MONITORING AND MODELING WATER AND NITROGEN TRANSPORT IN THE VADOSE ZONE OF A VEGETABLE FARM IN THE SUWANNEE RIVER BASIN

By

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This document is dedicated to my family and friends

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TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS iv

LIST OF TABLES viii

LIST OF FIGURES ix

CHAPTER

1 INTRODUCTION 1

Background 1
Objectives 3
Literature Review 3
Suwannee River Basin 3
Nitrogen Cycle 5
Potato Crop Management 7

2 FIELD EXPERIMENTS AND METHODOLOGIES 13

Site Description 13
Field Sampling Methodologies 14
Field Results 17
Spring 2001 Potato Crop 18
Planting details, crop management, and weather 18
Moisture content results 19
Nitrate-nitrogen results 21
Crop monitoring results 24
Spring 2002 Potato Crop 26
Planting details, crop management and weather 26
North half moisture content results 27
South half moisture content results 29
North half bed nitrate-nitrogen results 31
South half bed nitrate-nitrogen results 35
North half furrow nitrate-nitrogen results 37
South half furrow nitrate-nitrogen results 38
Crop monitoring 42
Comparisons of Final Yield/Nitrogen Lost and Nitrogen Applied 44

3 MODEL DESCRIPTION AND RESULTS 47

DSSAT Model Description 47
Hydrology Component 48
Nitrogen Component 50
Crop Growth Component 51
Model Calibration and Results 53

4 DSSAT MODIFICATIONS 67

HYDRUS Model Description 68
Governing Flow Equation 69
Root Water Uptake 70
The Unsaturated Soil Hydraulic Properties 71
Governing Transport Equation 72
HYDRUS Results and DSSAT Modifications 74
HYDRUS Results 74
DSSAT Modifications 81

5 MODIFIED DSSAT RESULTS AND DISCUSSION 85

Soil-Water Transport Results 85
2001 Potato Crop 85
2002 Potato Crop 89
Nitrate-Nitrogen Transport Results 93
2001 Potato Crop 93
2002 Potato Crop 96
Crop Growth Results 99
2001 Potato Crop 99
2002 Potato Crop 102

6 CONCLUSIONS 108

APPENDIX

A SOIL SAMPLE ANALYSIS RESULTS 115

B PLANT SAMPLE ANALYSIS RESULTS 136

C SUBSTOR/DSSAT INPUT FILES 140

D HYDRUS INPUT FILES 156

E DSSAT MODIFICATIONS 212

F MODIFIED DSSAT/SUBSTOR INPUT FILES 216

LIST OF REFERENCES 229

BIOGRAPHICAL SKETCH 233

LIST OF TABLES

Table page

2-1. Retentivity data measured at the research site. 14

2-2. Spring 2001 potato crop planting information obtained from farmer. 18

2-4. Statistical analysis of 2001 north half soil samples moisture content results. 20

2-5. Important dates related to planting, harvest, and phenological events (2001). 24

2-6. Spring 2002 approximate nitrogen fertilizer schedule and amounts. 27

2-7. The standard deviations of the 2002 north half measured volumetric moisture contents.....29

2-8. The standard deviations of the 2002 south half measured moisture contents. 31

2-9. Nitrate-nitrogen content results for north soil samples taken on May 1, 2002 for wells. 34

2-10. Statistical analysis of spring 2002 furrow soil samples nitrate-nitrogen results. 40

2-11. Important dates related to planting, harvest, and phenological events (2002). 42

A-1. Soil sample results at the project site. 116

B-1. Potato crop analysis results (2001).....137

B-2. Potato crop analysis results (2002).....138

LIST OF FIGURES

Figure page

1-1. Suwannee River Basin (Pittman et al., 1997).....1

2-1. North half average moisture contents for the spring 2001 potato crop.....19

2-2. Average 2001 north half nitrate-nitrogen content in top 90 cm of the bed area. 22

2-3. North half cumulative nitrogen applied and total crop uptake (2001). 26

2-4. North half average volumetric moisture contents for the spring 2002 potato crop in the center of bed. 28

2-5. South half average volumetric moisture contents for the spring 2002 potato crop in the center of bed. 30

2-6. Average 2002 north half nitrate-nitrogen content in top 90 cm taken in the center of bed. 32

2-7. Average 2002 south half nitrate-nitrogen content in top 90 cm taken in the center of bed. 35

2-8. Average 2002 north half nitrate-nitrogen content in top 90 cm taken in the center of furrow. 38

2-9. Average 2002 south half nitrate-nitrogen content in top 90 cm taken in the center of furrow. 39

2-10. Nitrogen applied and total crop uptake (2002).....44

2-11. Comparison between the total nitrogen applied and the dry tuber yield.....45

3-1. DSSAT spring 2001 potato crop soil moisture content results for the north half at 0-15 cm. 55

3-2. DSSAT spring 2001 potato crop soil moisture content results for the north half at 15-30 cm. 56

3-3. DSSAT spring 2001 potato crop soil moisture content results for the north half at 30-60 cm. 56

3-4. DSSAT spring 2001 potato crop soil moisture content results for the north half at 60-90 cm. 57

3-5. Cumulative water balance for the north half of the field for the spring 2001 potato crop. 58

3-6. Spring 2001 potato crop nitrate-nitrogen concentration results for the north half of the field at 0-15 cm. 60

3-7. Spring 2001 potato crop nitrate-nitrogen concentration results for the north half of the field at 15-30 cm. 60

3-8. Spring 2001 potato crop nitrate-nitrogen concentration results for the north half of the field at 30-60 cm. 61

3-9. Spring 2001 potato crop nitrate-nitrogen concentration results for the north half of the field at 60-90 cm. 61

3-10. DSSAT dry leaf weight predictions for the spring 2001 potato crop on the north half of the field. 63

3-11. DSSAT dry stem weight predictions for the spring 2001 potato crop on the north half of the field. 64

3-12. DSSAT dry tuber weight predictions for the spring 2001 potato crop on the north half of the field. 64

3-13. Cumulative nitrogen balance for the spring 2001 potato crop on the north half of the field. 65

4-1. Illustrations of the potato plant beds (01/28/2003) and root distribution (04/12/2003). 67

4-2. SMCC of the hydraulic conductivity versus moisture content using the Brooks and Corey equation. 76

4-3. SMCC of the soil matric potential versus moisture content for the top 45 cm of the soil profile using the Brooks and Corey equation. 76

4-4. SMCC of the soil matric potential versus moisture content for the bottom 45 cm of the soil profile using the Brooks and Corey equation. 77

4-5. Flat upper boundary nitrate concentration spectral map for the top 90 cm on the north half of the field for 01/10/02 through 01/14/02 (a-e) 79

4-6. Irregularly shaped upper boundary nitrate concentration spectral map for the top 90 cm on the north half of the field for 01/10/02 through 01/14/02 (a-e). 80

4-7. Cumulative nitrate-nitrogen leached out of the top 90-cm from the January 10, 2002 fertilizer application. 81

4-8. A comparison of the light interception and root domain for flat (a) and bedded (b) rows. 83

4-9. Potato plant canopy illustration. 84

5-1. Comparisons between the predicted and measured moisture contents at 0-15 cm for the north half of the field 2001 potato crop 86

5-2. Comparisons between the predicted and measured moisture contents at 15-30 cm for the north half of the field 2001 potato crop. 87

5-3. Comparisons between the predicted and measured moisture contents at 30-60 cm for the north half of the field 2001 potato crop. 87

5-4. Comparisons between the predicted and measured moisture contents at 60-90 cm for the north half of the field 2001 potato crop. 88

5-5. Cumulative water balance for the north half of the field for the spring 2001 potato crop. 88

5-6. Comparisons between the predicted and measured moisture contents at 0-15 cm for the 2002 potato crop. 90

5-7. Comparisons between the predicted and measured moisture contents at 15-30 cm for the 2002 potato crop. 90

5-8. Comparisons between the predicted and measured moisture contents at 30-60 cm for the 2002 potato crop. 91

5-9. Comparisons between the predicted and measured moisture contents at 60-90 cm for the 2002 potato crop. 91

5-10. Cumulative water balance for the north half of the field for the spring 2002 potato crop. 92

5-11. Cumulative water balance for the south half of the field for the spring 2002 potato crop. 93

5-12. Comparisons between the predicted and measured nitrate-nitrogen contents at 0-15 cm for the north half of the field (2001). 94

5-13. Comparisons between the predicted and measured nitrate-nitrogen contents at 15-30 cm for the north half of the field (2001). 94

5-14. Comparisons between the predicted and measured nitrate-nitrogen contents at 30-60 cm for the north half of the field (2001). 95

5-15. Comparisons between the predicted and measured nitrate-nitrogen contents at 60-90 cm for the north half of the field (2001). 95

5-16. Comparisons between the predicted and measured nitrate-nitrogen concentrations at 0-15 cm (2002). 97

5-17. Comparisons between the predicted and measured nitrate-nitrogen concentrations at 15-30 cm (2002). 97

5-18. Comparisons between the predicted and measured nitrate-nitrogen concentrations at 30-60 cm (2002). 98

5-19. Comparisons between the predicted and measured nitrate-nitrogen concentrations at 60-90 cm (2002). 98

5-20. Cumulative nitrogen balance for the 2001 potato crop on the north half of the field.....100

5-21. Dry leaf weight predictions for the spring 2001 potato crop on the north half of the field.....100

5-22. Dry stem weight predictions for the spring 2001 potato crop on the north half of the field.....101

5-23. Dry tuber weight predictions for the spring 2001 potato crop on the north half of the field.....101

5-24. North half cumulative nitrogen balance for the2002 potato crop. 103

5-25. South half cumulative nitrogen balance for the 2002 potato crop. 103

5-26. North half dry leaf weight predictions for the spring 2002 potato crop.....104

5-27. South half dry leaf weight predictions for the spring 2002 potato crop.....104

5-28. North half dry stem weight predictions for the spring 2002 potato crop. 105

5-29. South half dry stem weight predictions for the spring 2002 potato crop. 105

5-30. North half dry tuber weight predictions for the spring 2002 potato crop.....106

5-31. South half dry tuber weight predictions for the spring 2002 potato crop.....106

Abstract of Thesis Presented to the Graduate School
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MONITORING AND MODELING WATER AND NITROGEN TRANSPORT IN THE VADOSE ZONE OF A VEGETABLE FARM IN THE SUWANNEE RIVER BASIN

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Chair: Wendy D. Graham
Major Department: Agricultural and Biological Engineering

The Suwannee River Basin has become a source of major concern over recent years due to the increased nitrogen loads within the basin. In 1995, nitrate loads increased from 2,300 to 6,000 kg/day over a 53.1 km reach of the Suwannee River that began in Dowling Park, FL and ended in Branford, FL. Eighty-nine percent of the increase occurred in the lower 2/3 of the reach. With the increasing nitrogen loads, it is evident that serious problems may arise if nothing is done to correct the current situation.

The ultimate goal of this research was to develop Best Management Practices (BMPs) to reduce nutrient loadings to the ground water from vegetable farms in the Suwannee River Basin. To achieve the objective, nitrogen and water transport in the vadose zone was monitored and modeled under a 56.7 ha center pivot at a 2020 ha vegetable farm just west of O'Brien, FL. This farm lies just a few miles from the Suwannee River in the upstream direction of ground water flow. The sandy soils on the

farm are extremely susceptible to leaching nitrogen out of the vadose zone and into the underlying Floridan Aquifer.

Monitoring well samples, soils samples, and plant samples was used to obtain onsite nitrogen, plant, and soil moisture information over time to track nitrogen movement and calibrate mathematical models. The measured data show that the sandy soils at the project are highly susceptible to leaching nitrate-nitrogen following rainfall events and irrigation applications. The data collected in 2001 show that 24% of the total nitrogen applied (fertilizer plus irrigation nitrate-nitrogen) to the north half of the field was recovered by the potato plants, leaving 325 kg/ha of the 427 kg/ha nitrogen applied in the fertilizer and irrigation to be leached out of the soil profile and into the underlying Floridan Aquifer. The 2002 data indicate that the potato crops currently grown at the project site are receiving more than adequate amounts of nitrogen fertilizer and irrigation.

The DSSAT35 crop model and the HYDRUS2D vadose zone model were used to produce an estimate of the total load and concentration of nitrogen and the quantity of water leaching through the vadose zone into the Floridan Aquifer. The DSSAT model significantly over predicted the volume of water drained out of the top 90 cm, which directly affects the nitrate-nitrogen leaching. As a results, the 2001 potato crop simulation results show that the DSSAT model under predicted the dry tuber yield by 3,105 kg/ha relative to the 6,840 kg/ha measured. These results indicate that DSSAT is unable to accurately predict potato crop growth on sandy soils located at the project site. Results from the 2001 calibration and from the HYDRUS simulations illustrate the importance of incorporating multi-dimensional water and nutrient transport and the need to replace or improve upon the current methods implemented by the DSSAT plant model.

CHAPTER 1
INTRODUCTION

Background

The Suwannee River Basin, shown in Figure 1-1, has become a source of major concern over recent years due to increased nitrogen loads within the basin. The sandy soils located in the basin are susceptible to nitrogen leaching into the underlying Floridan Aquifer. In 1995, Pittman et al. (1997) conducted a study, during base flow, on a 53.1 km reach of the Suwannee River that began in Dowling Park, FL, and ended in Branford, FL (Figure 1-1).

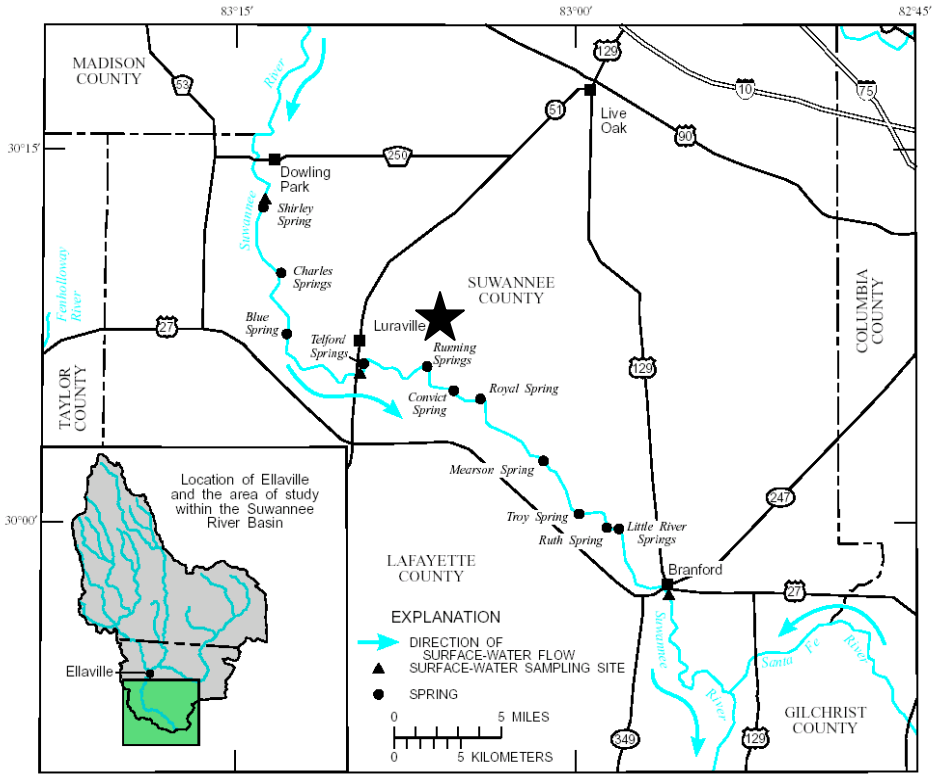


Figure 1-1. Suwannee River Basin (Pittman et al., 1997)

Results from the study showed that the nitrogen loads increased from 2,300 kg/day to 6,000 kg/day over the entire reach with 89% of the increase occurring in the lower 2/3 of the reach. Ham and Hatzell (1996) found that nitrate concentrations in the Suwannee River increased at a rate of 0.02 mg/L per year over a twenty-year period from 1971-1991. The source of the increased nitrogen loads is not evident because of several possible non-point sources of the pollution, which include dairy farms, row-crop farms, poultry farms, residential communities, etc. The waters in the basin are used for recreation, a potable water source, and support an intricate diverse ecosystem. With the increasing nitrogen loads, it is evident that serious problems may eventually arise if nothing is done to alleviate the current problem.

In an attempt to determine the possible sources of the increased nitrogen loads, a joint research venture involving the University of Florida, Suwannee River Water Management District (SRWMD), the Florida Department of Agricultural and Consumer Services (FDACS), and the Florida Department of Environmental Protection (FDEP) was developed. The overall purpose of the study was to evaluate nitrate loadings from three different agricultural operations (including a dairy farm, poultry farm, and row-crop farm) to the Floridan Aquifer. The primary focus of the research reported here is the study conducted at the row-crop operation located in O'Brien, FL, approximately 16-km northwest of Branford, FL (Figure 1-1). The cultivars grown on the 2,020-ha farm include crops such as corn, peanuts, soybean, potatoes, etc. Several of the crops grown on the farm are known to have poor recovery of applied nitrogen. Of these crops, potatoes appear to contribute a large amount of the cumulative nitrogen being leached out of the vadose zone and into the Floridan Aquifer (Albert, 2002).

In an effort to evaluate and reduce the amount of nitrogen being leached out of the soil profile, potato crops have been studied since spring 2001. By studying the system and processes that influence the nitrogen and water transport, a better understanding of the system can be developed that can aid in the development of an effective best management practice (BMP).

Objectives

The objectives of this research included monitoring nitrate and water transport in the vadose zone on a 56.7 ha potato field located at Pivot 12 of the research farm, and implementing a mathematical model that can accurately predict the spatial and temporal distribution of nitrate and water in the soil profile as well as crop yield. These objectives were developed to assist in reaching the goals outlined by the FDEP, FDACS, and SRWMD funded project to develop BMPs for the arable crops in the region.

Literature Review

Suwannee River Basin

The Suwannee River basin comprises an area of 25,770 km^2 with 43% of the total area located in north central Florida. The primary land use in the Florida portion of the basin is agriculture, including forestry, pasture, row crops, and intensive animal husbandry (Hornsby, 2000). The basin has several karst characteristics that result in a direct linkage between the surface and ground waters, resulting in a single dynamic flow system (Katz et al., 1996). As a result of the land use and direct interactions between surface and ground waters, there has been a noticeable increase in nitrate-nitrogen concentrations in surface and ground waters in the basin. Over the past 40 years, the nitrate-nitrogen concentrations in many of the springs in the Suwannee River basin have increased from less than 0.1 mg/L (Katz, 1992; Maddox et al., 1992) to more than 5 mg/L

(Hornsby and Ceryak, 1999), which has resulted in high nitrogen loading rates in the Suwannee and Santa Fe Rivers (Katz, 2000). The total nitrate-nitrogen load in the basin in the 1998 water year was estimated to be 7,113 tons with 45.5% of the increase occurring in the middle Suwannee River Basin (Hornsby, 2000).

The Suwannee River is the second largest river in Florida with a mean annual flow of 6.7 billion gallons per day, and is designated as an ”Outstanding Florida Water”. Katz and Dehan (1996) found that the high nitrate-nitrogen levels in the Suwannee River and in parts of the Upper Floridan Aquifer were caused by the high nitrogen loading from the wastes generated by poultry and dairy farms, and fertilizers applied to cropland along the Suwannee River in Lafayette and Suwannee Counties. Ceryak and Hornsby (1996) reported that the median nitrate-nitrogen concentration of the ground water near the Suwannee River between Ellaville, FL and Branford, FL ranged from 0.5 mg/L to 4.0 mg/L. The high nitrate-nitrogen concentrations near Branford, FL were attributed to ground water discharge because there are no major stream inputs to the Suwannee River in this region of the middle Suwannee River Basin (Katz et al., 1999). Also, these researchers concluded that the elevated nitrate-nitrogen concentrations during low flow periods increase the probability that the ground water inflow from springs and riverbed leakage were the cause of the increased nitrate concentrations and loads in the lower Suwannee River.

These high nitrogen concentrations can eventually have detrimental effects on the Suwannee River basin ecosystem and on human health. Eutrophication can occur due to elevated nitrate-nitrogen concentrations in rivers, which results in algal blooms and depletion of dissolved oxygen in the water that can lead to fish kills. The Environmental

Protection Agency (EPA) has set a maximum contaminant level (10 mg/L) for nitrate-nitrogen in drinking water to reduce the possibility of human health complications resulting from high nitrate-nitrogen concentrations. The limit was set because of the health risk to infants who consume high-nitrate water, who may contract methemoglobinemia (Mueller and Helsel, 1996).

Nitrogen Cycle

Elevated nitrogen concentrations in surface and ground waters have resulted in extensive studies related to nitrogen load contributions from many non-point sources of pollution. Leaching is the primary mechanism that contributes to the increased nitrogen loads, especially in sandy soils. But to fully understand nitrogen transport in the soil, the dynamics of the nitrogen cycle must be thoroughly understood.

The nitrogen cycle is a complex system that has many factors that affect nitrogen transport. Nitrogen exists in soils as both inorganic and organic forms. Nitrogen sources for the soil include fertilizers, atmospheric nitrogen fixation by plants, nitrogen deposition by lightning, and animal waste. Nitrogen is primarily removed from the soil through leaching, but is also removed by erosion and runoff, plant uptake of ammonium and nitrate, denitrification of nitrate, and volatization of ammonia. There are several chemical processes that affect nitrogen content in the soil, but the two microbial processes that primarily dictate the amount of nitrogen available for transport and plant availability of natural systems are mineralization and immobilization. Mineralization is the process by which ammonia is released from organic matter. Immobilization is the reverse reaction by which inorganic forms of nitrogen are converted to organic forms. Inorganic forms of nitrogen are the most common forms of fertilizer used by farming operations and are the most susceptible to chemical transport. Typical forms of inorganic

nitrogen used as fertilizer are ammonium, anhydrous ammonia, urea, and ammonium-nitrate. Some inorganic fertilizers go through chemical transformations, which make nitrogen readily available to plants. For instance, ammonium is a compound transformed by a process that is termed nitrification into nitrate, which is the form of nitrogen that is more available to plants compared to NH_4^+ sources (Roberts et al., 1991).

Nitrification is the process by which ammonium (NH_4^+) is transformed into nitrate (NO_3^-). The process is a two-step reaction that requires autotrophic bacteria (Nitrosomonas) to convert NH_4^+ to nitrite (NO_2^-). Then, a second group of autrophs (Nitrobacter) rapidly converts nitrite to NO_3^-. Knowing the characteristics of the nitrification process and the charge of each ion, it is possible to determine the mobility of nitrogen during certain stages of the transformation. Ammonium is a positively charged ion that readily sorbs to negatively charged soil colloids, which can reduce its mobility in the soil. Nitrite and nitrate are both highly mobile forms of nitrogen. Both forms of nitrogen are negatively charged, which results in negligible interaction and sorption to soil colloids. Also, nitrite and nitrate forms dissolve quite easily in water. As a result, nitrite and nitrate are extremely susceptible to leaching by advection when adequate water is available. However, nitrate is the primary focus of most nitrogen contamination studies because the transformation of nitrite to nitrate occurs relatively quickly and nitrite is usually found in small quantities.

By knowing the mobility of certain forms of nitrogen, it is possible to determine effective types of fertilizers that can be applied to crops to reduce leaching. The most common forms of nitrogen fertilizer that reduce leaching include those that contain ammonium compounds. Ammonium's adsorption to the soil colloids renders it less

susceptible to leaching out of the soil (Paramasivam, 2000) and can be an acceptable form of fertilizer that can reduce total nitrogen leaching. The most common types used are ammonium nitrate, anhydrous ammonia, and ammonium sulfate. Bundy et al. (1986) observed significantly higher yields in potatoes when ammonium sulfate was used instead of nitrate fertilizer and concluded that the higher yields were attributed to the nitrate fertilizer leaching out of the root zone more easily than the ammonium sulfate.

Extensive research has been conducted over recent years examining the chemical transport of fertilizers, specifically nitrogen fertilizers, due to concerns about water quality pertaining to nitrate-nitrogen leaching into the ground water. Leaching occurs when excess water flows through the bottom boundary of the root system. Factors that affect nitrate-nitrogen leaching on agricultural lands include soil type, organic matter content, moisture content, plant rooting depth, irrigation management, fertilizer management, etc. Of these, irrigation and nitrogen fertilizer management are perhaps the most important factors that influence nitrate-nitrogen leaching in Florida's sandy soils.

Potato Crop Management

Potatoes (solanum tuberosum) grown in Florida are generally planted in spring and represent a substantial portion of the total vegetable industry in Florida. In 1996-1997, potato production in Florida represented 6.1% of the state's $1.6 billion vegetable industry with 81% of the potatoes harvested during May and June following spring planting (Hochmuth and Cordasco, 2000). The production of most fresh vegetables usually requires large applications of nitrogen and irrigation water (Home et al., 2002). Thus, the two most important aspects of potato production are usually related to proper irrigation and nitrogen management (Waddell, 1999).

Proper irrigation management is essential to achieve acceptable potato yields in areas with inadequate rainfall and soils with low water holding capacity. Even though potatoes are generally grown in areas where sandy soils are present, the plants have relatively shallow root systems (46-60 cm) because of the low root penetration strength of the plant roots. As a result, misconceptions often arise that potatoes are a high water use crop. However, there are many other crops that have equal or greater water requirements (King and Stark, 1997). In reality, potatoes are sensitive to water stress due to their complex physiological responses to moderate plant water deficits (Curwen, 1993). Ojala et al. (1990) stated that to achieve maximum productivity for potatoes, the soil must be consistently kept moist. Hochmuth et al. (2000) reported that potato plant water requirements for potatoes in Florida varied over the season increasing from 40% of the reference evapotranspiration (ET_o) during initial plant growth periods to approximately 110% of ET_o at peak growth and tuber development and then decreasing to 70% of ET_o during the final growth period of tuber development.

King and Stark (1997) showed that potatoes are particularly sensitive to water stress during tuber initiation and early tuber development. They also determined that water stress during tuber bulking has more of an effect on tuber yield than quality. Also, water stress accelerates leaf senescence and disrupts new leaf formation, which results in an unrecoverable loss of tuber bulking. Belanger et al. (2000) showed that supplemental irrigation could improve yield significantly during dry years. From their trials, the average yield increase in irrigated versus non–irrigated crops was 6.5 tons/ha and 5.1 tons/ha for the total and marketable yields, respectively.

Even though supplemental irrigation is essential for potato production, over irrigation can also have negative impacts on potato yield. Providing excess water at planting promotes seed piece decay, delays emergence because of decreased soil temperature, and leaches nitrate-nitrogen out of the root zone causing nitrogen deficient plants (King and Stark, 1997). Belanger et al. (2000) concluded that excess water could result in negligible increases or even decreases in final yield. These findings demonstrate the importance of proper irrigation scheduling and the need for an adequate irrigation system that can apply supplemental light water applications uniformly, frequently, and economically.

Poor irrigation scheduling can have adverse effects on nutrient availability for potatoes, especially nitrogen. Nitrogen is usually the most limiting nutrient for potato growth, especially in sandy soil regions (Errebhi et al., 1998). The most readily available form of nitrogen that potato plants utilize is nitrate-nitrogen, which is also highly mobile in the soil. Potatoes, in general, have a high demand for nitrogen with a rather low total recovery (Zvomuya et al., 2003). The low recovery is partially due to the rather shallow root system of the plants. Potato plants can have a maximum root depth of up to 60 cm, but 90% of the roots are typically located in the upper 25 cm (Tanner et al., 1982). As a result, excess water can result in nitrate-nitrogen being leached out of the plant root zone.

Nitrogen fertilizer application scheduling is critical to have adequate potato crop yield, especially in sandy soils. Nitrogen uptake by potato plants varies depending on the growth stage of the plants. Even with optimum levels of nitrogen available for plant uptake, the nitrogen recovery tends to vary considerably. Neetson (1990) found that potato plants utilized only 50% of the applied fertilizer and Unlu et al. (1999) found that

only 20% was taken up by the plants. Consequently, extensive studies have been conducted on the nitrogen uptake of potato plants at different growth stages in order to determine the high demand periods during the potato plant growth cycle. Sullivan et al. (1999) found that potato plants take up the majority of nitrogen during vine growth of the vegetative growth stage. Also, it was determined that the total crop uptake of nitrogen was reached at approximately 100 days after planting during tuber growth. Osaki et al.'s (1992) research suggests that nitrogen applied after flowering has little or no effect on final tuber yield. Current IFAS recommendations for Florida, state that the nitrogen application rate should be approximately 200 kg/ha with roughly 2/3 of the nitrogen fertilizer band-applied at planting or crop emergence and the remaining fertilizer applied 35 to 40 days later as side-dress (Hochmuth and Cordasco, 2000). With minimal irrigation application and proper fertilizer timing, maximum fertilizer recovery can be achieved with reduced leaching and acceptable yields can be maintained.

Irrigation scheduling and fertilizer management significantly influences nitrate-nitrogen leaching. Errebhi et al. (1998) stated that early applications of nitrogen on sandy soils could lead to nitrate-nitrogen being leached below the root zone during heavy rainfall events and excess irrigation. Neetson et al. (1990) found that nitrogen application recommendation of potato crops in sandy soils of the Netherlands were too large, which increased the probability of nitrate-nitrogen leaching. The researchers' modeled results indicated that the current Dutch nitrogen application recommendation (300 kg/ha) could be reduced by 25% and would result in a total yield decrease of only 2% for clay and loam soils. Neetson et al. (1990) also determined that the nitrogen application

requirements were higher for sandy soils when compared to the requirements of loams and clays.

Results from Verhagen's (1997) model simulations using the WAVE model showed that the current Dutch fertilizer recommendation of 250 kg/ha of nitrogen for potatoes was too high. During the 1994 experiment, it was determined that using the current recommendation resulted in 75 kg/ha of nitrate-nitrogen being leached out of the root zone of loamy soils, which caused the ground water concentrations to exceed the pre-set standard of 50 mg-NO_3/L. Verhagen (1997) further concluded that a 75 to 100-kg/ha reduction in nitrogen fertilizer would result in dramatic decreases in total nitrogen leached.

In spring 2001, Albert (2002) conducted a study monitoring and modeling water and nitrogen transport of a potato crop produced on a 56.7 ha field in the Middle Suwannee River Basin in O'Brien, FL. Results from this study showed that nitrate-nitrogen leached rapidly out of the sandy soils located on the vegetable farm. Albert showed that only 30% of the 313 kg/ha of the applied nitrogen was taken up by the potato plants. Model results indicated that yields stabilized around 225-kg/ha of applied nitrogen and that irrigation could have been reduced as much as 30%, resulting in reduced leaching and acceptable yields. However, there were inconsistencies in the modeling methods used by Albert (2002). In Albert's first simulations, he found that the computer model under predicted crop yield considerably. To remedy this problem, fertilizer applications were doubled in the model's input files because it was thought that the model simulations were restricted to the bed rather than the entire field area. Since the fertilizer was band-applied to the bed, it appeared that doubling the fertilizer rate

applied on a field area basis was reasonable. The doubled fertilizer applications produced fairly accurate results for the 2001 crop. This methodology was subsequently called into question because the computer model actually simulates the entire area, not just the bed area as previously thought. After these findings, it was clear that further calibration and modifications of model were necessary so that it could adequately represent the potato crop system at the field scale project site.

The main objectives of this research were to extend Albert's previous work of monitoring and modeling the water and nitrate transport in the vadose zone at the same research site in O'Brien, FL and to modify the numerical crop model to more accurately simulate the 2001 and 2002 potato crop data. Once the model is modified and calibrated properly, it can be implemented as a tool to assist in the development of a BMP that effectively reduces nitrate-nitrogen leaching and maintains acceptable yields.

CHAPTER 2
FIELD EXPERIMENTS AND METHODOLOGIES

Site Description

The research farm is a 2020-ha row-crop operation located in O'Brien, FL that is approximately 16-km northwest of Branford. The soils (Penney fine sand) located in this portion of the Middle Suwannee River Basin are very sandy and susceptible to drought, so irrigation is critical in the economic viability of the farming operation.

Pivot 12 was selected as the field scale project site based on ground penetrating radar (GPR) and soil profile evaluation (Albert 2002). The land surface elevations at pivot 12 range from 13.7 to 15.3 meters above mean sea level (msl). Long-term piezometric head levels indicate that the average elevation of the top of the Floridan Aquifer fluctuates from 7.3 meters (annual low) to 8.5 meters (annual high) above msl. The site has a semi-continuous clay layer that varies from 0.9 to 7.6 meters below the soil surface based on the GPR analysis of the selected sites by Natural Resources Conservation Service personnel.

Soil characteristics for the site including the saturated hydraulic conductivity, bulk density, porosity, field capacity, and wilting point were determined based on laboratory experiments (Sanchez, oral communication). Results from the laboratory measurements of the soil-moisture release curve (Table 2-1) indicated that the volumetric moisture content at field capacity (-345 cm) and wilting point (-15,000 cm) was approximately 6-7% and 2%, respectively (Albert, 2002). From the laboratory results, it was also determined that the saturated hydraulic conductivities for the 0-50 cm and 50-100 cm

depths were 4,515 cm/day and 3,759 cm/day, respectively. The bulk densities for the 0-50 cm and 50-100 cm depths were measured to be 1.48 g/cm^3 and 1.56 g/cm^3.

Table 2-1. Retentivity data measured at the research site.

Soil Tension (cm)	Volumetric Moisture Content (0-50 cm)	Volumetric Moisture Content (50-100 cm)
0	38.8	35.3
4	38.8	35.2
20	35.8	34.4
30	29.9	31.2
45	20.3	17.2
60	14.2	12.6
80	11.1	9.3
100	9.7	8.0
150	8.2	6.9
200	7.3	6.2
345	6.6	5.8
15300	1.8	1.8

Field Sampling Methodologies

In 1999, research began at the project site with periodic monitoring of the Upper Floridan Aquifer and the vadose zone. The aquifer monitoring consisted of biweekly shallow groundwater samples and the vadose zone monitoring included taking soil samples from the soil surface down to the clay layer every six weeks. The data were used to observe long-term trends in the ground water nitrate-nitrogen concentrations, water table elevations, and vadose zone soil-water nitrate-nitrogen content at the research farm. These data results indicate that the leached nitrate-nitrogen from the farm may be a significant source of the increased nitrogen loads to the Suwannee River Basin (Albert, 2002).

Beginning in 2001, soil samples were taken biweekly from the soil surface to a depth of 90 cm during the spring potato growing season in addition to the deep soil samples that were taken every six weeks throughout the year. The samples were taken at 10 locations in the center of the potato plant beds at depths of 0-15, 15-30, 30-60, and 60-

90 cm for the 2001 and 2002 spring potato growing seasons. These soil samples were taken in close proximity to the 10 wells located on the project site. Refer to Albert (2002, pp 19) for well locations.

The samples were analyzed at the Department of Soil and Water Science at the University of Florida for KCL extractable nitrate and ammonium concentrations, bulk density, and moisture content (Albert, 2002). To determine the moisture contents of the soil samples, the soil samples were weighed wet then oven dried and reweighed. Results from the analysis yielded gravimetric water content (Eq. 2-1). Volumetric water content was then calculated from the gravimetric water content (Eq. 2-2).

$$\theta_g = \frac{m_{wet} - m_{dry}}{m_{dry}} \tag{2-1}$$

$$\theta_{vol} = \theta_g \times \rho_b \tag{2-2}$$

where θ_g is the gravimetric moisture content; θ_{vol} is the volumetric moisture content; m_{wet} is the wet weight of the soil sample; m_{dry} is the dry weight of the over-dried sample; ρ_b is the bulk density of the soil. Appendix A shows the field measurements and detailed calculations for the spring 2001 and 2002 potato crop soil samples.

The shallow soil samples were taken in order to obtain a more accurate representation of the water and nitrate movement in the upper portion of the vadose zone associated with plant roots, which affects nitrogen and water uptake. An on site weather station was set up in December 2000 approximately ½-km from the project site to record hourly rainfall, solar radiation, and temperature. Weather station instruments included a Texas Electronics TR525 rain gauge, a Campbell scientific thermometer, and a LiCor LI200X pyranometer that were attached to a CR-10X data logger.

During the 2001 and 2002 potato crops, plant biomass sample sets were taken based on the sampling methodologies outlined in the DSSAT User's Manual (Tsuji et al., 1999). The biomass sample dates specified by Tsuji et al.. are based on critical growth stages of the potato crop development including tuber initiation, 20 days after tuber initiation, and 40 days after tuber initiation. Each biomass harvest consisted of eight individual samples of average size with two samples taken in each quadrant. In 2001, the plant samples were taken on a per plant basis, while in 2002 the samples were collected on a per area basis.

The analysis of the plant samples included dry/wet weight measurements of leaves, stems, and tubers, measurement of the leaf area index (LAI), and nitrogen content measurements of the leaves, stems, and tubers. The plants were separated into leaves, stems, and tubers, then weighed wet. Plant roots were not examined as recommended by Dr. K.J. Boote (2001, oral communication), because of the negligible amounts of nitrogen in roots (Albert, 2002). The samples were then dried at 75°C in an oven until a constant weight was reached and reweighed. The dried samples were sent to the Analytical Research Laboratory at the University of Florida and analyzed for total kjeldhal nitrogen (TKN). Results from the analysis and calculations are shown in Appendix B.

In addition to the biomass harvests, a final harvest was conducted at the end of 2001 and 2002 growing seasons to determine final yield. In 2001, twenty, 9.1 m long sections of row, 10 on each half of the field, were harvested by manually digging up all the potatoes. At the end of the 2002 growing season, twelve, 7.6 m long sections of row, three in each quadrant, were harvested manually by digging up the potatoes. The

harvested potatoes were then divided up into three grades based on size, weight, and quality to determine final tuber yield.

Field Results

The following is a detailed discussion related to the field methods and results of the spring 2001 and 2002 potato crops. The vadose zone and crops were monitored closely throughout each crop season in order to accurately estimate the amount of nitrogen entering the underlying Floridan Aquifer and to determine the nitrogen recovered by the potato crops.

Two different management practices were used on the north and south halves of the field for the spring 2001 potato crop. Both management practices were similar except for a slight reduction in fertilizer application amount applied to the south half of the field. The north and south halves of the field received 313 and 280 kg/ha of nitrogen fertilizer, respectively. The irrigation schedule was the same for both halves of the field. As a result, only the north half results for the 2001 crop are presented in this section.

The spring 2002 potato crop has similar planting details as those of the 2001 crop. Two management practices were used on the north and south halves of the field in 2002. The north half of the field received 292 kg/ha of nitrogen fertilizer with the farmer's typical irrigation management. The south half of the field received 261 kg/ha of nitrogen fertilizer with a 21% reduction in applied irrigation. The data collection during the spring 2001 and 2002 potato crops were focused on accurately quantifying the movement of nitrogen for the different management practices implemented at the site.

Spring 2001 Potato Crop

Planting details, crop management, and weather

Essential information including planting geometry, fertilization scheduling, cultivar type, etc. for the north and south halves of the field were obtained from the farmer and are shown in Table 2-2 and 2-3. Irrigation amounts were determined from the irrigation records kept by the farmer and can be found in Appendix C in the SUBSTOR input files under irrigation. The farmer's irrigation strategy was to maintain the soil moisture at field capacity in order to meet the crop's water requirement during the growing season.

Table 2-2. Spring 2001 potato crop planting information obtained from farmer.

Cultivar -	Red LaSoda
Previous Crop -	Cotton
Planting Depth -	15.2 cm
Row Spacing -	101 cm
Planting Density* -	27,110 plants/ha
Seed Weight -	99.2 grams

*The actual growing density assumes that only 90% emergence of planting density (24,387 plants/ha).

Table 2-3. Spring 2001 approximate nitrogen fertilizer schedule and amounts.

		Applied Nitrogen (kg/ha)		
Date	Julian Day	North Half Nitrogen Applied	South Half Nitrogen Applied	Fertilizer Type/Application Method
01/18/2001	18	38.2	29.2	34-0-0 pre-plant, in bed
02/15/2001	46	16.8	16.8	10-34-0 starter, at plant
03/05/2001	64	112.3	105.5	18-0-0-3 sidedress, liquid
03/25/2001	84	112.3	94.3	18-0-0-3 sidedress, liquid
04/28/2001	118	33.7	33.7	30-0-0, fertigation

As previously stated, weather data were collected from an onsite weather station that included hourly solar radiation, rainfall, and temperature. The data were downloaded from the CR-10X periodically.

Moisture content results

As previously discussed, the vadose zone monitoring consisted of measurements of the moisture contents and soil-water nitrogen concentrations over consecutive depths and times. The soil sampling was comprised of biweekly samplings at depths of 0-15 cm, 15-30 cm, 30-60 cm, and 60-90 cm. In 2001, soil samples consisted of 10 soil sample sets taken in the center of the row at different locations.

The results for the average volumetric moisture content of the soils over the growing season are shown in Figure 2-1.

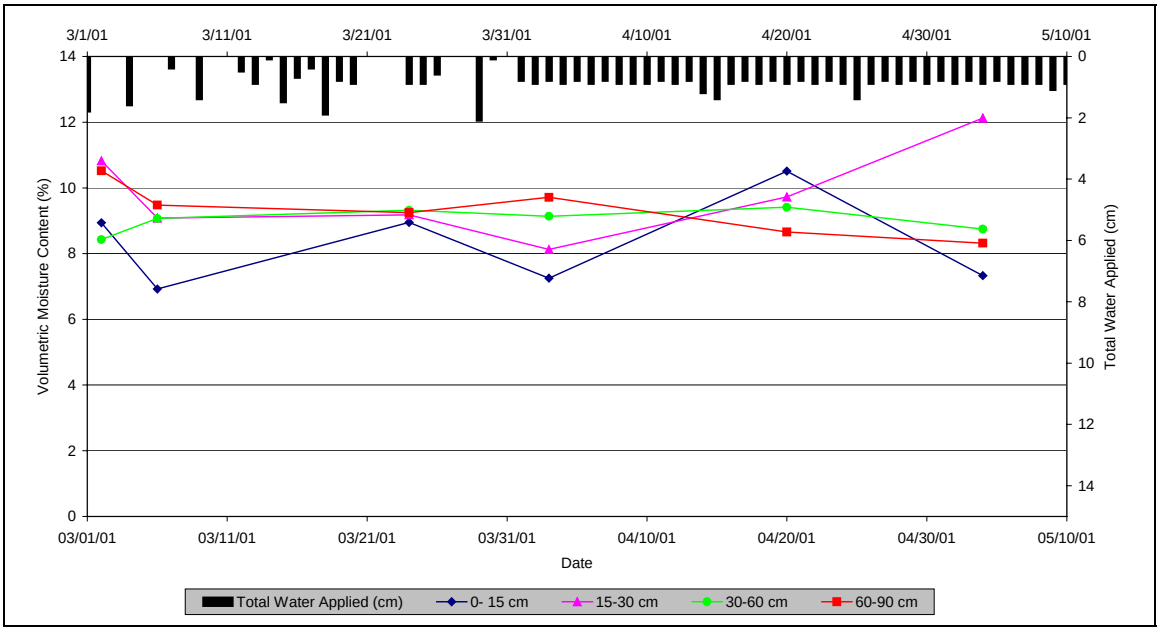


Figure 2-1. North half average moisture contents for the spring 2001 potato crop. Total water includes rainfall plus irrigation.

The results indicate the entire soil profile tended to remain at or above field capacity throughout the season. Note that only small fluctuations (Table 2-4) were observed in the measured moisture contents, due to the frequency that the soil samples were taken and the well-drained characteristics of the soils located at the project site. Also, note the moisture contents are above the field capacity of 6% determined in the

laboratory at –345 cm soil matric potential, which indicates that field capacity (or gravity drained water content) may occur at slightly lower (less negative) tensions than –345 cm.

Table 2-4. Statistical analysis of 2001 north half soil samples moisture content results.

Date	Depth (cm)	Average (%)	Maximum (%)	Minimum (%)	Standard Deviation (%)
03/02/01	0-15	8.94	10.82	7.71	1.20
	15-30	10.82	19.58	7.71	4.94
	30-60	8.43	9.10	6.79	1.10
	60-90	10.52	15.95	7.98	3.67
03/06/01	0-15	6.92	7.54	6.38	0.52
	15-30	9.08	9.38	8.71	0.32
	30-60	9.07	10.62	7.42	1.15
	60-90	9.48	11.08	8.39	1.04
03/24/01	0-15	8.95	11.36	7.30	1.53
	15-30	9.18	9.90	7.77	0.85
	30-60	9.32	10.29	8.26	0.79
	60-90	9.25	10.10	8.09	0.78
04/03/01	0-15	7.25	9.12	6.08	1.25
	15-30	8.13	9.08	6.74	0.86
	30-60	9.14	10.53	8.42	0.82
	60-90	9.71	14.09	7.69	2.63
04/20/01	0-15	10.51	12.54	7.82	1.89
	15-30	9.73	10.81	8.00	1.05
	30-60	9.41	10.45	8.25	0.80
	60-90	8.66	9.01	7.78	0.51
05/04/01	0-15	7.33	12.17	4.57	3.07
	15-30	12.13	32.75	5.42	11.58
	30-60	8.75	9.49	7.81	0.68
	60-90	8.32	9.23	7.21	0.74

The relatively high average value shown on 05/04/2001 for the 15-30 cm depth implies that there may have been various sources error during the analysis of the sample set. The standard deviation for the 15-30 cm depth was 11.6% (Table 2-4) with maximum and minimum values of the moisture content measuring to be 32.8% and 5.4%,

respectively. This indicates that the samples may have either been compromised in storage or that there may have been errors in the moisture content measurements. In any case, it is obvious that the soils tend to drain to field capacity relatively quickly even when substantial amounts of water are applied to the crop. For example, from 4/1/2001 to the end of the crop season, the field received approximately 1.0 cm of applied water daily. This applied water had very little impact on moisture content. The fact that field capacity was maintained throughout the season, even after large water applications, provides evidence that the potato crop was over-irrigated. Also, the drainage features of the soils on the site show that there is little impedance of the downward movement of the soil-water in the soil profile, which has a large influence on nutrient leaching.

Nitrate-nitrogen results

Figure 2-2 depicts the temporal and spatial nitrate-nitrogen mass transport in the bed. The figure is a good illustration of how the nitrate-nitrogen moves through the soil profile and into the Floridan Aquifer. It should be noted that plant roots extend to a maximum root depth of approximately 30-45 cm, which makes it improbable that any nutrients are removed from the soil by plants below this depth. Therefore, nutrients below this depth will eventually enter the underlying Floridan Aquifer. Also it should be noted that fertilizer application rates were reported on a total field area basis when the applied nitrogen was actually concentrated in the bed. As a result, the values shown and discussed for nitrate-nitrogen loads in Figure 2-2 represent the bed area only, and the reported fertilizer application rates are for the entire field area.

After the pre-plant and starter nitrogen fertilizer applications on January 18, 2001 and February 16, 2001, respectively, there was minimal leaching because there was no water applied. After March 2, 2001, steady nitrate-nitrogen leaching occurred as a result

of the 1.7 cm rainfall event on March 4, 2001 (see the results for the soil samples taken on March 6, 2001). Information provided by the grower indicated there was nitrogen fertilizer applied on March 5, 2001. However, the data indicate that this information may be inaccurate and fertilizer was actually applied after March 6, 2001. If the fertilizer was really applied on March 5, 2001, there should have been an increase in the nitrate-nitrogen content in the soil, but none was found from the soil samples taken on March 6, 2001. Albert (2002) observed that reported and actual fertilization dates had discrepancies. For example, Albert (2002) stated that it was reported that a fertilizer application occurred on March 25, 2001 when it was actually observed being applied the day before.

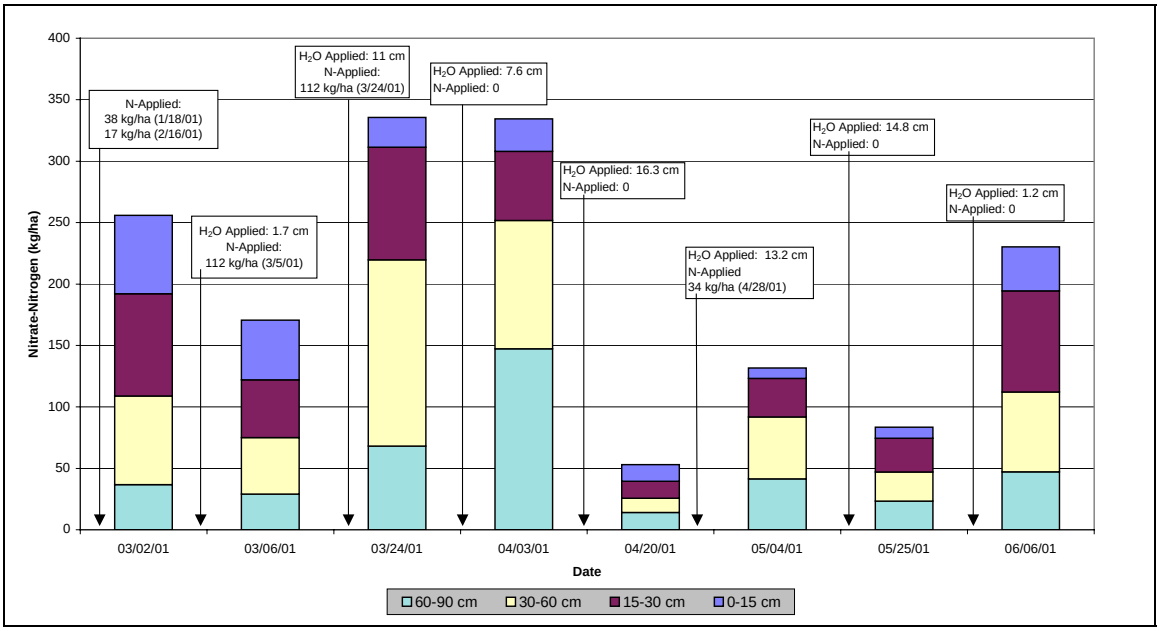


Figure 2-2. Average 2001 north half nitrate-nitrogen content in top 90 cm of the bed area. Each depth increment is an average of five samples. The applied nitrogen is the total nitrogen applied for the total area. All fertilizer application dates are approximate.

After March 6, 2001, the majority of the 112 kg/ha of nitrogen fertilizer leached out of the soil profile because there was a considerable amount of rainfall received by the

field. Another nitrogen fertilizer application of 112 kg/ha, applied on March 24, 2001, resulted in the total nitrate-nitrogen content in the soil increasing to approximately 335 kg/ha in the top 90 cm on March 24, 2001. After March 24, 2001, the nitrate-nitrogen content remained relatively constant through April 3, 2001 with a slight decrease due to the 7.6 cm of applied water and root uptake. The decrease in total nitrate-nitrogen content was small, likely because the plant canopy had started to reach the maximum leaf area index (LAI), which reduced the total effective rainfall. The decreased effective rainfall in decreased infiltration and nitrate-nitrogen leaching. However, during the period from March 24, 2001 to April 3, 2001, there was still considerable nitrate-nitrogen movement in the soil profile. In fact, 32.8 kg/ha of nitrate-nitrogen was leached out of the top 30 cm and into the lower 60 cm with the majority of the leached nitrate-nitrogen residing at the 60-90 cm depth out of the reach of plant roots.

