INTEGRATED MANAGEMENT OF WATER AND AGROCHEMICALS IN AGRICULTURAL CROP PRODUCTION SYSTEMS

James L. Fouss, Guye H. Willis, and Lloyd M. Southwick
USDA, ARS, Soil and Water Research Unit
Baton Rouge, Louisiana

INTRODUCTION

In the lower Mississippi River Valley, frequent rainfall events, shallow water table conditions, and the extensive use of agrochemicals can result in significant losses of applied agrochemicals and potential contamination of surface and subsurface water resources. Integrated methodology is being developed 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 potential 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 crop 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 both 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 1996 growing season in an alluvial soil (Commerce silt loam) 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] Automatically Controlled Water Table at a 0.45 m depth, and [4] Automatically 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, Louisiana; the experimental layout and design was reported by Willis et al. (1991). 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 6mil thickness plastic film vertical 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 (HDPE) plastic draintubes installed at a 1.25 m depth and 15 m spacing. The drainlines outlet ends were connected to small sump structures (300 mm dia. riser pipes in the experiment) within which the outlet water level was controlled. The center (experimental) drainline and the two plot border (buffer) lines were connected to separate outlet sumps (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 automatically 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) are 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) automatically 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).

Subsurface 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 1995 growing season are reported by Southwick et al. in this Proceedings (analyses of the 1996 growing season results were not complete at this writing).

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 greater than a certain percentage, 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 1996 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.

Conventional Subsurface Drainage

In the conventional subsurface drainage mode, the water level in the outlet riser pipe is controlled with a sump pump to keep the water level between 0.90 and 1.10 m depth, which maintained the water table at about a 1.00 m depth in the field plot, which is about 0.25 m above the bottom of the 1.25 m deep drainage conduit. 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 a 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 two predetermined water levels about 0.15 m apart. 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 or 1996 growing seasons to adjust the two outlet water levels in the risers. 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) is 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.

Subirrigation

In the subirrigation mode, the water level in the outlet riser pipe is also maintained between two predetermined water levels about 0.15 m apart. 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 outlet water level had to be set at an average 0.35 m depth (0.275 to 0.425 m range) to maintain a desired average water table depth of 0.45 m [Method 3]. For the Medium Controlled Water Table (0.75 m) [Method 4] 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 two outlet water levels at which the irrigation water supply valve is either opened or closed are automatically adjusted upward 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 not made; instead, additional irrigation water is not supplied into the riser pipe until the field water table depth increases (recedes) into the desired range. Adjustments of the two 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).

Control Override Options

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 1996 growing season (defined as Days-of-the-Year, 92-221, for 1996) are used to illustrate most of the performance parameters. The total rainfall during the 1996 growing season was 502 mm, which was about 90% of the long-term (30-yr) normal. In 1996 there were periods of up to 25 days with essentially no rain and droughty soil conditions began to occur.

Water Table Depth

The average and standard deviation of water table depth maintained during the 1996 growing season by each method was: [1] Surface Drainage Only, 0.80 ± 0.22 m; [2] Conventional Subsurface Drainage, 1.21 ± 0.15 m; [3] Shallow Controlled Water Table, 0.50 ± 0.09 m; and [4] Medium Controlled Water Table, 0.78 ± 0.11 m. For each method of water table control, the hourly 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).

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 120 to 185 during the 1996 growing season. The hourly average water table depths are plotted in these graphs, which are for replication 1 only. Rainfall events occurred early and late in this selected period of record, and very little rain fell during the middle 30 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 0.50 m depth for the first 20 days of the selected period, but with very little rainfall in the next two weeks of the season the water table depth increased to about 0.90 m, and occasional rainfall in the latter portion of the period (days 160-185) caused the water table to rise and then fall again over a 5-day period. For the Conventional Subsurface Drainage method (Figure 2), the water table was maintained at about a 1.10 m depth during the first 25 days of the selected period, and during the last half of the period (days 145-185) the water table depth increased to below the pumped drainage range, except for short periods following rainfall events, and intensive pumped drainage was required for the infiltrated rainfall on day 177. 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.

