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SUFFIELD MEMORANDUM NO. 56/73

SUBSURFACE HYDROLOGY AT THE RADIOACTIVE WASTE DISPOSAL SITE, DEFENCE RESEARCH ESTABLISHMENT SUFFIELD - A PRELIMINARY DESCRIPTION (U)

by

F.W. Schwartz

PROJECT NO. 99-30-15

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Results indicate that the permeabilities of the five major stratigraphic units, composing the soil at the site, vary from 2.0×10^{-7} cm./sec for Cretaceous Shales to 1.1×10^{-5} for the middle sand layers. Hydraulic head measurements indicate that the principal direction of groundwater flow is vertically downward and that water so flowing would pass through an unsaturated zone with a maximum thickness of 120 feet.//

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INTRODUCTION

The rate of migration of radioactive contaminants in a geologic system depends upon three important processes, convective transport, dispersive transport and chemical interaction with the porous medium. Hydrogeologic studies at the radioactive waste disposal site, Defence Research Establishment Suffield focus on the detailed evaluation of these processes. This report describes field studies initiated in June 1973, at DRES and presents a preliminary description of the groundwater system. Studies dealing with the chemical retardation capability of the porous medium and the influence of limited recharge to the groundwater system on contaminant migration are currently underway.

Achieving a clear understanding of the role of physical transport processes in contaminant migration required knowledge of the groundwater system. Consider first convective transport, wherein groundwater moves radioactive contaminants from one point to another within the system with the same velocity and in the same direction as the groundwater. The overall effect of dispersive transport is to spread the contaminant front. The velocity of the contaminants in a porous medium is higher or lower than that of the convective front because of movement along longer or shorter flow path lengths. Accordingly, dispersion, which also includes a component of Fickian type mass flow, depends in part upon the velocity of groundwater flow and the structure of the porous medium.

Field Investigations

A groundwater flow system is said to be defined when the subsurface hydraulic conductivity variations and the hydraulic head distributions are known throughout that system. Piezometers (Fig. 1) emplaced at various depths within the groundwater system provide the instrumentation necessary to measure these two parameters. The waterlevel elevation in each standpipe (Fig. 1) is a measure of hydraulic head at the bottom or intake portion of the well. The spatial array of hydraulic head measurements forms the data base required to outline the principal directions of groundwater flow.

The resistance offered by the porous medium to groundwater flow is termed hydraulic conductuvity. A useful procedure for determining the hydraulic conductivity of units adjacent to the intake portion of the piezometer is outlined by Hvorslev (1). This test involves bailing water out of the piezometer and using water level recovery rates to calculate hydraulic conductivity.

Fifteen piezometers ranging in depth from 100 to 230 feet were emplaced after rotary drilling at the radioactive waste disposal site. Water levels in these piezometers and in 8 existing water table observation wells are measured at regular intervals. Drawdown response testing of all wells has been completed.

Soil moisture blocks have been installed at the site and are being calibrated to measure moisture content and temperature at specific depths in the unsaturated zone. At each of 7 sites, 6 to 8 soil moisture blocks were emplaced at depths ranging from 1 to 60 feet (Fig. 1) in holes drilled with a truck mounted auger. A regular monitoring program has been initiated to gather temporal and spatial soil moisture data necessary to define patterns of recharge to the groundwater system. Sites selected for soil moisture block nests include most of the diverse topographic environments found at the site such as hilltops, small depressions and valley bottoms.

The locations of piezometers, soil moisture block nests and existing water table observation wells are indicated in Fig. 2. Low level radioactive material is currently contained in a series of three trenches located in the vicinity of soil moisture site A (Fig. 2).

Throughout the drilling program, grab samples were collected for detailed mineralogic and stratigraphic analysis. The deepest bore hole in each piezometer nest was electric logged to provide additional stratigraphic data. Shelby tube samples of near surface drift deposits, collected in conjunction with the auger drilling program, will be utilized in ion exchange studies.

Geologic Framework

A generalized description of the geology at DRES Experimental Proving Ground is given in Suffield Special Publication No. 64 (2). Near surface units range in age from Cretaceous to Recent.