Starting April 1, 2001, the field was continuously irrigated applying approximately 0.8 cm of water daily. During this period, nitrate-nitrogen was leached out of the soil rapidly as seen from the soil samples taken on April 20, 2001. Between April 3, 2001 and April 24, 2001, there was a net reduction in nitrate-nitrogen in the soil of 281 kg/ha. As a result, an additional 34 kg/ha of nitrogen fertilizer was applied on April 28, 2001. With the continuous irrigation, the nitrate-nitrogen applied to the field on April 28, 2001 was leached out of the soil profile reducing the total nitrate-nitrogen to 83.2 kg/ha on May 25, 2001. On May 20, 2001, the center pivot was shutdown, herbicides were applied to the crop to kill the vegetation, and there were no additional nitrogen fertilizer applications. This would create an environment in which there would be minimal leaching and no nutrient uptake by the plants. However, there was a substantial increase

in total nitrogen content after May 25, 2001 that can be seen from the data for June 6, 2001. There are a few possibilities that may have contributed to the increased nitrogen content in the soil. One possibility is that there was an upward flux of soil-water and nitrate-nitrogen due to the evaporation occurring at the soil surface. But the soils located at the project site are extremely sandy and are probably self-mulching, which makes it unlikely that there was upward flux of water and nitrogen. The most probable explanation is related to the re-bedding of the beds on June 4, 2001 before harvest to prevent potato decay. During this procedure, the dead plant material was incorporated into the soil, which could have been mineralized by the soil microorganisms.

Crop monitoring results

Crop monitoring of the spring 2001 potato crop included obtaining information from the farmer, visual field observations of timing of particular phenological events, and crop biomass sampling during the growing season. The crop development was well documented from weekly field visits to the farm over the growing season and information including planting date, emergence, tuber initiation, maximum LAI, and killed date were noted (Table 2-5).

Table 2-5. Important dates related to planting, harvest, and phenological events (2001).

Event	Date	Days After Planting
Planting	02/15/2001	0
Emergence	03/07/2001	20
Tuber Initiation	04/01/2001	45
Anthesis	04/04/2001	49
Maximum LAI	04/20/2001	64
Killed Date	05/21/2001	95
Harvest	06/01/2001	106

The biomass samples were taken 37, 40, 47 and 78 days after planting. Total final yields based on all the potatoes harvested was 38.7 Mg/ha for the north half and 33.7

Mg/ha for the south half. The biomass samples and the final yield were used to estimate total nitrogen uptake of the potato crop. The nitrogen concentrations determined from the plant tissue analysis were multiplied by each plant part and then summed to determine the total nitrogen mass in each plant sample. The average plant nitrogen mass per plant was then determined for each sample date and multiplied by the planting density of the entire field area to determine the nitrogen uptake per unit area. At the time of the final yield harvest, the vegetative growth had been killed by herbicides, so it was not possible to measure the final nitrogen uptake. Thus, the final nitrogen uptake was extrapolated using the plant data collected on May 4, 2001 and June 1, 2001. Leaf and stem weight at the kill date on May 21, 2001 were assumed to be the same as those on May 4, 2001. Also, the nitrogen concentrations of stems, leaves, and tuber were assumed to be the same as those measured from the May 4, 2001 plant samples. The tuber weight measured on June 1, 2001 was used as an estimate of the tuber weight on May 21, 2001. Figure 2-3 compares the total nitrogen uptake to the cumulative nitrogen applied on the north half of the field. The cumulative nitrogen includes the fertilizer applications plus the nitrogen that was applied through irrigation due to increased nitrate concentrations (20 mg/L) in the irrigation well water.

Figure 2-3 indicates that approximately 101.7 kg/ha of the nitrogen applied was actually recovered by the plants. The field experiments that were conducted provide valuable knowledge related to nitrogen uptake and leaching for potato crops. Soil samples indicated that the irrigation applied to the field was more than adequate to maintain field capacity. Also, soil-water nitrate concentrations show that nitrate-nitrogen tends to move through the soil profile quickly and out of the zone that plant roots take up

the nitrogen effectively due to the over irrigation of the crop. This was substantiated from the four biomass harvest taken over the growing season, which indicate that approximately 30% of the total nitrogen applied was utilized by the crop.

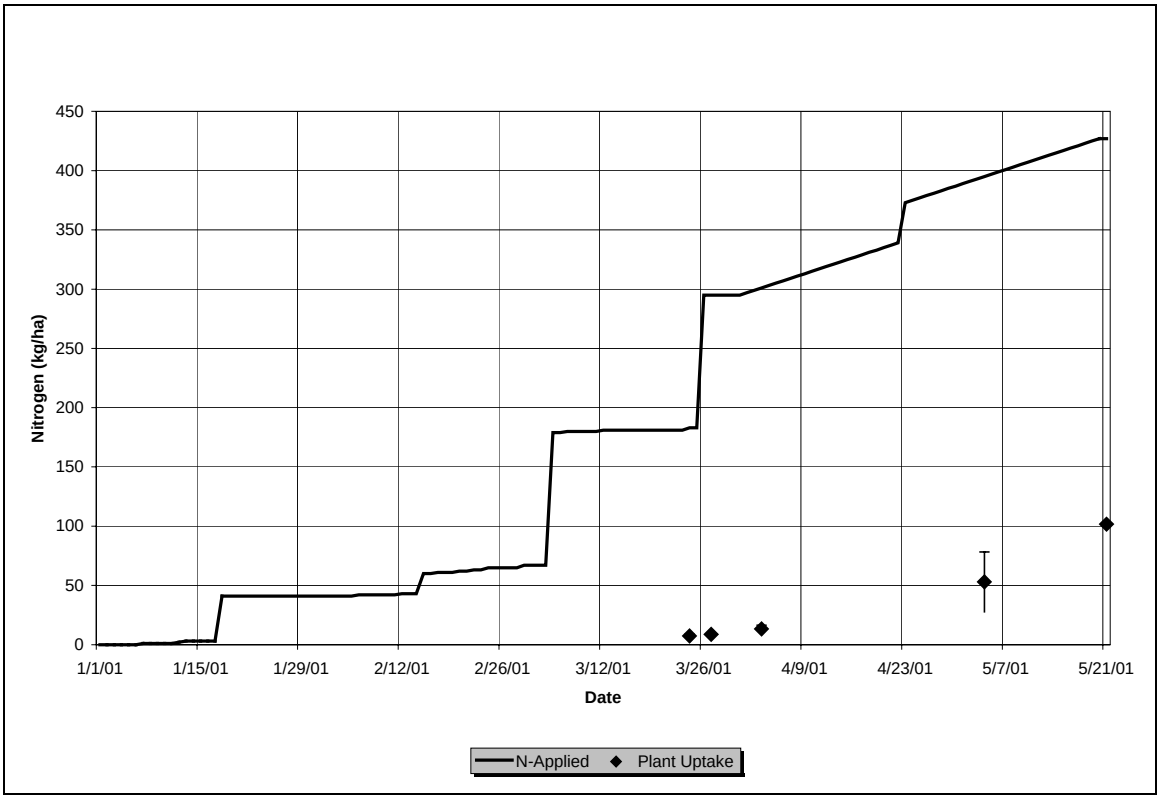


Figure 2-3. North half cumulative nitrogen applied and total crop uptake (2001). Error bars represent one standard deviation about the mean of the measured values. No standard deviation was calculated for the final point because point was extrapolated. Also, error bars are present on the all other samples but cannot be seen due to the small standard deviations relative to the measured values.

Spring 2002 Potato Crop

Planting details, crop management and weather

The spring 2002 potato crop had similar planting details to those of the spring 2001 potato crop. All the planting information listed in Table 2-2 for the 2001 potato crop are the same for the 2002 potato crop, except that corn was the previous crop planted and row spacing was 90 cm. As previously stated, two different management practices were

implemented on the field. The south half received approximately a 21% reduction in irrigation from that used on the north half and a 12% reduction in nitrogen applied (Table 2-6). The south half irrigation was managed according to weather conditions and crop status, which was monitored daily by Justin Jones from the University of Florida Research Center located in Live Oak, FL and Joel Love, a FDACS employee. The irrigation schedules for the north and south halves of the field are shown in Appendix C. Weather data were collected weekly from an onsite weather station adjacent to the field, which include hourly solar radiation, rainfall, and temperature.

Table 2-6. Spring 2002 approximate nitrogen fertilizer schedule and amounts.

Date	Julian Day	Applied Nitrogen (kg/ha)	Fertilizer Type/Application Method
		North	
1/10/2002	10	41	4-10-27, pre-plant in bed
1/15/2002	15	28.5	19-0-0, pre-plant in bed
2/13/2002	44	17	10-34-0, at plant
3/13/2002	72	101.5	19-0-0, sidedress
3/25/2002	84	104	19-0-0, sidedress
		South	
1/16/2002	16	90.5	19-0-0, in-bed
2/16/2002	47	17	10-34-0, at plant
3/15/2002	74	56	19-0-0, sidedress
3/26/2002	85	97.5	19-0-0, sidedress

North half moisture content results

The methods used to monitor vadose zone for the spring 2002 potato crop were similar to methods discussed previously for the spring 2001 potato crop with a few modifications in the field methods. Soil samples were taken on a biweekly basis at 10 locations in close proximity to the wells, alternating between the north and south halves of the field each week. The 10 biweekly sample sets were comprised of five sets of

samples taken in the center of the beds and five taken in the center of the furrow. The additional furrow samples were taken in order to observe the lateral movement of nitrogen and water between the bed and furrow. The samples were taken at the same depth increments, 0-15, 15-30, 30-60, and 60-90 cm, as the 2001 soil samples. The complete set of field measurements and results for spring 2002 potato crop soil samples are shown in Appendix A. The results for the north half average volumetric moisture contents of the bed soil samples are shown in Figure 2-4. Refer Table 2-7 for the standard deviations of the measured values.

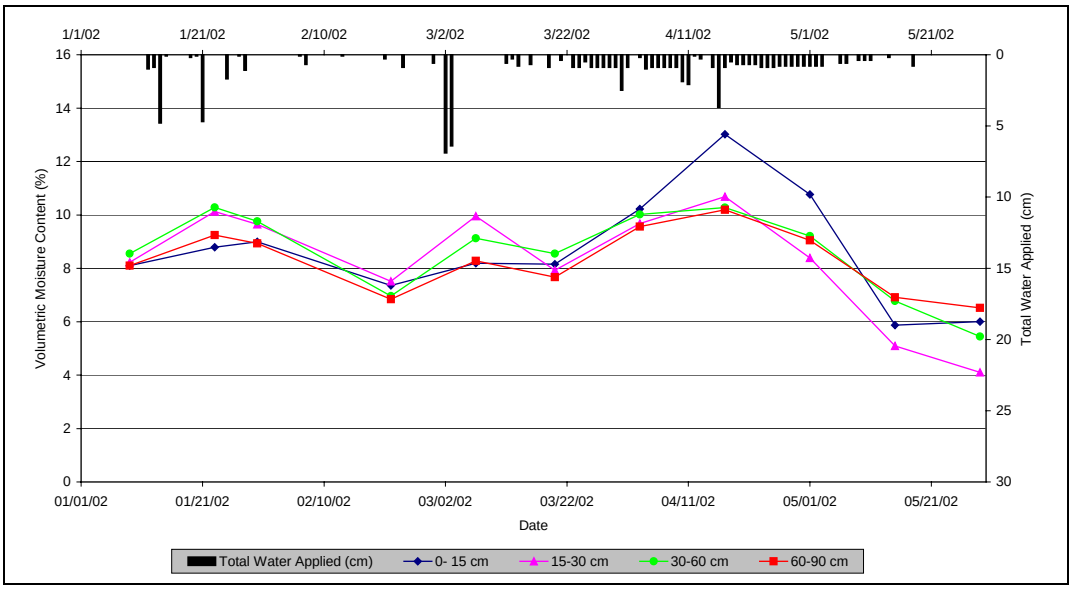


Figure 2-4. North half average volumetric moisture contents for the spring 2002 potato crop in the center of bed. Total water includes rainfall plus irrigation.

The results shown in Figure 2-4 for the north half moisture contents provide a good illustration of how the soil tended to remain at or above field capacity in the bed over the growing season. Even with excessive amounts of water applied to the field, the soils generally drained to field capacity rapidly. Significant increases in moisture content are apparent only in instances when the soil samples were taken directly following a large rainfall event. This is shown in the January 23, 2002, March 7, 2002 and April 17, 2002

soil moisture content results. On January 23, 2002, the moisture content increase is due to the 4.7 cm of rainfall that occurred on January 21, 2002. The increase in the moisture contents for the samples taken on March 7, 2002 are a direct result of the 6.9 cm and 6.4 cm of rainfall that occurred on March 3, 2002 and March 4, 2002, respectively. The last noticeable increase in the moisture contents on April 17, 2002 was caused by the 3.7 cm of rainfall on April 16, 2002. The soil drained considerably after May 5, 2002, because there was little rainfall and irrigation was minimal. On May 11, 2002, the pivot was shut down, so no supplemental water was applied to the field. Thus, this was the cause of the low moisture contents from the May 15, 2002 soil samples.

Table 2-7. The standard deviations of the 2002 north half measured volumetric moisture contents.

Date	Standard Deviation (%)			
	Depth			
	0-15 cm	15-30 cm	30-60 cm	60-90 cm
01/09/02	0.60	0.25	0.51	0.49
01/23/02	0.32	0.96	1.62	0.46
01/30/02	0.59	0.86	0.91	0.65
02/21/02	1.28	0.39	0.58	0.72
03/07/02	0.58	0.46	0.79	0.38
03/20/02	0.26	0.63	0.45	0.49
04/03/02	0.39	0.91	0.98	0.83
04/17/02	0.92	0.46	0.81	0.92
05/01/02	1.22	0.81	0.80	0.68
05/15/02	1.02	0.84	1.06	0.78
05/29/02	1.99	1.18	0.42	0.56

South half moisture content results

Figure 2-5 shows the results for the south half average volumetric moisture contents for the bed soil samples. The standard deviations of the measured values for the south half moisture contents are contained in Table 2-8.

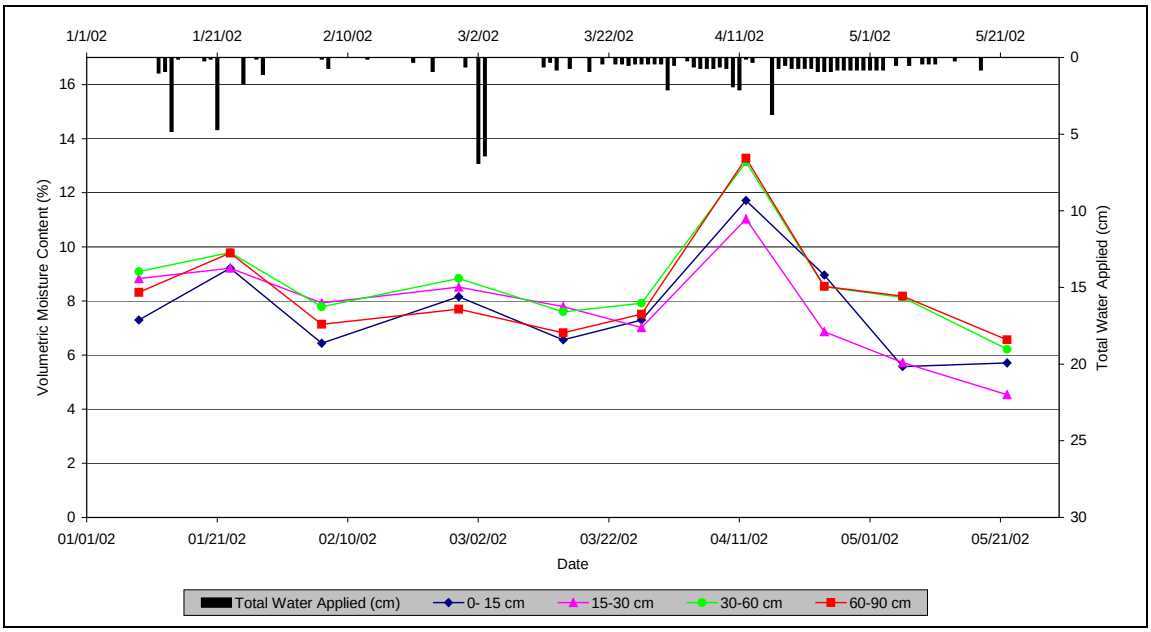


Figure 2-5. South half average volumetric moisture contents for the spring 2002 potato crop in the center of bed. Total water applied includes rainfall and irrigation.

The results from the experiment conducted on the south half of the field gives valuable insight on how plant water availability was affected by the reduction in the irrigation applied. During the experiment, there were a few noticeable increases in the moisture content of the soil. The first two sets of the average moisture content results shown in Figure 2-5 are identical to those shown in Figure 2-4. The field was still undergoing preparation for the crop at this time and the plant beds had not been made yet. So, the cause of the increase in moisture content that was observed from the January 23, 2002 samples are the same as those previously discussed. The high moisture contents measured from the April 12, 2002 soil samples were caused by 0.1 cm of rainfall occurring the day of sampling and by prior rainfall events of 1.9 cm on April 10, 2002 and 2.1 cm on April 11, 2002. Besides the soil sample sets collected directly following a large rainfall event, the majority of the moisture content measurements of the soil samples generally remained at or slightly above field capacity. The moisture content

results indicate the reduced irrigation applied had very little impact on plant water availability and shows that the north half of the field was over-irrigated.

Table 2-8. The standard deviations of the 2002 south half measured moisture contents.

Date	Standard Deviation (%)			
	Depth			
	0-15 cm	15-30 cm	30-60 cm	60-90 cm
01/09/02	0.66	0.26	0.32	0.57
01/23/02	1.73	0.81	0.68	0.77
02/06/02	0.45	0.96	0.42	0.27
02/27/02	0.78	0.99	1.79	1.30
03/15/02	0.46	0.76	0.57	0.47
03/27/02	1.10	0.41	0.96	0.57
04/12/02	0.13	0.05	2.50	1.75
04/24/02	1.06	0.73	0.58	0.40
05/06/02	1.22	1.91	0.75	0.85
05/22/02	2.68	1.20	1.24	0.95
01/09/02	0.66	0.26	0.32	0.57

North half bed nitrate-nitrogen results

The results from the soil samples taken in the beds also provided information pertaining to the nitrate-nitrogen transport in the soil profile. The bed soil sample results for the north half of the field are shown in Figure 2-6. The figure shows the nitrate-nitrogen movement in the soil over time and the possibility of the nitrogen leaching into the underlying Floridan Aquifer on the north half of the field. Remember, the plant roots occupy only the top 30-45 cm and are restricted to the bed only, so any nitrate-nitrogen below this depth eventually enters the aquifer. At the beginning of the spring 2002 potato crop season, two pre-plant nitrogen fertilizer applications of 41 kg/ha and 28.5 kg/ha were applied to the north half of the field on January 10, 2002 and January 15, 2002, respectively. After the fertilizer applications, there was a noticeable increase in the nitrate-nitrogen content that is shown in the results from the soil samples taken on January 23, 2002. The majority of the applied nitrogen had already leached to the 15-30

cm depth in the soil profile due to the 11.8 cm of rainfall that occurred between January 9, 2002 and January 23, 2002.

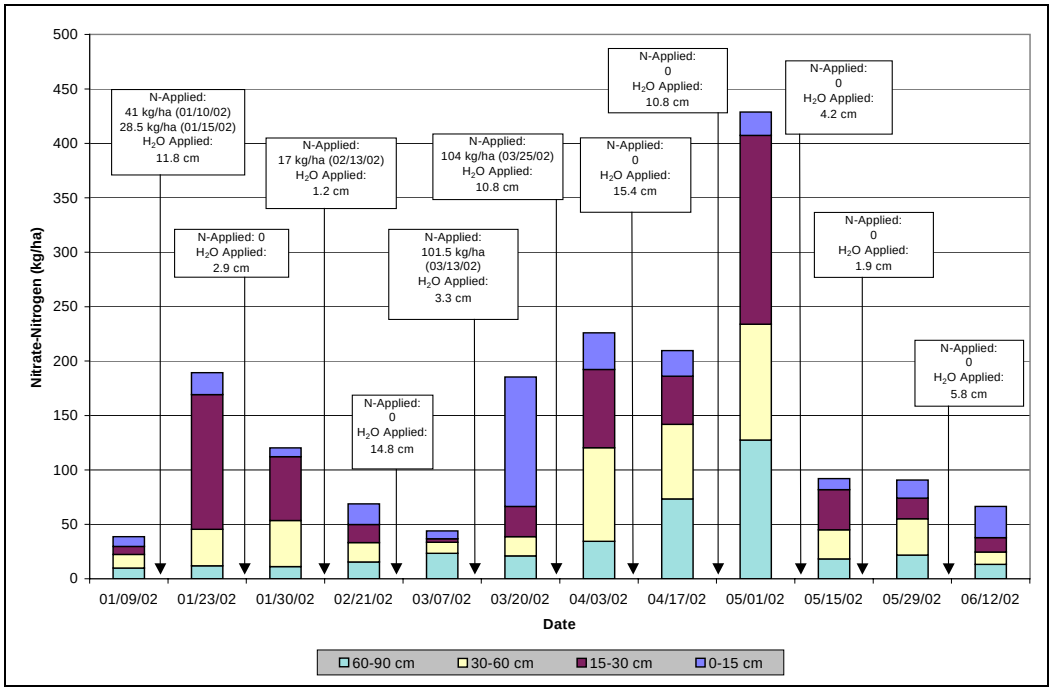


Figure 2-6. Average 2002 north half nitrate-nitrogen content in top 90 cm taken in the center of bed. Each depth increment is an average of five samples. The applied nitrogen is the total nitrogen applied for the total area. All fertilizer application dates are approximate.

After January 23, 2002, the nitrate-nitrogen continued to be leached out of the soil profile, which decreased the amount of nitrate-nitrogen in the top 30 cm. This is shown in the January 30, 2002 soil sample results. There was a slight increase in the total average nitrate-nitrogen content at 30-90 cm, but the majority of the nitrate-nitrogen had already leached out of the soil profile by this time. Another nitrogen fertilizer application of 17 kg/ha was applied on February 13, 2002 and the soil samples taken on February 21, 2002 display an 11.5 kg/ha increase in the nitrate-nitrogen content at 0-15 cm. However, considerable leaching still occurred over this period. The nitrate-nitrogen that was observed at the 30-60 cm depth on January 30, 2002 had leached out of the soil profile by

February 21, 2002. The north half of the field had received large amounts of total applied water between February 21, 2002 and March 7, 2002, which reduced the average total nitrogen content to 43.9 kg/ha by March 7, 2003.

On March 13, 2002, 101.5 kg/ha of nitrogen fertilizer was applied to the field, which was around the time of crop emergence. The fertilizer increased the nitrate-nitrogen amount at 0-15 cm to approximately 119 kg/ha, which is shown in the results from the soil samples taken on March 20, 2002. Small increases in the nitrate-nitrogen content were observed at lower depths due to the leaching from the upper 0-15 cm that occurred from the 3.3 cm of total water received. After March 20, 2002, the majority of the nitrate-nitrogen in the soil leached out of the top 90 cm. This was evident after examining the results for the soil samples taken on April 3, 2002. Between March 20, 2002 and April 4, 2002, there was an additional nitrogen fertilizer application on March 25, 2003. The fertilizer application had little affect on the total average nitrate-nitrogen content in the top 90 cm of the soil profile according to the April 4, 2002 soil results. Approximately 25% of the nitrogen that was located in the top 30 cm on March 20, 2002 was taken up by the potato plants by April 4, 2002 (Figure 2-10), which left the majority of the nitrate-nitrogen to be leached out of the soil profile by the 3.1 cm of irrigation applied from March 20, 2002 through March 24, 2002. The nitrate-nitrogen then increased on March 25, 2002 as a result of the 104 kg/ha of nitrogen fertilizer applied on that day, which explains why the total average nitrate contents for March 20, 2002 and April 4, 2002 are virtually the same. Leaching occurred over the next 10 days following the fertilizer application, which is shown in the April 17, 2002 soil sample results. The majority of the applied fertilizer was leached out of the top 15 cm and into the lower 60

cm of the soil profile. However, the majority of the nitrate-nitrogen remained in the top 90 cm of the soil because the crop canopy was starting to develop, which reduced the infiltration.

There were no additional fertilizer applications after March 25, 2002. However, the May 1, 2002 results show that there was a dramatic increase in nitrate-nitrogen content, which exceeded all previous measurements. The data from the soil samples taken on May 1, 2002 have significant variations in the measured values for each depth increment, especially for the samples taken in close proximity to observation wells 9 and 10 (Table 2-9), which were the cause for the anomaly.

Table 2-9. Nitrate-nitrogen content results for north soil samples taken on May 1, 2002 for wells.

Well	Depth (cm)	Average (kg/ha)
8	0-15	8.67
	15-30	8.25
	30-60	10.27
	60-90	15.10
9	0-15	42.87
	15-30	215.06
	30-60	361.32
	60-90	206.52
10	0-15	39.50
	15-30	450.35
	30-60	45.47
	60-90	270.50
11	0-15	10.63
	15-30	85.89
	30-60	69.24
	60-90	45.69
3	0-15	5.40
	15-30	107.86
	30-60	45.87
	60-90	99.11

The center pivot was shutdown on May 13, 2002 and the plants were killed with herbicide on May 17, 2002. Following May 1, 2002, the nitrate-nitrogen content decreased due to leaching. As in 2001, there are some noticeable increases in the nitrate-nitrogen content in the top 15 cm of the soil profile that were observed from the May 29,

2002 and June 12, 2002 samples. The increased nitrate-nitrogen contents were most likely caused by the mineralization of the dead plant material that was incorporated into the soil at re-bedding.

South half bed nitrate-nitrogen results

The bed soil sample results for the south half of the field are shown in Figure 2-7.

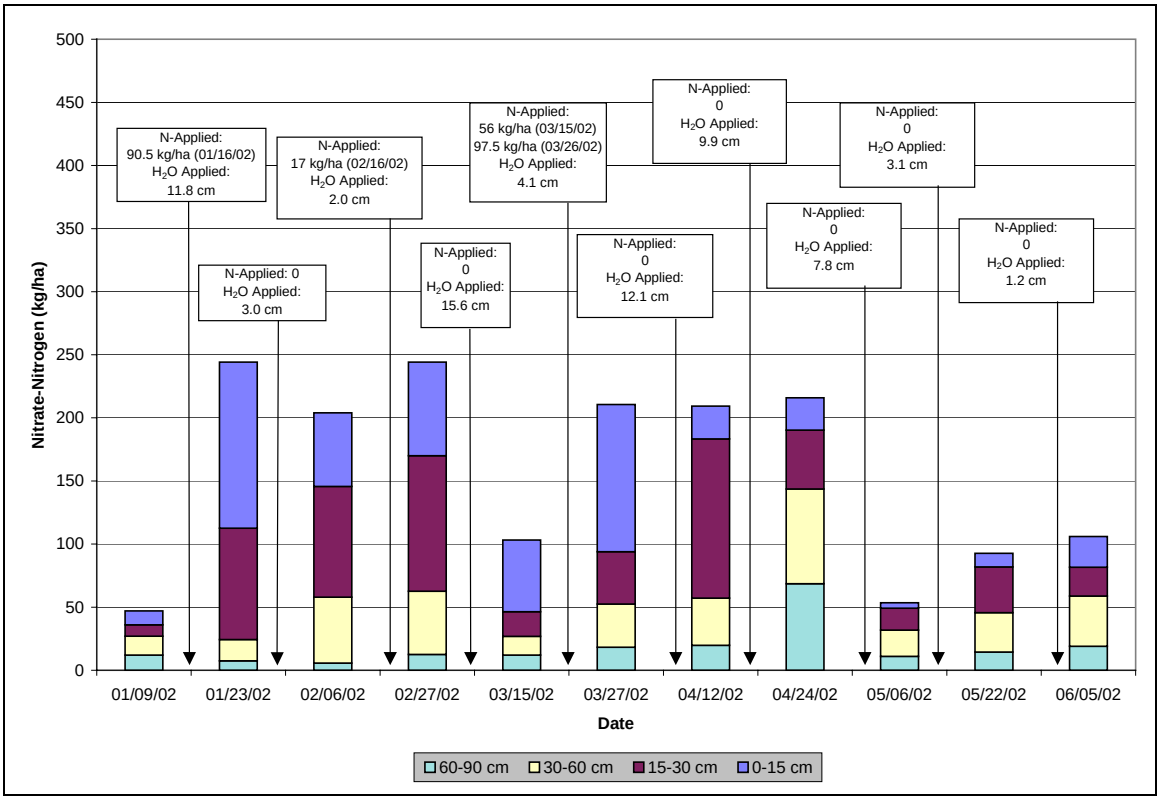


Figure 2-7. Average 2002 south half nitrate-nitrogen content in top 90 cm taken in the center of bed. Each depth increment is an average of five samples. The applied nitrogen is the total nitrogen applied for the total area. All fertilizer application dates are approximate.

The bed soil samples results provide evidence that the reduced nitrogen fertilizer and irrigation applied to the south half of the field reduced the rate and quantity of nitrate-nitrogen leached out of the vadose zone (Figure 2-7). In the beginning of spring 2002, 90.5 kg/ha of pre-plant nitrogen fertilizer was applied to the south half of the potato

field. The applied fertilizer resulted in an increase in nitrate-nitrogen in the top 30 cm of the soil profile, which can be seen from the January 23, 2002 soil sample results.

After January 23, 2002, the south half of the field received 3 cm of water, which leached approximately half of the nitrate-nitrogen out of the top 30 cm of the soil profile. Some of the leached nitrate-nitrogen was retained in the bottom 60 cm, but approximately 40 kg/ha was leached of the soil profile. A slight increase in total average nitrate-nitrogen content on February 27, 2002 was observed, which was caused by the 17 kg/ha of nitrogen fertilizer applied on February 16, 2002. The subsequent soil samples taken on March 15, 2002 indicated that there was a substantial amount of nitrate-nitrogen leached out of the soil profile, which can be attributed to the 14.2 cm of rainfall and 1.4 cm of irrigation applied from February 27, 2002 through March 15, 2002. It appeared that there was no significant leaching of nitrate-nitrogen from 0-15 cm depth according to the soil samples results taken on March 15, 2002, but the sustained nitrate-nitrogen concentration can be attributed to the 56 kg/ha of nitrogen fertilizer applied on that day.

A large increase in nitrate-nitrogen content was noticed on March 27, 2002 for the top 30 cm, which was a result the 97.5 kg/ha of nitrogen fertilizer applied the day before. The results obtained on April 12, 2002 indicated that the 6.3 cm of rainfall and 9.9 cm of irrigation applied between March 27, 2002 and April 12, 2002 reduced the nitrate-nitrogen content in the top 15 cm to 26 kg/ha. Most of the nitrate-nitrogen lost from the top 15 cm was retained in the 15-30 cm depth of the soil profile. The amount leached was not as dramatic as that seen on March 15, 2002, because the crop had begun to develop good canopy cover. As previously discussed, the plant canopy reduced the effective water applied to the beds, which reduced the infiltration and nitrate-nitrogen

leached. An additional 9.9 cm of water was applied to the south half of the field from April 12, 2002 through April 4, 2002. This resulted in approximately half of the nitrate-nitrogen in the top 30 cm being leached into the bottom 60 cm of the soil profile.

Senescence started to occur after April 24, 2002, which led to the large majority of the nitrate-nitrogen being leached out of the soil profile by the 7.8 cm of water applied between April 24, 2002 and May 6, 2002. The center pivot was shutdown on May 13, 2002 and the potato crop was killed by herbicides on May 18, 2002. There were noticeable increases in nitrate-nitrogen content in the top 30 cm observed from the soil samples taken on May 22, 2002 and June 6, 2002, which were most likely caused by mineralization of dead plant material incorporated in the bed at re-bedding.

North half furrow nitrate-nitrogen results

Originally, it was assumed that the nitrogen transport in the soil was one-dimensional with the transport of the nitrogen fertilizer being restricted to the bed, because the fertilizer was band-applied to the crop. However, no data had been taken in the furrow prior to this experiment to substantiate this hypothesis. The results from the samples taken in the furrows for the north half are shown in Figure 2-8. Note that nitrate-nitrogen content results for the furrow soil samples are an order of magnitude smaller than that measured for the bed samples.

As shown Figure 2-8, the nitrate-nitrogen content in the furrow tends to remain stable throughout the growing season. The only source of the nitrate-nitrogen in the furrows was from the irrigation water due to the elevated nitrate-nitrogen concentrations in the irrigation well water. Most of the measured values tended to range between 5 kg/ha to about 16 kg/ha for the both the north and south halves of the field with no noticeable increases in nitrate-nitrogen content following fertilizer applications. For

example, on March 13, 2002 there was a side-dressed nitrogen fertilizer application of 101.5 kg/ha on the north half of the field and the results from the March 20, 2002 furrow soil samples for the soil nitrate-nitrogen content showed that the nitrate-nitrogen content in the furrow remained at about 15 kg/ha. However, there are some noticeable increases in average nitrate-nitrogen content for the north half of the field observed on February 21, 2002, May 1, 2002, and May 29, 2002.

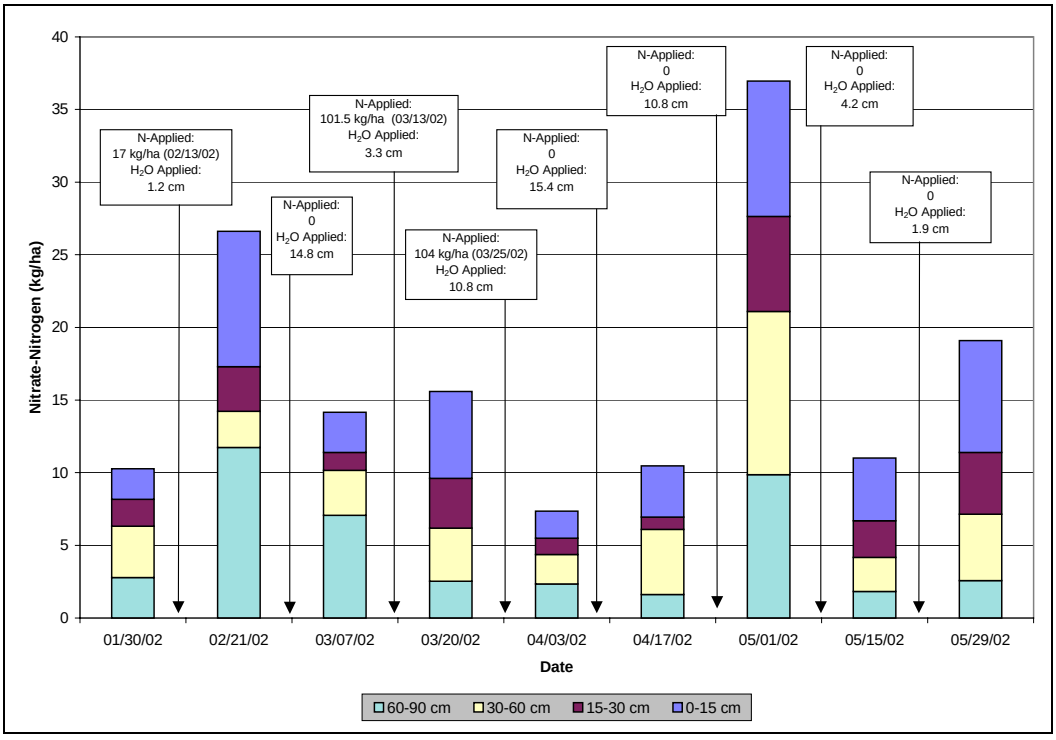


Figure 2-8. Average 2002 north half nitrate-nitrogen content in top 90 cm taken in the center of furrow. Each depth increment is an average of five samples. The applied nitrogen is the total nitrogen applied for the total area. All fertilizer application dates are approximate.

South half furrow nitrate-nitrogen results

Similar discrepancies were observed in the furrow soil samples taken on the south half of the field (Figure 2-9) on February 27, 2002 and June 5, 2002. But for the majority of the results, there were no noticeable increases in nitrate-nitrogen content over the growing season or following fertilizer applications. The south half of the field received

two side-dressed nitrogen fertilizer applications on March 15, 2002 and March 26, 2002 of 56 kg/ha and 97.5 kg/ha, respectively. Results from the south half furrow soil samples taken on March 27, 2002 showed that there was little change in the nitrate-nitrogen content in the soil.

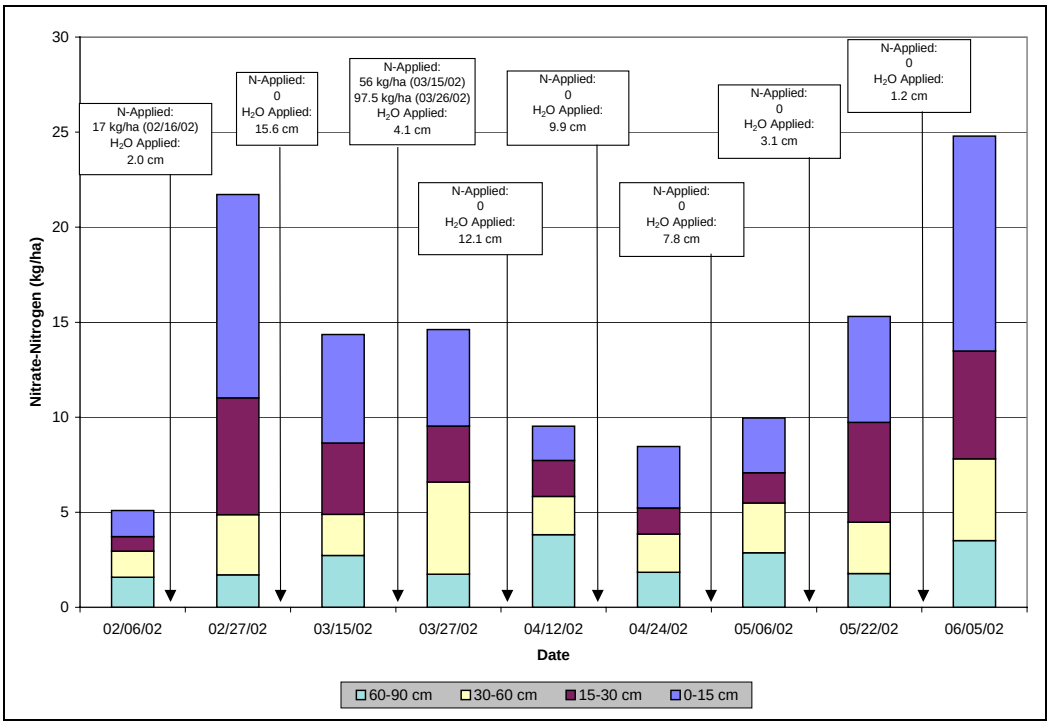


Figure 2-9. Average 2002 south half nitrate-nitrogen content in top 90 cm taken in the center of furrow. Each of the depth increments is an average of five samples. The applied nitrogen is the total nitrogen applied for the total area. All fertilizer application dates are approximate.

The results shown in Figures 2-8 and 2-9 show that the nitrate nitrogen in the furrow tended to remain fairly constant for the entire field during most the growing season, but reasons for the relatively high nitrate-nitrogen contents were not clear. After further examination of the analysis results for the furrow soil samples that showed increased nitrate-nitrogen content, it was obvious that there were substantial deviations in the measured values. These relatively high deviations in the measured values for several soil sample depths indicated spatial variabilities in the nitrate-nitrogen measurements.

Table 2-10 contains the results from the statistical analysis of the data taken on those dates.

Table 2-10. Statistical analysis of spring 2002 furrow soil samples nitrate-nitrogen results.

Date	Half	Depth (cm)	Average (kg/ha)	Maximum (kg/ha)	Minimum (kg/ha)	Standard Deviation (kg/ha)
02/21/02	N	0-15	9.3	14.4	3.6	4.5
		15-30	3.1	5.4	1.2	1.7
		30-60	2.5	3.7	1.5	0.9
		60-90	11.7	48.3	1.5	20.4
02/27/02	S	0-15	10.7	25.0	5.0	8.3
		15-30	6.1	9.1	3.9	2.0
		30-60	3.2	3.8	2.7	0.5
		60-90	1.7	2.5	0.9	0.6
05/01/02	N	0-15	9.3	17.1	5.2	4.9
		15-30	6.5	13.4	2.9	4.7
		30-60	11.2	21.7	5.9	6.6
		60-90	9.9	18.4	5.6	5.8
05/29/02	N	0-15	7.7	26.2	2.1	10.4
		15-30	4.3	8.4	1.3	3.1
		30-60	4.6	7.6	2.8	1.9
		60-90	2.6	4.1	1.5	0.9
06/05/02	S	0-15	11.3	14.7	7.7	2.9
		15-30	5.7	8.7	3.6	1.9
		30-60	4.3	6.8	3.0	1.4
		60-90	3.5	5.2	2.5	1.0

As shown in the Table 2-10, several of the layers had large variability in the measured values. For example, the samples taken on February 21, 2002 had significant variation between the maximum and minimum measured values in the nitrate-nitrogen contents for the soil samples taken at 60-90 cm. The maximum value was measured to be 48.3 kg/ha, which is relatively high when compared to the minimum value of 1.5 kg/ha. This accounts for the high average value of 11.7 kg/ha. When the maximum value is not included in the average for the 60-90 cm depth, a more reasonable average nitrate-nitrogen content of 2.6 kg/ha was obtained.

In the soil samples taken on February 27, 2002, there was significant variation (coefficient of variation = 0.78) in the measured values for the samples taken at 0-15 cm. The majority of the samples varied from approximately 5.0 kg/ha to 6.5 kg/ha for the nitrate-nitrogen content, but there were two relatively high measured values of 10.5 and 25 kg/ha. The May 1, 2002 samples had a few discrepancies in the measured nitrate-nitrogen contents for all of the sample depths. The 0-15 cm samples had two large measured values of 11.4 and 17.1 kg/ha, while the remaining three samples had an average nitrate-nitrogen content of 6.0 kg/ha.

The samples taken at 15-30 cm had two high measured values of 9.6 and 13.4 kg/ha, while the other measured values ranged from 2.9 to 3.8 kg/ha for nitrate-nitrogen. Two relatively high nitrate-nitrogen contents of 13.7 and 21.7 kg/ha were measured from the 30-60 cm samples. The three other samples taken at 30-60 cm averaged out to be approximately 7.0 kg/ha for nitrate-nitrogen. The 60-90 cm samples had two measured values of 18.4 and 13.2 kg/ha for the nitrate-nitrogen content. These two measured values are relatively high when compared to the three other soil sample measurements that ranged from 5.7 to 6.3 kg/ha for nitrate-nitrogen.

There was slightly less variation in the measured nitrate-nitrogen contents for the samples taken on May 29, 2002. The average measured value was slightly higher than expected. Only one nitrate-nitrogen measurement of 26.2 kg/ha at 0-15 cm was significantly higher relative to the other sample measurements, whose values ranged from 2.4 kg/ha to 5.3 kg/ha for nitrate nitrogen. The high average nitrate-nitrogen content measured from the soil samples taken on June 6, 2002 can be attributed to variations in the measured values for all of the sample depths. There were no substantial deviations in

the measured values, but there were noticeable increases for the measurements taken at each depth interval. After the analysis of these sample results, it was clear that measurement error was the likely cause of the high average total nitrate nitrogen content on the previously mentioned dates and that nitrate-nitrogen transport of the fertilizer was restricted to the bed.

Crop monitoring

As previously discussed, crop monitoring for the spring 2002 potato crop consisted of obtaining information from the farmer, visual field observations of timing of certain phenological events, and crop biomass sampling during the growing season. The crop development was documented from weekly visits to the farm (Table 2-11).

Table 2-11. Important dates related to planting, harvest, and phenological events (2002).

Event	Date		Days After Planting	
	North	South	North	South
Planting	02/12/02	02/15/02	0	0
Emergence	03/10/02	03/10/02	20	23
Tuber Initiation	04/01/02	04/01/02	42	45
Anthesis	04/01/02	04/01/02	42	45
Maximum LAI	04/20/02	04/20/02	61	64
Killed Date	05/17/02	05/18/02	91	92
Harvest	05/24/02	05/24/02	98	98

Biomass samples for the north half of the field were taken at 47, 68, and 80 days after planting. The biomass samples for the south half were taken at the same times as those listed for the north half, except for the first set of samples. The first biomass harvest taken for the south half was done at 56 days after planting. Total final yields based on all the potatoes harvested was 36.5 Mg/ha for the north half and 36.0 Mg/ha for the south half.

The three biomass samples and final tuber yield were used to estimate total nitrogen uptake of the potato crop. The methods used to determine nitrogen uptake are

identical to those previously discussed for the 2001 potato crop. The estimates calculated for the total nitrogen uptake provided critical information regarding the effectiveness of the reduced nitrogen and irrigation applied. Figure 2-10 compares the cumulative nitrogen applied to the total plant nitrogen uptake for the north and south halves of the field. The cumulative nitrogen includes the fertilizer applications shown in Table 2-6 plus nitrogen applied through the irrigation applied due to elevated nitrate-nitrogen concentrations (10 mg/L) of the irrigation well water.

Figure 2-10 provides insight on how fertilizer and irrigation scheduling can be modified in order to reduce nitrate-nitrogen leaching. This figure indicates that the potato plants on the north half of the field recovered 155 kg/ha of the total 364 kg/ha of nitrogen applied from the fertilizer applications and the irrigation, which is a 42% recovery of nitrogen. This was a major improvement from the 30% that was recovered during the 2001 season. The south half plants recovered 132.2 kg/ha of the total 316 kg/ha of nitrogen applied, which is also a 42% recovery of nitrogen. However, it is clear from the soil sample results that nitrogen was more readily available for crop uptake over the entire growing season on the south half of the field and that the lower irrigation reduced the rate that nitrogen leached out of the top 30 cm. More nitrogen was taken up on the north half despite that nitrogen was more readily available to the south half plants. This was mostly likely due to the differences in the planting dates (Table 2-11). The north half plants were planted earlier, so were able to take up nitrogen for a longer period of time. Also, there may have been some error in the extrapolated final dry tuber yield estimate because there were no nitrogen concentration measurements of the tubers, stems, and leaves at final harvest. The soil moisture results also show that the north half of the

field was still being over irrigated, which resulted in the nitrogen quickly leaching out of the top 30 cm of the soil profile.

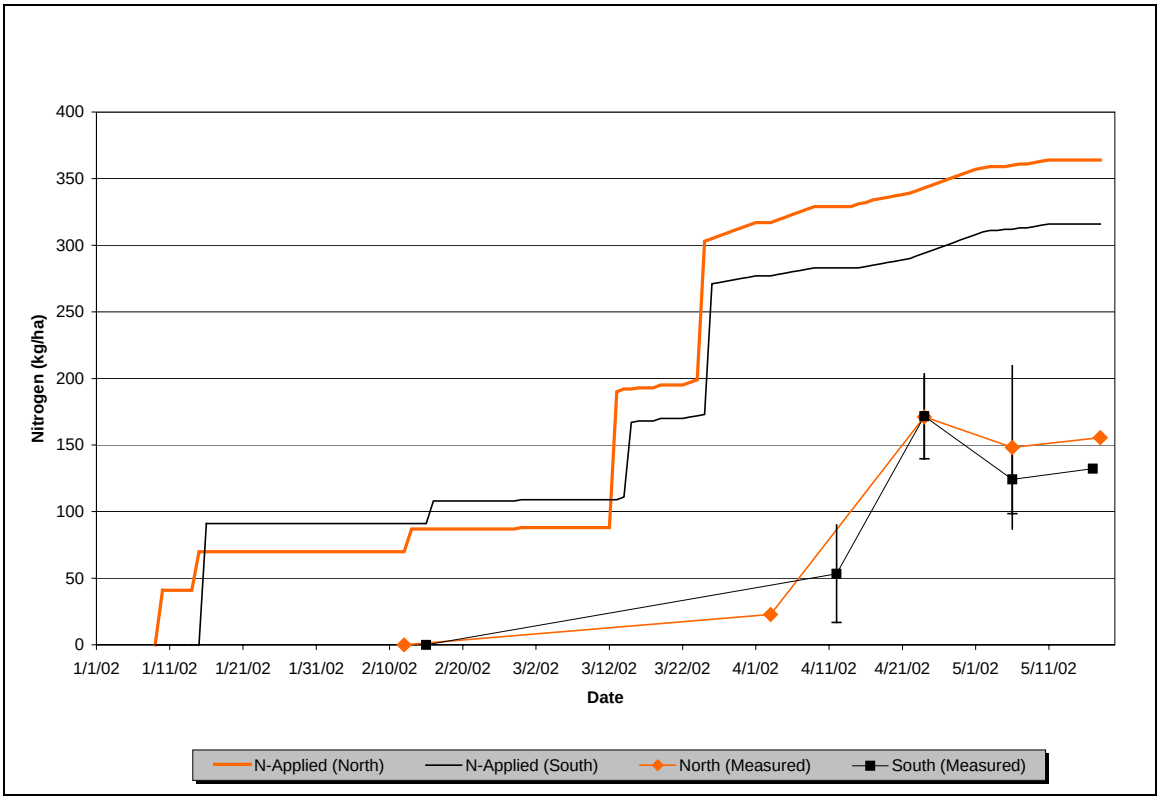


Figure 2-10. Nitrogen applied and total crop uptake (2002). Error bars represent one standard deviation about the mean of the measured values. No standard deviation was calculated for the final point because point was extrapolated.

Comparisons of Final Yield/Nitrogen Lost and Nitrogen Applied

Figures 2-11 and 2-12 show the general trend in the dry tuber yield and nitrogen lost in relation to total nitrogen applied. The data shown include information for all four treatments that were implemented during the 2001 and 2002 growing seasons. Note that the nitrogen applied is comprised of the fertilizer applications plus the nitrogen applied through the irrigation due to the elevated nitrate-nitrogen concentrations in the irrigation well water.

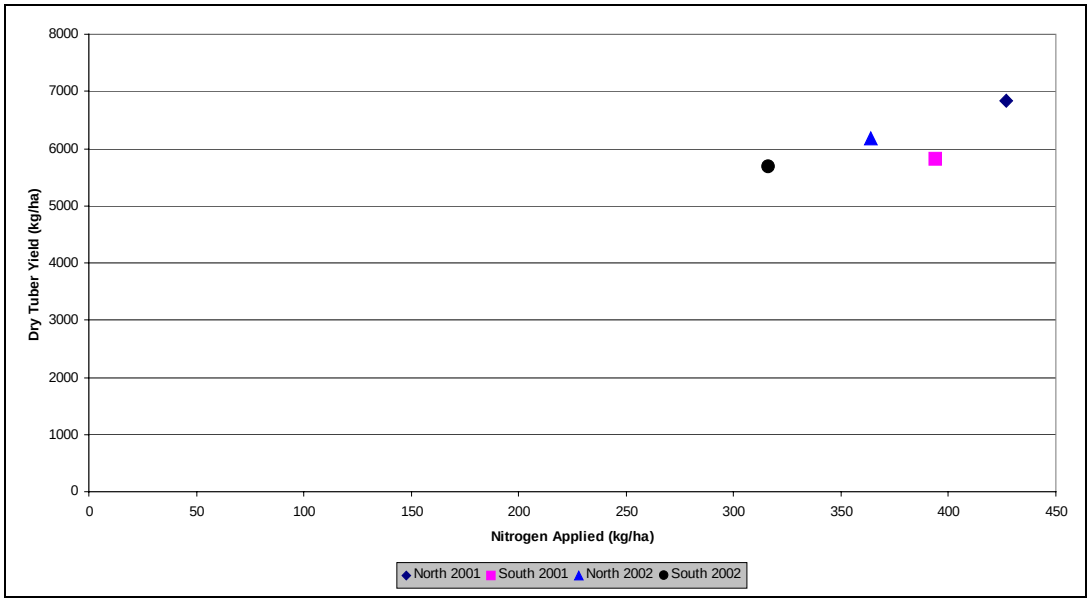


Figure 2-11. Comparison between the total nitrogen applied and the dry tuber yield.