The water table depth midway between the 15 m spacing drainlines with the Shallow (0.45 m depth) Controlled Water Table method (Figure 3) was maintained between an average hourly depth of 0.40 and 0.60 m for the selected period (days 120-185), except for short periods following rainfall events. The desired water table depth range was 0.375 to 0.525 m for this method (treatment), and during the first 20 days of the selected period the water table depth was maintained at about an average depth of 0.50 m, and at about an average depth of 0.55 m during the latter 45 days of the period. Or stated another way, during the latter 45 days of the period the hourly water table varied about $\pm$ 0.10 m from an average depth which was slightly deeper then the maximum of the desired water table range (0.375 to 0.525 m). The typical outlet water level was maintained in this control method between 0.30 and 0.40 m depths (0.35 m average) below the ground surface elevation in the plot, or 0.10 m shallower than the desired average water table depth of 0.45 m in the plot. The outlet water level was held at this average 0.35 m depth as long as the field water table depth (at the midpoint between drains) remained within the desired range of 0.375 and 0.525 m. The water table depth in the plot at a 2-m distance from the experimental drainline (at 1/8 the drain spacing) was typically about 0.05 m deeper than the depth of the controlled water level in the outlet riser pipe (see Figure 3). When the water table in the plot midway between drains increased to a depth greater than this desired range (e.g., after Day 150), the feedback control system raised the outlet water level to the 0.20 m depth (i.e., a 0.10 m step-change at 1200 or 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 1200 or 2400 h, where it remained until another feedback adjustment was needed. The automatic changes in mode of water table control made by the data-logger/controller unit are illustrated for days 130-132, and 177-178, 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). On day 177 the control mode was initially switched to conventional subsurface drainage (Mode DD) 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 1200 h when the mode was switched to controlled-drainage (CD). At the next 2400 h interval the mode was switched back to subirrigation with the feedback option activated. 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 water table depth control provided with the Medium (0.75 m depth) 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. Because of the early spring rains in the 1996 growing season (from days 104-118), the subirrigation mode (SF) that was started on day 94 after corn was planted was switched to controlled-drainage (CD) on day 104 when appreciable rainfall occurred. The CD mode remained active until day 150 (see Figure 4) and the water table was maintained in the desired range of 0.625 to 0.825 m depth. Beginning on about day 140 the average daily water table depth began to increase and on day 150 it had increased to a depth greater than the desired range. The mode of control was then switched to subirrigation with feedback (SF), and only the rainfall events on days 175-177 resulted in a short-term switch to conventional and controlled-drainage modes, with subirrigation continuing again on day 188 (Figure 4). The water table was maintained at about an average depth of 0.80 m during this subirrigation period (i.e., beyond day 150). The rainfall event on day 177 caused the mode to be switched to conventional drainage (Figure 4, which is similar to the response shown in Figure 3), however, it was 18 h before the mode of operation was switched to controlled-drainage, and then 12 h more to switch back to subirrigation with feedback. For the subirrigation period, days 150 to 185, the average hourly water table depth varied about $\pm$ 0.10 m from an average depth that was near the maximum of the desired water table depth range (0.675 to 0.825 m); this control response is similar to that shown in Figure 3 for the same period. For this Medium (0.75 m depth) Controlled Water Table method, the drainage outlet water level was controlled (or maintained) within the same range as the desired water table depth in the plot, namely, 0.625 to 0.825 m; it was not necessary to hold the outlet water level higher than the desired water table depth as the case for the Shallow-Controlled (0.45 m) Water Table method. The feedback adjustments required in the outlet water level to maintain the plot water table depth within the desired range were similar for both the medium and shallow depth methods, that is, step-wise adjustment steps of 0.1 m. As shown in Figure 4, beginning about day 154, an occasional upward adjustment step of 0.10 m in the outlet water level was required to force a falling water table to rise again into the desired range. Automated water table control in this medium depth range, 0.675 to 0.825 m, was somewhat easier to achieve throughout the 1996 growing season than at the shallow water table depth range, 0.375 to 0.525 m, mainly because early season control required no subirrigation and water table fluctuations that occurred did not cause potential excessive soil-water conditions in the active root zone. The differences in subirrigation volumes required are discussed below.

<u>Surface Runoff</u>

The cumulative runoff volumes during the selected period, days 120 to 185 of the 1996 growing season, for plots with the four different methods of water table control are shown in Figure 5a. These data are for replication 1 only of each treatment; comparisons madé with data from the other replications (not shown) are similar. The three storm events on days 120, 130-133, and 175-177 caused essentially all the runoff for the 1996 growing season (days 92-221); the total rainfall for these three storm event periods was about 150 mm. The most runoff during the period, days 120 to 185, occurred from the Surface Drainage Only plot (131 mm) and the least from the Conventional Subsurface Drainage plot (78 mm). The runoff from the plots with 0.45-m depth controlled water table treatment was 100 mm, and 108 mm of runoff occurred from the 0.75-m depth controlled water table treatment. 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 layer caused by farming operations, especially for the surface drained only plot where normally soil moisture was higher than for the other treatments, may have contributed to less infiltration and greater runoff volume for the surface drained only treatment. All plots were subsoiled following the 1995 corn harvest to improve infiltration characteristics; soil profile compaction during final construction of the research plots in 1993 and 1994 caused essentially the same runoff volume to occur from all treatments in early seasons of the project.