Figure 3 is a detailed three dimensional representation of the geology in the study area. The insert at the top of the figure indicates the location of the cross sections in relation to the four legal subdivisions that comprise the radioactive waste disposal site. Five important rock stratigraphic units are defined and for simplicity, these are designated upper till unit, middle sand unit, lower till unit, brown silt unit and Cretaceous shale unit.

Characteristically, the till units are stony with sand and silt sized material comprising the matrix. Fractures are evident but not abundant in the upper till unit. Soluble-salts are deposited along fracture traces.

The middle sand unit is a glacio-lacustrine sediment, typically variable in thickness (Fig. 3) and texture. This unit is thickest beneath hill sites, ranging to a maximum thickness of 60 feet. Texturally, the unit varies from well sorted fine sand to poorly bedded silts.

The brown silt unit is a compact, bedded and well sorted silt that reaches a maximum thickness of 140 feet. The Cretaceous shale unit is comprised predominantly of shale but siltstone and sandstone interbeds are common.

Hydraulic Conductivity

The velocity of groundwater flow through a porous medium is in part a function of hydraulic conductivity. Table 1 summarizes values for each of the units.

TABLE 1

Hydraulic Conductivity (cm./sec.)

Unit	Median	Range
Upper Till n = 4	2.0×10^{-5}	8.1×10^{-4} 1.3×10^{-6}
Middle Sand n = 3	1.1×10^{-5}	9.8×10^{-5} 1.0×10^{-5}
Lower Till n = 7	3.1×10^{-5}	1.5×10^{-3} 3.8×10^{-7}
Brown Silt n = 3	7.6×10^{-5}	3.1×10^{-5} 3.7×10^{-7}
Cret. Shale n = 6	2.0×10^{-7}	1.7×10^{-5} 2.4×10^{-8}

n = number of tests

Because the unsaturated zone is up to 130 feet thick, hydraulic conductivity values for the upper till unit and middle sand unit have in some cases been approximated from falling head tests on dry holes that were saturated before the test.

The rather low hydraulic conductivity values from the middle sand unit are somewhat misleading because no piezometer terminates in the well sorted sands that could have values as high as 1×10^{-2} cm./sec. In contrast to the four overlying units, the Cretaceous bedrock unit consistently has hydraulic conductivity values lower than 10^{-6} cm./sec. A single value, 1.7×10^{-5} cm./sec., measured from a fractured sandstone close to the bedrock surface is the only exception.

Groundwater Flow

The spatial variation in hydraulic head on July 17, 1973 and the groundwater flow pattern derived from these measurements are depicted in Fig. 4. Results from drawdown response tests indicate that weter levels in all wells with the exception of well number 34 had reached a stable position after installation and development. Wells emplaced at the end of July, 1973 are being monitored and will provide additional flow system information.

The data in Fig. 4 indicate that this portion of the site is a potential recharge area with groundwater moving downward, away from the water table. Accordingly, radioactive material entering this flow system will be moved downward by convective transport. Additional piezometric data obtained in an area approximately 4 miles Southeast of this site suggest that regionally, groundwater is moving south toward the buried Lethbridge Channel.

Water level monitoring in individual wells can indicate the location and extent of recharge to a groundwater system. The yearly hydrographs of seven water table wells installed in 1972 are presented in Fig. 5. Of note here is the fact that water levels in six of seven wells have virtually remained constant over this time. The water level in well number 2 has gradually fallen approximately 2.5 feet in one year. Water levels in all wells showed no response to 4 inches of rain that fell in a single storm during June 1973 (Fig. 5). These data suggest that the quantity of water moving across the thick unsaturated zone is small. Under these conditions, the decomposition products of solid waste material will enter the groundwater system very slowly.

SUMMARY

On this basis of data obtained from geologic and geophysical logs, it is possible to define five stratigraphic units, upper till unit, middle sand unit, lower till unit, brown silt unit and Cretaceous shale unit. Median values of hydraulic conductivity for the four upper non-consolidated units are in the order of 10^{-5} cm.sec. The Cretaceous shale unit is less permeable with hydraulic conductivity values consistently less than 10^{-6} cm./sec.

