Sea-water intrusion

Where aquifers form a coastline, a natural gradient exists towards the coast and groundwater discharges into the sea. Because sea water is slightly heavier than fresh water, it intrudes into aquifers in coastal areas forming a saline wedge below the fresh water. The boundary, or interface, between the two is in a state of dynamic equilibrium, moving with the seasonal variations of the water table and daily tidal fluctuations. These movements mean the interface is actually a transition zone of mixed salinity.

The theoretical interface actually occurs at a depth below sea level that is 40 times the height of fresh water above sea level; this relationship is called the Ghyben-Herzberg relation, after the two European scientists who independently recognised it at the turn of the century. In practise geological variability makes the relationship more complex.

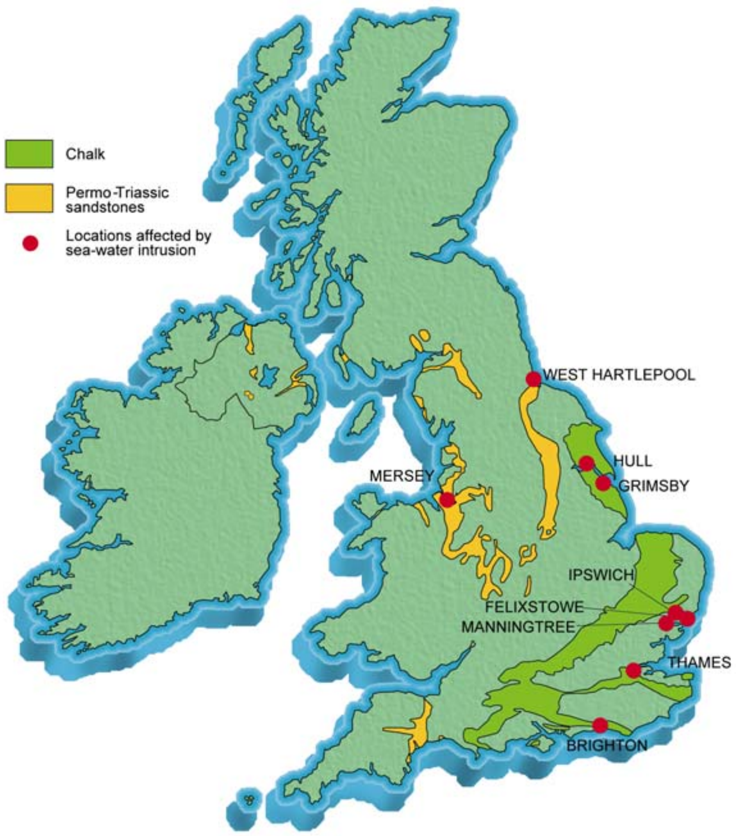
When groundwater is pumped from a coastal aquifer the fresh-water level is lowered and the sea intrudes further into the aquifer.

With excessive pumping the natural hydraulic gradient towards the sea may be reversed and the intrusion can then extend to the pumping borehole which becomes saline.

Saline intrusion has occurred in Britain at a limited number of locations where the Chalk and Permo-Triassic sandstones have been extensively exploited. The cause is usually industrial abstraction concentrated in coastal areas of large towns. The volume of water pumped is generally limited by the chloride concentration and, if the increase in salinity cannot be controlled, the boreholes are eventually abandoned. To this extent the problem is self-correcting.

In many sandstones, where the flow is mainly intergranular, saline intrusion moves slowly inland on a broad front, but in fractured aquifers, such as the Chalk, intrusion can be rapid along individual fractures and extend inland for considerable distances.

To control saline intrusion, a seaward hydraulic gradient should be maintained and a proportion of the natural fresh-water recharge allowed to



Main areas of sea-water intrusion. Except for West Hartlepool, the aquifers affected are the Chalk and Permo-Triassic sandstones. At West Hartlepool the aquifer affected is the Permian Magnesian Limestone.

