United States
Environmental Protection
Agency

Industrial Environmental
Research Laboratory
Cincinnati OH 45268

Research and Development

EPA-600/S7-84-050 Apr. 1984

EPA

# Project Summary

# Infiltration and Permeability Testing at Geokinetics Oil Shale Site

Edward W. Holyman and George W. Quinn

**Infiltration (double-ring) and pressure permeability (packer) tests were conducted in or near true *in-situ* oil shale retorts and at adjacent undisturbed locations to obtain comparative data to evaluate the potential for groundwater pollution due to increased fluid migration resulting from this retorting methodology. Tests were performed at the Geokinetics' oil shale site located in Section 2, Township 14 South, Range 22 East, Uintah County, Utah.**

**Three infiltration test sites were selected for study. Two of the sites were located in disturbed surface soils overlying two retorts. The third site was situated in nearby undisturbed soils similar to those found at the two retorts. Pressure permeability tests were conducted in a newly constructed angle hole and in an existing core hole. The angle hole was drilled so the permeability measurements could be made near and below a burned retort. An existing core hole in nearby undisturbed rock was tested for comparison.**

**Test results suggest a slight increase in surface infiltration rates and hydraulic conductivity in or near the retort areas. This will allow additional surface waters to enter into and pass through the vadose zone increasing the possibility of contact with potential pollution sources generated by retorting activities. However, before drawing any conclusions regarding the extent of threat to groundwater resources in the area, the hydrogeologic conditions, especially permeability of the stratigraphic interval between the retorts and the closest aquifer, should be carefully defined. Extrapolation of results from this study to other sites is valid only to the extent that retorting and hydrogeologic conditions can be defined to be the same as for this test site.**

***This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

## Introduction

This report discusses the results of Kaman Tempo's infiltration and permeability testing at the Geokinetics' oil shale site located in Section 2, T14S, R22E, Uintah County, Utah. Comparative evaluations for each of the testing methods were performed in areas affected and unaffected by retort development. All work performed herein was conducted pursuant to EPA Contract No. 68-03-2449.

The objectives of this research program were to: (1) evaluate possible alteration of surface infiltration rates due to retort development, burning and associated surface fracturing and uplift; and (2) measure, by means of packer testing, possible changes in the permeability of rocks affected by retort development and burning.

The Geokinetics' site was selected for testing because of the true *in-situ* oil shale retorting methodology utilized

there. The process entails drilling a pattern of drill holes from the surface, through the overburden, and into the oil shale bed. The holes are loaded with explosives and fired, using a pre-determined blast system. The blast results in a fragmented, highly permeable mass of oil shale. The void space in the fragmented zone comes from lifting of the overburden that produces a small arch in the ground surface.

The fragmented zone within the oil shale horizon constitutes an *in-situ* retort. The bottom of the retort is sloped to facilitate drainage of the oil to a sump where it is lifted to the surface by a number of oil production wells. Air injection holes are drilled at one end of the retort and offgas holes are drilled at the other end. The oil shale is ignited at the injection wells. Air is then injected to establish and maintain a burning front that occupies the full thickness of the fragmented zone. The front is moved in a horizontal swell through the fractured shale towards the offgas wells at the far end of the retort. The hot combustion gases from the burning front heat the kerogen in the oil shale, inducing destructive distillation and draining out the oil. The oil drains to the bottom of the retort, where it flows along a sloping surface to the oil production wells. As the burn front moves from the air into the offgas wells, it burns the residual carbon in the retorted shale as fuel. The combustion gases are recovered at the offgas wells. This gas is combustible and can be used for power generation.

This study tested infiltration and permeability characteristics of soil and rock formations at the Geokinetics' oil shale retorting facilities and should have wider application in other oil shale locales. The report is divided into four sections: introduction, testing program, test results, and conclusions.

## Testing Program

Kaman Tempo performed the infiltration and permeability testing at the Geokinetics' site during September and October, 1981. Autumn was selected for testing in order to avoid water-saturated soil conditions resulting from spring snow melt and summer thunderstorms. Frozen soil conditions and access problems of winter were likewise avoided.

