EVALUATION OF SUBSURFACE DRAINAGE FOR SUGARCANE LANDS AND ITS EFFECTS ON SOIL TRAFFICABILITY [1]

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INTRODUCTION

The need for further water management research on sugarcane land in Louisiana was highlighted over the past several years because of concerns about the quality of runoff water from sugarcane lands. Research was needed to develop methods to reduce the potential of polluting adjacent streams, wetlands, and water resources with agrochemicals (fertilizer nutrients and pesticides) carried in surface drainage waters. Additionally, poor trafficability became an increasing issue during this same period because heavy modern Cane Combine and Transport equipment was beginning to be used in Louisiana. A new field project to address these research needs has been planned and is being initiated on an alluvial soil in the Lower Mississippi Valley. The high clay content of soils in this region and the heavy rainfall amounts that can occur during the growing and cane harvest seasons can cause flooding of fields, excessive runoff, and poor trafficability. If heavy rainfall occurs soon after application of agrochemicals, the runoff can carry potentially polluting chemicals. Delays in conducting field operations caused by poor trafficability can significantly decrease harvesting efficiencies and increase overall costs for sugarcane production.

This research is intended to show the benefits of subsurface drainage and water table control to improve water quality and trafficability for sugarcane lands. This research will also be used to develop criteria for predicting both water quality factors and trafficability through modeling and simulation. The field project will serve as a demonstration site to show Louisiana's sugarcane growers and industry officials the benefits of subsurface drainage and/or water table control for increasing potential sugar yields and the longevity of the cane stand, and for improving trafficability for planting, cultivating, and harvesting field operations. A major thrust area of this research will be to show potential environmental benefits such as water quality improvements that may be achieved through managed (controlled) runoff and subsurface drainage.

Field demonstrations and workshops are needed in the Lower Mississippi Valley (LMRV) region to assist farmers in becoming better acquainted with the multiple benefits of subsurface drainage and water table management. For example, harvesting of sugarcane with cane combine equipment on experimental land where conventional surface drained only plots and subsurface drained plots are in the same large field area will make it possible to demonstrate to farmers and sugarcane industry officials the potential benefit of improved trafficability provided by subsurface drainage. Assistance may also be needed for the installation of subsurface water management systems on the farmlands of key or influential farmers in a given area. If the performance of the demonstration systems are favorable and benefits evident, neighbors may then become interested and want to try the practice. Such technology transfer or demonstration activities are considered an important part of this proposed research project. Having this cooperative research project located on the Sugarcane Research Farm at the St. Gabriel station of the Louisiana Agricultural Experiment Station (LAES), where farmer demonstration projects are conducted routinely, is a very important approach for making the ***Water Table Management-Water Quality-Trafficability*** aspects of the new project more visible and accessible to sugarcane growers and industry representatives.

The effect of agricultural operations and practices on the quality of water resources is a concern of many people. This concern encompasses not only streams, rivers, lakes, and groundwater, but also wetland areas adjacent to and/or downstream from agricultural lands. Much of the farm land in the Lower Mississippi River Valley (LMRV) is low lying and adjacent to large bodies of water. Average annual rainfall in the area is 1400 mm but varies between approximately 1000 mm and 2000 mm. During the winter and spring months each year, excessive rainfall causes the water table to rise and fluctuate near the soil surface. High rainfall amounts can cause both surface runoff and leaching

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throughout much of the year. The presence of pesticides and nutrients in surface runoff and in nearby aquatic habitats has long been noted in the area, and there have been recent reports of these chemicals in the Mississippi River alluvial aquifer. The LMRV contains about 2.5 million hectares (6.2 million acres) that have been assessed as highly vulnerable to groundwater pollution by leachable chemicals, and a slightly smaller amount of land evaluated as moderately vulnerable. Thus, degradation of the soil and water resources in the LMRV region represents a serious threat to the long-term sustainability of agriculture under high water table conditions common to the region.

