AUTOMATED OPERATION OF WATER TABLE CONTROL SYSTEMS FOR WATER QUALITY MANAGEMENT

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INTRODUCTION

Frequent rainfall events, shallow water table conditions, and the extensive use of agrochemicals in the lower Mississippi River Valley, result in losses of applied agrochemicals and potential contamination of surface and subsurface water resources. Integrated methodology is needed to manage soil, water, ground cover, pesticide and fertilizer applications in such a way that pesticides and fertilizers are contained within their "action zones" of the soil profile, thus reducing the risk of water pollution. Improved soil-water management technology, such as water table control, may reduce transport and loss of applied agrochemicals and also reduce the amount of pesticides and fertilizer required for good yields. Thus, crop production efficiency and farmer profitability may be increased while reducing pollution. The "optimal" management of soil-water for agricultural cropland in humid areas of the U.S. by control of water table depth involves complex daily operational/management decisions because of the erratic spatial and temporal distribution of rainfall. Periods of excess and deficit soil-water conditions in the active root-zone often occur within the same growing season. The farm management decisions are even more complex when soil-water management is integrated with improved fertilizer and pesticide application practices. Thus, controlling water table depth within a desired range relative to the root-zone requires facilities for regulating both subsurface drainage from and subirrigation into the soil profile.

The primary purposes of water table control are to minimize the time of excess or deficit soil-water conditions in the root-zone and to maximize the utilization of natural rainfall, thus minimizing the amount of subirrigation water required from external sources. Water table management technology has also begun to be used to improve water quality. Controlled-drainage practices have been developed in the Atlantic Coastal Plains region (Gilliam et al. 1985; Deal et al. 1986) for reducing nitrogen and phosphorus levels in surface/subsurface effluent from agricultural lands. Successful water table control on a large field scale has been reported by Fouss et al. (1989, 1992) for an alluvial soil in the lower Mississippi Valley when subsurface conduits were used for the dual purpose of controlled-drainage and subirrigation. Water table management has a high potential for achieving maximum crop production, water use efficiency, and improved water quality if properly controlled to compensate for changes in weather conditions. Determining when changes are needed in controlled-drainage and subirrigation to optimally manage the water table depth is a major problem for farmers, especially in coastal areas with fine textured soils. In the lower Mississippi Valley, frequent rainfall events can cause large variations in water table depth because of the small, 3 to 8%, drainable soil porosity. Rainfall probability information included in daily and 7-day forecasts issued by the U.S. National Weather Service can be useful to aid the farmer in making management decisions in anticipation of predicted weather changes (Fouss and Willis 1994). This paper presents field test results and performance evaluations for various methods of water table control during the 1995 growing season in an alluvial soil of the lower Mississippi River Valley.

DESCRIPTION OF PROJECT

Four water table management treatments were evaluated in a replicated field experiment: [1] Surface Drainage Only, [2] Conventional Subsurface Drainage at a 1.00 m depth, [3] Auto-Controlled Water Table at a 0.45 m depth, and [4] Auto-Controlled Water Table at a 0.75 m depth. Four replications of these treatments in a randomized complete block design were imposed on sixteen (16) 0.21-ha (35 m x 61 m) corn plots on a Commerce silty clay loam soil near Baton Rouge, LA.; the experimental layout and design was reported by Willis et al. in the 1995 *Proceedings* of the Mississippi Water Resources Conference, p. 119. All plots were surface drained with a precision graded uniform ground surface slope of 0.2 %. Each plot was hydraulically isolated from adjacent plots and the surrounding area by 0.3 m high surface dikes and vertical plastic film barriers that extended from 1.8 m deep to within 0.3 m of the soil surface. Each plot had three 100-mm diameter corrugated high-density polyethylene plastic draintubes installed at a 1.25 m depth and 15 m spacing. The drainlines were connected to outlet riser pipes (300 mm dia.) within which the outlet water level was controlled. The center (experimental) drainline and the two plot border (buffer) lines were connected to separate outlet risers to permit more precise control of the water table depth in the experimental area of each plot (i.e., the 15 m width centered over the middle drainline). The buffer drain lines compensated for leakage, if any, between adjacent plots. In the auto-controlled water table treatments [3 & 4], a subsurface conduit drainage system was operated in three different modes, as needed, to maintain the water table depth in the soil profile within a desired range relative to the crop root zone: (a) conventional subsurface drainage with a partially submerged outlet; (b) controlled-drainage where drain outflow was regulated; and (c) subirrigation where water from an external source (e.g., well) was supplied to the soil profile through the subsurface conduit. Subsurface drainage and subirrigation flows were regulated by control of the water level in a riser pipe (or sump structure) at the outlet for the subsurface conduit system; water was pumped from the riser for sub-drainage and into the riser for subirrigation.

An automated system of electronic data-loggers, water table depth sensors, and computers (PCs) is used for the water table control aspects of the project to: (a) operate drainage pumps and irrigation valves to control outlet water levels and water table depth in the plots; (b) monitor and acquire all experimental/control data; (c) collect flow-proportional pumped subsurface drainage samples; (d) auto-download data to PCs hourly and perform error-checking and backup; and (e) send precoded E-mail messages if detected errors in data or operations occur. The field water table depth is monitored with a linear-resistor type water level sensor housed within a 50-mm diameter, perforated, plastic pipe, installed to a depth of 1.5 m; the accuracy of the water table depth measurement is typically within $\pm$ 5 mm. The water level in the drainage outlet riser pipe is monitored with a spiral stain-gage type pressure sensor (0 to 17.2 KPa pressure range) which is accurate to about $\pm$ 3 mm. The data-logger/controller units are programmed to scan (read) the outlet water level sensors every 10 seconds and operate the drainage pumps or irrigation valves as needed. The 10-second scan rate permits the outlet water level to be held accurately between the upper and lower limits (typically a range of 0.15 m). A detailed description of the experimental design, instrumentation, and procedures is given by Willis et al. (1991).

Drainage effluent pumped from the experimental riser pipes was sampled (flow-proportional; 0.2 % of pumped volume), collected in a refrigerated container, and subsequently analyzed for agochemicals. Each plot was also equipped with a 450-mm H-Flume and automated runoff measuring/sampling equipment (refrigerated). The runoff samplers were programmed to collect an initial-flow sample and thereafter 50 mL samples were collected for every 1000 L of flow through the H-Flume for a total of 500 mL per sample bottle. The results of the analyses of subsurface drainage and surface runoff samples for agrochemical content for the 1994 and 1995 growing seasons are presented in a separate paper (Southwick et al. 1996) in this *Proceedings*.