### *Infiltration Testing*

Double-ring infiltration tests were performed at nine locations--six overlying burned retorts (14 and 15) and three in undisturbed areas. The purpose of the study was to evaluate changes in infiltration rates due to surface heave over the retorts. Double-ring infiltrometers were selected because they provide data that is considered representative of the vertical component of the infiltration flow and for their operational simplicity in the field that facilitated multiple tests useful for comparative analysis. It is generally acknowledged that infiltration rates determined by sprinkling a large area are more reliable than cylinder-type determination. However, the need for multiple test sites and the high cost of utilizing sprinkler infiltrometers precluded their use during this study.

Tests at all sites were conducted in the following manner: a metal cylinder 30cm (12 in) in diameter was driven to a depth of approximately 15cm (6 in) into the soil at the test site. A larger cylinder, 46cm (18 in) in diameter, was placed concentrically around the 30cm (12 in) cylinder. The areas within the inner and outer cylinders were flooded, and the rate of recession of the water level in the inner ring was measured by means of a meter staff. Tests were conducted for 90 minutes, which in the soil type tested was considered sufficient time to obtain a steady state condition. Care was taken to conduct all infiltration tests on the same soil type; namely Luhon Loam.

### *Pressure Permeability Testing*

Pressure permeability tests were conducted in two drill holes. Angle Hole No. 1 was drilled between retort 24 (burned) and retort 26 (unburned) in a manner so that it would pass within three meters (10 feet) of the base of the burned core of retort 24 and bottom approximately 38 meters (124 ft) below the base of the retort. Total length of this hole is 75 meters (247 ft). (Permeability testing could not be done in any of the burned retorts because of residual high rock temperature and very high permeability.) The other drill hole tested was Core Hole 12, drilled in 1978 by Geokinetics. This hole is vertical, was found to be in good condition, and was suitable for testing. It is 30 meters (100 ft) deep and is located well enough away from any effects of rubblizing or retorting. Both holes are NX 7.6cm (3 in) diameter and are bottomed above the water table. The shallowest substantial aquifer underlying the Geokinetics' site is the Douglas Creek Member of the Green River Formation, approximately 244 to 274 meters (800 to 900 ft) below the surface.

Dual packers spaced 3.6 meters (11.8 feet) apart were placed on the end of the drill string. Subtracting the space occupied by the packers, this resulted in testing a 3 meter (10-foot) interval. Testing started at the bottom of each hole and progressed upward at intervals approximately equal to the packer spacing. Testing and calculation of permeabililty for each zone were done in accordance with the method discussed in *Ground Water Manual* published by the U.S. Department of the Interior, Bureau of Reclamation, 1977.

## Test Results

### *Infiltration*

Infiltration rates expressed in centimeters per hour were calculated directly from field measurements. Infiltration rates were plotted against time, resulting in a curve showing the change in tendency of the soil to absorb water with time. The areas under the curves represent the infiltration capacity or the capacity of the soil to absorb water up to a particular time.

Results of the infiltration tests indicate moderate to slow infiltration rates. Infiltration rates were slower in the undisturbed area than over both retorts, but the retort rates are still considered to be slow. All plots indicate roughly the same attainment of near-steady-state conditions.

On the basis of eight tests, there were no statistically significant differences in the surface infiltration rates. The ninth test (site C, retort 14) was not included in the analysis. The heavy vegetative cover producing extensive root structure within the tested soil horizon provided pathways for the infiltrating water, thus giving nonrepresentative results. From the limited amount of data developed, the range of final infiltration rates appeared somewhat larger overlying the retorts as compared to the undisturbed area. However, no statistical significance could be developed for this apparent characteristic nor for the slightly higher overall infiltration rates found overlying the retorts.

### *Permeability*

Angle Hole No. 1 was utilized to evaluate permeability near a burned retort, and in the area underlying the retort. During the drilling of the hole, 7.6 meters (25 feet) of rich tar sand was encountered at approximately 59m (195 feet). Between completion of the hole and packer testing a substantial amount of wax-like hydrocarbon material had seeped into the well bore and drill string clogging 30m (100 feet) of drill pipe. This

prevented testing of the interval between 24m and 69m (80 feet to 227 feet). A single packer test was conducted between 69 meters and the bottom of the hole at 75 meters (227 and 247 feet). Double-packer tests were conducted at 3 meter (10 foot) intervals from 24 to 3 meters (80 feet to 10 feet).