The integrated management of soil and water resources and agronomic cultural practice is necessary to insure environmentally sound crop production on fine-textured, shallow-water-table soils in humid areas (like the LMRV), and to reduce or eliminate potential pollution of adjacent wetland areas. This new project will extend the past and current research to investigate and develop Best Management Practices that integrate soil and cultural management practices (minimum tillage, traffic control, grass filter strips, etc.) with the water-chemical management practices to improve water quality of runoff, subsurface drain effluent, and lateral seepage into adjacent drainage channels and wetlands, and percolation to groundwater.

BACKGROUND

Sugarcane is one of the most important crops in Louisiana's agriculture and economy. About 167,000 ha of sugarcane are grown each year and in an area of high rainfall and high fluctuating water tables that often rise to the soil surface. Research conducted by Carter et al. (1985) showed that a high water table during the dormant season caused significant yield decrease for sugarcane. Research conducted by the Soil and Water Research Unit in Baton Rouge has shown that the soils, particularly the alluvial silt loams and silty clay loams, responded favorably to subsurface drainage (Carter and Camp 1983; Camp and Carter 1983). In addition, sugarcane responded favorably to subsurface drainage of the soil profile in terms of yield increase and stand longevity in comparison with those where fields are typically surface drained only (Gayle et al. 1987). Further, field experiments in the 1980s by the Baton Rouge Unit's Soil and Water engineers and scientists showed that water table control (involving controlled-drainage and subirrigation) was particularly responsive and effective in these fine textured soils (Fouss et al. 1989). Despite these results, farmers in the LMRV have not accepted or installed subsurface drainage as a common soil-water management practice. Lack of acceptance by LMRV farmers appears to be primarily linked to either installation costs or lack of knowledge.

Many farmers in the LMRV are not aware of the multiple benefits of subsurface drainage. These benefits include increased crop yields, cane stand longevity, or improved trafficability for planting, cultivation, pest management, and harvesting operations. For those farmers familiar with the practice, many are reluctant to install subsurface drainage because of the high initial cost to install the systems. The improved crop production efficiency and yield increases provided by subsurface drainage will typically offset the installation cost in 3 to 5 years for sugarcane production (Carter et al. 1988). Complicating this situation is the fact that most lands used for sugarcane production are rented or leased, and improvements on the land (such as subsurface drainage) are not typically paid by the land owners; these costs must generally be paid by the grower. Additionally, the marketing infrastructure for sugarcane provides that the sugar mills receive a contract percentage of the selling price for the sugar produced, but the mills do not share in the cost of production or the cost for land improvements (such as drainage). The costs for purchasing and maintaining the farming equipment, including the harvesting machines, are paid by the sugarcane grower.

From 1993 to 1997, the percentage of Louisiana sugarcane harvested with a modern chopper harvester (Cane Combine) has increased from 0 to 50%, and in the next few years 100% of the cane will be harvested by the chopper harvester. The change from the soldier harvester system is being brought about by the development of high yielding, usually lodged, cultivars and by pending restrictions on burning cane. Improved trafficability for operation of modern cane combine and transport equipment in sugarcane production harvesting operations will likely be a major future benefit provided to the grower by subsurface drainage. Improvements in stand longevity (e.g., a 6-year cane cycle rather than the current 3-year cycle for plowing out and replanting cane) and higher sugarcane yields should increase overall profitability of sugarcane production for the grower.

RESEARCH PLAN

Comprehensive research is needed to develop techniques to measure trafficability parameters in terms of soil physical properties related to soil strength and soil moisture. The research should involve field experimentation, laboratory investigation, modeling and simulation methods. The field research will be conducted on relatively large plot areas for each water management treatment (e.g., 36.5 x 85 m) to create realistic conditions in farming operations and to serve as a demonstration site for farmers. Since optimizing trafficability parameters is a very complex process and field experiments alone will not provide a complete understanding of trafficability parameters, modeling and simulations will be needed to supplement field and laboratory results. An existing subsurface drainage simulation model, DRAINMOD, will be modified or expanded to permit predicting trafficability conditions in a given field with subsurface drainage installed. Acquired data from the experimental site will be transferred electronically from the field to computers housed in the researcher's office to monitor and evaluate the subsurface drainage performance, and for model validation of predicted trafficability by comparison with field observed trafficability.

