Hydrogeologic studies at a subsurface radioactive waste management site in west-central Canada

11:30 D. W. Goss, O. R. Jones: Movement and accumulation of suspended sediment during basin recharge

FRIDAY AFTERNOON, SEPTEMBER 28

Regionally Related Case Histories

1:30 I. W. Marine: Geohydrology of buried Triassic basin at Savannah River Plant

2:00 H. S. Puri, G. L. Faulkner, G. O. Winston: Hydrogeology of liquid-waste storage in Florida

2:30 J. I. García-Bengochea, C. R. Sproul, R. O. Vernon, H. J. Woodard: Artificial recharge of treated waste waters and rainfall runoff into deep saline aquifers of peninsula of Florida

3:00 M. I. Kaufman, D. A. Goolsby, G. L. Faulkner: Injection of acidic industrial waste into saline carbonate aquifer—geochemical aspects

3:30 W. E. Wilson, J. S. Rosenshein, J. D. Hunn: Hydrologic evaluation of industrial-waste injection at Mulberry, Florida

4:00 H. M. Peek, R. C. Heath: Feasibility study of liquid-waste injection into aquifers containing salt water, Wilmington, North Carolina

4:30 J. A. Leenheer, R. L. Malcolm: Case history of subsurface waste injection of an industrial organic waste

5:00 A. DiTommaso, G. H. Elkan: Role of bacteria in decomposition of injected liquid waste at Wilmington, North Carolina

SATURDAY MORNING, SEPTEMBER 29

Case Histories, Decision and Evaluation

9:00 E. G. Dennison, F. Simpson: Hydrogeologic and economic factors in decision making under uncertainty for normative subsurface disposal of fluid wastes, northern Williston basin, Saskatchewan, Canada

9:30 E. C. Donaldson, R. T. Johansen: History of two-well industrial waste disposal

10:00 B. F. Latta: Subsurface disposal of waste in Kansas

10:30 T. F. Lomenick, A. L. Boch: Site investigations for bedded-salt pilot plant in Permian basin

11:00 R. J. Schicht: Deep-well injection of desalting-plant waste brine

Abstracts

BARLOW, A. C., E. I. du Pont de Nemours and Co., Wilmington, Del.

Philosophy of Deep-Well Disposal

In recent years, deep-well disposal has been the subject of much discussion and criticism. Of the latter, some has been justified as a result of misapplication, but most has been unwarranted. Nevertheless, a fear factor has been aroused concerning deep-well disposal which is unjustified if the technique is properly applied and operated. Unfortunately, the public has confused the misapplication of the technique with the technique itself.

Deep-well disposal is not advanced as a cure-all for problems related to waste-liquid disposal. Its use is relatively limited considering the wide divergence in chemical composition of wastes. However, if installations are properly conceived, constructed, and operated, and are installed in a suitable geologic setting, they can fulfill a need without creating other problems such as can occur with waste-retention basins, incineration, or possibly even with sludge disposal. At the least, the deep-well method removes the waste from the biosphere.

Because the capacity of potential receiving formations is enormous, but finite, unrestricted deep-well disposal should not be allowed. The use of a formation for this purpose in any specific area should be controlled. Control in this context includes the awarding of permits and the delineation of factors such as acceptable injection rates and pressures, materials of construction, and such tests and monitoring facilities as can be justified to insure the utility and safety of the installation.

If expertise on these matters does not exist in the state, then it should be empowered to employ such experts on a consulting basis or to use the services of experienced government agencies, such as the U.S. Geological Survey or others. In any case, the equitable application of reasonable regulations can operate only to the benefit of all.

BARR, FRED J., JR., Petty Geophysical Engineering Co., San Antonio, Tex.

Feasibility Study of Seismic-Reflection Monitoring System for Underground Waste-Material Injection Sites

Injection of waste materials into deep subsurface formations is becoming an increasingly popular method of waste disposal. Attendant to this growing practice is an increasing possibility of accidental damage to the subsurface and surface environments. An effective method of monitoring the movement and distribution of these injected waste materials is needed.

In most cases, the acoustical properties of the receiving formation material (*i.e.*, its density and velocity of propagation of compressional sound waves) will be changed upon contacting the injected waste materials. These changes subsequently will change the reflection coefficient encountered by a vertically traveling sound wave at the receiving formation. This change in acoustical properties suggests the application of modern seismic-reflection and data-processing techniques to this monitoring problem.

The seismic-reflection technique involves introduction of acoustical energy into the earth from the surface, and recording of signals at or near the surface. The signals are indicative of the travel time and amount of energy reflected from each of many closely spaced points along each subsurface formation. The use of the seismic method therefore is proposed on a periodic basis to detect changes of acoustical properties in the receiving formation and surrounding formations to monitor effectively the movement and position of the waste materials.

The assumed seismic field system for this monitoring system includes the following components: (1) permanent arrays of velocity geophones buried a short depth below the surface of the earth; (2) a multichannel digital recording system of the instantaneous-floating-point, binary-gain type; (3) truck-mounted seismic surface energy sources; and (4) use of a digital seismic data-processing center with special software.

The feasibility of the monitoring system has been studied by means of an acoustical model derived from well-log information for a typical Gulf Coast injection well. This model and the characteristics of the seismic field system determine the smallest detectable lateral

change in reflection coefficient. This information then is related to the range of expected changes in reflection coefficient due to the injected waste materials, and subsequently to the feasibility of the seismic monitoring system.

BOND, D. C., Illinois State Geol. Survey, Urbana, Ill.