AUTOMATED WATER TABLE CONTROL LOGIC

Automatic operation of a dual purpose controlled-drainage/subirrigation system can take on many different options or modes for control of the drainage outlet water level to maintain the field water table within desired minimum and maximum depth limits. The control may also include the option of **feedback** of the monitored water table depth between drainlines in the field. With feedback the outlet water levels at which the drainage pumps or irrigation valves are turned on/off can be automatically adjusted upward or downward for more accurate control of field water table depth. The logic for automated control requires decisions of several operational parameters, including: (a) desired range of water table depth control in the field (e.g., at the midpoint between drainlines), (b) magnitude and frequency of outlet water level adjustments, (c) duration permitted for water table depth to be outside of the desired range without adjusting the range or limits of outlet water level control, (d) minimum water table depth and duration before controlled-drainage is switched to conventional drainage, (e) maximum field water table depth permitted, and duration before switching the system operation to subirrigation, etc. Other factors may be considered in managing the system operation, such as when to override the automatic controller. For example, when the probability of rainfall is high, it is often desirable to stop subirrigation, and when rainfall is imminent, to switch operation to controlled-drainage.

The type of drainage outlet structure, gravity flow outlet or pumped-sump, will also dictate to some degree the type of system automation which can be implemented. In this discussion, a sump-type structure is assumed at the subsurface drainage outlet and all subdrainage discharge is considered pumped to a gravity outlet such as a surface drainage ditch or other drainage main conduit. The water table depth in the field is defined in this paper with respect to the ground surface elevation at the midpoint between drainlines and midway of the drain line length. The drainage outlet water level is expressed as a depth parameter which is also referenced to this same ground surface elevation in the field.

The actual water table control parameters used in the field evaluation during the 1995 growing season are given below along with descriptions and explanations of the different modes of system operation. The scenarios or conditions which cause the automatic control system to switch from one mode of operation to another are explained; for example., switching from subirrigation to controlled-drainage and/or conventional drainage and vice versa. Some modifications of certain operational parameters were not active for the entire growing season (such as feedback control option in the subirrigation mode), thus the period or day-of-the-year that each modification was initiated or activated is given.

Conventional Subsurface Drainage

In the conventional subsurface drainage mode, the water level in the outlet riser pipe is controlled with a sump pump to maintain the water level between 0.85 and 1.00 m depth, which is about 0.25 m above the bottom of the 1.25 m deep drainage conduit in the field. Thus, the draintube outlet connection into the riser pipe is submerged, much like many gravity flow outlet subsurface drainage systems with the outlet pipe under the water level in the outlet ditch or channel. The conventional drainage mode is typically used during the preplant season and beginning shortly before crop harvest to insure the water table is maintained deep enough for farm equipment trafficability. During the growing season when rainfall events occur and infiltration causes the water table to rise, the system operation can be automatically switched from subirrigation or controlled-drainage operation to the conventional drainage mode so that the water table in the field does not remain too shallow during and following the rainfall event. The conditions which cause this switching of modes are given below under the discussions for controlled-drainage and subirrigation. The system operation can be automatically switched back from the conventional drainage mode to controlled-drainage and subsequently to subirrigation depending upon the water level in the riser pipe or the water table depth in the field. If the feedback option of the monitored field water table depth is not activated, then after drainage discharge (pumping) ceases and the water level in the outlet riser falls to a depth greater than 1.15 m, the system operation is automatically switched to the subirrigation mode. If the feedback control option is activated, then the system operation will be automatically switched to the controlled-drainage mode whenever the field water table depth has exceeded the maximum range of the desired depth for more than 12 or 24 hours. For example, if the desired range for the field water table depth is 0.675 to 0.825 m (for the Method 4 water table depth of 0.75 m), then the system operation is switched to controlled-drainage when the monitored water table depth exceeds the 0.85 m depth for more than 12 or 24 hours (the control mode changes can be programmed to occur either at 1200 h or 2400 h each day).

Controlled-Drainage

In the controlled-drainage mode, the water level in the outlet riser pipe is maintained between predetermined shallow and deep water levels. For the Shallow Controlled Water Table method (0.45 m depth), the outlet water level was maintained between the 0.375 and 0.525 m depths, and for the Medium Controlled Water Table (0.75 m depth) between 0.675 and 0.825 m depths, which are the same ranges for the desired water table depths in the field for these two methods. In the controlled-drainage mode, the feedback option was not used in the 1995 growing season to adjust these shallow and deep outlet water levels. Instead, the system operation was switched either to conventional drainage if the water table depth remained too shallow (i.e., less than 0.2 m depth) for some time interval (e.g., 2 h), or switched to the subirrigation mode if the water table remained too deep (i.e., more than 0.025 m deeper than the desired range) for longer than a specified time interval (e.g., 12 or 24 h). The specified time intervals for switching the system operation were based on the assumption that the occurrences of short periods of excess soil-water conditions (i.e., water table is too shallow) may be more detrimental to crop roots and plant growth than the occurrences of the same or longer periods of deficient soil-water conditions (when the water table is too deep). For the layered alluvial soil conditions at the experimental site, the water table depth can be lowered much faster with subsurface drainage than it can be raised by subirrigation. As noted above under the Conventional

Drainage mode, the system operation is automatically switched back to controlled-drainage when feedback is activated. For the Shallow Water Table Control method (0.45 m depth), the system operation is switched back to controlled-drainage at the next 1200 h (or at 2400 h), if the monitored field water table depth exceeds 0.55 m (i.e., 0.025 m deeper than the desired range of 0.375 to 0.525 m), and for the Medium Water Table Control method (0.75 m depth) when the water table depth exceeds 0.85 m (or 0.025 m deeper than the desired 0.675 to 0.825 m range). After this switch back to the controlled-drainage mode of operation, the system is subsequently switched to the subirrigation mode at the next 1200 or 2400 h if the monitored water table depth is still deeper than the desired range.

<u>Subirrigation</u>

In the subirrigation mode, the water level in the outlet riser pipe is maintained between predetermined deep and shallow levels. In many soils, to maintain a relatively shallow water table depth by subirrigation, the average depth of the controlled outlet water level must be shallower than the desired field water table depth. For example, at the field site the average outlet water level had to be set at about a 0.35 m depth to maintain a desired water table depth of 0.45 m [Method 3]. For the Shallow Controlled Water Table method (0.45 m), the range of outlet water level control was 0.275 to 0.425 m depth, and for the Medium Controlled Water Table method (0.75 m) the outlet control range was the same as for the controlled-drainage mode, or 0.675 to 0.825 m depth. If the feedback control option is not activated for subirrigation, the outlet water levels are maintained in these predetermined ranges without adjustment. With the feedback option activated for subirrigation, the deep and shallow outlet water levels at which the irrigation water supply valve is opened or closed are automatically adjusted <u>upward</u> if the monitored field water table depth is greater than the desired range. If the monitored water table depth is shallower than the desired range, downward adjustments of the outlet water levels are <u>not</u> made; instead, additional irrigation water is not supplied into the riser pipe until the field water table depth increases into the desired range. Adjustments of the deep and shallow outlet water level depths are made only at 1200 or 2400 h. Upward adjustments of the outlet water levels are made in 0.10 m steps; successive upward adjustments are made at the 1200 or 2400 h times, as needed. If upward adjustments of the outlet water level have been made, then the outlet control levels are returned to the original predetermined levels in a single downward step after the field water table depth returns to within the desired range. The system operation is automatically switched from subirrigation to the controlled-drainage mode whenever the amount of rainfall (monitored with a tipping-bucket type raingage) exceeds some specified amount in a given period of time (e.g., more than 25 mm in 2 h).

