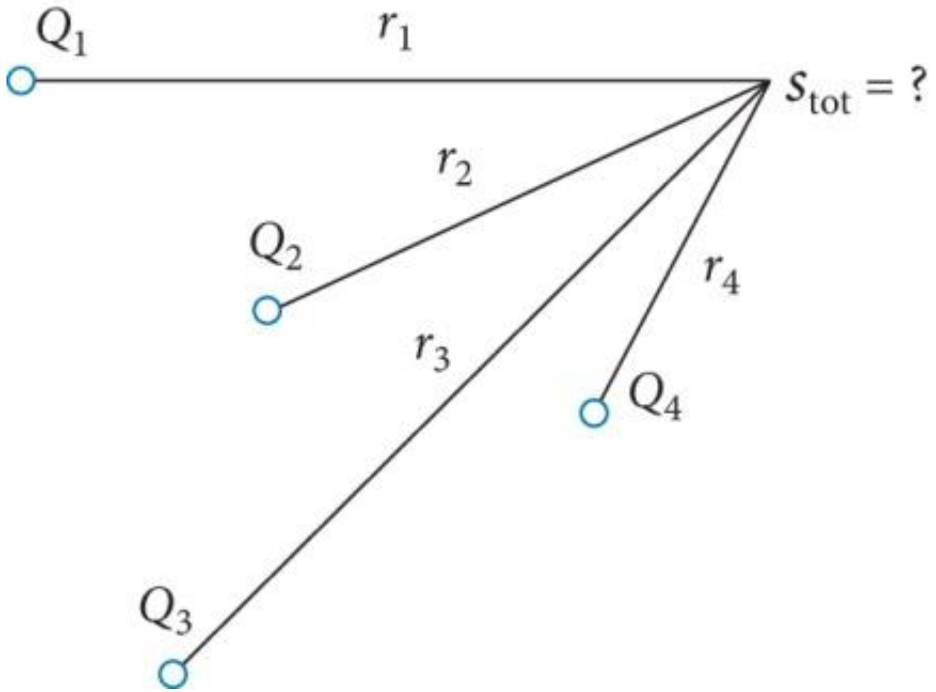
More than 100 million people worldwide are exposed to toxic levels of naturally occurring arsenic in groundwater used for drinking, with the greatest human health toll in poor, rural communities of South and Southeast Asia. Many strategies have been proposed to mitigate the arsenic crisis, but few examples of arsenic-safe water interventions have been sustained, particularly in decentralized areas. This presentation will describe a simple, scaled-up, and economically viable technology to remove arsenic from contaminated groundwater sources that has been operating continuously in a rural community of West Bengal, India for nearly two years. The technology, called electrocoagulation, is based on the electrochemical production of reactive Fe oxide precipitates with a strong affinity for binding arsenic. Existing challenges and inefficiencies with the technology will be highlighted along with new improvements derived by geochemical approaches at Utrecht University (molecular-scale characterization and arsenic uptake experiments). The presentation will close with pictures and descriptions of recent field experiments using a 10,000 L per day pilot plant implemented in an arsenic-affected community in West Bengal, India.

fest.aw@uu.nl

Superposition

$$s = h - h_R = \frac{Q_0}{2\pi K\overline{D}} \ln \frac{r}{R}$$

$s < 0$ for a pumping well ($Q_0 > 0$)
$s > 0$ for a recharge well ($Q_0 < 0$)