Subsurface Drainage

The cumulative subsurface drainage volumes during the selected period (days 120-185) of the 1996 growing season for the Conventional Subsurface Drainage method and the Medium (0.75 m) and Shallow (0.45 m) Controlled Water Table methods are plotted in Figure 5b. The Conventional method required the most pumped drainage (about 11 mm) during the selected period, with the two Controlled Water Table methods requiring only about 40-60% as much pumped drainage volume; 6.1 mm of drainage for the Medium (0.75 m) and 4.5 mm for the Shallow (0.45 m) Controlled Water Table methods. After about day 180 (Figure 5b) the drainage required was reduced even with continuing occasional rain because of the increased evapotranspiration demand of the corn crop.

Subirrigation

The comparison of the volumes of subirrigation water required during the selected period of the 1996 growing season for the Shallow and Medium Controlled Water Table methods are shown in Figure 6. The total subirrigation volume required to maintain the shallow water table at about the 0.45 m depth (33 mm) was approximately 75% higher that required for water table control at the 0.75 m depth (19 mm). The demand for subirrigation water for the Medium Controlled Water method began about 30 days after the initial subirrigation water was required for the Shallow Controlled Water Table method (Figure 6). The rate that subirrigation water was supplied was about the same for both methods during the 35-day period, days 150 to 185, as shown by the similar slopes of the cumulative subirrigation versus time (days) curves; the slope of the Shallow (0.45 m) Controlled Water Table was slightly greater than the slope for the Medium (0.75 m) method (see Figure 6).

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, LA. 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, 0.80 ± 0.22 m; [2] Conventional Subsurface Drainage, 1.22 ± 0.15 m; [3] Shallow Controlled Water Table, 0.50 ± 0.09 m; and [4] Medium Controlled Water Table, 0.78 ± 0.11 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 some rainfall events.

The total rainfall during the 1996 growing season was 502 mm (days-of-the-year 92-221), which was about 90% of the long-term normal. Runoff and subsurface drainage volumes were compared for a 65-day period (days 120-185), which produced most of the runoff and drainage for the 1996 growing season. The total surface runoff volume for this period was the greatest for the Surface Drained Only plots, 131 mm, and the least for the Conventional Subsurface Drained plots, 78 mm; runoff was 100 mm for the Shallow (0.45 m) and 108 mm for the Medium (0.75 m) depth Controlled Water Table methods. Subsurface drainage volume during the selected period of the 1996 growing season was greatest for the Conventional Subsurface Drainage method (11 mm), with the two Controlled Water Table methods requiring only about 40-60% as much pumped drainage volume; 6.1 mm of drainage for the