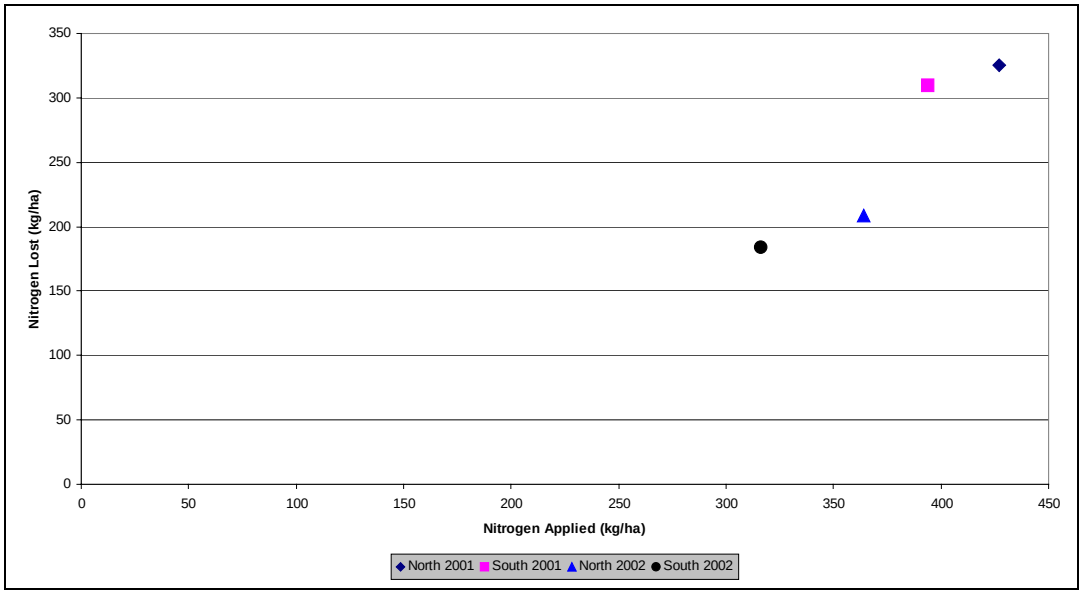


Figure 2-12. Comparison between the total nitrogen applied and the nitrogen lost

Figure 2-11 illustrates how the dry tuber yield is affected by the total amount of nitrogen applied over the growing season. The figure indicates that the yield usually increases with increasing fertilizer applications amounts. However, the results in the figure show that the yields are generally stable for the nitrogen fertilizer amounts applied during 2001 and 2002 growing season. As shown in Figure 2-11, the dry tuber yield

ranges from 5,684 kg/ha for the south half of the field in 2002 to 6,840 kg/ha in 2001 for the north half of the field. The yield stability indicates that there is specific amount of nitrogen fertilizer that can be applied to the crop that will produce the maximum yield, and any additional fertilizer applied will result in negligible increases in dry tuber yield.

Unlike the dry tuber yield, the nitrogen lost depends significantly on the amount of nitrogen applied. Figure 2-12 shows that as the nitrogen fertilizer application increases the amount nitrogen lost also increases. In 2001, 427 kg/ha of nitrogen fertilizer was applied to the north half of the field and 325.3 kg/ha was lost. On the south half of the field, the fertilizer applied was reduced to 394 kg/ha, which resulted in 310.3 kg/ha being lost. The nitrogen fertilizer applied in 2002 was lower than that applied in 2001. The total applied nitrogen to the north and south halves of the field was 364 kg/ha and 316 kg/ha, respectively. With the reduced fertilizer application amounts, the nitrogen lost was 208.5 kg/ha and 183.8 kg/ha for the north and south halves of the field, respectively, which is somewhat lower than that lost in 2001. This indicates that acceptable yields can be achieved at the project site with substantial reductions in nitrogen fertilizer amounts while still maintaining acceptable yields.

CHAPTER 3
MODEL DESCRIPTION AND RESULTS

An existing crop model was used to predict crop yield and nitrate-nitrogen transport for the spring 2001 and 2002 potato crops that were monitored at the project site. The primary goal was to properly calibrate the model using the data collected during the two growing seasons in order to accurately represent the potato crop system. The Decision Support System for Agrotechnology Transfer (DSSAT) Version 3.5 was the model used in the analysis of the potato crops. DSSAT is a product of the International Benchmark Sites for Network for Agrotechnololgy Transfer (IBSNAT) project and is well known throughout the world. The model was chosen because of its ability to accurately predict crop yield and nutrient uptake.

DSSAT Model Description

DSSAT is a shell that utilizes a collection of crop models in order to perform crop growth simulations. The primary use of the shell is to allow the user to enter, store, and retrieve information necessary for crop simulations, sensitivity analyses, model calibrations, and model validations. The DSSAT model simulates plant development based on plant processes, which are directly affected by interactions with the environment. Also, the model contains a graphical interface that permits the user to analyze and view model results. The graphical user interface can also be used to navigate between the various programs and models contained within DSSAT. The crop models contained in DSSAT include the CERES model (Tsuji et al., 1998 pp. 78-98)for grains, the CROPGRO model (Tsuji et al., 1998 pp. 99-128) for legumes, and the SUBSTOR

model (Griffin, 1993) for potatoes. The SUBSTOR model was the only model used in the research conducted. All the models in DSSAT use the same nutrient transport and hydrologic routines and differ only in the methods used for plant growth. Also, DSSAT is able to perform both seasonal and sequence analyses. Seasonal analysis relates to the temporal variability of weather within the growing season and from year to year. Sequence analysis allows the user to examine the behavior of the crop system over time. The minimum data required to run the crop model include a weather file, a soil file, a cultivar file, and a control file (FILEX). Weather data that is used by DSSAT includes measured data or stochastically generated data that is based on historic weather. The soil file contains various parameters and information that include porosity, drained upper limit, soil family, etc. for specific site locations and soil types. The crop file includes genetic coefficients that affect plant development. FILEX contains information regarding management practices and references the executable file to the correct soil, weather, and crop files.

The following is a brief model description of the DSSAT model. For a more detailed description of the methods used in the DSSAT model including equations, input file structure, etc, refer to Tsuji (1994) and Tsuji (1998). Also, the input files used in the crop growth simulations are shown in Appendix C.

Hydrology Component

The soil-water balance routines implemented in DSSAT are described by Ritchie (Tsuji et al., 1998 pp. 41-54) and are used to predict the vertical one-dimensional soil-water transport under variably saturated conditions within the soil profile. The soil-water budget is determined daily and predicts plant transpiration, root water adsorption, soil evaporation, runoff, infiltration, and drainage.

Runoff and infiltration are determined using the USDA-Soil Conservation Service (SCS) curve number (CN) with a modification for layered soils. The antecedent moisture condition used to determine the CN is based on the moisture content in the top layer of soil. Runoff is calculated using the daily rainfall only, because it is assumed that irrigation does not affect runoff. The infiltration is defined as the difference between the total water applied (precipitation plus irrigation) and runoff.

In order to determine the soil-water transport, the soil profile is divided into layers. When infiltration occurs, drainage is calculated using a cascading method that predicts the soil-water movement from one soil layer to the next. Drainage only occurs when the moisture content in a layer exceeds the drained upper limit (DUL). The volume of water that can drain out of a specified layer is the difference between the current moisture content and the DUL. The drainage is then calculated using a proportionality constant, which transports the water into the underlying layer. The volume of water drained from a layer in a day is dependent on the volume of water above the DUL. If the soil-water flux entering the soil layer exceeds the volume it can hold (saturated moisture content minus current moisture content), the excess water is moved into the lower layer.

The potential evapotranspiration (PET) is calculated using a modified Priestly-Taylor (1972) equation. Parameters needed for the calculation include total daily solar radiation, maximum temperature, and minimum temperature. The calculated PET is then separated into potential evaporation and transpiration in order to determine the actual soil evaporation and actual plant transpiration. During evaporation, an upward water flux is calculated for the top four soil layers using a soil-water diffusivity function.

Actual root water uptake is determined from the potential uptake per root length. Reduction factors are used to account for nonideal soil moisture content conditions. The uptake does not exceed the maximum daily uptake that is assumed to be 0.03 cm^3 of water per cm of root.

Nitrogen Component

The nitrogen balance routines used by DSSAT estimate the nitrogen transformations, nitrate transport in the soil profile, and nitrogen uptake by plants. The nitrogen transformation routines include denitrification under anaerobic conditions, mineralization of organic nitrogen, and nitrification of ammonium. The model can also predict the transport of nitrogen in the soil profile. Urea and nitrate are assumed to be mobile in the soil profile, while organic nitrogen and ammonium are considered to be immobile. Also, the model assumes that the nitrogen located in a specific layer is uniformly distributed in the layer.

The organic nitrogen is divided into humic material and organic matter. The organic matter is then separated into carbohydrates, cellulose, and lignin. Each type of organic matter is assigned a distinct decay constant that corresponds to maximum decay under non-limiting conditions. Factors that limit the decomposition of organic matter, which include moisture content, soil temperature, and the effect of the carbon/nitrogen ratio of the soils, are all accounted for in the decay calculations. The decomposition of humic material into inorganic nitrogen is calculated in a similar manner to the decay of organic matter, except the reactions occurs at a much slower rate and carbon/nitrogen of the soils is not taken into account.

The nitrification of ammonium to nitrate is calculated using a potential nitrification rate that is based on the Michaelis-Menton kinetic function. This nitrification calculation

method is independent of soil type and depends only on the ammonium concentration. Factors that reduce the nitrification rate, including temperature, soil moisture content, and soil ammonium concentration, are taken into account using an environmental limit on nitrification capacity that ranges from zero to one.

Advection is the only mechanism considered in nitrate transport. As a result, nitrogen transport in the soil profile from layer to layer is only dependent on the soil-water transport calculated in the hydrology routines. The equations used to determine nitrate transport assume that the entire nitrate in the soil is in aqueous form.

Ammonium and nitrate are the two nitrogen forms that are taken up to meet the nitrogen requirements of the plant. The nitrogen uptake from the soil is dependent on the amount of nitrogen in the soil and the demand by the plant. The plant demand for nitrogen is a function of the top weight, concentration of nitrogen currently in the vines, and the critical nitrogen concentration, which is the minimum amount of nitrogen required for maximum growth. The actual crop nitrogen uptake is affected by the soil moisture content, root length density, and nitrogen concentration in the soil solution. To account for moisture content, a soil water factor that ranges from zero to one is introduced that reduces the nitrogen uptake potential. Two additional reduction factors are then determined based on the ammonium and nitrate concentrations. Finally, the root length density factor is calculated to determine actual plant nitrate and ammonium uptake.

Crop Growth Component

During this study, the SUBSTOR-Potato Version 2.0 crop model was used to simulate the biomass accumulation and phenological development of the spring 2001 and 2002 Red LaSoda potato crops based on the soils, weather, and different management

practices used at the project site. The SUBSTOR-Potato Version 2.0 was developed with the intent to be used over a wide range of geographical locations and for different cultivars. The inputs used in the potato growth simulation are retrieved from the weather file, soil file, cultivar file, and a temporary file made from the FILEX created by DSSAT. The temporary file is created by DSSAT so that the input file is converted to the format used by SUSTOR. The cultivar file includes five genetic coefficients that characterize crop growth and development. The five genetic coefficients located in the cultivar file include the leaf expansion rate (G2), tuber growth rate (G3), determinacy (PD), temperature (P2), and sensitivity of tuber initiation to photoperiod (TC). There are also several other crop growth parameters and coefficients that are located in the SUBSTOR code and species file that are species specific and should not be modified by the unknowledgeable user. Due to the large number of these parameters and coefficients, they are not listed here (refer to Griffin et al., 1993). The SUBSTOR outputs include daily dry matter weights of the leaves, stems, tubers, and roots; daily leaf area index (leaf area per horizontal ground surface area); and the phenological growth stage.

The simulation of crop development and growth is divided into five stages in SUBSTOR, which include pre-planting, planting to sprout germination, sprout germination to emergence, emergence to tuber initiation, and tuber initiation to maturity. In SUBSTOR-Potato model, the partitioning and accumulation of biomass during the computer simulation for the leaves, stems, tubers, and roots are dependent on the growth stage of the crop. Also, growth restrictions caused by high/low temperatures, long photoperiods, water stresses, and nitrogen stresses are all accounted for in the model.

Model Calibration and Results

In the original DSSAT simulation, Albert (2002) assumed that the computer simulation was restricted to the bed only. As a result, Albert doubled the fertilizer applications in the input file because it was presumed that this would be an appropriate method to concentrate the nitrogen fertilizer in the bed. After further examination of the source code and consultations with model developers, it was determined that DSSAT simulates plant growth for the entire row rather than just the bed.

Because of the inconsistencies in Albert's (2002) approach for the spring 2001 potato crop growth simulations, the north half of the field that used the farmer's typical management practices was re-simulated using a modified FILEX with the correct fertilizer amounts. All the previous soils data (i.e. CN, porosity, DUL, etc.) and plant generic coefficients (G2, G3, PD, P2, TC) were used in the new simulation. During the spring 2001 potato crop, soil sampling did not begin until March 2, 2001, which was well past the time of the pre-plant fertilizer application and planting. As a result, the initial conditions for soil moisture content were set equal to the measurements taken from the March 2, 2001 soil samples and initial nitrogen content was estimated. The initial nitrogen content measured on January 9, 2002 soil samples were used as initial nitrogen content for the 2001 simulation. In order to minimize effect of errors in initial conditions, the simulation was started on January 1, 2001, which was well before the first fertilizer application on January 18, 2001. The calibration of the model consisted of comparisons between the measured and simulated values for each sampling depth described in Chapter 2.

The calibration comprised first adjusting the soil parameters in order to accurately represent the soil-water conditions in the soil profile. Initially, it appeared that the soil

parameters needed no further adjustments from the values used by Albert (2002). This was concluded from the comparisons between the measured and predicted results shown in Figures 3-1 through 3-4. Note that the DSSAT simulation predictions illustrated in the figures represent weighted averages of the results for each soil layer listed in the output file in relation to the actual measurement depths. Also, remember that the DSSAT predictions were calculated daily, so the results represent the daily averages.

The moisture content results for the corrected computer simulation displayed the same general trends as Albert's (2002) simulation. There were slight differences in the initial soil moisture content predictions because of the differences in the initial conditions used in each simulation. For example, at 0-15 cm the corrected model predicted the moisture content to 0.068 on January 7, 2001, while in Albert's (2002) simulation it was predicted to be 0.069. But in general, the moisture content predictions for the corrected simulation and Albert's simulation were virtually the same.

The results indicate that the majority of the simulated values fairly accurately predicted the measured values. Most of the soil moisture predictions remained within one standard deviation of the measured values with the majority of the model predictions being greater than the measured values. The soil moisture predictions displayed very little variation over the growing season, except for the simulation results at 0-15 cm depth. The model predictions at 0-15 cm exhibited noticeable increases in the moisture content following every irrigation application and/or rainfall event. This was caused by the soil surface exposure to irrigation, rainfall, and evapotranspiration. Also, the magnitude of the increase depended on the amount of water applied to the field and the previous moisture content of the soil layer. For example, on January 20, 2001 there was

a 7 mm rainfall event that resulted the simulated moisture contents to increase from 7.6% on January 19, 2001 to approximately 9% on January 20, 2001. The largest predicted moisture content observed occurred on March 16, 2001. Prior to March 16, 2001, the field received 4.5 cm of water from March 14, 2001 through March 18, 2001, which caused the predicted moisture content to increase from 8% on March 14, 2001 to almost 20% on March 18, 2001.

The simulation results at 0-15 cm also provide valuable information of the soils ability to drain to field capacity relatively quickly, which is shown in the simulated moisture content results for March 24, 2001. By March 24, 2001, the moisture content of the top 15 cm reduced from the 20 to 8%. The decrease may be attributed to the evapotranspiration and drainage that occurred. The 4.5 cm of applied water also had significant impacts on the predicted moisture contents for the lower soil depths.

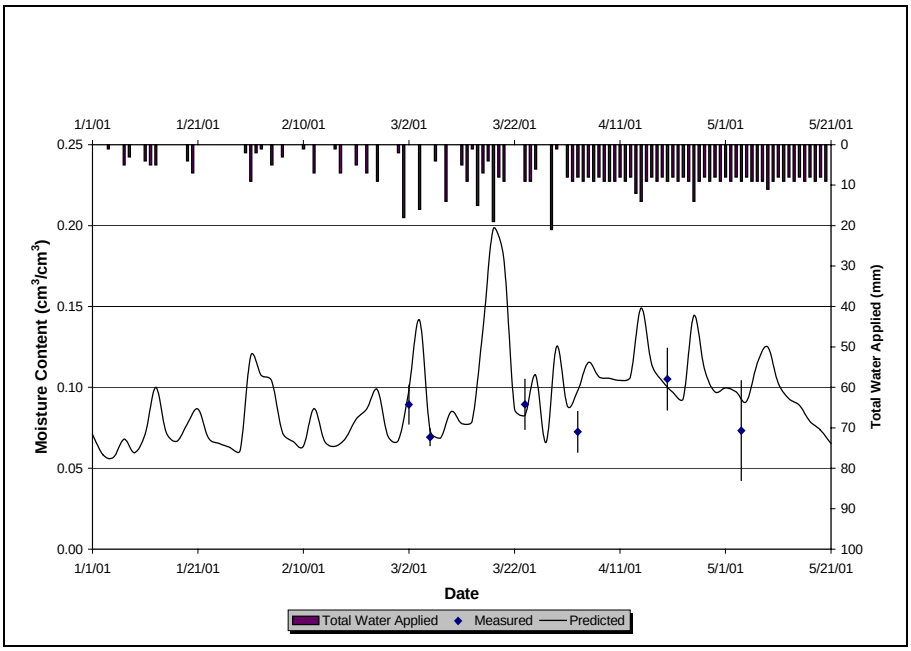


Figure 3-1. DSSAT spring 2001 potato crop soil moisture content results for the north half at 0-15 cm. Error bars represent one standard deviation about the measured mean.

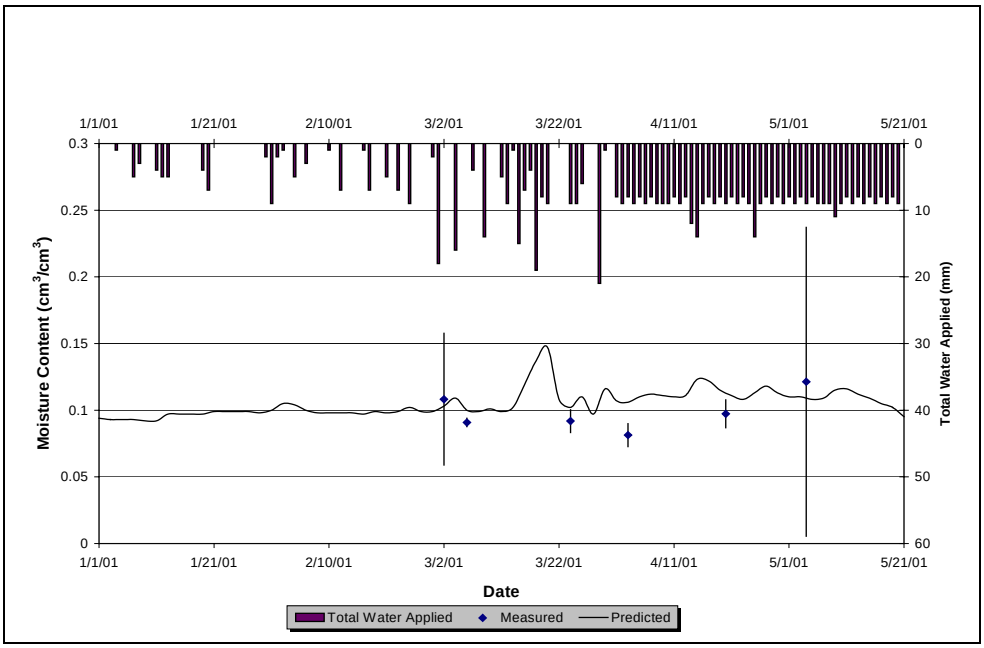


Figure 3-2. DSSAT spring 2001 potato crop soil moisture content results for the north half at 15-30 cm. Error bars represent one standard deviation about the measured mean.

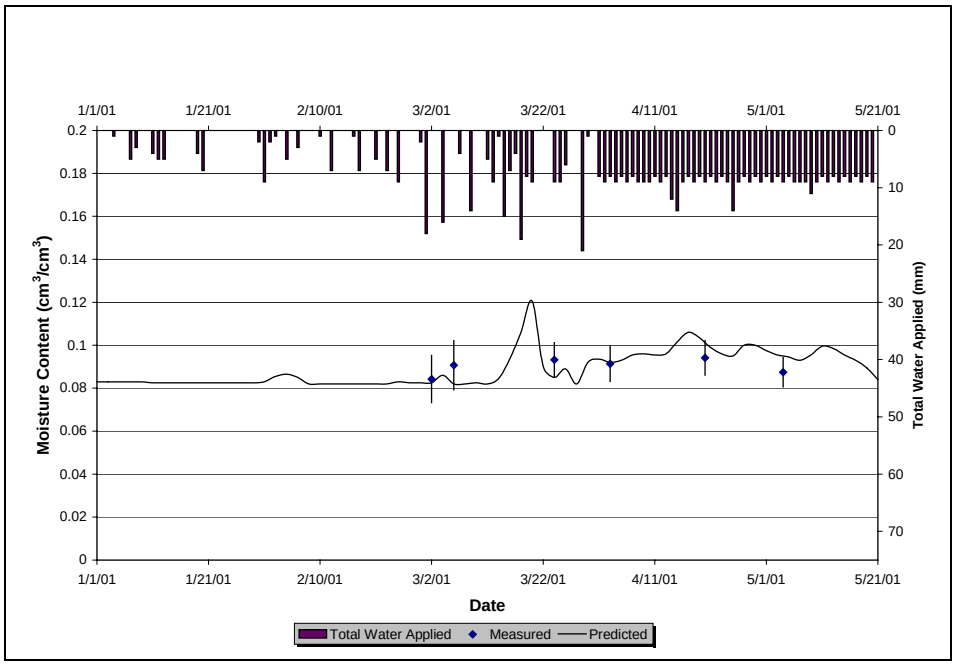


Figure 3-3. DSSAT spring 2001 potato crop soil moisture content results for the north half at 30-60 cm. Error bars represent one standard deviation about the measured mean.

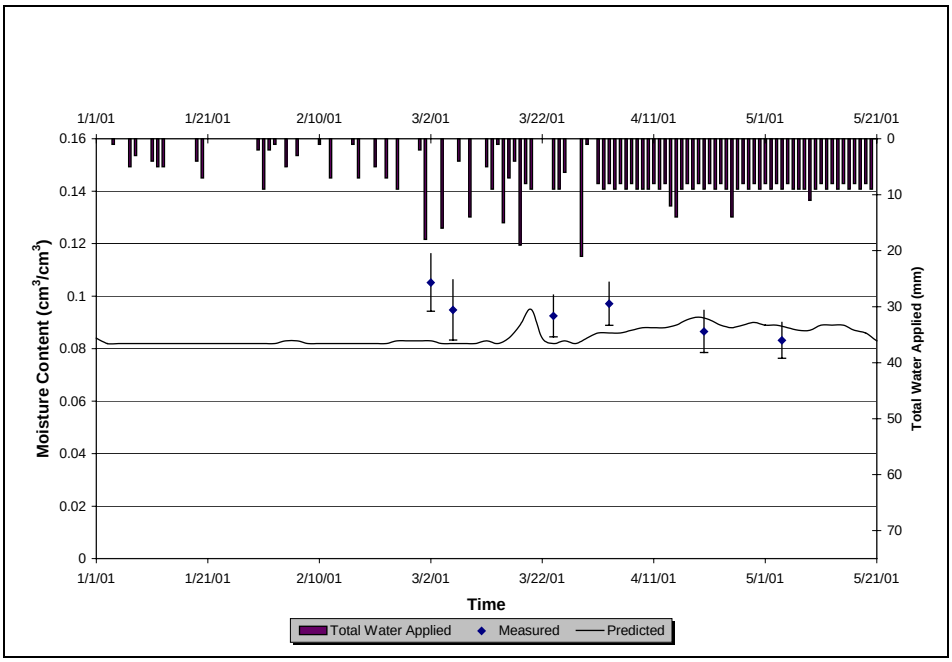


Figure 3-4. DSSAT spring 2001 potato crop soil moisture content results for the north half at 60-90 cm. Error bars represent one standard deviation about the measured mean.

As expected, the maximum simulated moisture content also occurred on March 18, 2001 for the lower depths of 15-30, 30-60, and 60-90. After March 18, 2001, the predicted moisture contents for the lower layers remained relatively stable, but were slightly higher than the moisture contents predicted earlier in the season by 1-2%. The elevated moisture contents were caused by the daily 0.8 cm irrigation applications that began around April 1, 2001.

Figure 3-5 shows the results for the water balance for the entire simulation period. No runoff was predicted during the entire simulation period. As a result, the total 71.5 cm of water received by the field was infiltrated into the soil surface. Fifty-four percent of the 71.5 cm water received by the north half of the field was lost by soil evaporation. Only 6.1 cm of water was taken up by the plant from the soil, while 21.8 cm was lost to deep drainage.

Like the moisture content results, the water balance results for the corrected simulation compared relatively well to Albert's (2002) simulation. Approximately the same amount of drainage was predicted in both simulations. However, more transpiration and evaporation occurred during Albert's simulation. In Albert's simulation, the transpiration and evaporation was predicted to be 11 cm and 48 cm, respectively. The differences in the water balances were mostly likely caused by differences in crop growth for each computer simulation.

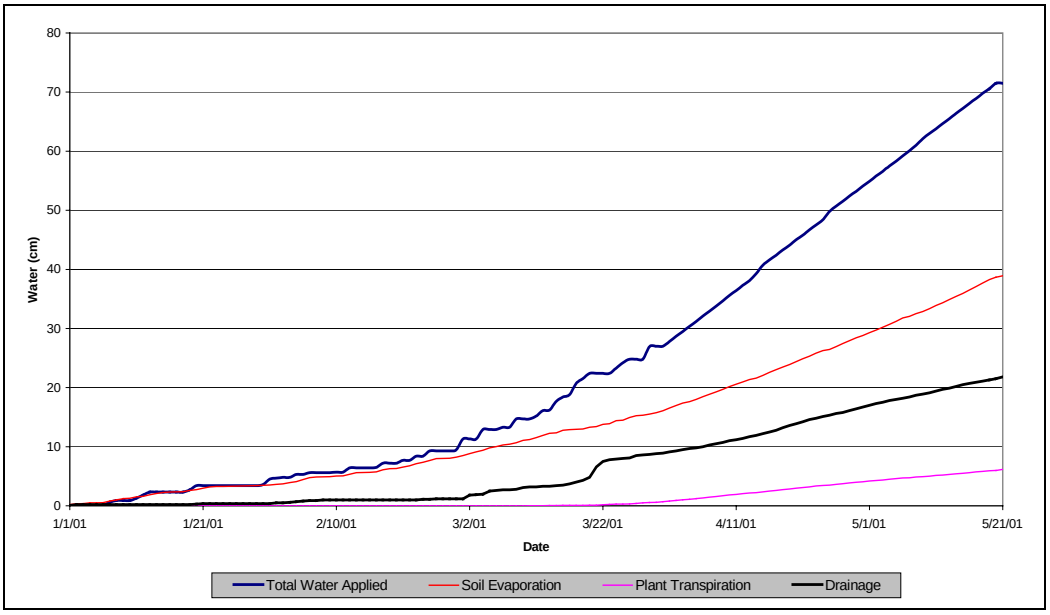


Figure 3-5. Cumulative water balance for the north half of the field for the spring 2001 potato crop.

Similar to the moisture content predictions, the predicted nitrate-nitrogen concentrations compared relatively well to the measured values. Figures 3-6 through 3-9 show that DSSAT generally predicted the temporal and spatial changes in nitrate concentration within at least one standard deviation of the measured results. Also, the model responded appropriately to fertilizer applications and changes in moisture content for the entire soil profile, which is more apparent in the top 15 cm. The large changes

were more evident in the top 15 cm because this zone in the soil profile was where the nitrogen fertilizer was applied and displayed the largest variations in moisture content. For example, the nitrate-nitrogen concentration prediction for the top 15 cm increased to 2,500 mg/L on March 8, 2001, which was caused by the 112 kg/ha of nitrogen fertilizer applied on March 5, 2001. On January 29, 2001, the nitrate-nitrogen concentration increased to 1,037 mg/L due to nine consecutive days with no water applied.

Even though the model did predict most of the nitrate concentrations within on standard deviation, there were noticeable under predictions for the nitrate-nitrogen concentrations below the top 15 cm. For example, the March 2, 2001 soil samples had measured nitrate concentrations values of 603, 293, and 131 mg/L for the 15-30, 30-60, and 60-90 cm sampling depths, respectively. These measured values are significantly higher than the predicted values of 229 mg/L at 15-30 cm, 163 mg/L at 30-60 cm, and 90 mg/L at 60-90 cm. These results indicate that modeled nitrate may be leaching out of the soil profile too quickly, which could reduce the amount of applied nitrogen recovered by the potato crop.

When the corrected simulation was compared to Albert's (2002) simulation results with the doubled fertilizer application rates, there were significant differences between the predicted values. For example, on March 8, 2001 the nitrate-nitrogen concentration was predicted to be 10,080 mg/L in the top 15 cm, which is approximately four times greater than the corrected prediction. On January 29, 2001, the nitrate-nitrogen concentration in the top 15 cm was approximately two and a half times greater than the corrected model prediction of 2,500 mg/L. Similar trends are observed through the

duration of the computer simulation. Albert's (2002) results were usually two to four times larger than the corrected simulation predictions.

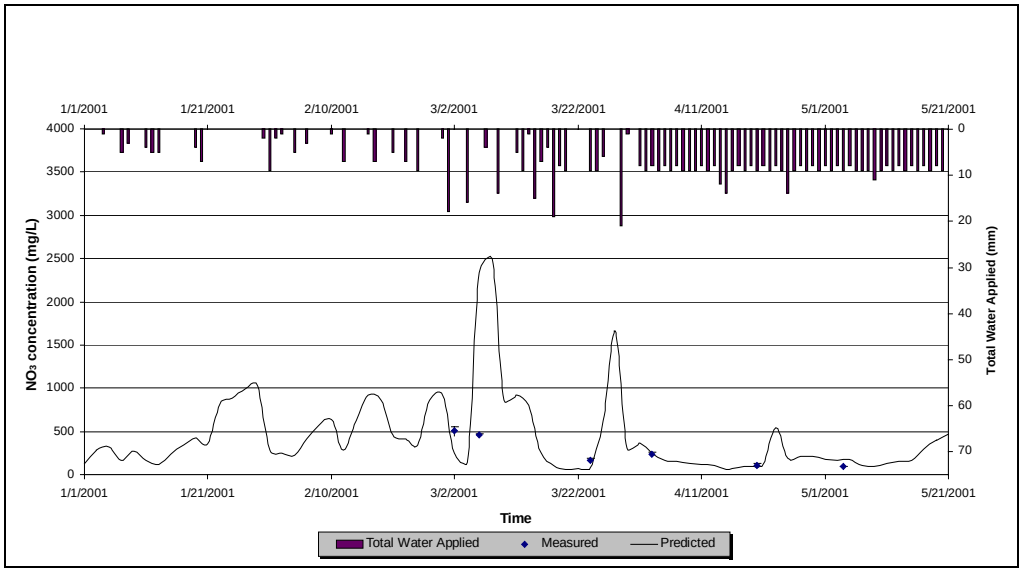


Figure 3-6. Spring 2001 potato crop nitrate-nitrogen concentration results for the north half of the field at 0-15 cm. Error bars for the measured values represent one standard deviation about the measured mean.

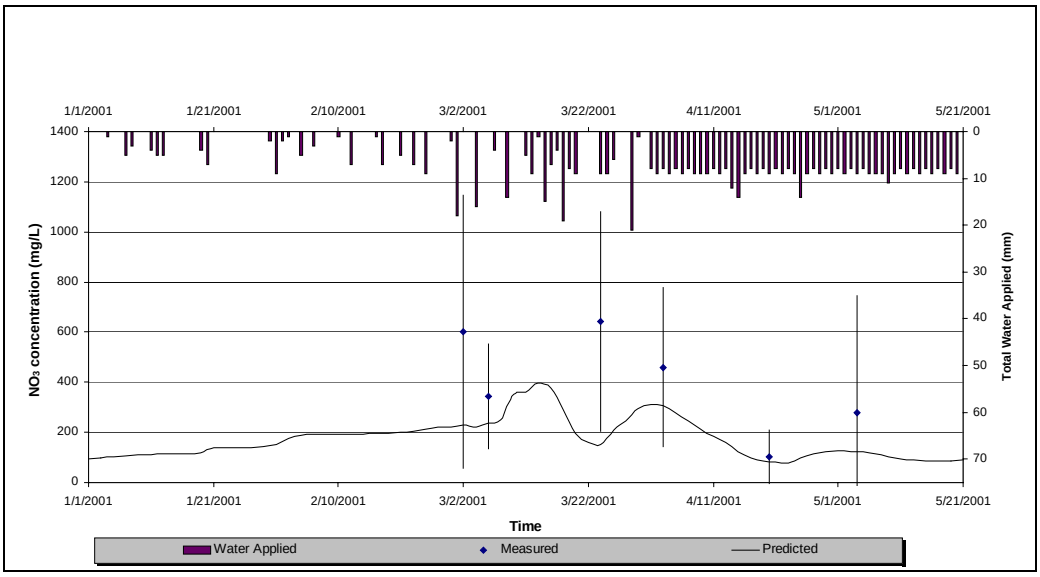


Figure 3-7. Spring 2001 potato crop nitrate-nitrogen concentration results for the north half of the field at 15-30 cm. Error bars for the measured values represent one standard deviation about the measured mean.

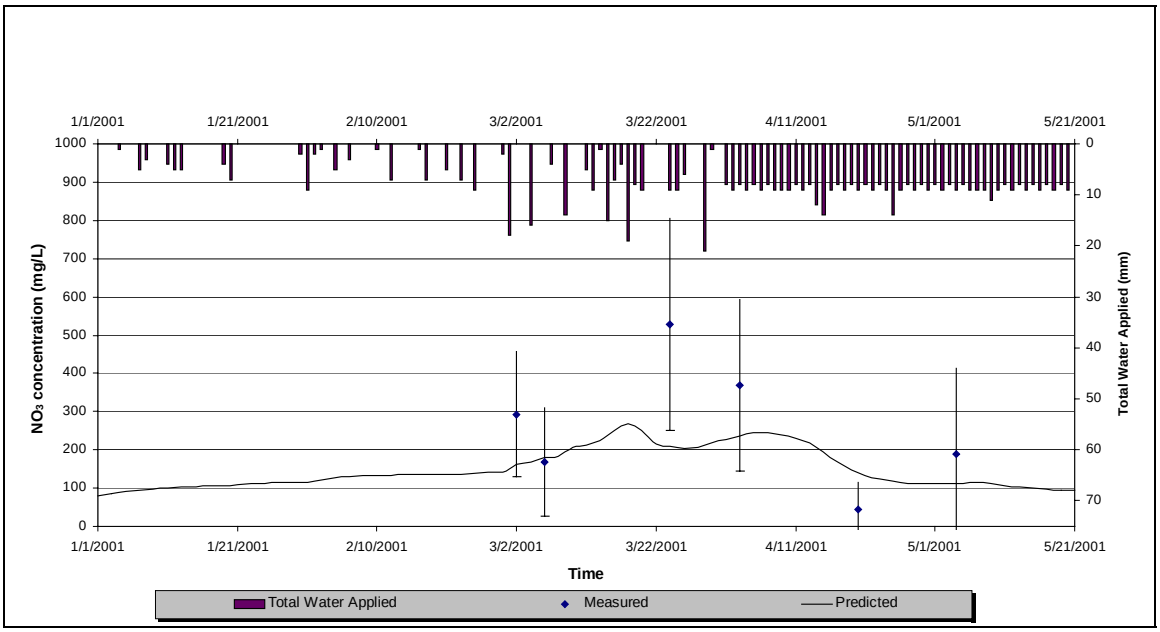


Figure 3-8. Spring 2001 potato crop nitrate-nitrogen concentration results for the north half of the field at 30-60 cm. Error bars for the measured values represent one standard deviation about the measured mean.

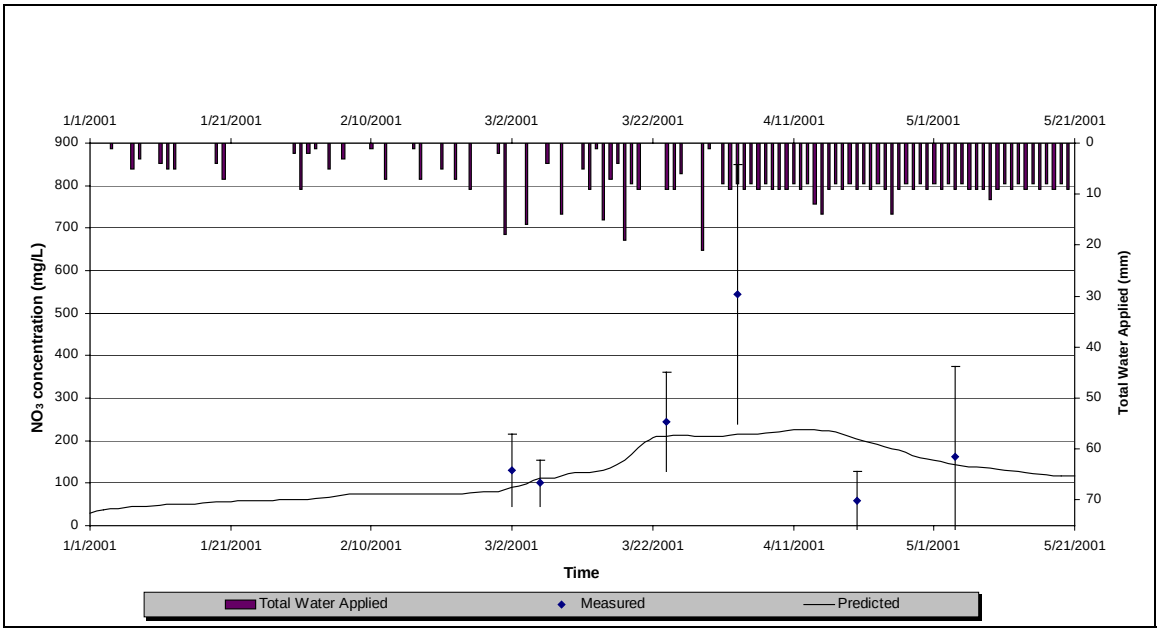


Figure 3-9. Spring 2001 potato crop nitrate-nitrogen concentration results for the north half of the field at 60-90 cm. Error bars for the measured values represent one standard deviation about the measured mean.

Noticeable differences were also observed between the predicted crop growth results for Albert's (2002) simulation and the corrected simulation. In Albert's results,

the model tended to agree very well with the measured biomass values, especially dry tuber yield. For example, the predicted dry tuber yield was approximately 6,900 kg/ha, which is relatively close to the measured value of 6,840 kg/ha. Also, the results appeared to accurately represent the generally trend in leaf and stem growth relatively well, but were usually greater than the average measured values. The ageement between modeled and measured values was most likely due to the doubled fertilizer application rates, which provided more nitrogen for plant uptake during the simulation.

When the corrected model's plant growth predictions were examined, it was noticed that there were significant inaccuracies in the model simulations. The predictions compared relatively well to the analysis results from the four biomass sample sets collected by Albert (2002) for the dry leaf (Figure 3-10), dry stem (Figure 3-11), and dry tuber (Figure 3-12) weights. The first indication that DSSAT was inaccurate was when the final dry tuber yield predictions were compared to the actual measured yield. The measured dry tuber yield was determined to be 6,840 kg/ha while the predicted yield was 3,735 kg/ha. The 45% underprediction in dry tuber yield was substantial and the cause for the underprediction was not initially apparent.

According to Albert's (2002) analysis results, the model predictions were accurate until final harvest. However, after evaluating the biomass collection method used by Albert (2002), it was determined that the technique used to collect the biomass samples was biased. The samples were taken on a per plant basis and the mass per area was then determined from the planting density. Early in the season the method would be somewhat correct, but it is virtually impossible to distinguish between individual plants once the vegetation is well developed later in the growing season. Thus, the biomass

analysis results for the four sets of biomass samples contained a large degree of inaccuracy and the weight per plant was probably underpredicted, which was why the early model predictions were similar to the early measured values. However, it still was not clear why the model under predicted the final tuber yield. The genetic coefficients used for the Red LaSoda potato crop were reasonable and the moisture content predictions indicated that there was an ample amount of water available to the plant. After examining the nitrogen balance (Figure 3-13), it was clear that the model notably under predicted the amount of nitrogen that was taken up by the plants because the nitrate was leaching out of the root zone too quickly.

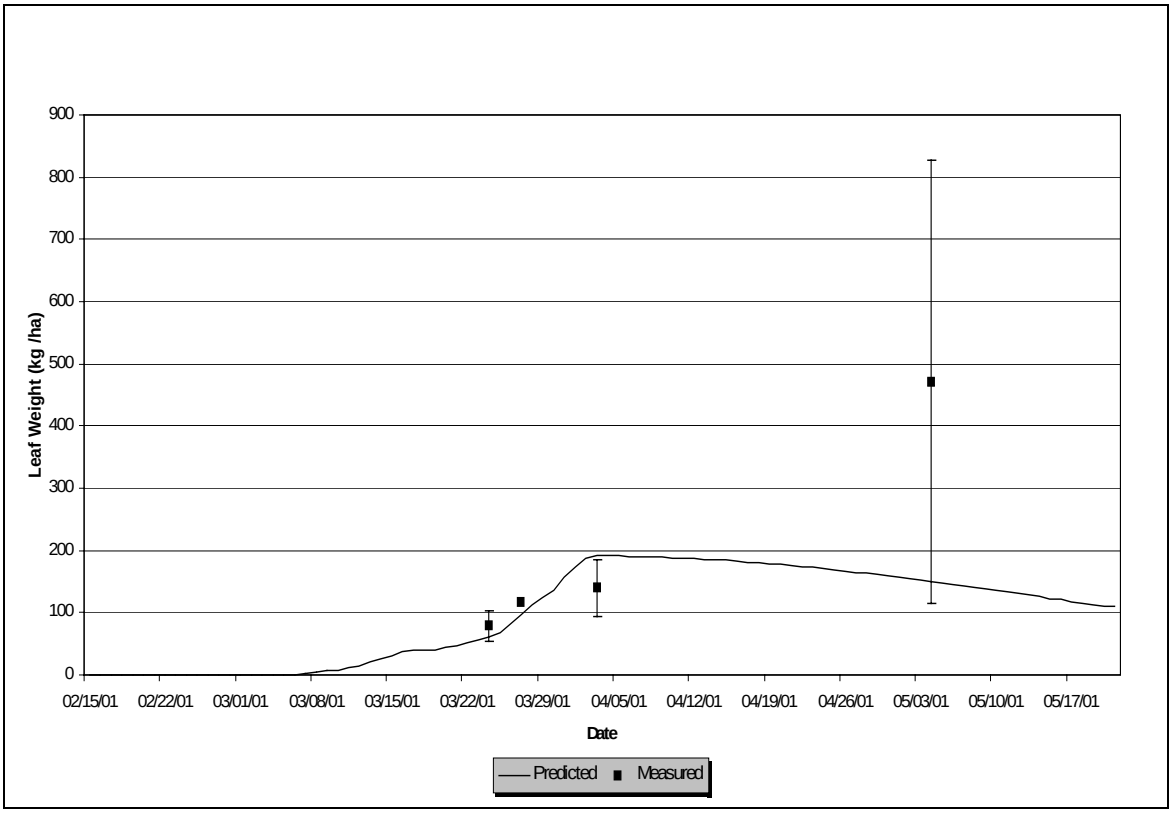


Figure 3-10. DSSAT dry leaf weight predictions for the spring 2001 potato crop on the north half of the field. Error bars represent one standard deviation about the measured mean.

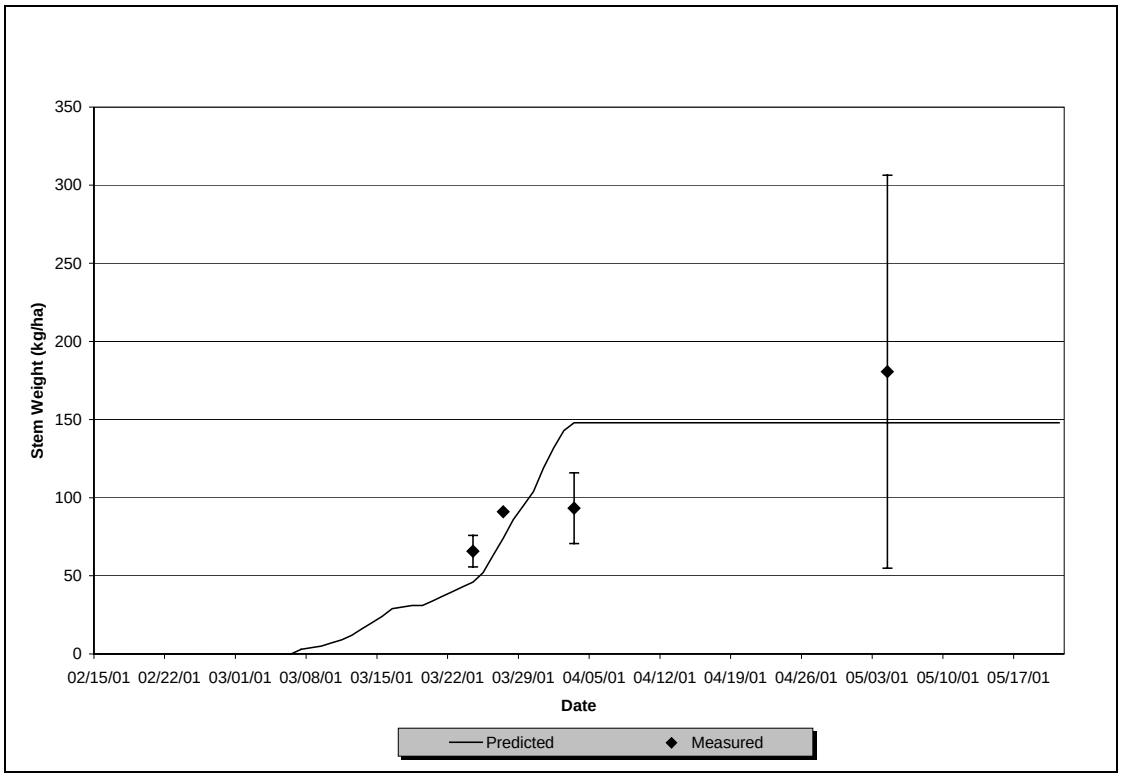


Figure 3-11. DSSAT dry stem weight predictions for the spring 2001 potato crop on the north half of the field. Error bars represent one standard deviation about the measured mean.

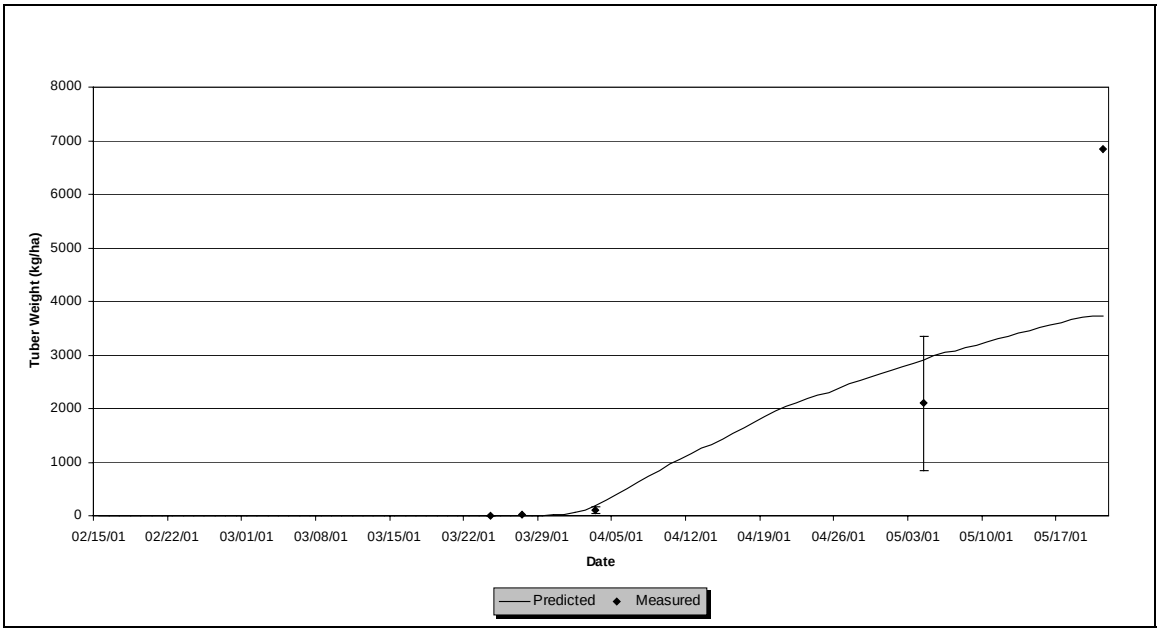


Figure 3-12. DSSAT dry tuber weight predictions for the spring 2001 potato crop on the north half of the field. Error bars represent one standard deviation about the measured mean.

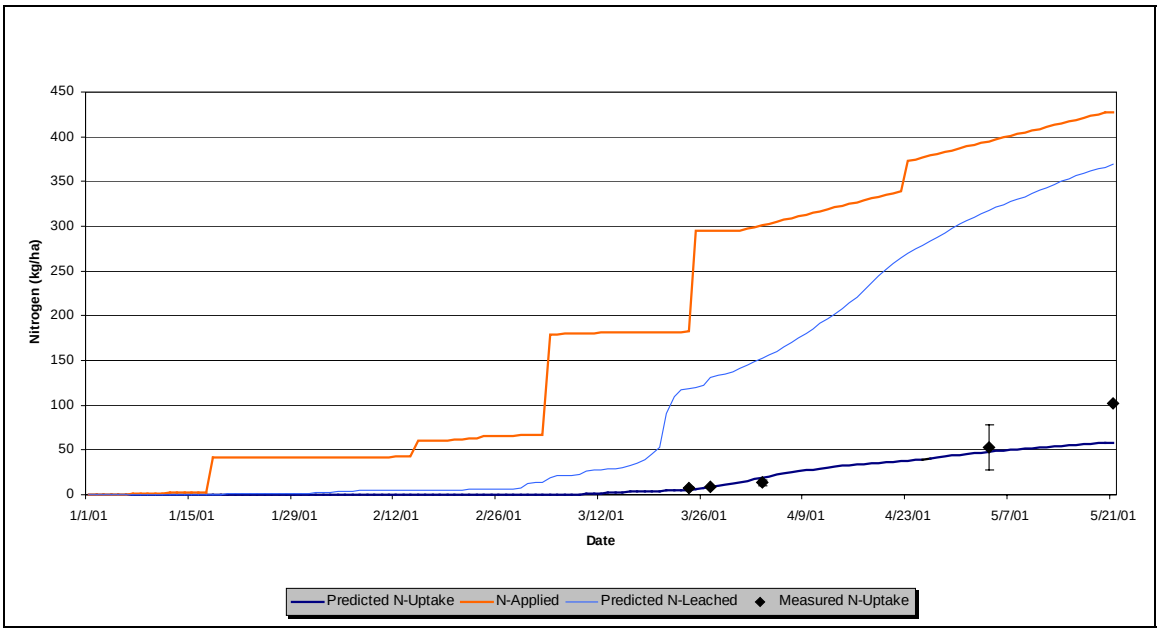


Figure 3-13. Cumulative nitrogen balance for the spring 2001 potato crop on the north half of the field. Error bars represent one standard deviation about the mean.

DSSAT predicted that only 58.4 kg/ha of the total nitrogen applied was utilized by the plant, which was 43.3 kg/ha below what was measured. This value is also significantly lower than that predicted in Albert's simulation. Since Albert doubled the fertilizer application, the plants took up more nitrogen over the computer simulation. The total nitrogen taken up was predicted to be approximately 101 kg/ha, which is much larger than the corrected model prediction. This also shows that Albert's dry tuber yield prediction was accurate because the increased nitrogen uptake resulted in more plant growth, and the accuracy of Albert's simulation was purely coincidental.

