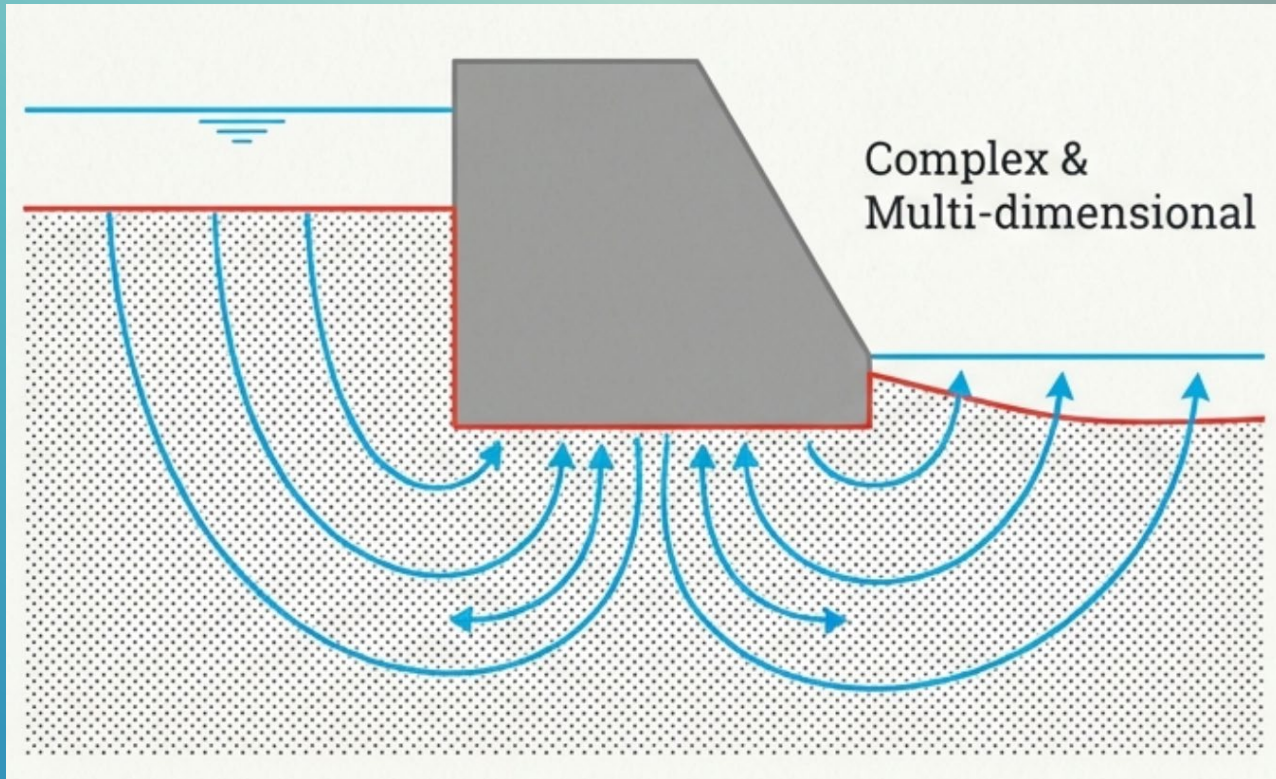


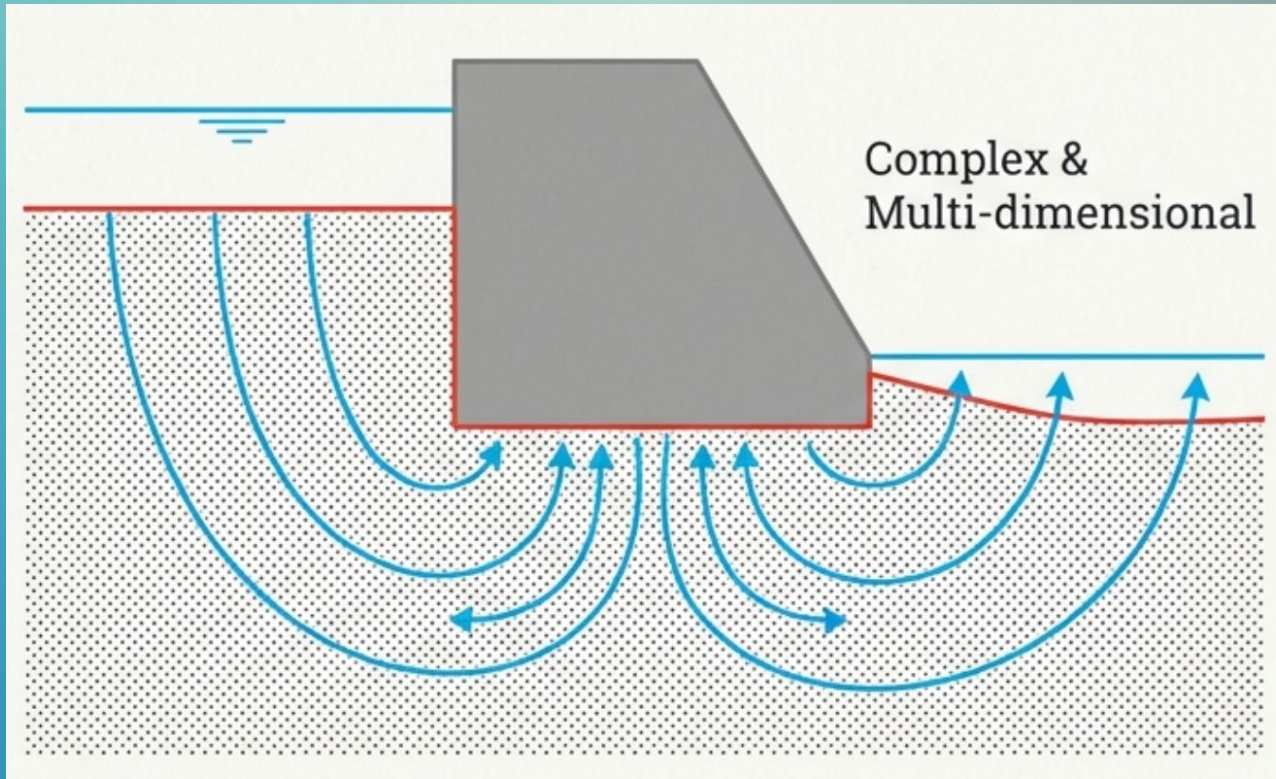


Groundwater
flow

Multi-dimensional Flow

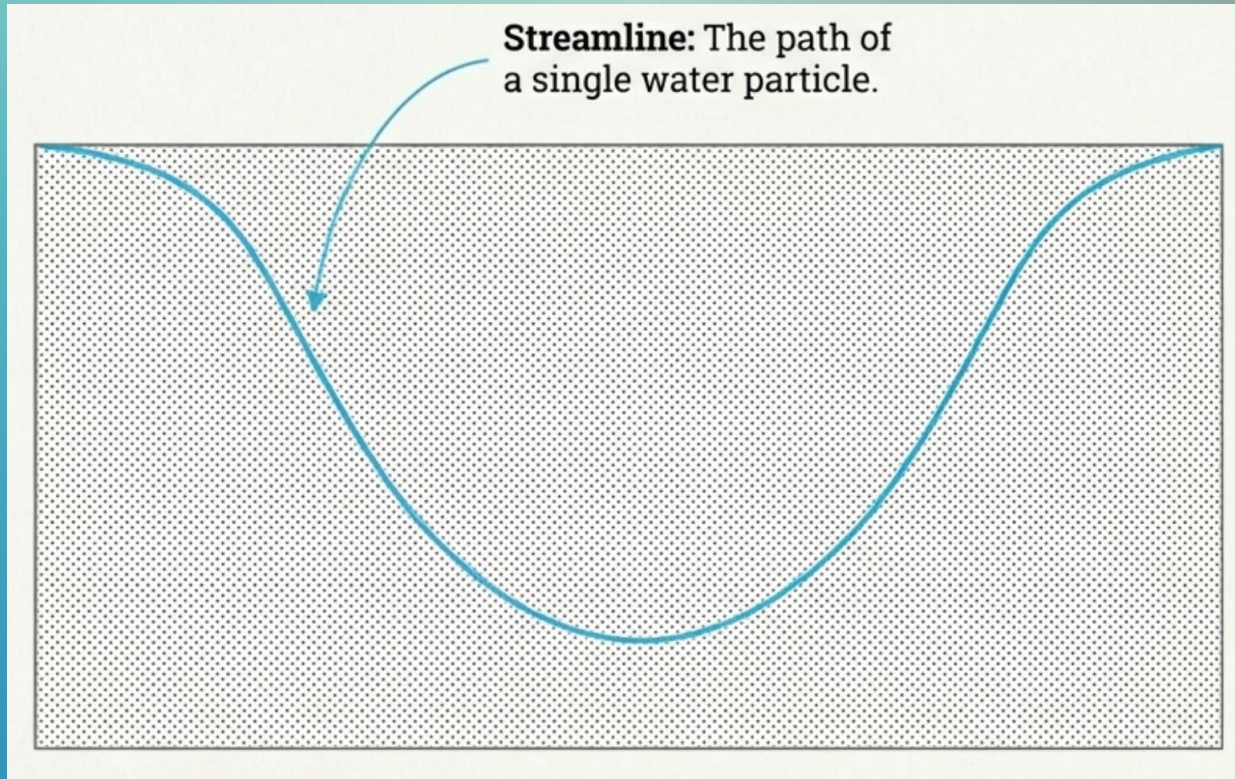


Multi-dimensional Flow



A flow net is a graphical solution to the 2-D steady-state groundwater flow equation (Laplace's equation) for porous media.

Flow Nets



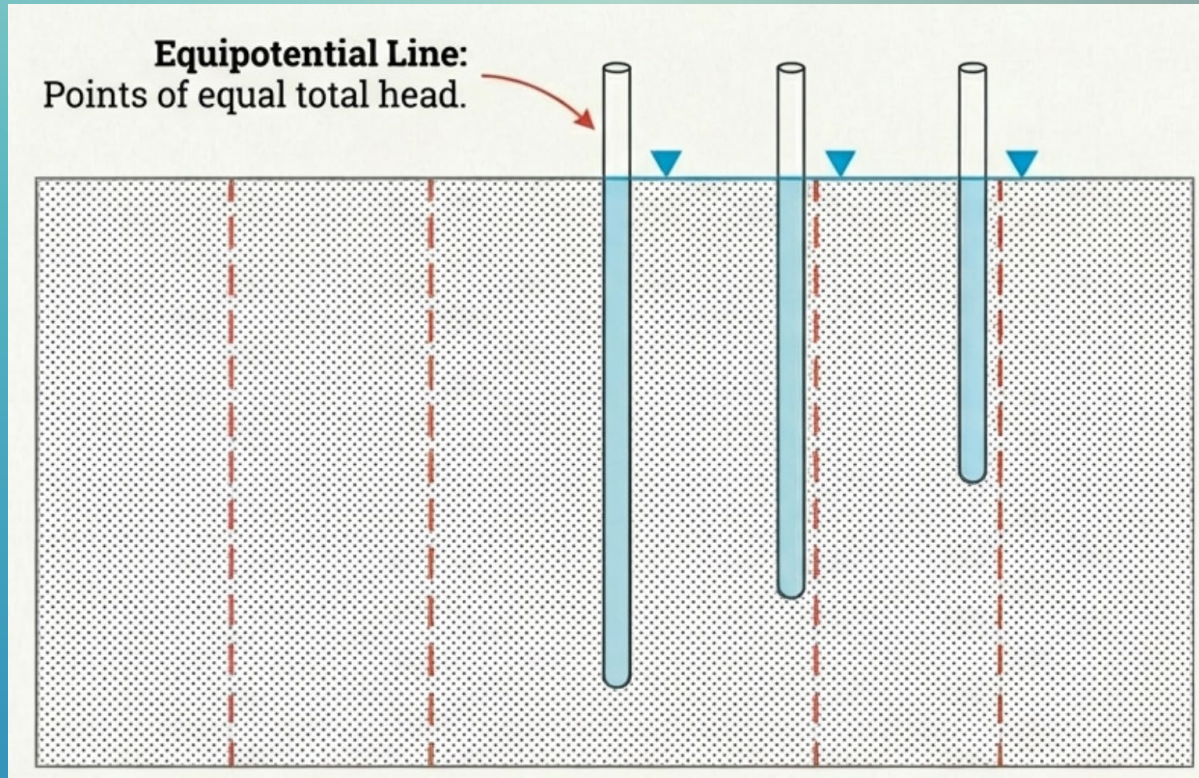
Component 1: The Flow Line

There are infinite possible paths for the water to flow, we draw selected “streamlines” to represent the physical route.

Flow Nets

Component 2: The Equipotential Line

There are lines connecting points where the hydraulic potential is constant.

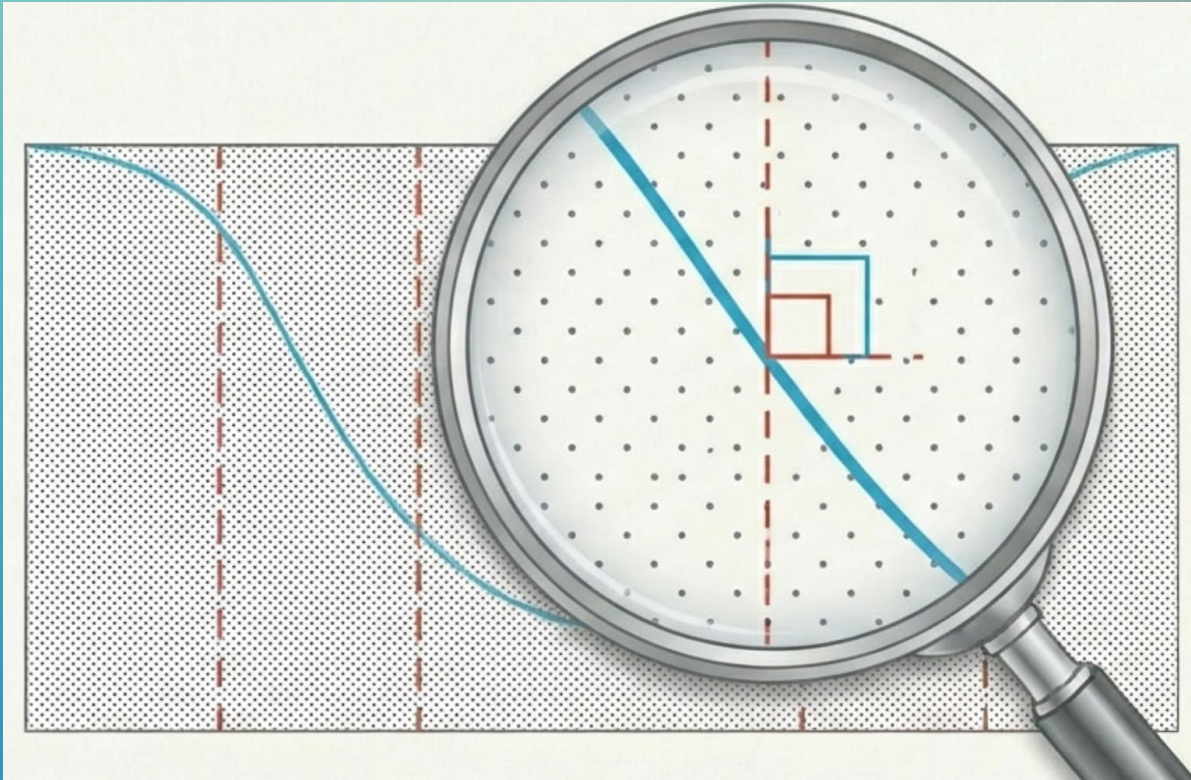


Flow Nets

Component 3: The Mesh

Flow lines and equipotential lines must intersect at right angles.

The grid forms the flow net visualising how hydraulic energy is dissipated through the medium.



Flow Nets

Component 4: The Maths

The Laplace Equation
derived from Darcy's Law
and Mass Continuity.