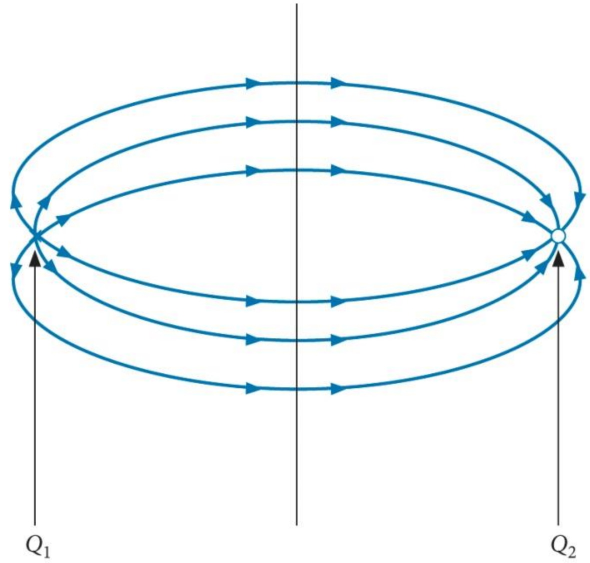


$$s_{tot} = s_1 + s_2 + s_3 + s_4$$

$$h = h_R + s_{tot}$$

Open-water linear boundary