Medium (0.75 m) and 4.5 mm for the Shallow (0.45 m) Controlled Water Table methods. The subirrigation volume required in the same period was about 33 mm for the Shallow-Depth Controlled Water Table, and 19 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 very 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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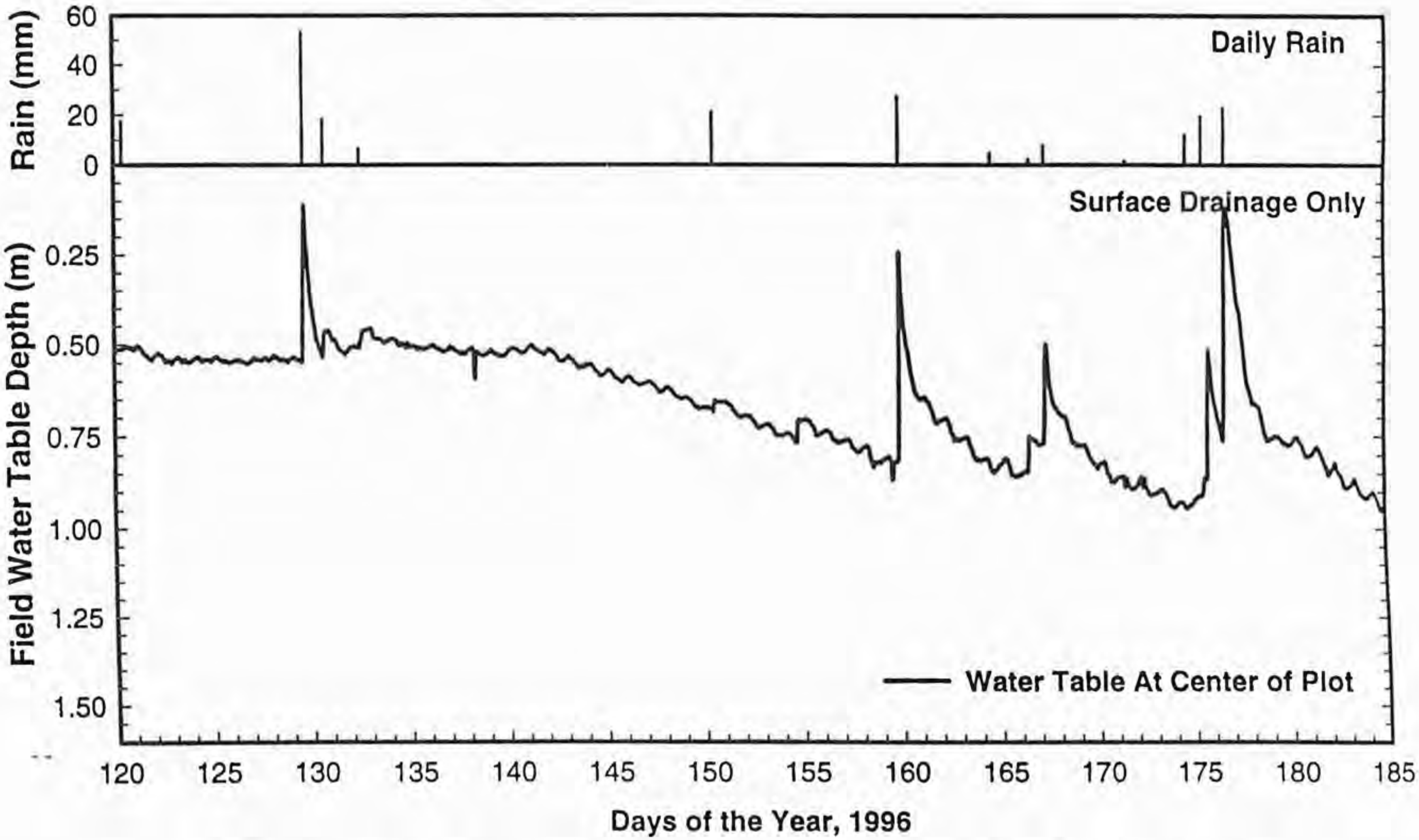

Fig. 1 - Water table depth fluctuation with **Surface Drainage Only** (Rep 1, Plot 2)

