# WATER MOVEMENT IN SOIL AS SHOWN BY TIME LAPSE MOTION PICTURES

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Water is nearly always moving in soil. The water itself is a plant nutrient, but of equal importance is the fact that mineral nutrients are carried as solvents in the water. Mineral nutrition depends to a large degree upon the water present. Water is removed from the soil by evaporation from the soil surface, absorption and transpiration by plants and by deep percolation below the root zone. Immediately after rainfall or irrigation, water moves through the soil at a rate which depends upon the amount added, initial moisture conditions and upon porosity and porosity changes within the soil profile. How deeply the soil is wetted, the quantity of water retained in the soil, and the fineness of the pores which hold water determine how much water will be available for plant growth. How water moves or is retained in soil is not evident from observations or measurements made only in the plow zone. Underlying strata have a profound effect upon water penetration characteristics.

The effects of various kinds of stratification upon water movement and retention can be shown graphically in time-lapse motion pictures of artifical soil profiles into which water is moving. With an interval between pictures of from a few seconds up to $\frac{1}{2}$ minute, when the film is run in a projector at 24 frames per second action requiring several hours is reduced to minutes. The types of stratification shown in the moving picture were selected to illustrate principles of water movement. A few of these principles are shown in photographs here. These principles, although not always so strikingly evident, may be observed in nature if trouble is taken to examine soil profiles soon after water has been applied.

Under unsaturated conditions water movement is controlled more by absorptive forces than by gravitation. These absorptive forces are due to the attraction of soil particles for water. Under unsaturated conditions water moves in thin films on the surfaces of particles and at contact points between them; liquid water does not move through the large air-filled pores. Water movement under unsaturated conditions is illustrated in Figure 1 where water has been introduced at the center of a model and the wetting-front has moved out in all directions almost equally. The small effect of gravitation may be observed in the slight difference in downward and upward movement. Under saturated conditions or as saturation is approached gravitation would play a much greater role.