Several combinations of the crop's genetic coefficients were then used in various simulations, but none increased plant nitrogen uptake or yield. From these findings and the observations of low soil nitrate concentrations in the model predictions, it was determined that the nitrate was leaching out of the soil to quickly because the water balance was incorrect.

As previously discussed, the soils located at the project site are sandy and tend to drain relatively quickly. All the samples taken in the field were obtained at times when the soils had drained to field capacity. So, while the steady-state drained water content was correct, the volume and rate of water moving through the profile seemed to be incorrect. This underscores the difficulty in calibrating the hydrology component in the model. However, the soil parameters were determined from lab experiments and were reasonable considering the characteristics of the soils located on the project site. After these findings, it was determined that the DSSAT hydrology component and plant growth component needed to be modified in order to account for the bed slope and canopy effects on infiltration; the fertilizer placement effects; and the bed width and depth to hard pan effects on root depth, root density, and nitrogen uptake.

CHAPTER 4
DSSAT MODIFICATIONS

After the initial DSSAT simulations for the spring 2001 potato crop, it was clear that DSSAT required modifications in order to properly simulated the potato crop system. The model underpredicted crop yield and overestimated the nitrate leaching. A possible source of the modeling error is that DSSAT assumes that water and nitrogen are uniformly distributed in each soil layer and that the field surface is flat. In actuality, the potato plants are planted in beds (Figure 4-1) that are maintained throughout the growing season. The beds, along with a underlying plow pan, reduced the volume of soil available to plant roots for water and nitrate-nitrogen uptake by approximately half (Figure 4-1).



Figure 4-1. Illustrations of the potato plant beds (01/28/2003) and root distribution (04/12/2002).

To investigate these issues and provide motivation and justification to modify DSSAT, the HYDRUS2D/MESHGEN vadose zone model was implemented. HYDRUS is a product of the International Ground Water Modeling Center and was developed at the

U.S. Salinity Laboratory Riverside, California. HYDRUS was selected due to its ability to accurately predict two-dimensional soil-water and solute transport. The primary purpose of using HYDRUS was to give a general idea of how the nitrate-nitrogen was being transported through the soil. For examples of the HYDRUS input files, refer to Appendix D.

HYDRUS Model Description

HYDRUS is a Microsoft Windows based modeling environment used for the analysis of water and solute flow in a variable saturated porous media. HYDRUS includes the SWMS_2D two-dimensional finite element model for simulating water and solute transport and the MESHGEN-2D mesh generator to create unstructured finite element grids. The model has a graphical user interface that is used for creating input files, structured mesh generation, and a graphical presentation of the results.

The input files required by HYDRUS vary depending on the simulation options selected by the user. The model has the ability to predict solute and water transport for both rectangular and irregularly shape boundaries. The model can simulate a maximum of six solutes during a simulation, whether they are independent of one another or if they are part of a chain species. Solute boundary conditions that are specified by the user include Dirichlet (boundary concentration), Cauchy (prescribed flux concentration), Neumann, and volatile types (e.g. volatilization of ammonia). Water transport boundary conditions are comprised of three system independent and three system dependent types. The three system independent boundary conditions include Dirichlet (specified pressure), Neumann (specified flux), and specified gradient types (free/deep drainage). The system dependent boundary conditions consist of an atmospheric type, seepage face type, and tile drain type. Each water transport boundary condition can be used in combination with

any other water transport boundary condition, but two different boundary conditions types cannot be applied to the same boundary segment. The same is true for the solute transport boundary conditions. Also, the variable flux (Neumann type) and atmospheric boundary conditions are assigned one value per time step and are not allowed to vary spatially.

Governing Flow Equation

The model considers two-dimensional isothermal Darcian flow of water in variably saturated rigid porous medium and assumes the air phase flow is negligible. The governing flow equation for these conditions is given by a modified Richard's equation (Eq. 4-1).

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x_i}\left[K\left(K_{ij}^{A} \frac{\partial h}{\partial x_j} + K_{iz}^{A} \right)\right] - S \qquad (4\text{-}1)$$

where θ is the volumetric water content [L^3L^{-3}], h is the pressure head [L], S is a sink term [T^{-1}], x_i *(i = 1, 2)* are the spatial coordinates [L], t is time [T], K_{ij}^{A} are components of the dimensionless anisotropy tensor K^A, and K is the following unsaturated hydraulic conductivity function [L T^{-1}]:

$$K(h, x, z) = K_s(x, z) K_r(h, x, z) \qquad (4\text{-}2)$$

where K_r is the relative hydraulic conductivity and K_s is the saturated hydraulic conductivity (L T^{-1}). The anisotropy tensor is used to account for anisotropic conditions. The matrix becomes an identity matrix for an isotropic medium. If (4-1) is applied to planar flow in a vertical cross-section, $x_1 = x$ is the horizontal coordinate and $x_2 = z$ is the vertical coordinate (positive upward).

Root Water Uptake

The volume of water that is removed per unit time from a unit volume of soil is accounted for using the sink term (*S*) in (4-1). The root water uptake routines in HYDRUS are relatively simplified compared to the methods used by DSSAT. Unlike DSSAT, HYDRUS requires that the user specify the root distribution and it is considered to be static throughout the simulation. There are two main root water uptake functions used in HYDRUS that includes the Feddes and van Genuchten models. The root water uptake function used in the potato crop simulations was the Feddes model. The Feddes model is given by the following equation.

$$S(h) = a(h)S_p \tag{4-3}$$

where *a(h)* is a dimensionless water stress response function and S_p is the potential water uptake rate [T^{-1}]. The van Genuchten equation is similar to the Feddes equation, except the water stress function was expanded to account for osmotic stress.

The potential root water uptake for a non-uniform root distribution of an arbitrary shape is defined as

$$S_p = b(x,z)L_t T_p \tag{4-4}$$

where L_t [L] is the width of the soil surface associated with plant transpiration, T_p [L T^{-1}] is the potential plant transpiration specified by the user, and b(x,z) is the normalized water uptake distribution [L^{-2}]. The actual root water uptake is then determined by substituting (4-4) into (4-3):

$$S(h) = a(h)L_t T_p \tag{4-5}$$

The Unsaturated Soil Hydraulic Properties

Unsaturated soil hydraulic properties, $\theta(h)$ and $K(h)$, are generally highly nonlinear functions of the soil-water matric potential, which is dependent on soil texture (e.g. clay, sand, silt). HYDRUS utilizes three different analytical models to describe the hydraulic properties of soils. The models contained in HYDRUS include the Brooks and Corey (1964), the van Genuchten (1980), and Vogel and Cislervoa (1998) models. The soil-moisture characteristics curve for the soils located at the project site were fitted to the Brooks and Corey (1964) soil-water retention and hydraulic conductivity functions, which are given by

$$S_e = \begin{cases} |\alpha h|^{-n} & h < -1/\alpha \\ 1 & h \geq -1/\alpha \end{cases} \tag{4-6}$$

$$K = K_s S_e^{2/n+l+2} \tag{4-7}$$

respectively, where S_e is the effective water content defined as follows

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} \tag{4-8}$$

where θ_r and θ_s are the residual and saturated moisture contents, respectively; K_s is the saturated hydraulic conductivity, h is the matric potential [L], α is the inverse of the air-entry pressure, n is the pore-connectivity index, an l is the pore-connectively parameter (assumed to be 2.0). HYDRUS considers α, l, and n to be empirical coefficients that affect the shape of the hydraulic functions.

To account for the spatial variability of the unsaturated soil hydraulic properties in the flow domain, HYDRUS uses a scaling procedure that simplifies the description of the variability. It is assumed that the hydraulic variability in a specified domain can be

approximated using linear scaling transformations (refer to Simunek et. al, 1999 pp. 18-19) that relate the individual soil hydraulic characteristics to reference characteristics. There are three independent scaling factors that are used by HYDRUS, which define a linear model of the actual spatial variability in the soil hydraulic properties.

Governing Transport Equation

The HYDRUS model assumes solutes can exist as liquid, solid, and gaseous phases and that the decay and production processes can differ in each phase. For example, the liquid and solid phases can be described as nonlinear nonequilibrium equations, while the interactions between the liquid and gaseous phases can be assumed to be linear and instantaneous. The solutes are transported by advection and dispersion in the liquid phase and by diffusion in the gas phase. The partial differential equations governing two-dimensional nonequilibrium solute transport involved in a sequential first-order decay chain during transient water flow in variably saturated rigid porous medium are given by

$$\frac{\partial \theta c_1}{\partial t} + \frac{\partial \rho s_1}{\partial t} + \frac{\partial a_v g_1}{\partial t} = \frac{\partial}{\partial x}\left(\theta D_{ij,1}^{w} \frac{\partial c_1}{\partial x_j}\right) + \frac{\partial}{\partial x}\left(a_v D_{ij,1}^{g} \frac{\partial g_1}{\partial x_j}\right) - \frac{\partial q_i c_1}{\partial x_i} - Sc_{r,1}$$
$$- \left(\mu_{w,1} + \mu_{w,1}^{/}\right)\theta c_1 - \left(\mu_{s,1} + \mu_{s,1}^{/}\right)\rho s_1 - \left(\mu_{g,1} + \mu_{g,1}^{/}\right)a_v g_1 + \gamma_{w,1}\theta + \gamma_{s,1}\rho + \gamma_{g,1}a_v \qquad (4\text{-}9)$$

$$\frac{\partial \theta c_k}{\partial t} + \frac{\partial \rho s_k}{\partial t} + \frac{\partial a_v g_k}{\partial t} = \frac{\partial}{\partial x_i}\left(\theta D_{ij,k}^{w} \frac{\partial c_k}{\partial x_j}\right) + \frac{\partial}{\partial x_i}\left(a_v D_{ij,k}^{g} \frac{\partial g_k}{\partial x_j}\right) - \frac{\partial q_i c_k}{\partial x_i}$$
$$- \left(\mu_{w,k} + \mu_{w,k}^{/}\right)\theta c_k - \left(\mu_{s,k} + \mu_{s,k}^{/}\right)\rho s_k - \left(\mu_{g,k} + \mu_{g,k}^{/}\right)a_v g_k + \mu_{w,k-1}^{/}\theta c_{k-1} \qquad (4\text{-}10)$$
$$+ \mu_{s,k-1}^{/}\rho s_{k-1} + \mu_{g,k-1}^{/}a_v g_{k-1} + \gamma_{w,k}\theta + \gamma_{g,k}\rho + \gamma_{g,k}a_v - Sc_{r,k} \qquad k\varepsilon(2, n_s)$$

where c, s, and g are solute concentrations in the liquid [M L^{-3}], solid [M M^{-1}], and gaseous [M L^{-3}] phases, respectively; q_i is the i-th component of the volumetric flux density [L T^{-1}]; μ_w, μ_s, and μ_g are first-order rate constants for solutes in the liquid, solid,

and gas phases [T^{-1}], respectively, μ_w', μ_s', and μ_g' first-order rate constants for solutes in the liquid, solid and gas phases [T^{-1}], respectively, for a chain species, γ_w, γ_s, and γ_g are zero-order rate constants for the liquid [$M\ L^{-3}\ T^{-1}$], solid [T^{-1}], and gas [$M\ L^{-3}\ T^{-1}$], respectively; ρ is the soil bulk density [$M\ L^{-3}$], a_v is the air content [$L^3\ L^{-3}$], S is the sink term in the water flow equation (4-1), c_r is the concentration of the sink term [$M\ L^{-3}$], D_{ij}^w is the dispersion coefficient tensor [$L^2\ T^{-1}$] for the liquid phase, and D_{ij}^g is the diffusion coefficient tensor [$L^2\ T^{-1}$] for the gas phase. The subscripts *w*, *s*, and *g* correspond to the liquid, solid, and gas phases, respectively; the subscript *k* represents the *k*th chain number, and n_s is the number of solutes in the chain reaction. The nine zero-order and first-order rate constants in (4-9) and (4-10) can be used to represent a variety of reactions or transformations that include biodegradation, volatilization, and precipitation.

HYDRUS assumes equilibrium interactions between the solution and gas phases of the solute in the soil system. In the graphical user interface, the user can specify nonequilibrium or equilibrium conditions between the solution and solid phases of the solute in the soil system. A generalized nonlinear equation (4-11) is used to describe the adsorption isotherm relating the solid and solution phases of the solute in the soil system.

$$s_k = \frac{k_{s,k} c_k^{\beta_k}}{1+\eta_k c_k^{\beta_k}} \qquad k\varepsilon(1, n_s)$$

$$\frac{\partial s_k}{\partial t} = \frac{k_{s,k}\beta_k c_k^{\beta_k-1}}{\left(1+\eta_k c_k^{\beta_k}\right)^2}\frac{\partial c_k}{\partial t} + \frac{c_k^{\beta_k}}{1+\eta_k c_k^{\beta_k}}\frac{\partial k_{s,k}}{\partial t} - \frac{k_{s,k} c_k^{2\beta_k}}{\left(1+\eta_k c_k^{\beta_k}\right)^2}\frac{\partial \eta_k}{\partial t} + \frac{k_{s,k} c_k^{\beta_k}\ln(c_k)}{\left(1+\eta_k c_k^{\beta_k}\right)^2}\frac{\partial \beta_k}{\partial t} \tag{4-11}$$

where $k_{s,k}$ [$L^3\ M^{-1}$], β_k [-], and η_k [$L^3\ M^{-1}$] are empirical coefficients. Equation (4-11) can be used to represent Langmuir (β_k=1), Freudlich (η_k=0), and linear (β_k=1 and η_k=0) adsorption isotherms. Solute transport without adsorption is represented by $k_{s,k}$=0. The empirical coefficients are assumed to be independent of solute concentration, but are

allowed to change as a function of temperature if the user selects the option. The concentrations of the solution and gas phases are related by the linear equation

$$g_k = k_{g,k} c_k \tag{4-12}$$

where $k_{g,k}$ is an empirical constant [-] that is to $(K_H R_u T^A)^{-1}$. K_H is Henry's Law constant [M T^2 M^{-1} L^{-2}], R_u is the universal gas constant [M L^2 T^{-2} K^{-1} M^{-1}], and T^A is the absolute temperature [K].

HYDRUS Results and DSSAT Modifications

HYDRUS Results

The HYDRUS model was used to simulate nitrate transport for both flat and bedded soil surfaces in order to investigate the influences of model geometry and fertilizer placement on water and nitrate-nitrogen transport. The first simulation was based on the DSSAT geometry, which assumes that the field is flat and that the nitrogen fertilizer is evenly distributed across the entire field. The fertilizer was applied uniformly over the entire soil surface. The second run simulated the two-dimensional bedded surface to demonstrate the effects of the bed shape and fertilizer placement on water and nitrate-nitrogen transport. In the second simulation, the fertilizer application was introduced in the soil profile using two circular 1 cm diameter variable boundaries with specified fluxes to simulate the field practice of banding the nitrogen fertilizer in the beds. Both simulations received identical fertilizer application amounts. To illustrate the differences between the flat and bedded soil surfaces, the nitrate transport of the January 10, 2002 fertilizer application (refer to Table 2-6) on the north half of the field was analyzed. The rainfall and irrigation applied during the HYDRUS simulation was identical to that used in the DSSAT simulations. The transport of the January 10, 2002

fertilizer application was analyzed because there were significant amounts of rainfall received by the crop over this period. Over the duration of the simulation, there were three consecutive rainfall events of 1.1, 0.8, and 4.9 cm that occurred from January 12, 2002 through January 14, 2002, respectively, which contributed to the relatively rapid nitrate-nitrogen leaching. Note that HYDRUS does not determine runoff and any water that does not infiltrate is immediately removed from the soil surface.

The boundary conditions used for the upper and lower boundaries of the soil profile were atmospheric and free drainage, respectively. It is required in HYDRUS that the user specifies the potential evaporation and potential transpiration in the input file for atmospheric boundary conditions. Thus, the potential evaporation and potential transpiration that was calculated by DSSAT was used in the HYDRUS simulation.

Plant roots were distributed evenly in the soil profile to a maximum depth of 30 cm in the HYDRUS simulations in order to account for plant root uptake effects on nitrate-nitrogen concentration and moisture content. The default parameters contained in HYDRUS for potatoes were used to estimate the root water uptake, however the wilting point was reduced from –15, 000 to –6,000 cm due to instabilities in the model at low moisture contents.

Flow was assumed to be symmetrical from row to row, so no flux boundary conditions were used in the center of each furrow. Soil parameters for porosity, wilting point, bulk density, hydraulic conductivity are the same as those used in DSSAT. Figure 4-2 through Figure 4-4 are the soil-moisture characteristic curves (SMCC) for the soils at the project site.

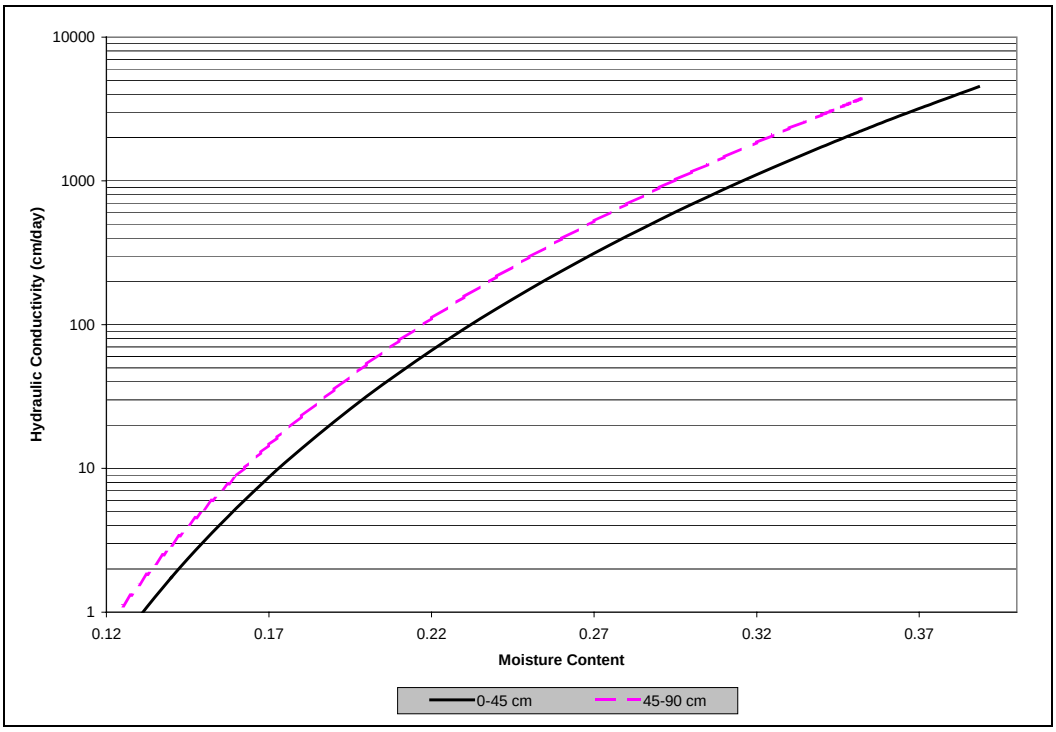


Figure 4-2. SMCC of the hydraulic conductivity versus moisture content using the Brooks and Corey equation.

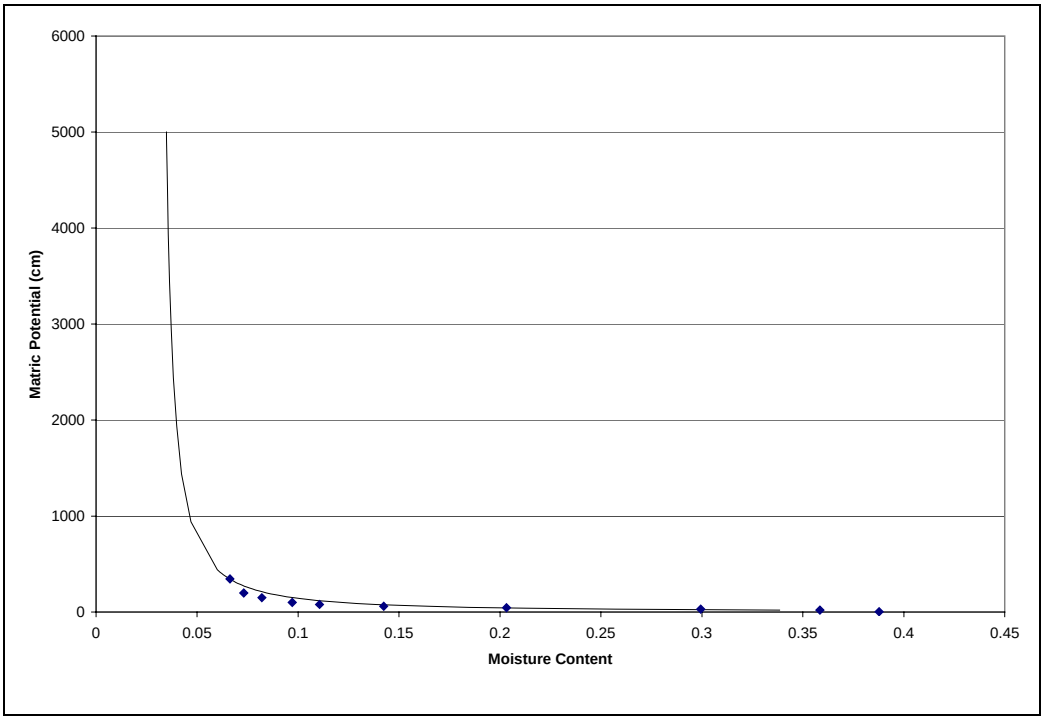


Figure 4-3. SMCC of the soil matric potential versus moisture content for the top 45 cm of the soil profile using the Brooks and Corey equation. Note the points represent measured values.

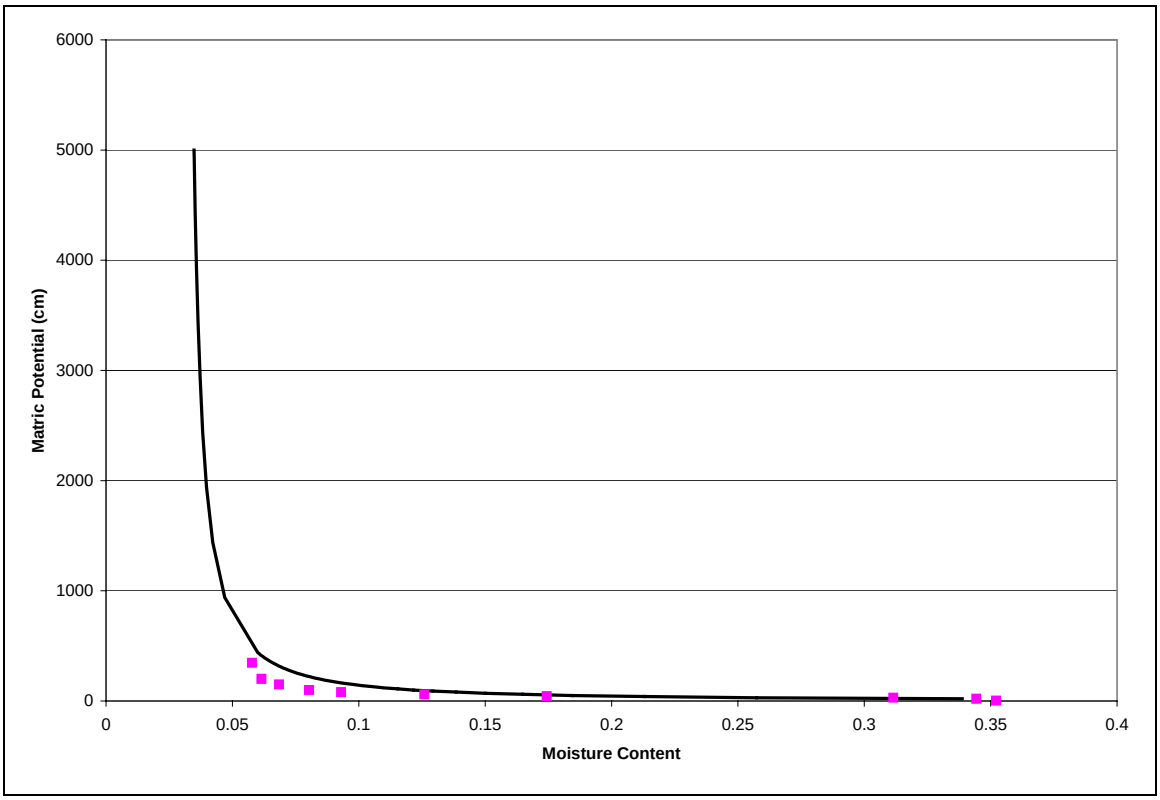


Figure 4-4. SMCC of the soil matric potential versus moisture content for the bottom 45 cm of the soil profile using the Brooks and Corey equation. Note the points represent measured values.

Nitrogen transport and degradation parameters were based on the values used by Albert (2002). The fertilizer was applied to the field as ammonium-nitrate with equal portions of each nitrogen species. The degradation of the compound from ammonium to nitrate was calculated for the entire nitrification chain (refer to Chapter 1) using first-order kinetics. The sorption of ammonium to the soil colloids was modeled as a Langmuir Isotherm. Both sets of parameters for sorption and degradation were based on default values for sandy soil contained in an example problem in the HYDRUS program.

Both sets of results for the flat (Figure 4-5) and bedded (Figure 4-6) indicate that nitrate is transported rapidly out of the soil profile regardless of the upper boundary condition. Figure 4-7 shows that the flat row simulation begins to leach nitrate out of the

bottom of the profile sooner than the bedded row, but both cases leach nitrate at the same rapid rate on day 5 (01/14/02) when 4.9 cm of rainfall occurred. Figures 4-5 and 4-6 show that until day four, most of the nitrate-nitrogen remained in the top 30 cm of the soil profile, which encompasses the root zone. On day 5 of the simulation, 4.9 cm of rainfall infiltrated into the soil profile, which caused the nitrate-nitrogen to move into the bottom 30 cm of the soil profile and out of the root zone for both simulations. It should also be noted, however that HYDRUS does not account for canopy effects, which likely reduce infiltration rates for the potato crop system.

In the flat row simulation, the nitrate-nitrogen transport is virtually one-dimensional, while the bedded simulation displays two-dimensional transport of the nitrate-nitrogen in the soil profile due to the limited lateral dispersion in the soil profile. The bedded simulation results show that there are significant increases in the nitrate concentrations in the bed when the fertilizer is band applied. The maximum nitrate-nitrogen concentrations for the bedded surface were generally two to three times greater than those for the flat surface. Also, the nitrate-nitrogen was concentrated in the bed, particularly the root zone, which provides more nitrogen was available for plant uptake. Thus, the results of the HYDRUS simulations indicate that although nitrate moves at the same rate through the flat and bedded simulations (especially when canopy effects are neglected) the nitrogen remains concentrated in the root zone in the bedded simulations, which is very important for accurately simulating plant growth. This illustrates the importance of incorporating the actual bed geometry in the DSSAT model.

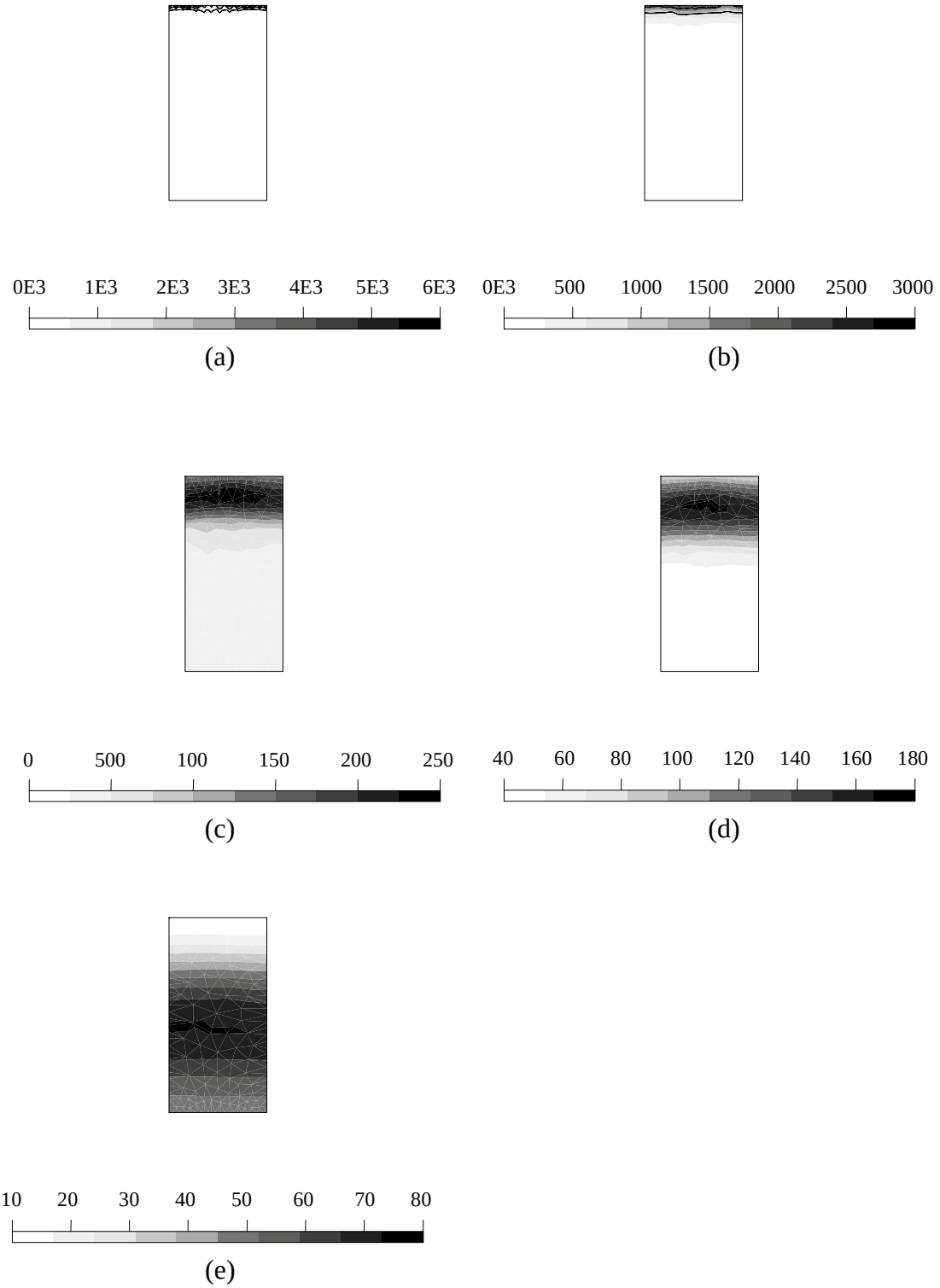


Figure 4-5. Flat upper boundary nitrate concentration spectral map for the top 90 cm on the north half of the field for 01/10/02 through 01/14/02 (a-e). Spectral scale units are in mg/L.

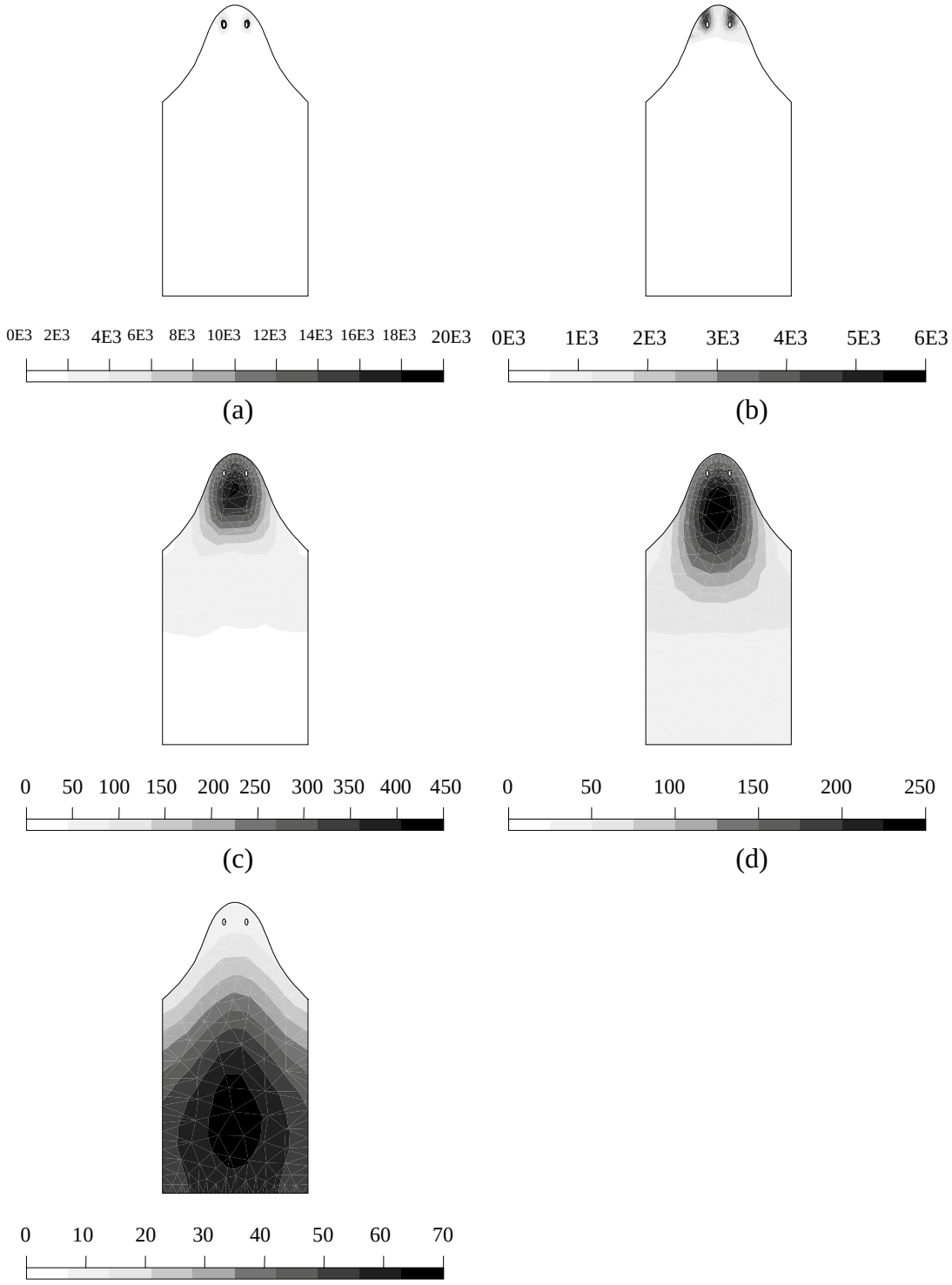


Figure 4-6. Irregularly shaped upper boundary nitrate concentration spectral map for the top 90 cm on the north half of the field for 01/10/02 through 01/14/02 (a-e). Spectral scale units are in mg/L.

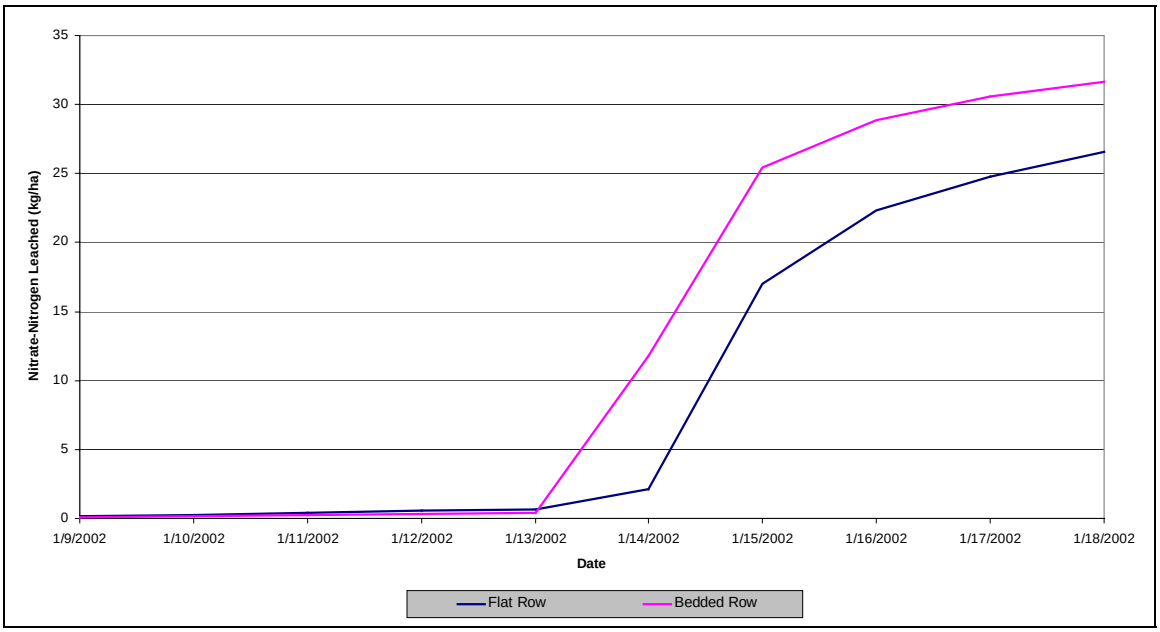


Figure 4-7. Cumulative nitrate-nitrogen leached out of the top 90-cm from the January 10, 2002 fertilizer application.

These results, along with the field observations, show that to improve its predictive ability, the DSSAT model should be modified to reduce the amount of soil volume accessible by the plant roots, concentrate the applied fertilizer into the beds, and reduce the amount of infiltration due to canopy effects. The next step was to review the DSSAT source code and make the proper modifications within the code to account for these conditions.

DSSAT Modifications

Before any modifications were made to the model, one of the DSSAT model developers, James W. Jones, was consulted in order to determine the necessary changes in the DSSAT source code. As previously stated, the goal was to reduce the soil volume accessible to the plant roots and concentrate the fertilizer applications in the beds. Following Dr. Jones's suggestions, it was decided that the best approach for modifying DSSAT was to leave the water balance unchanged, while making all the needed changes

in the crop growth module (GROSUB). Since the water balance was the same, it was necessary to change the row width used in the DSSAT input file to the bed width, which reduced the amount of soil volume available to plants by 50%. In order to account for the fertilizer applications being concentrated in the beds, the fertilizers application rates in the input file were doubled to concentrate the fertilizer applications in the bed rather than distribute the application across the entire field. The source code was then modified, with the aid of Cheryl Porter and Dr. James Jones of the Agricultural and Biological Engineering Department at the University of Florida, in order to maintain the same light interception by the potato plants in spite of using bed width rather than row width as the basis of the simulation.

In the GROSUB module, the potato plants are grown as individual plants and the variable PLTPOP is the number of plants per square meter at emergence. The daily growth is calculated by dividing the overall growth per square meter by the plant population. The leaf area index (LAI) is calculated by multiplying the leaf area per plant (PLA) by PLTPOP. Plant biomass per meter square ground area is determined by multiplying the biomass per plant by PLTPOP to get plant mass per ground area.

In order to account for the plants being grown on a bed area basis rather than on a row basis (Figure 4-8), the PLTPOP must be entered as plants per bed area rather than plants per row area in the input file. This allows the soil computations to remain the same. Since the model simulates plant growth on a row area basis, the actual LAI must then be calculated by multiplying the LAI computed on a bed basis by BWRATIO (bed width/row width). The variable BWRATIO is not included in the input file so it is declared locally in the GROSUB module.

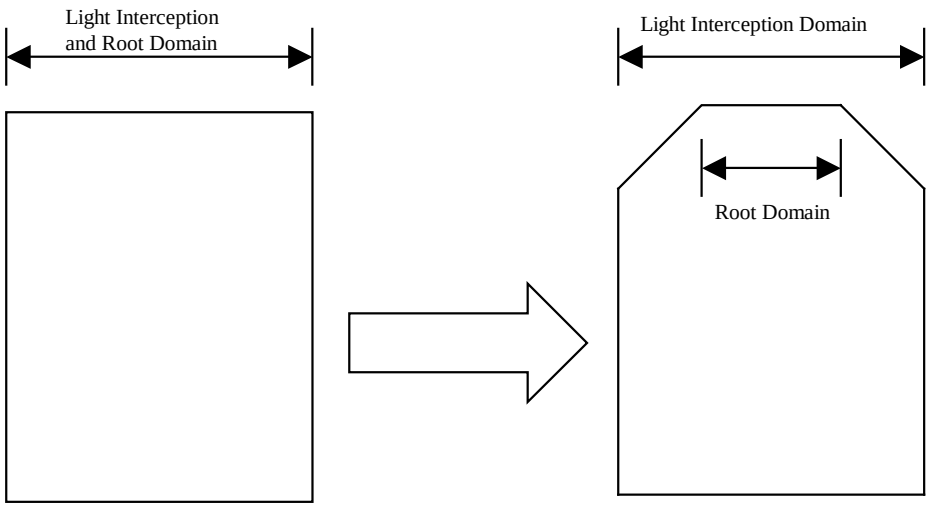


Figure 4-8. A comparison of the light interception and root domain for flat (a) and bedded (b) rows.

The daily growth (PCARB, grams per plant per day) accounts for the plant growth on a row area basis. Since the LAI has already been modified to account for the entire row area, the daily growth is then computed on a row area basis. The daily growth must then be calculated on a bed area basis by dividing PCARB by BWRATIO. The resulting biomass output file is then on a bed area basis and must be multiplied by BWRATIO in order to convert them to a row area basis. The LAI in the output file is on a row area basis and does not need to be adjusted. To review the actual changes in the source code refer to Appendix E.

The dense plant canopy (Figure 4-9) and steep bed slope have a major influence on the amount of effective rainfall infiltrating into the plant bed. However, the SCS curve number method used in the DSSAT model does not adequately predict the reduction in infiltration caused by the bed slope and potato plant canopy. As a result, the infiltration that occurs over the growing season usually results in the model leaching the nitrogen fertilizer out of the soil profile too quickly with significant under predictions in dry tuber

yield (Chapter 3). In an attempt to account for the bed and canopy effects on infiltration, a modified SCS curve number curve number was introduced. Determination of the modified CN was primarily comprised of increasing the CN until the nitrate-nitrogen concentration and moisture content results, shown in the following chapter, agreed relatively well with the measured values. The modified CN is necessary to decrease the infiltration in the bed, which should increase the nitrogen available to the potato plants and significantly increase plant growth. Note that a more physically-based method should be developed for future research for potato crops grown on sandy soils, which can accurately predict the spatial and temporal variability in the effective rainfall and the localized runoff caused by the developing plant canopy and bed slope.



Figure 4-9. Potato plant canopy illustration.

CHAPTER 5
MODIFIED DSSAT RESULTS AND DISCUSSION

After all the appropriate modifications were made in the DSSAT source code and in the input files, the model was then calibrated using both the spring 2001 and 2002 potato crop data. The calibration methods for the modified model were the similar to those discussed in Chapter 3. The genetic coefficients for crop growth used by the model were the same as those used by Albert (2002). Soil parameters including porosity, drained upper limit, wilting point, drainage coefficient (SWCON), and porosity were also identical to those used by Albert, except the CN was increased from 75 to 95 in order to account for plant canopy and bed slope effects on infiltration. Note that the irrigation and rainfall were not modified for the bed simulation because the water was applied uniformly over the soil surface. As previously stated, the spring 2001 potato crop received similar management practices on the north and south halves of the pivot, so only the north half results will be shown in this section. Since the spring 2002 potato crop had more pronounced differences between management practices on the north and halves, simulation results for both the north and south halves of the field are included in this section. Refer to Appendix F for the modified DSSAT input files.

Soil-Water Transport Results

2001 Potato Crop

Figures 5-1 through 5-4 illustrate the insensitivity of the soil moisture prediction from the DSSAT model to changes in the volume of infiltrating water. Even with the increased CN, the model still tended to agree quite well with the measured values and

displayed the same general temporal and spatial changes in the moisture contents as the previous simulation results shown for the 2001 crop discussed in Chapter 3. However, the peaks in the moisture contents were usually 1-3% lower using the modified model relative to the previous simulation, because of the decreased infiltration volume due to the increased CN.

Even though the increased CN had a small effect on the predicted moisture content results, there were noticeable differences between the original DSSAT model and the modified model for the cumulative water balance (Figure 5-5). Unlike the previous simulations (Figure 3-5), localized runoff (to the furrows) occurred because of the increased CN. Thus, the cumulative infiltration in the beds was reduced by 4.88 cm and the drainage decreased from 21.8 to 17.6 cm due to the runoff.

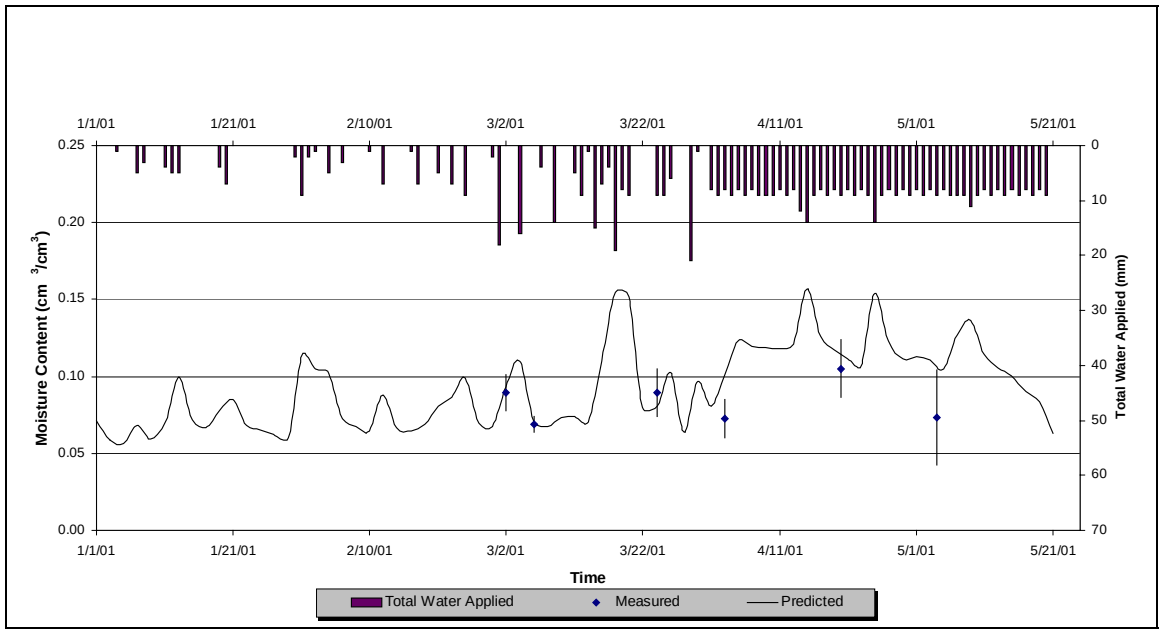


Figure 5-1. Comparisons between the predicted and measured moisture contents at 0-15 cm for the north half of the field 2001 potato crop. Error bars represent one standard deviation about the average measured value.

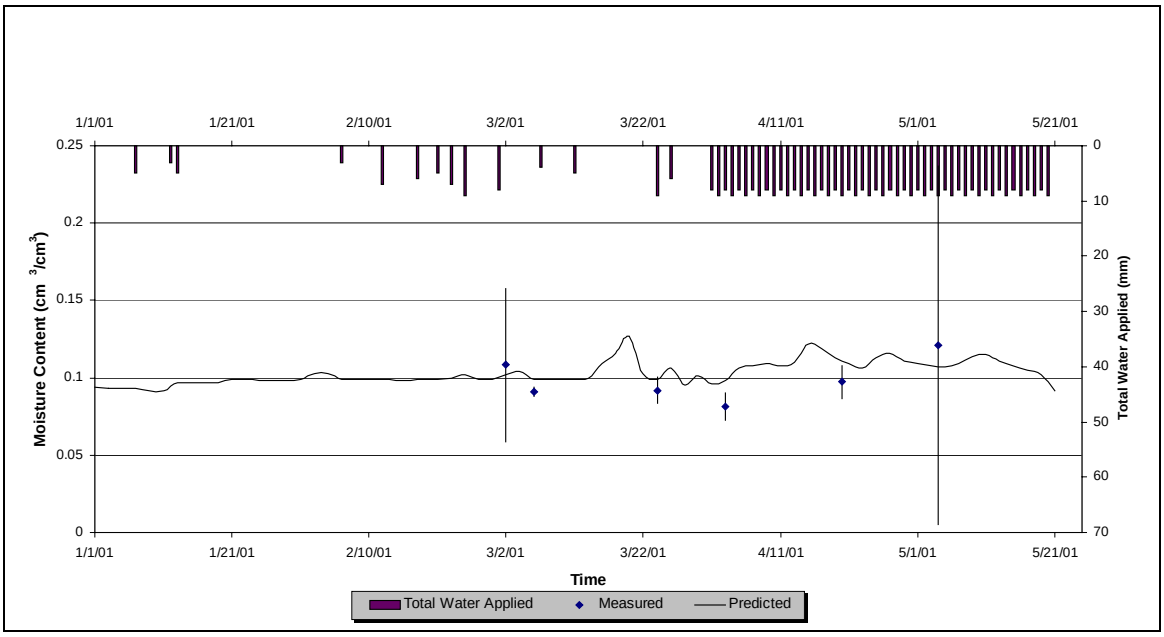


Figure 5-2. Comparisons between the predicted and measured moisture contents at 15-30 cm for the north half of the field 2001 potato crop. Error bars represent one standard deviation about the average measured value.

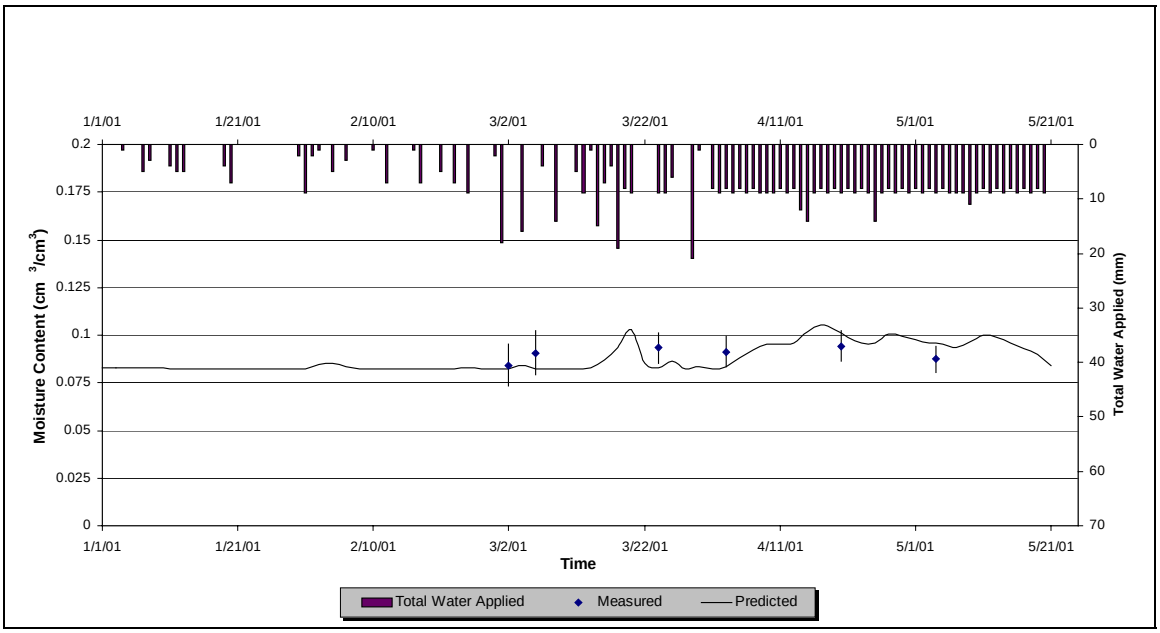


Figure 5-3. Comparisons between the predicted and measured moisture contents at 30-60 cm for the north half of the field 2001 potato crop. Error bars represent one standard deviation about the average measured value.