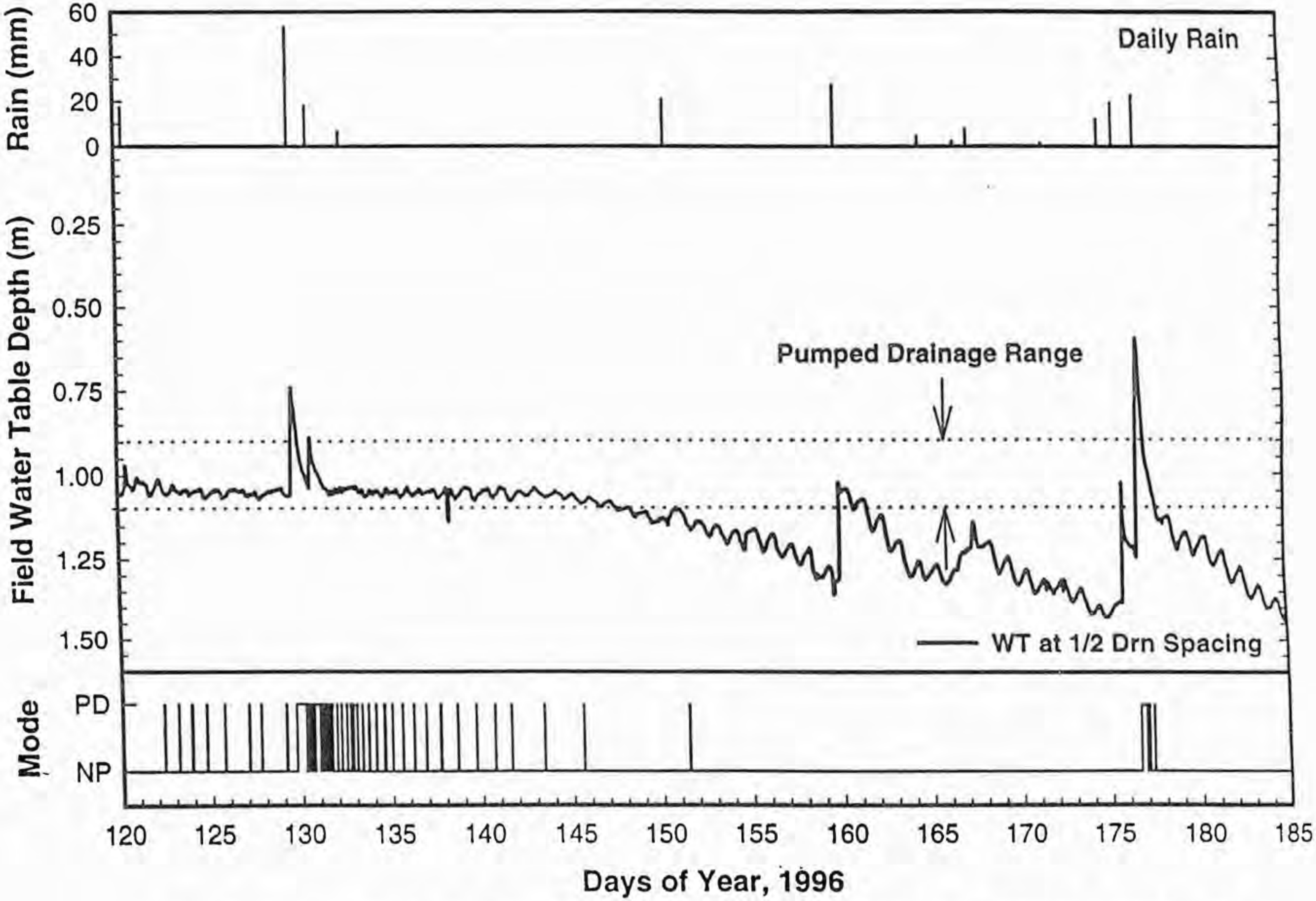

Fig. 2 - Water table depth fluctuation with **Conventional Subsurface Drainage** (Rep 1, Plot 9)