<u>Control Override Options</u>

The system control may occasionally be switched from the subirrigation to the controlled-drainage or conventional drainage mode in advance of predicted significant rainfall or to adjust the water table depth prior to application of fertilizer or pesticide. This can be accomplished off-site by remote computer and modem communications to send reprogramming codes to the microprocessor of the data-logger/controller that automatically operates the water table control system. Similarly, a signal can be remotely sent to restart subirrigation if the threat of heavy rainfall diminishes. Remote communications from a PC to the data-logger/controller can also provide a status report on the operation of the water table control system.

RESULTS

The performance of the four methods of water table control is illustrated primarily by the variations in water table depth during the growing season. Other performance parameters or factors discussed are surface runoff, subsurface drainage in conventional and controlled-drainage modes, and subirrigation. Results from the 1995 growing season (defined as Days-of-the-Year, 104-256) are used to illustrate most of the performance parameters. The total rainfall during the 1995 growing season was 412 mm, which was about 61% of the long-term (30-yr) normal. In 1995 there were periods of up to 30 days with essentially no rain and droughty soil conditions occurred.

<u>Water Table Depth</u>

The average and standard deviation of water table depth maintained during the 1995 growing season by each method was: [1] Surface Drainage Only, 0.85 ± 0.22 m; [2] Conventional Subsurface Drainage, 1.19 ± 0.15 m; [3] Shallow Controlled Water Table, 0.60 ± 0.18 m; and [4] Medium Controlled Water Table, 0.84 ± 0.13 m. For <u>each</u> method of water table control, the <u>hourly</u> water table depths and their variations were about the same in all 4 replications. Some surface and subsurface leakages between experimental plots were detected during the growing season, but these did not adversely affect the water table control in the experimental area of each plot (i.e., the 0.1 ha area centered over the drainline in the middle of the plot). The effects of leakage between plots on runoff, subsurface drainage, and subirrigation are discussed below.

Automated control of water table depth in the 0.21 ha field plots was successfully accomplished by the feedback adjustment of the water level in the outlet riser pipes to regulate controlled-drainage and subirrigation flows. The graphical comparisons for the four methods of water table control are shown in Figures 1, 2, 3, and 4 for days 210 to 256 during the 1995 growing season. The hourly average water table depths are plotted in these graphs, which are for replication I only. Several rainfall events occurred early in this selected period (the first 25 days) and no rain fell during the latter 20 days of the time interval; the daily rain bars in Figures 1 to 4 are centered at about the hour of each day for which the greatest hourly rainfall intensity occurred.

For the Surface Drainage Only method (Figure 1), the water table depth remained relatively constant at 0.80-0.85 m depth for the first half of the season, but with no rainfall in the last 20 days of the season the water table depth increased to about 1.0 m. For the Conventional Subsurface Drainage method (Figure 2), the water table was maintained deeper at 1.10 to 1.15 m during the first half of the season, and during the last 20 days the depth increased to about 1.25 m. The drainage pumping events required for the conventional drainage method to maintain the outlet water level within the desired range are illustrated by the Mode chart at the bottom of the water table depth graph (Figure 2). NP is for No Pumping, and PD is for Pump Drainage. Pumping of the drainage discharge was required on day 234 during and following the rainfall event.

The water table depth midway between the 15 m spacing drainlines with the Shallow Controlled Water Table method (Figure 3) was maintained between an 0.45 and 0.60 m average hourly depth for the period (days 220-254). Thus, the controlled water table depth varied about $\pm$ 0.10 m from the maximum depth of the desired water table range (0.375 to 0.525 m). The water table depth about 2 m from the experimental drainline (at 1/8 the drain spacing) was maintained about 0.05 m deeper than the depth of the controlled water level in the outlet riser pipe. The feedback control of the outlet water level caused it to vary from an average hourly depth of 0.35 m to 0.25 m from day 220 to 254 (Figure 3). The outlet water level was held at the 0.35 m depth when the field water table depth (at the midpoint between drains) was within the desired range of 0.375 and 0.525 m. When the water table depth increased to greater than this range, the feedback control raised the outlet water level to the 0.25 m depth (i.e., a 0.10 m step change at 2400 h) for about a one-day period. When the water table depth returned to within the desired range, the outlet water level was lowered again to the 0.35 m depth at 2400 h, where it stayed for about two days before the next step-wise adjustment was needed. Towards the end of the study period (after day 248), the outlet water level adjustments were made by the feedback controller, as needed, at 1200 and/or 2400 h (Figure 3), which reduced the magnitude of fluctuations in water table depth during a period without rainfall. The automatic changes in mode of water table control made by the data-logger/controller unit are illustrated for days 215 and 233 when significant rainfall events occurred; the changes in control modes are illustrated by the graphical display at the bottom of the water table depth graphs (Figure 3). The control Mode codes shown with the water table depth graphs are: MO - monitor only; DD - conventional (deep) drainage; CD - controlled-drainage; SI - subirrigation without feedback; and SF - subirrigation with feedback. On day 215, the control mode was initially switched to conventional subsurface drainage for a short time due to a shallow water table condition caused by infiltrated rainfall; the water table depth increased quickly and was back in the desired range at 2400 h when the mode was switched to controlled-drainage. At the next 2400 h interval, the mode was switched back to subirrigation -- the feedback option was deactivated manually after the rain event (on days 217 and 218), but was reactivated on day 219. The rainfall event on day 233 caused the system operation to switch to the controlled drainage mode for three days (233-236). When the water table depth increased to within the desired range on day 237, the system operation was switched back to subirrigation. These automatic changes of control to the drainage mode reduced the time that the water table depth would have been shallower than the desired range. The auto-controlled water table systems were switched to conventional subsurface drainage on day 254 in preparation for crop (corn) harvest on day 257.

The water table depth control provided with the Medium Controlled Water Table method (Figure 4) was more variable, even with the feedback option, than that achieved with the Shallow Controlled Water Table method (Figure 3). The larger fluctuations in water table at the 0.75 m depth were not considered as critical, however, since the typical fluctuations did not cause excessive soil-water conditions in the active root zone. During periods without rainfall, the water table was typically controlled between 0.7 and 0.9 m depth. The average hourly water table depth, similar to the Shallow Controlled Water Table method, varied about $\pm$ 0.10 m from the maximum depth of the desired water table range (0.675 to 0.825 m). When rainfall events occurred, switching to the controlled-drainage mode of operation typically maintained the water table deeper than 0.5 m. There were no rainfall events during the 1995 growing season that caused the water table to become less than about 0.5 m, and, therefore, switching to the conventional subsurface drainage mode was not required at any time. Thus, water table control in this medium depth range, 0.675 to 0.825 m, was easier to achieve with the automated system throughout the 1995 growing season than at the shallow water table depth range, 0.375 to 0.525 m. Figure 4 shows that the feedback adjustments of the outlet water level at both 1200 and 2400 h caused a different type of response in the adjusted outlet water levels and the corresponding controlled field water table depth (from day 248 to 254). The drainage system operation was switched to the conventional drainage mode on day 254 to end the auto-controlled period prior to corn harvest.

