The less conservative cationic solutes also have been successfully modeled. The modeling results indicate that hydraulic dispersion (especially transverse) is a much more significant influence than has been previously suggested by earlier studies. The model may be used to project future waste migration patterns for varied hydrologic and waste conditions.

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ARTIFICIAL RECHARGE IN UNITED KINGDOM, ESPECIALLY IN LONDON BASIN

The Water Resources Board, in its role as advisor to the United Kingdom government on water resources development in England and Wales, prepared regional planning studies setting out the alternative strategies, costs, and consequences for 3 regions covering most of the country. More recently a National Planning Study for all of England and Wales has been completed. The program of research and development includes such subjects as water resources instrumentation, mathematical modeling, desalination, combined use of surface and groundwater, artificial recharge, and ecologic problems.

In England and Wales, about 25% of all public water supplies are taken from groundwater which is recharged naturally by percolating rainfall. In many places groundwater levels have been lowered extensively causing saline intrusion and other problems. In recent years there has been much increased interest in the development potential of groundwater, with the result that some schemes for the combined use of naturally recharged underground resources and rivers are under construction and others are under investigation.

Artificial recharge, considered in the United Kingdom to be the final stage of groundwater development, is not yet used, but it is considered to have major potential both for using underground storage to supplement surface storage and for the partial purification of polluted surface water where suitable aquifers crop out at the surface. The Board's artificial recharge program includes hydrogeologic, engineering and economic, analogue and digital model studies and field experiments in most of the techniques of artificial recharge.

One important example, the London basin, is taken as an illustration. A hydrogeologic study has been carried out to assess the potential for recharge beneath London. The aquifers are the Chalk overlain by the lower London Tertiary strata which comprise the fine-grained Thanet Sands and the sands, gravels, and clays of the Woolwich and Reading Beds. These strata form an asymmetric syncline with an axis striking east-west through London's center. The Chalk crops out in the Chilterns of Oxfordshire and Buckinghamshire in the north, and the North Downs of Kent and Surrey in the south. Over the last 170 years, groundwater levels have fallen, in some areas more than 250 ft, creating a storage volume exceeding 200 billion gal—about 5 times the total surface storage available in the Thames basin. Three areas were identified where hydrogeologic conditions are suitable for recharge.

During the hydrogeologic study, an electrical analogue was constructed to assist in proving the transmissivity and storativity maps calculated from pumping test data obtained during the last 100 years. The model highlighted problems of saline intrusion from the Thames and has been used to illustrate the effectiveness of proposed control measures.

More recently an engineering and economic investigation has been undertaken using 2 main techniques: (1) digital groundwater models of the selected recharge areas, and (2) a digital simulation, using the 84 years' records of daily flows in the Thames. This work has shown that additional yields of more than 70 million gal/day could be made available at low cost without the need of further surface storage.

To substantiate this work further, 2 field experiments have been carried out. One involved the recharge of an existing Chalk well and adit system; in the other, water was injected into a pair of new wells, one open only to the Chalk and one open only to the Thanet Sands. There was a comprehensive program of recharge and water-quality sampling and analysis.

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DEEP-WELL INJECTION OF DESALTING-PLANT WASTE BRINE

The production and desalting of saline waters stored in a deep artesian aquifer, the Mount Simon Sandstone in northeastern Illinois, to aid in meeting projected water deficits for the Chicago region, are being considered. Because of the characteristics of the predicted Mount Simon water quality it would be necessary to dispose of large quantities of desalting-plant waste brine. Evaluation of brine disposal methods led to selection of disposal by injection through wells open to the lower Mount Simon aquifer. As feedwater for desalting plants would be withdrawn from the upper Mount Simon aquifer, injection-well fields were designed to eliminate contamination of feedwater and to keep injection pressures within acceptable limits. Wells capable of injecting 1 million gal/day (mgd) were designed. Injection costs were 12.5–19% of the total cost of producing water. Injection costs ranged from 17 cents per 1,000 gal for injection of brine from a 1-mgd reverse osmosis plant to 58 cents per 1,000 gal for brine from a 5-mgd distillation plant. The effect of brine injection may have a harmful effect on the quality of water withdrawn from existing wells open to the aquifers above the Mount Simon.

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SWISS MODIFICATION OF ARTIFICIALLY RECHARGED WATER

Experiences based on some existing plants, where Pleistocene gravels are artificially replenished by polluted river water and which have recharge capacities of 1–25 mgd, demonstrate the importance of retention time and of oxygen balance in the highly permeable aquifers.

The retention time of the single water particles has considerable variation and depends on hydraulic dispersion which may be proved by tracer investigations. In one case, for a distance of 1,350 ft, the minimal flow time is 3.4 days, the average 22 days. The flow times of the different water particles prove a logarithmic normal distribution function.

The oxygen content of the artifically recharged groundwaters depends on the oxygen concentration and on the biochemical oxygen demand (BOD) of the raw water. From the data the oxygen balance of a groundwater can be evaluated. For example, on an average, a groundwater with 3.4 ppm O_2 and only 0.5 ppm full BOD was obtained from a river water with 12.6 ppm O_2 and 9.7 ppm full BOD (equal to a 5-day BOD of 4.5 ppm) after a retention time of 7 days. As