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

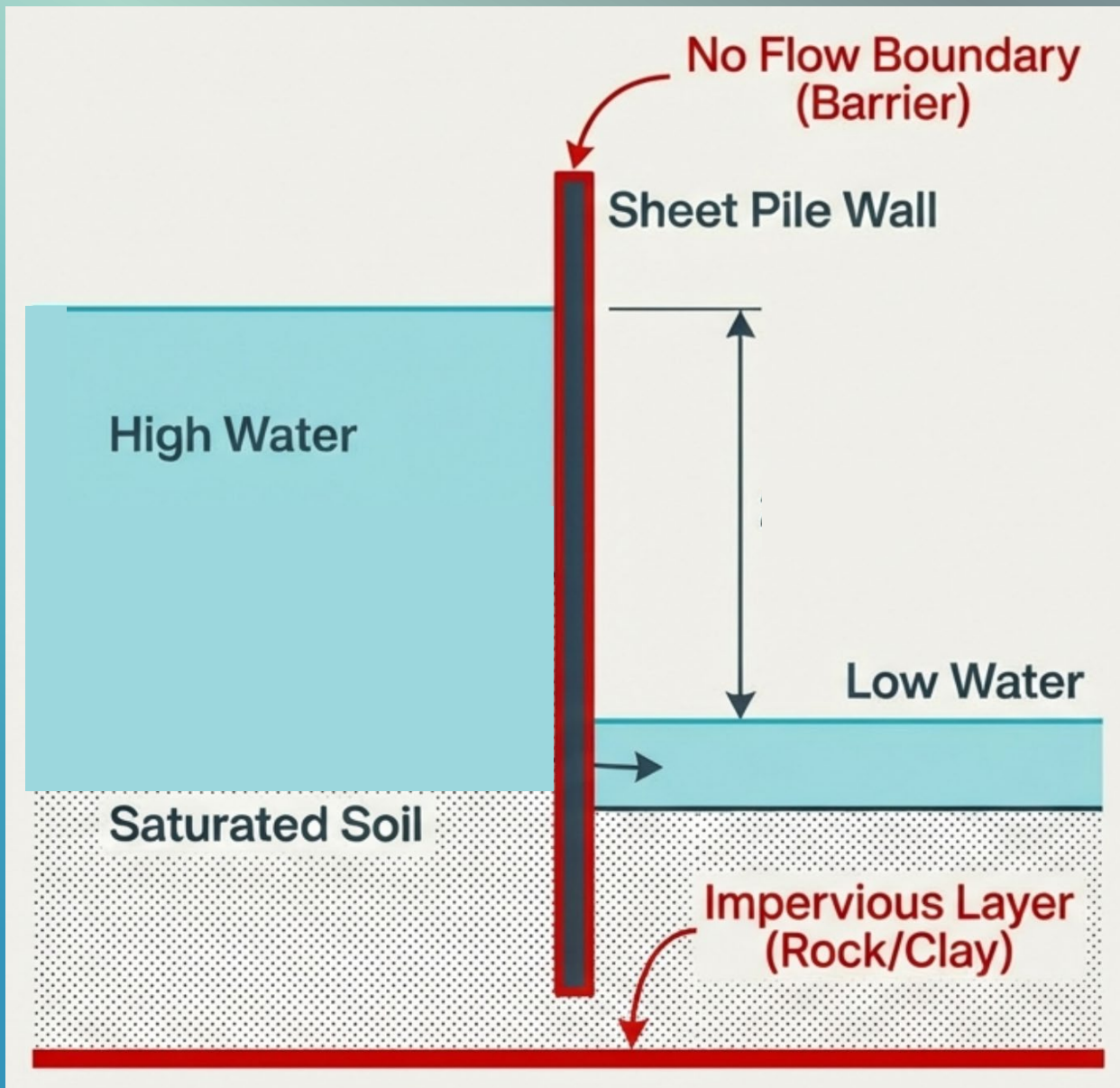
Flow Nets

Component 4: The Maths

The Laplace Equation
derived from Darcy's Law
and Mass Continuity.

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





Flow Nets

Assumptions:

1. Saturated
2. Homogenous
3. Isotropic

Seepage

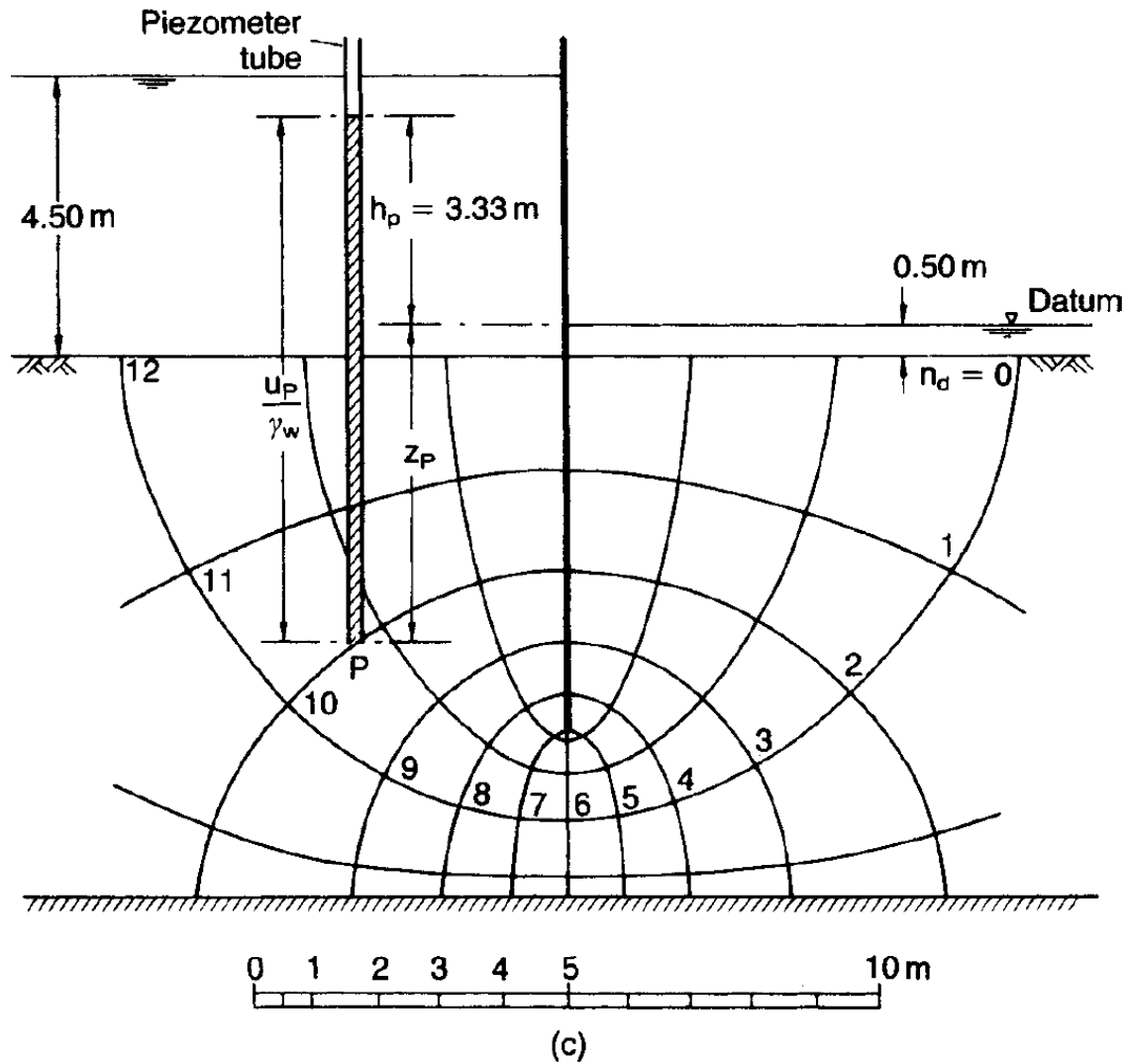
$$Q = kh \frac{N_f}{N_d}$$

Q= Total Discharge
(Seepage)

K= Hydraulic Conductivity

h=Head Difference

$\frac{N_f}{N_d}$ = Shape Factor



$$Q = kh \frac{N_f}{N_d}$$

Q = Total Discharge
(Seepage)

K = Hydraulic Conductivity

h = Head Difference

$\frac{N_f}{N_d}$ = Shape Factor

Up lift Pressure

$$u = \gamma_w h$$

u = Up lift pressure

γ_w = Unit Weight Water

h = head at point

Exit Gradient

$$i_{exit} = \frac{h_{last}}{\Delta l_{exit}}$$

i_{exit} = Exit Gradient

h_{last} = Last Equipotential
Drop

l_{exit} = Length of final flow
element

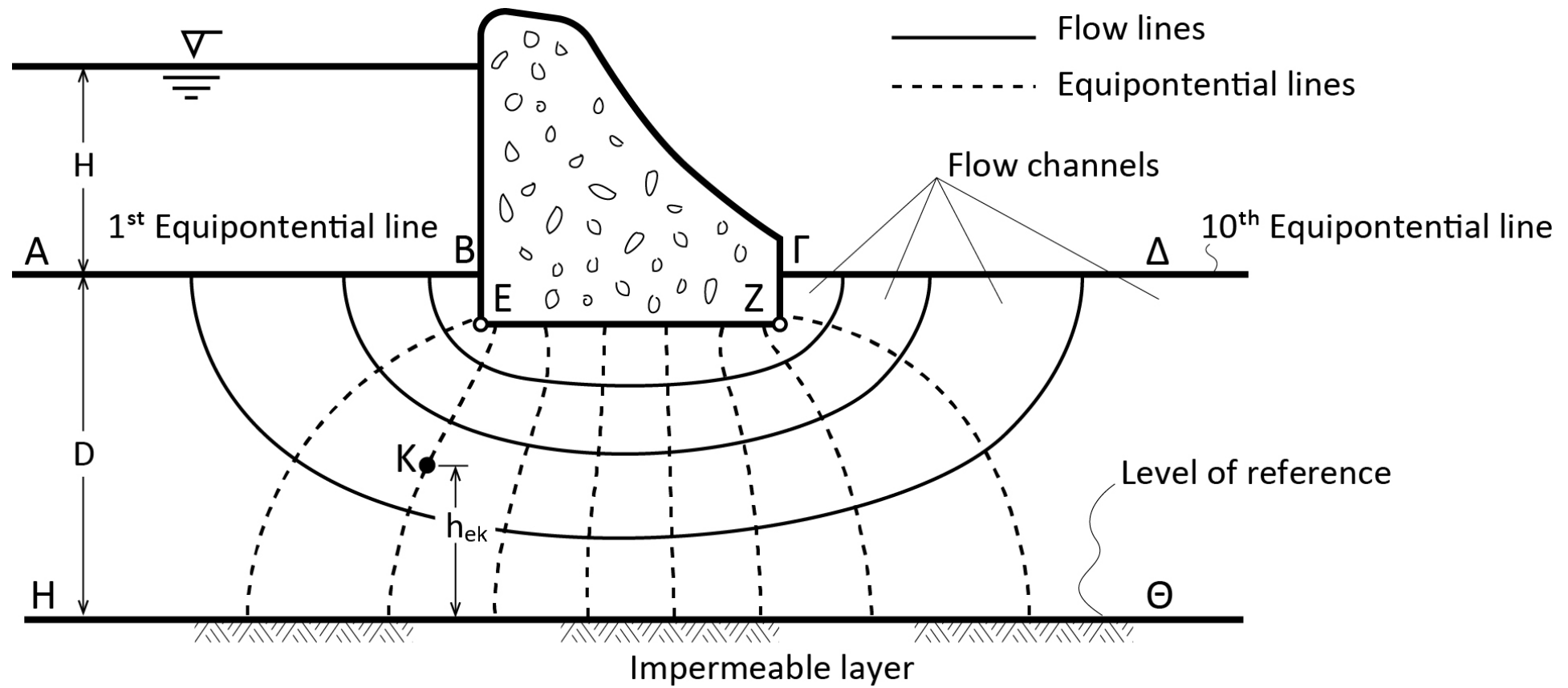
Critical Gradient

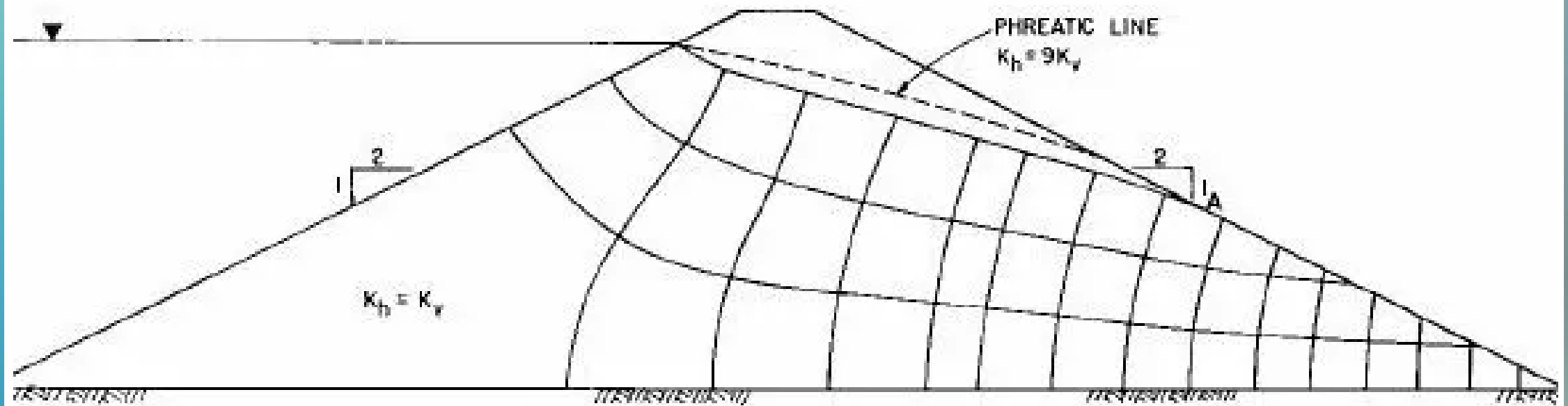
$$i_c = \frac{G_s - 1}{1 + e}$$

i_c = Critical Gradient

G_s = Specific Gravity of Soil Solids

e = Void Ratio



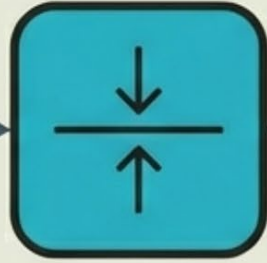


FLOW NET FOR HOMOGENEOUS DAM – NO UNDERDRAINS



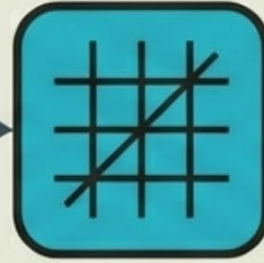
Define Boundaries

Identify wall & impervious layers.



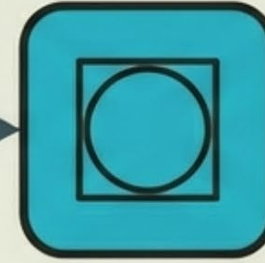
Set Datum

Find Total Head (H).



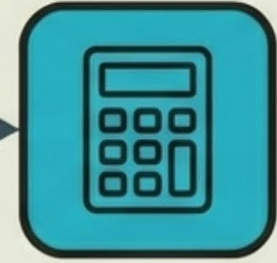
Draw Net

Sketch flow & equipotential lines.



Validate

Check 90° angles & squares.



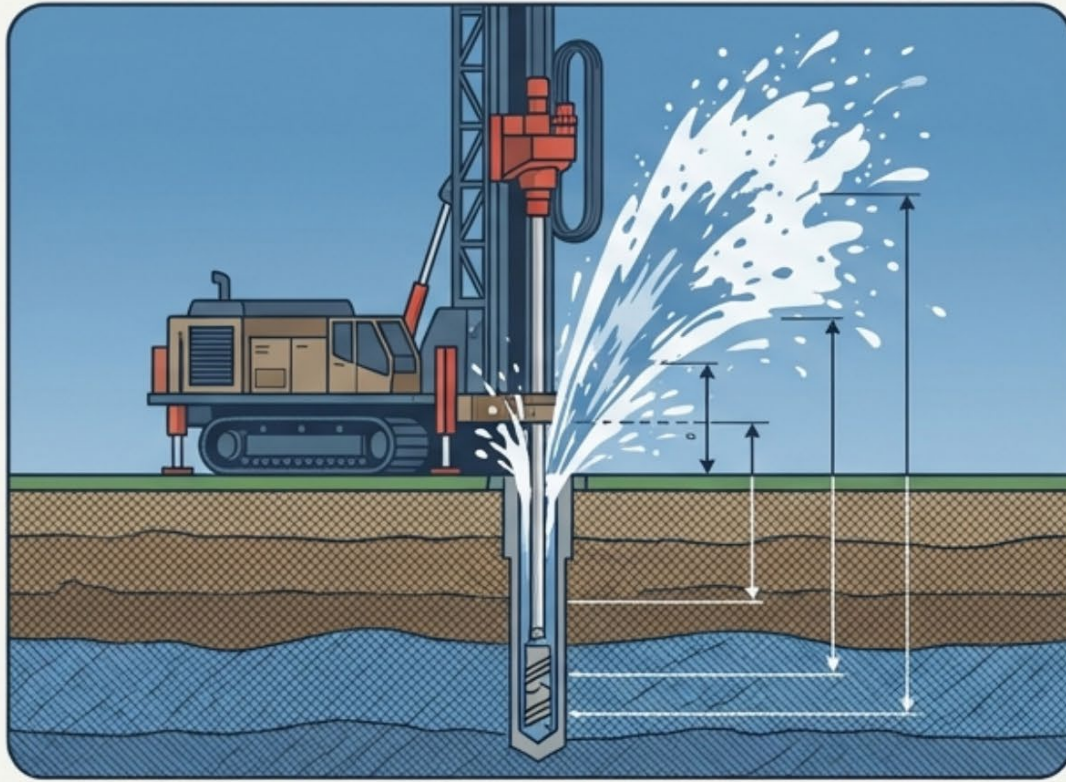
Calculate

Apply $Q = kH(N_f/N_d)$.