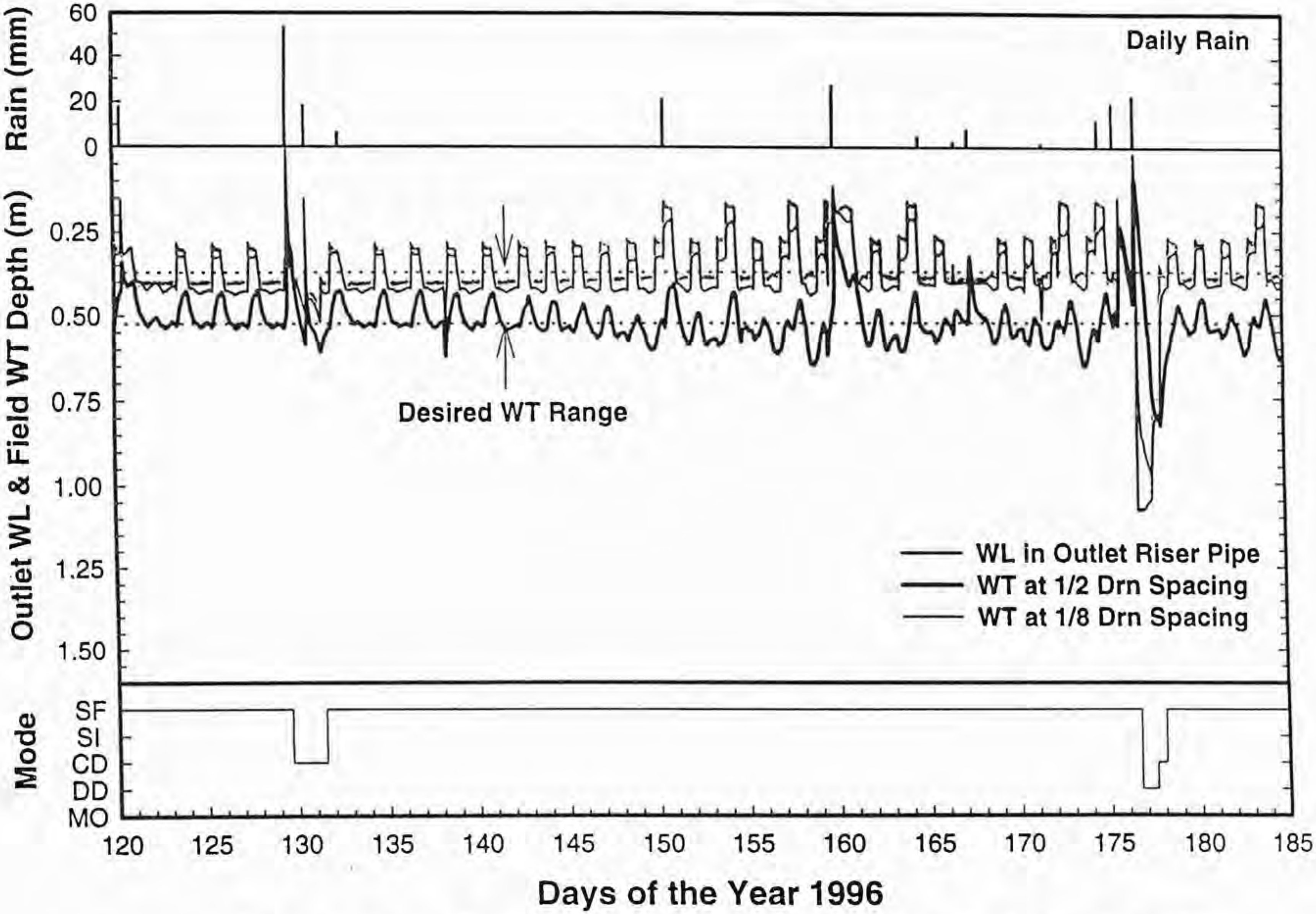

Fig. 3 - Automated **Shallow-controlled water table depth (0.45 m)**, (Rep 1, Plot 10)