A more detailed graph of the controlled outlet water level and the corresponding water table depth for the Shallow Controlled Water Table method is shown in Figure 5. This graph better illustrates the difference between the 1/8 and 1/2 drain spacing field water table depths controlled by the outlet water level. The amount of rainfall in the afternoon of day 233 (more than 25 mm) and the rise of the water table to less than 0.2 m depth for more than 2 h caused the auto-control system to switch operation to the conventional drainage mode. Since the water table depth quickly returned to the desired range during day 234, the system operation was automatically switched to the controlled-drainage mode at 2400 h on day 234. Control was subsequently switched to the subirrigation mode one day later at 2400 h.

Surface Runoff

The cumulative runoff volumes during the 1995 growing season for plots with the four different methods of water table control are shown in 6a. These data are for replication I of each treatment, for which the newly constructed earthen dikes between plots were not damaged or washed out by the early season major rainfall events on days 113 and 128. These two storms caused nearly all the runoff for the 1995 growing season. The most runoff occurred from the Surface Drainage Only plot (250 mm) and the least from the Conventional Subsurface Drainage plot (125 mm). The runoff from the plots with Shallow or Medium depth controlled water tables were less than the Surface Drainage Only plots but more than for the Conventional Subsurface Drainage plots (Figure 6a). Infiltration into the alluvial soil is affected to a large extent by the clay surface layer rather than the depth to the water table in the soil profile. Soil compaction in the surface layers caused by construction equipment during the project installation may have contributed to less infiltration than was expected. Subsoiling of the plots following the 1995 corn harvest confirmed the presence of a shallow compact soil layer.

Subsurface Drainage

The cumulative subsurface drainage volumes during the 1995 growing season for the Conventional Subsurface Drainage method and the Medium and Shallow Controlled Water Table methods are plotted in Figure 6b. The Conventional method required the most pumped drainage (about 85 mm) with the two Controlled Water Table methods requiring only about 30-40% as much pumped drainage volume. After about day 180 (Figure 6b), the drainage required was reduced even with continuing occasional rain because of the increased evapotranspiration demand of the corn crop. The short-term pumped drainage events required to maintain the Shallow and Medium controlled water table depths during and following the rainfall events on days 182 and 214 are evident in this graph.

Subirrigation

The comparison of the volume of subirrigation water required during the 1995 growing season for the Shallow and Medium Controlled Water Table methods was difficult because of detected subsurface leakage between some of the Shallow controlled plots and adjacent plots with Conventional Subsurface Drainage or Medium Controlled Water Table depth. Thus, the comparison is provided here with data from plots where neither surface or subsurface leaks were detected during 1995 [Plot 1 (Rep I) for CWT @ 0.75 m and Plot 8 (Rep IV) for CWT @ 0.45 m]. The cumulative subirrigation volumes for the Shallow and Medium Controlled Water Table methods are shown in Figure 7. The total subirrigation volume required to maintain the shallow water table at about the 0.45 m depth (210 mm) was approximately two times that required for water table control at the 0.75 m depth.

The demand for subirrigation water for the Medium Controlled Water method began about 40 days after the initial subirrigation water was required for the Shallow Controlled Water Table method (Figure 7). The rate that subirrigation water was supplied was about the same for both methods during the 50-day period, days 165 to 215, as shown by the slopes of the cumulative subirrigation vs. time (days) curves.

SUMMARY AND COMMENTS

Four methods of water table control on agricultural cropland were evaluated in field tests on an alluvial soil (Commerce clay loam) near Baton Rouge, Louisiana. The four methods included: [1] Surface Drainage Only; [2] Conventional Subsurface Drainage to a depth of 1.0 m; [3] Shallow Controlled Water Table at a 0.45 m depth; and [4] Medium Controlled Water Table at a 0.75 m depth. All experimental plots were surface drained with a uniform slope of 0.2%. The Controlled Water Table methods were designed to regulate subsurface drainage and subirrigation flows by automatically adjusting the drainage outlet water level (in a riser pipe) based on the monitored field water table depth midway between drainlines. Objectives were: a) to determine the controllability of water table depth under field conditions, and b) to determine the effects of water table control on movement and loss of agrochemicals (pesticides and fertilizers) in surface runoff, subsurface drainage discharge, and deep seepage.

The average and standard deviation of water table depth maintained during the 1995 growing season by each method was: [1] Surface Drainage Only, 0.85 $\pm$ 0.22 m; [2] Conventional Subsurface Drainage, 1.19 $\pm$ 0.15 m; [3] Shallow Controlled Water Table, 0.60 $\pm$ 0.18 m; and [4] Medium Controlled Water Table, 0.84 $\pm$ 0.13 m. For the auto-controlled water table methods [3 & 4], the water table depths midway between drainlines (during periods without rain) were maintained about $\pm$ 0.10 m of the maximum depths of the desired water table ranges. Since the water table depth was maintained near the maximum depth of the desired range, soil-water storage capacity for infiltration of rainfall was available, thus often minimizing or eliminating fluctuations of the water table to depths shallower than the desired range during rainfall events.

The total rainfall during the growing season was 412 mm (days-of-the-year 104-256), which was about 61 % of the long-term normal. The total surface runoff volume for the 1995 growing season was the greatest for the Surface Drained Only plots, 250 mm, and the least for the Conventional Subsurface Drained plots, 125 mm. Surface runoff varied considerably from the plots with automatically controlled water table depths during periods with heavy rainfall and periods with occasional rainfall events; some leakage between plots was detected. Subsurface drainage volume in the 1995 growing season was greatest for the Conventional Subsurface Drainage method (85 mm), and least for the Medium-Depth Controlled Water Table method (30 mm); the subsurface drainage volume for the Shallow-Depth Controlled Water Table method was about 40 mm. The subirrigation volume required in the 1995 growing season was about 200 mm for the Shallow-Depth Controlled Water Table and 100 mm for the Medium-Depth Controlled Water Table method.

We concluded that automated adjustment of the drainage outlet water level based upon the monitored field water table depth midway between drainlines was a successful method of water table control for the alluvial soil conditions. Demands for subirrigation water greatly increases as the controlled water table depth becomes shallower. Optimum control of water table depths in the lower Mississippi Valley should be based on not only the impact on the loss of applied agrochemicals (See paper by Southwick et al., this *Proceedings*), but also the demand for subirrigation water to optimize yields, and the cost for pumping both subirrigation and subsurface drainage.

