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# Infiltration Research Planning Workshop

## Part I. State of the Art Reports

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# INFILTRATION RESEARCH PLANNING WORKSHOP
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# INFILTRATION EFFECTS OF SOIL AIR PRESSURE

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Water infiltration into soils involves displacement of soil air with water. Such displacement is usually manifested as a simultaneous exchange of surface water and soil air across the air-earth interface. For surface water to displace soil air, the pressure of upstream soil air must rise above the ambient atmospheric pressure. Several workers have observed water movement response to air pressure changes within laboratory columns of porous media (Powers, 1934; Horton, 1940; Free and Palmer, 1940; Peck, 1965; Adrian and Franzini, 1966; and Wilson and Luthin, 1963).

These column studies and capillary tube theory lead to several obvious generalizations. In short columns, air pressure rises more rapidly but to a lower maximum than in long columns. Similarly, in coarse porous media with large pores, air pressure rises rapidly but to a lower maximum than in fine media with small pores. Under a surface having a high-bubbling pressure, air pressure rises more slowly but to a higher maximum than under a low-bubbling pressure surface. The surface may lift or rupture to reduce air pressure where a high-bubbling pressure surface caps a short column.

Theoretical analyses of infiltration often neglect the effect of displaced air pressure on the advancing wetting front (Philip, 1958; Wilson and Luthin, 1963). The simplifying assumption is usually made that the air pressure component of soil water pressure is negligible compared to the matrix or capillary component. The idea is often expressed that soil macropores readily vent displaced soil air and thereby keep the pressure to negligible levels. The authors reporting these column studies suggest that two primary field conditions are conducive to rapid soil air pressure rise. These are a large water-saturated surface area and a small antecedent soil air volume. Thus, border and basin irrigation, large ground water recharge basins, and high intensity rainfall would favor development of displaced soil air pressure; whereas furrow, trickle, and low intensity sprinkler irrigation and low intensity rainfall would produce little or no soil air pressure. The rate of air pressure rise would be increased by a small initial displaceable air volume caused by high initial soil moisture or a shallow air barrier, or both, such as a water table, wet plow sole or pan, wet clayey subsoil, cemented soil layer, impervious rock stratum or any combination of these. Field infiltrometers and rainfall simulators do not wet a sufficiently large surface to cause measurable rise in soil air pressure, since the air displaced by infiltrating water can escape freely to surrounding dry soil. One somewhat rare exception would be where the infiltrometer frame extends downward into a soil air barrier.

The Committee on Soil Physics Terminology of the International Society of Soil Science concluded that soil air pressure was not important enough under field conditions to justify inclusion in their final report (ISSS Committee, 1963; Rose, 1966). Contrary to this conclusion, the air-earth interface AEI concept (Dixon, 1972) indicates that soil air pressure interacts with soil surface conditions to give an order-of-magnitude control over infiltration. This concept states that the AEI conditions, surface microroughness and surface macroporosity, interact hydraulically to control free surface water infiltration by regulating the flow of air and water in underlying macropore and micropore systems. During the past 5 years, the infiltration role of soil air, as envisioned by the air-earth interface concept, has been verified and reported in a series of papers (Dixon and Linden, 1972a, 1972b; Linden and Dixon, 1973, 1975, 1976; Dixon, 1975, 1977; and Linden et al., 1977).

The main contributions of these papers include the (1) conception and definition of a new infiltration parameter--the effective surface head--defined as ponded water head minus soil air pressure head; (2) further verification and refinement of the AEI concept; and (3) development of closed top and "closed bottom" infiltrometers, which can produce a realistic range of effective surface heads surrounding zero head taken as ambient atmospheric pressure head. The experimental results reported in these papers show clearly that soil air is a major component of natural infiltration systems, and that the soil air pressure effect on infiltration occurs principally within the macropore system. Thus, an infiltration model, to be useful, must consider both soil air and soil macropores. To assume that soil macropores take care of the soil air pressure problem, as theorists have done, is not in the interest of advancing our understanding, prediction, and control of natural infiltration processes. However, experimentally controlling or eliminating the air pressure effect (for example, side and bottom venting of soil columns) is often useful in isolating other components of infiltration system for independent study.

## CRITICAL RESEARCH NEEDS

1. Further development of closed-top and "closed-bottom" infiltrometers of both the ponded-water and sprinkled-water types.
2. Determine the range of effective surface heads occurring naturally in all major soils.
3. Determine infiltration response of all major soils to the natural range in effective surface heads using both ponded-water and sprinkled-water infiltrometers having the best open-top or "closed-bottom" design, as determined by #1.
4. Relate the effective surface heads measured in #2 to the parameters in Kostiakov's equation.
5. Determine the effective surface heads associated with major land management systems.
6. Improve old and develop new cultural practices having appropriate effective surface head levels to achieve desirable land management objectives such as infiltration, runoff, erosion, and evaporation control for improved crop stands and greater and stabler crop yields.
7. Determine effective surface heads and soil surface geometries associated with optimal routing of irrigation and rainwater into the soil for maximum crop production.

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