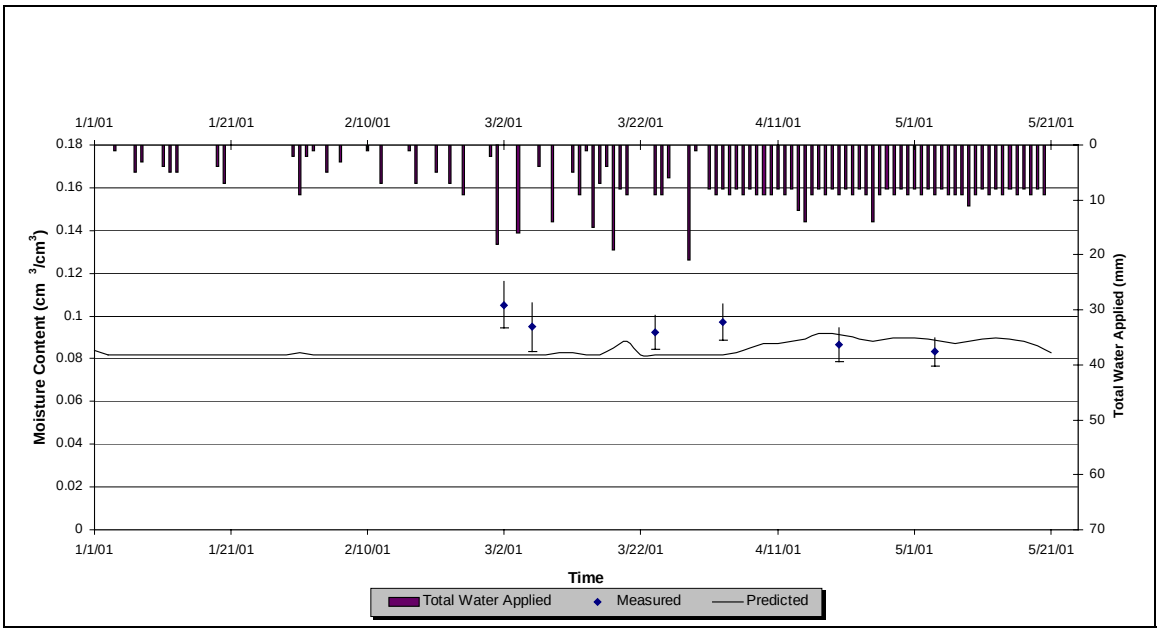


Figure 5-4. Comparisons between the predicted and measured moisture contents at 60-90 cm for the north half of the field 2001 potato crop. Error bars represent one standard deviation about the average measured value.

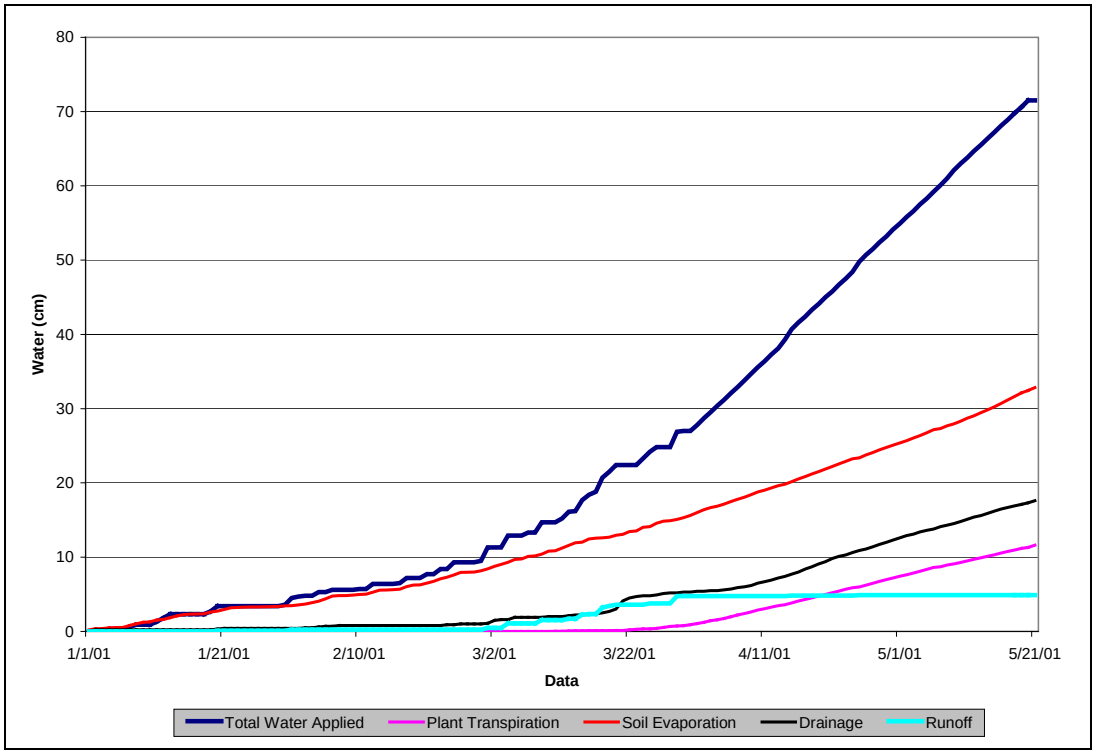


Figure 5-5. Cumulative water balance for the north half of the field for the spring 2001 potato crop.

The cumulative transpiration almost doubled, increasing from 6.2 to 11.6 cm. The increase in transpiration was most likely caused by an increase in the nitrogen recovered by the plants, which directly affects the growth of the plant biomass. The larger amount of nitrogen recovered caused the plant growth to increase, which increased the model predictions for LAI. The larger LAI in turn increased the potential transpiration calculated by the model.

2002 Potato Crop

Similar results for the model's moisture content predictions were observed for the 2002 crop. Figures 5-6 through 5-9 depict the spatial and temporal moisture content predictions for the north and south halves of the field. The model is relatively accurate in predicting the soil moisture contents for most of the depth increments over the 2002 growing season, considering the methods used for the water balance. Similar to the 2001 moisture content results, the predicted moisture contents tend to be stable, ranging from 8-11%, for the majority of the growing season. Also, the soil moisture content model predictions illustrate how the soil tended to remain at or above field capacity. The model appears to behave correctly because there are significant moisture content increases following a rainfall event or irrigation application, primarily in the top 30 cm. The model drains the soil to field capacity within four to five days following the rainfall event or irrigation application.

The water balances for the north (Figure 5-10) and south (Figure 5-11) halves of the field indicate that there are noticeable differences in the drainage that occurred on each half of the field. The south half of the field received 7.1 cm less irrigation than the north half of the field. The reduction in water resulted in 6.1 cm less water draining out

of the 90 cm soil profile. Like the 2001 crop season, the decrease in irrigation reduced the rate nitrate-nitrogen leached out of the soil profile.

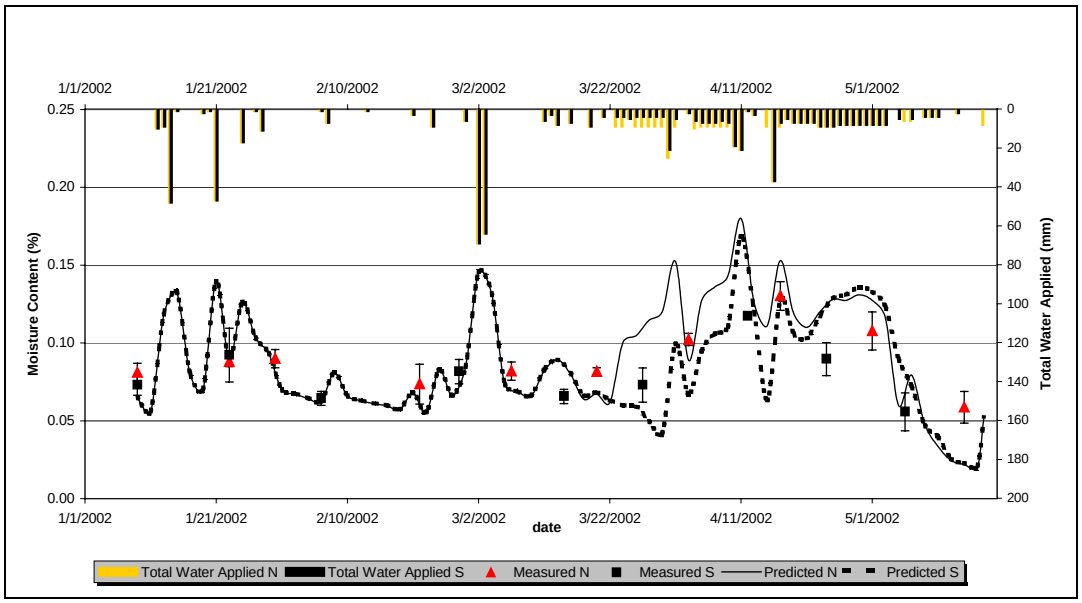


Figure 5-6. Comparisons between the predicted and measured moisture contents at 0-15 cm for the 2002 potato crop. Error bars represent one standard deviation about the average measured value.

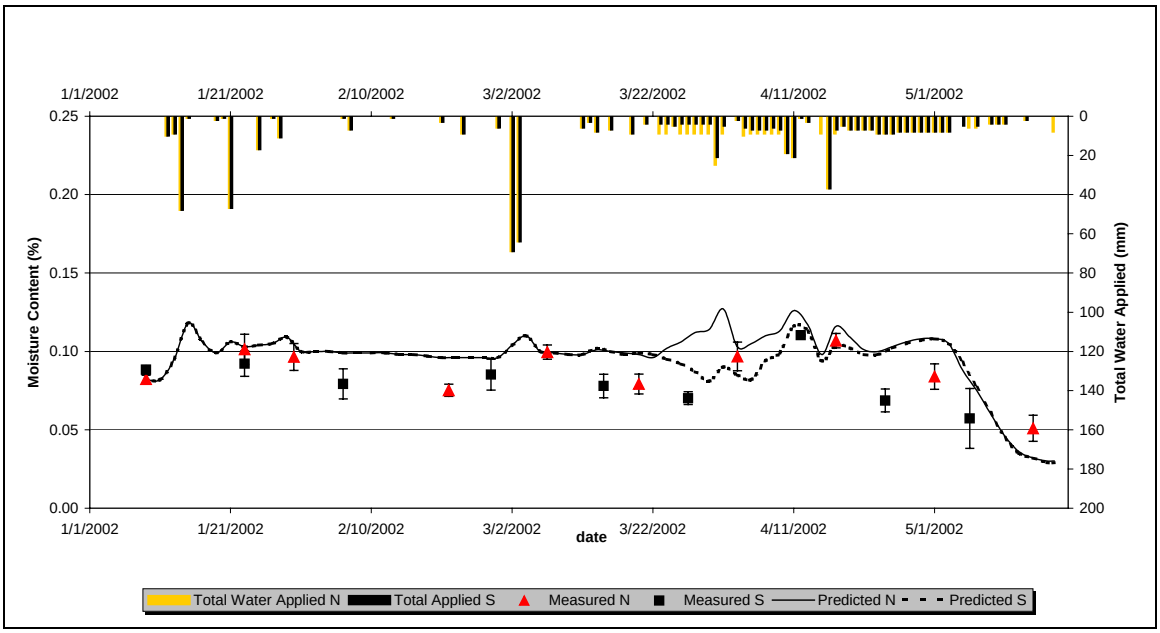


Figure 5-7. Comparisons between the predicted and measured moisture contents at 15-30 cm for the 2002 potato crop. Error bars represent one standard deviation about the average measured value.

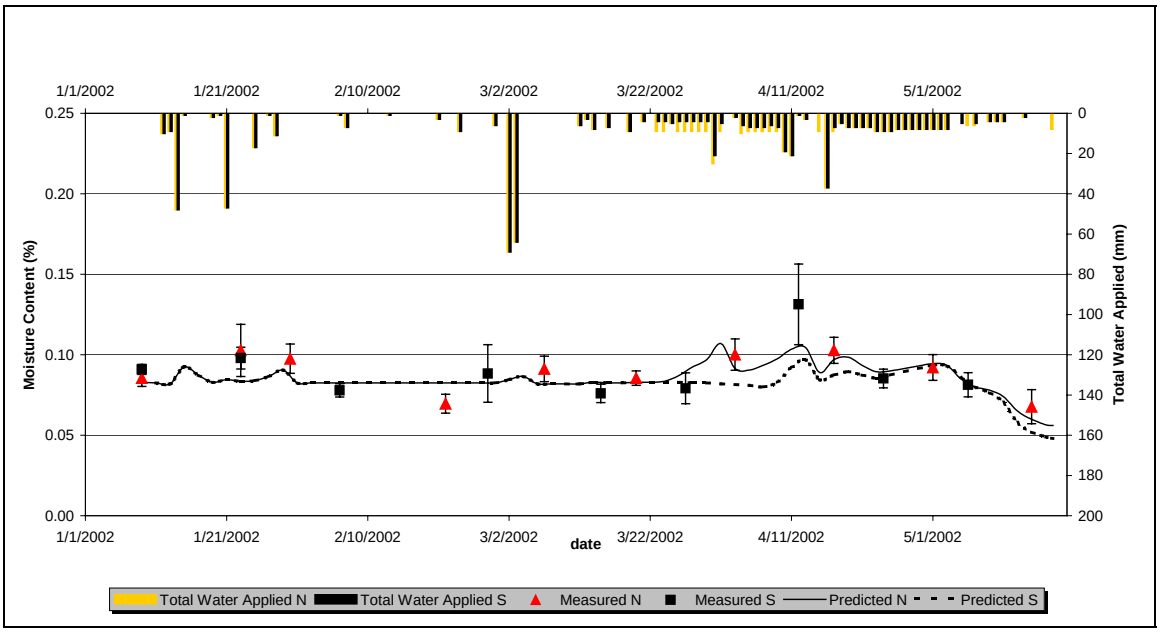


Figure 5-8. Comparisons between the predicted and measured moisture contents at 30-60 cm for the 2002 potato crop. Error bars represent one standard deviation about the average measured value.

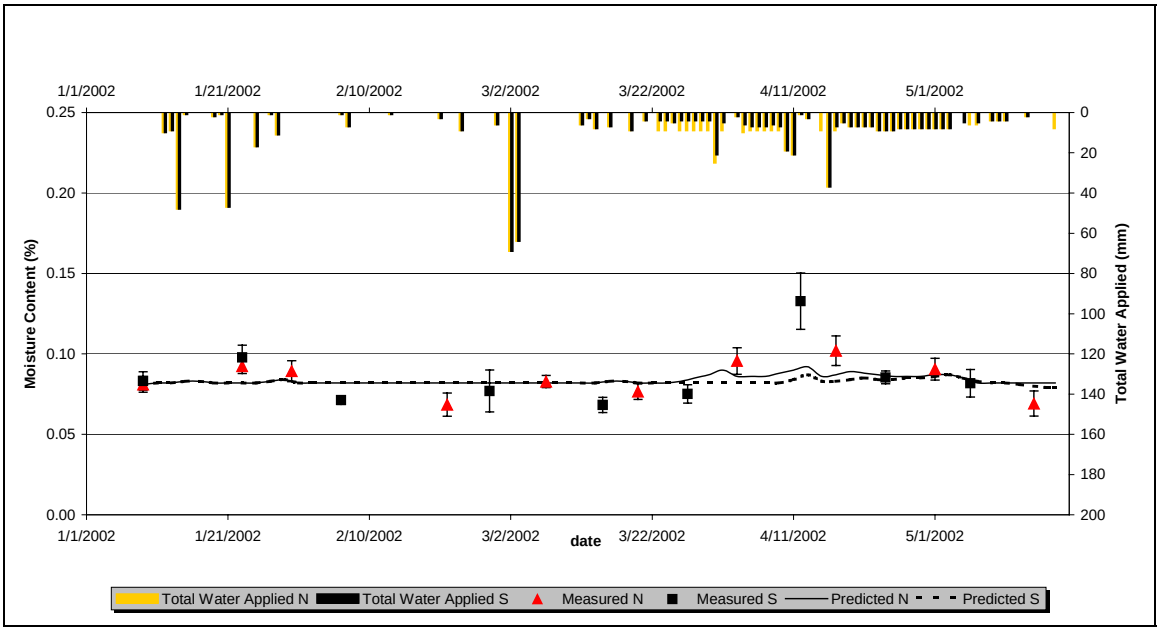


Figure 5-9. Comparisons between the predicted and measured moisture contents at 60-90 cm for the 2002 potato crop. Error bars represent one standard deviation about the average measured value.

Even though the cumulative irrigation and rainfall were approximately the same for both years, the predicted runoff for the 2002 crop season was significantly larger than

that of the 2001 crop season. During the 2001 growing season, the runoff was calculated to be 4.88 cm, while the runoff calculated for the north and south halves of the field for the 2002 crop was determined to be 23.53 and 23.36 cm, respectively. The cause of the large difference between the two years is that the crop received more rainfall in 2002. The total rainfall for the 2001 and 2002 crops was 20.8 and 40.7 cm, respectively. DSSAT assumes runoff is only caused by rainfall, and that all the irrigation applied infiltrates into the soil profile. Therefore, since there was more rainfall in 2002, more runoff occurred. Also, there were different planting dates (Table 2-5) and management practices (Table 2-3) implemented on each half of the field in 2002, which resulted in different crop growth rates and soil moisture contents. The difference in growth rates directly affected the plant leaf area on each half of the field, which in turn affected the transpiration rates. The difference in the transpiration rate, along with the variation in the irrigation management for each half of the field, was the cause of the slight difference in the predicted cumulative runoff for the 2002 crop.

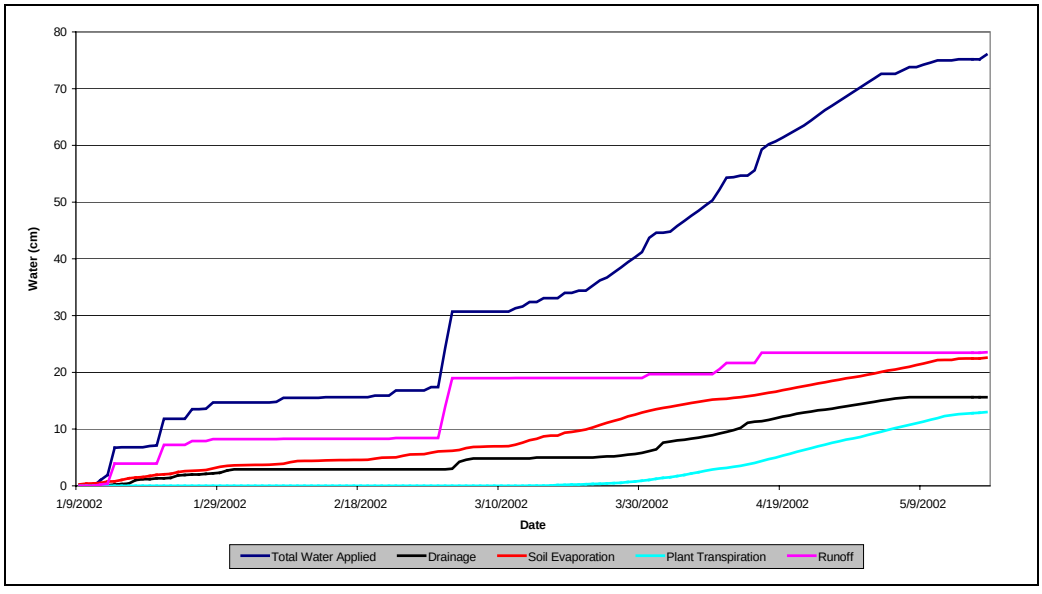


Figure 5-10. Cumulative water balance for the north half of the field for the spring 2002 potato crop.

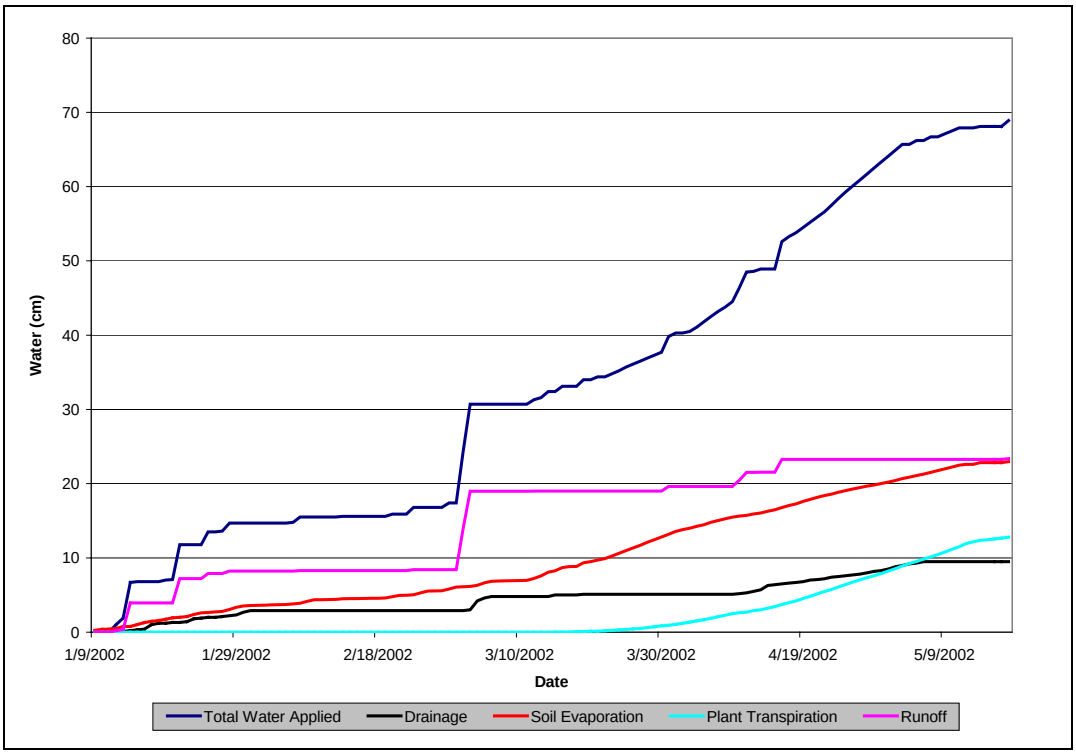


Figure 5-11. Cumulative water balance for the south half of the field for the spring 2002 potato crop.

Even with fairly accurate soil-moisture predictions, it is still not clear that the model's water balance is correct because the soil samples were taken at times when the soil moisture contents were approximately at field capacity. As a result, there is still significant uncertainty in the volume of water infiltrating past the root zone. It is difficult to determine if the model's water balance is correct for the sandy soils located at the project site, because the soils have a tendency to drain to field capacity quickly.

Nitrate-Nitrogen Transport Results

2001 Potato Crop

Figures 5-12 through 5-15 depict the nitrate-nitrogen transport in the top 90 cm of the soil profile for the 2001 potato crop. The model appears to do a relatively good job predicting the nitrate transport in the soil. The majority of the predicted nitrate-nitrogen concentrations remain within one standard deviation of the measured values. With the

decreased infiltration, the nitrate-nitrogen concentrations increased significantly. The figures show that the lower infiltration rates caused the nitrate-nitrogen concentrations to generally be two or more times greater than in the previous simulation predictions (refer to Chapter 3) due to the decreased leaching.

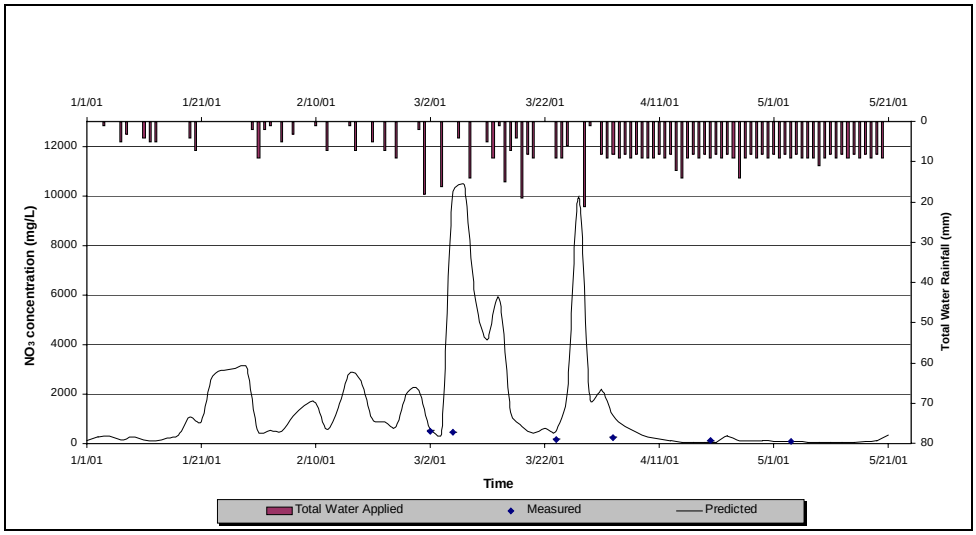


Figure 5-12. Comparisons between the predicted and measured nitrate-nitrogen contents at 0-15 cm for the north half of the field (2001). Error bars represent one standard deviation about the average measured value.

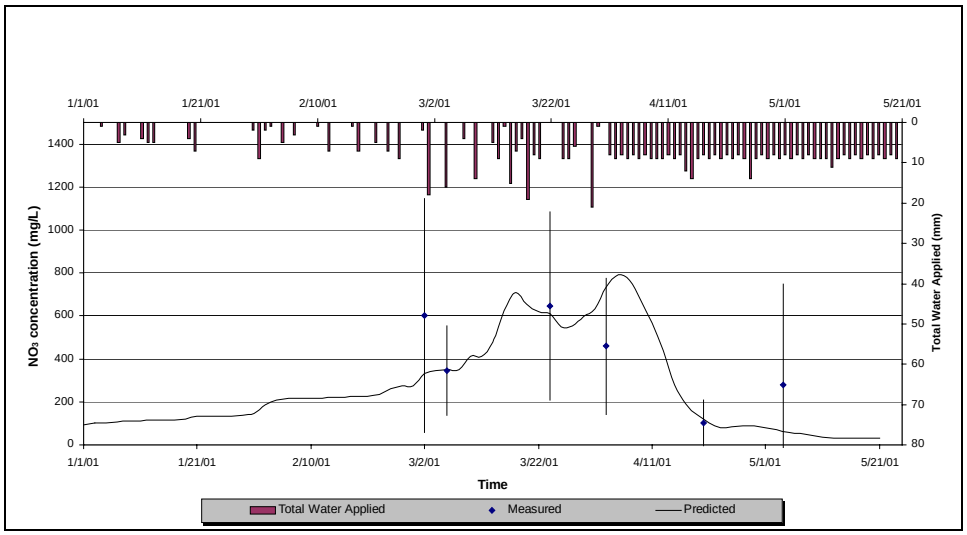


Figure 5-13. Comparisons between the predicted and measured nitrate-nitrogen contents at 15-30 cm for the north half of the field (2001). Error bars represent one standard deviation about the average measured value.

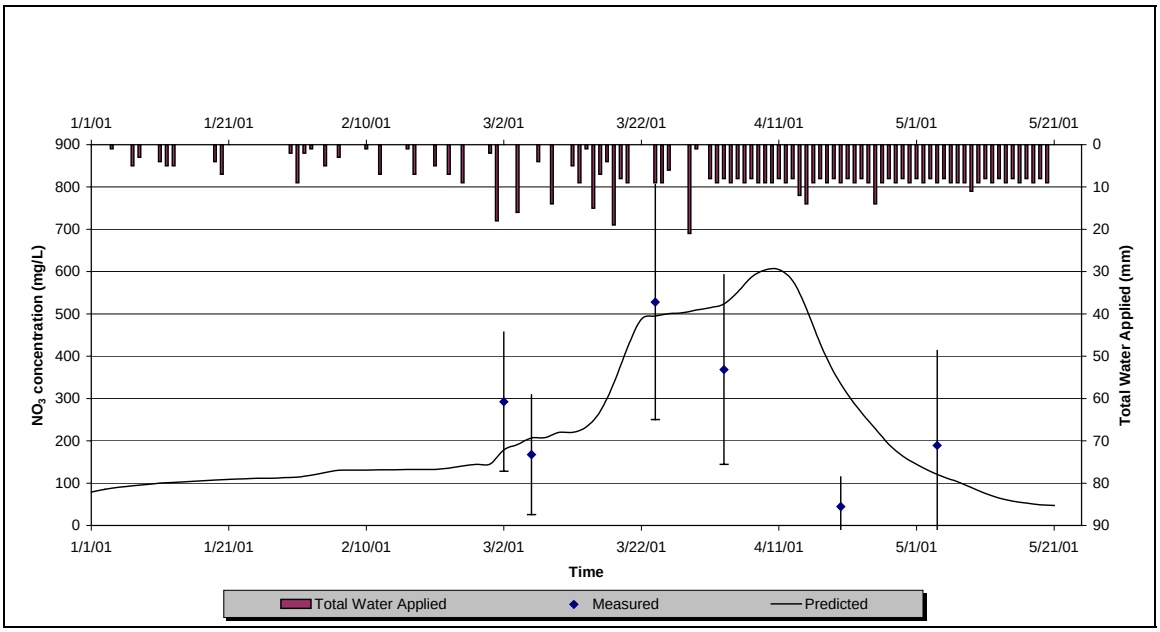


Figure 5-14. Comparisons between the predicted and measured nitrate-nitrogen contents at 30-60 cm for the north half of the field (2001). Error bars represent one standard deviation about the average value.

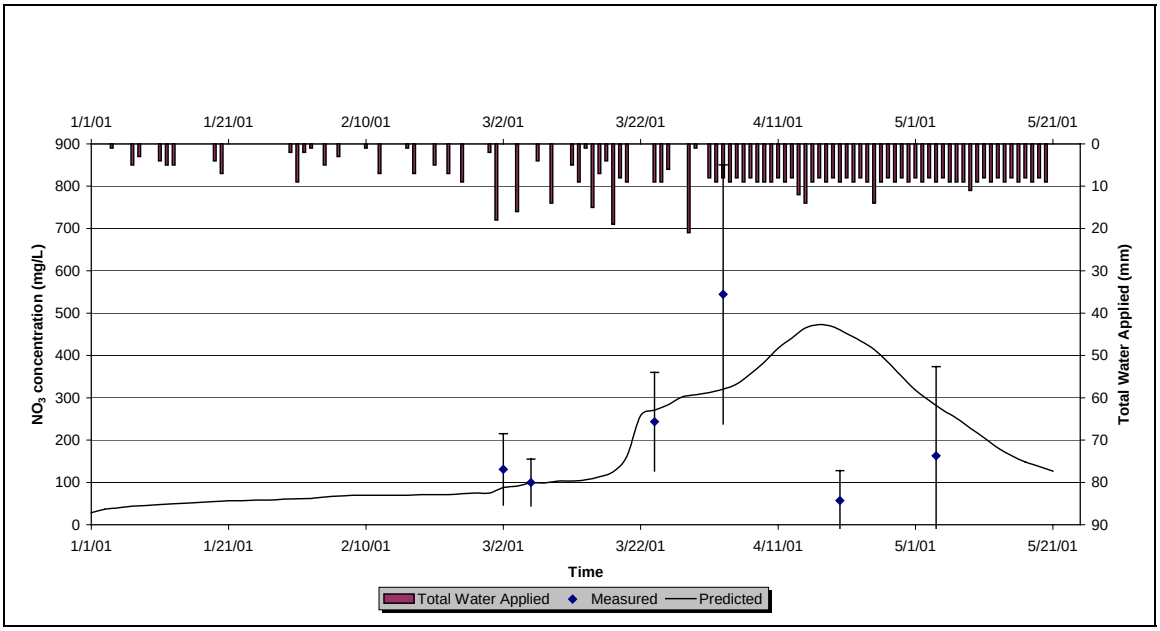


Figure 5-15. Comparisons between the predicted and measured nitrate-nitrogen contents at 60-90 cm for the north half of the field (2001). Error bars represent one standard deviation about the average value.

The largest increases in the nitrate-nitrogen concentrations are observed in the peak concentration values predicted by the model over the growing season, especially in the

top 15 cm. For example, at 0-15 cm the peak nitrate-nitrogen concentration increased from the previous prediction of 2,497 mg/L on March 8, 2001 to 10,476 mg/L using the modified model. On March 28, 2001, the nitrate-nitrogen concentration was previously predicted to be 1,659 mg/L in the top 15 cm. The modified model predictions increased to 9,948 mg/L, which is approximately six times larger. These predicted nitrate-nitrogen concentrations, primarily in the top 30 cm, indicate that more nitrogen was available to the plants during the growing season during the model simulation.

2002 Potato Crop

Figures 5-16 through 5-19 depict the nitrate-nitrogen concentrations for the 2002 crop. These figures provide illustrations of the general behavior of the soil system in response to fertilizer applications and rainfall/irrigation. The predictions for the 2002 crop did not compare as well to the measured values with the 2001 simulation results, but the predicted values generally fall within one to two standard deviations of the predicted values. The model does a fairly good job in predicting the nitrate-nitrogen concentrations in the top 30 cm, especially for the south half of the field. The majority of the predicted nitrate-nitrogen concentrations were larger than measured values at most depths. The over predictions are most likely caused by the decrease in the cumulative infiltration for the 2002 crop.

The model predictions provide insight on the effectiveness of the reduced nitrogen and irrigation applied to the south half of the field in 2002. The south half of the field had higher nitrate-nitrogen concentrations than the north half of the field for the majority of the growing season, despite the reductions in the fertilizer applications rates. This can be attributed to the 21% reduction in the irrigation applied to the south half of the field and the fertilizer application timing. The higher nitrate-nitrogen concentrations result in

higher nitrate-nitrogen recovery in the south half crop relative to the north half of the field.

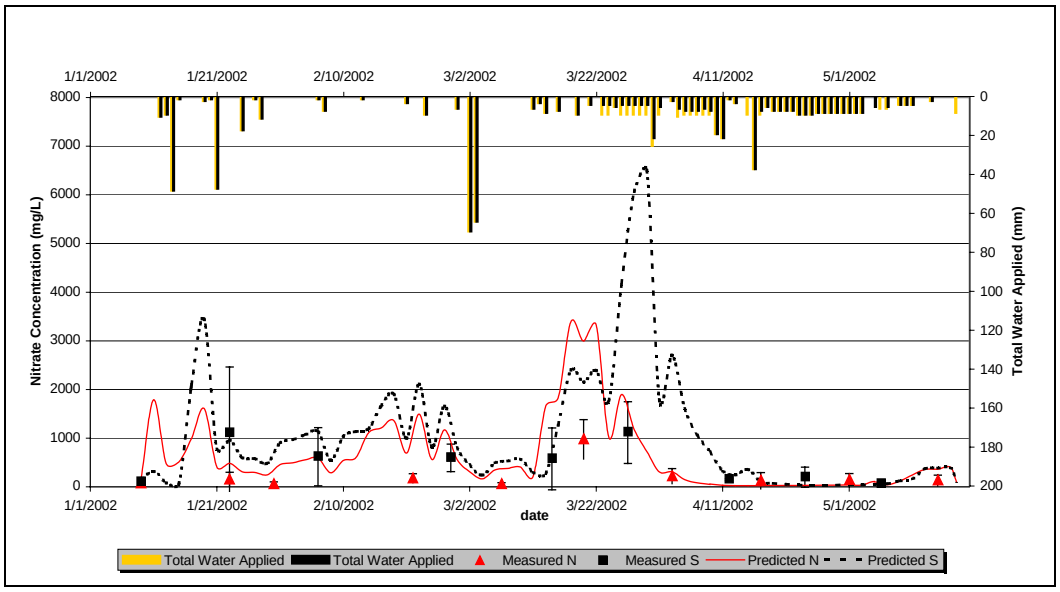


Figure 5-16. Comparisons between the predicted and measured nitrate-nitrogen concentrations at 0-15 cm (2002). Error bars represent one standard deviation about the average measured value.

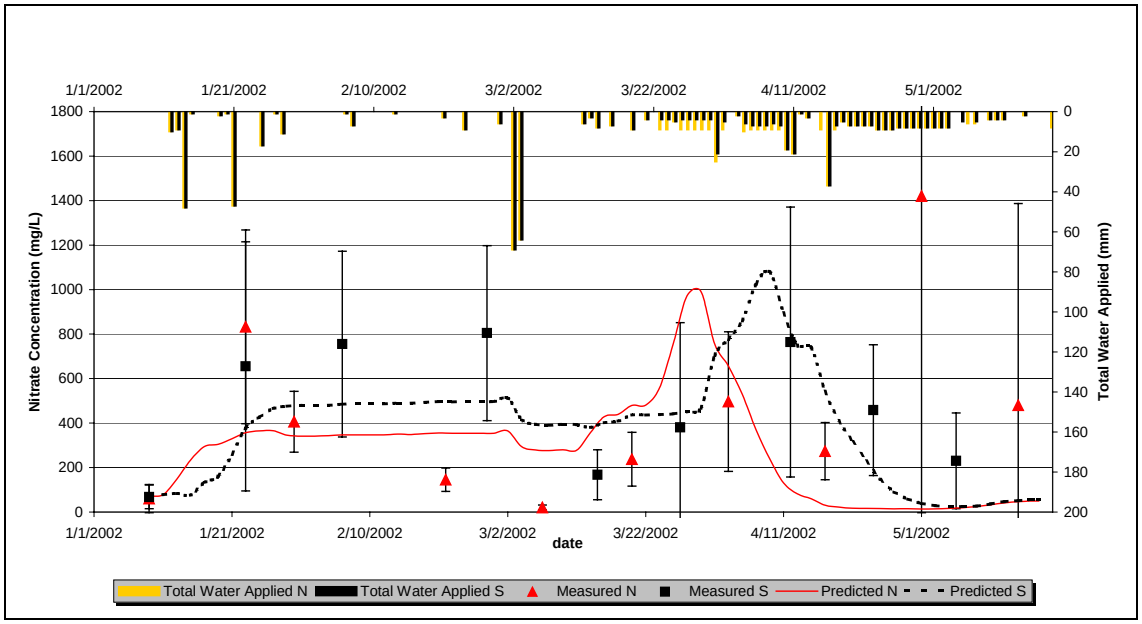


Figure 5-17. Comparisons between the predicted and measured nitrate-nitrogen concentrations at 15-30 cm (2002). Error bars represent one standard deviation about the average measured value.

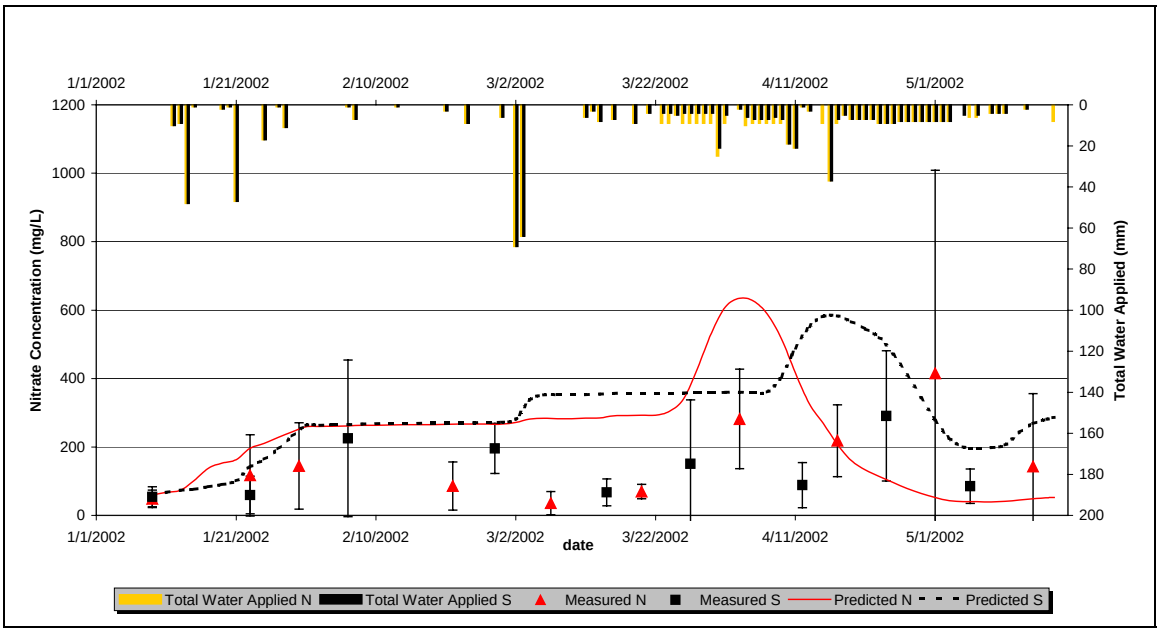


Figure 5-18. Comparisons between the predicted and measured nitrate-nitrogen concentrations at 30-60 cm (2002). Error bars represent one standard deviation about the average measured value.

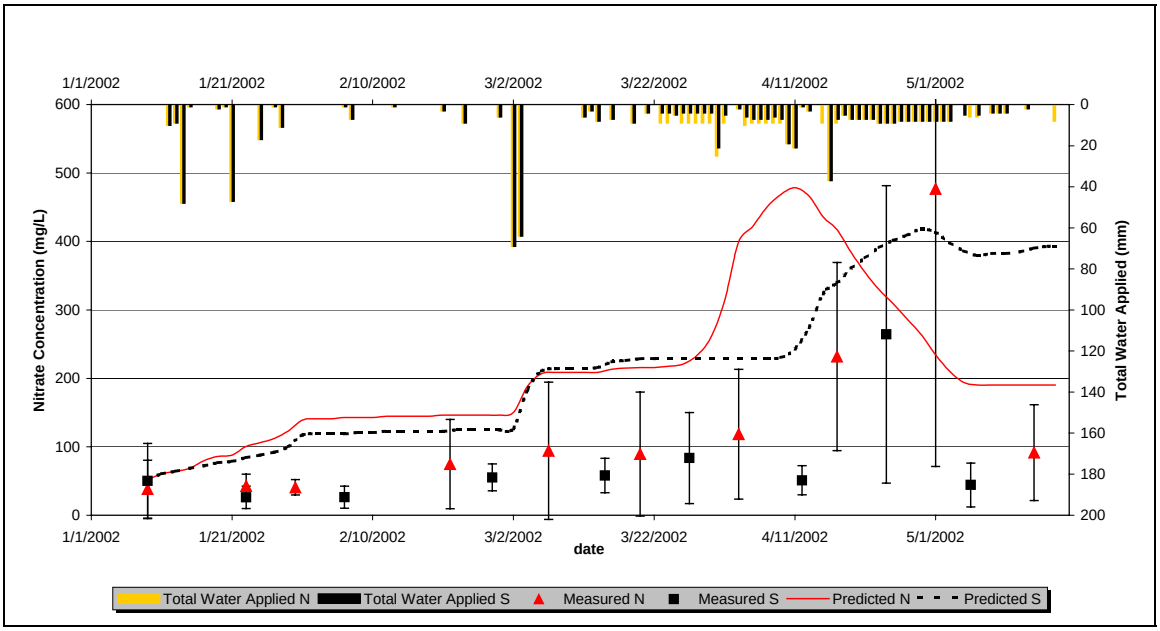


Figure 5-19. Comparisons between the predicted and measured nitrate-nitrogen concentrations at 60-90 cm (2002). Error bars represent one standard deviation about the average measured value.

Crop Growth Results

After it was determined that the soil moisture contents and nitrate-nitrogen concentrations predicted by the model were relatively accurate for both years, the nitrogen balances and crop growth results were then evaluated. The two main purposes for examining the nitrogen balances and crop growth results were to evaluate the improvements in the model's crop growth predictions and nitrogen uptake for the 2001 potato crop, and to evaluate the model's accuracy for the 2002 crop.

2001 Potato Crop

Figure 5-20 shows the cumulative nitrogen balance predicted by DSSAT and accuracy of the model's nitrogen uptake predictions. The figure shows that there was a significant improvement in the nitrogen uptake prediction made by modified model compared to the original model (Chapter 3). The model prediction for plant nitrogen uptake increased from 58.5 kg/ha to 115 kg/ha, approximately two times the original prediction. The figure shows that the model predicted approximately 252 kg/ha of nitrogen leached out of the soil profile, while the crop recovered only 27% of the nitrogen fertilizer applied to the field. The increased predictions in the nitrogen uptake also significantly increased the crop growth prediction made by the model previously (Chapter 3).

Figures 5-21 through 5-23 show the comparisons between the predicted and measured crop growth for the leaves, stems, and tubers, respectively. The results show that the model predictions for the leaves, stems, and tubers significantly increased due to the modifications. For example, the maximum predicted leaf weight increased from 200 kg/ha to approximately 380 kg/ha. The maximum stem weight increased from the previous prediction of 150 kg/ha to 275 kg/ha. These predictions for the leaf and stem

weights were usually greater than the measured values, which was a result of the sampling methods used during the 2001 growing season (Chapter 2).

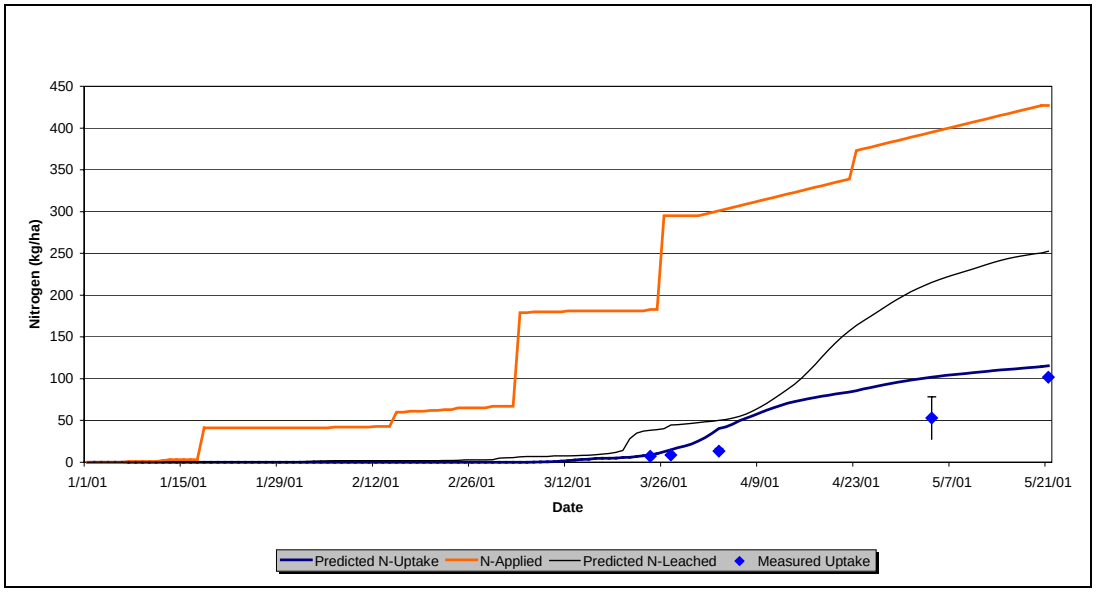


Figure 5-20. Cumulative nitrogen balance for the 2001 potato crop on the north half of the field. Error bars represent one standard deviation about the average value. Note that the error bars for the first three sample points are present, but are several orders of magnitude smaller than the scale used for the y-axis.

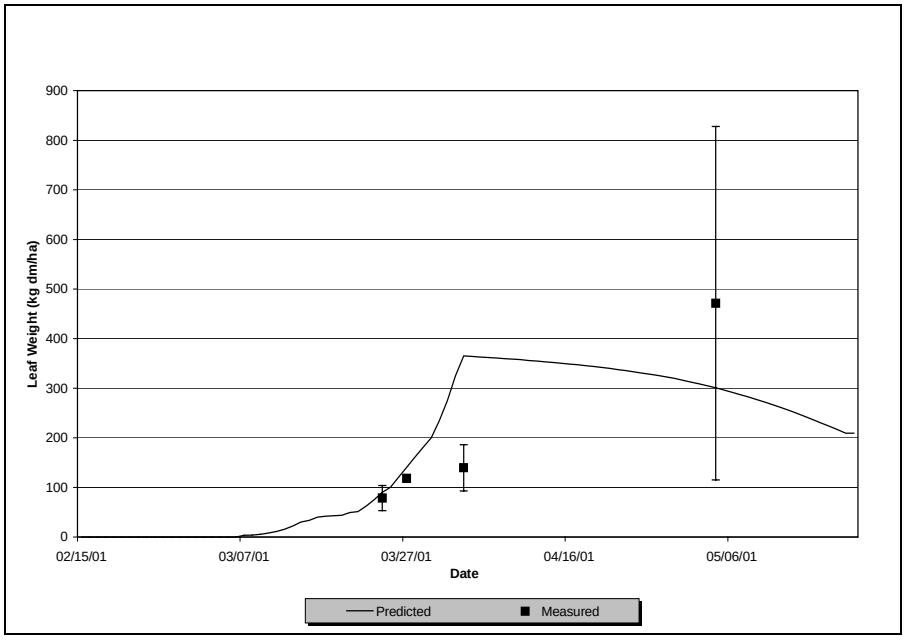


Figure 5-21. Dry leaf weight predictions for the spring 2001 potato crop on the north half of the field. Error bars represent one standard deviation about the mean measured value.

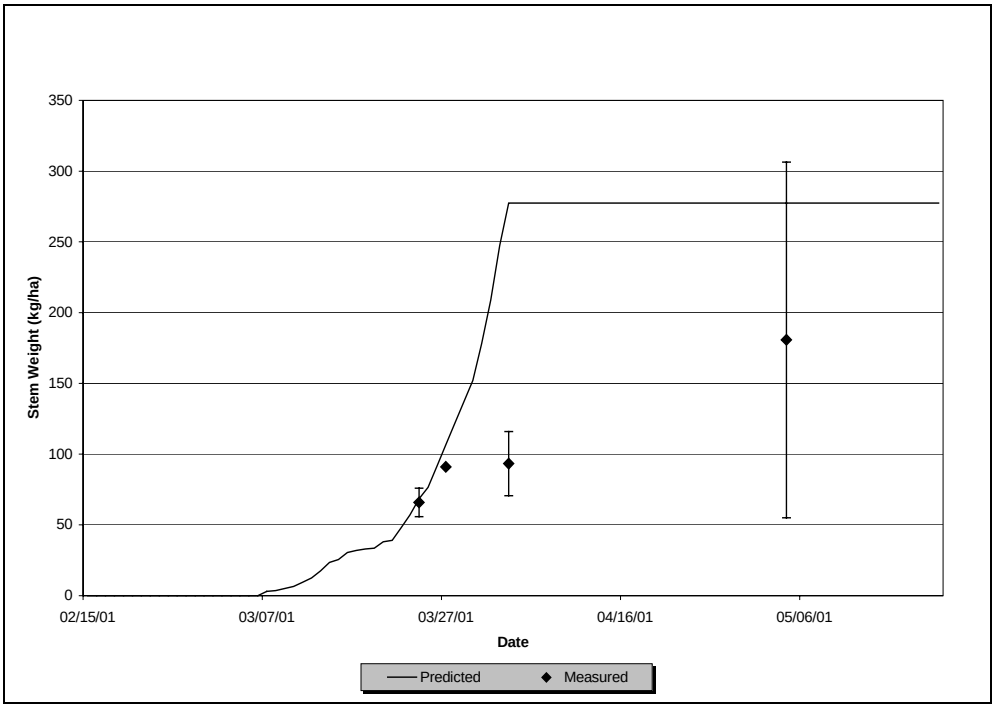


Figure 5-22. Dry stem weight predictions for the spring 2001 potato crop on the north half of the field. Error bars represent one standard deviation about the mean measured value.