OBJECTIVES

1. Determine the interactive effects of subsurface drainage and water table control, and selected cultural management practices on soil-water excess/deficit conditions, on crop growth, yield, and quality, and on soil trafficability for conducting farming operations, for sugarcane production.
2. Determine the interactive effects of subsurface drainage and water table control, and cultural management practices, on the availability, use, and loss of plant nutrients, on the fate of applied pesticides for sugarcane production, and quantify the off-site impacts of sediment and agrochemical losses.
3. For agricultural lands with and without subsurface drainage or water table control systems installed, determine the effectiveness of grassed waterways in reducing the losses of sediment and agrochemicals carried off-site by surface runoff.
4. Develop or enhance models to simulate the performance of subsurface drainage and water table control systems for sugarcane production that have the ability to predict trafficability factors and potential crop (sugarcane) yield.

TREATMENTS

The field experiment for sugarcane production will have three (3) treatments and three (3) replications, consisting of the following water management treatments:

I - Surface Drainage Only (**SDO**) with about a 0.2 % surface slope
II - Conventional Subsurface Drainage (**CSD**) plus Surface Drainage at 0.2 % slope
III - Water Table Control (**WTC**) plus Surface Drainage at 0.2 % slope

EXPERIMENTAL PLAN

Site Characterization and Plot Layout

The experimental site is located on the St. Gabriel Sugarcane Research Farm of the Louisiana Agricultural Experiment Station, which is about 20 km from the Louisiana State University Campus in Baton Rouge. The site was established on soils of the Commerce Association, with intermingled silt loam and clay soils. The study will be conducted on nine (9) 0.77 ha plots (see Figure 1), six (6) of which will include drainage conduits for subsurface drainage and/or water table control, and three (3) will be surface drained only (the conventional drainage practice for sugarcane production in LA). These surface drained only (SDO) plots will have the usual shallow "quarter-drains" and field ditches to remove excess surface water from the field. Outlets for subsurface drainage will be provided by sump structures for the subsurface drainage or water table control treatment plots, and subsurface drainage discharge will be pumped into a surface drainage ditch at the lower end of the field site; subirrigation water will be pumped from a well back into three of these sumps for the water table control treatment plots.

The conventional subsurface drainage (CSD) and water table control (WTC) areas of the experimental field will be separated hydraulically from the SDO area and other surrounding land by a vertical plastic film barrier (i.e., a 6-mil thickness polyethylene film buried vertically in the soil to a depth of about 2.1 m; see Figure 1). A small dike will be constructed around the perimeter of each plot to insure that surface ponded water or runoff from rainfall does not flow to adjacent plots, but is channeled to a lower corner of each plot where it is directed through a flume for measurement of flow rate and volume and is sampled proportional to the flow volume. Each plot will be instrumented for automatic computer-controlled measurement and sampling of surface runoff and subsurface drainage discharge (Figure 2.).

All sugarcane rows will be planted parallel to subsurface drainlines and to field ditches in the SDO plots; the "quarter-drains" in the SDO plots connect to these field ditches. The crop will be a variety of sugarcane selected by USDA-LAES researchers to grow on flat culture (slight ridges) in order to accommodate modern sugarcane combine harvester equipment. Surface runoff from sugarcane fields upslope from the experimental site will be diverted into subsurface culvert pipes to route it around the site and to discharge it to a surface outlet downslope from the site (Figure 1). A National Weather Service Class-A automated weather station will be located approximately 150 m from the experiment site (Figure 1). Meteorological data (e.g., rainfall, air temperature, soil temperature, relative humidity, pan evaporation, wind speed and direction, and total radiation) from the weather station's automatic data-logger will be used in conjunction with the study. Evaportranspiration (ET) will be estimated from pan evaporation and the modified Penman equation (Jensen et al. 1971).