Hydraulic head measurements indicate that the principal direction of groundwater flow is vertically downward. Hence, radioactive contaminants entering the groundwater system will be moved downward by convective transport. Perched water or groundwater mounds can develop beneath small depressions that form favourable sites for Spring recharge to the groundwater system.

To reach the zone of saturation, water must pass downward through an unsaturated zone with a maximum thickness of 120 feet. The lack of watertable fluctuations in observation wells suggests that recharge to the groundwater system is limited.

REFERENCES

1. Hvorslev, M.J., 1951, Time Lag and Soil Permeability in Groundwater Observations, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi, Bull. 36.
2. DRES Experimental Proving Ground, Description and Technical Data, Suffield Special Publication No. 64, 1973.

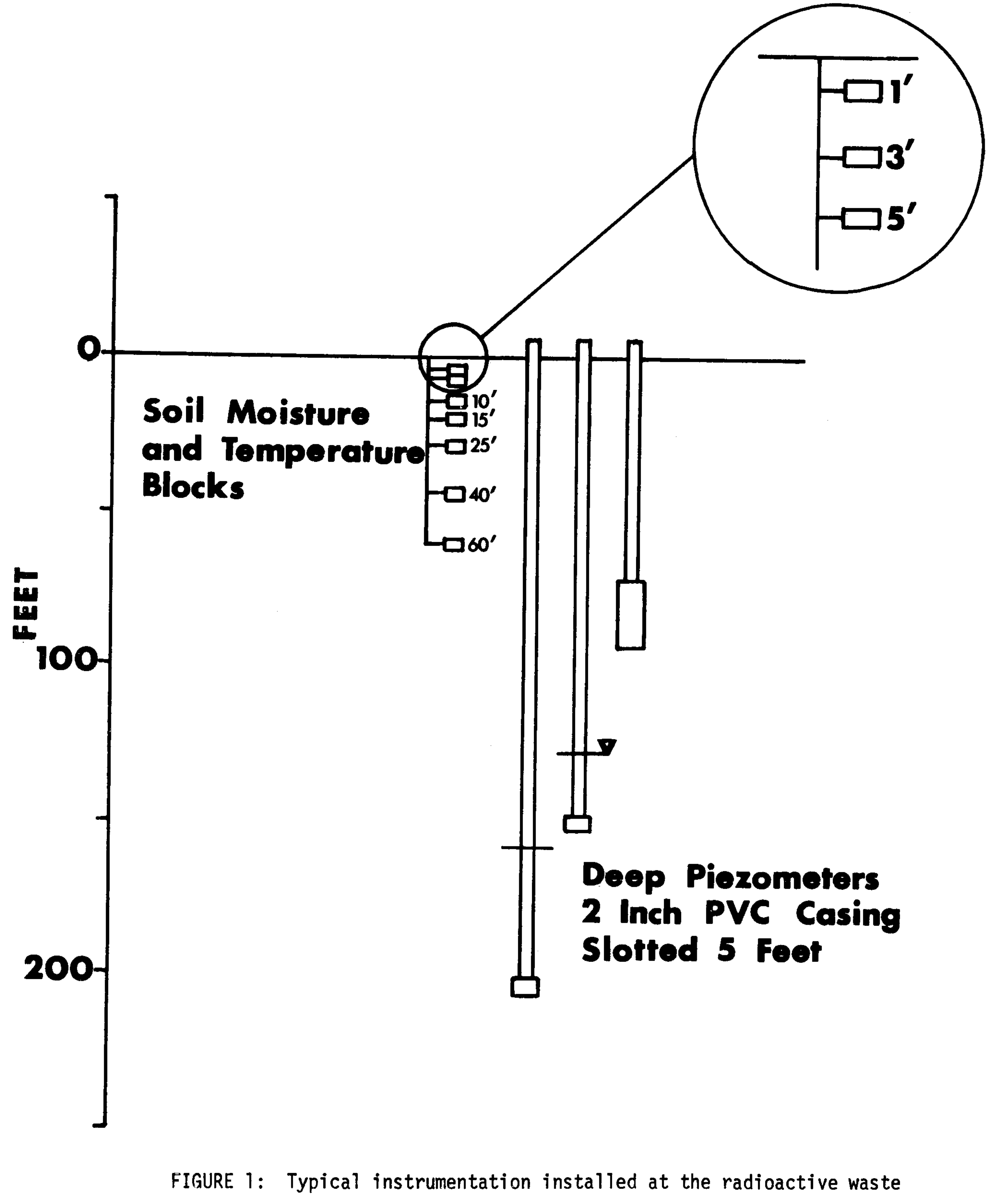

FIGURE 1: Typical instrumentation installed at the radioactive waste disposal site.

