

Editorial/

Management of a Coastal Aquifer

by Jacob Bear¹

Unless properly managed, a coastal aquifer will be destroyed (salinized) by sea water intrusion within a rather short period. In principle, the management of a coastal aquifer is no different from an inland one. In both cases, management should be implemented within the framework of an established (regional or national) water resources policy that sets up the objective function (or functions) and constraints that govern management decisions. In most cases, the objective function is to maximize the sustainable yield of the aquifer (here defined to be the volume of water that can be withdrawn annually), subject to quality, economic, reliability level, legal, and other constraints.

The main difference is that the sea constitutes a boundary that continuously threatens the quality of water pumped in the vicinity of the coast, due to excessive sea water intrusion. Here, excessive means beyond the planned, or optimal, extent of sea water intrusion. The latter is a decision variable, as it is a function of the discharge of fresh aquifer water to the sea. Its effect on the yield is, thus, obvious. Under certain conditions, sea water intrusion up to its optimal position may be enhanced by temporarily increasing the yield to above the sustainable level. The optimal extent of sea water intrusion should take into account the costs involved, including the need to abandon existing wells. Under certain constraints, pumping above the intruding sea water wedge is possible.

Many coastal aquifers are heavily populated. This means that (1) large surface areas are covered by concrete and asphalt resulting in a significant reduction in natural replenishment from precipitation (in addition to causing drainage/flooding problems), and (2) many sources of contamination are present on the ground surface causing (in almost all cases) severe deterioration of water quality in the underlying (phreatic) aquifer. These two effects strongly affect the management of the coastal aquifer. The obvious conclusion is that the management of what happens above ground surface, i.e., management of land use (e.g., the location and structure of landfills, storage facilities for hazardous materials, zoning for waste-discharging industries), cannot be separated from that of the underlying coastal aquifer. An appropriate administrative structure must be established that will enable a comprehensive management of the coastal zone for the benefit of its inhabitants. Such

management, incorporating expertise from a number of disciplines, and not only hydrogeology, may require the introduction of land use regulations to enhance infiltration and, mainly, to prevent subsurface contamination. The danger from excessive sea water intrusion is salinization of wells, while contamination originating at ground surface may strongly affect human health. Models that describe variable density flow and salinity/contaminant transport are available to predict sea water intrusion in response to proposed management schemes, thus facilitating the decision-making process.

Obviously, it would be best to start managing the coastal zone (aquifer and land use) when both land and aquifer are still under practically unexploited conditions. Unfortunately, this situation seldom occurs. In most cases, the first role of management is to restore the coastal aquifer to conditions that will enable the withdrawal of the sustainable yield. This goal can be achieved by introducing land use regulations to prevent further subsurface contamination and by controlling well locations and yields, perhaps combined with artificial recharge. Usually, restoration of a coastal aquifer is a very lengthy operation, requiring many tens of years, and may be rather costly, especially if aquifer cleanup operations and (or) the relocation of wells is required. Proper management should ensure the prevention of further water quality deterioration while permitting appropriate withdrawal levels. This may require artificial recharge or aquifer storage and recovery.

Contaminated aquifers need not be abandoned as sources for drinking water, as long as treatment of the pumped water to the required quality standards is economic. It is possible that a coastal zone includes surface water sources, in addition to the underlying aquifer(s). Such sources should be incorporated in a comprehensive approach for the management of water resources in the coastal zone including the possibilities of artificial recharge and of induced recharge from rivers, making use of riverbank filtration.

Three additional sources of water should be considered when planning water resource allocation in coastal zones—desalinated sea water, reclaimed sewage water, and pumped saline ground water. Reclaimed sewage water, when properly treated, may be used for irrigation or as gray water for household use. Pumped saline ground water can be used in certain cases such as swimming pools and some industrial processes.

To summarize, the management of a coastal aquifer should be implemented within the framework of management of the coastal zone. The optimal position of the intruding sea water wedge is a decision variable that is strongly related to the aquifer's yield.

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