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Studies of the Variations in Water Content in the Unsaturated Zone of an Esker

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In this study the changes in water content in the unsaturated zone of a large esker at Tärnsjö have been measured with a combined gamma/neutron probe. Periods of heavy rainfall and intense snow-melting have resulted in infiltration events, which later have been traced as zones with high water content moving downwards in the unsaturated zone towards the groundwater table. The results indicate a velocity of the movement of such zones of about 1.5-3.0 m/month. These results are compared with those obtained by Andersen and Sevel (1974) from a study in Denmark, and with preliminary results from a study of the movement of tritiated water in the unsaturated zone of the Tärnsjö esker performed by Z. Dressie.

Investigation Area and Research Program

In the Tärnsjö area, 50 km NW of Uppsala, Sweden, a hydrological research area has been established in order to study the water budget of and groundwater recharge to a large glaciofluvial esker aquifer. The project is performed by the Geological Survey of Sweden (SGU) in cooperation with the Department of Hydrology, University of Uppsala.

Data for the water budget study are obtained from different stations in the area recording climatic parameters, i.e. precipitation, snow accumulation, spring discharge, and groundwater level variations. The extension and composition of the esker aquifer have been investigated through geological mapping, borings and seismic investigations.

The studied esker is a typical representative of the large eskers of the eastern part of south central Sweden. It was formed below sea-level and has thus been exposed to wave-action which has caused some redeposition of sand and gravel. The esker forms a 0.5-1.0 km wide ridge, rising 20-60 m above the surrounding terrain, which is dominated by till, clay and redeposited sand. The glaciofluvial sand and gravel of the esker are partly covered by glacial clay, which has a low permeability, preventing substantial exchange of water between the esker aquifer and the small aquifers of the surrounding terrain. The visible discharge of the esker aquifer is concentrated to a few large springs and the recharge takes place through percolation of water which infiltrates on the top of the esker where the clay cover has been removed by wave erosion. The area is shown in Fig. 1, and is described in more detail by Nordberg and Persson (1974).

Studies of the Unsaturated Zone

The unsaturated zone through which the recharge to the esker aquifer takes place has locally a thickness of more than 40 m, in most areas however only 10-20 m.

The downward movement of water which has infiltrated through the surface of the esker has been studied by SGU for several years by means of a combined gamma/neutron probe at an observation station near the western margin of the esker (see Fig. 1). The station consists of an iron tube with a diameter of 50 mm penetrating the unsaturated zone down to the groundwater level, which is situated about 15.5 m below land surface at this place.

Measurements with the neutron probe of the soil moisture content are performed regularly once or periodically twice a month on each 10 cm level between land surface and the groundwater level. Measurements of the density with a gamma probe have made it possible to compute approximately the water content at the different levels. The interest in this study, however, has been focused on the variations from time to time in the water content. Figs. 2 and 3 present diagrams showing these variations during the autumn, winter and spring 1976/77. In the diagrams also information about stratigraphy, precipitation, snow cover and groundwater level are found.

In the diagram in Fig. 2 a great increase in the water content in the uppermost part of the unsaturated zone is registered both in August and November 1976. The high water content can easily be connected with two periods of heavy rainfall in late July/early August and early November. These rainfall periods evidently caused considerable infiltration of water. The further percolation of the water has taken place as zones with high water content are moving downwards through the

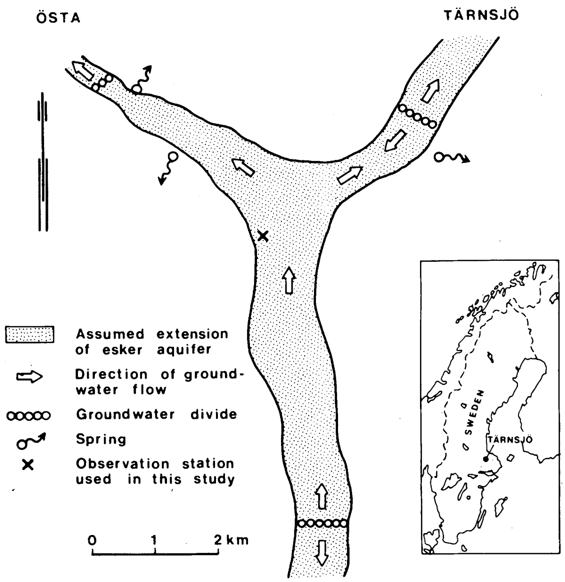

Fig. 1. Map showing the location of the studied esker aquifer at Tärnsjö.

unsaturated zone. The velocity of these moving zones is about 1.5 m/month.

Fig. 3 shows two infiltration events caused by two periods of intense snow melting in March and April 1977. The velocity of the moving wet zones caused by these events is about 2.5-3.0 m/month.

The recorded differences in velocities of the downward movement of the wet zones between the autumn 1976 and spring 1977, indicate that the velocity is governed not only by the properties of the geological material but also by the moisture content in the material.

A water content less than the field capacity would delay the movement of the front of percolating water as the percolation would not continue until field capacity is reached.

The summer of 1976 was very dry and therefore the water content in the unsaturated zone was low during the late summer and early autumn that year. As an effect of the rainfalls during the autumn the water content in the unsaturated zone was higher next spring.