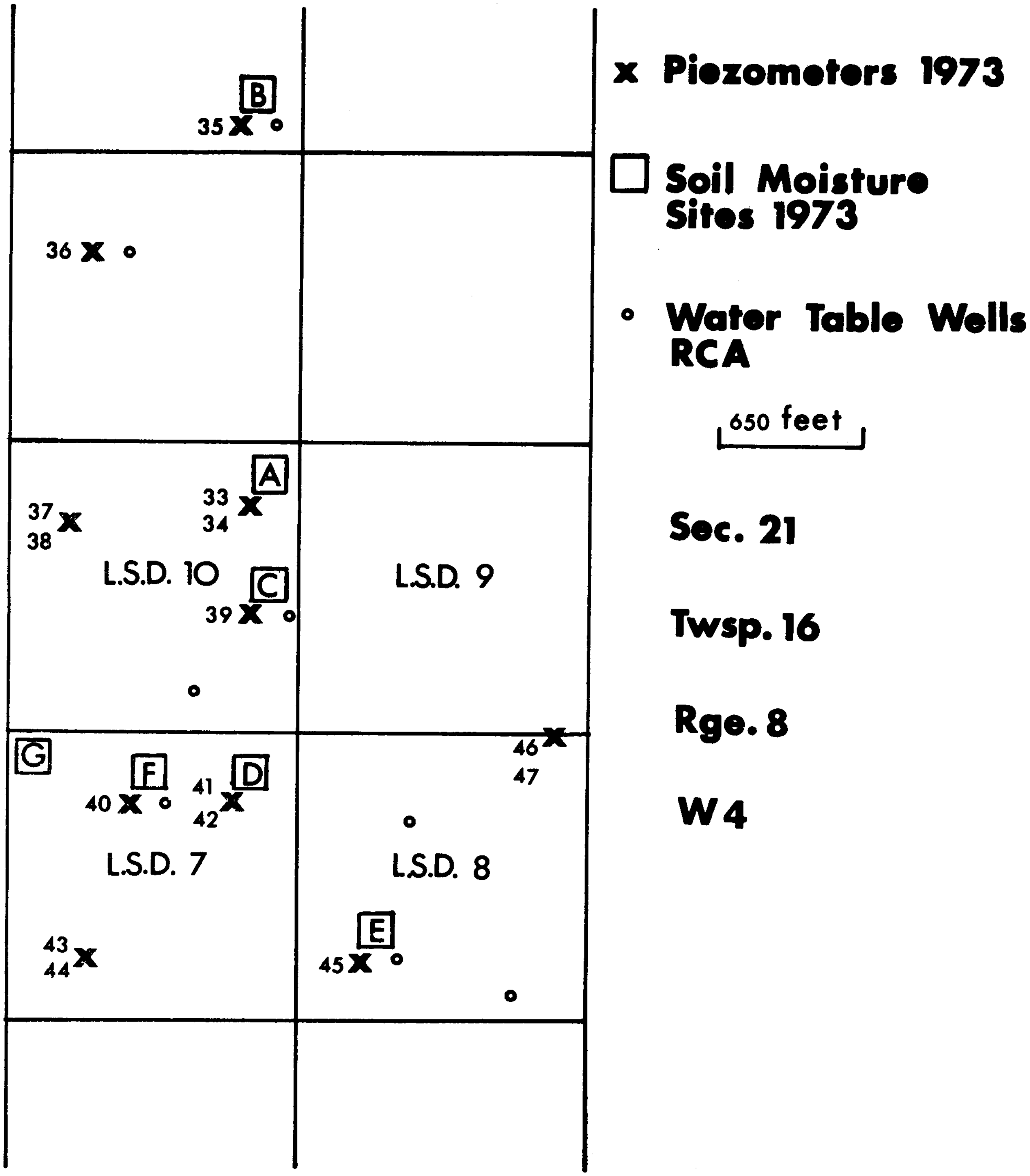

FIGURE 2: Location of the instrumentation in relation to the four legal subdivisions comprising the site.