Plot Design

Each treatment plot, 86 x 89 m, will have three (3) experimental and three (3) buffer 102-mm diameter subsurface corrugated plastic drain tubes (CPDT) installed at a 12.5 m spacing and a 1.0 m depth, a 1.2 x 1.2 x 3.0 m steel sump to control drainline outlet water levels (Figure 3), and a shallow flume equipped with a velocity-head sensor at the surface runoff outlet. Each of the lateral drainlines will be connected into 152 mm main drainlines at both ends of the plot (upslope and downslope) to provide for additional subsurface drainage at the turning areas for harvesting and transport equipment (Figure.2); trafficability at the ends (turn-rows) of the fields has been a major problem with getting heavy cane combine and transport equipment stuck in the fields during harvest. Each plot is precision-graded to a 0.18 percent slope in the direction of the cane rows and 0.19 percent cross-slope. The plot area centered over the center three drainlines (36.6 x 85 m) is assumed to be representative of an area in a larger field with the same drain spacing (Figure 2), and is thus identified as the "experimental area" in each plot. Only the runoff from these experimental areas are channeled through the flumes for measurement and sampling, rather than the entire plot area. The three buffer drainlines outside the experimental area of the plot are intended to control plot border effects with water management treatments in adjacent plots. Water table levels for experimental and buffer drainlines are controlled by separate chambers in the outlet sump and each chamber is continuously monitored by a float-sensor mechanism to operate a sump-pump installed at the bottom of each chamber (Figure 3). The upslope mains for the subsurface drains in the experimental and buffer areas of each plot are not physically connected; about a 2-m distance is provided between sub-mains for each of these areas. Two separate mains are provided at the downslope end of the plots for the subsurface drains in the experimental and buffer areas.

PROCEDURES

Experimental Measurements

The primary measurements to be made on the experimental site will include:

(1) Water table depth vs. time at the mid-point between subsurface drainlines or at plot center.
(2) Surface runoff volume vs. time, and sampled proportional to runoff volume.
(3) Subsurface drainage discharge vs. time, and sampled proportional to outflow volume.
(4) Soil temperature vs. time at 3 to 4 depths (near the automated weather station; see Figure 1).
(5) Soil moisture vs. depth and time (especially in the surface soil), re: trafficability.
(6) Soil physical parameters of the soil profile as related to trafficability vs. time.
(7) Crop yield (cane yield and sugar yield) for the various water management treatments.

The water table depth (WTD) at the mid-point between drainlines in the experimental area of each plot, or at the plot-center in the SDO plots, will be monitored with an *in-situ* manometer-type sensor (Fouss, et al. 1992). This WTD monitoring system consists of a buried section of perforated pipe connected via a small-diameter unperforated tube to a WT riser-pipe located near the drainage sump or runoff sampling equipment. An electrical water level sensor will be used in each riser-pipe to measure WTD vs. time via an electronic data-logger system.

The surface runoff and subsurface drainage discharge rates and volumes will be measured, and samples collected will be refrigerated, with automated instrumentation equipment. Runoff and subsurface drainage samples will be analyzed in the laboratory for agrochemical content (i.e., fertilizer nutrients and for various pesticides applied on the site), plus sediment contained in the samples to evaluate soil erosion occurring from the field site (some agrochemicals are carried on sediment particles).

Trafficability Characteristics

Special attention will be given to any improvements in trafficability provided by CSD and WTC on the experimental site which can be compared with the trafficability measured and observed on the areas that are SDO. This will be an especially important measurement and observation during the harvest season when modern Cane Combine and Transport equipment will be used. Measurements and observations on the trafficability in the turn-rows (ends) of the field (plots) will be of particular interest, and these will be documented separately from the trafficability for the center or interior portions of the field or plots. A key measurement will include penetrometer readings on the soil surface, and an associated observation will be the depth of rut made in the soil by weighted wheels traveling over the area.