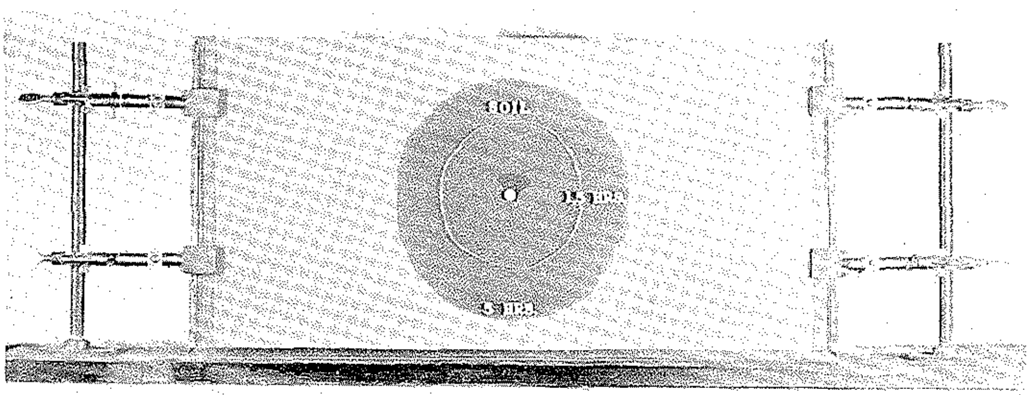

Fig. 1

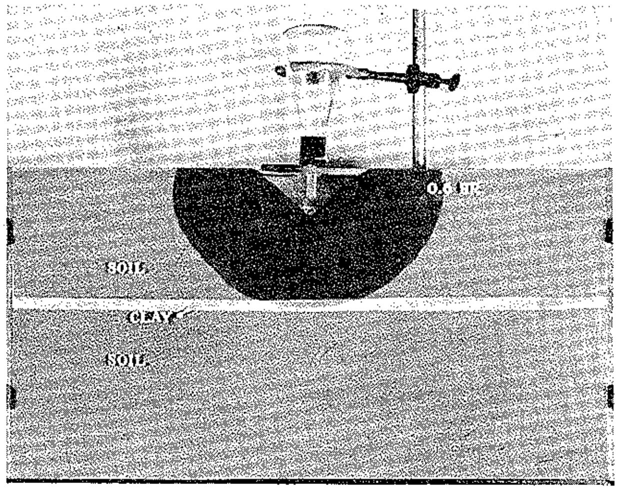


Fig. 2 A

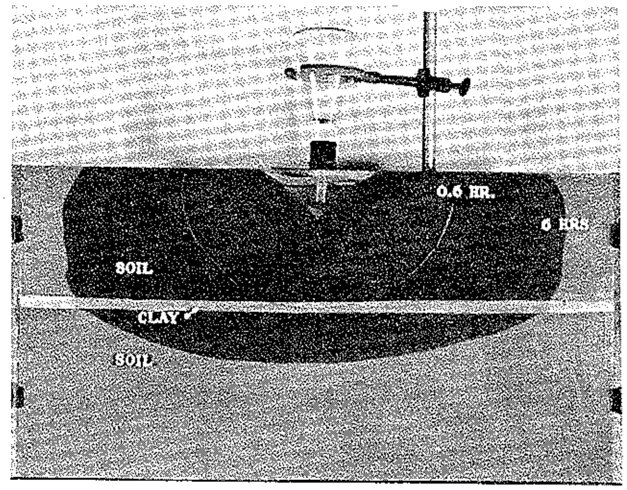


Fig. 2 B

Any change in porosity encountered by a wetting-front will affect the rate of movement of the wetting-front. Usually the rate of movement is decreased. When zones of very fine pores are reached the rate of movement is decreased because of flow resistance due to the smallness of the transmitting channels (Figure 2). Plow plans and clay pans, although they do wet up, transmit water so slowly that water tables are often built up above them.

When zones of larger pores are reached, as might occur where a fine soil material contains a layer of coarse sand, the advance of the wetting-front is stopped until such time as sufficient water is present to permit the much larger pores to fill (Figure 3). This is much the same as adding water to a piece of blotting paper which must become saturated before it will drip.