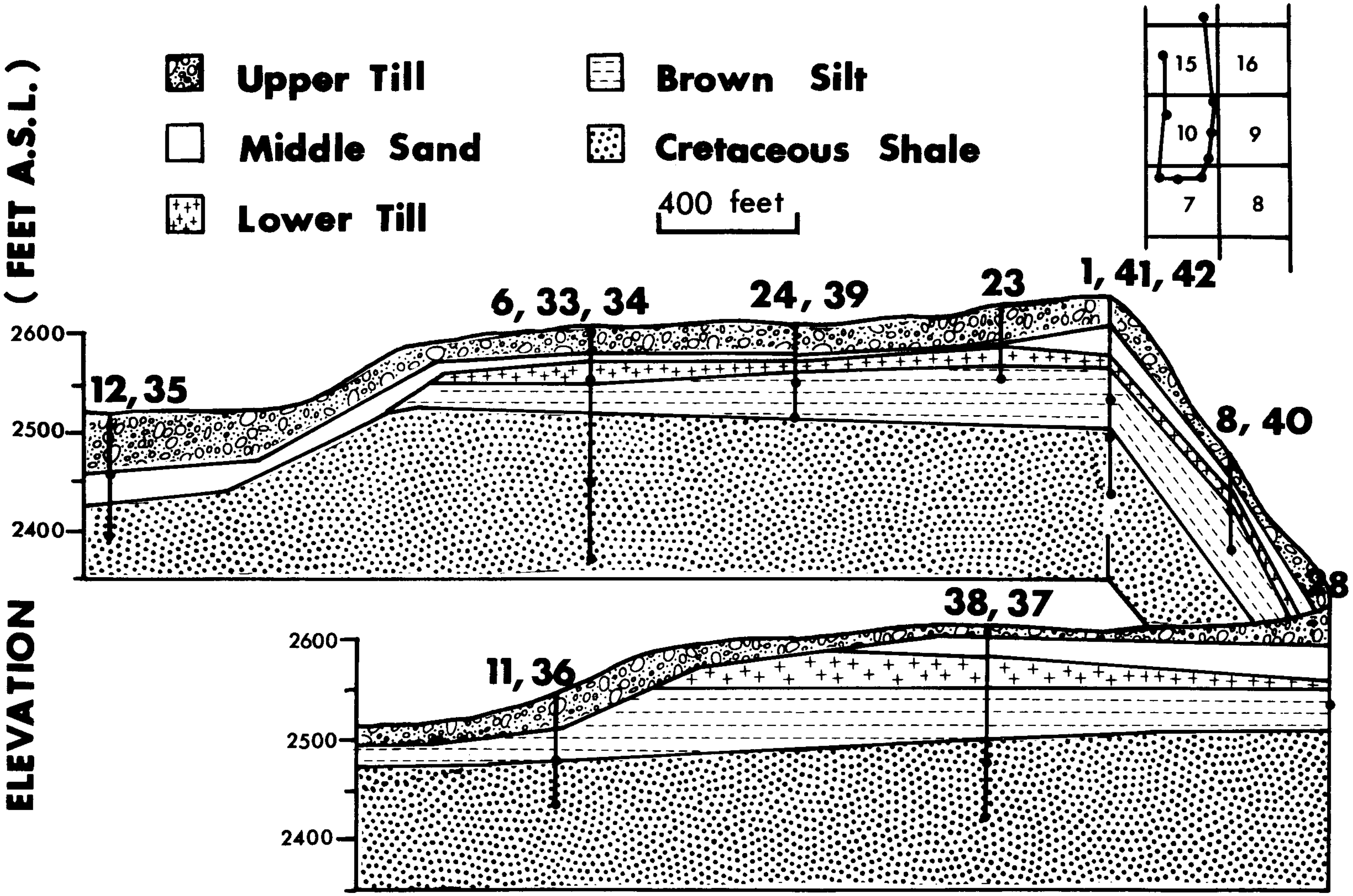

FIGURE 3: The distribution of stratigraphic units.