A sprinkler irrigation system may be needed beginning about the second year after the experiment is initiated (i.e., about 3 years after the cane is replanted to the site). Irrigation on the site will insure that sufficient water is received each season to simulate high-rainfall, wet soil years so that the effects of subsurface drainage on trafficability can be evaluated over a 4 to 5 year period, thus ensuring results from the project on the high priority Objective #1. Without supplemental irrigation, the project may need to be conducted for a much longer period to fully study the benefits of trafficability provided by subsurface drainage (the decision regarding the need for the irrigation system will of course depend largely on the natural rainfall received during the first few years of the project). Continued use of the site (without applying supplemental irrigation) to observe and document trafficability improvements over a period greater than 5 years will be needed to determine the frequency or recurrence interval for the seasons with trafficability problems when subsurface drainage is not available. Beyond the 5-year period, it may be desirable to continue the observations regarding trafficability improvements on the site for a period of 10 to 15 years, but the level of data collection and research measurements could be greatly reduced, thus lowering the annual costs of continued experimental uses for the demonstration site.

Laboratory Procedures

Laboratory studies on soil samples collected at the site will include measurements of soil physical properties such as shear strength, cohesion forces and moisture content to optimize these parameters for improved trafficability. Batch equilibrium and unsaturated/ saturated soil column media will be conducted to determine adsorption/desorption curves from soil samples collected from the surface, vadose and saturated zones in the experimental plots. Soil columns will be also utilized to study water flow through the swelling/shrinking clayey soils to determine pesticides/fertilizers leaching potential (Willis et al. 1990). Various chromatographic and spectrophotometric techniques will be applied to study the relationship between clayey soil colloidal systems and transport of pesticides.

Modeling Procedures

The field data acquired from this new project will permit the incorporation of more comprehensive trafficability factors or algorithms into current simulation/predictive models (e.g., DRAINMOD; see Skaggs, 1977 and 1982 and Fouss et al. 1987 and 1989) to enhance them for evaluating or designing subsurface drainage and water table control systems. The acquisition of these data over multiple years of the project will provide a means to validate the ability of the enhanced models to predict trafficability parameters under variable soil and weather conditions, and for different water management methods. Thus, it may be possible in the future to design drainage and water table control systems with these revised/ validated models to meet specified trafficability requirements as well as soil-water management requirements for optimum crop (sugarcane) production.

PROGRESS

The project site was precision land graded with laser-controlled equipment in October 1998, the subsurface drainage sumps were installed in December 1998 (Figures 1 and 2), and the upslope runoff diversion culverts were installed in February 1999. The water table depth (WTD) monitoring system will be installed in each experimental plot during April 1999, prior to the installation of the subsurface drainage system. The two plastic film barriers will also be installed, if possible, during April 1999. If the WT is shallow enough to prohibit the installation of the barriers at the 2.1 m depth because of trench-wall instability in the alluvial soil, a temporary subsurface drainline will be installed to a depth of about 2.5 m within 2.5 to 3.0 m of the location (path) for each barrier. The de-watering drain will be destroyed after the barriers are installed by digging through the de-watering drainlines to a depth of about 2.7 m. The subsurface drainage system (Figure 1) will be installed with a laser-controlled chain-type trencher during April-May 1999 (weather permitting).

Weather permitting, sugarcane will be planted on the site during the Fall of 1999. The initial water management treatments will be implemented during the spring of 2000. Surface runoff measurement and sampling systems will not be installed until the summer of 2000.