There are large acreages of soil in the Pacific Northwest and elsewhere where

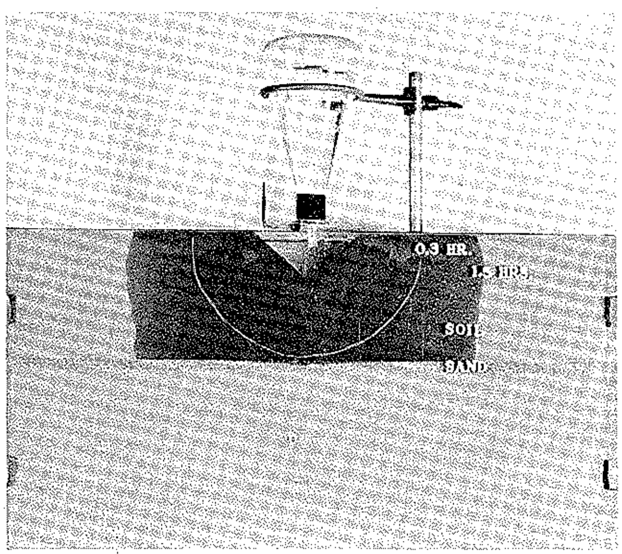


Fig. 3 A

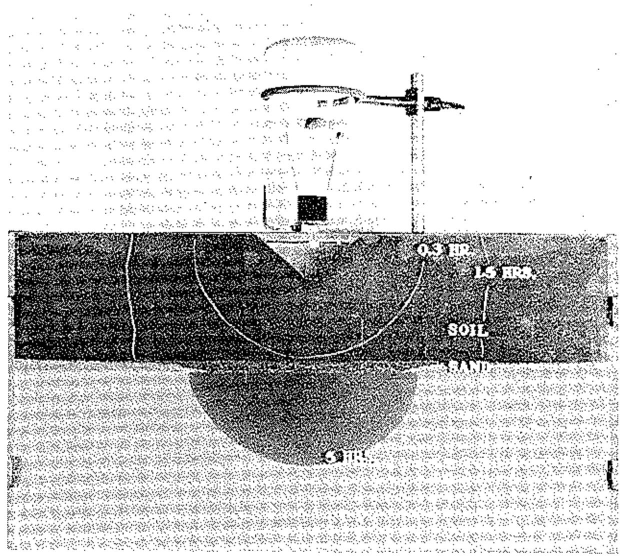


Fig. 3 B

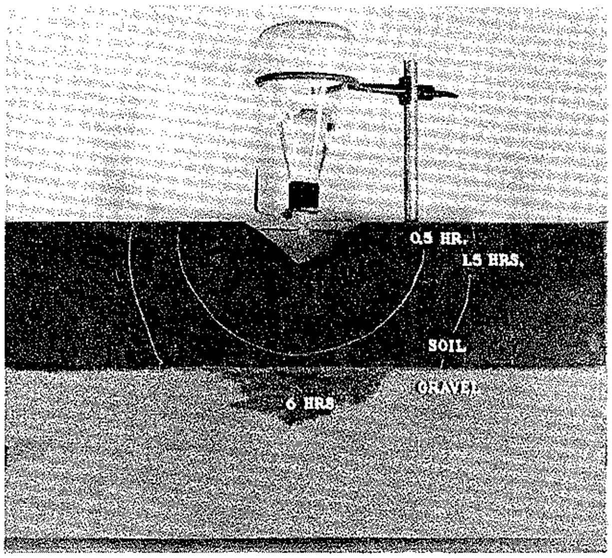


Fig. 4

a fine soil material overlies coarse sands and gravels. Under these conditions (figure 4) the overlying soil must become very wet before water will move down into the sands and gravels. The overlying soil will retain considerably greater quantities of water because of this.

For many kinds of soils the water content at 1/3 atmosphere tension is regarded as field capacity. For stratafied soils 1/3-atmosphere percentages are too low. As an example, the Ephrata soil in the Columbia Basin, composed of one or two feet of fine sandy loam overlying coarse sands and gravels, has a field capacity which would correspond to a tension of 0.01 atmosphere. It retains 2 to 3 times as much water as would the same soil material if coarse sands and gravels were not present.

Any change in porosity encountered by a wetting-front will affect water movement. Hence, a layer of coarse aggregates in finer soil materials acts in much the same way as a layer of sand (Figure 5). The effect of the aggregate layer differs from that of sand in one important respect: water can move through aggregates but the amount of water is limited by the relatively small number of contacts between