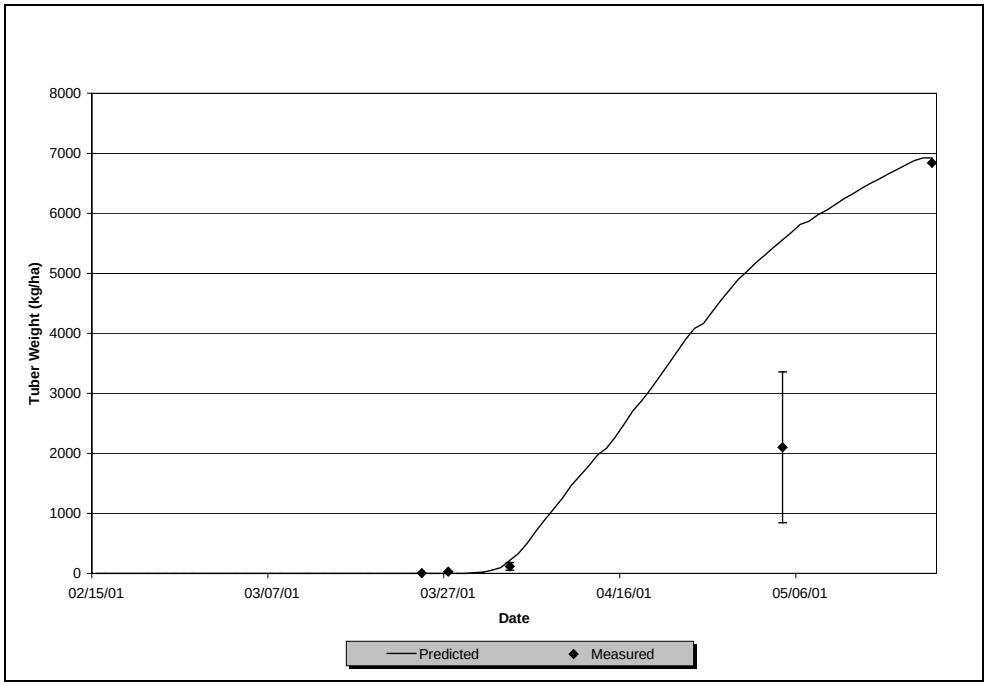


Figure 5-23. Dry tuber weight predictions for the spring 2001 potato crop on the north half of the field. Error bars represent one standard deviation about the mean measured value.

The most notable improvement in the model predictions for dry weight is shown in Figure 5-23 of the dry tuber yield. The original model estimated the final dry tuber yield to be approximately 3,800 kg/ha, which is substantially lower than the measured value of 6,840 kg/ha. With the modifications, the predicted final dry tuber yield increased to 6,925 kg/ha, which is 3,125 kg/ha greater than the previous predictions. These results show that the modifications in GROSUB improved the model's ability to predict the nitrogen recovery and crop growth for the potato crop grown on the sandy soils at the project site.

2002 Potato Crop

Figures 5-24 and 5-25 are good illustrations of the nitrogen transport in the soil and the model's accuracy in predicting crop nitrogen uptake. The model predictions for the nitrogen uptake agree quite well with the measured values. However, the results for the nitrogen uptake predictions for the south half of the field agree with the measured values better than those for the north half of the field. The model predicted that the crop nitrogen uptake was 141 kg/ha for the south half of the field, which relatively close to the estimated value of 132 kg/ha. The measured nitrogen uptake for the north half of the field was 155.5 kg/ha, which is much larger than the 107 kg/ha predicted. The underestimate in the nitrogen recovered by the plants in the north half can be attributed to the 7.1 cm of additional irrigation applied to the north half of the field, which resulted in the model predicting more nitrogen being leached out of the zone occupied by the plant roots. This can also be seen in the nitrate-nitrogen results shown in Figures 5-16 through 5-19. Notice that the nitrate-nitrogen concentrations for the bottom 30 cm of the soil profile of the south half of the field are approximately two times greater than those for the north half of the field at the end of the growing season. This shows that more nitrogen

was retained in the soil profile at the end of the growing season on the south half of the field.

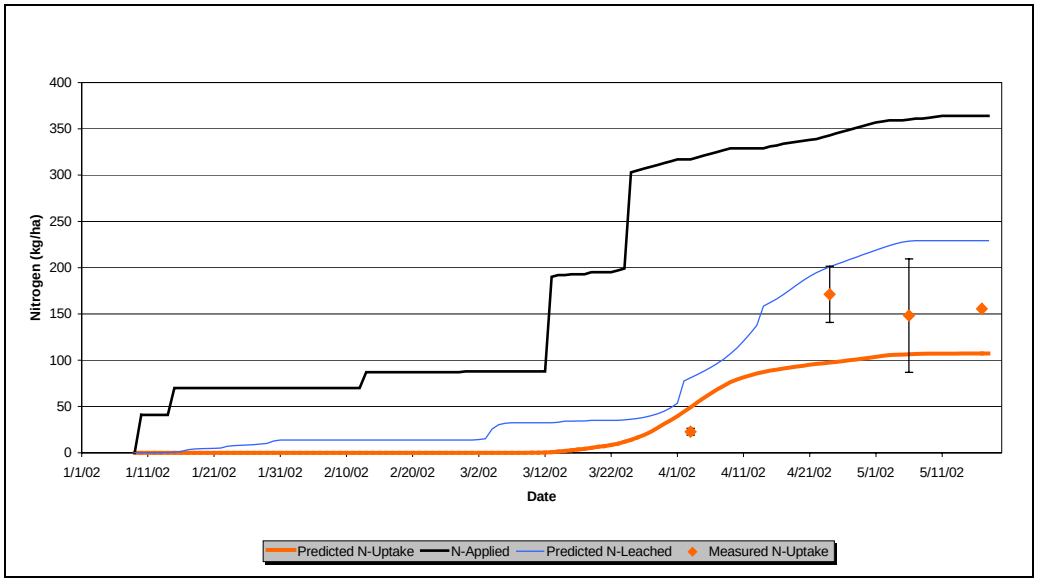


Figure 5-24. North half cumulative nitrogen balance for the2002 potato crop. Error bars represent one standard deviation about the average measured value.

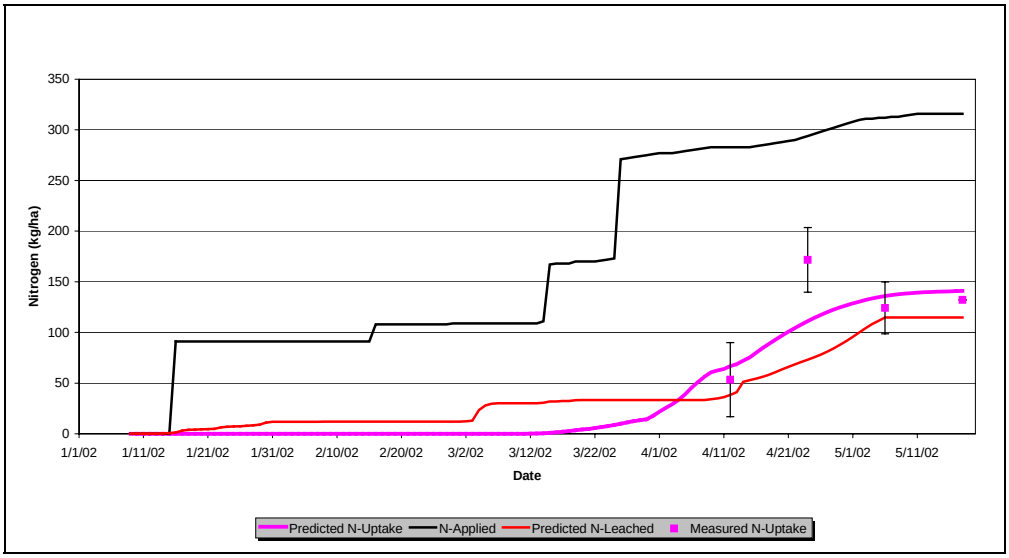


Figure 5-25. South half cumulative nitrogen balance for the 2002 potato crop. Error bars represent one standard deviation about the average measured value.

Figures 5-26 through 5-31 contain the model predictions for the crop development over the growing season. The figures show that the model was able to predict the overall

trends in the plant development, but tended to over estimate the dry stem and leaf weights. The dry weight predictions for the leaves and stems generally fell within one to two standard deviations the measured values.

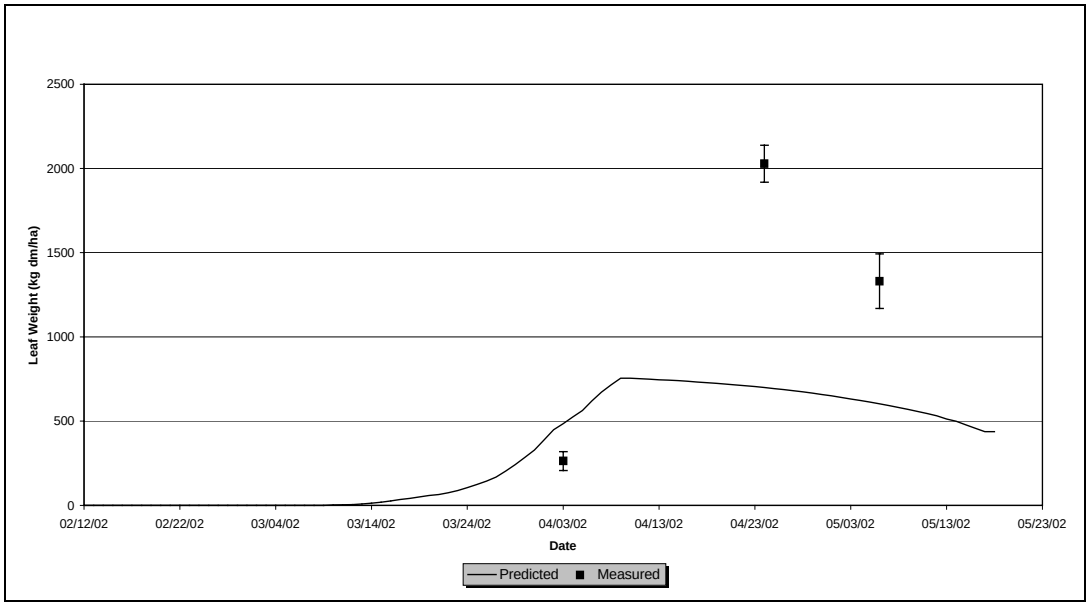


Figure 5-26. North half dry leaf weight predictions for the spring 2002 potato crop. Error bars represent one standard deviation about the mean measured value.

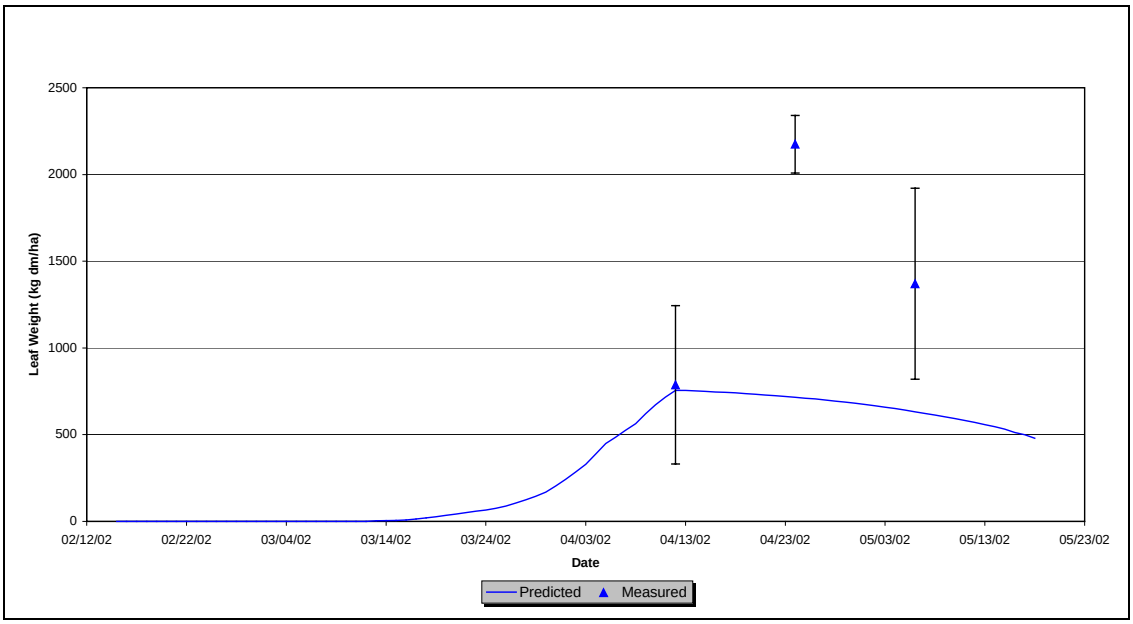


Figure 5-27. South half dry leaf weight predictions for the spring 2002 potato crop. Error bars represent one standard deviation about the mean measured value.

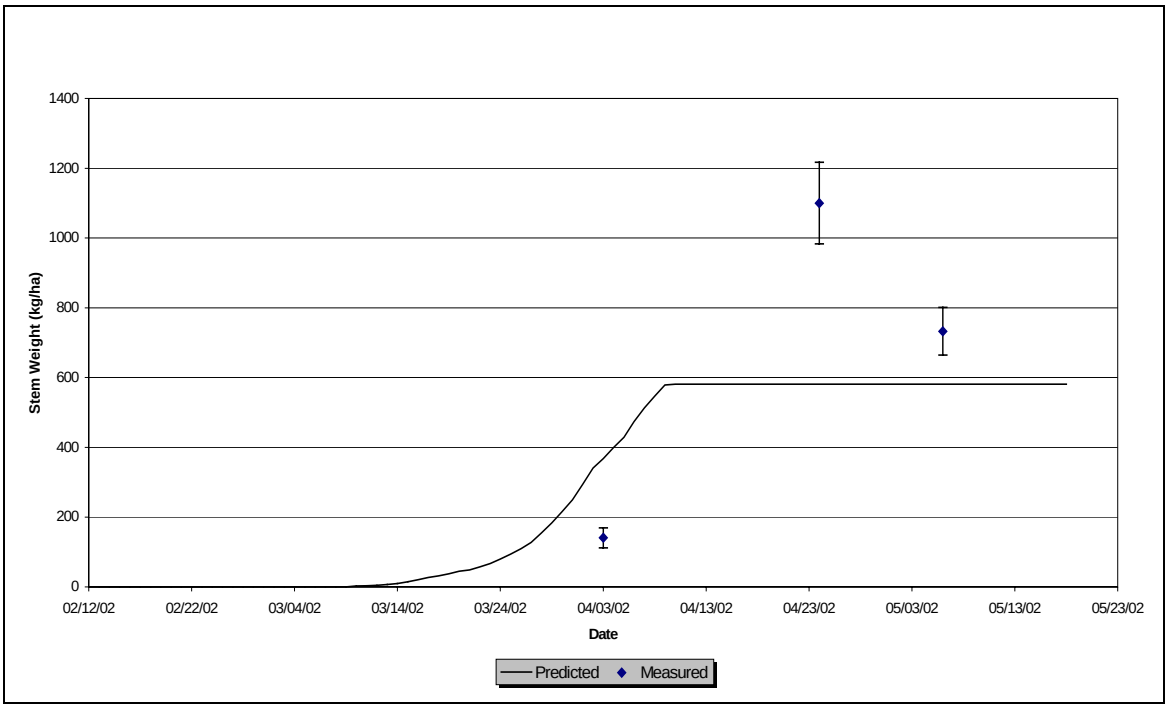


Figure 5-28. North half dry stem weight predictions for the spring 2002 potato crop. Error bars represent one standard deviation about the mean measured value.

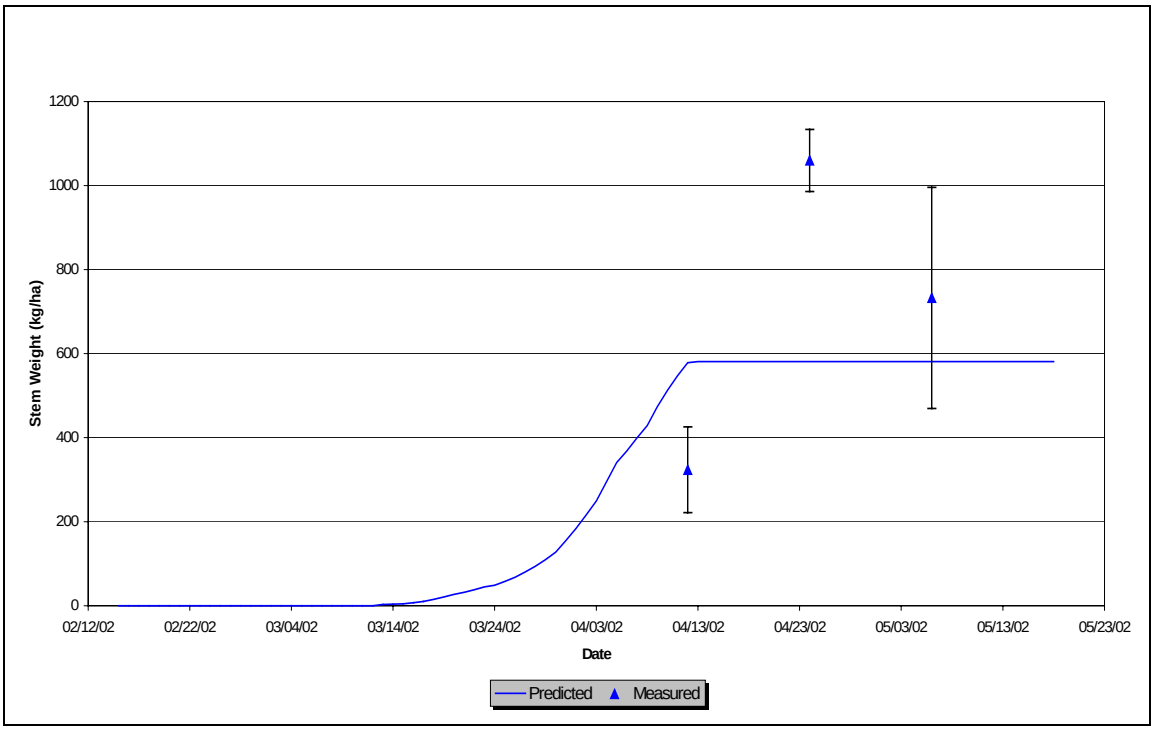


Figure 5-29. South half dry stem weight predictions for the spring 2002 potato crop. Error bars represent one standard deviation about the mean measured value

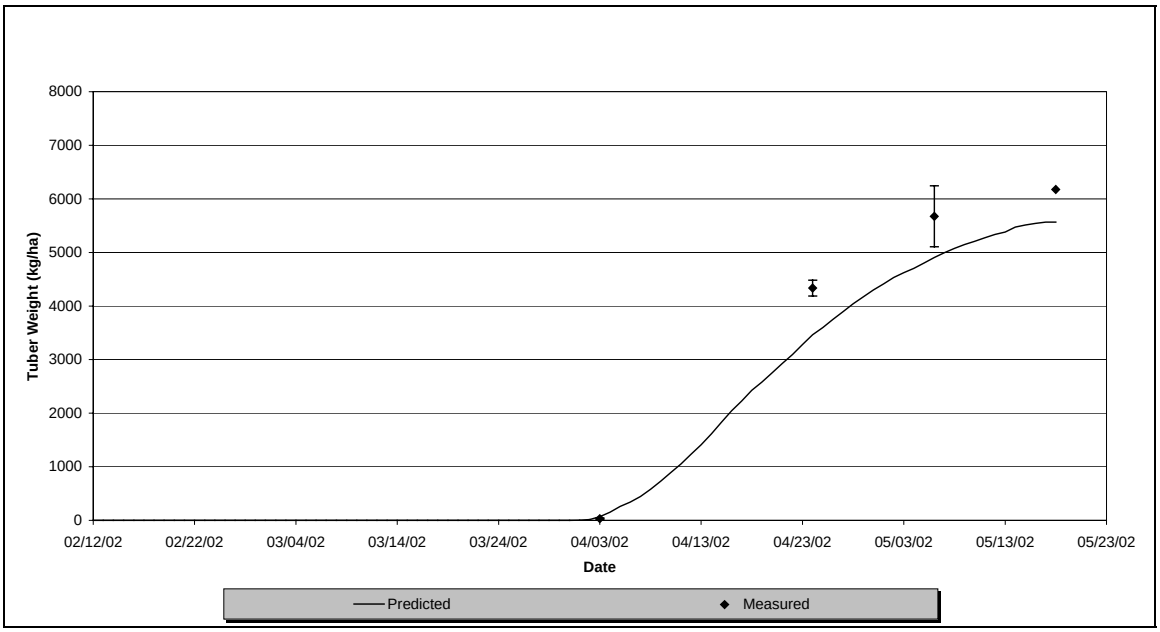


Figure 5-30. North half dry tuber weight predictions for the spring 2002 potato crop. Error bars represent one standard deviation about the mean measured value.

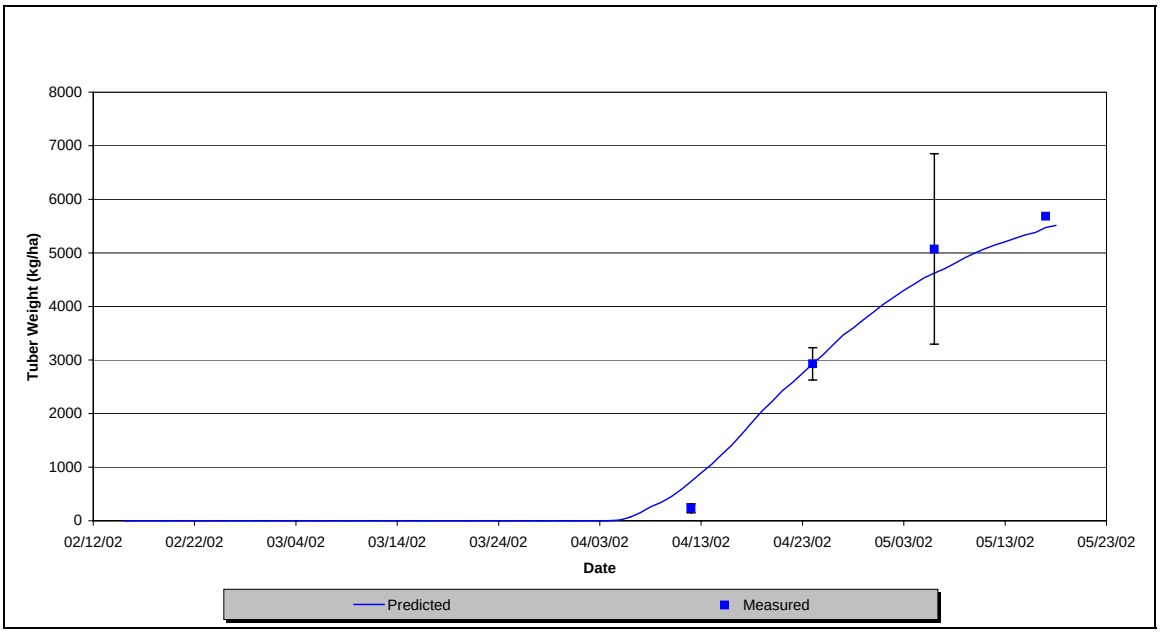


Figure 5-31. South half dry tuber weight predictions for the spring 2002 potato crop. Error bars represent one standard deviation about the mean measured value.

Even though the predicted and measured results indicate that the 2002 potato crop recovered more nitrogen than the 2001 crop, the simulated and observed dry tuber yield were higher for the 2001 crop. There was more vegetative growth and less tuber growth

during the 2002 growing season compared to the 2001 potato crop, which was primarily caused by the two different row widths used during the 2001 and 2002 potato crops. During the 2001 growing season, the row spacing was 101 cm, while in 2002 the row spacing was 90 cm. Since the plants were planted together more closely in 2002, there was more competition for light. As a result, more of the total daily plant growth was partitioned to vegetative growth rather than tuber growth during the 2002 growing season, which was also observed in the plant biomass samples taken in the field during the 2001 and 2002 growing.

The model did particularly well in predicting the dry tuber yield, which is shown in Figures 5-30 and 5-31. As was observed in the field, the model predicted that the north half dry tuber yield would be higher than the south half dry tuber yield. The south half dry tuber yield prediction of 5,512 kg/ha agreed relatively well with the estimated value of 5,684 kg/ha, but the north half's dry tuber yield results were not as accurate. The model predicted that the north half final dry tuber yield to be 5,564 kg/ha, which is somewhat lower than the estimated final dry tuber yield of 6,175 kg/ha. The under prediction in the north half's dry tuber yield was most likely caused by the under prediction in the nitrogen uptake, which is shown in Figure 5-24. But in general, the calibration results for the 2001 and 2002 potato crops indicate that the model is fairly accurate in predicting potato crop system and show that the model is properly calibrated for potato crop systems on the project site.

CHAPTER 6
CONCLUSIONS

This research provided valuable insight on nitrate-nitrogen and water transport through the sandy soils at the project site and their effects on potato crop growth. The measured results illustrate the susceptibility of nitrogen leaching through the typical Floridian sandy soils located at the research site. The data collected also aided in the calibration and modifications of the DSSAT crop growth model and provided valuable insight regarding the general trends of the water and nitrate-nitrogen transport at the project site.

The measured data show that the sandy soils at the project are highly susceptible to leaching nitrate-nitrogen following rainfall events and irrigation applications. As seen from the measured moisture content results for both years of data, the soils drain to field capacity relatively quickly. Thus, a considerable portion of the nitrogen fertilizer applied to the potato crop can leach out of the root zone and eventually into the underlying aquifer as a result of poor fertilizer management and irrigation scheduling.

The data collected in 2001 show that 24% of the total nitrogen applied (fertilizer plus irrigation nitrate-nitrogen) to the north half of the field was recovered by the potato plants, leaving 325 kg/ha of the 427 kg/ha nitrogen applied in the fertilizer and irrigation to be leached out of the soil profile and into the underlying Floridan Aquifer. The data show that after rainfall events and irrigation applications, the nitrate-nitrogen moved quickly out of the top 30 cm and into the subsequent 60 cm, beneath the active root zone. This indicates the importance of proper irrigation and fertilizer management.

The 2002 data also indicate that the potato crops currently grown at the project site are receiving more than adequate amounts of nitrogen fertilizer and irrigation. It was observed that the south half of the field, which received a 10% reduction in the 292 kg/ha of nitrogen fertilizer and a 21% reduction in the 343 mm irrigation applied, had a 491 kg/ha lower yield relative to the 6,175 kg/ha north half dry tuber yield. Also, the potato plants on the south half of the field recovered 23.3 kg/ha less nitrogen fertilizer than the 155.5 kg/ha that was recovered on the north half. However, the south half of the field was planted three days after the north half of the field, which accounts for the 8% reduction in yield and the 15% reduction in nitrogen uptake on the south half of the field. Surprisingly, the estimated marketable yields for the north and south halves of the field were measured to be 3,675 kg/ha and 5,260 kg/ha, respectively, by personnel from the University of Florida Research Center located in Live Oak, FL. The marketable yield was 1,585 kg/ha higher on the south half of the field because lenticels developed on some of the north half potatoes. The lenticels developed because of the wetter soil conditions due to the additional 7.1 cm of irrigation applied to the north half of the field.

The nitrogen recovery was about the same in 2002 for both halves of the field with each being approximately 42% of what was applied, but there was 24.5 kg/ha more nitrogen fertilizer available for leaching on the north half of the field. This indicates that the south half practices were effective in reducing the nitrate-nitrogen leaching at the project site. These results also show that careful irrigation and fertilizer management is critical to increase nitrogen recovery and reduce leaching. Irrigation scheduling should be based the crop status and environmental conditions in order to determine the amount of supplemental water needed to meet the crop’s water requirement. Further

investigations need to be conducted for different fertilizer management scenarios primarily consisting of fertilizer application timing, placement, and type. The most logical approach to evaluate these different BMP scenarios is to implement the calibrated modified DSSAT model once it has been properly validated using an independent data set.

The current DSSAT model does not adequately represent the potato crop system at the project site. From 2001 potato crop simulation comparisons for the original and modified computer models, it is apparent that the original algorithms used by DSSAT are not sufficient to simulate the soil-water and nitrate-nitrogen movement or crop growth for potatoes grown on beds in Florida. As shown in the 2001 model results (Chapter 3), while the model accurately predicted the soil moisture contents it did not accurately predict the total volume of water leached. It was clear after examining the nitrate-nitrogen concentrations and dry tuber yield results that the model significantly over predicted the volume of water drained out of the top 90 cm, which directly affects the nitrate-nitrogen leaching. As a result, the computer model underestimated the plant nitrogen uptake. Thus, the original model predicted the final crop yield to be 3,735 kg/ha while the actual yield was measured to be 6,840 kg/ha.

The soil moisture content results for the original and modified models illustrate the difficulties in calibrating the DSSAT water balance. Increasing the CN from 75 to 95 had negligible effects on the accuracy of the moisture content predictions, which shows the insensitivity of the soil moisture content to changes in the volume of water infiltrating into the soil surface. This is mostly likely due to the physical characteristics of the sandy soils located at the project site. The soils at the research site tend to drain to field

capacity relatively quickly, which makes it difficult to determine the accuracy of the drainage volume predictions made by the model. Given that most of the soil samples were taken when the soil had already drained to field capacity, it was uncertain whether or not the model predictions were accurate. Thus, the only way to determine if the water balance is correct is to take soil samples periodically immediately following a large rainfall event in order to measure transient infiltration rates and moisture contents.

The modifications in the original DSSAT model significantly improved the model's ability to predict nitrate-nitrogen transport, nitrogen uptake, and crop growth. In 2001, the modified CN, which was used to account for plant canopy and bed slope effects on infiltration, increased the original model prediction of 0.0 cm runoff to 4.9 cm, which reduced the rate that nitrate-nitrogen was leached out of the soil profile. The reduced bed width and doubled nitrogen fertilizer application rates used to concentrate the nitrogen fertilizer in the bed caused the nitrate-nitrogen concentration predictions to be three to six times larger than the original DSSAT predicted values. Also, the higher nitrate-nitrogen concentrations and reduced infiltration caused the 2001 nitrogen uptake predictions to improve from 58.4-kg/ha to 115-kg/ha, which is much closer to the measured value of 101.7-kg/ha. The predictions for crop growth greatly improved from 3,735-kg/ha to 6,924-kg/ha, which compares relatively well to the measured value of 6,840-kg/ha.

The calibration results for the 2001 and 2002 crops show that currently the modified DSSAT model adequately predicts the 2001 and 2002 data. However, data from the 2003 potato crop now need to be simulated to validate the modified computer model. Once the model is validated, several different BMP scenarios can be evaluated in order to determined their effects on nitrate-nitrogen leaching and plant growth.

After examining the water and solute transport algorithms used by the DSSAT crop model and the HYDRUS vadose zone model, it is obvious that a combination of the two models would be extremely beneficial. Combining both models would be beneficial because both models have relative advantages over each other. DSSAT simulates plant growth and estimates nutrient uptake, water uptake, and plant growth well, but the drained water volume is difficult to predict for sandy soils because of the simplified water balance. HYDRUS is a two-dimensional model that uses physically based equations to determine the nutrient and water transport in the soil and can properly represent systems with irregular shaped boundaries. Two-dimensional modeling is essential when attempting to represent physical systems with irregular boundaries. However, HYDRUS has a very limited plant model that does a relatively poor job of determining the plants ability to take up nutrients and soil-water. Thus, using the crop growth methods used by DSSAT and the water and solute transport methods used by HYDRUS would result in a more accurate representation of the potato crop system.

If both models are combined, the new model could more accurately represent the potato crop system, specifically fertilizer placement effects. However, the methods used to determine potential evapotranspiration used in DSSAT need to be replaced with a more widely accepted method, such as the Penman-Monteith equation. Also, since neither model takes into account the runoff from the beds into the furrows, runoff should be routed using either the kinematic wave equation or dynamic wave equation. Further examination of effective rainfall and irrigation must be conducted in order to take into account the spatial variability between water infiltrating in the bed and in the furrow due to the plant canopy.

Regarding the future research at the project site, several improvements can be made in the sampling methodologies that were used during the 2001 and 2002 potato crop growing seasons. During the 2001 and 2002 growing season, plant samples were taken randomly over the entire field generally close to the monitoring wells. After the 2002 season, it was obvious that the techniques used to collect the plant samples could be improved upon by increasing the number of plant samples taken over the season and implementing GIS software. More plant samples are needed in addition to the samples specified by the DSSAT documentation in order to obtain better representation of the crop growth and nitrogen uptake over the plant growing season. The increased plant sampling should consist of 16 or more samples taken during each sampling session with the number of samples divided evenly for each quadrant. Also, the plant samples should be taken more frequently, ideally once a week, in order to obtain better information regarding plant growth and nitrogen uptake.

The GIS software should be implemented in order to account the variations in crop growth over the field. It takes the farmer approximately 10 to 14 days to plant the potato crop on the 56.7-ha field, which results in significant differences in crop growth over the field depending on the rows sampled. Thus, using a GPS unit to mark the plant sample locations would provide valuable insight on the spatial variability of plant growth. GIS could also be used to examine the variability in the nitrogen transport over the field as well.

Given the results from this study, it is obvious that more research needs to be conducted at the project site in order to further evaluate different BMP scenarios and their effects on nitrate-nitrogen leaching. The data should be used to further determine the

accuracy of the modified DSSAT model. Also, the modeling should be expanded from modeling the collected data only to performing risk assessments in relation to different weather years.

APPENDIX A
SOIL SAMPLE ANALYSIS RESULTS

Table A-1. Soil sample results at the project site.

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
03/02/01	0 - 15	8	r	n	29.33	27.73	5.46	8.25	17.2	316.2	4185.5	39.1	518.0
03/02/01	15 - 30	8	r	n	29.2	27.63	5.38	8.47	71.9	1337.5	920.4	169.9	116.9
03/02/01	30 - 60	8	r	n	29.37	27.68	5.75	9.10	4.5	78.9	118.9	21.5	32.4
03/02/01	0 - 15	9	r	n	29.53	28.02	5.11	7.71	68.7	1342.8	3770.2	155.2	435.8
03/02/01	15 - 30	9	r	n	29.7	26.25	11.62	19.58	20.0	171.8	120.1	50.5	35.3
03/02/01	60 - 90	9	r	n	29.23	27.5	5.92	9.37	5.7	96.8	190.6	27.2	53.6
03/02/01	0 - 15	10	r	n	29.02	27.37	5.69	8.62	7.2	127.4	159.4	16.5	20.6
03/02/01	15 - 30	10	r	n	29.48	28.03	4.92	7.71	16.2	328.6	301.6	38.0	34.9
03/02/01	30 - 60	10	r	n	29.82	28.52	4.36	6.79	16.7	383.2	197.7	78.1	40.3
03/02/01	60 - 90	10	r	n	29.1	27.62	5.09	7.98	12.9	254.0	73.3	60.8	17.6
03/02/01	0 - 15	11	r	n	29.44	27.37	7.03	10.82	19.4	276.1	457.4	44.8	74.2
03/02/01	15 - 30	11	r	n	29.69	27.92	5.96	9.45	9.0	150.5	55.1	21.3	7.8
03/02/01	30 - 60	11	r	n	29.38	27.71	5.68	8.98	14.5	255.8	307.9	68.9	82.9
03/02/01	60 - 90	11	r	n	29.16	26.34	9.67	15.95	6.0	62.0	107.5	29.7	51.4
03/02/01	0 - 15	12	r	s	29.14	28	3.91	5.82	23.2	593.0	560.9	51.8	49.0
03/02/01	15 - 30	12	r	s	29.43	27.95	5.03	7.89	15.6	310.7	83.0	36.8	9.8
03/02/01	30 - 60	12	r	s	29.45	28.22	4.18	6.49	14.5	348.1	238.2	67.8	46.4
03/02/01	60 - 90	12	r	s	29.03	27.66	4.72	7.38	12.4	262.2	69.6	58.1	15.4
03/02/01	0 - 15	13	r	s	29.11	27.48	5.60	8.48	31.9	569.0	4395.0	72.4	559.2
03/02/01	15 - 30	13	r	s	29.19	27.49	5.82	9.21	48.1	825.9	865.0	114.1	119.6
03/02/01	30 - 60	13	r	s	29.81	28.1	5.74	9.07	3.6	63.1	80.5	17.2	21.9
03/02/01	60 - 90	13	r	s	29.35	27.82	5.21	8.19	3.3	64.2	20.4	15.8	5.0
03/02/01	0 - 15	3	r	n	29.14	27.36	6.11	9.30	27.5	450.7	1329.4	62.9	185.5
03/02/01	15 - 30	3	r	n	29.25	27.6	5.64	8.91	57.8	1025.3	1030.0	137.0	137.6
03/02/01	30 - 60	3	r	n	29.11	27.48	5.60	8.84	25.4	453.0	145.9	120.1	38.7
03/02/01	60 - 90	3	r	n	29.87	28.21	5.56	8.77	6.2	110.9	59.1	29.2	15.6
03/02/01	0 - 15	4	r	s	29.67	28.19	4.99	7.51	41.6	834.0	956.5	93.9	107.7
03/02/01	15 - 30	4	r	s	29.35	27.93	4.84	7.58	23.2	479.5	224.0	54.5	25.5
03/02/01	30 - 60	4	r	s	29.27	27.63	5.60	8.84	4.7	83.9	58.6	22.3	15.6
03/02/01	60 - 90	4	r	s	29.75	28.39	4.57	7.14	5.7	125.3	246.8	26.8	52.8
03/02/01	0 - 15	6	r	s	29.06	27.13	6.64	10.17	45.4	683.5	4307.5	104.3	657.3
03/02/01	15 - 30	6	r	s	29.43	28.02	4.79	7.50	23.2	484.2	105.7	54.5	11.9
03/02/01	30 - 60	6	r	s	29.64	28.01	5.50	8.67	20.0	362.8	641.4	94.4	166.8
03/02/01	60 - 90	6	r	s	29.26	27.86	4.78	7.49	5.8	122.0	59.4	27.4	13.3
03/02/01	0 - 15	7	r	s	29.13	27.64	5.12	7.71	18.9	368.9	6374.6	42.7	737.1
03/02/01	15 - 30	7	r	s	29.16	27.79	4.70	7.35	41.6	885.5	712.9	97.6	78.6
03/02/01	30 - 60	7	r	s	29.11	27.62	5.12	8.04	4.2	82.3	255.1	19.9	61.5
03/02/01	60 - 90	7	r	s	29.15	27.64	5.18	8.14	3.9	76.1	46.3	18.6	11.3
03/06/01	0 - 15	8	r	n	29.04	27.8	4.27	6.38	17.2	402.9	201.8	38.5	19.3
03/06/01	15 - 30	8	r	n	29.16	27.47	5.80	9.17	17.2	296.8	102.7	40.8	14.1
03/06/01	30 - 60	8	r	n	29.01	27.33	5.79	9.16	7.4	127.8	49.1	35.1	13.5
03/06/01	60 - 90	8	r	n	28.99	27.24	6.04	9.57	2.9	47.3	25.0	13.6	7.2
03/06/01	0 - 15	9	r	n	29.06	27.79	4.37	6.54	15.5	354.6	400.5	34.8	39.3
03/06/01	15 - 30	9	r	n	29.15	27.54	5.52	8.71	4.2	76.4	107.7	10.0	14.1
03/06/01	30 - 60	9	r	n	29.11	27.73	4.74	7.42	3.0	62.6	88.0	13.9	19.6
03/06/01	60 - 90	9	r	n	29.07	27.52	5.33	8.39	2.8	52.5	28.3	13.2	7.1
03/06/01	0 - 15	10	r	n	29.04	27.73	4.51	6.76	18.9	419.1	1485.0	42.5	150.5
03/06/01	15 - 30	10	r	n	29.09	27.47	5.57	8.79	35.4	635.2	338.2	83.7	44.6
03/06/01	30 - 60	10	r	n	29.1	27.47	5.60	8.84	9.4	168.6	122.1	44.7	32.4
03/06/01	60 - 90	10	r	n	29.12	27.51	5.53	8.72	5.2	94.8	27.3	24.8	7.1
03/06/01	0 - 15	11	r	n	29.09	27.66	4.92	7.39	26.3	534.7	545.8	59.3	60.5
03/06/01	15 - 30	11	r	n	29.04	27.32	5.92	9.38	26.3	443.8	415.5	62.5	58.5
03/06/01	30 - 60	11	r	n	29.01	27.08	6.65	10.62	4.7	70.2	29.4	22.4	9.4
03/06/01	60 - 90	11	r	n	29.03	27.02	6.92	11.08	8.6	124.9	15.4	41.5	5.1
03/06/01	0 - 15	12	r	s	29.12	27.65	5.05	7.60	52.4	1038.1	1784.7	118.4	203.5
03/06/01	15 - 30	12	r	s	29.12	27.65	5.05	7.92	44.5	880.7	513.9	104.6	61.1
03/06/01	30 - 60	12	r	s	29.02	27.66	4.69	7.33	4.4	93.7	70.1	20.6	15.4
03/06/01	60 - 90	12	r	s	29.06	27.53	5.26	8.28	4.8	90.9	11.8	22.6	2.9
03/06/01	0 - 15	3	r	n	29.15	27.69	5.01	7.54	29.7	592.9	411.5	67.1	46.5

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
03/02/01	15 - 30	3	r	n	29.25	27.6	5.64	8.91	57.8	1025.3	1030.0	137.0	137.6
03/02/01	30 - 60	3	r	n	29.11	27.48	5.60	8.84	25.4	453.0	145.9	120.1	38.7
03/02/01	60 - 90	3	r	n	29.87	28.21	5.56	8.77	6.2	110.9	59.1	29.2	15.6
03/02/01	0 - 15	4	r	s	29.67	28.19	4.99	7.51	41.6	834.0	956.5	93.9	107.7
03/02/01	15 - 30	4	r	s	29.35	27.93	4.84	7.58	23.2	479.5	224.0	54.5	25.5
03/02/01	30 - 60	4	r	s	29.27	27.63	5.60	8.84	4.7	83.9	58.6	22.3	15.6
03/02/01	60 - 90	4	r	s	29.75	28.39	4.57	7.14	5.7	125.3	246.8	26.8	52.8
03/02/01	0 - 15	6	r	s	29.06	27.13	6.64	10.17	45.4	683.5	4307.5	104.3	657.3
03/02/01	15 - 30	6	r	s	29.43	28.02	4.79	7.50	23.2	484.2	105.7	54.5	11.9
03/02/01	30 - 60	6	r	s	29.64	28.01	5.50	8.67	20.0	362.8	641.4	94.4	166.8
03/02/01	60 - 90	6	r	s	29.26	27.86	4.78	7.49	5.8	122.0	59.4	27.4	13.3
03/02/01	0 - 15	7	r	s	29.13	27.64	5.12	7.71	18.9	368.9	6374.6	42.7	737.1
03/02/01	15 - 30	7	r	s	29.16	27.79	4.70	7.35	41.6	885.5	712.9	97.6	78.6
03/02/01	30 - 60	7	r	s	29.11	27.62	5.12	8.04	4.2	82.3	255.1	19.9	61.5
03/02/01	60 - 90	7	r	s	29.15	27.64	5.18	8.14	3.9	76.1	46.3	18.6	11.3
03/06/01	0 - 15	8	r	n	29.04	27.8	4.27	6.38	17.2	402.9	201.8	38.5	19.3
03/06/01	15 - 30	8	r	n	29.16	27.47	5.80	9.17	17.2	296.8	102.7	40.8	14.1
03/06/01	30 - 60	8	r	n	29.01	27.33	5.79	9.16	7.4	127.8	49.1	35.1	13.5
03/06/01	60 - 90	8	r	n	28.99	27.24	6.04	9.57	2.9	47.3	25.0	13.6	7.2
03/06/01	0 - 15	9	r	n	29.06	27.79	4.37	6.54	15.5	354.6	400.5	34.8	39.3
03/06/01	15 - 30	9	r	n	29.15	27.54	5.52	8.71	4.2	76.4	107.7	10.0	14.1
03/06/01	30 - 60	9	r	n	29.11	27.73	4.74	7.42	3.0	62.6	88.0	13.9	19.6
03/06/01	60 - 90	9	r	n	29.07	27.52	5.33	8.39	2.8	52.5	28.3	13.2	7.1
03/06/01	0 - 15	10	r	n	29.04	27.73	4.51	6.76	18.9	419.1	1485.0	42.5	150.5
03/06/01	15 - 30	10	r	n	29.09	27.47	5.57	8.79	35.4	635.2	338.2	83.7	44.6
03/06/01	30 - 60	10	r	n	29.1	27.47	5.60	8.84	9.4	168.6	122.1	44.7	32.4
03/06/01	60 - 90	10	r	n	29.12	27.51	5.53	8.72	5.2	94.8	27.3	24.8	7.1
03/06/01	0 - 15	11	r	n	29.09	27.66	4.92	7.39	26.3	534.7	545.8	59.3	60.5
03/06/01	15 - 30	11	r	n	29.04	27.32	5.92	9.38	26.3	443.8	415.5	62.5	58.5
03/06/01	30 - 60	11	r	n	29.01	27.08	6.65	10.62	4.7	70.2	29.4	22.4	9.4
03/06/01	60 - 90	11	r	n	29.03	27.02	6.92	11.08	8.6	124.9	15.4	41.5	5.1
03/06/01	0 - 15	12	r	s	29.12	27.65	5.05	7.60	52.4	1038.1	1784.7	118.4	203.5
03/06/01	15 - 30	12	r	s	29.12	27.65	5.05	7.92	44.5	880.7	513.9	104.6	61.1
03/06/01	30 - 60	12	r	s	29.02	27.66	4.69	7.33	4.4	93.7	70.1	20.6	15.4
03/06/01	60 - 90	12	r	s	29.06	27.53	5.26	8.28	4.8	90.9	11.8	22.6	2.9
03/06/01	0 - 15	3	r	n	29.15	27.69	5.01	7.54	29.7	592.9	411.5	67.1	46.5
03/06/01	15 - 30	3	r	n	29.1	27.38	5.91	9.36	16.1	271.8	506.6	38.2	71.1
03/06/01	30 - 60	3	r	n	29.07	27.36	5.88	9.31	24.0	408.3	237.1	114.1	66.2
03/06/01	60 - 90	3	r	n	29.01	27.25	6.07	9.62	11.0	180.6	24.9	52.1	7.2
03/06/01	0 - 15	4	r	s	29.04	27.63	4.86	7.30	11.0	225.7	21.9	24.7	2.4
03/06/01	15 - 30	4	r	s	29.1	27.5	5.50	8.67	7.4	134.6	609.2	17.5	79.2
03/06/01	30 - 60	4	r	s	29.07	27.37	5.85	9.25	12.1	206.8	519.6	57.4	144.3
03/06/01	60 - 90	4	r	s	29.01	27.23	6.14	9.74	1.9	30.8	24.6	9.0	7.2
03/07/01	0 - 15	6	r	s	28.9	27.58	4.57	6.84	18.3	401.5	1758.5	41.2	180.5
03/07/01	30 - 60	6	r	s	29.08	27.54	5.30	8.33	3.4	64.6	137.5	16.2	34.4
03/07/01	60 - 90	6	r	s	29	27.44	5.38	8.47	2.3	42.5	11.5	10.8	2.9
03/07/01	15 - 30	7	r	s	29.36	27.93	4.87	7.63	7.5	155.0	158.7	17.7	18.2
03/24/01	0 - 15	8	r	n	29.08	27.29	6.16	9.38	4.2	68.6	1319.3	9.7	185.6
03/24/01	15 - 30	8	r	n	29.05	27.24	6.23	9.90	43.4	696.3	1488.7	103.4	221.1
03/24/01	30 - 60	8	r	n	29.09	27.21	6.46	10.29	52.0	805.0	312.1	248.6	96.4
03/24/01	60 - 90	8	r	n	29.02	27.23	6.17	9.79	9.1	147.9	24.5	43.5	7.2
03/24/01	0 - 15	9	r	n	29.02	27.61	4.86	7.30	3.5	72.7	85.9	8.0	9.4
03/24/01	15 - 30	9	r	n	29.05	27.61	4.96	7.77	14.6	293.9	693.6	34.3	80.9
03/24/01	30 - 60	9	r	n	29.13	27.6	5.25	8.26	19.8	376.2	400.9	93.2	99.3
03/24/01	60 - 90	9	r	n	29.14	27.64	5.15	8.09	13.4	260.7	37.9	63.2	9.2
03/24/01	0 - 15	10	r	n	29.02	27.41	5.55	8.40	8.9	161.3	19.2	20.3	2.4
03/24/01	15 - 30	10	r	n	29.15	27.48	5.73	9.05	21.5	375.0	34.1	50.9	4.6
03/24/01	30 - 60	10	r	n	29.26	27.62	5.60	8.85	18.0	321.6	58.6	85.4	15.6
03/24/01	60 - 90	10	r	n	29.01	27.36	5.69	8.99	6.2	108.7	26.5	29.3	7.1