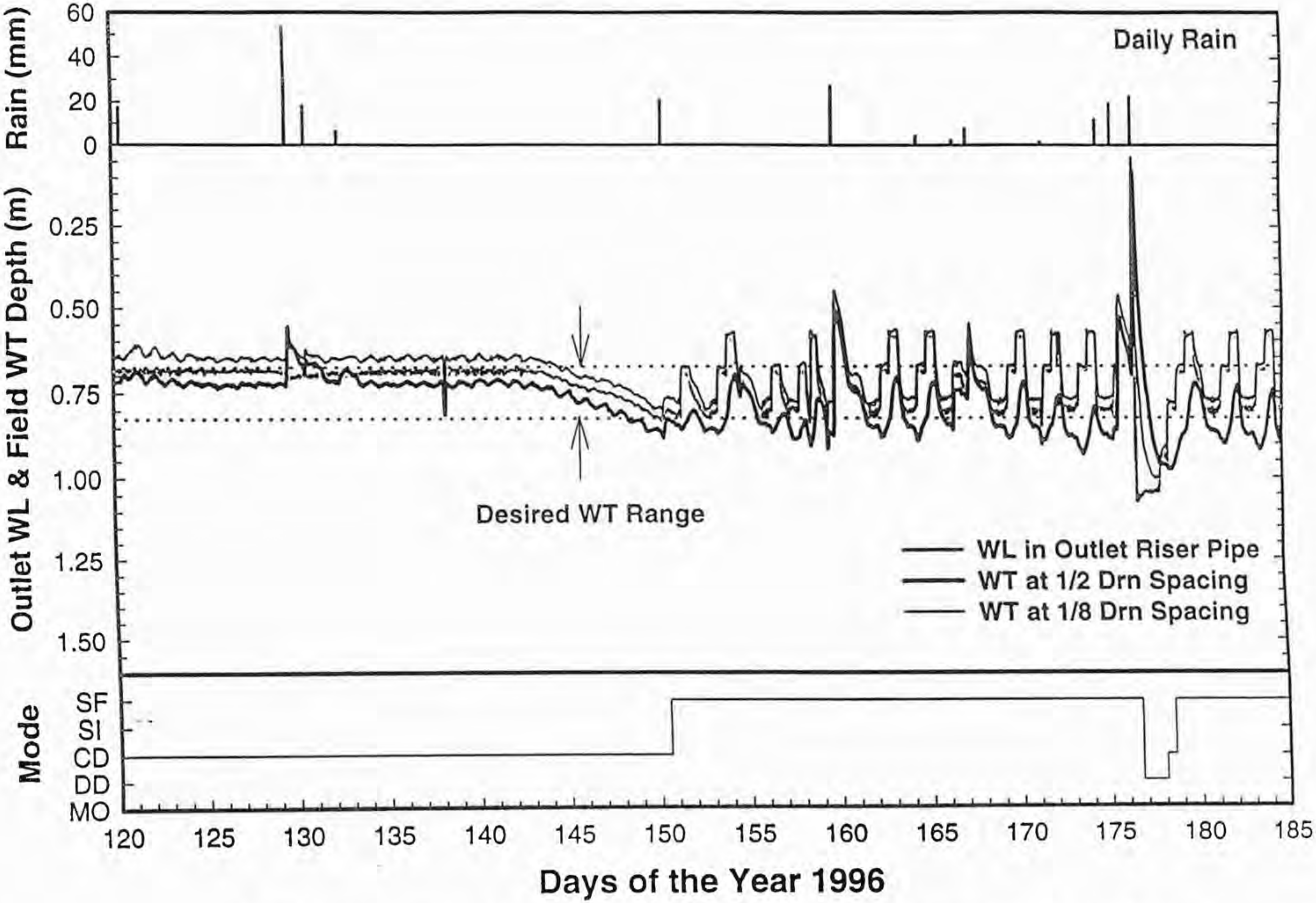

Fig. 4 - Automated **Medium-controlled water table depth (0.75 m)**, (Rep 1, Plot 1)

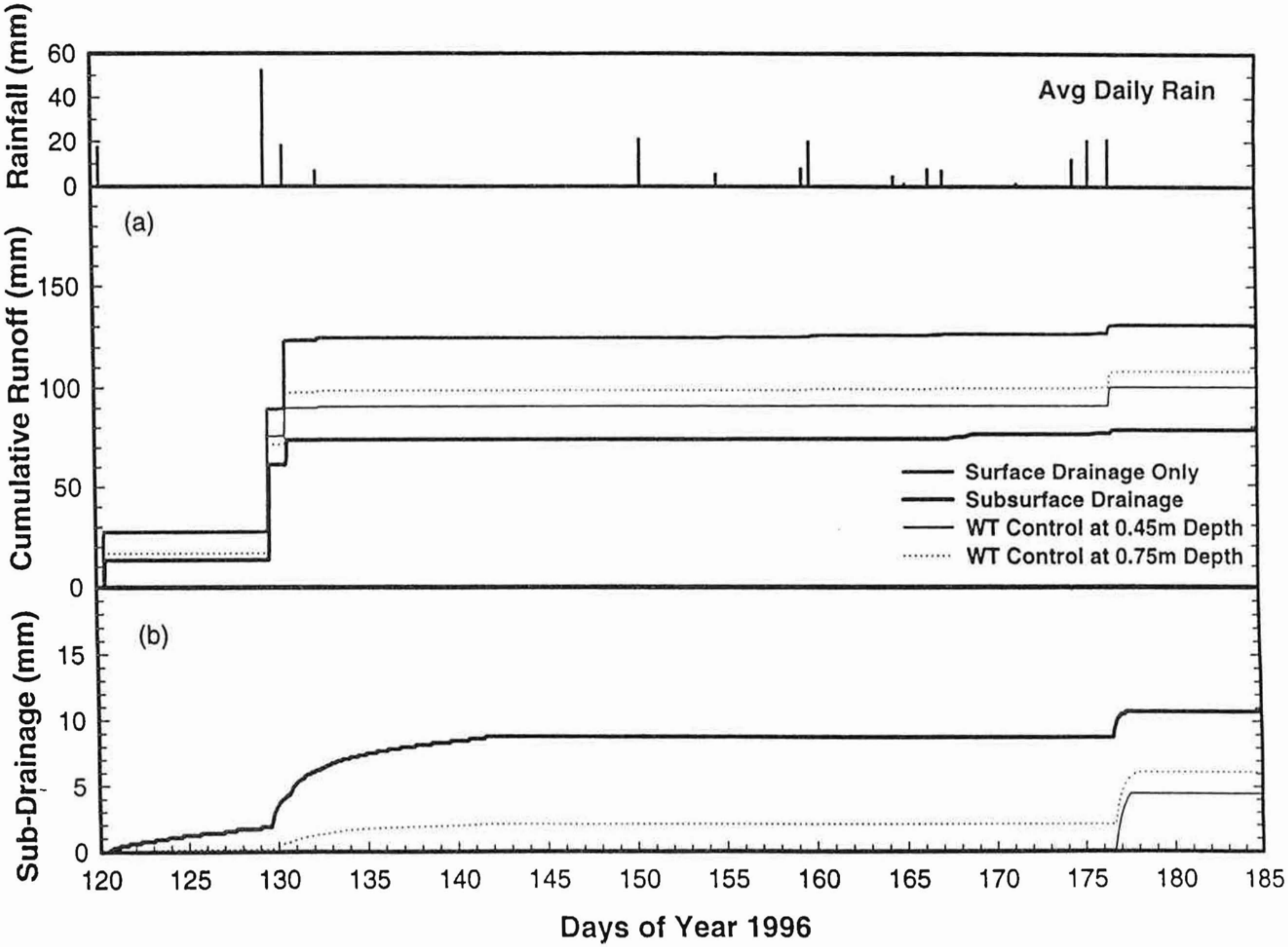

Fig. 5 - Cumulative surface runoff (a) and subsurface drainage (b) for the 1996 growing season (Rep 1)