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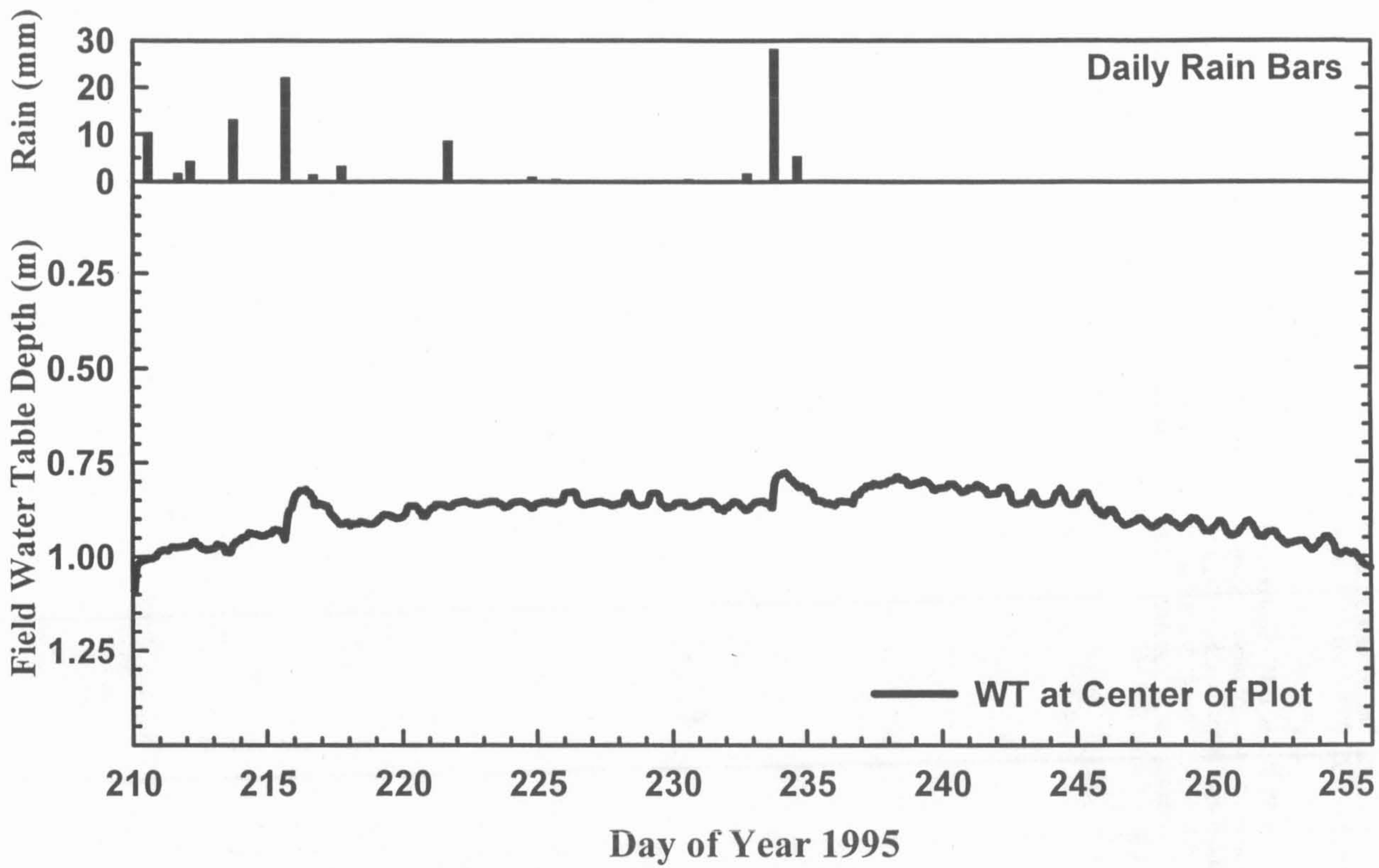

Fig. 1 - Water table depth fluctuation with **Surface Drainage Only** (Rep I, Plot 2)

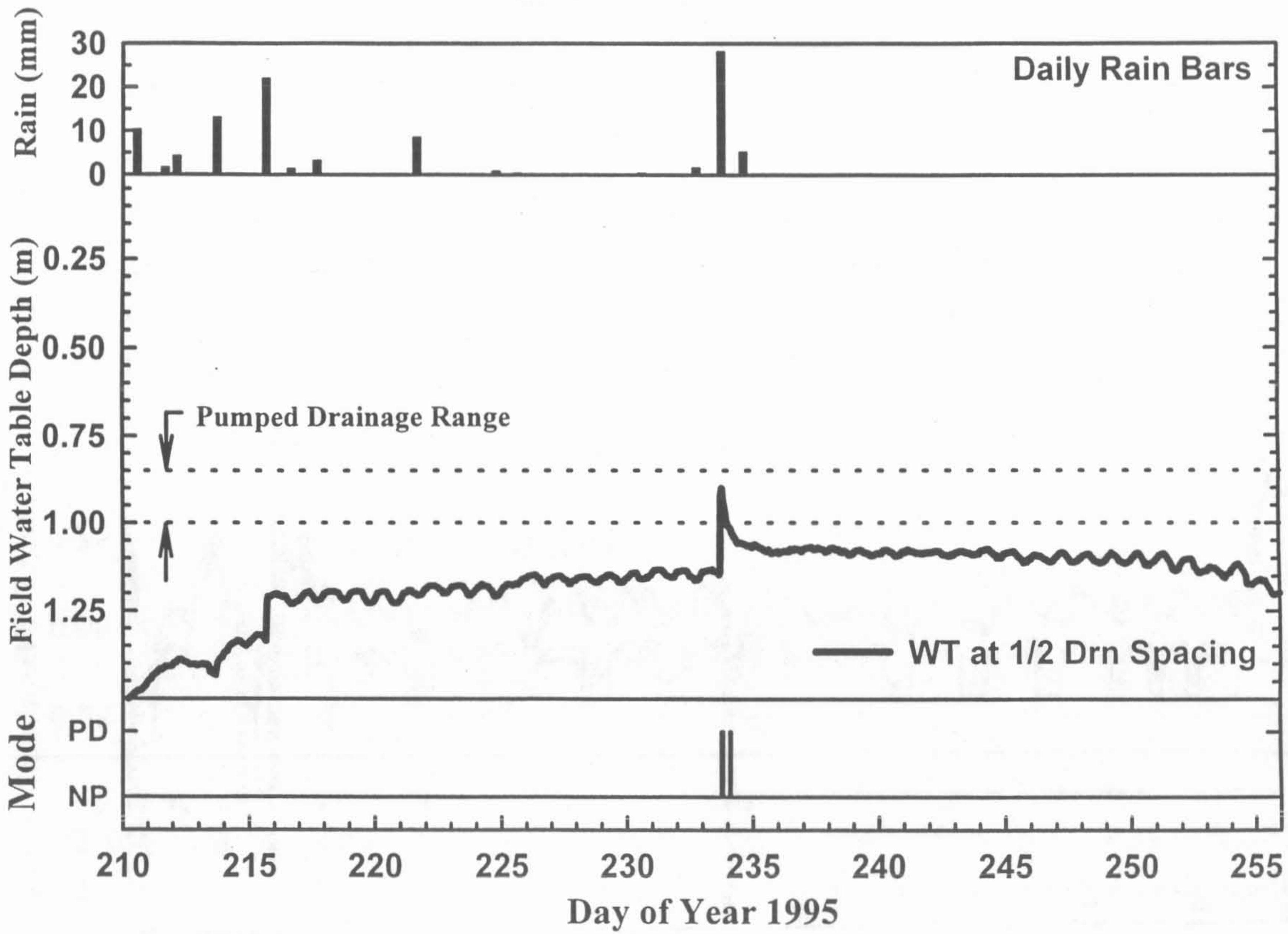

Fig. 2 - Water table depth fluctuation with **Conventional Subsurface Drainage** (Rep I, Plot 9)