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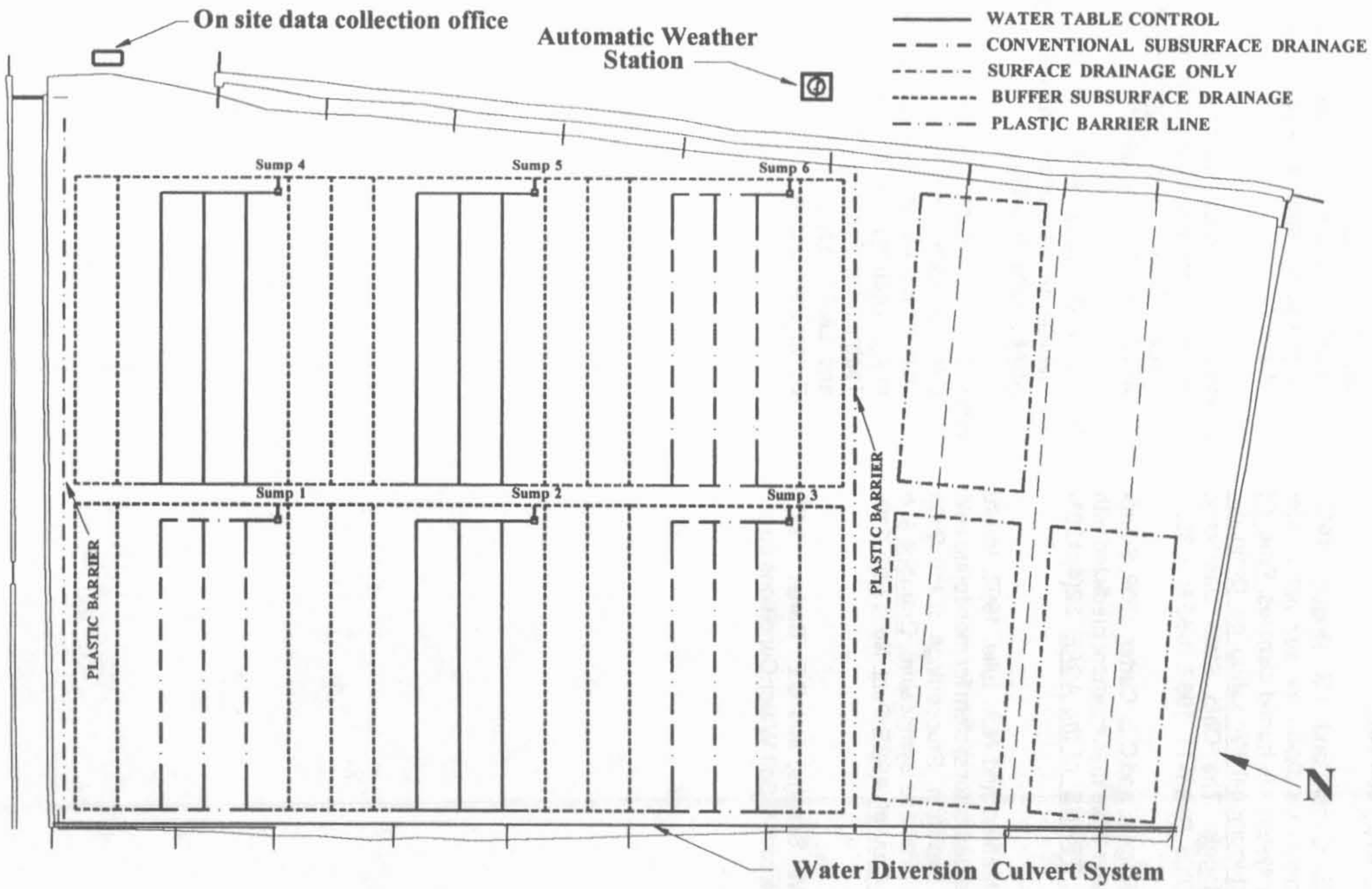

Figure 1. Experimental design for trafficability and water quality study at the St. Gabriel Sugarcane Research Farm of the Louisiana Agricultural Experiment Station near Baton Rouge.

