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PROBLEMS OF EFFLUENT DISPERSION IN KARST AQUIFERS

by

Philip PAPARD [1]

(3 figures)

RESUME. - Problèmes de dispersion d'effluents dans les aquifères karstiques.
Les pouvoirs publics, confrontés avec des questions d'effluents à petite échelle dans des questions d'alimentation en eau, omettent parfois de considérer le rôle de la dissolution dans certains aquifères. Deux exemples de problèmes en résultant sont présentés. Les conséquences en sont examinées; elles ne sont pas limitées aux roches karstiques typiques (calcaire, dolomie et évaporites). Les modèles conceptuels simples d'aquifères ne peuvent suffire que lorsqu'on les considère à une échelle suffisante. Il est proposé de faire connaître aux pouvoirs publics les résultats acquis grâce aux études karstiques concernant l'utilisation de ressources aquifères à une petite échelle.

ABSTRACT. - Officials dealing with small scale effluent and water supply problems, often do not appreciate the solutional nature of many aquifers. Two example problems resulting from this in a limestone aquifer are given. The possible extent of the problem is examined and is found not to be restricted to normal karst rocks. The problem occurs due to the incorrect use of conceptual aquifer models, these simple models are justified only when used on an aquifer of sufficient scale, the scale being a function of the problem and rock type. The terms, dynamic and static aquifers are defined. It is suggested that knowledge gained from karst studies needs to be more widely disseminated amongst officials who deal with small scale water supplies.

INTRODUCTION

The potential pollution of water supplies is a problem of concern not only to hydrogeologists and water quality scientists, but also to health and planning officials of local authorities. The nature of aquifers is varied and complex and researchers have approached the problem from different basic models. In engineering hydrology "Darcian" type models are the basic building blocks whereas karst hydrology is based on a conduit model.

An awareness of the problems that might arise in non mains supplied dwellings and farms is needed by an official dealing with the supply if he is to seek the correct advise. This problem is prevalent in limestone areas which cannot be described adequately by statistical averaging laws on a local scale. This paper describes some minor problems in a limestone area and suggests that one reason for not understanding the problem is the nature of the concept of aquifers held by the official.

THE INFLUENCE OF AQUIFER MODELS ON CONCEPTUAL IDEAS

The conceptual idea that we have of an aquifer depends upon our past experience or training. Most of the elementary texts on hydrology start from the simple homogeneous Darcy model. This model is then modified by adding anisotropy and inhomogeneity, fitting it to a real situation. Unfortunately if the student studies the subject only to an intermediate level, the complex examples are not given in any detail. If limestone aquifers are mentioned it is usually implied that a "fissure" model can be fitted. The detailed nature of karst aquifers may be taught to geomorphology students, but they are unlikely to be potential officials.

We find two types of aquifer concepts develop from the basic models :

a. Homogeneous aquifers. - flow can be described by some form of statistical law, if enough parameters can be added to the model it will fit reality.

b. Conduit aquifers. - flow analogous to a three dimensional river system, it is necessary to know about the dynamics of the system to model the flow.

These conceptual models are end members of a series, Darcy appreciated that in principal you could model a primary aquifer by modelling the intergranular flows. In reality this is unfeasible and unnecessary as

1 2 Featherbeck Close Ingleton, Carnforth, Lancs., England.

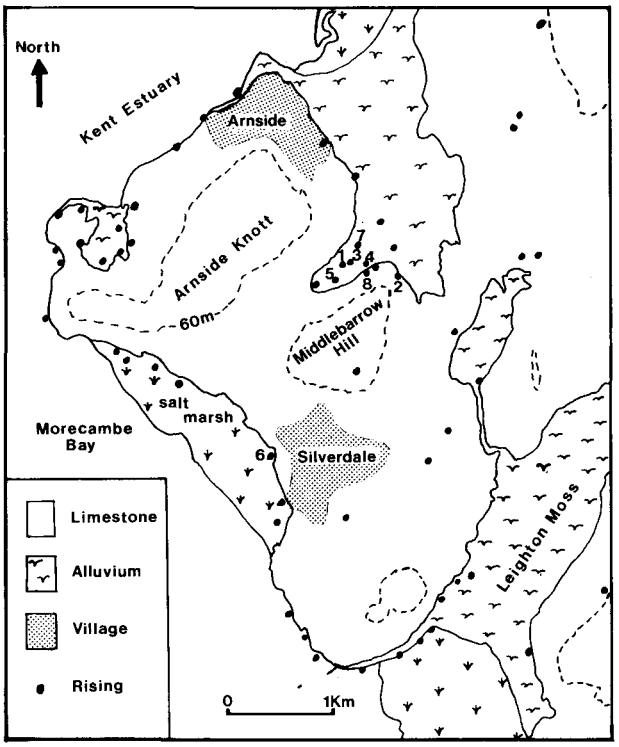

Figure 1. - Silverdale and Arnside
1. Arnside Tower Main Rising. — 2. Middlebarrow Well. 6. Cove Well. — Numbers of springs also apply to other figures.