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
03/24/01	0 - 15	11	r	n	29.1	27.5	5.50	8.32	7.9	143.9	738.5	18.0	92.2
03/24/01	15 - 30	11	r	n	29.07	27.34	5.95	9.43	28.4	477.2	391.1	67.5	55.3
03/24/01	30 - 60	11	r	n	29.1	27.37	5.95	9.42	16.9	283.9	130.0	80.2	36.7
03/24/01	60 - 90	11	r	n	29.17	27.46	5.86	9.28	18.0	307.5	33.3	85.6	9.3
03/24/01	0 - 15	12	r	s	29.2	27.9	4.45	6.66	22.1	495.5	832.2	49.5	83.2
03/24/01	15 - 30	12	r	s	29.17	27.69	5.07	7.96	34.2	673.3	169.8	80.4	20.3
03/24/01	30 - 60	12	r	s	28.99	27.41	5.45	8.59	23.8	436.5	158.1	112.5	40.7
03/24/01	60 - 90	12	r	s	29.26	27.76	5.13	8.05	22.6	441.6	46.8	106.7	11.3
03/24/01	0 - 15	13	r	s	29.4	27.03	8.06	12.54	8.7	107.4	128.9	20.2	24.2
03/24/01	15 - 30	13	r	s	29.41	27.62	6.09	9.66	34.7	570.8	83.2	82.7	12.0
03/24/01	30 - 60	13	r	s	29.17	27.42	6.00	9.51	16.9	281.3	25.1	80.2	7.2
03/24/01	60 - 90	13	r	s	29.25	27.58	5.71	9.02	8.5	148.7	73.1	40.2	19.8
03/24/01	0 - 15	3	r	n	29.07	26.93	7.36	11.36	28.4	385.8	382.6	65.8	65.2
03/24/01	15 - 30	3	r	n	29.11	27.32	6.15	9.76	84.9	1380.3	1262.8	202.1	184.9
03/24/01	30 - 60	3	r	n	29.06	27.27	6.16	9.78	52.6	854.0	168.7	250.6	49.5
03/24/01	60 - 90	3	r	n	29.31	27.45	6.35	10.10	24.9	393.1	30.8	119.1	9.3
03/24/01	0 - 15	4	r	s	29.28	27.74	5.26	7.94	2.7	51.8	28.7	6.2	3.4
03/24/01	15 - 30	4	r	s	29.09	27.76	4.57	7.14	2.0	44.5	246.8	4.8	26.4
03/24/01	30 - 60	4	r	s	29.13	27.59	5.29	8.32	3.4	63.5	230.2	15.9	57.4
03/24/01	60 - 90	4	r	s	29.04	27.5	5.30	8.34	3.6	68.8	62.0	17.2	15.5
03/24/01	0 - 15	6	r	s	29.29	27.8	5.09	7.66	61.2	1204.0	588.6	138.4	67.7
03/24/01	0 - 15	7	r	s	29.17	27.68	5.11	7.70	4.5	87.2	1328.9	10.1	153.4
03/24/01	15 - 30	7	r	s	29.26	27.57	5.78	9.13	58.4	1010.5	803.0	138.4	110.0
03/24/01	30 - 60	7	r	s	29.74	28.08	5.58	8.81	18.0	323.0	480.7	85.3	127.0
03/24/01	60 - 90	7	r	s	28.94	27.26	5.81	9.18	18.6	320.5	270.9	88.3	74.6
03/24/01	15 - 30	7	r	s	29.15	27.63	5.21	8.20	22.1	423.1	454.9	52.0	55.9
03/24/01	30 - 60	7	r	s	29.5	27.85	5.59	8.83	54.9	981.7	138.2	260.0	36.6
03/24/01	60 - 90	7	r	s	29.25	27.68	5.37	8.45	7.5	139.9	77.8	35.5	19.7
04/03/01	0 - 15	8	r	n	29.04	27.68	4.68	7.03	7.6	163.0	961.9	17.2	101.4
04/03/01	15 - 30	8	r	n	29.38	27.82	5.31	8.36	9.5	178.5	61.9	22.4	7.8
04/03/01	30 - 60	8	r	n	28.91	27.28	5.64	8.90	11.2	197.8	34.6	52.8	9.3
04/03/01	60 - 90	8	r	n	29.68	28.04	5.53	8.71	13.5	243.6	11.2	63.7	2.9
04/03/01	0 - 15	9	r	n	29.67	28.46	4.08	6.08	4.6	113.6	320.2	10.4	29.2
04/03/01	15 - 30	9	r	n	29.35	28.08	4.33	6.74	14.0	324.4	979.4	32.8	99.0
04/03/01	30 - 60	9	r	n	29.34	27.72	5.52	8.71	15.2	275.2	397.4	71.9	103.8
04/03/01	60 - 90	9	r	n	29.35	27.91	4.91	7.69	38.3	779.9	302.4	179.9	69.7
04/03/01	0 - 15	10	r	n	29.51	28.28	4.17	6.22	6.8	162.4	292.0	15.1	27.2
04/03/01	15 - 30	10	r	n	29.58	28.01	5.31	8.35	18.1	340.6	112.1	42.7	14.0
04/03/01	30 - 60	10	r	n	29.17	27.61	5.35	8.42	8.1	151.4	443.6	38.2	112.0
04/03/01	60 - 90	10	r	n	29.15	27.68	5.04	7.91	48.1	953.2	47.5	226.3	11.3
04/03/01	0 - 15	11	r	n	29.15	27.64	5.18	7.81	29.0	560.5	1670.6	65.7	195.8
04/03/01	15 - 30	11	r	n	29.82	28.28	5.16	8.11	51.5	997.8	958.3	121.4	116.6
04/03/01	30 - 60	11	r	n	29.29	27.6	5.77	9.12	34.8	603.2	133.9	165.1	36.7
04/03/01	60 - 90	11	r	n	29.75	27.18	8.64	14.09	29.0	336.1	58.6	142.1	24.8
04/03/01	0 - 15	12	r	s	29.49	28.21	4.34	6.49	2.2	50.9	55.2	5.0	5.4
04/03/01	15 - 30	12	r	s	29.21	28.2	3.46	5.34	14.6	422.7	69.3	33.8	5.5
04/03/01	30 - 60	12	r	s	29.04	27.5	5.30	8.34	40.6	765.0	355.2	191.5	88.9
04/03/01	60 - 90	12	r	s	29.43	27.89	5.23	8.23	70.0	1337.5	249.6	330.1	61.6
04/03/01	0 - 15	13	r	s	28.97	26.83	7.39	11.41	5.8	78.3	62.5	13.4	10.7
04/03/01	15 - 30	13	r	s	29.01	27.67	4.62	7.22	10.0	216.5	523.2	23.4	56.6
04/03/01	30 - 60	13	r	s	29.83	28.19	5.50	8.67	29.0	528.1	67.8	137.3	17.6
04/03/01	60 - 90	13	r	s	29.98	28.31	5.57	8.79	21.5	386.6	43.0	101.9	11.3
04/03/01	0 - 15	3	r	n	29.52	27.75	6.00	9.12	10.6	176.4	817.9	24.1	111.9
04/03/01	15 - 30	3	r	n	29.43	27.74	5.74	9.08	26.2	455.4	312.5	62.0	42.6
04/03/01	30 - 60	3	r	n	29.84	27.87	6.60	10.53	40.6	614.5	56.5	194.2	17.9
04/03/01	60 - 90	3	r	n	29.45	27.57	6.38	10.16	26.2	409.7	37.5	124.9	11.4
04/03/01	0 - 15	4	r	s	29.73	27.89	6.19	9.43	21.5	348.0	60.3	49.2	8.5
04/03/01	15 - 30	4	r	s	29.43	27.83	5.44	8.57	38.3	703.8	191.2	90.4	24.6
04/03/01	30 - 60	4	r	s	29.06	27.5	5.37	8.45	69.4	1293.0	61.2	327.9	15.5

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
04/03/01	60 - 90	4	r	s	29.35	27.72	5.55	8.76	29.0	522.8	19.2	137.4	5.0
04/03/01	0 - 15	6	r	s	29.37	28.81	1.91	2.78	5.6	294.5	498.5	12.3	20.8
04/03/01	15 - 30	6	r	s	29.76	28.28	4.97	7.80	40.6	815.8	1490.0	95.4	174.3
04/03/01	30 - 60	6	r	s	29.38	28.01	4.66	7.29	27.3	585.6	480.1	128.0	105.0
04/03/01	60 - 90	6	r	s	29.86	28.2	5.56	8.77	7.7	138.3	83.1	36.4	21.9
04/03/01	0 - 15	7	r	s	29.1	28.31	2.71	3.99	6.7	247.2	7101.4	14.8	425.1
04/03/01	15 - 30	7	r	s	29.72	28.7	3.43	5.30	26.2	762.0	264.0	60.5	21.0
04/03/01	30 - 60	7	r	s	29.5	27.9	5.42	8.54	12.9	237.6	85.1	60.9	21.8
04/03/01	60 - 90	7	r	s	29.08	27.5	5.43	8.56	13.5	247.8	44.1	63.6	11.3
04/20/01	0 - 15	8	r	n	29.48	27.67	6.14	9.35	0.9	14.2	116.7	2.0	16.4
04/20/01	15 - 30	8	r	n	29.04	27.18	6.40	10.20	0.8	11.8	44.5	1.8	6.8
04/20/01	30 - 60	8	r	n	29.23	27.47	6.02	9.55	0.5	8.8	37.1	2.5	10.6
04/20/01	60 - 90	8	r	n	29.56	27.93	5.51	8.70	0.9	15.8	40.5	4.1	10.6
04/20/01	0 - 15	9	r	n	29.69	28.15	5.19	7.82	24.0	462.1	90.6	54.2	10.6
04/20/01	15 - 30	9	r	n	29.24	27.75	5.10	8.00	13.2	259.5	152.7	31.1	18.3
04/20/01	30 - 60	9	r	n	29.37	27.83	5.24	8.25	8.8	168.7	54.4	41.7	13.4
04/20/01	60 - 90	9	r	n	29.42	27.96	4.96	7.78	9.0	180.5	57.4	42.1	13.4
04/20/01	0 - 15	10	r	n	29.1	26.94	7.42	11.47	1.8	23.9	38.4	4.1	6.6
04/20/01	15 - 30	10	r	n	29.38	27.56	6.19	9.84	5.0	80.7	75.9	11.9	11.2
04/20/01	30 - 60	10	r	n	29.78	28.05	5.81	9.19	1.5	25.7	80.9	7.1	22.3
04/20/01	60 - 90	10	r	n	29.11	27.45	5.70	9.01	3.1	53.9	50.0	14.6	13.5
04/20/01	0 - 15	11	r	n	29.31	27.15	7.37	11.38	1.9	25.6	72.1	4.4	12.3
04/20/01	15 - 30	11	r	n	29.38	27.57	6.16	9.78	9.7	157.3	186.3	23.1	27.3
04/20/01	30 - 60	11	r	n	28.98	27.08	6.56	10.45	1.0	15.9	306.7	5.0	96.2
04/20/01	60 - 90	11	r	n	29.48	27.8	5.70	9.00	1.4	25.2	114.9	6.8	31.0
04/20/01	0 - 15	12	r	s	29.76	28.2	5.24	7.91	1.3	24.1	54.4	2.9	6.5
04/20/01	15 - 30	12	r	s	29	27.51	5.14	8.07	1.0	19.1	43.5	2.3	5.3
04/20/01	30 - 60	12	r	s	29.37	27.91	4.97	7.79	2.1	42.5	44.9	9.9	10.5
04/20/01	60 - 90	12	r	s	29.85	28.23	5.43	8.55	1.9	34.8	41.2	8.9	10.6
04/20/01	0 - 15	13	r	s	29.23	27	7.63	11.81	1.2	15.1	37.4	2.7	6.6
04/20/01	15 - 30	13	r	s	29.22	27.32	6.50	10.36	0.5	7.3	24.9	1.1	3.9
04/20/01	30 - 60	13	r	s	29.18	27.54	5.62	8.87	1.4	24.5	61.7	6.5	16.4
04/20/01	60 - 90	13	r	s	29.21	27.52	5.79	9.15	0.9	16.0	49.3	4.4	13.5
04/20/01	0 - 15	3	r	n	29.15	26.8	8.06	12.54	1.2	15.0	65.9	2.8	12.4
04/20/01	15 - 30	3	r	n	29.313	27.33	6.76	10.81	0.6	9.5	42.1	1.5	6.8
04/20/01	30 - 60	3	r	n	29.96	28.14	6.07	9.64	0.4	5.9	67.2	1.7	19.4
04/20/01	60 - 90	3	r	n	29.06	27.44	5.57	8.80	0.6	10.5	51.1	2.8	13.5
04/20/01	0 - 15	4	r	s	29.39	27.54	6.29	9.61	0.8	12.9	45.3	1.9	6.5
04/20/01	15 - 30	4	r	s	29.07	27.26	6.23	9.89	0.5	8.5	45.8	1.3	6.8
04/20/01	30 - 60	4	r	s	29.28	27.63	5.64	8.90	0.2	4.4	50.6	1.2	13.5
04/20/01	60 - 90	4	r	s	29.87	28.09	5.96	9.44	0.4	6.1	47.8	1.7	13.5
04/20/01	0 - 15	6	r	s	29.04	27.32	5.92	9.00	2.5	42.4	58.5	5.7	7.9
04/20/01	15 - 30	6	r	s	29.37	27.86	5.14	8.08	6.1	119.2	55.4	14.4	6.7
04/20/01	30 - 60	6	r	s	29.28	27.77	5.16	8.10	1.6	31.1	31.4	7.6	7.6
04/20/01	60 - 90	6	r	s	29.13	27.61	5.22	8.20	5.0	95.8	31.0	23.6	7.6
04/20/01	0 - 15	7	r	s	29.13	27.12	6.90	10.60	1.1	15.9	41.3	2.5	6.6
04/20/01	15 - 30	7	r	s	29.02	27.22	6.20	9.85	0.5	8.5	36.0	1.3	5.3
04/20/01	30 - 60	7	r	s	29.48	27.74	5.90	9.35	0.3	5.2	37.8	1.4	10.6
04/20/01	60 - 90	7	r	s	29.93	28.3	5.45	8.58	0.9	17.0	41.0	4.4	10.6
05/04/01	0 - 15	8	r	n	29.01	28.07	3.24	4.79	6.8	211.1	65.6	15.2	4.7
05/04/01	15 - 30	8	r	n	29.02	27.76	4.34	6.76	48.0	1106.4	94.9	112.2	9.6
05/04/01	30 - 60	8	r	n	29.89	28.16	5.79	9.15	32.9	568.8	170.6	156.2	46.8
05/04/01	60 - 90	8	r	n	29.31	27.77	5.25	8.26	27.1	515.9	145.5	127.9	36.1
05/04/01	0 - 15	9	r	n	29.15	27.67	5.08	7.65	2.4	47.7	45.3	5.5	5.2
05/04/01	15 - 30	9	r	n	29.65	28.07	5.33	8.39	10.3	192.7	61.9	24.2	7.8
05/04/01	30 - 60	9	r	n	29.21	27.67	5.27	8.29	2.0	38.2	100.4	9.5	25.0
05/04/01	60 - 90	9	r	n	29.24	27.89	4.62	7.21	0.8	17.1	53.6	3.7	11.6
05/04/01	0 - 15	10	r	n	29.07	28.17	3.10	4.57	2.8	91.3	78.1	6.3	5.4
05/04/01	15 - 30	10	r	n	29.19	23.93	18.02	32.75	6.0	33.1	26.1	16.3	12.8

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
05/04/01	30 - 60	10	r	n	29.54	27.86	5.69	8.98	9.9	174.4	290.9	47.0	78.4
05/04/01	60 - 90	10	r	n	29.13	27.43	5.84	9.23	11.4	195.5	96.8	54.1	26.8
05/04/01	0 - 15	11	r	n	29.32	27.02	7.84	12.17	2.4	30.8	33.1	5.6	6.0
05/04/01	15 - 30	11	r	n	29.65	28.61	3.51	5.42	1.5	42.5	219.6	3.5	17.8
05/04/01	30 - 60	11	r	n	29.5	28.03	4.98	7.81	7.8	157.1	284.9	36.8	66.8
05/04/01	60 - 90	11	r	n	29.28	27.75	5.23	8.22	4.0	76.4	82.2	18.8	20.3
05/04/01	0 - 15	12	r	s	29.08	28.02	3.65	5.41	16.6	456.5	59.9	37.0	4.9
05/04/01	15 - 30	12	r	s	29.78	28.93	2.85	4.38	17.8	623.7	99.1	41.0	6.5
05/04/01	30 - 60	12	r	s	29.49	28.06	4.85	7.59	3.0	61.9	39.0	14.1	8.9
05/04/01	60 - 90	12	r	s	29.36	27.83	5.21	8.19	1.3	24.1	48.6	5.9	12.0
05/04/01	0 - 15	13	r	s	29.6	28.21	4.70	7.05	13.2	280.0	87.7	29.6	9.3
05/04/01	15 - 30	13	r	s	29.11	27.58	5.26	8.27	38.2	725.9	103.0	90.0	12.8
05/04/01	30 - 60	13	r	s	29.76	28.1	5.58	8.80	21.9	392.1	126.5	103.5	33.4
05/04/01	60 - 90	13	r	s	29.49	28.02	4.98	7.82	22.5	450.5	101.5	105.6	23.8
05/04/01	0 - 15	3	r	n	29.64	28.17	4.96	7.46	3.9	79.3	65.3	8.9	7.3
05/04/01	15 - 30	3	r	n	29.06	27.7	4.68	7.32	0.5	10.7	64.2	1.2	7.0
05/04/01	30 - 60	3	r	n	29.06	27.32	5.99	9.49	0.5	8.4	178.3	2.4	50.8
05/04/01	60 - 90	3	r	n	29.49	27.87	5.49	8.66	0.6	10.2	109.2	2.6	28.4
05/04/01	0 - 15	4	r	s	29.42	27.95	5.00	7.52	5.6	112.4	84.8	12.7	9.6
05/04/01	15 - 30	4	r	s	29.35	27.93	4.84	7.58	0.6	11.6	74.2	1.3	8.4
05/04/01	30 - 60	4	r	s	29.12	27.64	5.08	7.98	3.2	62.5	325.5	15.0	77.9
05/04/01	60 - 90	4	r	s	29.04	27.35	5.82	9.21	1.3	21.6	125.3	6.0	34.6
05/04/01	0 - 15	6	r	s	29.49	28.45	3.53	5.23	12.6	356.4	306.9	27.9	24.1
05/04/01	15 - 30	6	r	s	29.14	27.8	4.60	7.18	41.6	905.5	359.8	97.6	38.8
05/04/01	30 - 60	6	r	s	29.37	27.96	4.80	7.51	14.9	310.3	320.2	69.9	72.2
05/04/01	60 - 90	6	r	s	29.16	27.75	4.84	7.57	13.7	284.0	165.3	64.5	37.6
05/04/01	0 - 15	7	r	s	29.61	28.55	3.58	5.31	3.8	106.6	193.8	8.5	15.4
05/04/01	15 - 30	7	r	s	29.57	28.24	4.50	7.02	7.9	176.6	68.1	18.6	7.2
05/04/01	30 - 60	7	r	s	29.28	27.79	5.09	7.99	12.0	235.6	159.4	56.5	38.2
05/04/01	60 - 90	7	r	s	29.08	27.57	5.19	8.16	21.3	410.0	329.9	100.4	80.8
05/25/01	0 - 15	8	r	n	29.64	23.4	21.05	38.13	3.5	16.5	41.3	9.4	23.6
05/25/01	15 - 30	8	r	n	29.46	23.58	19.96	37.16	15.3	76.7	36.2	42.8	20.2
05/25/01	30 - 60	8	r	n	29.43	24.58	16.48	29.40	1.1	6.5	24.6	5.8	21.7
05/25/01	60 - 90	8	r	n	29.63	28.19	4.86	7.61	11.9	243.9	64.2	55.7	14.7
05/25/01	0 - 15	9	r	n	29.91	28.52	4.65	6.97	4.4	94.4	69.7	9.9	7.3
05/25/01	15 - 30	9	r	n	29.05	23.46	19.24	35.50	6.1	31.7	18.7	16.9	9.9
05/25/01	30 - 60	9	r	n	29.38	27.91	5.00	7.85	4.7	93.4	354.2	22.0	83.4
05/25/01	60 - 90	9	r	n	29.1	27.49	5.53	8.73	2.0	37.0	95.7	9.7	25.1
05/25/01	0 - 15	10	r	n	29.72	23.34	21.47	39.09	2.5	11.7	28.8	6.8	16.9
05/25/01	15 - 30	10	r	n	29.4	28.32	3.67	5.68	22.7	618.9	115.4	52.8	9.8
05/25/01	30 - 60	10	r	n	29.85	28.47	4.62	7.22	7.5	161.5	172.9	35.0	37.5
05/25/01	60 - 90	10	r	n	29.6	24.6	16.89	30.28	1.6	9.4	15.4	8.5	14.0
05/25/01	0 - 15	11	r	n	29.53	28.58	3.22	4.75	5.1	157.6	182.8	11.2	13.0
05/25/01	15 - 30	11	r	n	29.27	28.08	4.07	6.31	5.9	144.4	101.3	13.7	9.6
05/25/01	30 - 60	11	r	n	29.7	26.77	9.87	16.31	1.1	11.5	43.6	5.6	21.3
05/25/01	60 - 90	11	r	n	29.14	27.51	5.59	8.83	2.5	44.7	82.1	11.8	21.7
05/25/01	0 - 15	12	r	s	29.17	28.66	1.75	2.54	4.8	273.7	296.1	10.4	11.3
05/25/01	15 - 30	12	r	s	29.11	28.07	3.57	5.52	29.0	812.1	97.3	67.3	8.1
05/25/01	30 - 60	12	r	s	29.18	24.04	17.61	31.86	1.6	9.0	22.1	8.6	21.1
05/25/01	60 - 90	12	r	s	29.42	26.19	10.98	18.38	57.0	519.0	31.1	286.1	17.2
05/25/01	0 - 15	13	r	s	29.34	28.44	3.07	4.53	13.0	424.9	140.1	28.8	9.5
05/25/01	15 - 30	13	r	s	29.24	27.78	4.99	7.83	19.3	386.8	119.0	45.4	14.0
05/25/01	30 - 60	13	r	s	29.18	24.16	17.20	30.96	5.4	31.5	15.8	29.2	14.6
05/25/01	60 - 90	13	r	s	29.44	28.1	4.55	7.11	6.2	135.2	91.8	28.8	19.6
05/25/01	0 - 15	3	r	n	29.06	28.11	3.27	4.83	3.5	106.2	205.1	7.7	14.9
05/25/01	15 - 30	3	r	n	29.45	27.98	4.99	7.83	4.8	97.0	101.4	11.4	11.9
05/25/01	30 - 60	3	r	n	29.08	27.43	5.67	8.96	10.6	186.8	155.4	50.2	41.8
05/25/01	60 - 90	3	r	n	29.8	28.21	5.34	8.40	6.5	121.8	64.0	30.7	16.1
05/25/01	0 - 15	4	r	s	29.63	28.74	3.00	4.43	4.3	144.1	139.1	9.6	9.2

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
05/25/01	15 - 30	4	r	s	29.56	28.39	3.96	6.14	5.6	142.5	130.8	13.1	12.0
05/25/01	30 - 60	4	r	s	29.78	27.9	6.31	10.04	4.4	70.4	42.9	21.2	12.9
05/25/01	60 - 90	4	r	s	29.21	23.25	20.40	38.20	2.2	10.9	15.6	12.4	17.9
05/25/01	0 - 15	6	r	s	29.03	28.6	1.48	2.15	8.8	596.6	305.9	19.2	9.9
05/25/01	15 - 30	6	r	s	29.87	28.53	4.49	7.00	26.7	595.9	136.3	62.6	14.3
05/25/01	30 - 60	6	r	s	29.15	27.82	4.56	7.12	7.2	158.7	154.6	33.9	33.0
05/25/01	60 - 90	6	r	s	29.63	28.39	4.18	6.51	9.7	231.6	141.9	45.2	27.7
05/25/01	0 - 15	7	r	s	29.55	28.88	2.27	3.32	3.5	153.1	114.4	7.6	5.7
05/25/01	15 - 30	7	r	s	29.03	28	3.55	5.48	2.2	62.5	104.5	5.1	8.6
05/25/01	30 - 60	7	r	s	29.27	27.96	4.48	6.98	6.6	146.4	55.3	30.7	11.6
05/25/01	60 - 90	7	r	s	29.39	28.06	4.53	7.06	2.3	51.5	54.7	10.9	11.6
06/06/01	0 - 15	8	r	n	29.13	27.51	5.56	8.42	13.6	245.2	162.8	31.0	20.6
06/06/01	15 - 30	8	r	n	29.7	28.15	5.22	8.20	17.0	326.5	157.7	40.2	19.4
06/06/01	30 - 60	8	r	n	29.82	27.8	6.77	10.83	10.2	151.0	52.2	49.0	16.9
06/06/01	60 - 90	8	r	n	29.53	28.03	5.08	7.97	6.1	119.6	62.6	28.6	15.0
06/06/01	0 - 15	9	r	n	29.26	27.8	4.99	7.51	6.4	127.5	157.9	14.4	17.8
06/06/01	15 - 30	9	r	n	29.68	28.21	4.95	7.76	6.2	126.1	84.4	14.7	9.8
06/06/01	30 - 60	9	r	n	29.43	27.85	5.37	8.45	3.0	55.0	110.6	14.0	28.1
06/06/01	60 - 90	9	r	n	29.65	28.11	5.19	8.16	3.7	72.2	74.8	17.7	18.3
06/06/01	0 - 15	10	r	n	29.45	28.38	3.63	5.39	34.1	938.0	139.3	75.9	11.3
06/06/01	15 - 30	10	r	n	29.62	28.28	4.52	7.06	57.9	1280.6	339.8	135.6	36.0
06/06/01	30 - 60	10	r	n	29.34	28.11	4.19	6.52	10.1	241.1	189.3	47.2	37.0
06/06/01	60 - 90	10	r	n	29.64	24.54	17.21	30.97	6.6	38.3	37.9	35.6	35.2
06/06/01	0 - 15	11	r	n	29.39	27.82	5.34	8.07	8.9	165.9	138.7	20.1	16.8
06/06/01	15 - 30	11	r	n	29.29	27.86	4.88	7.65	41.5	849.3	196.2	97.4	22.5
06/06/01	30 - 60	11	r	n	29.25	27.86	4.75	7.43	31.2	657.4	186.8	146.6	41.7
06/06/01	60 - 90	11	r	n	29.39	27.93	4.97	7.79	27.3	548.8	129.0	128.2	30.1
06/06/01	0 - 15	12	r	s	29.74	28.62	3.77	5.60	6.9	184.0	100.1	15.4	8.4
06/06/01	15 - 30	12	r	s	29.43	28.2	4.18	6.50	60.2	1440.5	98.6	140.4	9.6
06/06/01	30 - 60	12	r	s	29.41	27.92	5.07	7.95	13.9	273.5	57.0	65.3	13.6
06/06/01	60 - 90	12	r	s	29.37	27.92	4.94	7.74	8.3	169.1	68.0	39.3	15.8
06/06/01	0 - 15	13	r	s	29.27	27.8	5.02	7.56	9.1	180.9	98.4	20.5	11.2
06/06/01	15 - 30	13	r	s	29.14	27.81	4.56	7.13	6.6	144.3	87.7	15.4	9.4
06/06/01	30 - 60	13	r	s	29.68	28.39	4.35	6.77	9.0	206.5	75.9	41.9	15.4
06/06/01	60 - 90	13	r	s	29.46	28.01	4.92	7.71	4.4	90.0	88.5	20.8	20.5
06/06/01	0 - 15	3	r	n	29.43	27.97	4.96	7.46	16.5	332.1	144.6	37.2	16.2
06/06/01	15 - 30	3	r	n	29.21	27.52	5.79	9.15	52.3	903.1	115.9	124.0	15.9
06/06/01	30 - 60	3	r	n	29.47	27.57	6.45	10.27	14.2	220.3	149.5	67.9	46.1
06/06/01	60 - 90	3	r	n	29.24	27.47	6.05	9.60	5.5	90.1	224.8	25.9	64.8
06/06/01	0 - 15	4	r	s	29.44	28.08	4.62	6.93	9.8	211.5	157.8	22.0	16.4
06/06/01	15 - 30	4	r	s	29.85	28.59	4.22	6.57	6.9	162.8	100.4	16.0	9.9
06/06/01	30 - 60	4	r	s	29.61	27.85	5.94	9.42	5.3	88.9	63.4	25.1	17.9
06/06/01	60 - 90	4	r	s	29.31	27.87	4.91	7.70	8.5	173.4	82.7	40.0	19.1
01/09/02	0 - 15	8	r	n	29.57	28.08	5.04	7.59	7.1	140.3	85.8	16.0	9.8
01/09/02	15 - 30	8	r	n	29.41	27.89	5.17	8.12	8.6	165.7	82.5	20.2	10.0
01/09/02	30 - 60	8	r	n	29.15	27.55	5.49	8.65	3.9	71.5	56.2	18.6	14.6
01/09/02	60 - 90	8	r	n	29.5	27.99	5.12	8.04	1.0	19.5	69.5	4.7	16.8
01/09/02	0 - 15	9	r	n	29.4	27.94	4.97	7.47	3.3	67.3	69.2	7.5	7.8
01/09/02	15 - 30	9	r	n	29.47	27.94	5.19	8.16	0.7	13.0	46.9	1.6	5.7
01/09/02	30 - 60	9	r	n	29.78	28.25	5.14	8.07	1.3	25.6	101.3	6.2	24.5
01/09/02	60 - 90	9	r	n	29.71	28.26	4.88	7.65	1.2	23.7	109.1	5.4	25.0
01/09/02	0 - 15	10	r	n	29.73	27.98	5.89	8.94	2.3	39.5	69.4	5.3	9.3
01/09/02	15 - 30	10	r	n	29.27	27.66	5.50	8.67	1.3	23.9	79.6	3.1	10.4
01/09/02	30 - 60	10	r	n	29.31	27.76	5.29	8.32	4.1	77.3	51.6	19.3	12.9
01/09/02	60 - 90	10	r	n	29.23	27.76	5.03	7.89	0.8	15.6	71.9	3.7	17.0
01/09/02	0 - 15	11	r	n	29.27	27.66	5.50	8.32	2.4	43.3	124.6	5.4	15.6
01/09/02	15 - 30	11	r	n	29.23	27.72	5.17	8.12	1.4	27.5	84.8	3.4	10.3
01/09/02	30 - 60	11	r	n	29.43	27.87	5.30	8.34	1.2	22.8	57.1	5.7	14.3
01/09/02	60 - 90	11	r	n	29.36	27.7	5.65	8.93	6.4	113.7	28.5	30.5	7.6

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
01/09/02	0 - 15	12	r	s	29.76	28.36	4.70	7.06	3.2	68.7	70.6	7.3	7.5
01/09/02	15 - 30	12	r	s	29.69	28.01	5.66	8.94	2.2	38.3	26.4	5.1	3.5
01/09/02	30 - 60	12	r	s	29.61	27.98	5.50	8.68	2.7	49.1	47.5	12.8	12.4
01/09/02	60 - 90	12	r	s	29.46	27.9	5.30	8.33	1.5	28.9	34.9	7.2	8.7
01/09/02	0 - 15	13	r	s	29.69	28.24	4.88	7.34	10.3	211.0	36.6	23.2	4.0
01/09/02	15 - 30	13	r	s	29.43	27.82	5.47	8.62	6.4	117.6	93.0	15.2	12.0
01/09/02	30 - 60	13	r	s	29.71	27.94	5.96	9.44	2.6	43.5	73.5	12.3	20.8
01/09/02	60 - 90	13	r	s	29.44	27.83	5.47	8.62	0.6	10.4	27.3	2.7	7.1
01/09/02	0 - 15	3	r	n	29.27	27.69	5.40	8.16	4.6	85.6	172.8	10.5	21.1
01/09/02	15 - 30	3	r	n	29.37	27.86	5.14	8.08	3.8	73.3	45.1	8.9	5.5
01/09/02	30 - 60	3	r	n	29.34	27.6	5.93	9.39	2.7	45.5	67.9	12.8	19.1
01/09/02	60 - 90	3	r	n	29.84	28.32	5.09	8.00	0.9	18.5	37.4	4.4	9.0
01/09/02	0 - 15	4	r	s	29.35	27.86	5.08	7.65	4.6	91.0	37.6	10.4	4.3
01/09/02	15 - 30	4	r	s	29.54	27.89	5.59	8.81	7.5	134.2	59.4	17.7	7.9
01/09/02	30 - 60	4	r	s	29.99	28.31	5.60	8.84	2.3	40.6	61.4	10.8	16.3
01/09/02	60 - 90	4	r	s	29.27	27.79	5.06	7.94	0.9	18.6	105.3	4.4	25.1
01/09/02	0 - 15	6	r	s	29.51	27.93	5.35	8.09	3.4	64.4	52.1	7.8	6.3
01/09/02	15 - 30	6	r	s	29.18	27.48	5.83	9.22	1.8	31.7	50.9	4.4	7.0
01/09/02	30 - 60	6	r	s	29.65	27.91	5.87	9.29	6.2	106.0	80.7	29.5	22.5
01/09/02	60 - 90	6	r	s	30.61	29.12	4.87	7.62	7.1	145.3	57.3	33.2	13.1
01/09/02	0 - 15	7	r	s	29.9	28.63	4.25	6.34	2.9	68.6	53.2	6.5	5.1
01/09/02	15 - 30	7	r	s	32.23	30.48	5.43	8.55	1.1	20.3	72.0	2.6	9.2
01/09/02	30 - 60	7	r	s	30.78	28.99	5.82	9.20	2.0	33.6	63.2	9.3	17.4
01/09/02	60 - 90	7	r	s	33.07	31.17	5.75	9.08	2.7	47.0	37.3	12.8	10.2
01/23/02	0 - 15	8	r	n	29.6	27.92	5.68	8.60	13.2	231.8	624.5	29.9	80.6
01/23/02	15 - 30	8	r	n	29.37	27.43	6.61	10.54	87.8	1328.6	736.3	210.0	116.4
01/23/02	30 - 60	8	r	n	29.85	27.94	6.40	10.19	5.4	83.9	50.0	25.6	15.3
01/23/02	60 - 90	8	r	n	29.44	27.72	5.84	9.25	3.8	64.5	27.3	17.9	7.6
01/23/02	0 - 15	9	r	n	29.48	27.72	5.97	9.08	1.4	23.8	161.2	3.2	22.0
01/23/02	15 - 30	9	r	n	29.63	27.52	7.12	11.42	9.8	138.2	248.0	23.7	42.5
01/23/02	30 - 60	9	r	n	29.72	27.47	7.57	12.20	4.9	65.2	91.5	23.9	33.5
01/23/02	60 - 90	9	r	n	29.61	27.8	6.11	9.70	2.3	37.2	49.5	10.8	14.4
01/23/02	0 - 15	10	r	n	29.45	27.72	5.87	8.92	0.5	7.9	114.0	1.1	15.3
01/23/02	15 - 30	10	r	n	29.03	27.15	6.48	10.32	51.5	795.6	582.7	123.1	90.2
01/23/02	30 - 60	10	r	n	29.52	27.39	7.22	11.59	2.2	30.8	34.8	10.7	12.1
01/23/02	60 - 90	10	r	n	29.49	27.78	5.80	9.17	1.0	17.2	25.5	4.7	7.0
01/23/02	0 - 15	11	r	n	29.64	27.88	5.94	9.03	9.4	157.7	365.1	21.3	49.4
01/23/02	15 - 30	11	r	n	29.46	27.72	5.91	9.35	55.8	944.5	425.3	132.5	59.7
01/23/02	30 - 60	11	r	n	29.97	28.36	5.37	8.46	4.3	80.0	70.2	20.3	17.8
01/23/02	60 - 90	11	r	n	29.05	27.48	5.40	8.51	2.6	48.0	56.0	12.3	14.3
01/23/02	0 - 15	12	r	s	29.56	28.19	4.63	6.95	126.2	2723.4	1829.1	283.9	190.7
01/23/02	15 - 30	12	r	s	29.67	28.17	5.06	7.93	71.8	1419.7	701.1	169.0	83.4
01/23/02	30 - 60	12	r	s	29.3	27.49	6.18	9.81	4.8	78.2	63.9	23.0	18.8
01/23/02	60 - 90	12	r	s	30	28.33	5.57	8.78	2.3	40.9	41.0	10.8	10.8
01/23/02	0 - 15	13	r	s	29.98	28.24	5.80	8.81	142.2	2450.2	1717.6	323.8	227.0
01/23/02	15 - 30	13	r	s	29.38	27.53	6.30	10.01	41.4	657.4	271.4	98.7	40.8
01/23/02	30 - 60	13	r	s	29.01	27.17	6.34	10.09	3.0	47.6	34.2	14.4	10.3
01/23/02	60 - 90	13	r	s	29.79	28.04	5.87	9.30	2.6	44.2	20.3	12.3	5.7
01/23/02	0 - 15	3	r	n	29.27	27.66	5.50	8.32	19.5	355.4	63.4	44.4	7.9
01/23/02	15 - 30	3	r	n	29.24	27.57	5.71	9.03	54.7	958.1	379.5	129.7	51.4
01/23/02	30 - 60	3	r	n	29.82	28.13	5.67	8.95	18.5	326.1	56.5	87.6	15.2
01/23/02	60 - 90	3	r	n	29.47	27.69	6.04	9.58	2.8	46.5	34.0	13.4	9.8
01/23/02	0 - 15	4	r	s	29.26	27.04	7.59	11.74	1.5	19.4	116.3	3.4	20.5
01/23/02	15 - 30	4	r	s	29.62	27.8	6.14	9.75	59.0	959.9	464.8	140.5	68.0
01/23/02	30 - 60	4	r	s	29.5	27.83	5.66	8.94	8.2	144.7	112.3	38.8	30.1
01/23/02	60 - 90	4	r	s	29.46	27.64	6.18	9.81	1.4	23.0	23.9	6.8	7.0
01/23/02	0 - 15	6	r	s	29.92	28.03	6.32	9.64	16.4	258.9	216.0	37.4	31.2
01/23/02	15 - 30	6	r	s	29.16	27.43	5.93	9.40	5.0	85.0	110.0	12.0	15.5
01/23/02	30 - 60	6	r	s	29.91	27.9	6.72	10.73	0.8	11.6	22.0	3.8	7.1

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
01/23/02	60 - 90	6	r	s	29.02	27.07	6.72	10.73	0.4	5.3	20.3	1.7	6.5
01/23/02	0 - 15	7	r	s	29.4	27.67	5.88	8.94	4.3	73.1	128.5	9.8	17.2
01/23/02	15 - 30	7	r	s	29.72	28.03	5.69	8.98	8.8	154.3	98.6	20.8	13.3
01/23/02	30 - 60	7	r	s	29.85	28.08	5.93	9.39	0.9	15.9	36.6	4.5	10.3
01/23/02	60 - 90	7	r	s	29.05	27.18	6.44	10.25	1.1	17.1	31.0	5.3	9.5
01/30/02	0 - 15	8	f	n	29.79	28.17	5.44	8.22	1.3	23.5	48.2	2.9	5.9
01/30/02	15 - 30	8	f	n	29.41	27.56	6.29	10.00	1.2	19.4	65.1	2.9	9.8
01/30/02	30 - 60	8	f	n	29.38	27.83	5.28	8.30	1.2	23.2	35.1	5.8	8.7
01/30/02	60 - 90	8	f	n	29.14	27.57	5.39	8.48	1.0	18.6	39.9	4.7	10.2
01/30/02	0 - 15	8	r	n	29.94	28.26	5.61	8.50	2.8	49.5	792.6	6.3	101.1
01/30/02	15 - 30	8	r	n	29.94	28.35	5.31	8.36	28.3	533.5	282.5	66.9	35.4
01/30/02	30 - 60	8	r	n	29.38	27.62	5.99	9.49	21.4	357.0	108.7	101.7	31.0
01/30/02	60 - 90	8	r	n	29.76	28.06	5.71	9.03	2.5	43.8	49.0	11.9	13.3
01/30/02	0 - 15	9	f	n	29.02	27.32	5.86	8.90	0.8	13.3	66.9	1.8	8.9
01/30/02	15 - 30	9	f	n	29.57	27.83	5.88	9.32	0.3	5.7	110.6	0.8	15.5
01/30/02	30 - 60	9	f	n	29.4	27.72	5.71	9.03	0.3	5.8	59.3	1.6	16.1
01/30/02	60 - 90	9	f	n	29.58	28.02	5.27	8.30	0.4	8.4	35.2	2.1	8.7
01/30/02	0 - 15	9	r	n	29.36	27.54	6.20	9.45	8.1	130.8	365.6	18.5	51.8
01/30/02	15 - 30	9	r	n	29.25	27.44	6.19	9.83	15.6	251.4	366.3	37.1	54.0
01/30/02	30 - 60	9	r	n	29.25	27.67	5.40	8.51	2.4	45.3	35.4	11.6	9.0
01/30/02	60 - 90	9	r	n	29.95	28.16	5.98	9.47	3.4	57.6	34.0	16.4	9.7
01/30/02	0 - 15	10	f	n	29.51	27.76	5.93	9.01	0.7	11.2	67.0	1.5	9.1
01/30/02	15 - 30	10	f	n	29.09	27.39	5.84	9.25	0.6	9.5	67.0	1.3	9.3
01/30/02	30 - 60	10	f	n	29.21	27.62	5.44	8.58	0.4	8.2	74.1	2.1	19.1
01/30/02	60 - 90	10	f	n	29.53	27.91	5.49	8.65	0.3	5.1	30.6	1.3	7.9
01/30/02	0 - 15	10	r	n	29.14	27.39	6.01	9.14	0.7	11.1	153.6	1.5	21.0
01/30/02	15 - 30	10	r	n	29.17	27.3	6.41	10.21	31.1	485.3	280.0	74.3	42.9
01/30/02	30 - 60	10	r	n	29.07	27.21	6.40	10.19	10.1	158.0	81.5	48.3	24.9
01/30/02	60 - 90	10	r	n	29.47	27.94	5.19	8.16	1.4	27.8	92.5	6.8	22.6
01/30/02	0 - 15	11	f	n	29.88	28.21	5.59	8.47	1.2	21.9	19.5	2.8	2.5
01/30/02	15 - 30	11	f	n	29.7	27.8	6.40	10.18	1.3	20.8	64.0	3.2	9.8
01/30/02	30 - 60	11	f	n	29.77	27.96	6.08	9.65	1.2	20.1	43.1	5.8	12.5
01/30/02	60 - 90	11	f	n	29.07	27.55	5.23	8.22	0.9	17.0	36.6	4.2	9.0
01/30/02	0 - 15	11	r	n	29.07	27.48	5.47	8.27	3.7	67.0	72.7	8.3	9.0
01/30/02	15 - 30	11	r	n	29.14	27.43	5.87	9.29	15.6	265.1	167.2	36.9	23.3
01/30/02	30 - 60	11	r	n	29.15	27.38	6.07	9.63	4.2	69.5	34.4	20.1	9.9
01/30/02	60 - 90	11	r	n	29.69	28.11	5.32	8.37	2.1	39.7	35.9	10.0	9.0
01/30/02	0 - 15	3	f	n	29.25	27.27	6.77	10.38	0.7	9.8	26.5	1.5	4.1
01/30/02	15 - 30	3	f	n	29.27	27.25	6.90	11.05	0.4	6.4	20.0	1.1	3.3
01/30/02	30 - 60	3	f	n	29.54	27.73	6.13	9.73	0.5	8.2	38.0	2.4	11.1
01/30/02	60 - 90	3	f	n	29.51	27.78	5.86	9.28	0.3	5.7	51.7	1.6	14.4
01/30/02	0 - 15	3	r	n	29.37	27.52	6.30	9.61	2.3	36.2	247.5	5.2	35.7
01/30/02	15 - 30	3	r	n	29.5	27.55	6.61	10.55	32.8	495.9	271.5	78.4	43.0
01/30/02	30 - 60	3	r	n	29.45	27.43	6.86	10.97	6.4	93.1	53.7	30.7	17.7
01/30/02	60 - 90	3	r	n	28.99	27.23	6.07	9.63	2.1	34.8	54.8	10.0	15.8
02/06/02	0 - 15	12	f	s	29.2	28.08	3.84	5.70	0.4	11.5	24.4	1.0	2.1
02/06/02	15 - 30	12	f	s	29.23	27.86	4.69	7.33	0.3	7.0	17.5	0.8	1.9
02/06/02	30 - 60	12	f	s	29.35	27.99	4.63	7.24	0.3	7.1	27.5	1.5	6.0
02/06/02	60 - 90	12	f	s	29.55	28.11	4.87	7.63	0.3	6.7	18.0	1.5	4.1
02/06/02	0 - 15	12	r	s	29.27	28.13	3.89	5.80	38.8	996.3	1023.8	86.6	89.0
02/06/02	15 - 30	12	r	s	29.8	28.53	4.26	6.63	31.9	749.1	577.4	74.5	57.4
02/06/02	30 - 60	12	r	s	29.49	28.03	4.95	7.76	29.6	598.5	96.5	139.4	22.5
02/06/02	60 - 90	12	r	s	29.64	28.21	4.82	7.55	1.1	23.4	42.8	5.3	9.7
02/06/02	0 - 15	13	f	s	29.2	27.82	4.73	7.09	0.8	17.8	29.3	1.9	3.1
02/06/02	15 - 30	13	f	s	29.9	28.35	5.18	8.15	0.3	6.3	14.8	0.8	1.8
02/06/02	30 - 60	13	f	s	29.48	28.04	4.88	7.65	0.3	5.5	9.9	1.3	2.3
02/06/02	60 - 90	13	f	s	29.79	28.41	4.63	7.24	0.3	7.1	39.7	1.5	8.6
02/06/02	0 - 15	13	r	s	29.84	28.53	4.39	6.57	65.2	1484.4	1500.7	146.2	147.8
02/06/02	15 - 30	13	r	s	29.31	27.75	5.32	8.38	41.1	772.1	281.8	97.0	35.4

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
02/06/02	30 - 60	13	r	s	29.2	27.69	5.17	8.13	12.8	247.6	42.1	60.4	10.3
02/06/02	60 - 90	13	r	s	29.51	28.18	4.51	7.03	1.0	22.5	22.0	4.7	4.6
02/06/02	0 - 15	6	f	s	29.11	27.71	4.81	7.22	0.6	12.8	30.0	1.4	3.3
02/06/02	15 - 30	6	f	s	29.1	27.72	4.74	7.42	0.3	6.9	16.1	0.8	1.8
02/06/02	30 - 60	6	f	s	29.61	28.27	4.53	7.06	0.3	7.2	36.9	1.5	7.8
02/06/02	60 - 90	6	f	s	29.57	28.36	4.09	6.36	0.3	8.0	39.4	1.5	7.5
02/06/02	0 - 15	6	r	s	29.22	27.86	4.65	6.98	8.5	181.9	322.2	19.0	33.7
02/06/02	15 - 30	6	r	s	29.18	27.62	5.35	8.42	9.4	175.2	87.3	22.1	11.0
02/06/02	30 - 60	6	r	s	29.52	27.97	5.25	8.26	0.6	10.6	16.7	2.6	4.1
02/06/02	60 - 90	6	r	s	29.12	27.77	4.64	7.24	0.6	12.0	39.7	2.6	8.6
02/06/02	0 - 15	7	f	s	29.58	28.33	4.23	6.31	0.4	10.4	48.9	1.0	4.6
02/06/02	15 - 30	7	f	s	29.59	28.13	4.93	7.73	0.3	6.6	45.3	0.8	5.3
02/06/02	30 - 60	7	f	s	29.15	27.73	4.87	7.63	0.3	5.5	34.3	1.3	7.8
02/06/02	60 - 90	7	f	s	29.05	27.9	3.96	6.14	0.4	11.1	55.0	2.1	10.1
02/06/02	0 - 15	7	r	s	29.2	27.98	4.18	6.24	3.9	92.9	223.6	8.7	20.9
02/06/02	15 - 30	7	r	s	29.42	27.75	5.68	8.97	41.1	724.0	533.1	97.4	71.7
02/06/02	30 - 60	7	r	s	29.33	27.91	4.84	7.58	3.5	73.0	75.4	16.6	17.1
02/06/02	60 - 90	7	r	s	29.52	28.2	4.47	6.97	0.9	20.1	46.2	4.2	9.7
02/06/02	0 - 15	4	f	s	29.33	28.18	3.92	5.84	0.7	18.6	51.2	1.6	4.5
02/06/02	15 - 30	4	f	s	29.83	28.54	4.32	6.73	0.3	7.6	29.5	0.8	3.0
02/06/02	30 - 60	4	f	s	29.21	27.85	4.66	7.28	0.3	5.8	27.4	1.3	6.0
02/06/02	60 - 90	4	f	s	29.15	27.8	4.63	7.24	0.3	5.8	47.0	1.3	10.2
02/06/02	0 - 15	4	r	s	29.19	27.9	4.42	6.61	14.2	320.3	608.0	31.8	60.3
02/06/02	15 - 30	4	r	s	29.32	27.96	4.64	7.25	62.9	1355.5	932.8	147.4	101.4
02/06/02	30 - 60	4	r	s	29.2	27.85	4.62	7.22	9.1	196.5	71.6	42.6	15.5
02/06/02	60 - 90	4	r	s	29.01	27.73	4.41	6.88	2.4	54.2	71.2	11.2	14.7
02/21/02	0 - 15	8	f	n	29.28	27.74	5.26	7.94	1.6	30.2	146.1	3.6	17.4
02/21/02	15 - 30	8	f	n	29.72	28.23	5.01	7.86	0.5	9.9	59.8	1.2	7.0
02/21/02	30 - 60	8	f	n	29.02	27.7	4.55	7.10	0.4	9.7	46.8	2.1	10.0
02/21/02	60 - 90	8	f	n	29.06	27.71	4.65	7.26	10.3	221.7	98.1	48.3	21.4
02/21/02	0 - 15	8	r	n	29.07	27.26	6.23	9.49	4.8	77.0	56.5	11.0	8.0
02/21/02	15 - 30	8	r	n	29.83	28.44	4.66	7.28	7.7	164.4	250.4	18.0	27.3
02/21/02	30 - 60	8	r	n	29.94	28.42	5.08	7.97	3.2	62.9	121.7	15.0	29.1
02/21/02	60 - 90	8	r	n	29.42	27.99	4.86	7.61	3.5	72.8	36.6	16.6	8.4
02/21/02	0 - 15	9	f	n	29.91	28.4	5.05	7.60	5.4	106.4	121.3	12.1	13.8
02/21/02	15 - 30	9	f	n	29.13	27.78	4.63	7.24	1.1	24.4	129.6	2.6	14.1
02/21/02	30 - 60	9	f	n	29.55	28.19	4.60	7.19	0.3	7.1	50.0	1.5	10.8
02/21/02	60 - 90	9	f	n	29.23	28.04	4.07	6.32	0.8	19.3	97.8	3.7	18.5
02/21/02	0 - 15	9	r	n	29.47	28.16	4.45	6.65	5.6	126.0	351.0	12.6	35.0
02/21/02	15 - 30	9	r	n	29.41	28.04	4.66	7.28	2.6	56.2	179.9	6.1	19.6
02/21/02	30 - 60	9	r	n	29.78	28.47	4.40	6.86	1.2	28.3	148.4	5.8	30.5
02/21/02	60 - 90	9	r	n	29.1	27.94	3.99	6.19	0.9	22.6	121.6	4.2	22.6
02/21/02	0 - 15	10	f	n	29.01	27.7	4.52	6.76	2.6	58.0	75.3	5.9	7.6
02/21/02	15 - 30	10	f	n	29.66	28.3	4.59	7.16	0.8	17.1	81.7	1.8	8.8
02/21/02	30 - 60	10	f	n	29.81	28.51	4.36	6.79	0.4	10.1	84.6	2.1	17.2
02/21/02	60 - 90	10	f	n	29.42	28.19	4.18	6.50	0.3	7.8	64.7	1.5	12.6
02/21/02	0 - 15	10	r	n	29.16	27.89	4.36	6.51	9.2	210.2	273.2	20.5	26.7
02/21/02	15 - 30	10	r	n	29.95	28.57	4.61	7.20	8.9	192.4	197.0	20.8	21.3
02/21/02	30 - 60	10	r	n	29.91	28.65	4.21	6.55	4.9	116.6	83.5	22.9	16.4
02/21/02	60 - 90	10	r	n	29.58	28.42	3.92	6.08	2.3	59.5	66.1	10.9	12.1
02/21/02	0 - 15	11	f	n	29.46	28.07	4.72	7.08	6.4	135.7	89.3	14.4	9.5
02/21/02	15 - 30	11	f	n	29.05	27.57	5.09	8.00	1.8	35.7	87.2	4.3	10.5
02/21/02	30 - 60	11	f	n	29.3	27.93	4.68	7.31	0.8	16.8	100.0	3.7	21.9
02/21/02	60 - 90	11	f	n	29.47	28.25	4.14	6.43	0.4	10.7	51.4	2.1	9.9
02/21/02	0 - 15	11	r	n	29.28	28	4.37	6.54	6.7	154.3	1307.8	15.1	128.2
02/21/02	15 - 30	11	r	n	29.01	27.58	4.93	7.73	8.4	169.4	232.0	19.6	26.9
02/21/02	30 - 60	11	r	n	29.4	28.1	4.42	6.89	8.6	194.0	86.1	40.1	17.8
02/21/02	60 - 90	11	r	n	29.54	28.25	4.37	6.80	8.1	186.0	91.1	38.0	18.6
02/21/02	0 - 15	3	f	n	29.44	27.98	4.96	7.46	4.7	94.4	184.2	10.6	20.6