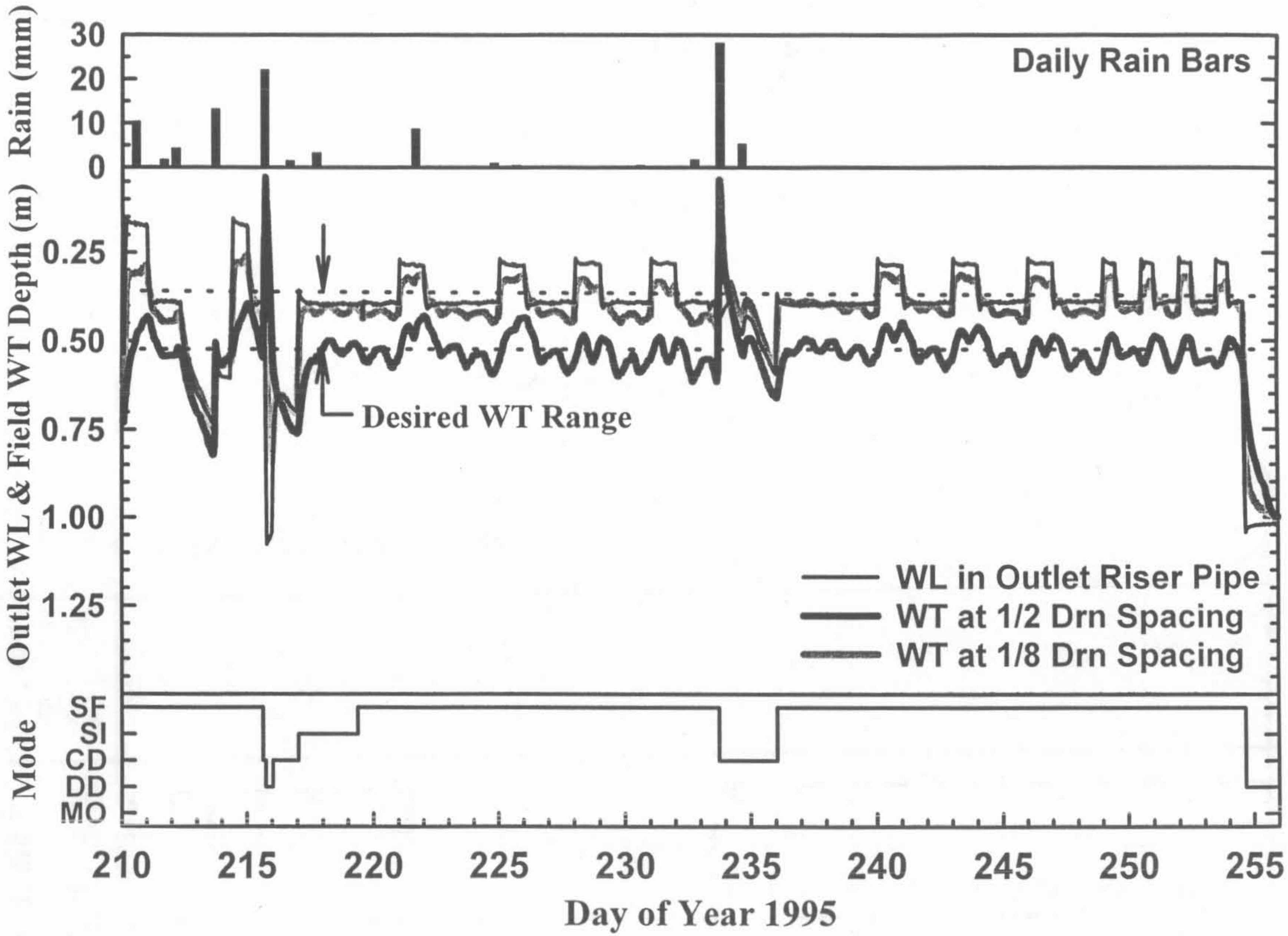

Fig. 3 - Automated **Shallow-controlled water table depth (0.45 m),** (Rep I, Plot 10)