Pumping and Extraction

Human activities, such as the extraction of groundwater through wells, can influence the flow within an aquifer.

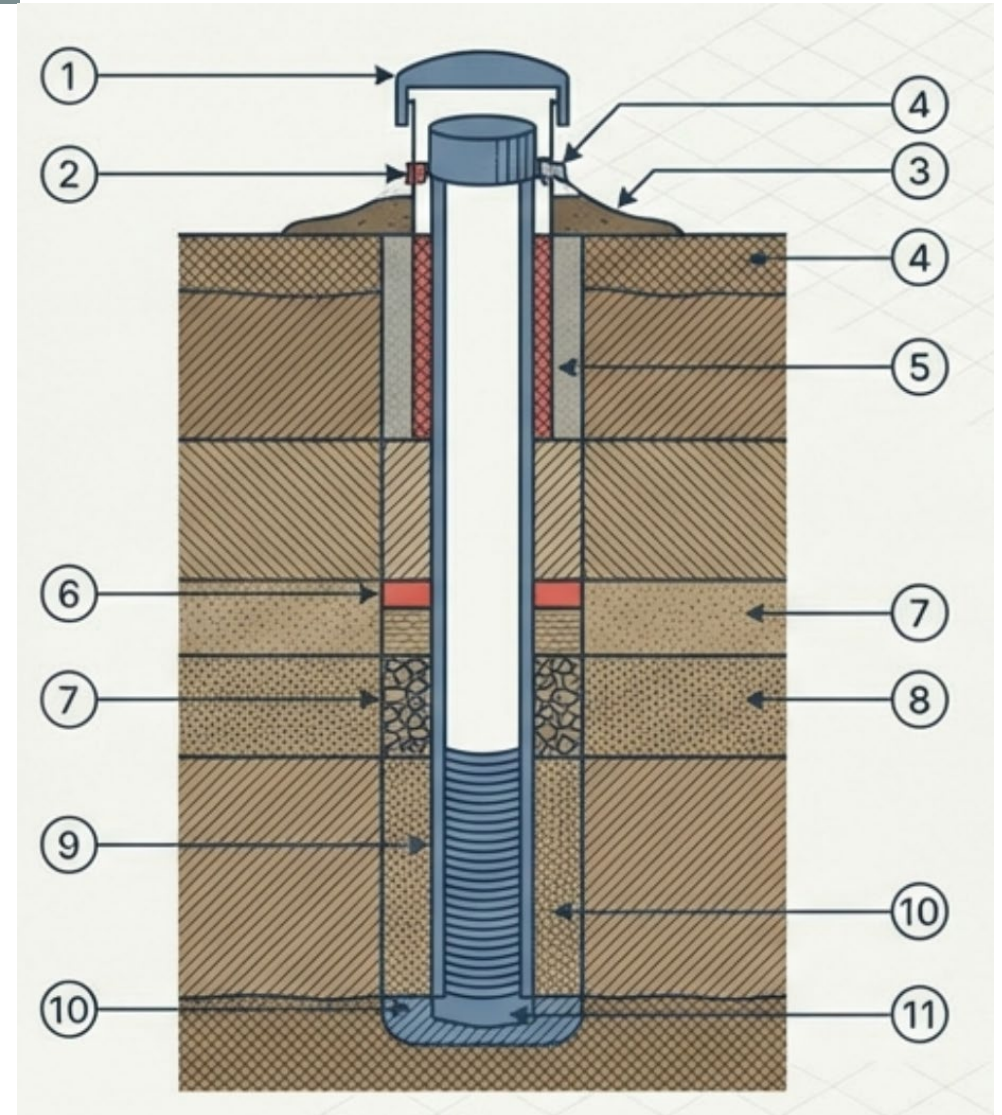


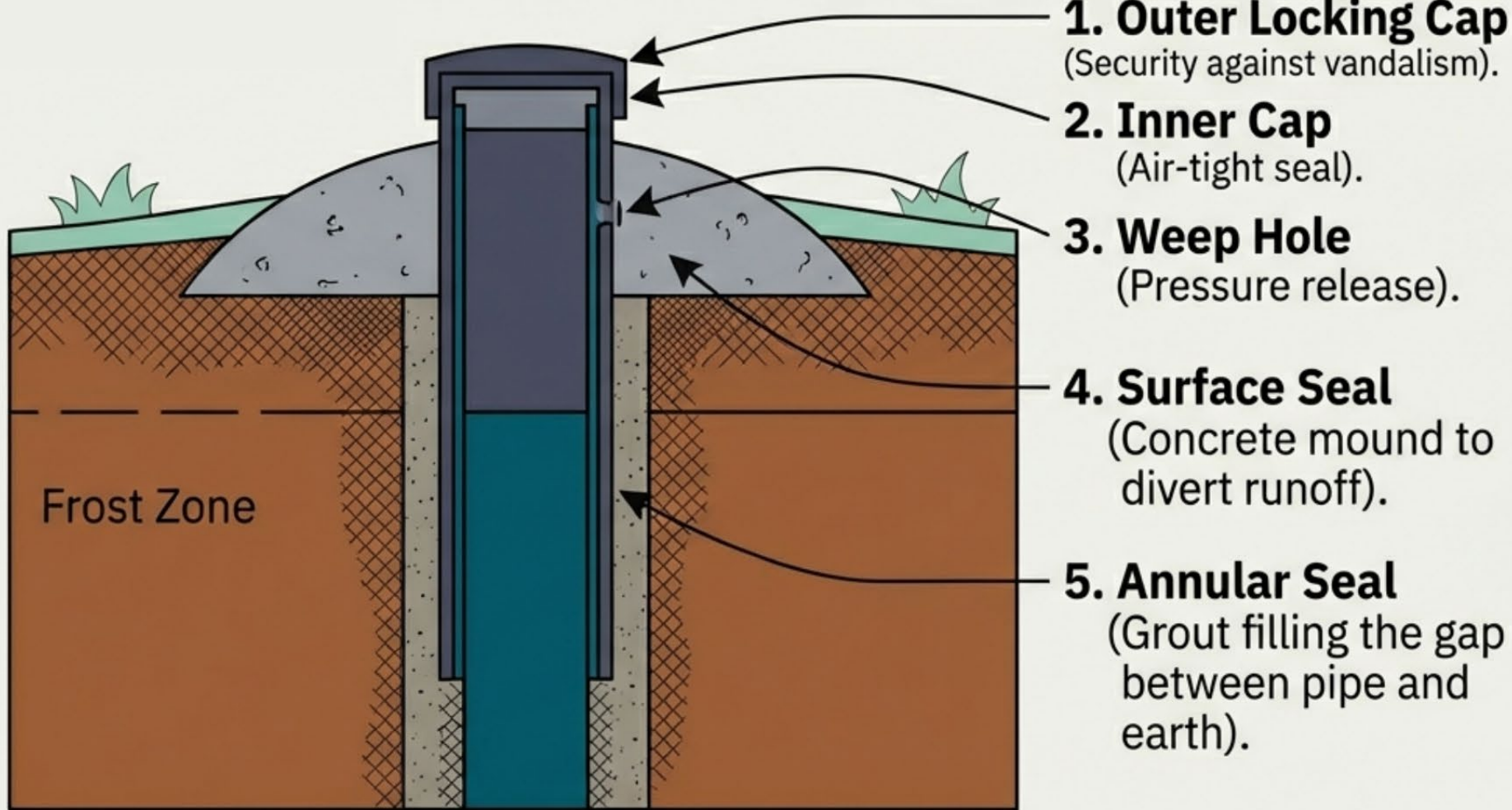
A water borehole is a narrow, deep shaft drilled to access subterranean reservoirs. It is the primary interface between surface demand and aquifer supply. These systems drive drinking water supply, irrigation, and industrial processes, but their operation fundamentally influences the flow within the aquifer itself.

Pumping & Extraction

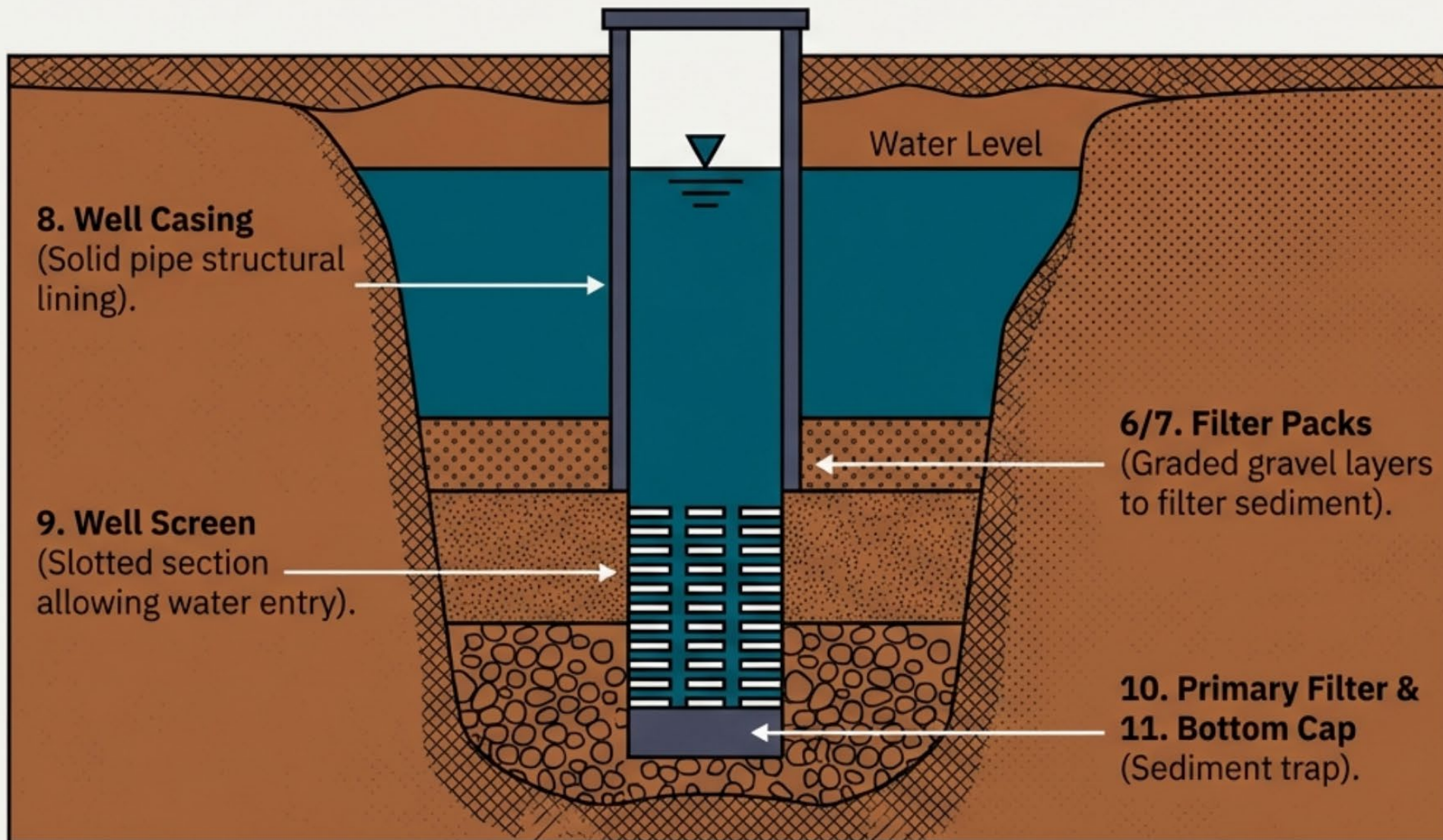
Boreholes

- + A borehole is engineered to balance structural integrity with hydraulic efficiency.
- + It is a complex assembly of casings, seal and filters designed to admit water while excluding sediment and contaminants.





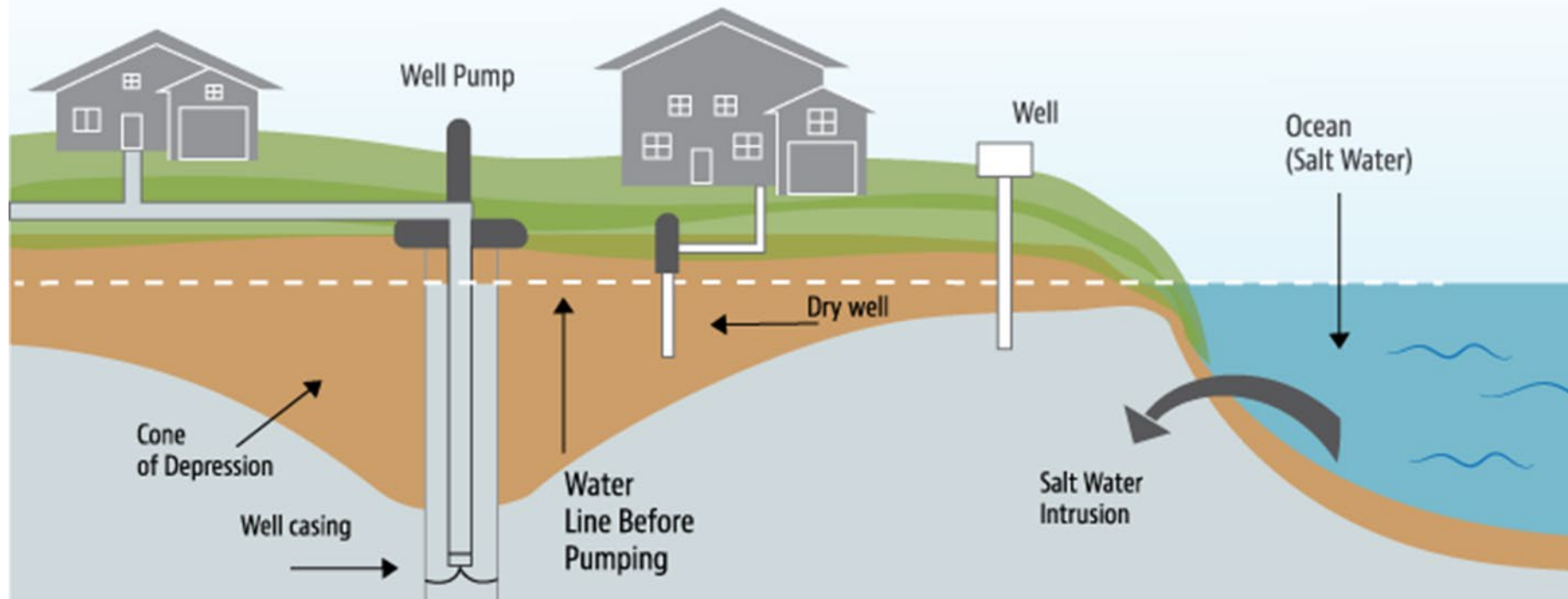
The primary goal of surface engineering is exclusion—preventing surface contaminants from migrating down the well casing.