It has not been possible to follow any zone of high moisture content below a depth of 7-8 m. Most zones seem to disappear at a depth of 5 m. At the depth of 7.5 m layers with low permeability (clay and silt) are found. They make further percolation difficult, and from time to time, for example in May 1977, full saturation seems to be reached just above these layers. Thus an upper groundwa-

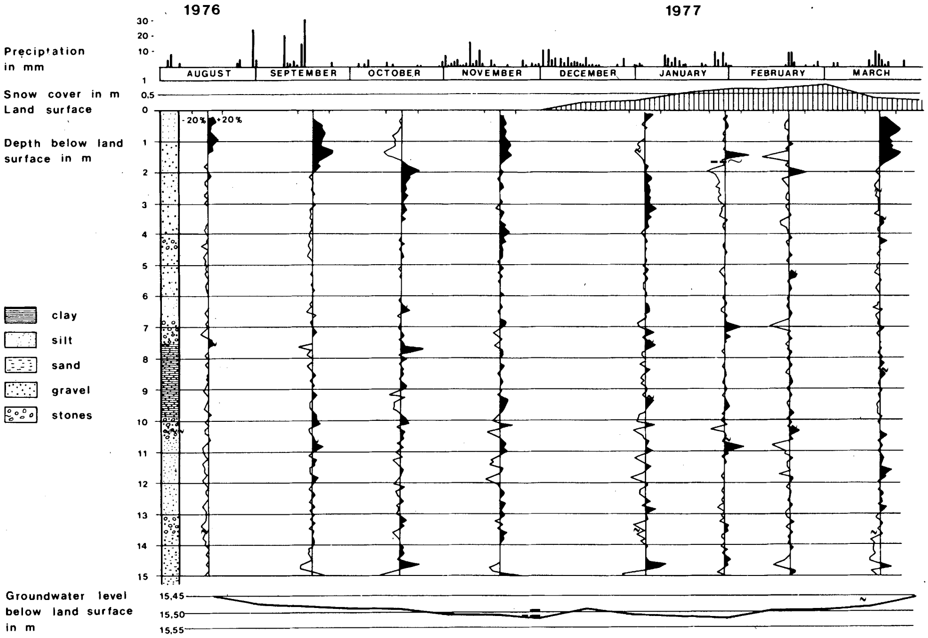

Fig. 2. Diagram showing the changes in soil moisture content in the unsaturated zone at an observation station in the Tärnsjö esker from August 1976 to March 1977. Each profile shows the changes in water content from the previous observation expressed as the difference in per cent units between the recorded degree of water saturation at the two occasions. In the diagram also precipitation, snow cover, changes in groundwater level and stratigraphy are shown.

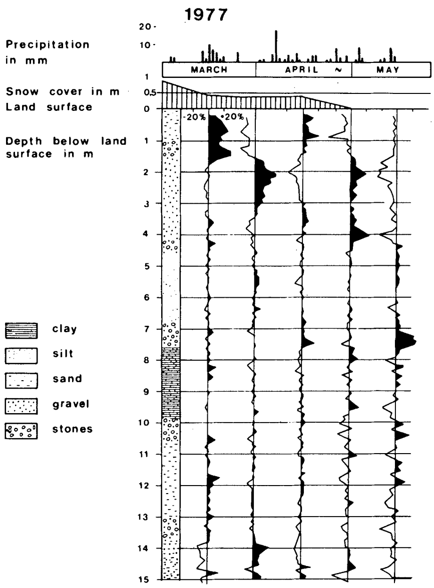

Fig. 3. Diagram showing the changes in soil moisture content in the unsaturated zone at the same station as in Fig. 2 from March to May 1977. For further explanation see Fig. 2.

ter table is formed temporarily. The upper groundwater is probably mainly drained laterally towards the west above the clay layer. In more central parts of the esker where no clay is found the percolation can continue making up groundwater recharge.

The rising groundwater level found in March 1977 probably is the result of recharge caused by the autumn precipitation from 1976, which has taken place in other parts of the aquifer. Due to the great differences in the thickness of the unsaturated zone in different parts of the esker, water that infiltrated simultaneously will cause groundwater recharge at different times in different parts of the aquifer. This will have a levelling effect on the groundwater level variations.

Comparisons with other Studies

The results can be compared with the results from a study made by Andersen and Sevel (1974) in a glaciofluvial outwash deposit at Grønhøj in Denmark. The deposit is built up mainly of sand and gravel. Andersen and Sevel also used a neutron moisture probe for identifying zones with high moisture content moving downwards through the unsaturated zone. In the Grønhøj study a velocity of 3-3.5 m/month was recorded which is somewhat higher than the velocity recorded at Tärnsjö. The difference probably is due to differences in grain size distribution between the two deposits.

By studying the changes in tritium content of the water in the unsaturated zone, Andersen and Sevel have shown that the true velocity of the percolating water in the studied profile is only 4.5 m/year. The velocity of the zones of high moisture content which was about 10-12 times higher apparently represents only the velocity of a wave movement through which new water is displacing old water successively when the wave moves downwards.

When studying the water budget of an aquifer the apparent wave velocity is the interesting one, as recharge is obtained when the wave reaches the groundwater level. Contrary, when studying for example the movements of pollutants in the ground the true velocity of the water is of great interest.

A study of the true water velocity in the unsaturated zone of the Tärnsjö esker was started in 1977 by the Department of Hydrology, Uppsala. In that study water with high tritium content is injected at a depth of 0.4 m and the downward movement of the water is followed by sampling on each 15 cm every month to a depth of 1.6 m. Only very preliminary results have been obtained yet. They indicate a velocity of about 0.5 m/month (personal communication by Z. Dressie), which would be about 1/3-1/6 of the apparent wave velocity.

The velocities obtained by Andersen and Sevel and those obtained from the studies at Tärnsjö are compared in the following table.

Table 1 – Velocities of the downward movement of water through the unsaturated zone.

	True velocity m/month	Apparent velocity m/month
Grønhøj		
(Andersen and Sevel 1974)	0.4	3.0 - 3.5
Tärnsjö	~0.5	1.5 - 3.0

Future investigation Program

The measurement of the variations in water content in the unsaturated zone will continue at the observation station used in this study, and will also start at stations in other parts of the aquifer.

References

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