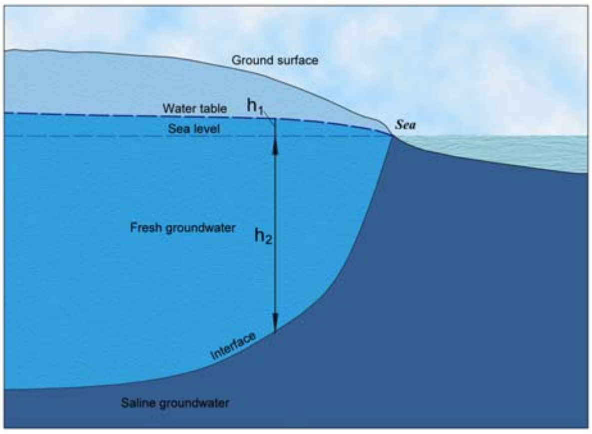
flow into the sea. The management of a coastal aquifer is actually concerned with deciding upon an acceptable ultimate landward extent of the saline water and calculating the amount of fresh-water discharge necessary to keep it in that position.

The risk of saline intrusion clearly limits the extent to which a coastal aquifer can be developed for water supply but the proportion of the infiltration that can be used can be increased by skilful management.

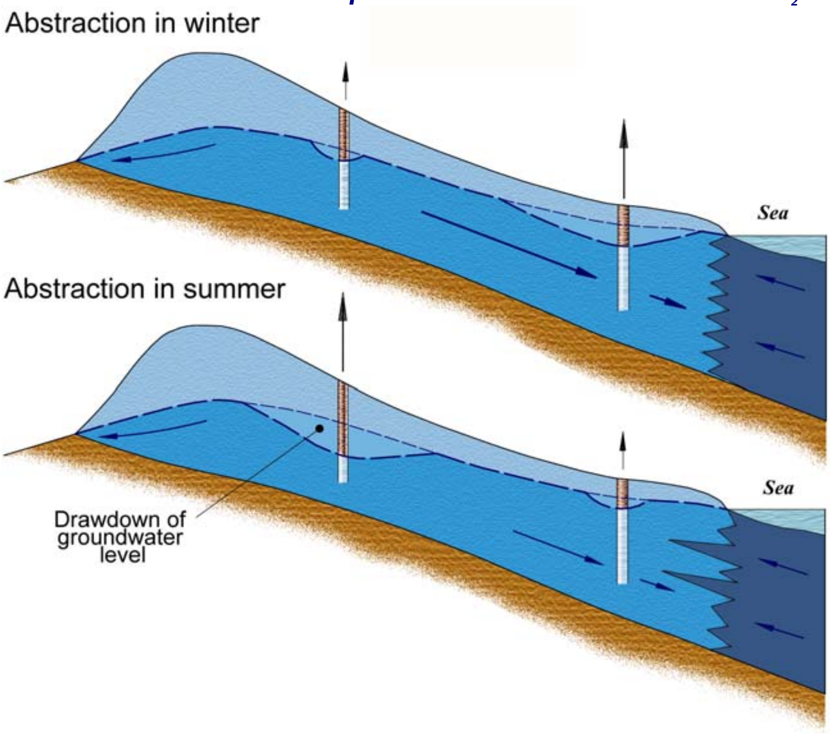
Controlling the sea

Various methods have been advocated for the control of saline intrusion but the pragmatic and cheapest solution is to reduce and / or rearrange the pattern of boreholes abstracting groundwater. This approach has been very successfully applied near Brighton where the Chalk is affected by intrusion, in this case because of abstraction for public supply. The policy adopted is that in the winter, when fresh-water flow to the sea is large, boreholes near the sea are used to provide most of the supply and inland boreholes are rested. This situation is reversed in the summer when the flow of fresh water to the sea is much reduced and the potential for intrusion thereby increased.

Along the south bank of the Humber, where the aquifer in question is again the Chalk, a similar problem has been overcome by using groundwater from the aquifer and surface water from the rivers Trent and Ancholme, in conjunction. Each source is used at different times of the year according to its availability.



The relationship between fresh and saline groundwater in a coastal aquifer. The position of the interface between the fresh and saline groundwater is related to the difference in density of the two waters. The depth of the interface below sea level is about 40 times the height of fresh-water above sea level. That is $h_2 = 40h_1$.



Seasonal abstraction patterns in the Chalk aquifers near Brighton. The Chalk is a fractured limestone and saline intrusion penetrates inland along individual fractures. To reduce this tendency, most of the abstraction in winter is near the coast, to intercept the strong groundwater flow to the sea at this time. This conserves groundwater storage and allows water levels to recover in the aquifer. In summer most of the abstraction is from inland boreholes when groundwater flow to the sea is weaker. Abstraction from coastal boreholes is then reduced or stopped altogether.