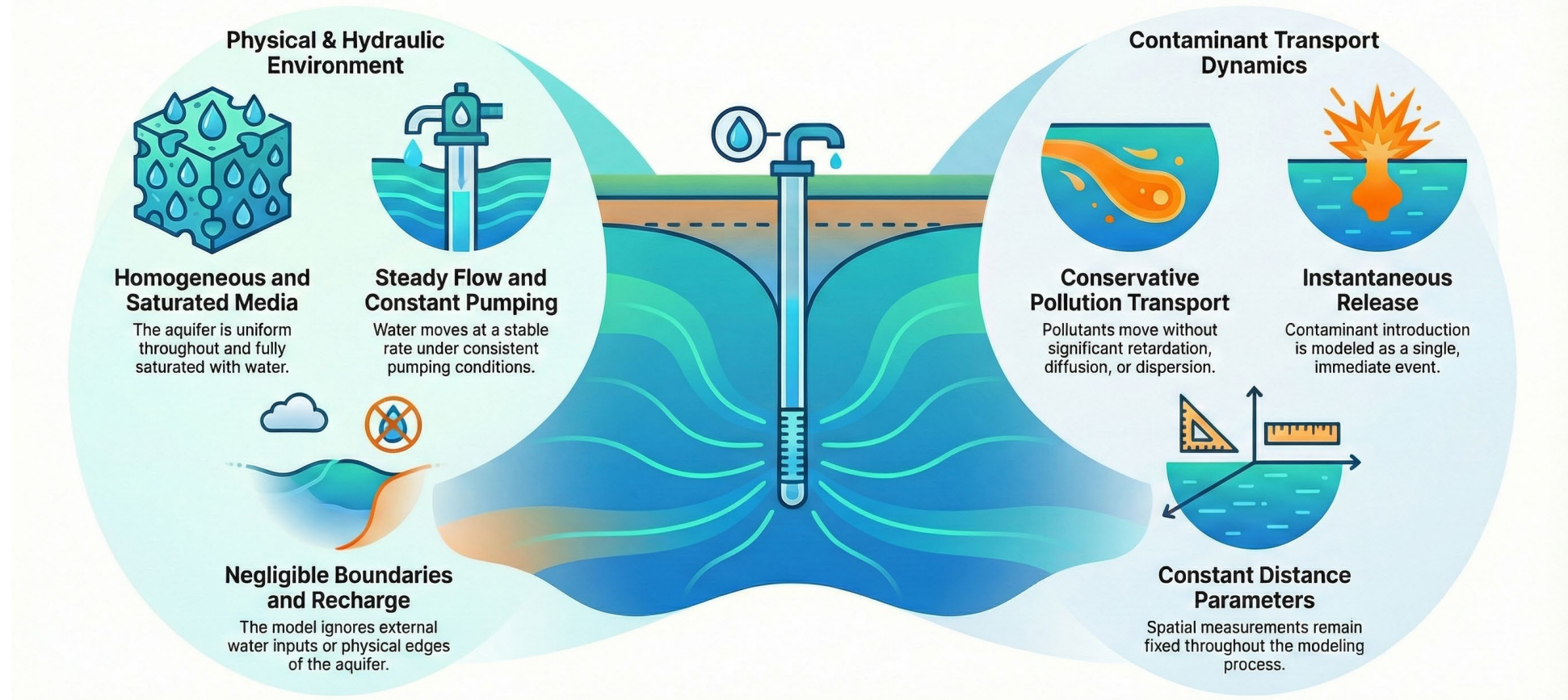
The primary goal of subsurface engineering is filtration—drawing in water while keeping out the sand and structural collapse.

Cone of Depression

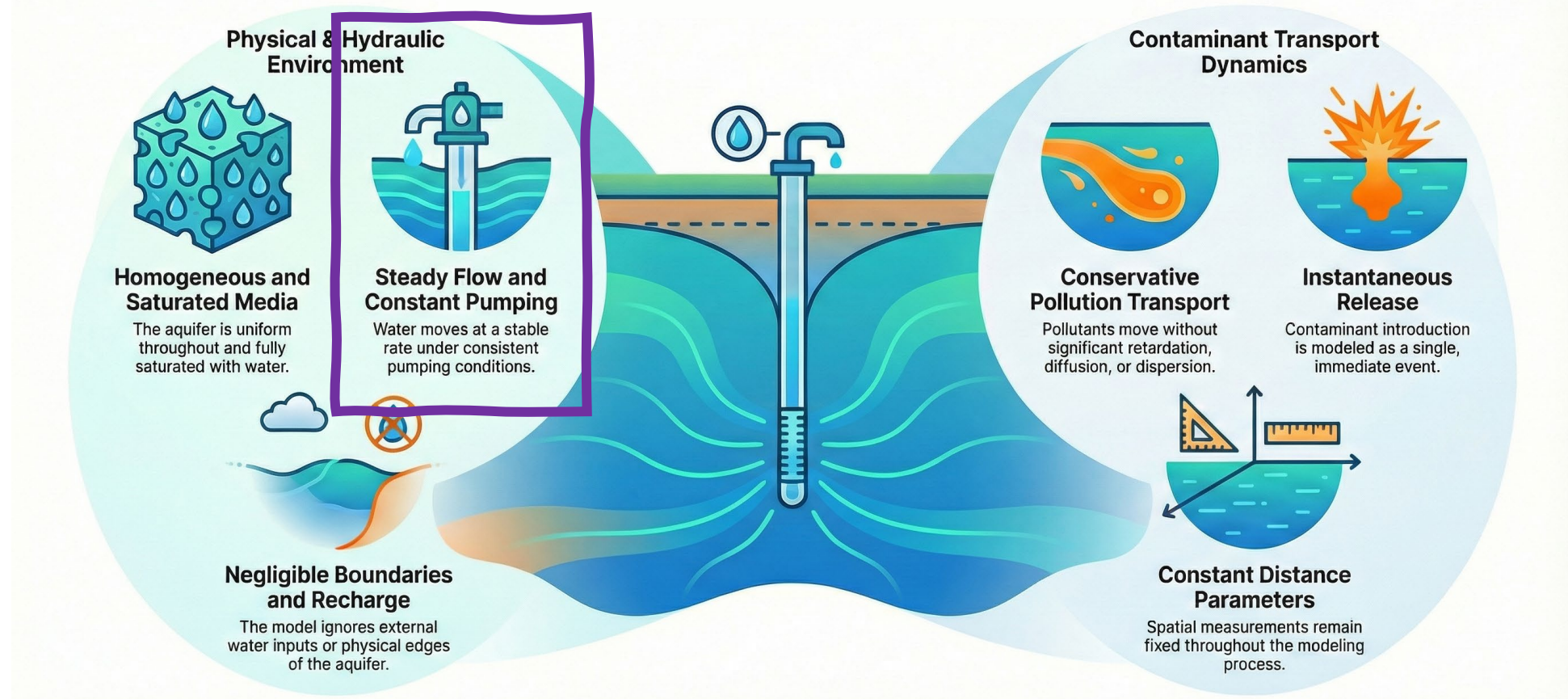
Large water withdrawals from an aquifer can lower the water table and create a "cone of depression" that can result in shallow wells going dry.