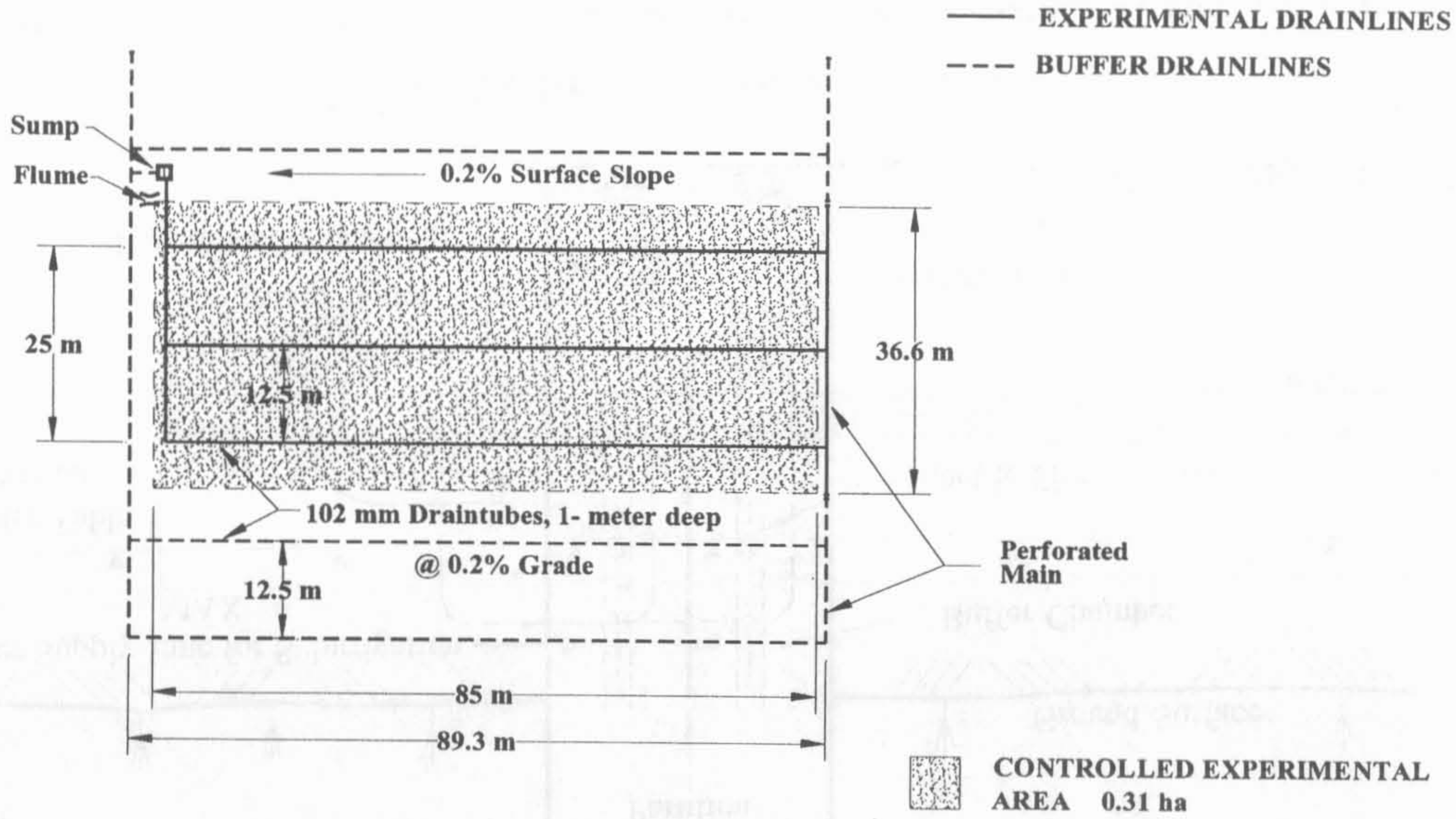

Figure 2. **Subsurface drainage schematic and sump location for each experimental plot.**