Dirichlet



$Q_1 = -Q_2$

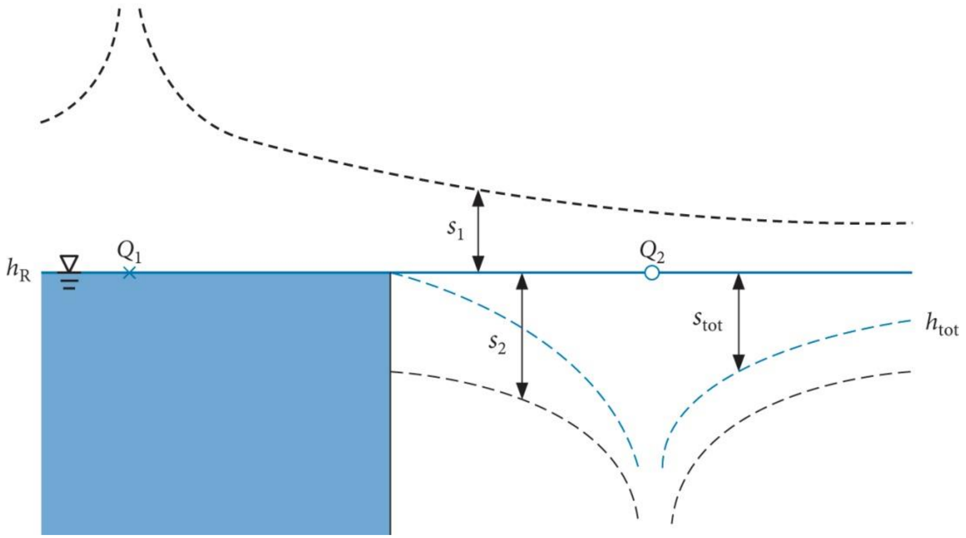
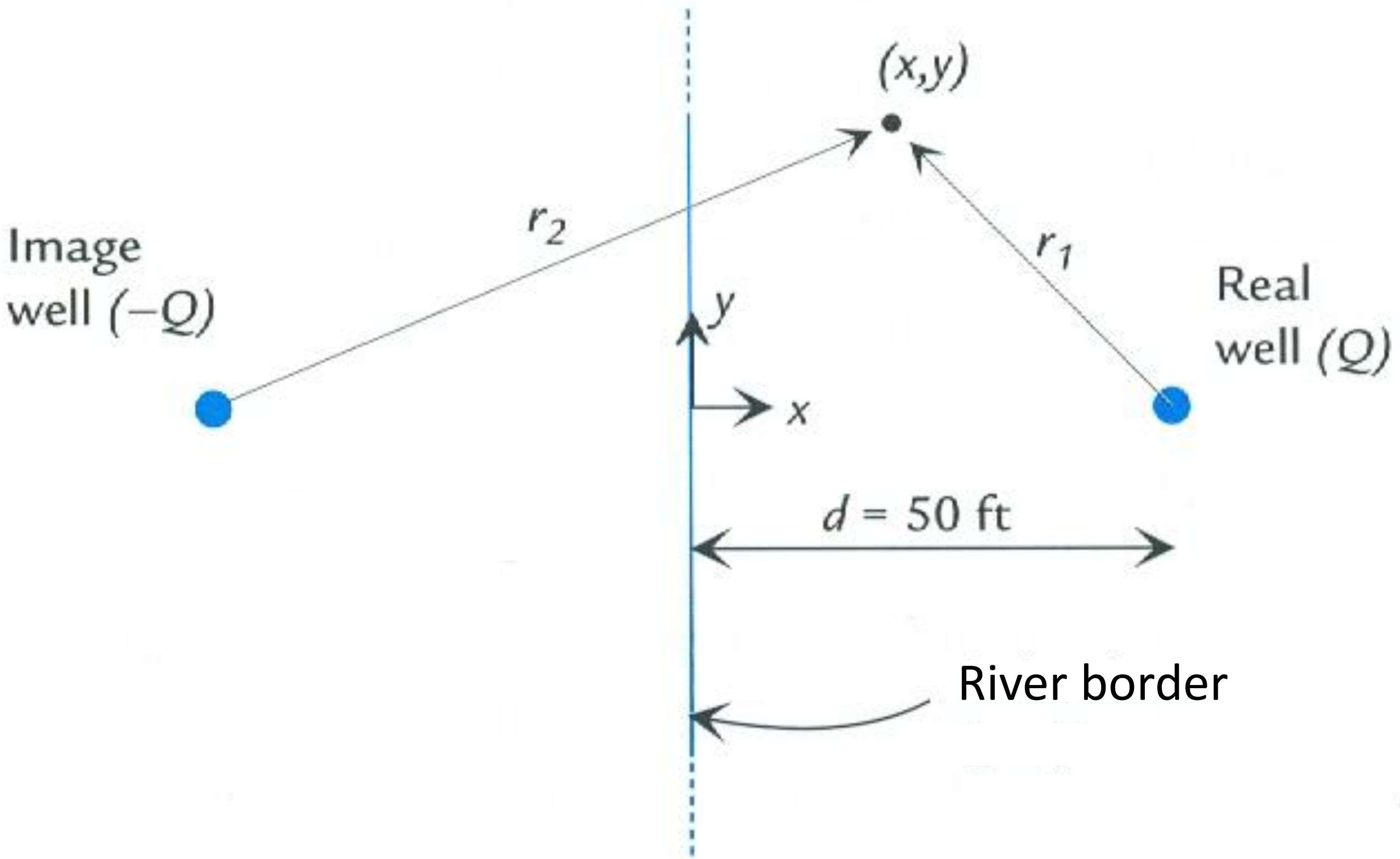