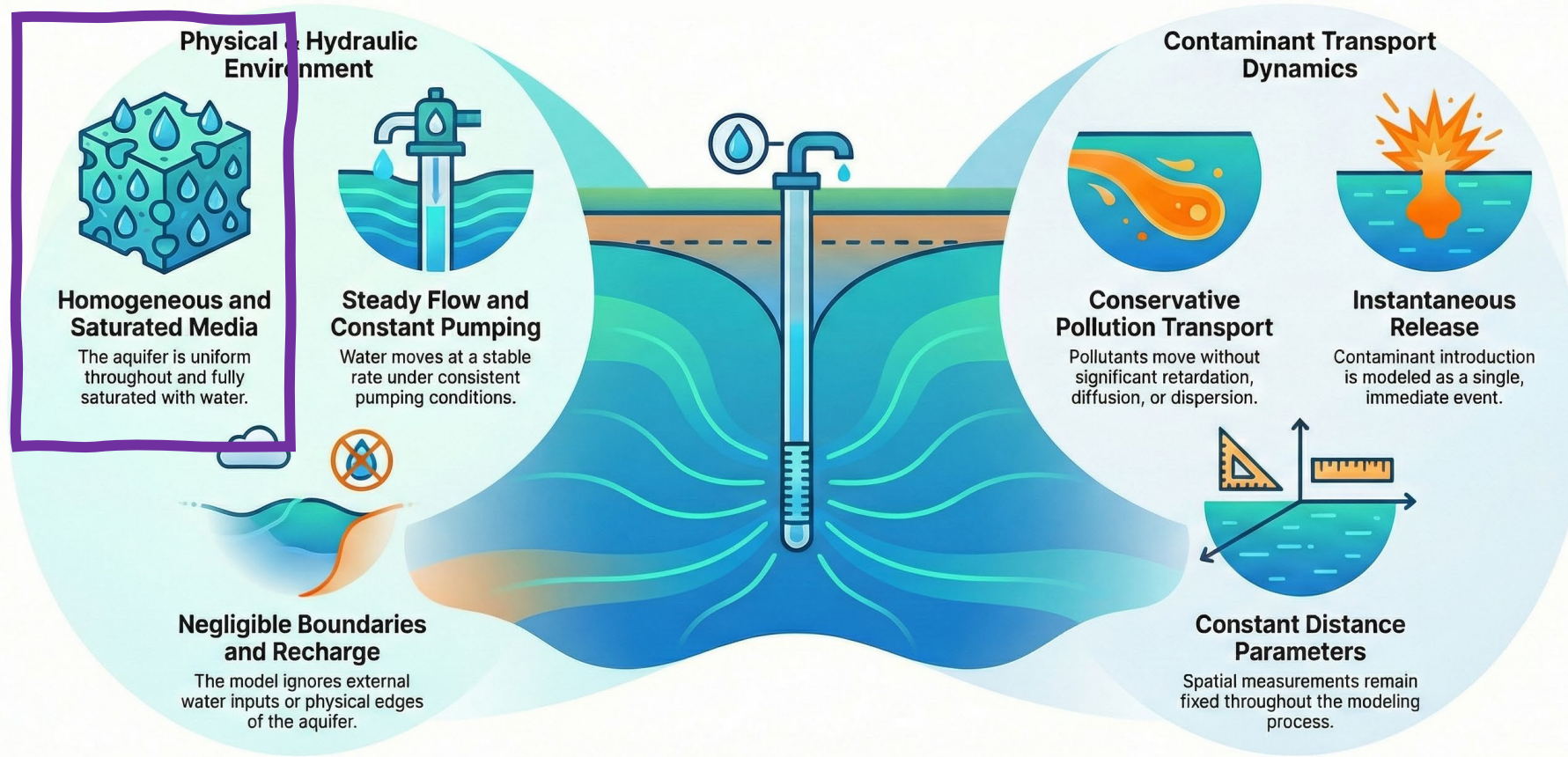
Core Assumptions for Well Flow Modeling



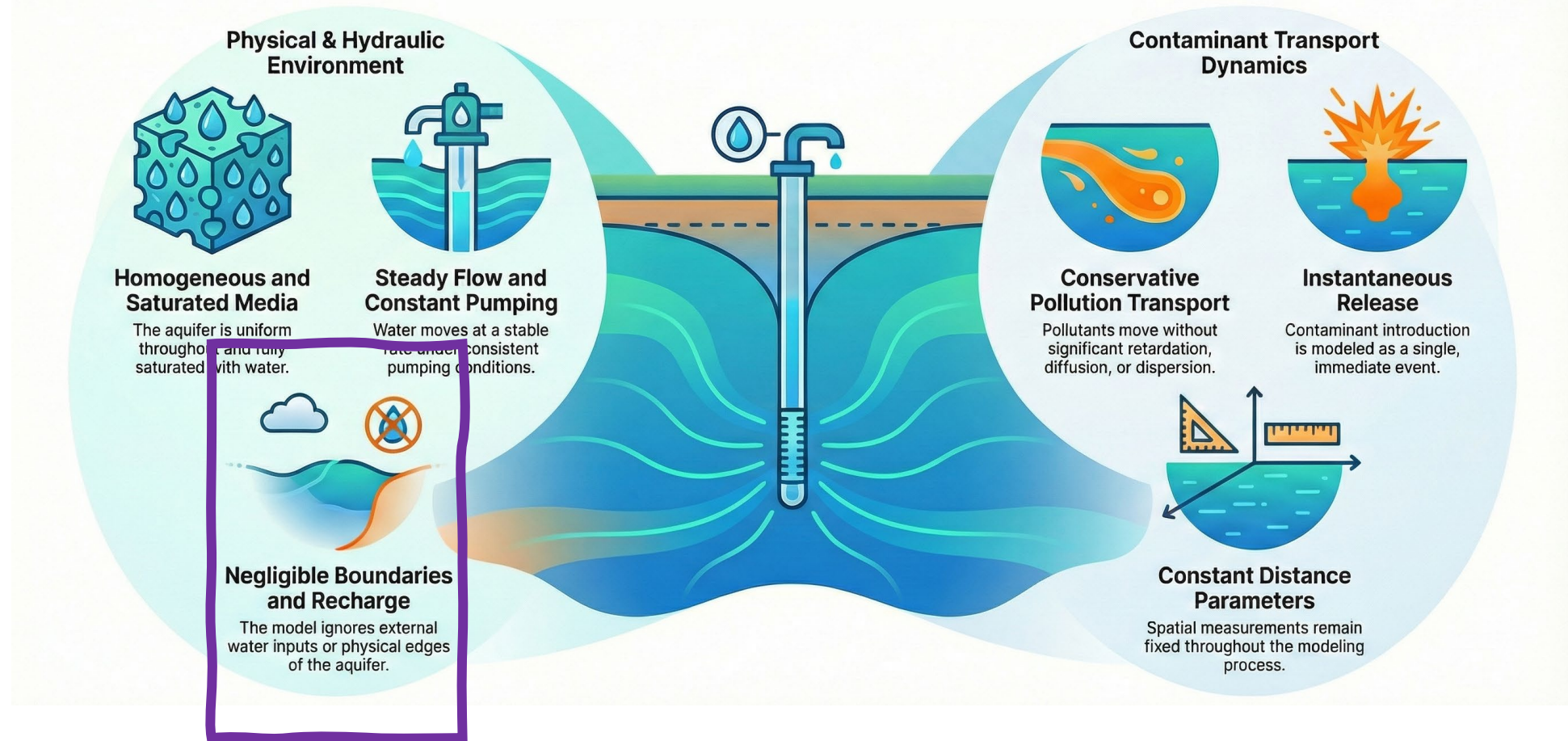
Core Assumptions for Well Flow Modeling



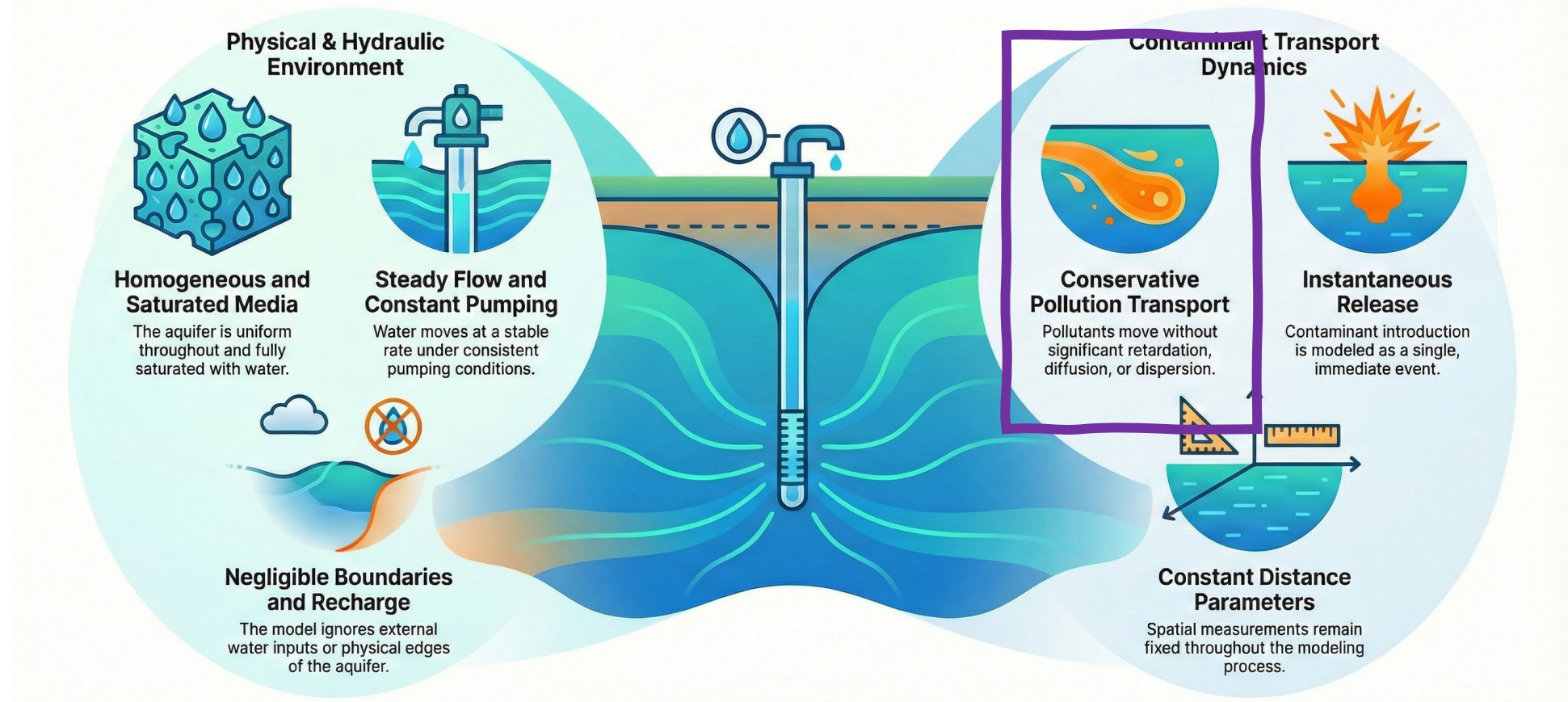
Core Assumptions for Well Flow Modeling



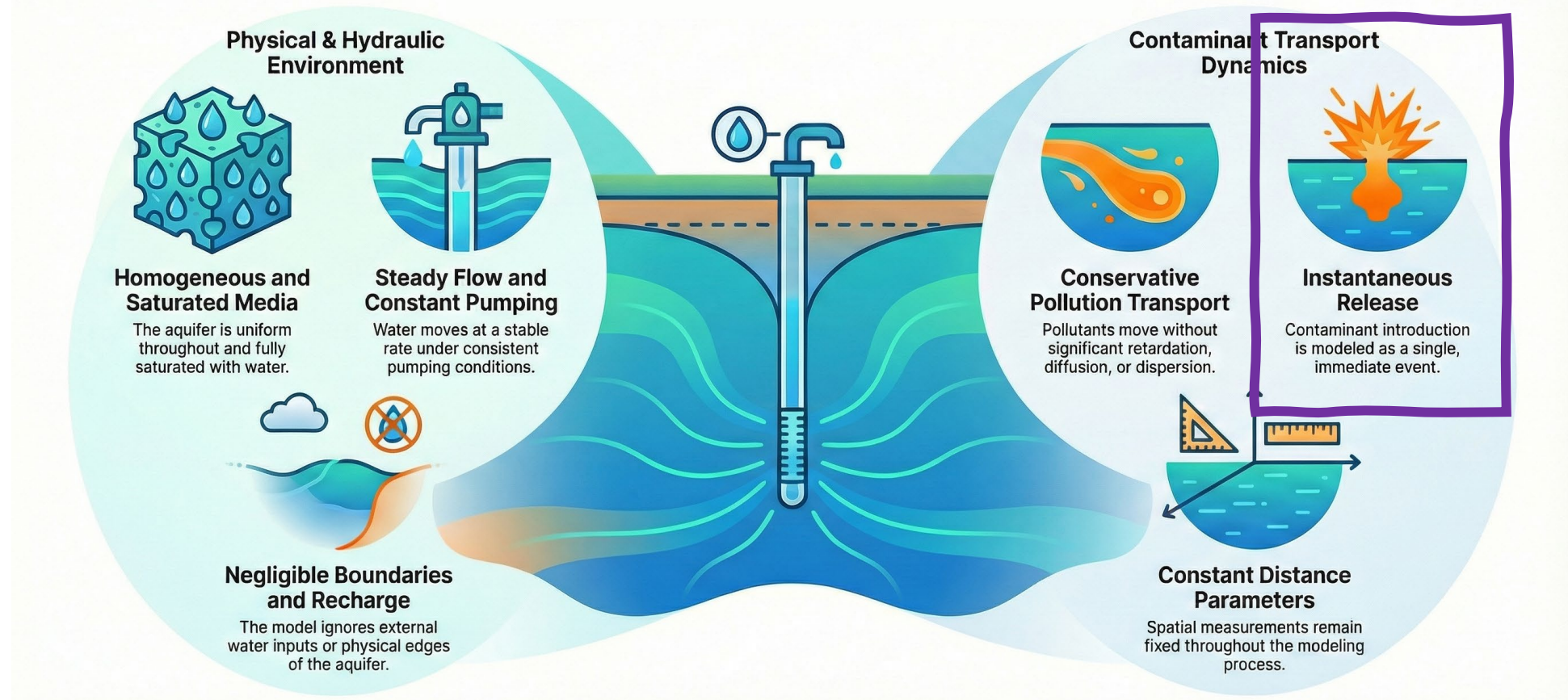
Core Assumptions for Well Flow Modeling



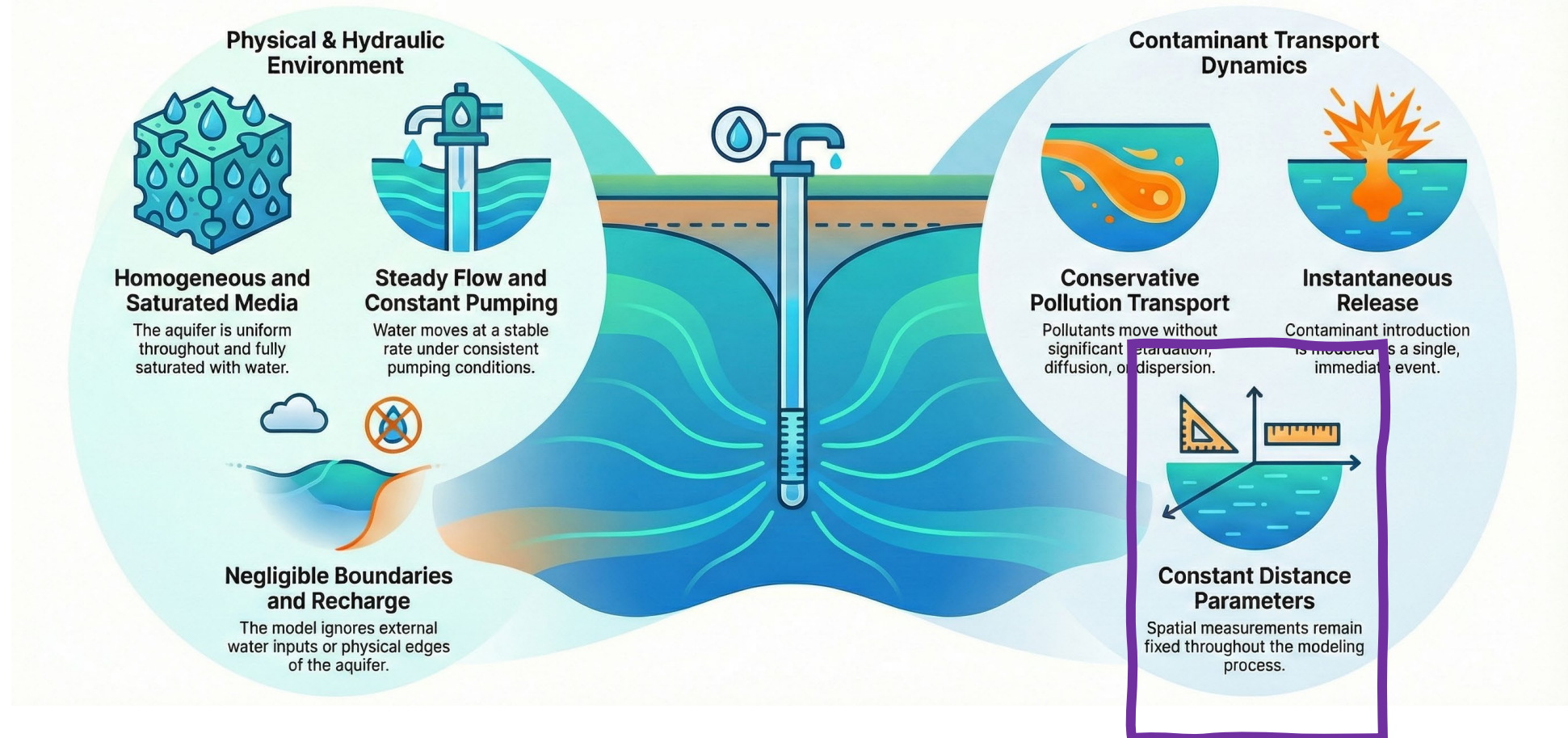
Core Assumptions for Well Flow Modeling

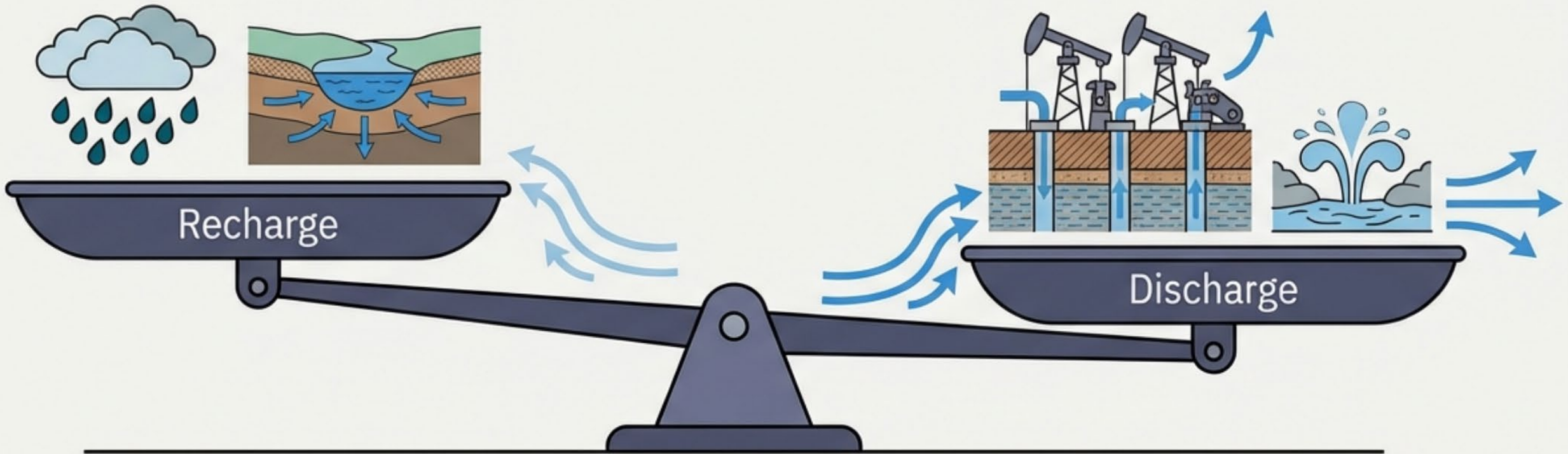


Core Assumptions for Well Flow Modeling



Core Assumptions for Well Flow Modeling





Overexploitation

Groundwater is often taken for granted and overexploited, leading to environmental and social problems such as land subsidence, seawater intrusion, and depletion of water resources.

Source Protection Zones

Source Protection Zones (SPZs) are designated areas around groundwater sources such as wells, boreholes, springs, or surface water intakes, where specific measures are put in place to protect the water quality from contamination.



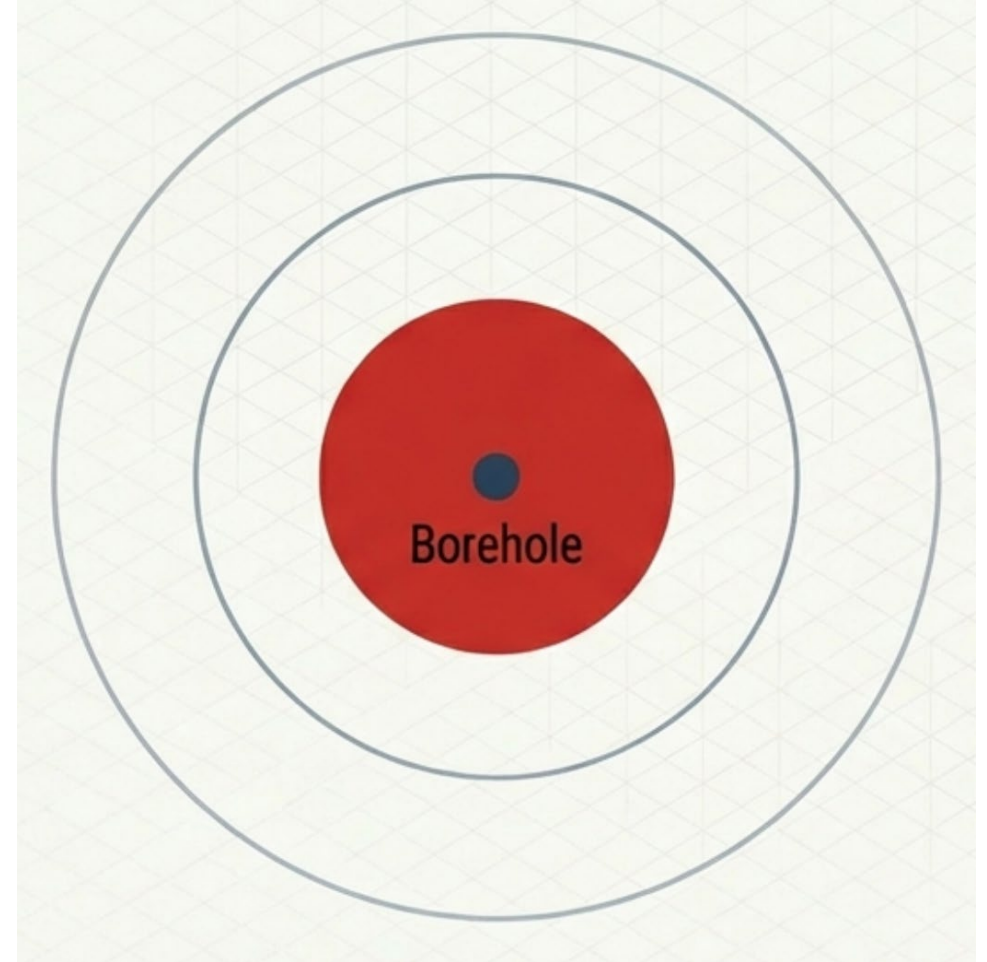
Source Protection Zones

Zone 1.

Radius: Immediately adjacent to borehole (50-100m)

Travel Time: Water reaches borehole in a few days.

Protocol: Any contamination here is catastrophic. Industry highly / strictly prohibited.



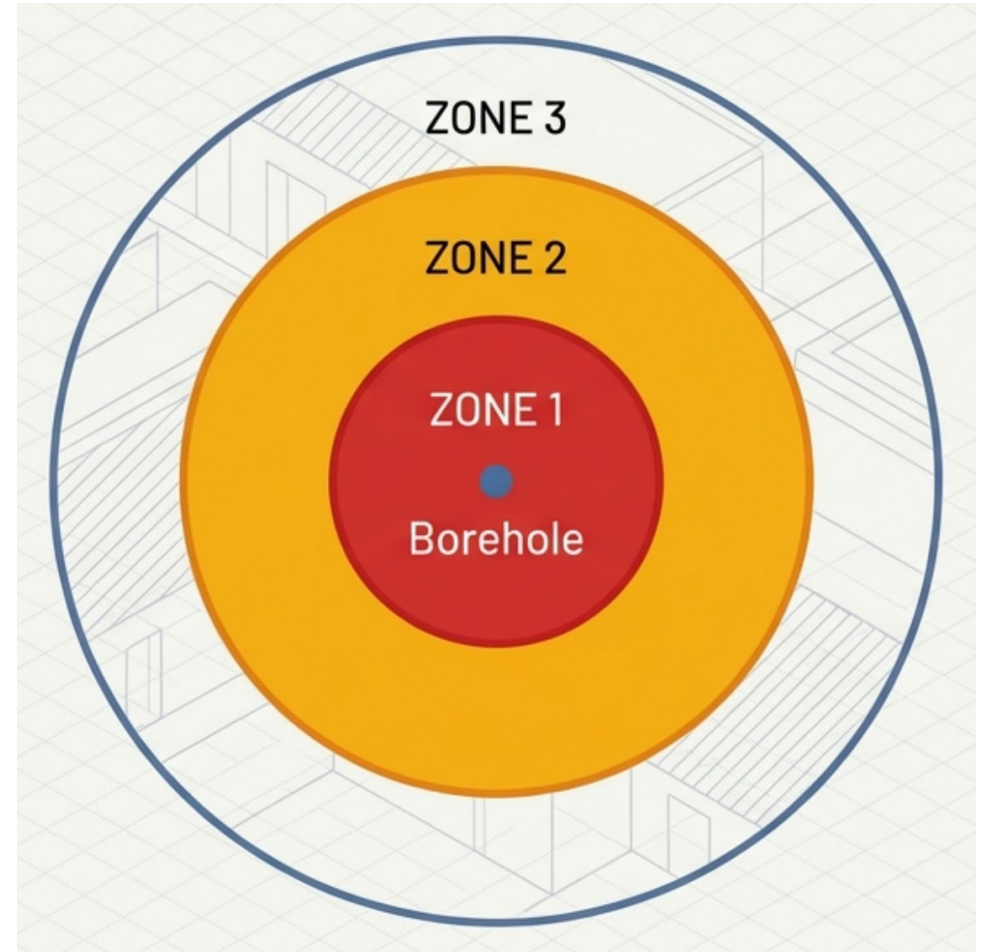
Source Protection Zones

Zone 2.