Existing core hole No. 12 was found to be in good condition for testing and did not penetrate the tar sand found deeper in Angle Hole No. 1. Located 304 meters (1,000 feet) from the nearest retort, it was selected to provide hydraulic conductive data for undisturbed material. Dual packer permeability tests were run throughout the hole.

Permeability measurements show a good correlation with rock discontinuities developed from core analysis. The correlation of permeability and secondary porosity (rock fractures) indicates that flow through the tight oil shale stratigraphy in this area is largely controlled by these discontinuities. Permeabilities varied by a factor of 1,000 from nearly impermeable rock at the bottom of the angle hole to moderately fractured rock near the surface. Conductivity values decrease very slightly as the angle hole approached the burned retort 24.

In general, permeability values were lower in the undisturbed area 304 meters (1,000 feet) southeast of the nearest retort. This is more apparent when you consider that four of the seven test sections in the undisturbed area would not take water at all. However, where fractures were penetrated, permeability values were similar to or higher than those found near the retort.

## Conclusions

Surface infiltration and pressure permeability tests were conducted at the Geokinetics oil shale site. Eight double-ring infiltration tests suggest that there is a slight increase in fluid entering the soil profile over the retorts compared to undisturbed areas. However, the statistical significance of this apparent characteristic could not be evaluated with the limited data compiled herein.

Pressure permeability tests near retort 24 indicated an overall increase in hydraulic conductivity adjacent to burned/uplifted retorts compared with the undisturbed area. Although permeability values varied over a wider range in the undisturbed area (both higher and lower conductivity measurements recorded) several test sections would not take water at all. This suggests that permeability is controlled by secondary porosity (rock fractures) that are enhanced by mining operations.

Surface infiltration and near surface permeability are the principal parameters that govern shallow fluid migration at the Geokinetics test site. Increased penetration of surface water and enhanced migration through the vadose zone increase the possibility of contact with and leachate generation from potential pollution sources generated by the mining and retorting activities. These fluids would have a negative impact on local groundwater quality should they reach the saturated zone.

However, before drawing any conclusions regarding the extent of threat to groundwater resources in the area, the hydrogeologic conditions, especially permeability of the stratigraphic interval between the retorts and the closest aquifer, should be carefully defined. At the test site this interval consists of several hundred feet of shale, marlstone, oil shale and tar sand. Although these lithologies normally have very low permeability, any secondary permeability introduced by fracturing or jointing must be defined before it may be concluded that a significant threat to groundwater resources does not exist. Extrapolation of results from this study to other sites is valid only to the extent that retorting and hydrogeologic conditions can be defined to be the same as they are for this test site.

## References

*Ground Water Manual* published by the U.S. Department of the Interior, Bureau of Reclamation, 1977. Copies can be obtained from the Bureau's Engineering and Research Center, P.O. Box 25007, Denver Federal Center, Denver, Colorado 80225, Stock #024-003-00106-6.

*Edward W. Hoylman and George W. Quinn are with Kaman Tempo, Santa Barbara, CA 93102.*

***Leslie G. McMillion** and **Edward R. Bates** are the EPA Project Officers (see below).*

*The complete report, entitled "Infiltration and Permeability Testing at Geokinetics Oil Shale Site," (Order No. PB 84-173 806; Cost: $8.50, subject to change) will be available only from:*

*National Technical Information Service*
*5285 Port Royal Road*
*Springfield, VA 22161*
*Telephone: 703-487-4650*

*EPA Project Officer Leslie G. McMillion can be contacted at:*

*Environmental Monitoring Systems Laboratory*
*U.S. Environmental Protection Agency*
*Las Vegas, NV 89114*

*EPA Project Officer Edward R. Bates can be contacted at:*

*Industrial Environmental Research Laboratory*
*U.S. Environmental Protection Agency*
*Cincinnati, OH 45268*

☆ U S GOVERNMENT PRINTING OFFICE; 1984 — 759-015/7678

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

D

Official Business
Penalty for Private Use $300