image well Q_1

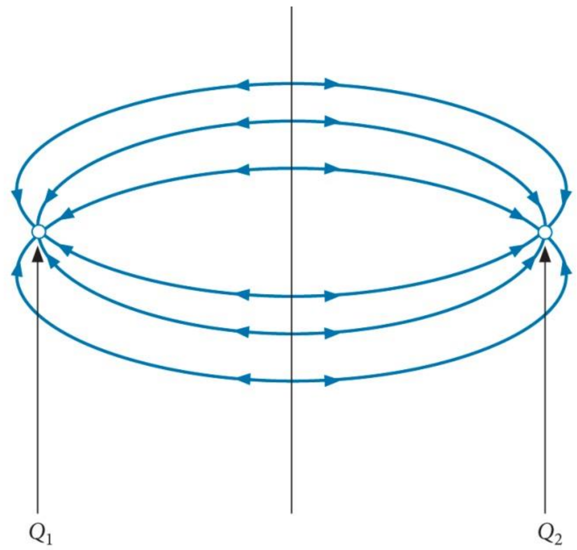
Open-water linear boundary



After Fitts (2002)

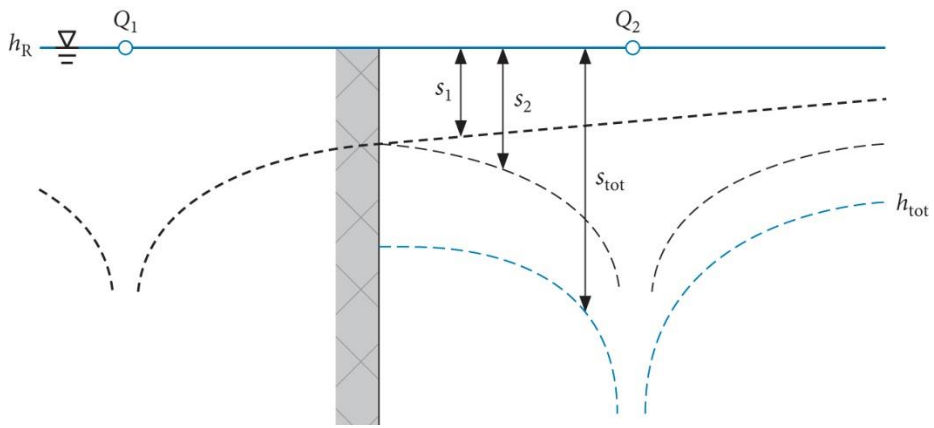
No-flow linear boundary

Neumann

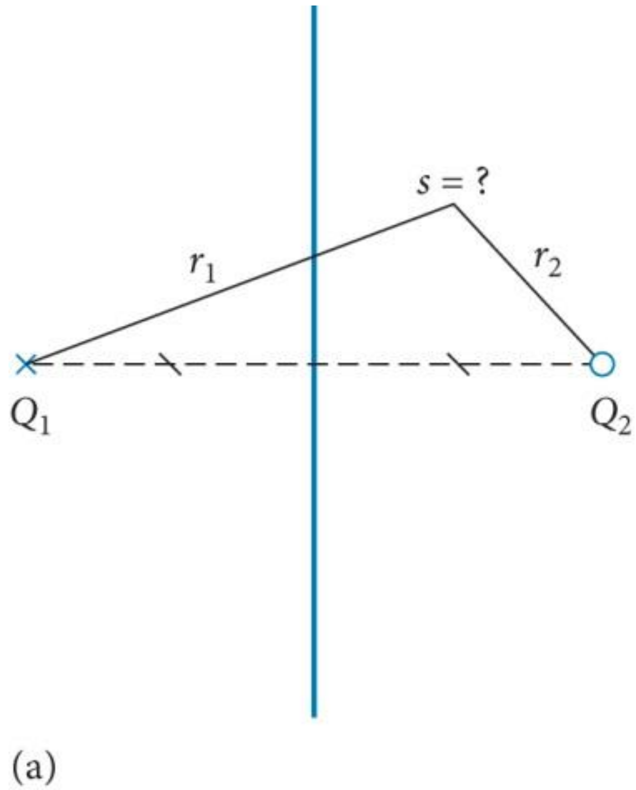


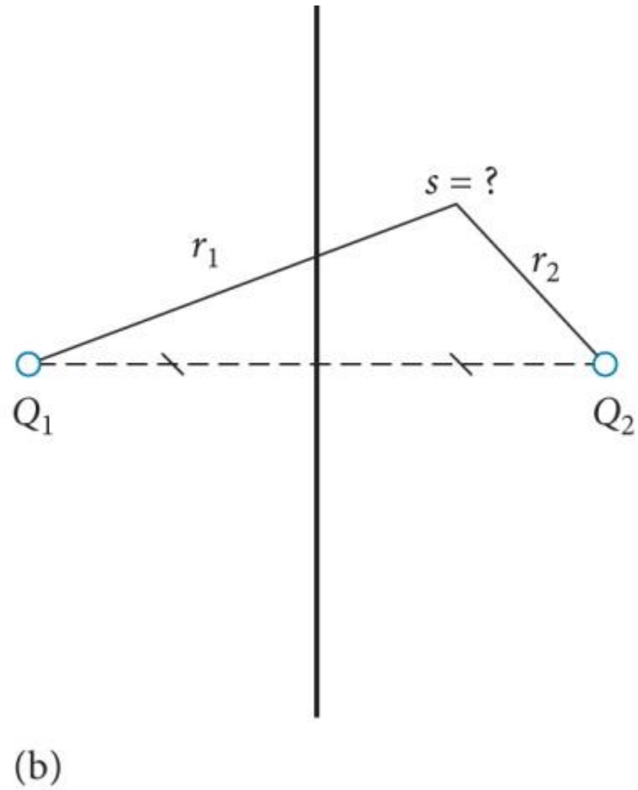
$Q_1 = Q_2$

image well Q_1



Linear boundaries

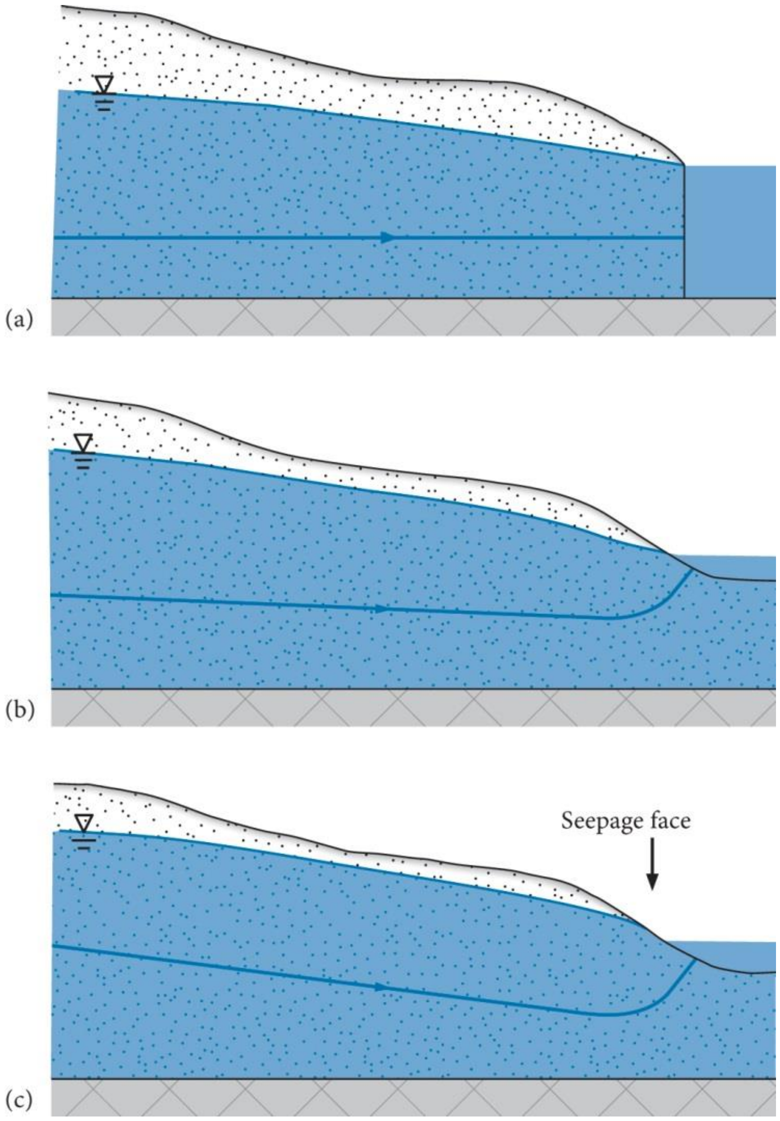




Dirichlet

Neumann

Extra resistance(s)



$$h^2 = -\frac{N}{K}x^2 + C$$

$$N = \frac{\Delta h}{\left(\frac{L^2}{2K\overline{D}}\right)}$$

$$2L = 2\sqrt{\frac{2K\overline{D}\Delta h}{N}}$$

$$N = \frac{\Delta h}{\left(\frac{L^2}{2K\overline{D}} + \Omega_N\right)}$$

Table 3.3 - Starting point of the exercises

One-dimensional steady groundwater flow

Confined $$\frac{d^2h}{dx^2}=0 \Rightarrow h=C_1x+C_2$$

Unconfined $$\frac{d^2h^2}{dx^2}=0 \Rightarrow h^2=C_1x+C_2$$

Leaky $$h=h_a+C_1e^{\frac{x}{\lambda}}+C_2e^{\frac{-x}{\lambda}} \quad \text{with} \quad \lambda=\sqrt{KDc}$$