it is the average flow that is important. As the scale increases a point is reached where it is feasible to model the aquifer by the individual fissure flows, but is it necessary ? The answer depends on the scale, the problem and "fissure" spacing. For a karst aquifer with cave spacing of the order of kilometers a very large area is needed to model the flow stastically. Hybrid models are often introduced where conduit flow can be superimposed on a flow net (Cullen IV, 1984). These models can be successful for predicting storage and flows, any unknown conduits will tend to increase the effective transmissivity. For water supplies there may be extra available water to that predicted, but the risk of pollution from point sources may not be predicted with certainty even if macroscopic dispersion is used (Smith, 1980). For point pollution problems the hydrogeological characteristics of the aquifer must be assessed (Young, 1981) so the geology, hydraulic gradient and geomorphology of the site needs to be examined to identify risk areas. These can then be tested in the field using tracing and other techniques.

EXAMPLES

Silverdale village in North West England, is built on a free limestone karst consisting of three hills on a line North to South bounded by Morecambe Bay, the Kent Estuary and low alluvial grazing land (10 m max.). Karst springs are situated around the edge, there being no permanent surface drainage above this level. Silverdale has no piped sewerage system and there is some problem with septic tank effluent in dry weather.

INFILTRATION CASE

In 1982 there was some controversy about a proposal to build on pasture in the middle of the village. There have been a few complaints about a smell of sewerage, allegedly from septic tank liquor. It was suggested that more dwellings in the area would aggravate the problem.

The complaint about smell had not been substantiated, having occurred only occasionally in dry weather when it was assumed that the groundwater had been contaminated, planning officials were sufficiently concerned to seek advice on the problem. In conversation with these officials it transpired that the problem was probably due to poor infiltration of liquor into the limestone at a few localities.

The only tests carried out had been on seepage in the soil cover. It was assumed that the effluent would go into the aquifer without any problems, they had not realised the nature of secondary permeable aquifers assuming the permeability to be homogeneous in detail. It was explained that it was possible for the liquor to travel along the limestone-soil boundary for a considerable distance until an open fissure was reached. Non dilution effects in dry weather could then cause the smell in those areas where the effluent had not yet entered the limestone.

FILTRATION CASE

At Arnside Tower a karst spring drains an area of wooded pavement around Middlebarrow Hill and the northern part of Silverdale, it exhibits small pulses at spring tides and occasionally becomes brackish. The spring is a multiple one, consisting of more than ten individual outlets each showing a different chemistry, but these have been shown to be different mixtures of two basic water types (fig. 2), they plot on a straight line with water from Cove Well and the Kent Estuary. Elevated nitrate and phosphate levels indicate some pollution of the aquifer in this area, the spring at Arnside Tower becomes anoxic in extended dry weather, the last occasion being August 1983. Dye breakthrough curves (fig. 3) indicate that there is conduit flow superimposed on the secondary storage and transmissivity of the limestone (Papard, 1984).

The preliminary results of tests on this spring complex were being discussed with two public health officers as a way of illustrating a possible cause of a problem they had near Kendal. When it was explained that a limestone aquifer can transmit water in a way not dissimilar to a stream, in a short time with little filtering, they were surprised. From their training/background they thought that most spring water would be fairly

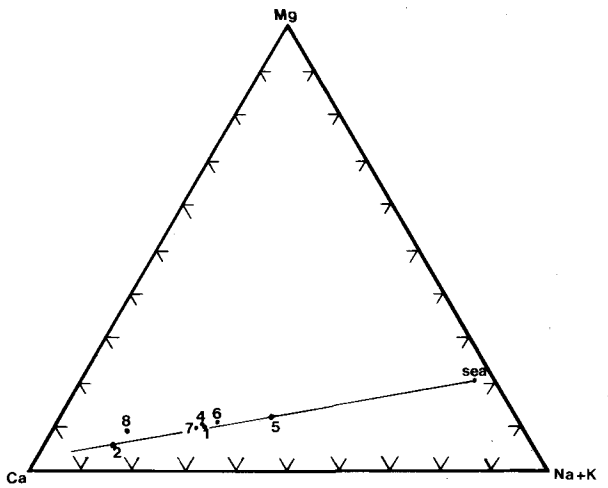

Figure 2
Trilinear diagram of cations for the Arnside Tower Complex, 13/10/1983.

pure, because it was filtered, they also assumed residence times would be long. This was surprising as one of the officials had been caving, but he had not associated the water flow in caves with the flow in the low lying limestone near Kendal.

