LABORATORY RESEARCH ON INTERCEPTOR DRAINS[a]

Closure by A. R. Robinson

A. R. ROBINSON,[1] M. ASCE.—The number of discussions that were prepared on the original paper was very gratifying. To some extent these discussions indicate the need for an expanded program of research in the field of subsurface drainage. It has been the writer's experience that there is a tremendous gap between the theoretical knowledge and that which is being applied to solve field drainage problems. The study which was reported in the original paper was an attempt to bridge this gap in one selected phase of the problem.

Subsurface drainage is a phenomenon which is very complex and each situation is different in some respect from every other situation. Soil variability, both in texture and profile, is probably the most predominant factor. Many variations in hydraulic conductivity for soils of similar texture but with different structural characteristics are common. The hydraulic conductivity also may vary with moisture content. Flow in the zone of partial saturation is very complex and has not received adequate treatment. Many studies, both laboratory and field, have been made of flow below the water table, that is fully saturated. In order to reduce the number of variables, in many cases laboratory studies have been idealized to the point of questionable adaptation. The results from many field evaluations are inconclusive because numerous unmeasured variables were not considered.

The discussions have pointed out several areas in which this model study was limited or deficient. Messrs. van Schilfgaarde and Bouwer indicated the importance of flow above the water table. They point out that the amount of flow in this region of partial saturation may be appreciable. In this study the material was very coarse so that the so-called capillary fringe was approximately 1.5 in. in height. The amount of flow in this zone was undoubtedly insignificant. It is certainly true that flow in the zone of partial saturation is important in drainage considerations and has received little attention from a research standpoint.

Maasland, Sutton, Donnan, Nelson, and Long each point out the importance of the shape of water table downstream from the drain. This portion of the water table was arbitrarily fixed in the study that was reported. Nelson pointed out the relationship of the downstream condition to the upstream one. He shows that the downstream water table in the model study was always set to a smaller depth than it should have been. As a result, the upstream water table would

---

[a] September, 1959, by Jack Keller and A. R. Robinson. A contribution from the Soil and Water Conservation Research Div., Agric. Research Service, U. S. Dept. of Agric., and Colorado Agric. Experiment Sta., Fort Collins, Colo.

[1] Agric. Engr., Western Soil and Water Mgt. Research Branch, U. S. Dept. of Agric., Agric. Research Service, Soil and Water Conservation Research Div., and Colorado Agric. Experiment Sta., Fort Collins, Colo.

be lowered from that which was observed. This condition would also cause the drain to intercept less of the flow than would have otherwise been removed under the natural condition. Possibly the most pressing need for further drainage research is in the area downslope from the interceptor drain.

It was pointed out by Maasland and Long that the problem has been simplified to the steady state one. According to Massland, solution of steady state flow problems is inadequate for most practical problems. It is the author's observation that the steady state solution is usually the only one used for practical problems. As a general rule, the solution for the transient state becomes so involved that it is rarely ever used for the field situation. This is unfortunate since the steady state assumption is one which rarely exists. Long states that the common situation is one where there is local accretion, usually from irrigation, as well as flow from an outside source. He states that it was unfortunate that the effect of this local accretion was not evaluated in the reported study. It is certainly true that this effect should have been evaluated although the model study was not intended as a general study of drainage but was to include only one selected phase. Maasland states that an exact equation can be obtained for the water table which includes the effect of both the sloping impervious layer and surface applied recharge. Maasland implies that this solution is not yet available but can be easily obtained.

Mr. Maasland seemed to be highly disturbed that a considerable amount of information, from which he quotes, was not used for background material for the study. He also states that neither the basic differential equation nor the formula reported by Donnan (1) and used in this paper as Eq. 10 were new or of recent date. It is recognized by those trained in the field of flow in porous media that the developments of Boussinesq and Forchheimer were made. The so-called Glover formula (Eq. 10) was derived independently by Glover from heat flow analogies and is being used for interceptor drain design. It should be re-emphasized that the reported study was not meant to be a general thesis on the entire field of interceptor drainage but was only intended to encompass certain portions of the problem. Mr. Maasland was correct in pointing out that the reported hydraulic conductivity of the material seemed very low. This conductivity should have been given as 0.038 ft per sec.

Mr. Donnan points out some of the developments that led to initiation of the study. The recognition of need for the study as well as some of the preliminary planning was made by Mr. Donnan. He points out that there should be more emphasis on drainage research conducted in large tilting flumes. The author agrees that there are many phases which can be studied in a large tank. The large model gives a scaled physical picture of the problem which makes the information obtained more understandable. However, as pointed out by Bouwer, an electrical analog is especially adapted for studies of this type. Data can be collected, using an analog, at much less expense and in a shorter time. The accuracy of the data should be as good or better than when using the large equipment. As stated by Mr. Bouwer, the resistance network analog affords a simultaneous solution of flow above, as well as below, the water table.

Two significant developments by van Schilfgaarde and Nelson are of note. Mr. Nelson's starts with the basic equation and gives the boundary conditions. From these equations he selects the dimensionless parameters that completely describe the flow system. This he terms inspectional analysis in contrast to dimensional analysis, which was used in the original paper. Using this procedure, the geometry of the downstream water table was included in the problem. Mr. van Schilfgaarde rearranged the original Eq. 10 into dimensionless form, which yielded his Eq. 2. From this, he obtained Fig. 1 which is a more usable solution than that obtained from Fig. 3 in the original paper.

From the comments of Mr. van Schilfgaarde relative to the introduction of H', an explanation is needed. In the original derivation of Eq. 10 it was evidently not recognized that in certain cases the flow in the system would not be constant before and after drain installation. In the case of a system where there is an increase in flow, a term was needed that would include the original depth, H, plus some additional depth to compensate for the additional energy in the system. The sum of these two was given the term, H', so as to not confuse the original depth of flow H.

The computational aid for the solution of Eq. 11, which was prepared by Mr. Nelson is very commendable. This will allow rapid solution of the equation for either shape of the drawdown curve or flux.

Mr. van Schilfgaarde stated that the author's data substantiate the assumptions underlying their theory and that therefore one should not hesitate to use the theory freely for solution of problems within the limitations of this study. This statement is certainly true and the major limitations should be repeated. The conditions were; (1) a sloping, impermeable boundary existed at some measurable distance below the water table, (2) a defined source existed at some determined distance from the drain location, and (3) a source that was constant in elevation and able to supply additional flow as needed to satisfy the system.