Specific storage

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Specific storage (S_s), **storativity** (S), **specific yield** (S_y) and **specific capacity** are material physical properties that characterize the capacity of an aquifer to release groundwater from storage in response to a decline in hydraulic head. For that reason they are sometimes referred to as "storage properties". In the field of hydrogeology, these properties are often determined using some combination of field hydraulic tests (e.g., aquifer tests) and laboratory tests on aquifer material samples.

Contents

Specific storage

The **specific storage** is the amount of water that a portion of an aquifer releases from storage, per unit mass or volume of aquifer, per unit change in hydraulic head, while remaining fully saturated.

Mass specific storage is the mass of water than an aquifer
releases from storage, per mass of aquifer, per unit decline in hydraulic head:

$$(S_s)_m = \frac{1}{m_a}\frac{\Delta m_w}{\Delta h}$$

where

$(S_s)_m$ is the mass specific storage ($[L^{-1}]$);
m_a is the mass of that portion of the aquifer from which the water is released ([M]);
Δm_w is the mass of water released from storage ([M]); and
Δh is the decline in hydraulic head ([L]).

Volumetric specific storage (or **volume specific storage**) is the volume of water than an aquifer releases from storage, per volume of aquifer, per unit decline in hydraulic head (Freeze and Cherry, 1979):

$$S_s = \frac{1}{V_a}\frac{\Delta V_w}{\Delta h}$$

where

S_s is the volumetric specific storage ($[L^{-1}]$);
V_a is the bulk volume of that portion of the aquifer from which the water is released ($[L^3]$);
ΔV_w is the volume of water released from storage ($[L^3]$); and
Δh is the decline in hydraulic head ([L]).

In hydrogeology, **volumetric specific storage** is much more commonly encountered than **mass specific storage**. Consequently, the term **specific storage** generally refers to **volumetric specific storage**.

In terms of measurable physical properties, specific storage can be expressed as

$$S_s = \gamma(\beta_p + n \cdot \beta_w)$$

where

γ is the specific weight of water (N•m^{-3} or [ML^{-2}T^{-2}])
n is the porosity of the material (dimensionless ratio between 0 and 1)
β_p is the compressibility of the bulk aquifer material (m^{2}N^{-1} or [LM^{-1}T^2]), and
β_w is the compressibility of water (m^{2}N^{-1} or [LM^{-1}T^2])

The compressibility terms relate a given change in stress to a change in volume (a strain). These two terms can be defined as:

$$\beta_p = -\frac{dV_t}{d\sigma_e}\frac{1}{V_t}$$
$$\beta_w = -\frac{dV_w}{dp}\frac{1}{V_w}$$

where

σ_e is the effective stress (N or [MLT^{-2}])

These equations relate a change in total or water volume (V_t or V_w) per change in applied stress (effective stress — σ_e or pore pressure — *p*) per unit volume. The compressibilities (and therefore also S_s) can be estimated from laboratory consolidation tests (in an apparatus called a consolidometer), using the consolidation theory of soil mechanics (developed by Karl Terzaghi).

Storativity

Storativity is the volume of water released from storage per unit decline in hydraulic head in the aquifer, per unit area of the aquifer, or:

$$S = \frac{dV_w}{dh}\frac{1}{A}$$

Storativity is the vertically integrated specific storage value for a confined aquifer or aquitard. For a confined homogeneous aquifer or aquitard they are simply related by:

$$S = S_s b$$

where *b* is the thickness of aquifer. Storativity is a dimensionless quantity, and ranges between 0 and the effective porosity of the aquifer; although for confined aquifers, this number is usually much less than 0.01.

The storage coefficient of an unconfined aquifer is approximately equal to the specific yield, S_y, since the release from specific storage, S_s is typically orders of magnitude less.

Specific yield

Specific yield, also known as the drainable porosity, is a ratio, less than or equal to the effective porosity, indicating the volumetric fraction of the bulk aquifer volume that a given aquifer will yield when all the water is allowed to drain out of it under the forces of gravity:

Values of specific yield, from Johnson (1967)

Material	Specific Yield (%)		
	min	avg	max
Unconsolidated deposits			
Clay	0	2	5
Sandy clay (mud)	3	7	12
Silt	3	18	19
Fine sand	10	21	28
Medium sand	15	26	32
Coarse sand	20	27	35
Gravelly sand	20	25	35
Fine gravel	21	25	35
Medium gravel	13	23	26
Coarse gravel	12	22	26
Consolidated deposits			
Fine-grained sandstone		21	
Medium-grained sandstone		27	
Limestone		14	
Schist		26	
Siltstone		12	
Tuff		21	
Other deposits			
Dune sand		38	
Loess		18	
Peat		44	
Till, predominantly silt		6	
Till, predominantly sand		16	
Till, predominantly gravel		16	

$$S_y = \frac{V_{w \cdot d}}{V_T}$$

where

V_{wd} is the volume of water drained, and
V_T is the total rock or material volume

It is primarily used for unconfined aquifers, since the elastic storage component, S_s, is relatively small and usually has an insignificant contribution. Specific yield can be close to effective porosity, but there are several subtle things which make this value more complicated than it seems. Some water always remains in the formation, even after drainage; it clings to the grains of sand and clay in the formation. Also, the value of specific yield may not be fully realized until very large times, due to complications caused by unsaturated flow.

Specific capacity

Specific capacity is a quantity that which a water well
can produce per unit of drawdown. It has units of or , and is expressed as:

$$S_c = \frac{Q}{h_0 - h}$$

where

S_c is the specific capacity ([L^2T^{-1}]; m²/day or USgal/day/ft)
Q is the pumping rate ([L^3T^{-1}]; m³/day or USgal/day), and
$h_0 - h$ is the drawdown ([L]; m or ft)

The specific capacity of a well is also a function of the pumping rate it is determined at. Due to non-linear well losses the specific drawdown will be greater at higher pumping rates than it is at low pumping rates. This complication makes the absolute value of specific capacity of little use; though it is useful for comparing the efficiency of the same well through time (e.g., to see if the well requires rehabilitation).

See also

- Aquifer test
- Soil mechanics
- Groundwater flow equation describes how these terms are used in the context of solving groundwater flow problems

References

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