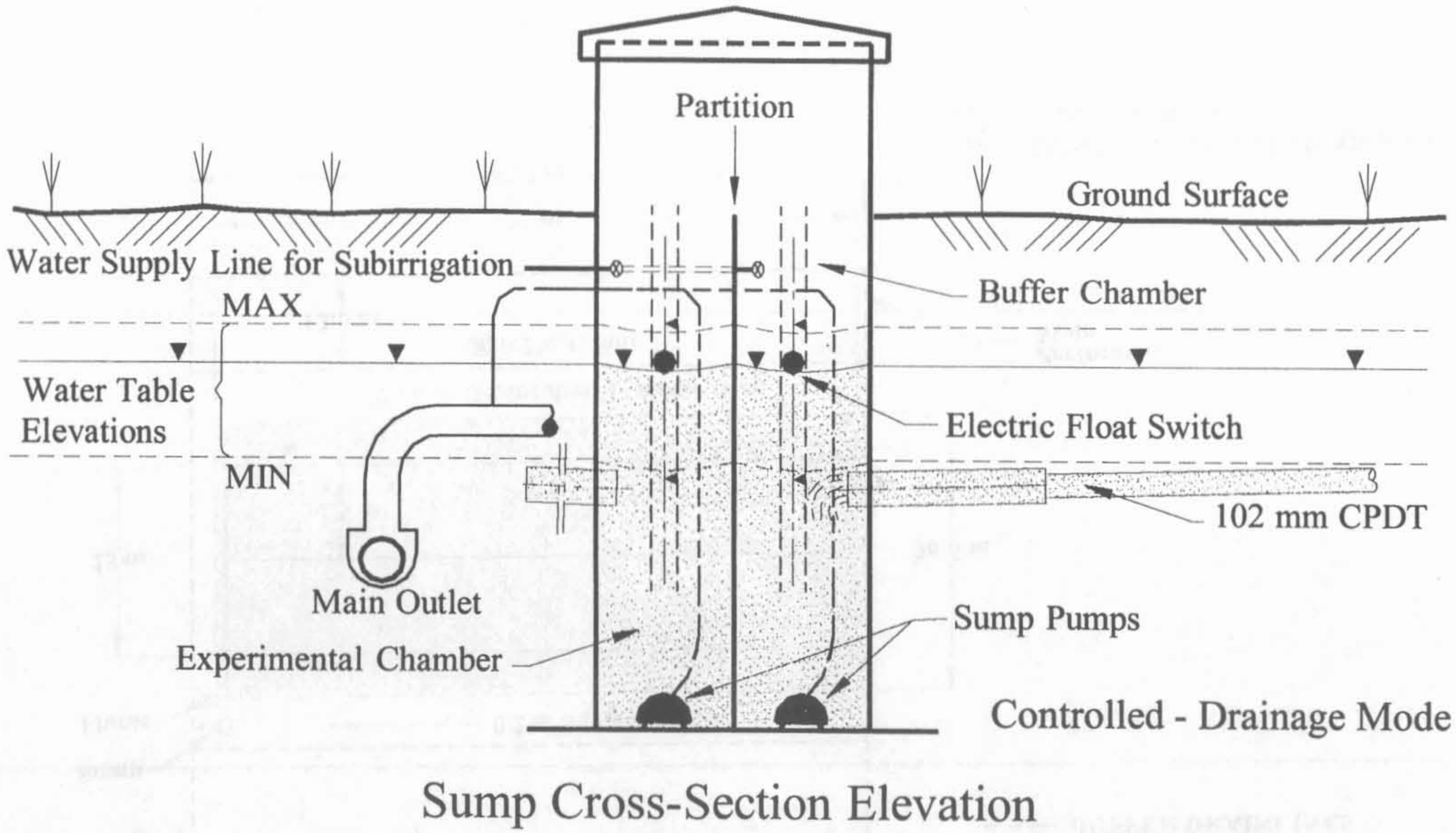

Figure 3. Elevation cross-section of steel sump structure for subsurface drain outlet water level control of sugarcane research plot.