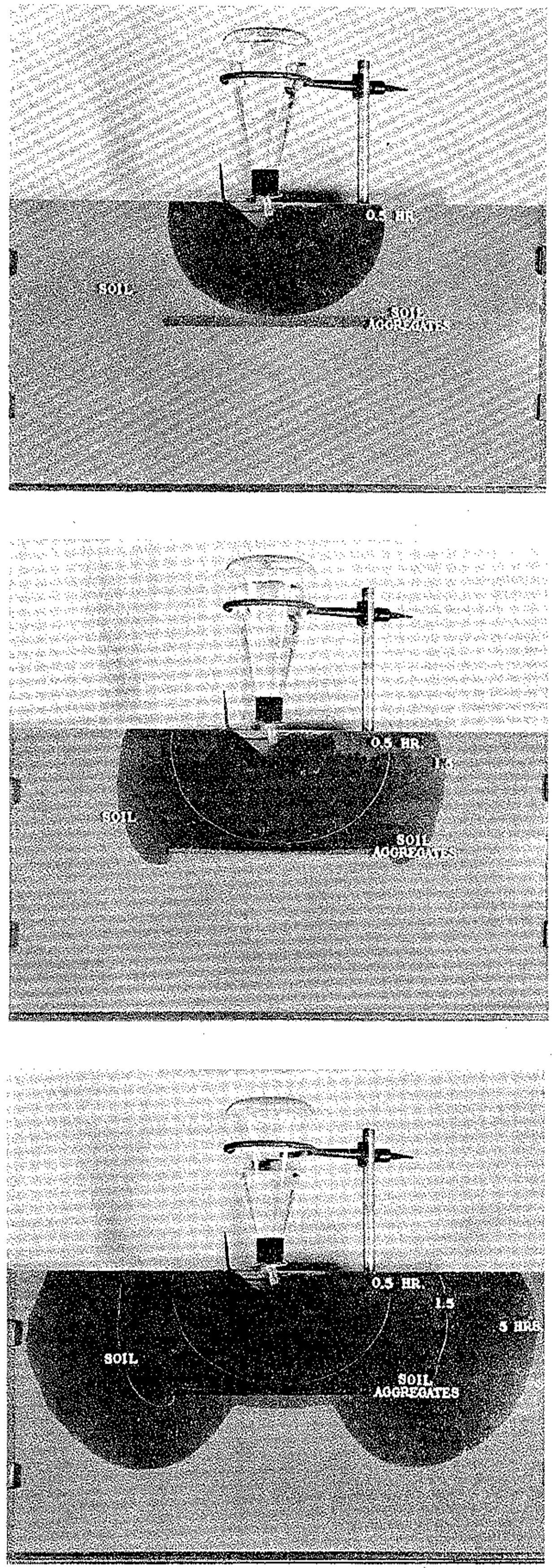


Fig. 5

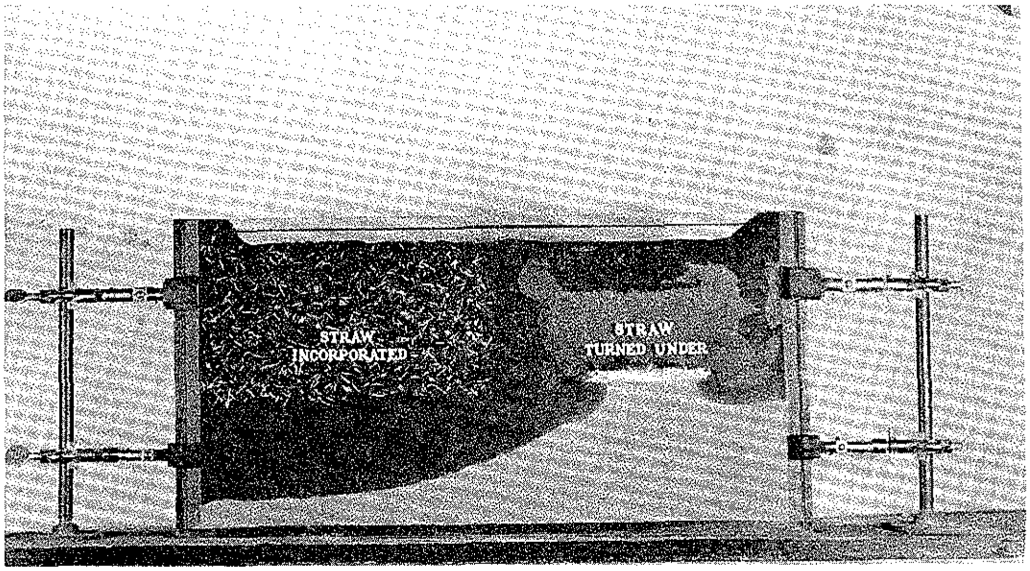


Fig. 6

aggregates. In unsaturated flow the larger pores remain unfilled and do not constitute part of the water conducting channel. This has many practical implications. Straw turned under by the plow and left in a layer constitutes a barrier to the downward penetration of the water (Figure 6). If the straw is incorporated into the soil to help promote good soil aggregation and to keep an open porous structure, downward penetration of water is aided. Large pores connecting to a source of free water transmit water readily.