NON KARST AQUIFERS

Conduit flow is not restricted to those rocks normally considered to show karstic hydrology, ie limestones, dolomite and evaporites. In a recent report on double-packer injection testing of the Penrith sandstone, Cumbria (Price *et al.*, 1982), conduit flow was shown to be important. This Permian, aeolian sandstone is considered to be a good example of a Darcian type aquifer, although it is known to show anisotropy. The results on a 60 m deep bore hole with a rest water level at 16 m indicated that two of the twenty intervals tested were responsible for the majority of water flow. CCTV showed a fissure in each of these sections was responsible for the high flow. "... two fissures together contribute 85 °/o of the transmissivity . . ." (Price *et al.*, 1982).

If this is true for a randomly drilled borehole in a rock with high primary porosity, it must be a possible consideration in any aquifer dispersion problem. Any "dynamic" aquifer may show an increased anisotropy ratio due to solution, given enough time, the time required being a function of the rock, water chemistry and degree of dynamism of the aquifer. The implications for effluent dispersion need to be examined in more detail.

DEFINITIONS

Dynamic aquifer - An aquifer in which the fluid is in measurable macroscopic motion.

Static aquifer - An aquifer in which the fluid is macroscopically static.

CONCLUSIONS

The basic nature of karst hydrology is simple to understand, being largely descriptive. There is no reason why entrants into the planning and environmental health professions should not have an understanding of the potential problems of conduit flow. The appraisal methods of pollution risk need not be taught, as long as expert help is available, but the problem has to be recognised before getting the relevant advice.

The dissemination of information on the nature of aquifers examined by karst hydrologists needs to be actively persued, especially to those involved in small scale water supplies. This needs to be done in two ways.

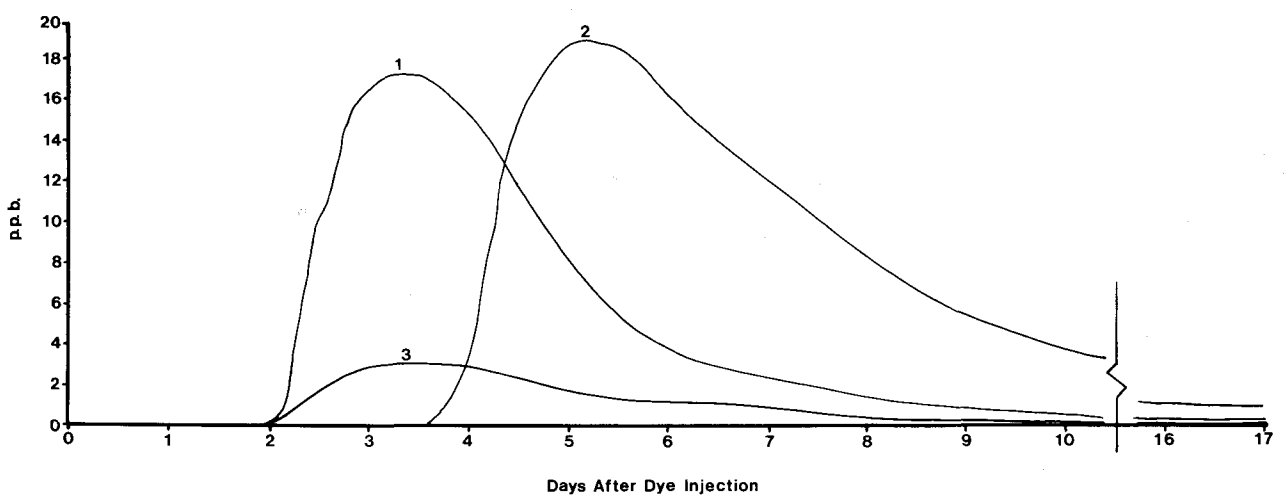

Figure 3.- Rhodamine W.T. breakthrough curves, for Arnside Tower Complex. Dye injected into Cove Well, noon 19/03/1984.

a) Bring the approach of karst hydrology into the curriculum of all hydrology courses.

b) Bring to the attention of existing officials the nature of the possible problems.

This paper is presented in the hope it will stimulate discussion on the best way to achieve the above aims.

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