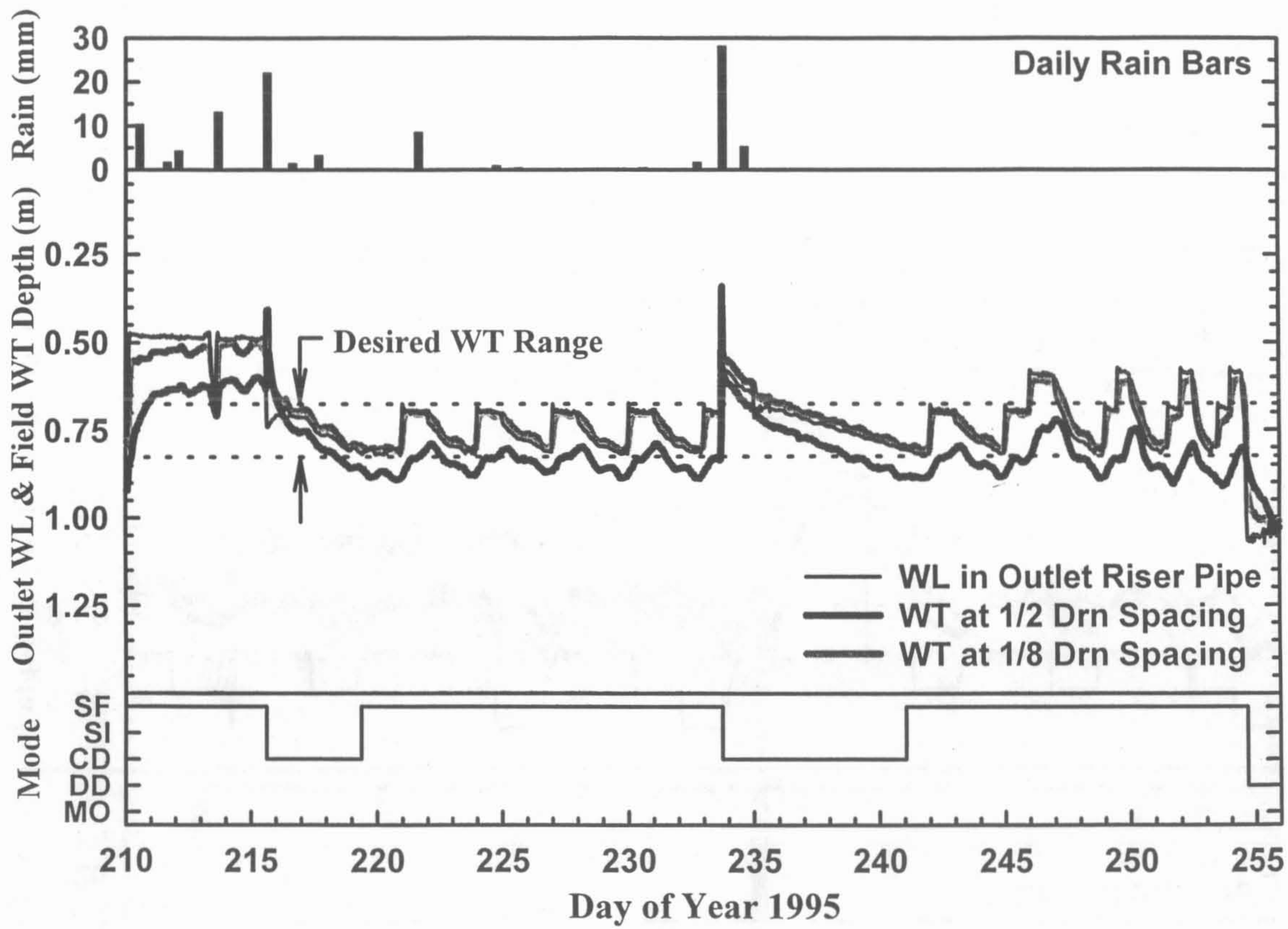

Fig. 4 - Automated **Medium-controlled water table depth (0.75 m)**, (Rep I, Plot 1)

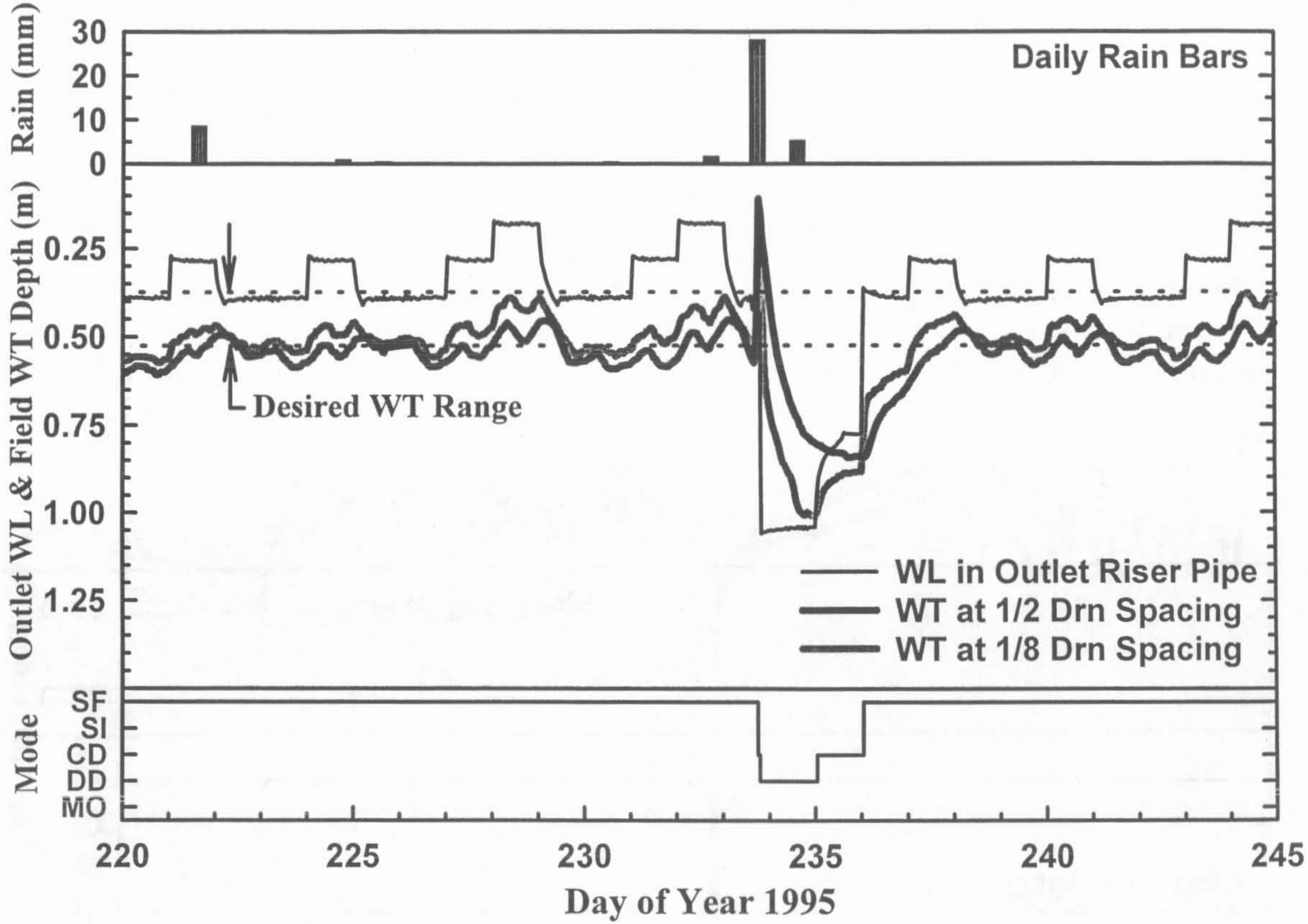

Fig. 5 - Short-term period of automated water table control at the 0.45 m desired depth.