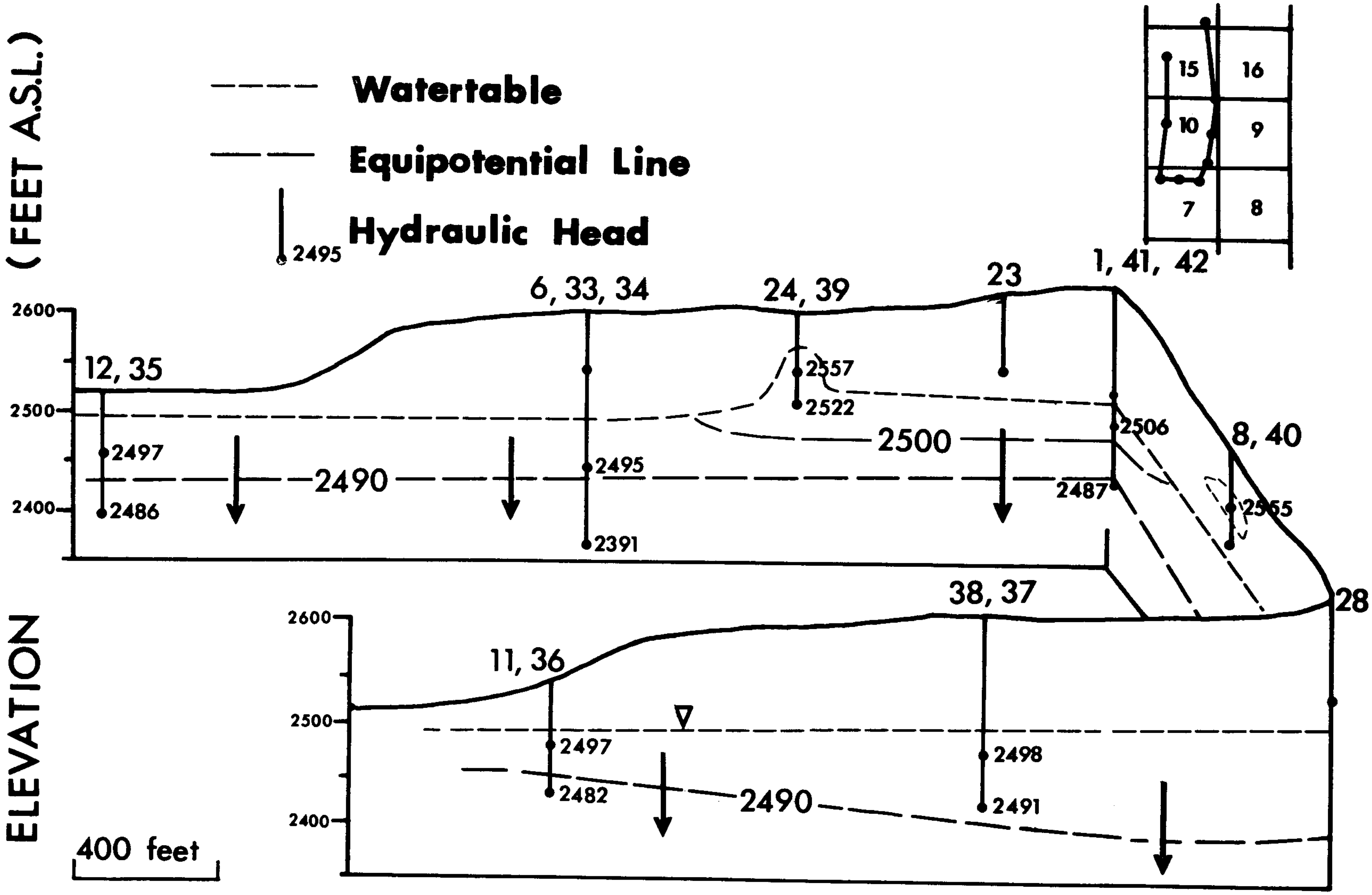

FIGURE 4: Hydraulic head distributions and principal groundwater flow direction.

