existing native water, and air entrainment or dissolution of gases in interstices of the porous medium.

A comprehensive study of factors affecting artificial groundwater recharge should include laboratory determinations of the relation of the various causes of hydraulic-conductivity reduction. Problems pertaining to the effect of water quality in relation to the lithologic environment of a recharge system also should be studied in the laboratory.

A laboratory facility has been designed and equipped to provide means of testing flow through porous media columns. Any quality of recharge water from distilled water to activated sludge, can be constituted in quantities providing for indefinite term tests. Flow can be through repacked or field cores under constant flow or constant pressure.

A flow-test data acquisition and computation system provides punched tape data storage and real time computation and plotting of intrinsic permeability changes with column depth and time.

Water quality data are taken during the test, and characteristics of the porous media and suspended solids are determined. Accumulation of material in porous media interstices is visually observed with scanning electron microscopy.

The data are analyzed to relate the physical, biologic, and chemical effects in the porous media flow system with the objective of obtaining data that can be transferred to field situations and thus develop more economical artificial-recharge systems.

SUN, REN JEN, U.S. Geol. Survey, Washington, D.C.

HYDRAULIC FRACTURING AS TOOL FOR DISPOSAL OF WASTES IN SHALE

The growth of modern society and technology requires an increasing level of protection of the environment, and waste disposal is a growing problem, particularly for radioactive and toxic industrial wastes.

The injection of wastes mixed with cement grout into thick shale formations is a promising method for effectively immobilizing wastes in a nearly impermeable medium. Hydraulic fracturing serves as a tool to increase the permeability of shale during the grout injection. Ion exchange and adsorption agents can be added to the grout when it is mixed. After hardening of the grout, the injected wastes will become an integral part of the shale and remain there as long as the shale is not subject to erosion.

Problems concerning the safety of the method are phase separation and orientation of the hydraulically induced fractures. During hardening of the grout, phase separation may occur, that is, some liquid may separate. In such an instance, the mobility of wastes in the separated liquid may be greatly retarded by the very low permeability and high ion-exchange capacity of shale. If the separated liquid reached a groundwater reservoir, the concentration of contaminants would be greatly reduced further by dilution in the native groundwater.

In bedded shale there is a great difference in tensile strength between the direction normal to and parallel with bedding planes. This difference in tensile strength may favor the formation of fractures along low-angle bedding planes within a zone of limited vertical extent. However, not all shale formations produce bedding fractures, therefore before construction of a waste-disposal plant it is necessary to test the site by water or nontoxic grout injections tagged with radioactive isotopes to judge whether a "zone" of fractures can be induced parallel with the shale bedding planes. Injection pressure, movement of the ground surface, and gamma-ray logs made in observation wells are used to interpret the orientation of the hydraulically induced fractures during the site-selection tests. A case history of hydraulic fracturing at West Valley, New York, illustrates the method of selection of a site.

Waste disposal through an injection well is conducted in multiple-layered injection stages. The first injection starts from the deepest depth, then the injection zone is plugged by cement, and the second injection will be started about 10 ft above the first one. The repeated use of the injection well distributes the high cost of construction of injection and monitoring wells over many injections, thereby making hydraulic fracturing economically feasible as a tool for the disposal of certain types of wastes.

WALKER, WILLIAM R., and WILLIAM E. COX, Virginia Polytechnic Inst. and State Univ., Blacksburg, Va.

LEGAL AND INSTITUTIONAL CONSIDERATIONS OF DEEP-WELL WASTE DISPOSAL

Deep-well injection of wastes is subject to two levels of legal and institutional constraints. The first consists of regulatory procedures established by state and federal legislation. Waste injection has traditionally been regulated by the states through use of a variety of statutory constructions and administrative organizations. Federal control over subsurface disposal has essentially been limited to radioactive wastes, but influence currently is being extended into the general area of underground waste management. The apparent intent of the Federal Water Pollution Control Act Amendments of 1972 is the subjugation of state regulatory procedures to federal standards, with actual administration of controls ultimately to remain with the states.

The second level of constraints consists of the property rights of adjacent landowners. These adjacent rights are important because injected wastes do not respect property boundaries and therefore may produce conflict with certain aspects of property ownership. The most obvious type of infringement involves injurious contamination of property interests by the injected waste. A more indirect case of contamination may involve the pressure-induced migration of naturally occurring pollutants such as mineralized water. Another potential type of pressure-related interference with property consists of structural damage from seismic activity initiated by injection. In some jurisdictions, even the unauthorized occupation of underlying space without measurable damage to the landowner may constitute a violation of property rights. The courts in most states have not been confronted with all these issues, but the party adversely affected by injection generally will be able to invoke a variety of legal actions, including nuisance, negligence, and trespass. In addition, some states accept the concept of strict liability regarding hazardous activities and the escape of deleterious substances, with the result that the injured party is relieved of the requirement of proving fault.

WARNER, DON L., and DONALD H. ORCUTT, Univ. Missouri, Rolla, Mo., and Wapora, Inc., Washington, D.C.

INDUSTRIAL WASTEWATER-INJECTION WELLS IN UNITED STATES—STATUS OF USE AND REGULATION, 1973

Recent inventories of industrial wastewater-injection wells in the United States show that at least 250 wells have been completed to date (March 1973) in 24