Radius: Extends several hundred metres to a few kilometres.

Travel Time: Groundwater has further to travel, providing temporal buffer for contaminants to dilute / degrade.

Protocol: High risk activities are permitted but carefully managed.



Source Protection Zones

Zone 3.

Radius: The largest zone which covers the entire catchment contributing to aquifer.

Objective: Long term sustainability and replenishment.

Protocol: Land use activities are monitored to ensure volume of water entering ground is not compromised.

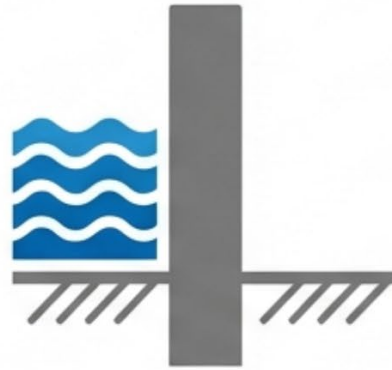


Subsurface Water Control



1. Pumping

Construction Dewatering



2. Exclusion

Physical Barriers



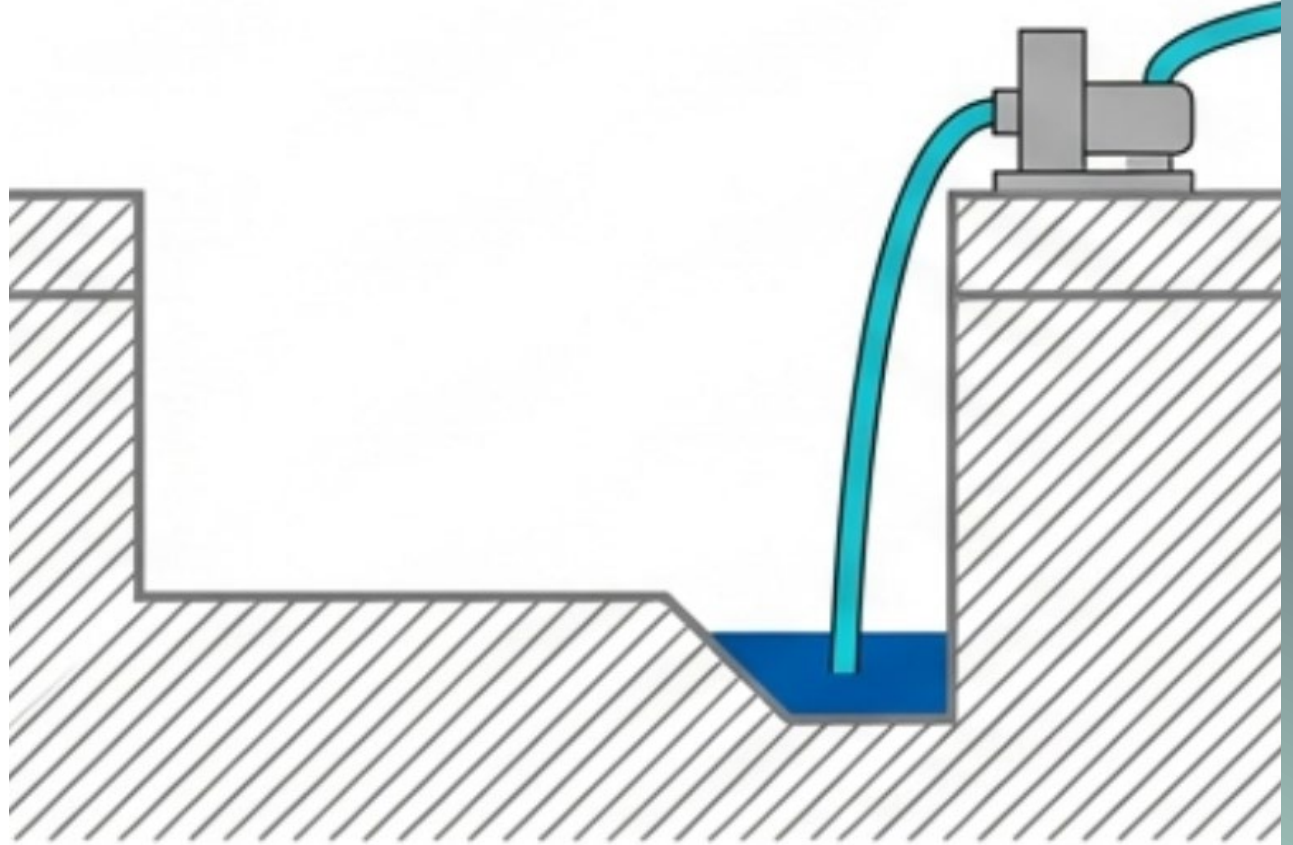
3. Specialized

Passive & Environmental

Goal: Maintain structural stability, ensure safety and prevent flooding.

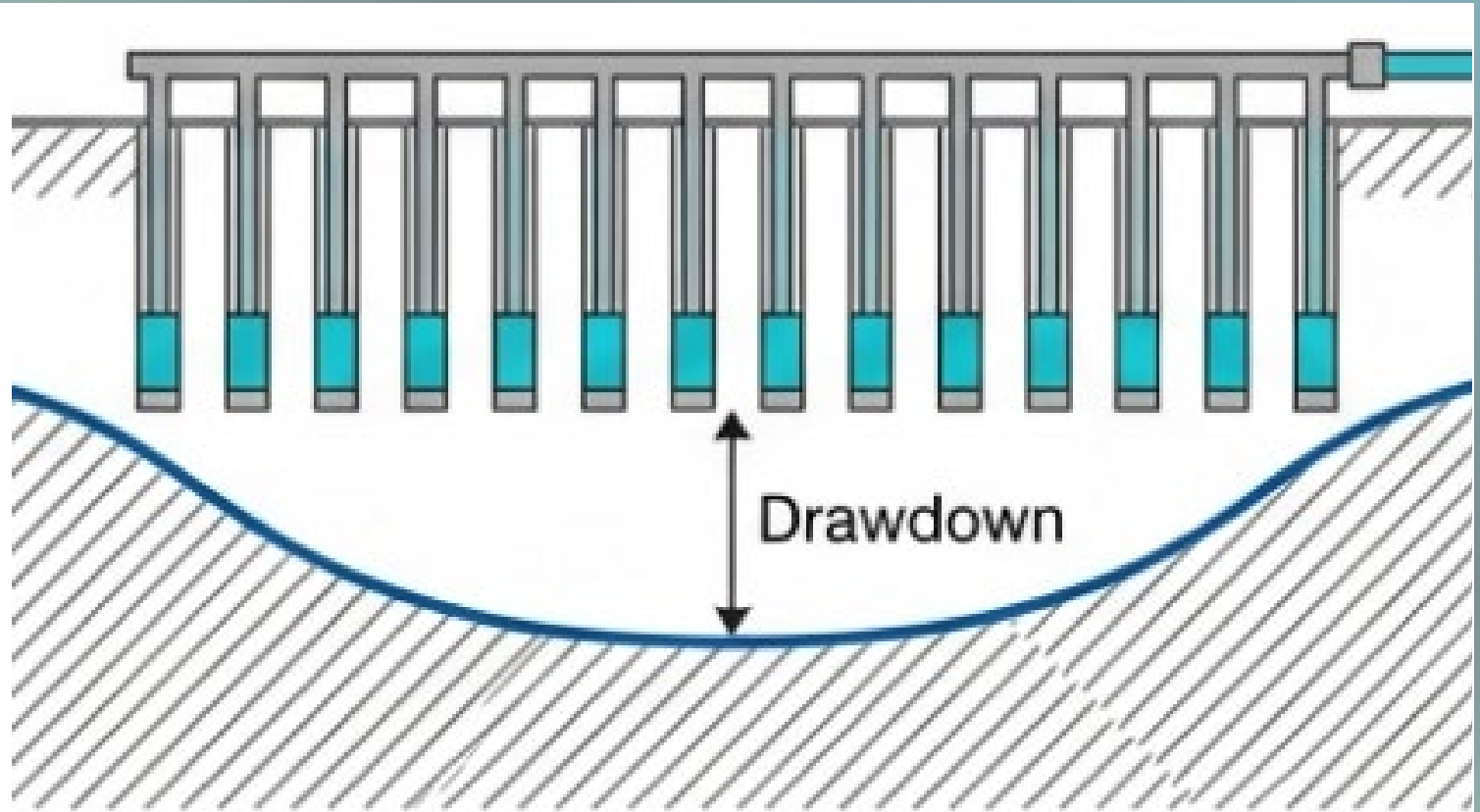
Sump Pumping

Water entering the excavation is directed toward shallow pits (sumps), from which it is pumped away.



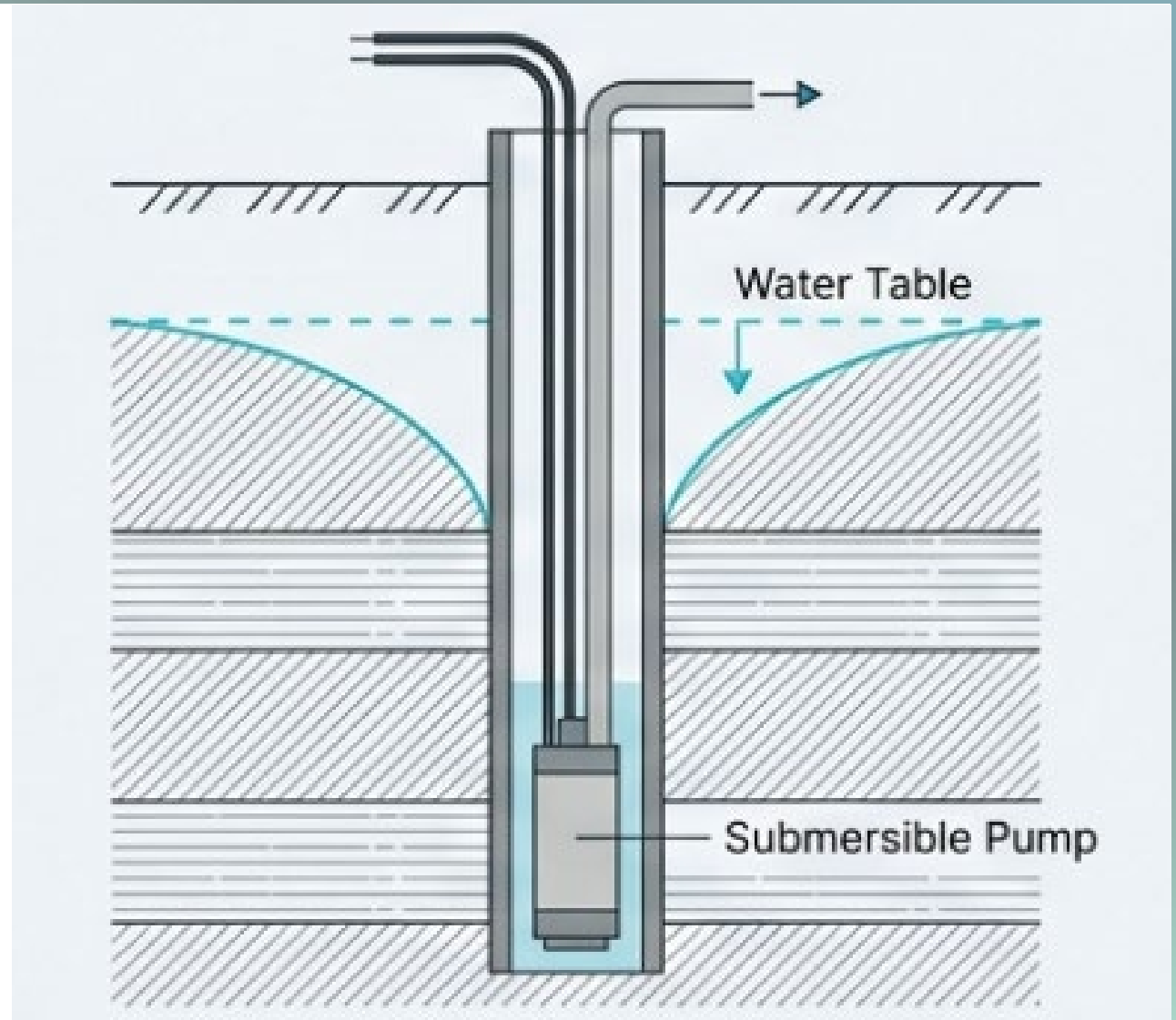
Wellpoint Systems

Suction draws groundwater toward the wellpoints, lowering the water table.



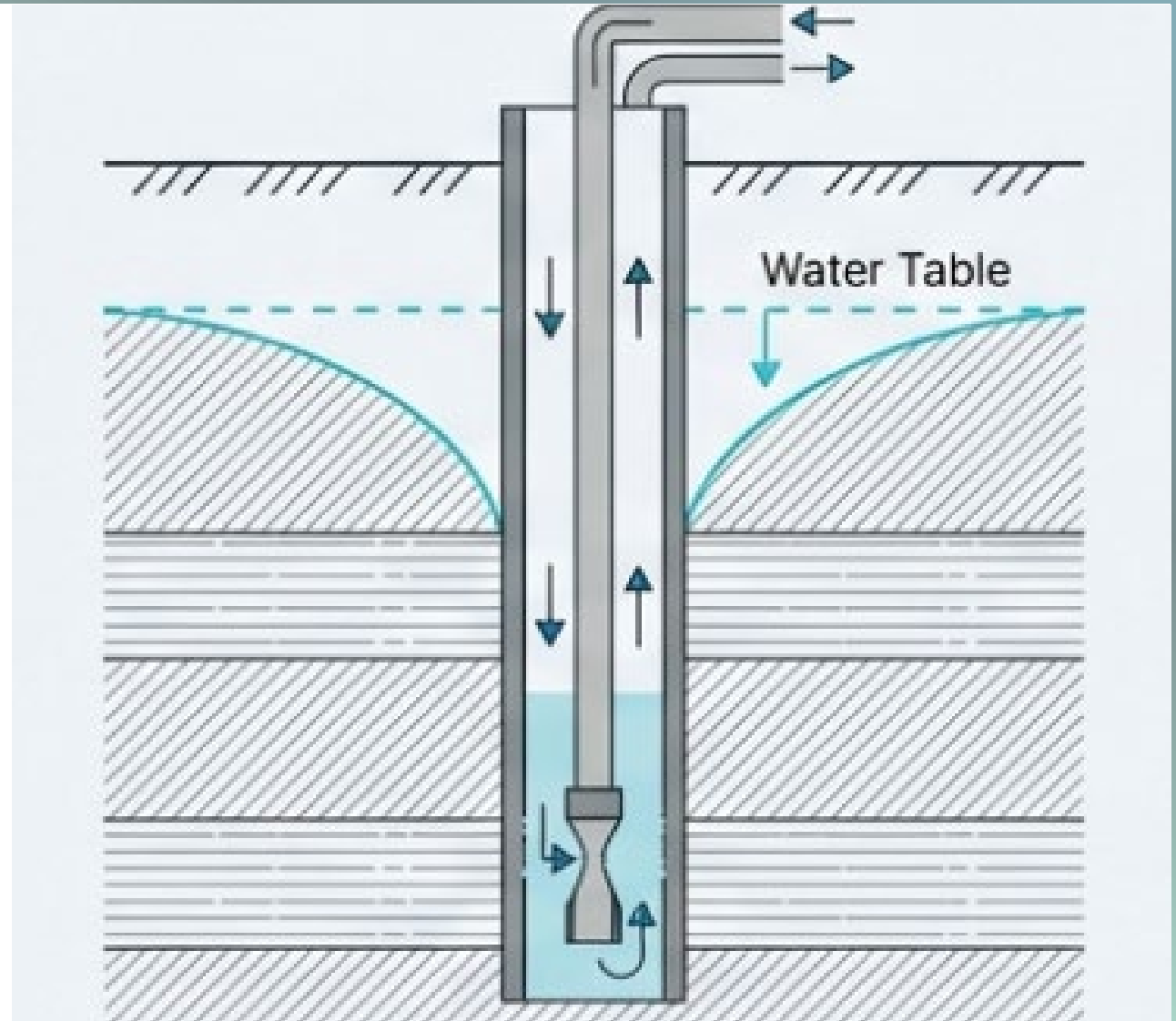
Deep Wells

Larger-diameter boreholes equipped with submersible electric pumps that operate below the water level.