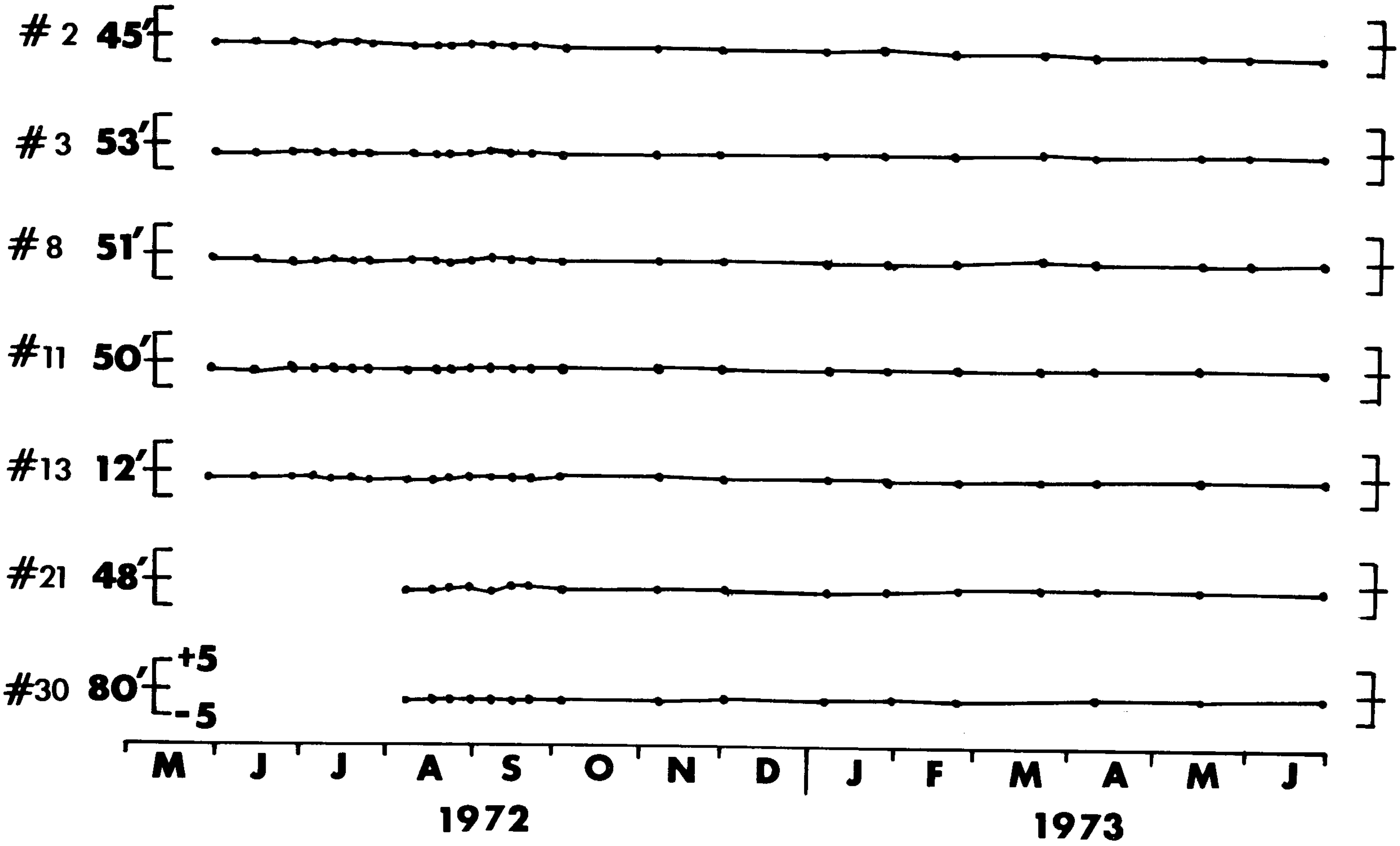

FIGURE 5: Waterlevel fluctuations in seven watertable observation wells.

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