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DRAINMOD REFERENCE REPORT

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METHODS FOR DESIGN AND EVALUATION OF DRAINAGE-WATER MANAGEMENT SYSTEMS FOR SOILS WITH HIGH WATER TABLES

CHAPTER 1

INTRODUCTION

The design of efficient agricultural water management systems is becoming more and more critical as competitive uses for our water resources increase, and as installation and operational costs climb. In humid regions, artificial drainage is necessary to permit farming of some of the nation's most productive soils. Drainage is needed to provide trafficable conditions for seedbed preparation and planting in the spring and to insure a suitable environment for plant growth during the growing season. At the same time, excessive drainage is undesirable as it reduces soil water available to growing plants and leaches fertilizer nutrients, carrying them to receiving streams where they act as pollutants. In some cases, water table control or subirrigation can be used to maintain a relatively high water table during the growing season thereby supplying irrigation water for crop growth, as well as preventing excessive drainage. This type of irrigation has many advantages over other methods for certain conditions and has been practiced in scattered locations for many years (Clinton, 1948, Renfro, 1955). However, these lands constitute only a small percentage of the total land area suitable for subirrigation. This practice has not been rapidly accepted because of the lack of established design criteria and information characterizing the operation of systems in the field.

The design and operation of each component of a water management system should be dependent on soil properties, topography, climate, crops grown and trafficability requirements. Further, the design of one component should depend on the other components. For example, a field with good surface drainage will require less intensive subsurface drainage than it would if surface drainage is poor. This has been clearly demonstrated in both field studies of crop response (Schwab, et al, 1974) and by theoretical methods (Skaggs, 1974). The relative importance of water management components varies with climate, so, in humid regions, a well-designed drainage system may be critical in some years yet provide essentially no benefits in others. Thus, methods for designing and evaluating multicomponent water management systems should be capable of identifying sequences of weather conditions that are critical to crop production and of describing the performance of the system during those periods.

The purpose of this report is to describe methods for the design and evaluation of water management systems for soils with natural or induced high water tables. The basic tool that will be used for design and evaluation is a computer simulation model called DRAINMOD which was developed at North Carolina State University (Skaggs, 1978b). The simulation program characterizes the response of the soil water regime to various combinations of surface and subsurface water management. It can be used to predict the response of the water table and the soil water above the water table to rainfall, evapotranspiration (ET), given degrees of surface and subsurface drainage, and the use of water table control or subirrigation practices. Surface irrigation can also be considered and the model has been used to analyze sites for land disposal of waste water. Climatological data are used in the model to simulate the day to day performance of a given water management system over several years of record. In this way, an optimum water management system can be designed on a probabilistic basis as initially proposed for subsurface drainage by van Schilfgaarde (1965) and subsequently used by Young and Ligon (1972) and Wiser, et al, (1974).

The model establishes a link between the water management system and the water table and soil water conditions. Results of investigations of the effect of soil water stresses (due to both excessively dry and wet conditions) on crop yield responses will allow the model to be used to relate the water management system design to crop yields. Approximate methods for accomplishing this task are now being developed and will be available in the near future. More sophisticated methods are on the horizon. Ongoing research toward developing crop models will provide much more accurate approximations of water management system effects on yields and will increase the value of simulation models of the type discussed here.

This report begins with a description of each of the components now used in DRAINMOD. In some cases, a number of methods could be employed to quantify a single hydrologic component. Therefore, whenever possible, the discussion of each component, such as infiltration or subsurface drainage, includes alternative methods that could be used and which may be advantageous for some applications. Water management model objective functions are discussed in Chapter 3 and the procedures for simulating the performance of a water management system are discussed in Chapter 4. Input data requirements for DRAINMOD, sources of available data and methods for measuring the needed inputs are discussed in Chapter 5. Several examples showing the use of the model for design and analysis of water management systems are given in Chapter 6. Sensitivity analyses which examine the effect of errors in the various input data on the model predictions are given in Chapter 7. While the emphasis in this report is on the simulation model, design and evaluation of subirrigation or water table control systems also requires analysis of short-term effects such as the time required to raise the water level at the beginning of an irrigation cycle, etc. Methods for making these analyses are given in Chapter 8 and the subject of seepage losses during subirrigation is treated in Chapter 9. Finally, field tests of the validity of the simulation model based on data obtained in North Carolina, Ohio, Florida, and California are presented in a separate Appendix.

The methods presented herein for the design and evaluation of water management systems are not exact. Approximations are involved in almost every component of the model as more exact treatments were bypassed in favor of methods that have feasible computational requirements and for which necessary input data can be obtained. Nevertheless, field tests of the model have shown it to be reliable for a wide range of soils and climatological conditions. Although research efforts to improve this and related models will continue, the most efficient means of improving the methodology lies in its application. Application of DRAINMOD to real world situations which are frequently complicated by a lack of input data have already resulted in modifications. It is anticipated that modifications will continue to be made as the model is applied to an ever widening range of conditions.

Limitations of the Model

The model, as developed and presented herein, can be used to analyze a broad range of drainage, subirrigation, and waste water application problems. However, DRAINMOD should not be applied to situations which are widely different than conditions for which it was developed, without further testing. DRAINMOD was developed and tested for use in humid regions. Although research to test and, if necessary, modify the model for irrigated agriculture in semi-arid climates is ongoing, its application should be confined to humid regions at the the present time. The methods were developed for field-sized units with parallel subsurface drains. Lateral seepage due to a sloping landscape is not considered in the present methodology. This limits application of the model to fields with slopes of less than about 5 percent, although the exact slope limitation is dependent on drain spacing, hydraulic conductivity, and other factors. Lateral seepage losses from a water table control system are considered in Chapter 9. Freezing conditions are not considered in the model so its application at the present time is confined to periods when the soil is not frozen.