Another application of these principles may be seen in the practice of vertical mulching (Figure 7). Here deep vertical channels are cut in the soil and filled with chopped organic materials. If the channels remain open to the surface the large pores in the organic materials readily take the free water from rainfall, transmitting it deeply into the soil where it is absorbed under unsaturated conditions. If the channel is not maintained open to the surface, it does no good. A short distance beneath the surface of the soil the water is present under negative pressure or positive tensions and under these conditions the large pores remain unfilled. Holes and channels left in the soil by angleworms, burrowing rodents, or decaying straw behave in exactly the same way: if they remain open to the surface where they are accessible to free water, they will transmit water readily. They cannot assist in the transmission of water unless

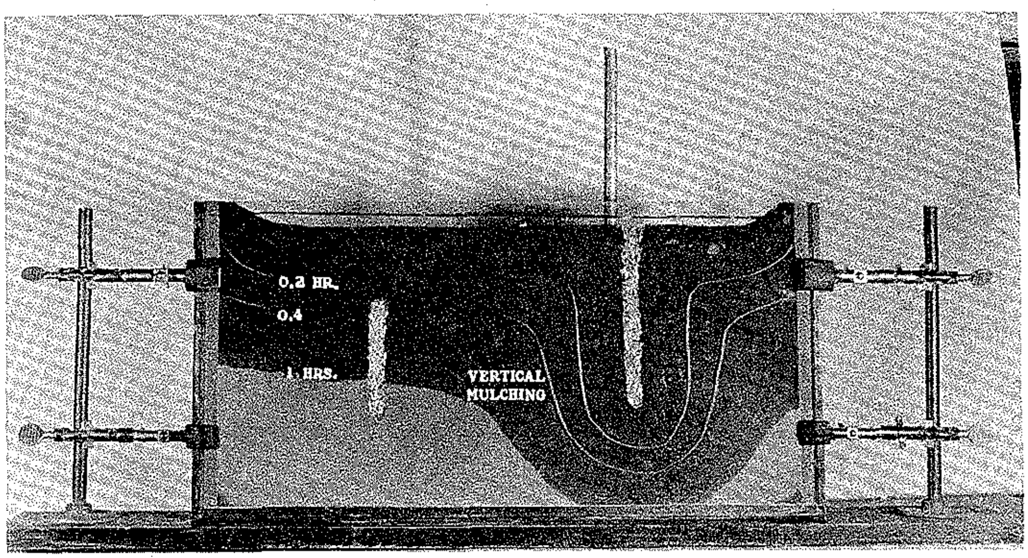


Fig. 7

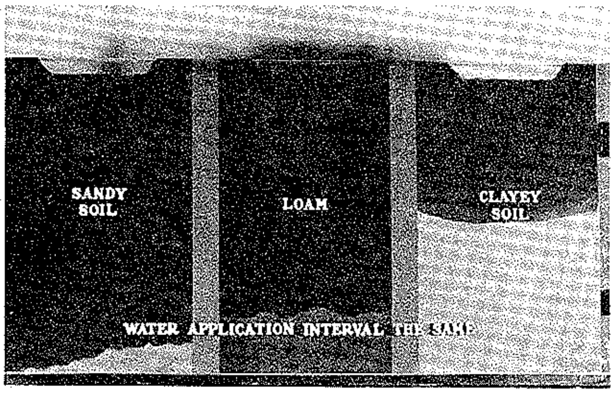


Fig. 8

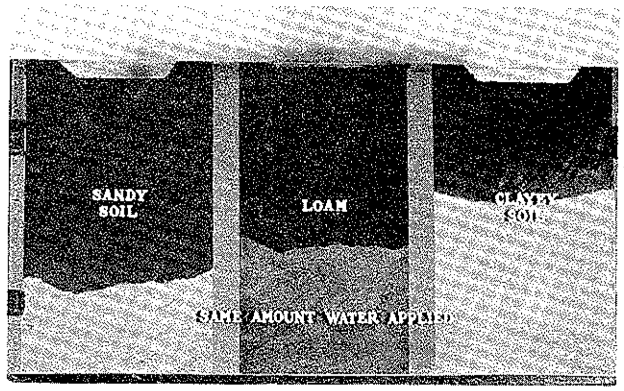


Fig. 9

they are accessible to free water. Under conditions where aeration may otherwise be critical such open channels do serve a useful purpose in permitting rapid exchange of gases between the soil atmosphere and the air above.