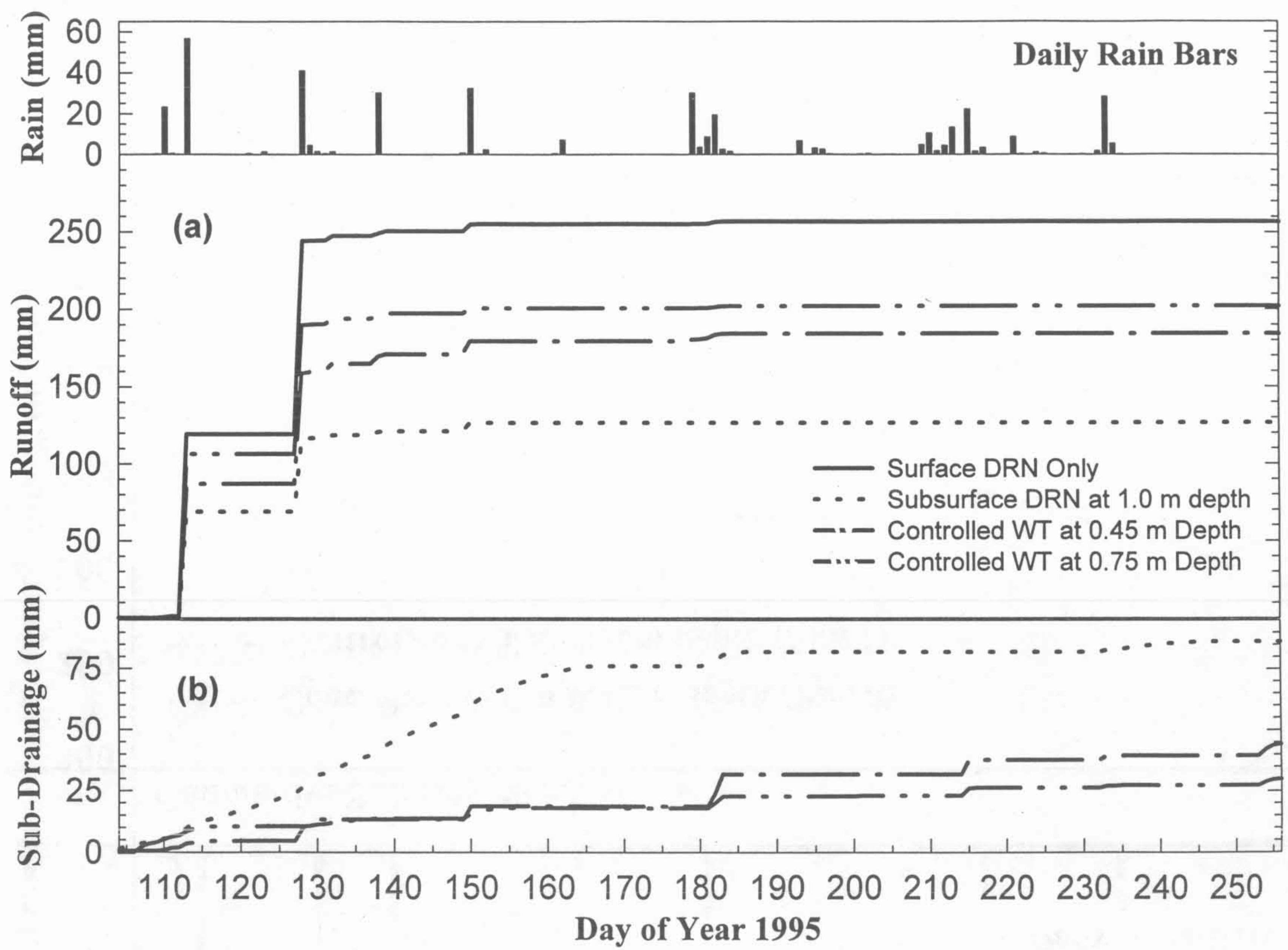

Fig. 6 - Cumulative surface runoff (a) and subsurface drainage (b) for the 1995 growing season.

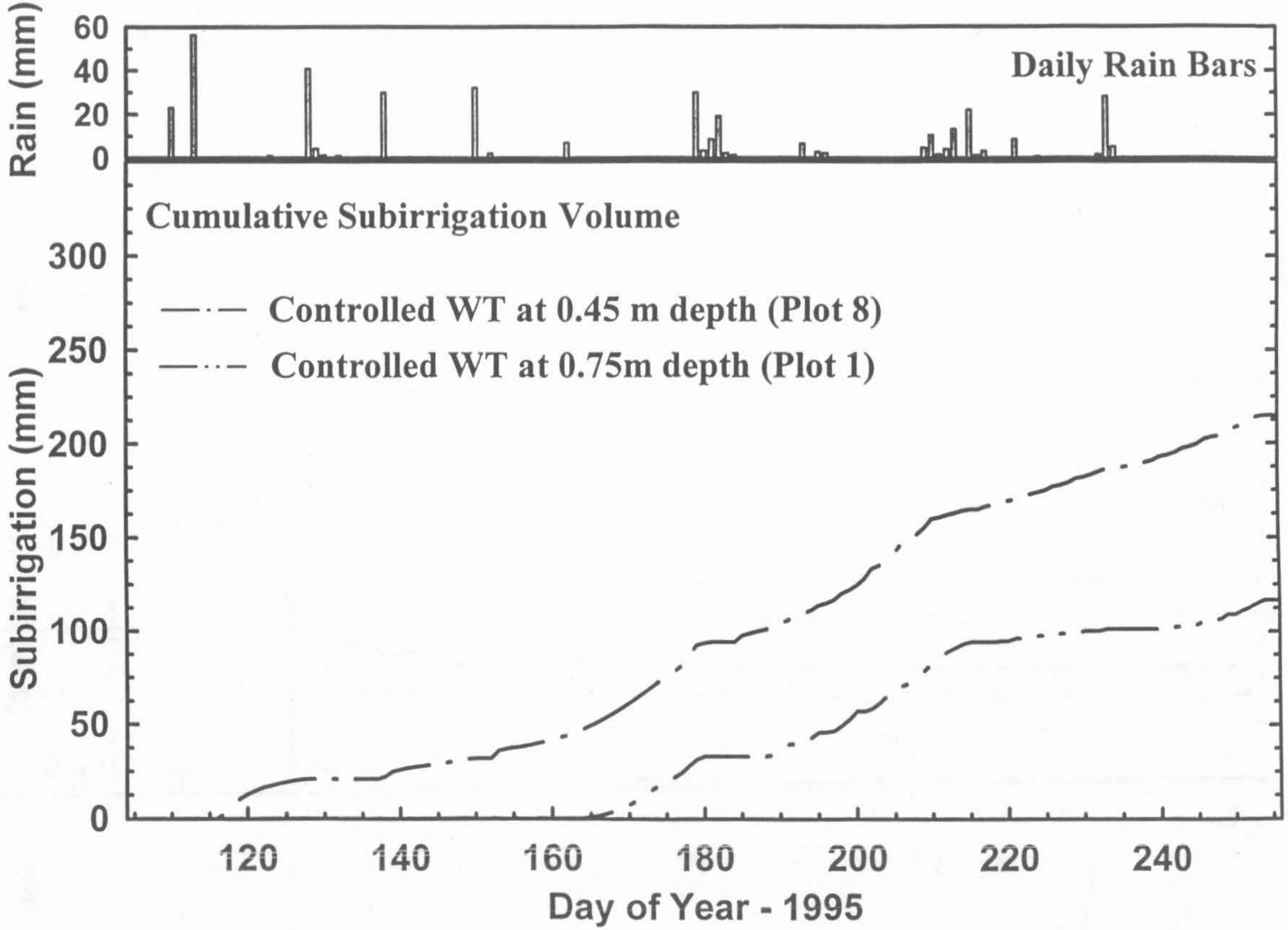

Fig. 7 - Cumulative subirrigation required to maintain a Shallow and Medium water table depth.