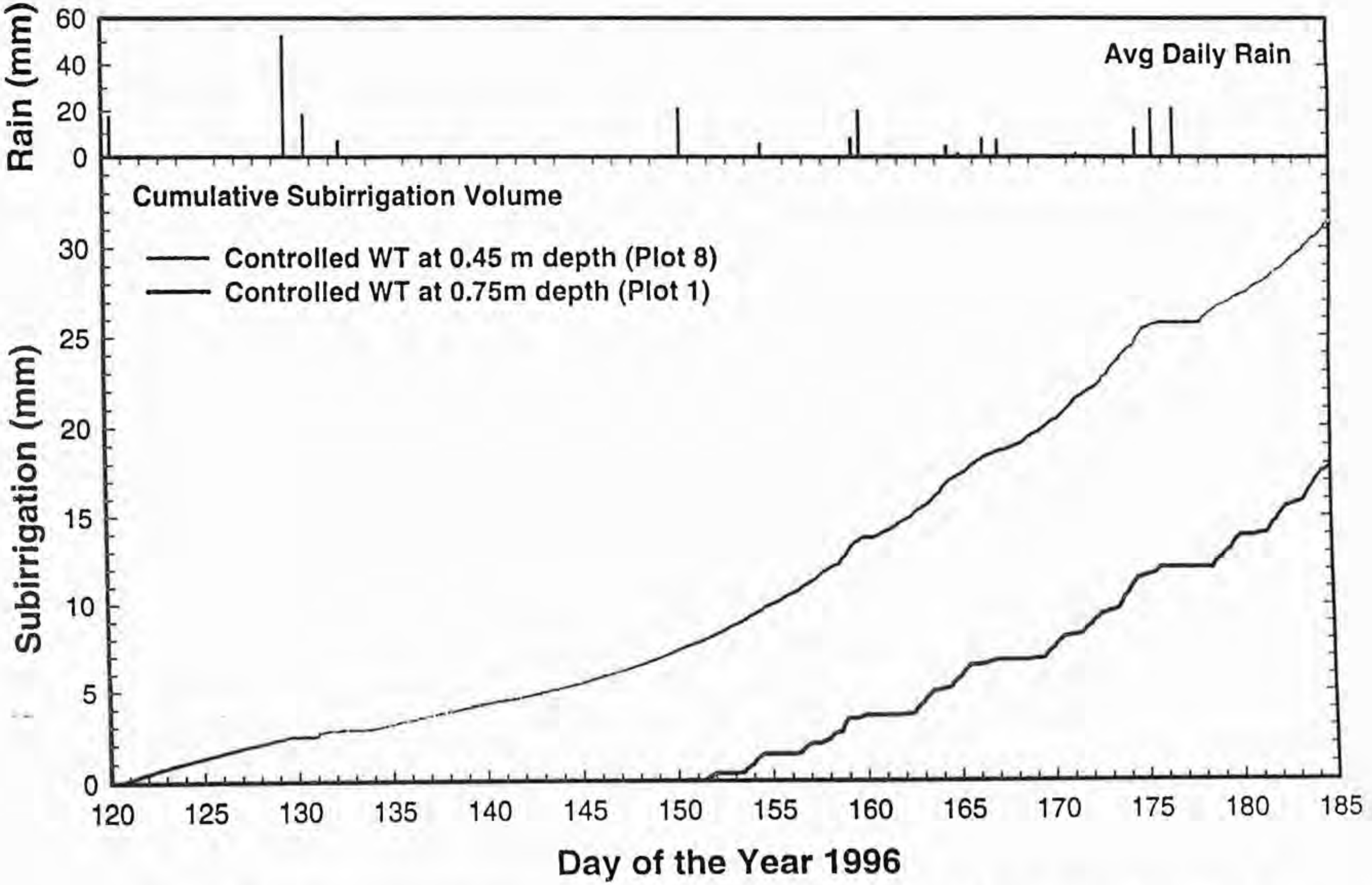

Fig. 6 - Cumulative subirrigation required to maintain a Shallow and Medium water table depth.