Recharge; equal water levels $$h^2=-\frac{N}{K}x^2+C$$

Recharge; different water levels $$h^2=-\frac{N}{K}x^2+C_1x+C_2$$

Radial-symmetric steady groundwater flow

Confined $$h=h_R+\frac{Q_0}{2\pi KD}\ln\frac{r}{R} \quad \text{for} \quad r_w\le r\le R$$

Unconfined $$h^2=h_R^2+\frac{Q_0}{\pi K}\ln\frac{r}{R} \quad \text{for} \quad r_w\le r\le R$$

Laplace and Boussinesq

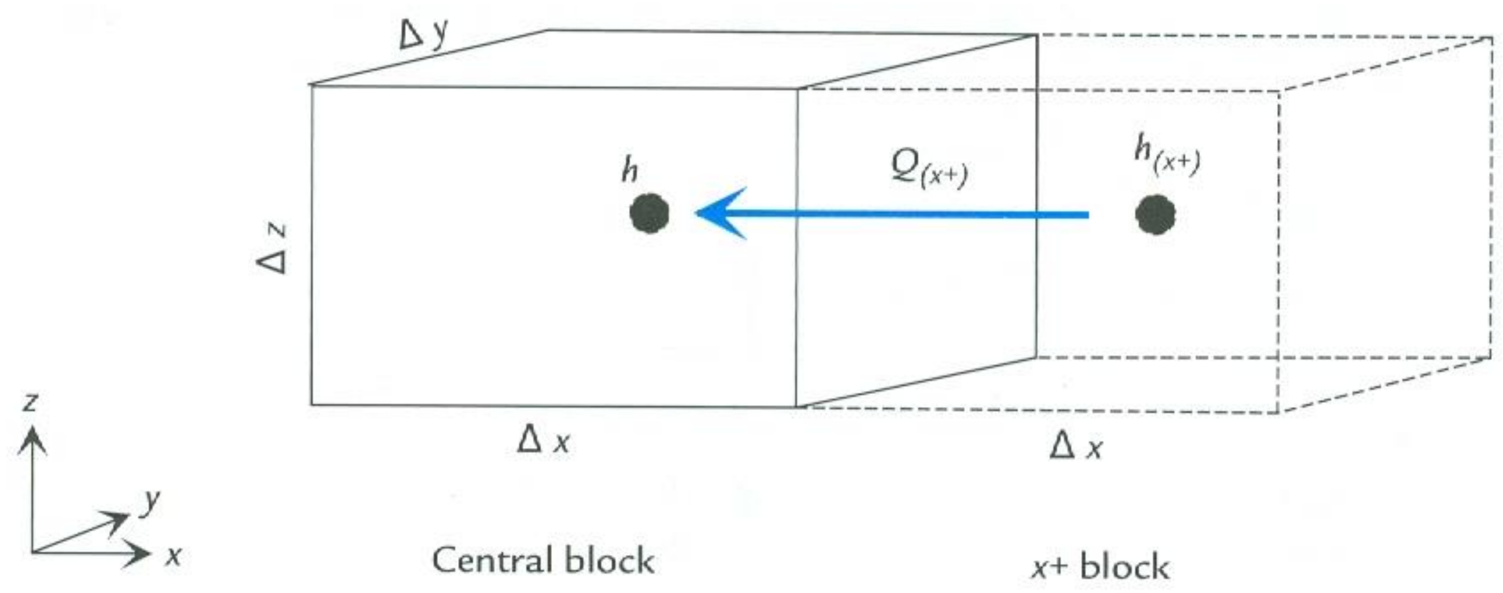
$$\frac{d^2h}{dx^2}=0 \qquad \frac{d^2h^2}{dx^2}=0$$

$$\frac{\partial^2 h}{\partial x^2}+\frac{\partial^2 h}{\partial y^2}+\frac{\partial^2 h}{\partial z^2}=0$$

$$\frac{\partial^2 h}{\partial x^2}+\frac{\partial^2 h}{\partial y^2}=\frac{S_y}{K\overline{D}}\frac{\partial h}{\partial t}$$