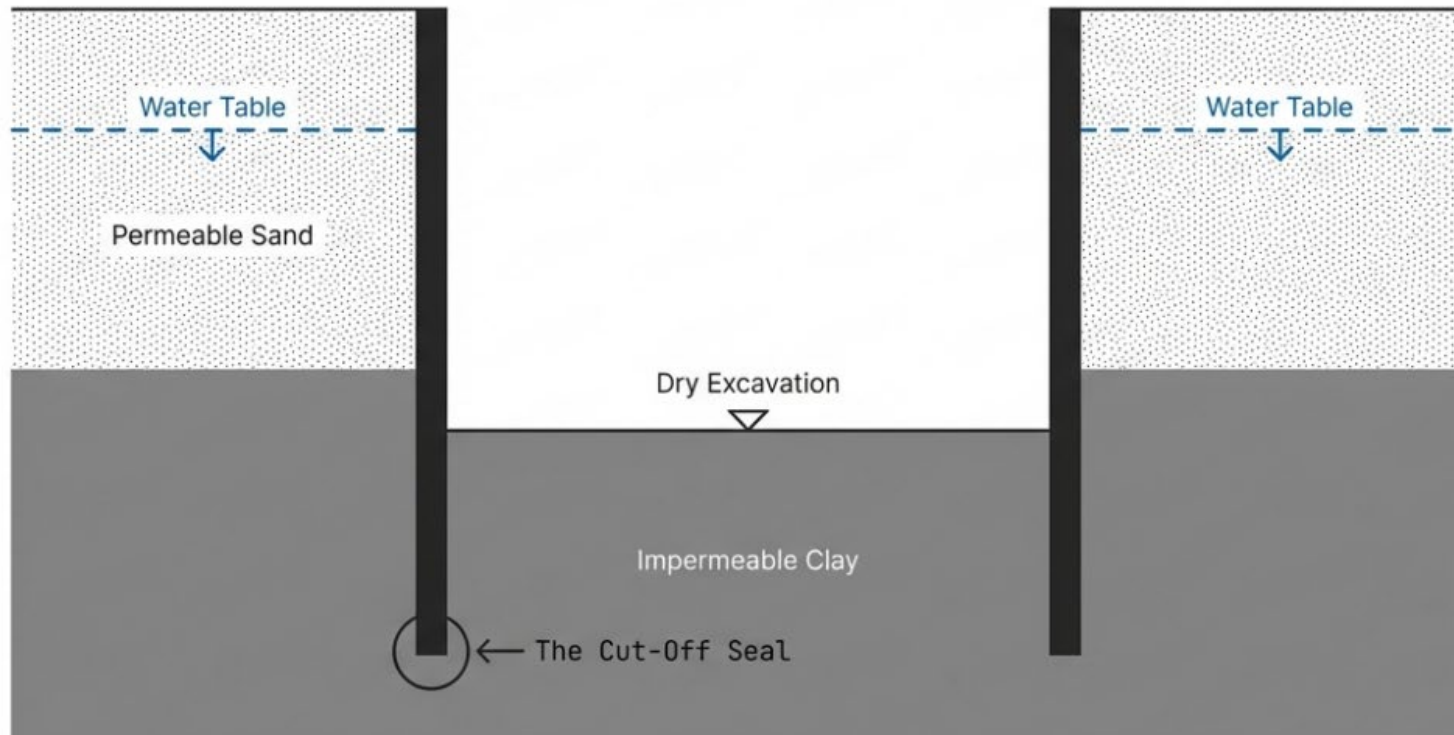
Ejector Systems

Use high-pressure water circulated through a nozzle to create a vacuum via the Venturi effect, inducing groundwater flow into the well



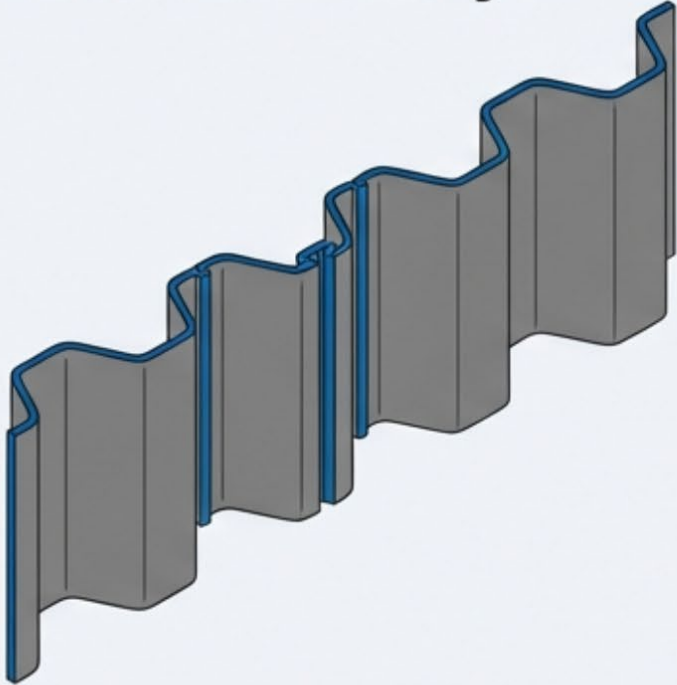
Structural Cut-Off Walls

These include steel sheet piles, diaphragm walls, and secant or contiguous pile walls.



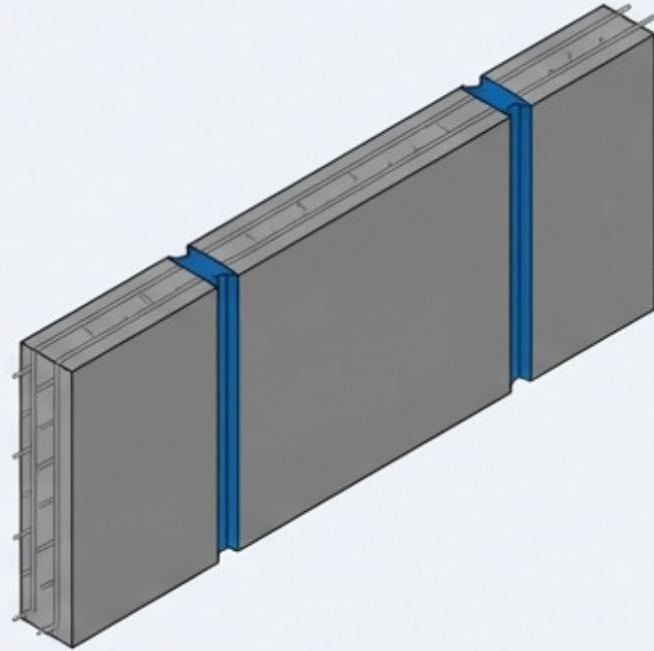
Dual Function: Structural Support + Water Exclusion

Steel Sheet-Piling



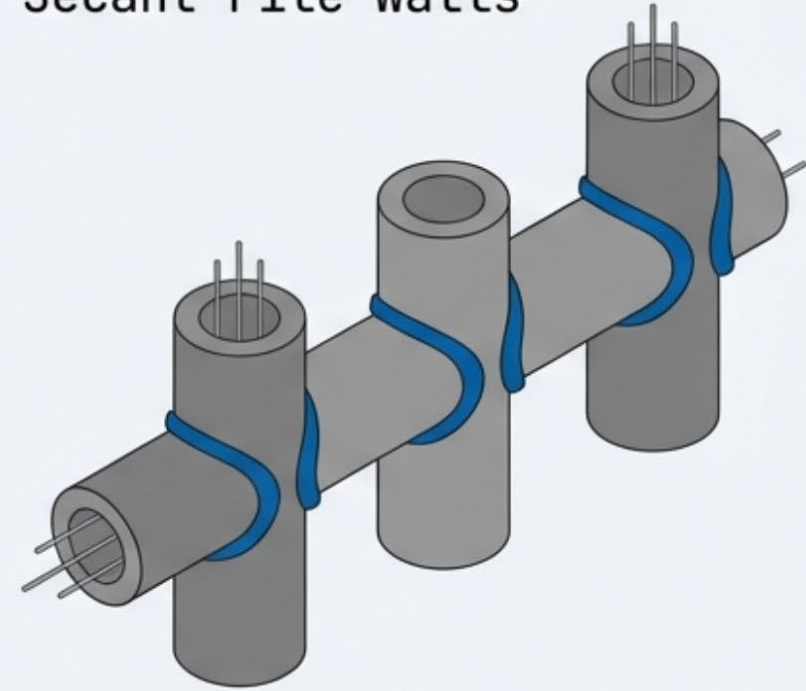
Driven interlocking steel sections.
Fast installation.

Diaphragm Walls



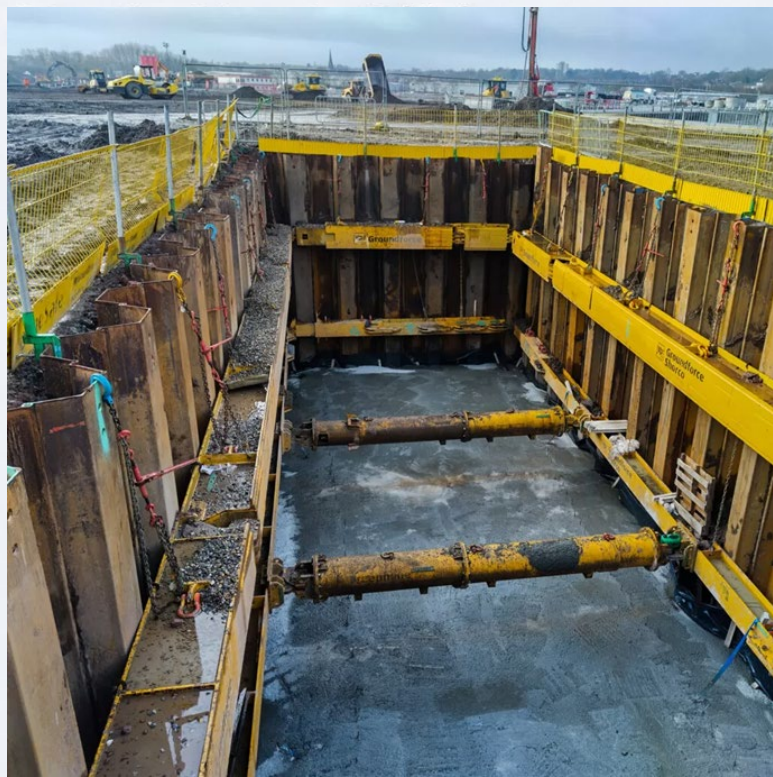
Reinforced concrete panels
constructed in slurry trenches.

Secant Pile Walls

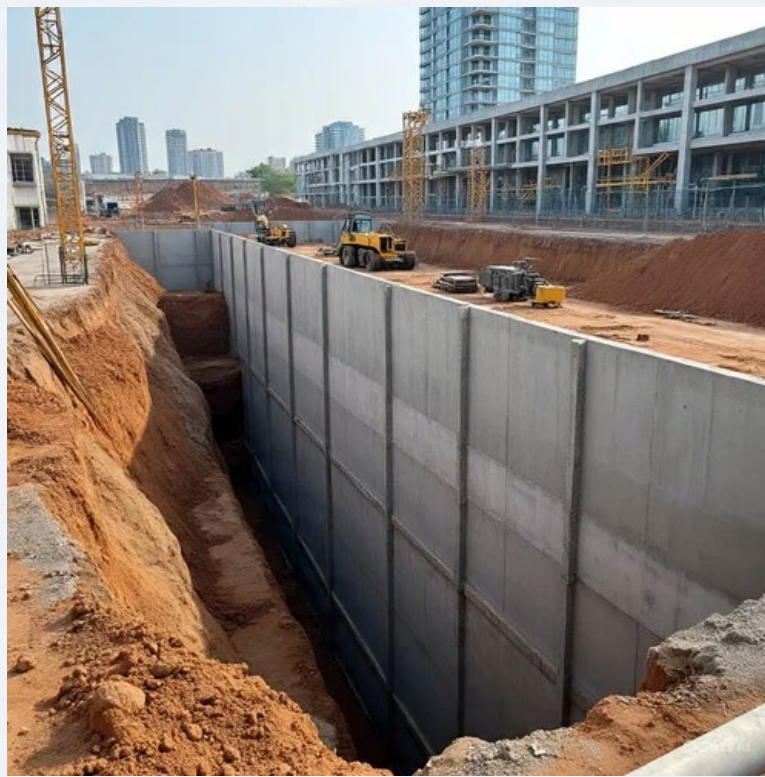


Intersecting concrete piles
creating a continuous barrier.

Dual Function: Structural Support + Water Exclusion



Driven interlocking steel sections.
Fast installation.



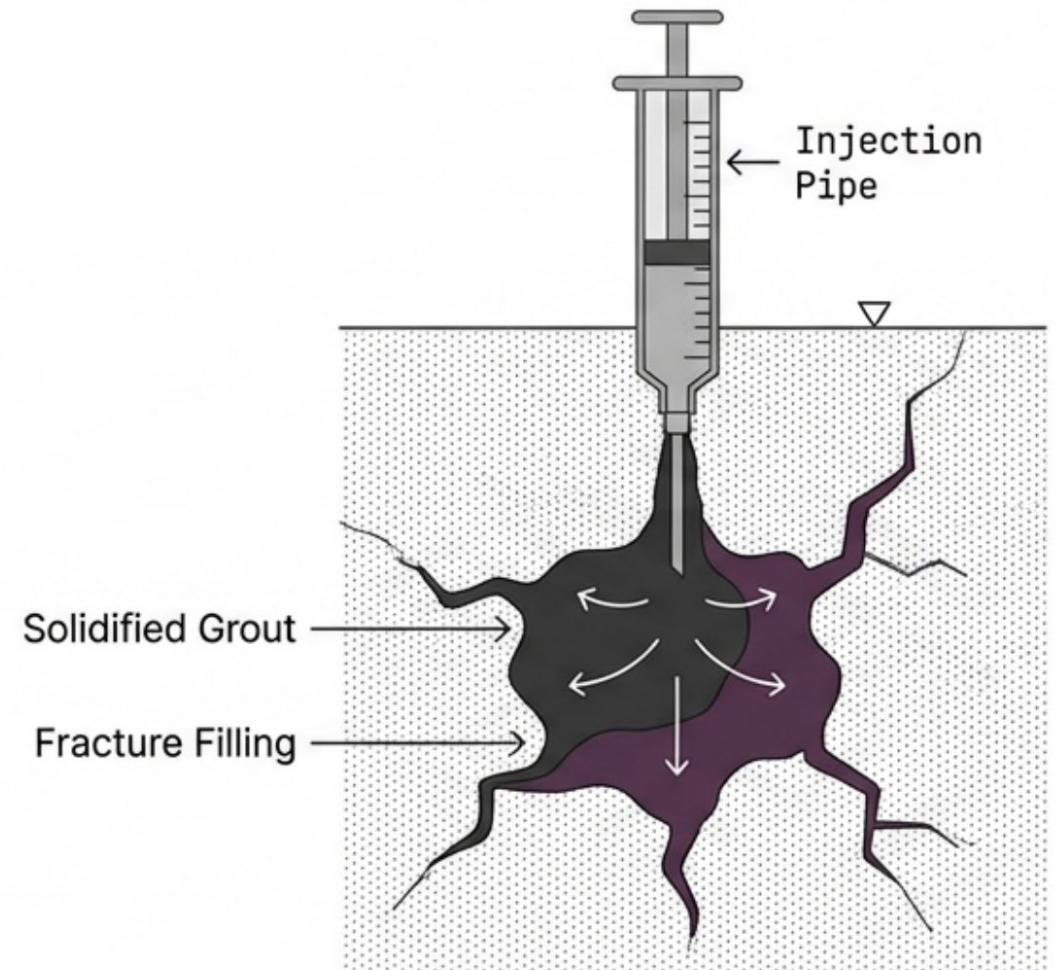
Reinforced concrete panels
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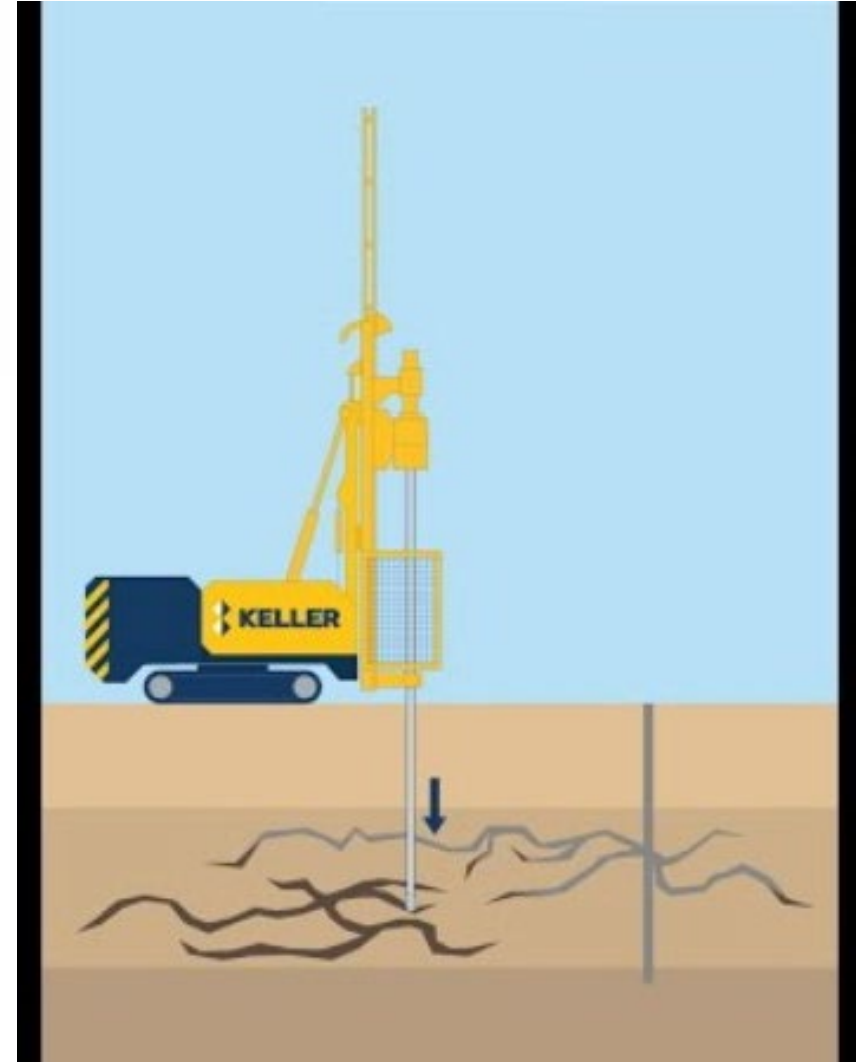
Grouting