DEDUCTION OF FLOW PATTERNS IN VARIABLE-DENSITY AQUIFERS FROM PRESSURE AND WATER-LEVEL OBSERVATIONS

In previous potentiometric studies of variable-density aquifers, particularly studies related to oil exploration, certain gravitational effects apparently have been ignored. These include the effects of troughs formed by permeability barriers within the aquifers, and the effects of structural troughs, saddles, anticlines, and synclines. In intermontane regions these gravitational effects probably are negligible in comparison with observed head differences; in most other regions they can change appreciably the heads, or the potentials, that are available to cause flow.

A gradient in potential is not necessarily associated with flow, even though corrections are made for the average rate of change in density of water. Gravitational effects can cause the interface between water and an oil or gas deposit to be tilted, even if the water under the deposit is static. These effects can reduce the rate of flushing of brine by fresh water, or they can prevent flushing.

Previous potentiometric studies should be reevaluated to ensure that all gravitational effects have been taken into account.

BOUWER, HERMAN, U.S. Dept. of Agriculture, Phoenix, Ariz.

DESIGN AND OPERATION OF LAND-TREATMENT SYSTEMS FOR MINIMUM CONTAMINATION OF GROUNDWATER

The increasing interest in land-treatment systems for sewage effluent and other liquid wastes, as well as some solid wastes, poses a threat to the quality of the native groundwater even though the waste water itself undergoes a marked improvement in quality as it moves through the ground and becomes "renovated" water. To avoid large-scale spread of the renovated water into the groundwater basin, the renovated water should be collected again at some point by wells (deep aquifers) or drains (shallow aquifers) for reuse or release into the surface water. For the Salt River Valley, the effective transmissibility of the aquifer for recharge was evaluated from a pilot project and then used in the design of a full-scale system. This effective transmissibility was less than the aquifer transmissibility.

BROWN, DONALD L., Hydrologist, Norfolk, Va., and WILLIAM D. SILVEY, Chemist, Richmond, Va.

UNDERGROUND STORAGE AND RETRIEVAL OF FRESH WATER FROM BRACKISH-WATER AQUIFER

In 1967, the U.S. Geological Survey, in cooperation with the City of Norfolk, Virginia, began a study concerning the injection of fresh water into a confined aquifer containing brackish water. The objectives of the study were (1) to determine whether the host formation would physically accept large volumes of fresh water, (2) to determine the degree of mixing of the injected fresh water with the saline water, and (3) to determine the percentage of recoverable potable water after long periods of storage.

During late 1971 and early 1972, three injection and withdrawal tests were carried out. In test 1, fresh water was injected at a rate of 400 gpm (gallons per minute). The specific capacity of the well decreased from an initial value of 15.4 to 9.3 gpm/ft of drawdown at the end of 260 minutes of injection. In test 2, the initial injection rate of 400 gpm decreased to 215 gpm after 7,900 minutes of injection. The specific capacity dropped from 14.2 to 3.7 gpm/ft during the same time interval. Test 3 began with the aquifer accepting water at a maximum rate of 290 gpm, and the injection rate fell to 100 gpm within 150 minutes and continued to decline to a low of 70 gpm after approximately 1,300 minutes. The specific capacity decreased from an initial value of 3.7 to 0.93 gpm/ft at the end of the test.

Specific capacities during the withdrawal phases dropped from 19.7 gpm/ft at the beginning of test 1 to 6.7 gpm/ft at the end of test 3. All attempts at redevelopment of the injection well failed to improve the specific capacity. Current-meter surveys conducted during injection and withdrawal pumping indicated that the reduction in flow rate and specific capacities was due to a uniform reduction in permeability of all contributing zones in the aquifer rather than to a complete shut-off of flow from selected parts of the aquifer.

All of the hydraulic data collected during the three tests indicated that a physical change of the formation materials had occurred. Specifically, it was felt that the uniform loss of specific capacity of the contributing zones was due to clay dispersion, a phenomenon well known to the petroleum industry. Chemical data collected during the three tests indicated that the sodium-rich clays also were involved in cation exchange. As fresh water was being injected, calcium and magnesium replaced sodium on the clays. During withdrawals, a reversible reaction occurred as the sodium concentration in the mixed fresh and formation water increased. The net effect of the replacement of sodium with calcium and magnesium was to decrease very slightly the tendency of the clays to disperse during the injection of fresh water. The cation exchange activity during both the injection and withdrawal phases had little to do with clay dispersion, which is more nearly a physical than chemical characteristic. However, the exchange activity noted during all three tests did indicate that the clays would readily respond to chemical treatment for the purposes of decreasing or eliminating clay dispersion.

Subsequently, a preflush of 3,000 gal of 0.2 *N* calcium chloride solution was injected in front of the fresh water in injection test 4. The initial specific capacity was 4.3 gpm/ft compared with the ending injection specific capacity of 0.93 gpm/ft in test 3. By redevelopment pumping during injection, the specific capacity was improved to a high of 5.3 gpm/ft. After 4 million gal of water had been injected, an additional 3,000 gal of 0.4 *N* calcium chloride solution was added to the formation. The injection specific capacity increased to a high of 7.12 gpm/ft.

The injection specific capacity fell off with time because only the area around the bore hole was treated to prevent clay dispersion. The data from test 4 indicated a maximum injection rate could be maintained by injecting for periods of 1,200 and 1,400 minutes, then withdrawing water for 30 minutes to remove from the aquifer any sand and clay particles that were clogging the injection zones.

A total of 20 million gal of fresh water was injected in test 4. The water was left in the aquifer for about 6 weeks before beginning the withdrawal phase. It had been determined from the first three injection tests that about 85% of the injection water could be recovered