Numerical methods

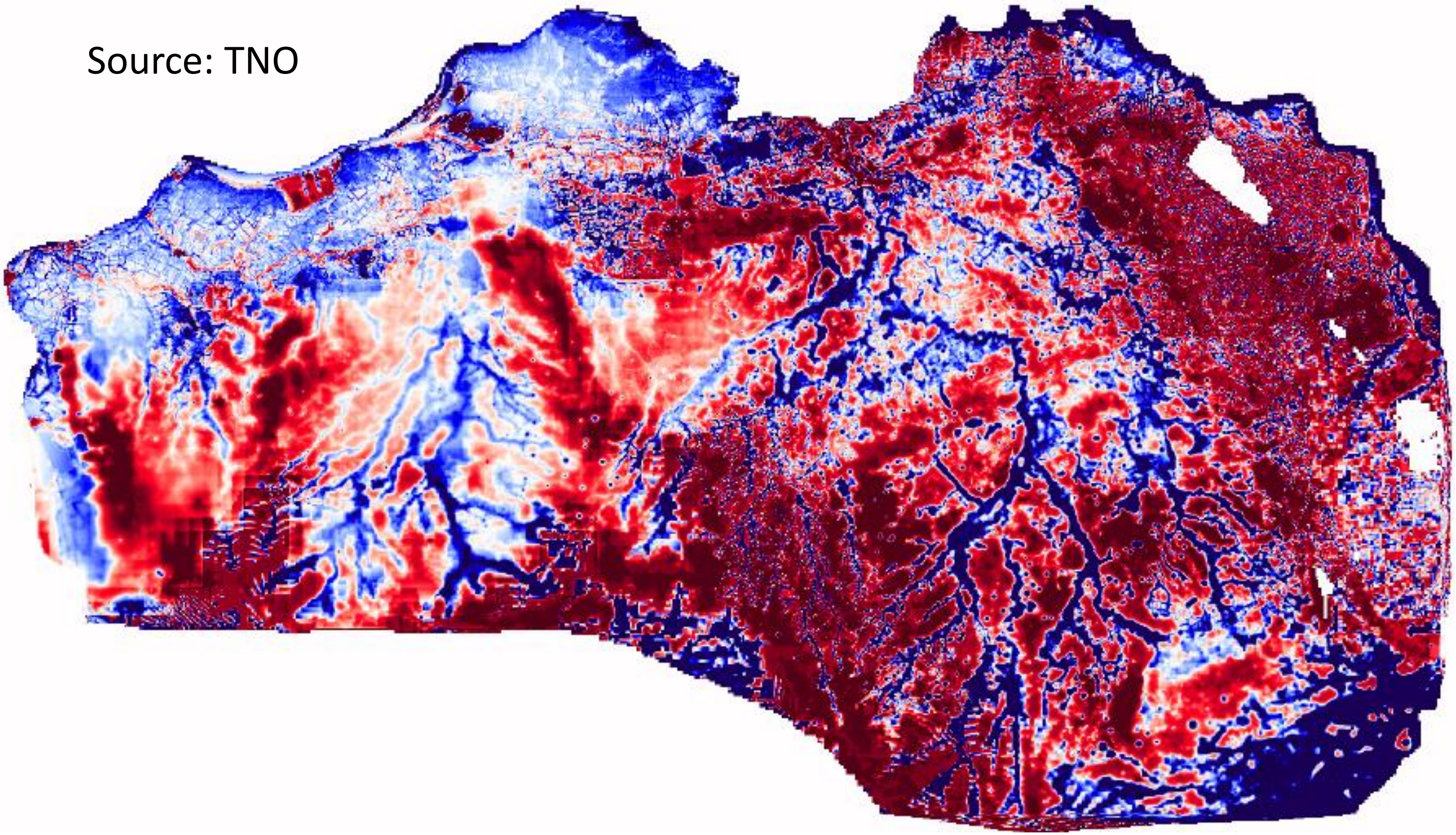
Source: Fitts (2002)



Finite difference method (FDM)

Brabant model

Source: TNO



Infiltration **(red)** and upward fluxes **(blue)** of groundwater

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