Grouting involves injecting cementitious or chemical grouts into soil or rock to reduce permeability.



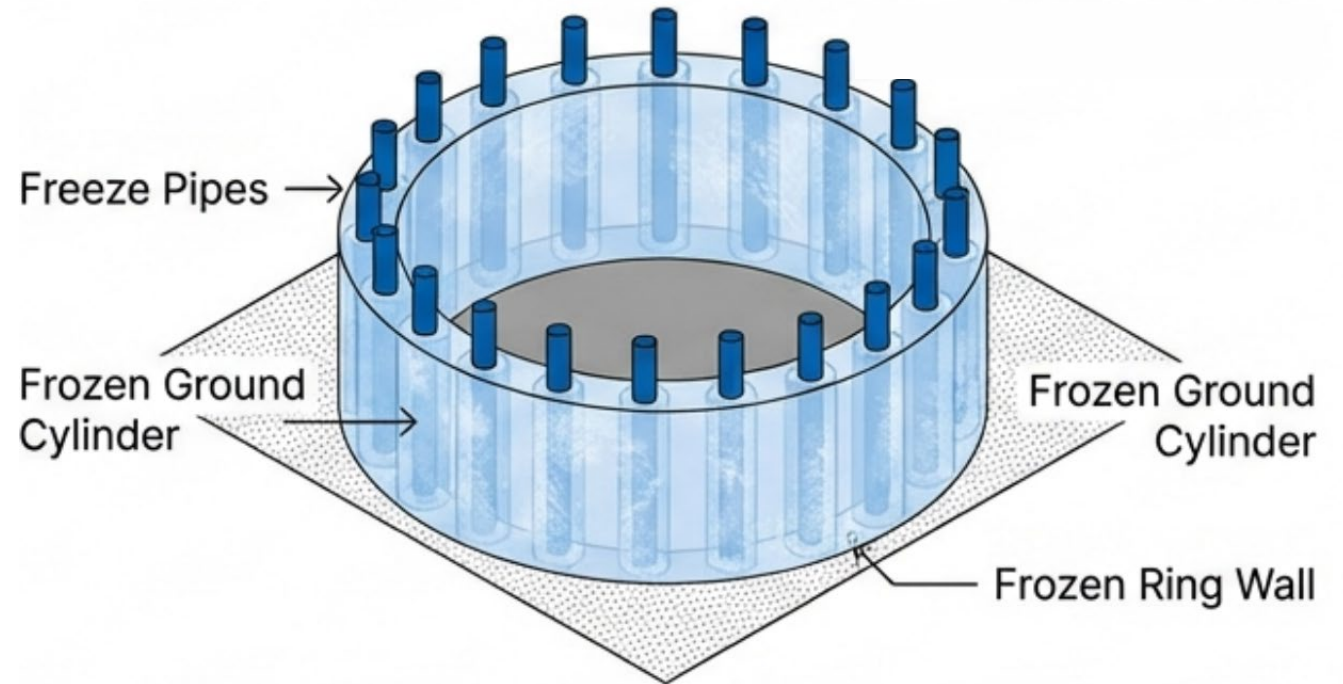
Grouting

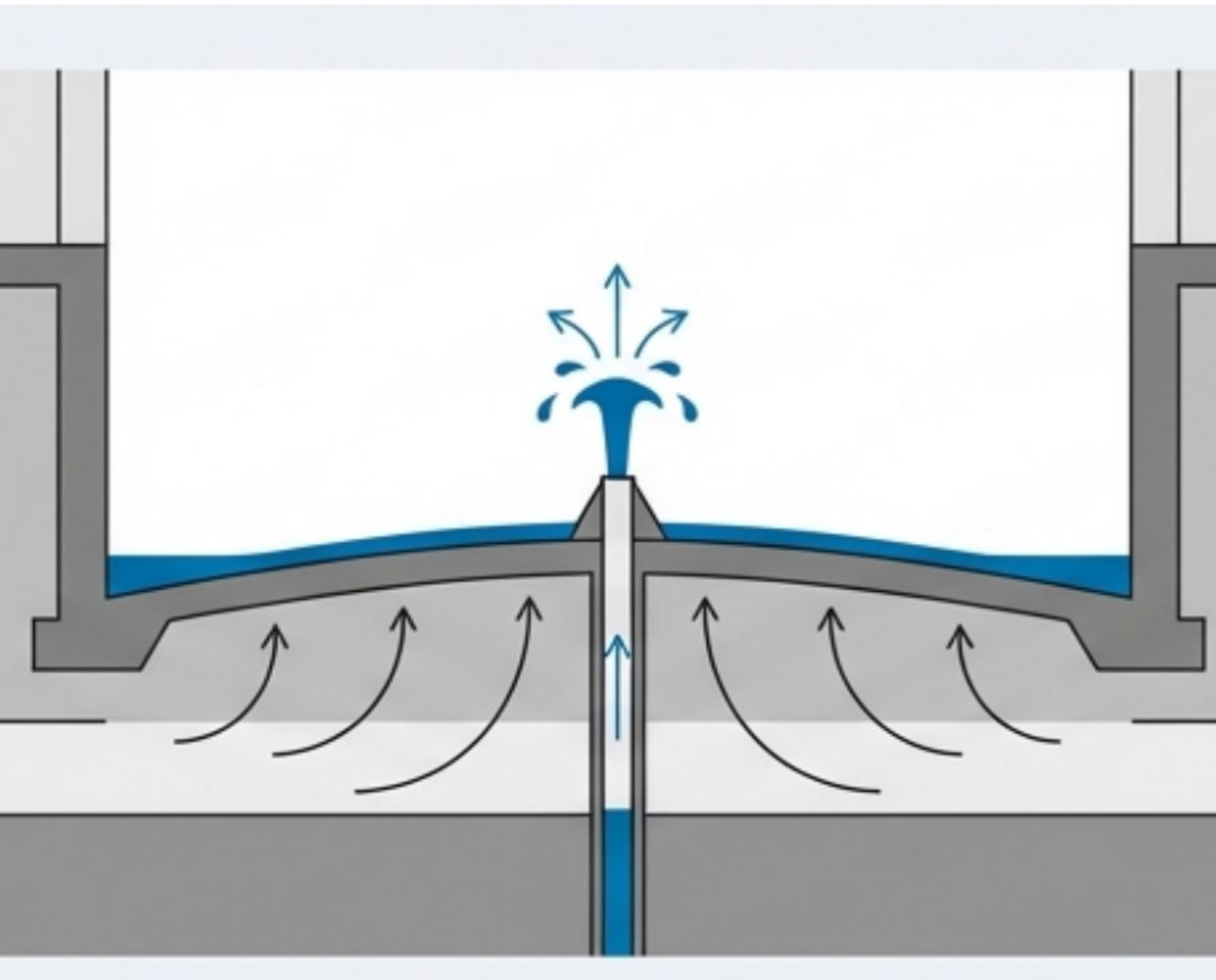
Grouting involves injecting cementitious or chemical grouts into soil or rock to reduce permeability.



Artificial Ground Freezing

Temporarily freezes the ground by circulating refrigerants (brine or liquid nitrogen) through an array of boreholes.

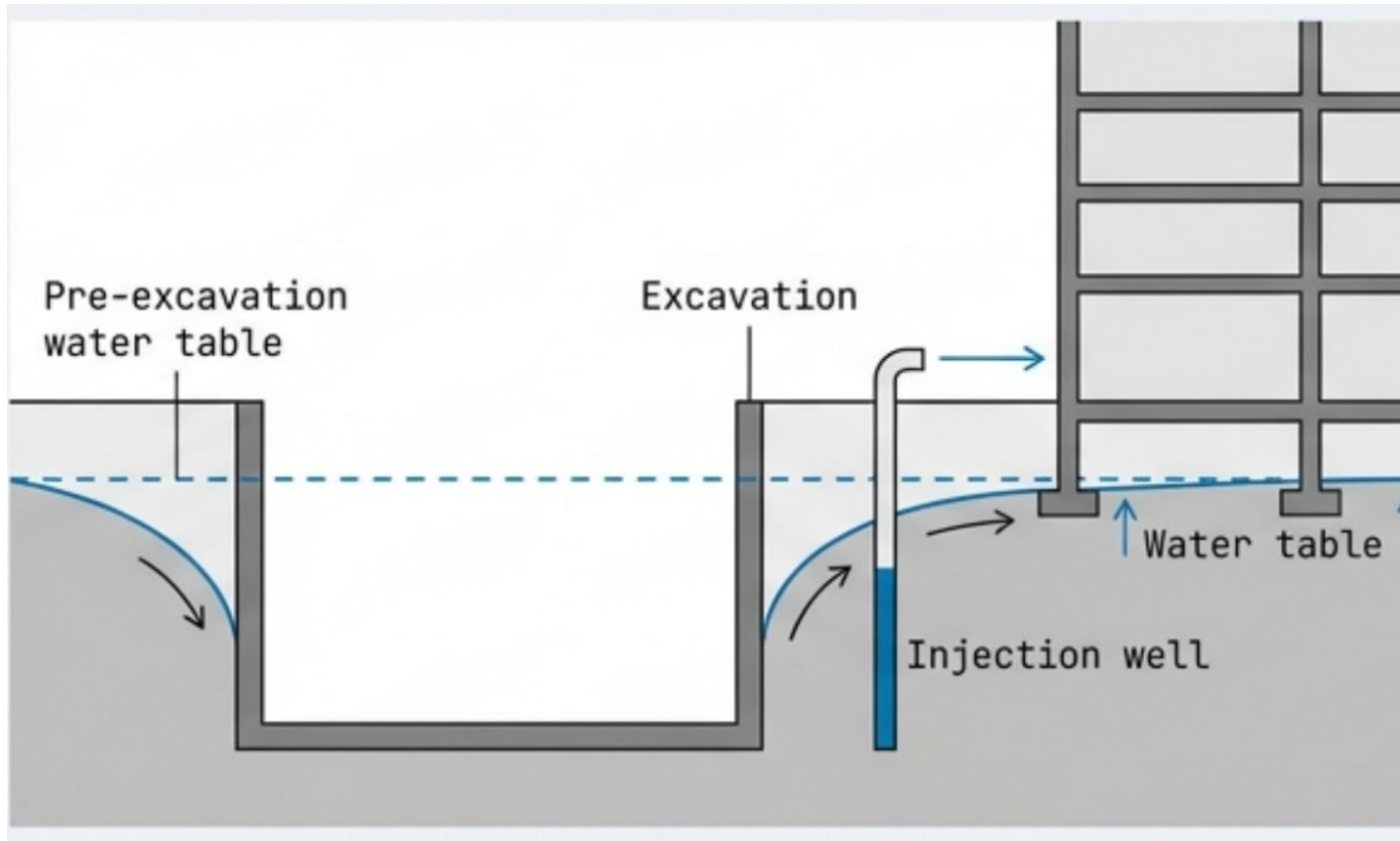




Relief Wells

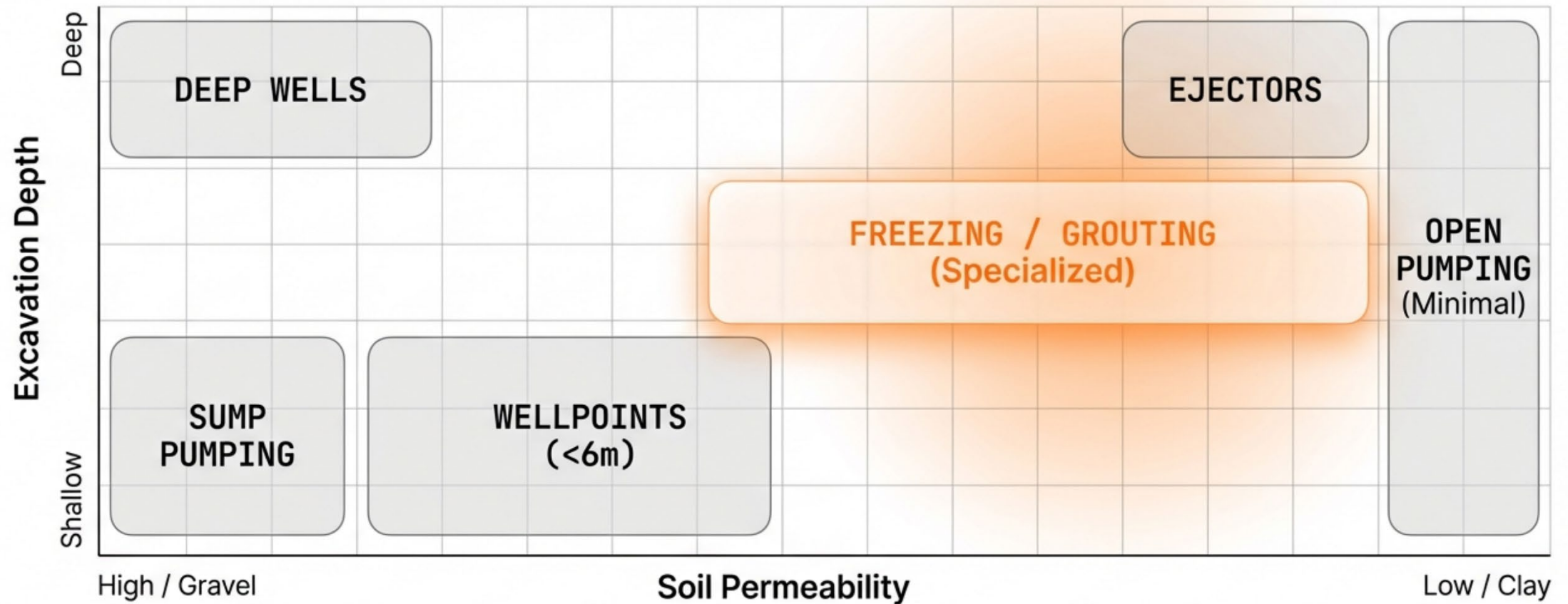
Passive boreholes that relieve upward water pressure beneath an excavation.





Recharge Systems

Recharge involves reinjecting pumped groundwater into the ground outside the excavation.



Matching the method to the geology is the primary determinant of project safety and cost.