The porosity of uniform soils has an important effect on water movement quite apart from the effect of porosity changes which occur within the soil. Infiltration and advance of the wetting-front is more rapid in a sandy than in a loam or clay soil (Figure 8). On the other hand the amount of water retained in the clay soil will be greater than in the loam or sandy soil (Figure 9). Also, a greater amount of water will remain in the finer soil materials when plants wilt so that the most available water is found in the clay soil. Silt loam and clay loam soils are likely to be better soils under dryland farming conditions than the coarser sandy soils because of the large amount of water which is retained through the season for plant use. However, such soils are not as good as the sandier soils under irrigation conditions, because of poor water transmission properties which make irrigation difficult.

One other problem of water movement is illustrated in Figure 10 where water is added too rapidly to a hilly terrain. When water is added at a rate at which it can be absorbed by the soil uniform wetting results (Figure 11). The principle

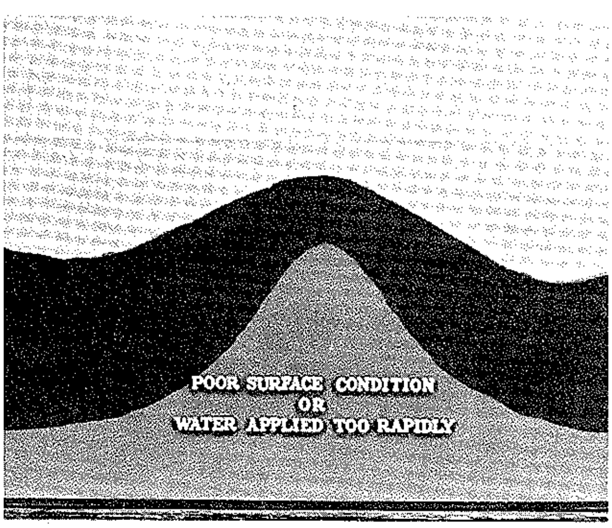


Fig. 10

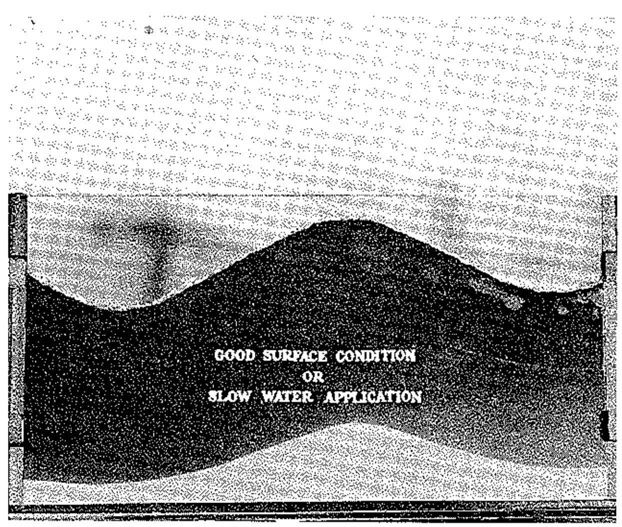


Fig. 11

is the same whether applied to the hills of southeastern Washington, to the irregular surface of the farmer's field being irrigated by sprinklers, or the irregular surface of a home lawn. The maintenance of open porous surface conditions increases infiltration rates and reduces water runoff. Where it is possible to control water applicate rate, a rate consistent with the infiltration properties of the soil prevents water runoff.

Principles of water movement and retention under both saturated and unsaturated conditions are important in water and soil conservation and in the movement of plant nutrients and their use by plants. The movement of plant nutrients depends upon the direction of water flow, the degree of absorption in soil colloids, and upon the rate of water flow and the characteristics of the flow of channel. Such principles must be considered in problems of fertilizer placement as well as in irrigation practice.