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
02/21/02	15 - 30	3	f	n	29.71	28.01	5.72	9.04	2.3	39.8	45.3	5.4	6.1
02/21/02	30 - 60	3	f	n	29.06	27.62	4.96	7.77	0.7	13.5	38.3	3.2	8.9
02/21/02	60 - 90	3	f	n	29.38	28.13	4.25	6.62	0.7	15.8	73.1	3.1	14.5
02/21/02	0 - 15	3	r	n	29.17	27.7	5.04	7.59	16.0	316.7	571.5	36.1	65.1
02/21/02	15 - 30	3	r	n	29.08	27.58	5.16	8.10	7.5	146.3	288.9	17.8	35.1
02/21/02	30 - 60	3	r	n	29.2	27.97	4.21	6.55	1.1	26.8	116.5	5.3	22.9
02/21/02	60 - 90	3	r	n	29.25	27.84	4.82	7.55	1.6	32.9	118.6	7.5	26.8
02/27/02	0 - 15	12	f	s	29.44	27.42	6.86	10.53	4.5	66.2	51.5	10.5	8.1
02/27/02	15 - 30	12	f	s	29.11	27.35	6.05	9.59	3.8	63.3	38.2	9.1	5.5
02/27/02	30 - 60	12	f	s	29.23	27.87	4.65	7.27	0.7	14.9	53.4	3.2	11.6
02/27/02	60 - 90	12	f	s	29.73	28.32	4.74	7.42	0.4	7.7	64.6	1.7	14.4
02/27/02	0 - 15	12	r	s	29.44	28.04	4.76	7.14	12.6	265.1	877.6	28.4	94.0
02/27/02	15 - 30	12	r	s	29.39	27.92	5.00	7.84	34.3	685.0	519.8	80.6	61.2
02/27/02	30 - 60	12	r	s	29.64	28.25	4.69	7.33	12.9	275.8	77.8	60.7	17.1
02/27/02	60 - 90	12	r	s	29.86	28.67	3.99	6.18	3.5	87.8	55.0	16.3	10.2
02/27/02	0 - 15	13	f	s	29.64	27.54	7.09	10.90	10.8	153.1	60.5	25.0	9.9
02/27/02	15 - 30	13	f	s	29.8	27.95	6.21	9.86	2.8	45.7	30.6	6.8	4.5
02/27/02	30 - 60	13	f	s	29.25	27.77	5.06	7.94	0.7	13.7	21.4	3.3	5.1
02/27/02	60 - 90	13	f	s	29.64	28.07	5.30	8.33	0.3	5.8	38.1	1.5	9.5
02/27/02	0 - 15	13	r	s	29.45	27.8	5.60	8.49	58.1	1036.5	3288.1	132.0	418.6
02/27/02	15 - 30	13	r	s	29.08	27.44	5.64	8.91	44.2	783.0	440.3	104.6	58.8
02/27/02	30 - 60	13	r	s	29.52	28.05	4.98	7.81	12.7	255.3	113.1	59.8	26.5
02/27/02	60 - 90	13	r	s	29.29	27.78	5.16	8.10	2.5	48.6	88.9	11.8	21.6
02/27/02	0 - 15	6	f	s	29.5	26.99	8.51	13.30	2.7	31.4	37.4	6.3	7.5
02/27/02	15 - 30	6	f	s	29.69	28	5.69	8.99	2.0	34.4	47.7	4.6	6.4
02/27/02	30 - 60	6	f	s	29.85	28.4	4.86	7.61	0.6	12.0	37.9	2.7	8.7
02/27/02	60 - 90	6	f	s	29.27	28.24	3.52	5.43	0.2	5.6	52.4	0.9	8.5
02/27/02	0 - 15	6	r	s	29.47	27.99	5.02	7.56	28.2	561.8	1329.9	63.7	150.8
02/27/02	15 - 30	6	r	s	29.73	28.16	5.28	8.31	36.1	683.1	348.9	85.1	43.5
02/27/02	30 - 60	6	r	s	29.23	27.77	4.99	7.83	9.0	180.1	94.0	42.3	22.1
02/27/02	60 - 90	6	r	s	29.15	27.93	4.19	6.51	1.7	40.2	84.4	7.9	16.5
02/27/02	0 - 15	7	f	s	29.2	27.33	6.40	9.78	2.9	46.0	73.4	6.8	10.8
02/27/02	15 - 30	7	f	s	29.77	27.53	7.52	12.12	2.6	34.8	29.1	6.3	5.3
02/27/02	30 - 60	7	f	s	29.26	27.31	6.66	10.64	0.8	12.0	39.9	3.8	12.7
02/27/02	60 - 90	7	f	s	29.67	27.92	5.90	9.34	0.4	7.1	35.2	2.0	9.9
02/27/02	0 - 15	7	r	s	29.47	27.8	5.67	8.59	35.6	628.9	1374.0	81.0	177.0
02/27/02	15 - 30	7	r	s	29.37	27.52	6.30	10.02	92.2	1463.3	579.3	219.8	87.0
02/27/02	30 - 60	7	r	s	29.35	27.22	7.26	11.66	12.8	176.7	65.5	61.8	22.9
02/27/02	60 - 90	7	r	s	29.67	27.94	5.83	9.23	3.4	59.0	74.6	16.3	20.6
02/27/02	0 - 15	4	f	s	29.82	27.94	6.30	9.62	2.2	34.5	45.9	5.0	6.6
02/27/02	15 - 30	4	f	s	29.58	27.87	5.78	9.14	1.6	28.2	34.9	3.9	4.8
02/27/02	30 - 60	4	f	s	29.49	27.95	5.22	8.21	0.6	11.2	42.0	2.7	10.3
02/27/02	60 - 90	4	f	s	29.48	27.93	5.26	8.27	0.5	10.0	67.2	2.5	16.7
02/27/02	0 - 15	4	r	s	29.51	27.76	5.93	9.01	29.0	489.6	713.5	66.2	96.5
02/27/02	15 - 30	4	r	s	29.39	27.98	4.80	7.51	19.7	410.4	56.6	46.2	6.4
02/27/02	30 - 60	4	r	s	29.75	27.96	6.02	9.54	5.5	91.0	51.9	26.1	14.9
02/27/02	60 - 90	4	r	s	29.73	28.13	5.38	8.47	2.2	40.5	54.8	10.3	13.9
03/07/02	0 - 15	8	f	n	29.4	27.72	5.71	8.67	0.8	14.5	86.3	1.9	11.2
03/07/02	15 - 30	8	f	n	29.53	27.78	5.93	9.39	0.3	4.6	97.0	0.6	13.7
03/07/02	30 - 60	8	f	n	29.31	27.67	5.60	8.83	0.3	4.9	106.9	1.3	28.3
03/07/02	60 - 90	8	f	n	29.82	28.35	4.93	7.73	0.3	5.5	154.4	1.3	35.8
03/07/02	0 - 15	8	r	n	29.71	28.1	5.42	8.19	3.8	70.7	393.7	8.7	48.4
03/07/02	15 - 30	8	r	n	29.59	27.74	6.25	9.94	1.1	16.8	210.8	2.5	31.4
03/07/02	30 - 60	8	r	n	29.11	27.53	5.43	8.55	1.4	25.5	105.9	6.5	27.2
03/07/02	60 - 90	8	r	n	29.22	27.75	5.03	7.89	3.0	59.6	121.2	14.1	28.7
03/07/02	0 - 15	9	f	n	29.63	28.02	5.43	8.22	0.9	17.3	69.3	2.1	8.5
03/07/02	15 - 30	9	f	n	29.3	27.56	5.94	9.41	0.3	4.6	65.4	0.6	9.2
03/07/02	30 - 60	9	f	n	29.73	28.2	5.15	8.08	0.3	5.3	93.5	1.3	22.7
03/07/02	60 - 90	9	f	n	29.7	28.15	5.22	8.20	0.3	5.2	83.3	1.3	20.5

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
03/07/02	0 - 15	10	r	n	29.06	27.54	5.23	7.89	0.8	15.8	54.2	1.9	6.4
03/07/02	15 - 30	10	r	n	29.61	27.86	5.91	9.36	0.4	6.5	38.1	0.9	5.3
03/07/02	30 - 60	10	r	n	29.24	27.69	5.30	8.34	0.3	5.1	71.0	1.3	17.8
03/07/02	60 - 90	10	r	n	29.93	28.39	5.15	8.08	0.3	5.3	34.7	1.3	8.4
03/07/02	0 - 15	11	f	n	29.03	27.39	5.65	8.56	1.2	20.6	40.9	2.6	5.2
03/07/02	15 - 30	11	f	n	29.5	27.56	6.58	10.49	0.4	5.8	20.9	0.9	3.3
03/07/02	30 - 60	11	f	n	29.41	27.82	5.41	8.52	0.3	5.0	45.9	1.3	11.7
03/07/02	60 - 90	11	f	n	29.01	27.52	5.14	8.07	0.3	5.3	37.0	1.3	9.0
03/07/02	0 - 15	11	r	n	29.88	28.13	5.86	8.90	3.7	63.5	881.7	8.5	117.7
03/07/02	15 - 30	11	r	n	29.68	27.87	6.10	9.68	1.9	31.8	184.6	4.6	26.8
03/07/02	30 - 60	11	r	n	29.79	27.98	6.08	9.64	0.7	10.9	85.9	3.1	24.9
03/07/02	60 - 90	11	r	n	29.38	27.81	5.34	8.41	3.6	66.5	53.0	16.8	13.4
03/07/02	0 - 15	3	f	n	29.17	27.75	4.87	7.32	1.1	21.6	27.1	2.4	3.0
03/07/02	15 - 30	3	f	n	29.35	27.43	6.54	10.43	0.6	9.3	25.5	1.4	4.0
03/07/02	30 - 60	3	f	n	29.3	27.46	6.28	9.98	0.3	4.3	32.1	1.3	9.6
03/07/02	60 - 90	3	f	n	29.68	28.05	5.49	8.66	0.3	4.9	34.6	1.3	9.0
03/07/02	0 - 15	3	r	n	29.5	28.05	4.92	7.39	4.3	87.0	255.2	9.6	28.3
03/07/02	15 - 30	3	r	n	29.31	27.39	6.55	10.44	1.2	17.7	459.1	2.8	71.9
03/07/02	30 - 60	3	r	n	29.25	27.37	6.43	10.23	5.6	87.3	70.4	26.8	21.6
03/07/02	60 - 90	3	r	n	29.69	28.15	5.19	8.15	13.8	266.9	31.0	65.3	7.6
03/15/02	0 - 15	12	f	s	29.67	28.03	5.53	8.37	1.4	25.5	36.4	3.2	4.6
03/15/02	15 - 30	12	f	s	29.57	27.78	6.05	9.60	0.9	14.2	38.6	2.0	5.6
03/15/02	30 - 60	12	f	s	29.18	27.69	5.11	8.02	0.4	8.2	39.4	2.0	9.5
03/15/02	60 - 90	12	f	s	29.21	28	4.14	6.44	0.5	11.4	30.2	2.2	5.8
03/15/02	0 - 15	12	r	s	29.21	27.97	4.25	6.34	7.9	185.5	1217.8	17.6	115.8
03/15/02	15 - 30	12	r	s	29.33	28.11	4.16	6.47	8.0	192.0	1426.0	18.6	138.3
03/15/02	30 - 60	12	r	s	29.55	28.17	4.67	7.30	5.3	114.5	803.9	25.1	176.0
03/15/02	60 - 90	12	r	s	29.42	28.12	4.42	6.89	3.2	71.7	283.0	14.8	58.5
03/15/02	0 - 15	13	f	s	29.14	28.13	3.47	5.13	1.7	48.5	83.2	3.7	6.4
03/15/02	15 - 30	13	f	s	29.87	27.55	7.77	12.55	0.6	8.2	46.9	1.5	8.8
03/15/02	30 - 60	13	f	s	29.68	28.42	4.25	6.61	0.5	11.1	73.0	2.2	14.5
03/15/02	60 - 90	13	f	s	29.63	28.35	4.32	6.73	0.4	9.7	74.3	2.0	15.0
03/15/02	0 - 15	13	r	s	29.74	28.39	4.54	6.80	75.7	1667.0	1498.6	170.0	152.9
03/15/02	15 - 30	13	r	s	29.12	27.64	5.08	7.98	10.3	202.6	331.7	24.2	39.7
03/15/02	30 - 60	13	r	s	29.18	27.69	5.11	8.02	2.1	41.6	165.2	10.0	39.7
03/15/02	60 - 90	13	r	s	29.37	27.95	4.83	7.57	3.7	76.9	120.4	17.5	27.4
03/15/02	0 - 15	6	f	s	29.25	27.8	4.96	7.46	4.8	97.2	38.4	10.9	4.3
03/15/02	15 - 30	6	f	s	29.69	27.99	5.73	9.05	4.2	72.6	61.8	9.9	8.4
03/15/02	30 - 60	6	f	s	29.64	28.11	5.16	8.11	0.6	12.4	36.9	3.0	9.0
03/15/02	60 - 90	6	f	s	29.62	28.24	4.66	7.28	0.8	17.2	57.2	3.8	12.5
03/15/02	0 - 15	6	r	s	29.63	28.2	4.83	7.25	7.1	146.5	131.9	15.9	14.4
03/15/02	15 - 30	6	r	s	29.6	28.09	5.10	8.01	3.3	65.3	60.8	7.8	7.3
03/15/02	30 - 60	6	r	s	29.86	28.31	5.19	8.16	0.9	16.5	47.2	4.0	11.5
03/15/02	60 - 90	6	r	s	29.19	27.92	4.35	6.78	0.7	15.9	48.8	3.2	9.9
03/15/02	0 - 15	7	f	s	29.25	27.74	5.16	7.78	3.7	70.9	30.5	8.3	3.6
03/15/02	15 - 30	7	f	s	29.44	27.95	5.06	7.94	1.7	34.3	37.6	4.1	4.5
03/15/02	30 - 60	7	f	s	29.71	28.4	4.41	6.87	0.5	12.0	40.7	2.5	8.4
03/15/02	60 - 90	7	f	s	29.77	28.55	4.10	6.37	0.5	11.5	70.4	2.2	13.4
03/15/02	0 - 15	7	r	s	29.81	28.59	4.09	6.10	10.1	246.2	1130.2	22.5	103.4
03/15/02	15 - 30	7	r	s	29.37	27.81	5.31	8.36	2.9	54.5	665.8	6.8	83.5
03/15/02	30 - 60	7	r	s	29.71	28.42	4.34	6.76	4.1	94.5	262.9	19.2	53.3
03/15/02	60 - 90	7	r	s	29.38	28.19	4.05	6.29	2.2	53.8	162.6	10.1	30.7
03/15/02	0 - 15	4	f	s	29.74	28.26	4.98	7.49	1.1	21.7	62.3	2.4	7.0
03/15/02	15 - 30	4	f	s	29.71	28.3	4.75	7.42	0.5	11.1	44.7	1.2	5.0
03/15/02	30 - 60	4	f	s	29.36	28.12	4.22	6.57	0.3	6.0	52.8	1.2	10.4
03/15/02	60 - 90	4	f	s	29.49	28.21	4.34	6.76	0.7	17.2	36.3	3.5	7.4
03/15/02	0 - 15	4	r	s	29.52	28.27	4.23	6.32	26.0	614.3	1478.0	58.3	140.2
03/15/02	15 - 30	4	r	s	29.31	27.79	5.19	8.15	16.9	326.6	703.0	39.9	85.9
03/15/02	30 - 60	4	r	s	29.24	27.79	4.96	7.77	3.4	69.4	1854.8	16.2	432.6

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
03/15/02	60 - 90	4	f	s	29.49	28.21	4.34	6.76	0.7	17.2	36.3	3.5	7.4
03/15/02	0 - 15	4	r	s	29.52	28.27	4.23	6.32	26.0	614.3	1478.0	58.3	140.2
03/15/02	15 - 30	4	r	s	29.31	27.79	5.19	8.15	16.9	326.6	703.0	39.9	85.9
03/15/02	30 - 60	4	r	s	29.24	27.79	4.96	7.77	3.4	69.4	1854.8	16.2	432.6
03/15/02	60 - 90	4	r	s	29.87	28.6	4.25	6.62	3.1	71.9	160.0	14.3	31.8
03/20/02	0 - 15	8	f	n	29.62	27.64	6.68	10.24	2.2	32.7	48.2	5.0	7.4
03/20/02	15 - 30	8	f	n	29.72	27.7	6.80	10.87	1.1	16.5	28.9	2.7	4.7
03/20/02	30 - 60	8	f	n	29.74	28.1	5.51	8.70	0.6	11.7	45.0	3.1	11.7
03/20/02	60 - 90	8	f	n	29.53	28.13	4.74	7.42	0.3	5.8	51.1	1.3	11.4
03/20/02	0 - 15	8	r	n	29.54	28	5.21	7.87	60.2	1154.5	640.0	136.2	75.5
03/20/02	15 - 30	8	r	n	29.32	27.87	4.95	7.75	18.4	371.9	444.0	43.2	51.6
03/20/02	30 - 60	8	r	n	29.89	28.21	5.62	8.87	3.4	59.8	390.7	15.9	104.0
03/20/02	60 - 90	8	r	n	29.86	28.29	5.26	8.27	3.6	67.9	150.3	16.9	37.3
03/20/02	0 - 15	9	f	n	29.74	27.86	6.32	9.65	1.9	29.6	47.4	4.3	6.9
03/20/02	15 - 30	9	f	n	29.76	27.82	6.52	10.39	1.4	22.1	37.2	3.5	5.8
03/20/02	30 - 60	9	f	n	29.62	28.01	5.44	8.56	0.7	12.9	128.6	3.3	33.0
03/20/02	60 - 90	9	f	n	29.18	27.87	4.49	7.00	0.4	8.5	43.8	1.8	9.2
03/20/02	0 - 15	9	r	n	29.46	27.85	5.47	8.27	38.6	706.4	777.6	87.6	96.4
03/20/02	15 - 30	9	r	n	29.78	28.09	5.67	8.96	9.6	169.8	127.1	22.8	17.1
03/20/02	30 - 60	9	r	n	29.64	27.92	5.80	9.18	3.7	63.4	122.4	17.5	33.7
03/20/02	60 - 90	9	r	n	29.53	28.03	5.08	7.97	12.7	249.5	130.8	59.7	31.3
03/20/02	0 - 15	10	f	n	29.43	27.5	6.56	10.04	2.9	44.7	43.1	6.7	6.5
03/20/02	15 - 30	10	f	n	29.56	27.71	6.26	9.95	1.2	19.7	26.9	2.9	4.0
03/20/02	30 - 60	10	f	n	29.63	28.03	5.40	8.51	0.8	14.9	39.6	3.8	10.1
03/20/02	60 - 90	10	f	n	29.45	28.08	4.65	7.27	1.2	26.5	75.4	5.8	16.4
03/20/02	0 - 15	10	r	n	29.91	28.34	5.25	7.92	83.6	1592.6	1037.8	189.2	123.3
03/20/02	15 - 30	10	r	n	29.58	28.14	4.87	7.62	8.9	182.6	79.1	20.9	9.0
03/20/02	30 - 60	10	r	n	29.62	28.08	5.20	8.17	5.1	97.3	70.8	23.9	17.3
03/20/02	60 - 90	10	r	n	29.4	28.05	4.59	7.17	2.5	54.6	85.1	11.7	18.3
03/20/02	0 - 15	11	f	n	29.73	27.83	6.39	9.76	3.4	53.4	57.6	7.8	8.4
03/20/02	15 - 30	11	f	n	29.63	27.81	6.14	9.75	1.7	27.0	46.0	3.9	6.7
03/20/02	30 - 60	11	f	n	29.24	27.66	5.40	8.51	1.0	18.8	45.9	4.8	11.7
03/20/02	60 - 90	11	f	n	29.56	28.19	4.63	7.24	0.4	9.3	31.4	2.0	6.8
03/20/02	0 - 15	11	r	n	29.88	28.21	5.59	8.47	48.5	867.5	382.7	110.2	48.6
03/20/02	15 - 30	11	r	n	29.36	27.99	4.67	7.29	16.8	359.9	59.3	39.4	6.5
03/20/02	30 - 60	11	r	n	29.2	27.66	5.27	8.30	4.4	83.9	158.4	20.9	39.4
03/20/02	60 - 90	11	r	n	29.09	27.65	4.95	7.76	1.7	33.5	98.5	7.8	22.9
03/20/02	0 - 15	3	f	n	29.31	27.32	6.79	10.42	2.6	38.5	32.3	6.0	5.1
03/20/02	15 - 30	3	f	n	29.16	27.36	6.17	9.80	1.7	27.7	22.6	4.1	3.3
03/20/02	30 - 60	3	f	n	29.69	28.03	5.59	8.82	0.7	12.5	37.2	3.3	9.9
03/20/02	60 - 90	3	f	n	29.73	28.32	4.74	7.42	0.4	8.0	34.3	1.8	7.6
03/20/02	0 - 15	3	r	n	29.07	27.48	5.47	8.27	31.5	575.2	162.2	71.4	20.1
03/20/02	15 - 30	3	r	n	29.33	27.84	5.08	7.97	5.3	103.8	192.6	12.4	23.0
03/20/02	30 - 60	3	r	n	29.19	27.66	5.24	8.24	2.3	43.8	174.7	10.8	43.2
03/20/02	60 - 90	3	r	n	29.05	27.72	4.58	7.15	1.9	40.8	145.1	8.8	31.1
03/27/02	0 - 15	12	f	s	29.71	27.78	6.50	9.93	2.3	35.4	44.0	5.3	6.6
03/27/02	15 - 30	12	f	s	29.31	27.29	6.89	11.03	1.2	18.1	19.7	3.0	3.3
03/27/02	30 - 60	12	f	s	29.33	27.66	5.69	9.00	1.4	23.8	44.1	6.4	11.9
03/27/02	60 - 90	12	f	s	29.13	27.6	5.25	8.26	0.3	5.8	21.5	1.4	5.3
03/27/02	0 - 15	12	r	s	29.34	28.16	4.02	5.99	75.8	1885.8	1399.9	169.5	125.8
03/27/02	15 - 30	12	r	s	29.07	27.87	4.13	6.42	7.9	191.1	112.6	18.4	10.8
03/27/02	30 - 60	12	r	s	29.08	27.37	5.88	9.31	6.3	107.8	95.7	30.1	26.7
03/27/02	60 - 90	12	r	s	29.4	27.84	5.31	8.35	1.7	31.8	34.3	8.0	8.6
03/27/02	0 - 15	13	f	s	29.81	27.79	6.78	10.39	1.6	23.3	25.2	3.6	3.9
03/27/02	15 - 30	13	f	s	29.2	27.4	6.16	9.79	1.4	22.0	23.9	3.2	3.5
03/27/02	30 - 60	13	f	s	29.47	27.96	5.12	8.05	0.7	13.5	55.8	3.3	13.5
03/27/02	60 - 90	13	f	s	29.44	28.13	4.45	6.94	0.4	8.1	56.5	1.7	11.8
03/27/02	0 - 15	13	r	s	29.76	28.08	5.65	8.56	21.7	384.9	343.0	49.4	44.0
03/27/02	15 - 30	13	r	s	29.55	28.2	4.57	7.13	11.2	245.4	524.9	26.3	56.2

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
03/27/02	30 - 60	13	r	s	29.5	28.07	4.85	7.59	3.2	66.8	206.6	15.2	47.1
03/27/02	60 - 90	13	r	s	29.22	27.85	4.69	7.33	1.9	40.7	121.3	9.0	26.7
03/27/02	0 - 15	6	f	s	29.45	27.37	7.06	10.87	4.6	64.7	36.4	10.5	5.9
03/27/02	15 - 30	6	f	s	29.28	27.31	6.73	10.75	1.9	28.4	30.5	4.6	4.9
03/27/02	30 - 60	6	f	s	29.59	27.93	5.61	8.86	1.6	28.1	27.3	7.5	7.3
03/27/02	60 - 90	6	f	s	29.49	28.15	4.54	7.09	0.5	11.6	59.1	2.5	12.6
03/27/02	0 - 15	6	r	s	29.74	28.32	4.77	7.17	78.9	1652.1	1420.9	177.7	152.8
03/27/02	15 - 30	6	r	s	29.34	27.97	4.67	7.30	6.0	128.6	150.2	14.1	16.4
03/27/02	30 - 60	6	r	s	29.36	27.78	5.38	8.47	1.7	31.4	100.3	8.0	25.5
03/27/02	60 - 90	6	r	s	29.55	28.08	4.97	7.80	2.0	40.6	50.5	9.5	11.8
03/27/02	0 - 15	7	f	s	29.22	27.21	6.88	10.56	1.6	22.9	16.4	3.6	2.6
03/27/02	15 - 30	7	f	s	29.48	27.84	5.56	8.78	0.9	15.4	34.8	2.0	4.6
03/27/02	30 - 60	7	f	s	29.24	27.93	4.48	6.99	0.9	20.4	31.6	4.3	6.6
03/27/02	60 - 90	7	f	s	29.53	28.19	4.54	7.08	0.3	6.7	30.0	1.4	6.4
03/27/02	0 - 15	7	r	s	29.32	28.04	4.37	6.53	31.3	716.5	311.4	70.2	30.5
03/27/02	15 - 30	7	r	s	29.3	28.02	4.37	6.81	5.3	122.3	58.9	12.5	6.0
03/27/02	30 - 60	7	r	s	29.45	28.13	4.48	6.99	3.0	67.3	74.1	14.1	15.5
03/27/02	60 - 90	7	r	s	29.14	27.85	4.43	6.90	5.3	120.7	78.9	25.0	16.3
03/27/02	0 - 15	4	f	s	29.38	27.71	5.68	8.62	1.0	18.0	44.2	2.3	5.7
03/27/02	15 - 30	4	f	s	29.31	27.44	6.38	10.15	0.8	12.6	47.5	1.9	7.2
03/27/02	30 - 60	4	f	s	29.09	27.42	5.74	9.07	0.6	10.1	29.7	2.8	8.1
03/27/02	60 - 90	4	f	s	29.41	27.99	4.83	7.56	0.4	7.5	41.3	1.7	9.4
03/27/02	0 - 15	4	r	s	29.14	27.55	5.46	8.25	51.2	938.5	158.2	116.2	19.6
03/27/02	15 - 30	4	r	s	29.49	28.09	4.75	7.43	57.8	1218.5	31.1	135.7	3.5
03/27/02	30 - 60	4	r	s	29.39	28.03	4.63	7.23	22.3	481.5	41.8	104.4	9.1
03/27/02	60 - 90	4	r	s	29.15	27.81	4.60	7.18	8.4	183.6	54.7	39.6	11.8
04/03/02	0 - 15	8	f	n	29.66	27.38	7.69	11.91	1.2	16.0	24.7	2.9	4.4
04/03/02	15 - 30	8	f	n	29.06	26.97	7.19	11.55	0.2	3.5	10.0	0.6	1.7
04/03/02	30 - 60	8	f	n	29.22	27.34	6.43	10.25	0.4	6.4	33.1	2.0	10.2
04/03/02	60 - 90	8	f	n	29.13	27.26	6.42	10.22	0.5	7.3	25.0	2.2	7.7
04/03/02	0 - 15	8	r	n	29.32	27.4	6.55	10.02	23.2	354.0	397.2	53.2	59.7
04/03/02	15 - 30	8	r	n	29.84	27.93	6.40	10.19	60.2	940.6	287.0	143.8	43.9
04/03/02	30 - 60	8	r	n	29	27.32	5.79	9.16	7.2	123.7	225.9	34.0	62.1
04/03/02	60 - 90	8	r	n	29	27.31	5.83	9.22	1.6	26.7	74.9	7.4	20.7
04/03/02	0 - 15	9	f	n	29.2	27.38	6.23	9.51	0.7	11.9	88.8	1.7	12.7
04/03/02	15 - 30	9	f	n	29.33	27.5	6.24	9.92	0.6	10.1	44.5	1.5	6.6
04/03/02	30 - 60	9	f	n	29.71	27.91	6.06	9.61	0.3	5.0	35.2	1.4	10.1
04/03/02	60 - 90	9	f	n	29.13	27.2	6.63	10.57	0.6	8.7	23.3	2.8	7.4
04/03/02	0 - 15	9	r	n	29.24	27.35	6.46	9.88	3.7	57.8	38.4	8.6	5.7
04/03/02	15 - 30	9	r	n	29.92	28.24	5.61	8.86	21.0	374.1	52.6	49.7	7.0
04/03/02	30 - 60	9	r	n	29.68	27.82	6.27	9.96	31.9	509.0	76.2	152.1	22.8
04/03/02	60 - 90	9	r	n	29.58	27.92	5.61	8.86	13.9	248.2	56.8	66.0	15.1
04/03/02	0 - 15	10	f	n	29.07	26.8	7.81	12.11	0.7	8.8	34.8	1.6	6.3
04/03/02	15 - 30	10	f	n	29.14	27.02	7.28	11.69	0.5	7.2	27.7	1.3	4.9
04/03/02	30 - 60	10	f	n	29.65	27.54	7.12	11.42	0.4	5.8	16.7	2.0	5.7
04/03/02	60 - 90	10	f	n	29.53	27.59	6.57	10.48	0.3	4.6	14.6	1.5	4.6
04/03/02	0 - 15	10	r	n	29.29	27.36	6.59	10.09	19.9	302.3	269.9	45.7	40.8
04/03/02	15 - 30	10	r	n	29.55	27.71	6.23	9.89	38.4	617.2	200.7	91.6	29.8
04/03/02	30 - 60	10	r	n	29.86	27.98	6.30	10.01	15.6	247.2	88.0	74.2	26.4
04/03/02	60 - 90	10	r	n	29.04	27.32	5.92	9.38	4.5	75.9	26.1	21.4	7.3
04/03/02	0 - 15	11	f	n	29.01	26.9	7.27	11.22	0.8	10.9	34.1	1.8	5.7
04/03/02	15 - 30	11	f	n	29.52	27.37	7.28	11.70	0.5	6.4	8.3	1.1	1.5
04/03/02	30 - 60	11	f	n	29.06	27.03	6.99	11.19	0.7	9.8	22.1	3.3	7.4
04/03/02	60 - 90	11	f	n	29.25	27.39	6.36	10.12	0.8	13.3	13.2	4.0	4.0
04/03/02	0 - 15	11	r	n	29.49	27.52	6.68	10.24	23.2	347.1	204.7	53.3	31.4
04/03/02	15 - 30	11	r	n	29.02	27.43	5.48	8.64	25.4	462.9	51.8	60.0	6.7
04/03/02	30 - 60	11	r	n	29.25	27.53	5.88	9.31	12.3	209.1	40.2	58.4	11.2
04/03/02	60 - 90	11	r	n	29.61	27.86	5.91	9.36	3.2	54.0	53.9	15.2	15.1
04/03/02	0 - 15	3	f	n	29.53	27.21	7.86	12.19	0.6	7.3	37.6	1.3	6.9

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
04/03/02	15 - 30	3	f	n	29.22	26.95	7.77	12.55	0.5	6.0	16.1	1.1	3.0
04/03/02	30 - 60	3	f	n	29.22	27.26	6.71	10.71	0.3	4.5	16.0	1.5	5.1
04/03/02	60 - 90	3	f	n	29.78	27.82	6.58	10.50	0.2	3.8	11.8	1.2	3.7
04/03/02	0 - 15	3	r	n	29.12	27.06	7.07	10.89	3.1	43.5	53.4	7.1	8.7
04/03/02	15 - 30	3	r	n	29.14	27.17	6.76	10.80	6.0	89.1	118.4	14.4	19.2
04/03/02	30 - 60	3	r	n	29.98	27.81	7.24	11.63	23.2	320.3	118.7	111.7	41.4
04/03/02	60 - 90	3	r	n	29.69	27.65	6.87	10.99	12.8	186.9	125.0	61.6	41.2
04/12/02	0 - 15	13	f	s	28.98	26.39	8.94	14.03	0.7	7.7	27.1	1.6	5.7
04/12/02	15 - 30	13	f	s	29.42	27.02	8.16	13.23	0.4	5.1	24.7	1.0	4.9
04/12/02	30 - 60	13	f	s	29.23	27.23	6.84	10.94	0.4	5.2	19.1	1.7	6.3
04/12/02	60 - 90	13	f	s	29.69	27.75	6.53	10.42	0.9	13.8	14.6	4.3	4.6
04/12/02	0 - 15	13	r	s	29	26.82	7.52	11.62	12.3	163.6	172.3	28.5	30.0
04/12/02	15 - 30	13	r	s	29.08	27.07	6.91	11.06	23.2	335.4	47.8	55.7	7.9
04/12/02	30 - 60	13	r	s	29.21	27.14	7.09	11.36	3.0	41.9	19.3	14.3	6.6
04/12/02	60 - 90	13	r	s	29.95	27.71	7.48	12.04	4.9	65.9	33.2	23.8	12.0
04/12/02	0 - 15	4	f	s	29.46	26.85	8.86	13.90	0.8	9.6	24.1	2.0	5.0
04/12/02	15 - 30	4	f	s	29.65	26.94	9.14	14.99	1.1	12.3	13.0	2.8	2.9
04/12/02	30 - 60	4	f	s	29.77	26.92	9.57	15.77	0.5	4.9	18.0	2.3	8.5
04/12/02	60 - 90	4	f	s	29.4	27.04	8.03	13.00	0.7	8.5	13.4	3.3	5.2
04/12/02	0 - 15	4	r	s	29.36	27.12	7.63	11.81	10.2	133.2	31.0	23.6	5.5
04/12/02	15 - 30	4	r	s	29.25	27.24	6.87	10.99	82.0	1193.1	202.2	196.8	33.3
04/12/02	30 - 60	4	r	s	29.8	27.09	9.09	14.91	12.3	135.2	7.9	60.5	3.5
04/12/02	60 - 90	4	r	s	29.63	27	8.88	14.51	3.2	35.9	14.7	15.6	6.4
04/17/02	0 - 15	8	f	n	29.57	26.71	9.67	15.31	1.0	10.3	469.6	2.4	107.8
04/17/02	15 - 30	8	f	n	29.01	26.55	8.48	13.81	0.4	4.2	25.1	0.9	5.2
04/17/02	30 - 60	8	f	n	29.72	27.58	7.20	11.56	0.2	2.8	102.9	1.0	35.7
04/17/02	60 - 90	8	f	n	29.39	27.42	6.70	10.70	0.3	4.6	139.7	1.5	44.9
04/17/02	0 - 15	8	r	n	29.25	26.9	8.03	12.49	7.9	98.8	215.2	18.5	40.3
04/17/02	15 - 30	8	r	n	29.29	27.3	6.79	10.86	31.9	469.1	63.5	76.4	10.3
04/17/02	30 - 60	8	r	n	29.79	27.98	6.08	9.64	8.1	133.2	28.5	38.5	8.2
04/17/02	0 - 15	9	f	n	29.26	26.8	8.41	13.13	0.7	8.7	39.0	1.7	7.7
04/17/02	15 - 30	9	f	n	29.13	26.97	7.42	11.93	0.3	4.1	61.2	0.7	11.0
04/17/02	30 - 60	9	f	n	29.33	27.39	6.61	10.55	0.4	6.2	90.4	2.0	28.6
04/17/02	60 - 90	9	f	n	29.17	27.18	6.82	10.91	0.3	4.5	43.9	1.5	14.4
04/17/02	0 - 15	9	r	n	29.27	26.75	8.61	13.47	3.0	34.5	26.1	7.0	5.3
04/17/02	15 - 30	9	r	n	29.36	27.51	6.30	10.02	10.5	167.2	93.0	25.1	14.0
04/17/02	30 - 60	9	r	n	29.11	27.19	6.60	10.52	9.5	143.8	34.1	45.4	10.7
04/17/02	60 - 90	9	r	n	29.31	27.45	6.35	10.10	12.7	199.6	210.1	60.4	63.6
04/17/02	0 - 15	10	f	n	28.94	26.28	9.19	14.47	1.2	12.6	250.6	2.7	54.4
04/17/02	15 - 30	10	f	n	29.08	26.79	7.87	12.74	0.4	5.2	379.9	1.0	72.6
04/17/02	30 - 60	10	f	n	29.42	27.57	6.29	10.00	2.8	43.9	50.3	13.2	15.1
04/17/02	60 - 90	10	f	n	29.12	27.21	6.56	10.46	0.4	6.3	359.9	2.0	112.9
04/17/02	0 - 15	10	r	n	29.21	26.84	8.11	12.63	34.5	425.7	206.1	80.6	39.0
04/17/02	15 - 30	10	r	n	29.83	27.77	6.91	11.05	21.2	307.0	117.3	50.9	19.4
04/17/02	30 - 60	10	r	n	29.66	27.93	5.83	9.23	10.5	180.5	103.4	50.0	28.6
04/17/02	60 - 90	10	r	n	29.47	27.71	5.97	9.46	4.1	68.6	63.6	19.5	18.0
04/17/02	0 - 15	11	f	n	29.21	26.54	9.14	14.39	1.1	12.1	55.3	2.6	11.9
04/17/02	15 - 30	11	f	n	28.98	26.85	7.35	11.82	0.3	4.2	64.1	0.7	11.4
04/17/02	30 - 60	11	f	n	29.14	27.13	6.90	11.04	0.5	7.5	73.3	2.5	24.3
04/17/02	60 - 90	11	f	n	29.07	27.45	5.57	8.79	0.3	4.5	96.9	1.2	25.6
04/17/02	0 - 15	11	r	n	29.95	27.21	9.15	14.40	4.1	45.3	49.0	9.8	10.6
04/17/02	15 - 30	11	r	n	29.75	27.81	6.52	10.39	18.0	276.0	91.7	43.0	14.3
04/17/02	30 - 60	11	r	n	29.19	27.2	6.82	10.90	26.5	389.2	78.4	127.3	25.6
04/17/02	60 - 90	11	r	n	28.97	27.2	6.11	9.70	15.9	259.7	61.2	75.5	17.8
04/17/02	0 - 15	3	f	n	29.64	26.94	9.11	14.33	3.5	37.9	58.0	8.2	12.5
04/17/02	15 - 30	3	f	n	29.4	27	8.16	13.24	0.4	4.4	155.6	0.9	30.9
04/17/02	30 - 60	3	f	n	29.21	26.92	7.84	12.67	0.8	10.0	27.2	3.8	10.3
04/17/02	60 - 90	3	f	n	29.8	27.7	7.05	11.30	0.4	5.9	20.5	2.0	6.9
04/17/02	0 - 15	3	r	n	29.59	27.28	7.81	12.11	1.0	12.8	214.2	2.3	38.9

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
04/17/02	15 - 30	3	r	n	29.16	27.14	6.93	11.09	10.4	150.5	50.6	25.0	8.4
04/17/02	30 - 60	3	r	n	29.45	27.41	6.93	11.09	16.9	244.4	48.2	81.3	16.0
04/17/02	60 - 90	3	r	n	29.54	27.42	7.18	11.52	28.7	399.5	53.7	138.1	18.6
04/24/02	0 - 15	12	f	s	29.09	27.01	7.15	11.01	1.3	17.8	93.4	2.9	15.4
04/24/02	15 - 30	12	f	s	29.05	27.05	6.88	11.02	0.3	4.4	41.9	0.7	6.9
04/24/02	30 - 60	12	f	s	29.26	27.22	6.97	11.17	0.4	5.1	44.7	1.7	15.0
04/24/02	60 - 90	12	f	s	29.49	27.83	5.63	8.89	0.4	6.3	52.3	1.7	13.9
04/24/02	0 - 15	12	r	s	29.05	27.38	5.75	8.72	2.3	39.9	113.1	5.2	14.8
04/24/02	15 - 30	12	r	s	29.18	27.77	4.83	7.57	7.5	155.3	84.6	17.6	9.6
04/24/02	30 - 60	12	r	s	29.57	28.09	5.01	7.85	12.7	253.8	63.4	59.8	14.9
04/24/02	60 - 90	12	r	s	29.52	27.94	5.35	8.43	10.6	197.1	47.4	49.8	12.0
04/24/02	0 - 15	13	f	s	29.25	26.88	8.10	12.61	1.2	14.3	45.5	2.7	8.6
04/24/02	15 - 30	13	f	s	29.51	27.44	7.01	11.24	0.6	8.9	39.5	1.5	6.7
04/24/02	30 - 60	13	f	s	29.03	27.22	6.23	9.91	0.5	8.3	58.2	2.5	17.3
04/24/02	60 - 90	13	f	s	29.08	27.31	6.09	9.66	0.5	8.5	38.9	2.5	11.3
04/24/02	0 - 15	13	r	s	29.84	28.18	5.56	8.42	26.7	479.6	497.7	60.6	62.9
04/24/02	15 - 30	13	r	s	29.02	27.77	4.31	6.71	40.7	943.9	261.9	95.0	26.4
04/24/02	30 - 60	13	r	s	29.1	27.51	5.46	8.61	16.5	301.3	162.1	77.9	41.9
04/24/02	60 - 90	13	r	s	29.06	27.41	5.68	8.97	9.5	166.9	99.4	44.9	26.7
04/24/02	0 - 15	6	f	s	29.33	26.87	8.39	13.09	2.5	29.2	74.1	5.7	14.6
04/24/02	15 - 30	6	f	s	29.54	27.45	7.08	11.34	0.6	8.8	277.7	1.5	47.3
04/24/02	30 - 60	6	f	s	29.15	27.32	6.28	9.98	0.6	9.1	157.6	2.7	47.2
04/24/02	60 - 90	6	f	s	29.8	28.11	5.67	8.96	0.3	5.3	49.8	1.4	13.4
04/24/02	0 - 15	6	r	s	29.23	27.51	5.88	8.94	21.3	362.0	314.3	48.6	42.2
04/24/02	15 - 30	6	r	s	29.61	28.2	4.76	7.45	18.6	390.9	106.4	43.7	11.9
04/24/02	30 - 60	6	r	s	29.66	27.92	5.87	9.29	11.6	198.2	62.9	55.2	17.5
04/24/02	60 - 90	6	r	s	29.07	27.5	5.40	8.51	6.5	121.1	37.4	30.9	9.6
04/24/02	0 - 15	7	f	s	29.44	27.22	7.54	11.66	1.1	14.7	52.7	2.6	9.2
04/24/02	15 - 30	7	f	s	29.69	27.53	7.28	11.69	0.9	12.3	167.4	2.2	29.4
04/24/02	30 - 60	7	f	s	29.56	27.67	6.39	10.18	0.3	4.7	77.5	1.4	23.6
04/24/02	60 - 90	7	f	s	29.09	27.47	5.57	8.79	0.2	4.5	55.9	1.2	14.7
04/24/02	0 - 15	7	r	s	29.12	27.58	5.29	7.98	2.3	44.3	89.3	5.3	10.7
04/24/02	15 - 30	7	r	s	29.11	28.03	3.71	5.74	12.7	342.3	149.0	29.5	12.8
04/24/02	30 - 60	7	r	s	29.37	27.86	5.14	8.08	5.0	97.9	69.5	23.7	16.8
04/24/02	60 - 90	7	r	s	29.79	28.28	5.07	7.96	9.5	186.9	70.5	44.6	16.8
04/24/02	0 - 15	4	f	s	29.35	27.24	7.19	11.08	0.9	13.2	47.3	2.2	7.9
04/24/02	15 - 30	4	f	s	29.48	27.44	6.92	11.08	0.4	5.9	209.2	1.0	34.8
04/24/02	30 - 60	4	f	s	29.32	27.45	6.38	10.15	0.4	5.6	30.8	1.7	9.4
04/24/02	60 - 90	4	f	s	29.25	27.53	5.88	9.31	0.5	8.8	110.6	2.5	30.9
04/24/02	0 - 15	4	r	s	29.63	27.56	6.99	10.74	3.5	49.7	59.4	8.0	9.6
04/24/02	15 - 30	4	r	s	29.04	27.76	4.41	6.87	20.2	458.9	125.4	47.3	12.9
04/24/02	30 - 60	4	r	s	29.19	27.56	5.58	8.81	33.7	602.9	78.4	159.4	20.7
04/24/02	60 - 90	4	r	s	29.29	27.65	5.60	8.84	36.4	649.3	47.4	172.2	12.6
05/01/02	0 - 15	8	f	n	29.11	26.74	4.67	12.67	1.5	31.8	113.4	6.0	21.6
05/01/02	15 - 30	8	f	n	29.18	27.05	3.84	11.73	0.6	16.3	42.2	2.9	7.4
05/01/02	30 - 60	8	f	n	29.44	27.53	3.02	10.34	0.6	18.9	38.4	5.9	11.9
05/01/02	60 - 90	8	f	n	29.26	27.59	2.22	9.02	0.5	20.9	129.8	5.6	35.1
05/01/02	0 - 15	8	r	n	29.27	26.99	4.34	12.08	2.1	47.9	37.3	8.7	6.8
05/01/02	15 - 30	8	r	n	29.89	28.22	2.21	8.82	1.4	62.4	49.9	8.3	6.6
05/01/02	30 - 60	8	r	n	29.8	28	2.65	9.58	0.9	35.7	28.6	10.3	8.2
05/01/02	60 - 90	8	r	n	29.33	27.65	2.28	9.05	1.3	55.6	189.1	15.1	51.4
05/01/02	0 - 15	9	f	n	29.79	27.79	3.29	10.29	3.6	110.5	51.0	17.1	7.9
05/01/02	15 - 30	9	f	n	29.61	27.71	2.94	10.22	2.6	87.1	31.7	13.4	4.9
05/01/02	30 - 60	9	f	n	29.86	28.12	2.38	9.22	1.9	78.3	44.0	21.7	12.2
05/01/02	60 - 90	9	f	n	29.41	27.9	1.67	8.06	1.3	76.2	114.5	18.4	27.7
05/01/02	0 - 15	9	r	n	29.06	27.06	3.37	10.57	9.1	270.4	102.6	42.9	16.3
05/01/02	15 - 30	9	r	n	29.16	27.72	1.44	7.74	26.7	1852.3	104.5	215.1	12.1
05/01/02	30 - 60	9	r	n	29.11	27.59	1.31	8.21	19.2	1467.2	106.5	361.3	26.2
05/01/02	60 - 90	9	r	n	29.54	28.05	1.08	7.91	9.4	869.8	80.6	206.5	19.1

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
05/01/02	0 - 15	10	f	n	29.23	26.9	3.97	12.39	1.1	27.9	33.6	5.2	6.2
05/01/02	15 - 30	10	f	n	29.12	26.95	3.43	12.00	0.7	21.3	23.8	3.8	4.3
05/01/02	30 - 60	10	f	n	29.36	27.38	2.72	10.78	0.7	26.9	84.8	8.7	27.4
05/01/02	60 - 90	10	f	n	29.09	27.46	1.58	8.84	0.8	49.7	22.5	13.2	6.0
05/01/02	0 - 15	10	r	n	29.7	27.96	1.92	8.90	5.7	295.9	69.4	39.5	9.3
05/01/02	15 - 30	10	r	n	29.58	28.05	1.22	8.13	45.0	3694.1	180.3	450.3	22.0
05/01/02	30 - 60	10	r	n	29.41	27.5	2.48	10.35	3.6	146.5	51.4	45.5	16.0
05/01/02	60 - 90	10	r	n	29.54	27.75	2.10	9.61	19.7	938.1	140.1	270.5	40.4
05/01/02	0 - 15	11	f	n	29.14	26.81	4.26	12.43	1.6	37.4	48.9	7.0	9.1
05/01/02	15 - 30	11	f	n	29.3	27.45	2.59	10.04	0.5	19.9	46.9	3.0	7.1
05/01/02	30 - 60	11	f	n	29.52	27.73	2.37	9.62	0.5	21.8	141.0	6.3	40.7
05/01/02	60 - 90	11	f	n	29.23	27.54	1.98	9.14	0.4	20.7	38.2	5.7	10.5
05/01/02	0 - 15	11	r	n	29.09	27.07	3.13	10.67	2.1	66.4	44.4	10.6	7.1
05/01/02	15 - 30	11	r	n	29	27.58	1.03	7.67	7.7	746.4	145.5	85.9	16.7
05/01/02	30 - 60	11	r	n	28.96	27.3	1.93	9.06	4.9	254.7	71.9	69.2	19.5
05/01/02	60 - 90	11	r	n	29.49	27.72	2.17	9.51	3.5	160.1	40.2	45.7	11.5
05/01/02	0 - 15	3	f	n	28.92	26.97	2.90	10.34	2.1	73.3	43.9	11.4	6.8
05/01/02	15 - 30	3	f	n	29.1	27.06	3.16	11.23	1.8	57.2	38.5	9.6	6.5
05/01/02	30 - 60	3	f	n	29.01	27.24	2.24	9.68	1.1	47.1	59.5	13.7	17.3
05/01/02	60 - 90	3	f	n	29.41	27.9	1.36	8.06	0.4	26.2	68.4	6.3	16.6
05/01/02	0 - 15	3	r	n	29.53	27.31	4.10	11.62	1.3	31.0	22.7	5.4	4.0
05/01/02	15 - 30	3	r	n	29.09	27.33	2.27	9.60	17.0	749.4	122.0	107.9	17.6
05/01/02	30 - 60	3	r	n	29.55	27.89	2.23	8.87	3.9	172.4	118.8	45.9	31.6
05/01/02	60 - 90	3	r	n	29.17	27.48	2.37	9.16	8.5	360.5	202.1	99.1	55.5
05/06/02	0 - 15	12	f	s	29.62	28.40	4.12	6.14	1.1	27.6	118.5	2.5	10.9
05/06/02	15 - 30	12	f	s	29.32	27.76	5.32	8.37	0.4	6.7	97.2	0.8	12.2
05/06/02	30 - 60	12	f	s	29.28	27.82	4.99	7.82	0.4	7.2	102.6	1.7	24.1
05/06/02	60 - 90	12	f	s	29.58	28.18	4.73	7.40	0.4	7.6	81.1	1.7	18.0
05/06/02	0 - 15	12	r	s	29.43	28.54	3.02	4.46	2.4	78.0	165.3	5.2	11.1
05/06/02	15 - 30	12	r	s	29.51	28.79	2.44	3.73	5.7	233.5	228.6	13.0	12.8
05/06/02	30 - 60	12	r	s	29.56	28.16	4.74	7.41	2.5	53.3	58.9	11.9	13.1
05/06/02	60 - 90	12	r	s	29.19	27.85	4.59	7.17	1.1	24.8	68.4	5.3	14.7
05/06/02	0 - 15	13	f	s	29.83	28.11	5.77	8.75	2.7	46.7	61.5	6.1	8.1
05/06/02	15 - 30	13	f	s	29.40	27.37	6.90	11.05	1.5	21.3	51.4	3.5	8.5
05/06/02	30 - 60	13	f	s	29.89	27.56	7.80	12.60	1.5	18.9	73.0	7.1	27.6
05/06/02	60 - 90	13	f	s	29.15	27.19	6.72	10.74	1.7	26.0	42.4	8.4	13.7
05/06/02	0 - 15	13	r	s	29.76	28.38	4.64	6.95	1.9	40.1	92.7	4.2	9.7
05/06/02	15 - 30	13	r	s	29.18	27.86	4.52	7.06	6.0	133.3	154.1	14.1	16.3
05/06/02	30 - 60	13	r	s	29.20	27.59	5.51	8.69	7.4	134.6	78.0	35.1	20.3
05/06/02	60 - 90	13	r	s	29.64	28.00	5.53	8.73	4.9	88.9	113.4	23.3	29.7
05/06/02	0 - 15	6	f	s	29.21	27.67	5.27	7.96	1.4	25.8	133.3	3.1	15.9
05/06/02	15 - 30	6	f	s	28.96	27.42	5.32	8.37	0.7	14.1	74.3	1.8	9.3
05/06/02	30 - 60	6	f	s	29.48	27.92	5.29	8.33	0.3	5.7	53.8	1.4	13.4
05/06/02	60 - 90	6	f	s	29.45	27.81	5.57	8.79	0.3	5.4	46.0	1.4	12.1
05/06/02	0 - 15	6	r	s	29.29	28.40	3.04	4.48	2.6	85.0	126.3	5.7	8.5
05/06/02	15 - 30	6	r	s	28.96	27.98	3.38	5.22	19.9	586.9	188.9	45.9	14.8
05/06/02	30 - 60	6	r	s	29.11	27.56	5.32	8.38	6.8	126.8	52.4	31.9	13.2
05/06/02	60 - 90	6	r	s	29.68	28.14	5.19	8.15	3.5	66.9	67.2	16.4	16.4
05/06/02	0 - 15	7	f	s	29.76	28.29	4.94	7.43	0.6	11.8	65.9	1.3	7.3
05/06/02	15 - 30	7	f	s	29.24	27.74	5.13	8.06	0.4	7.0	62.3	0.8	7.5
05/06/02	30 - 60	7	f	s	29.69	28.04	5.56	8.77	0.4	6.4	62.8	1.7	16.5
05/06/02	60 - 90	7	f	s	28.94	27.46	5.11	8.03	0.4	7.0	87.5	1.7	21.1
05/06/02	0 - 15	7	r	s	29.38	28.35	3.51	5.20	1.8	51.4	253.5	4.0	19.8
05/06/02	15 - 30	7	r	s	29.78	28.94	2.82	4.32	5.3	186.2	197.8	12.1	12.8
05/06/02	30 - 60	7	r	s	29.01	27.66	4.65	7.27	4.5	96.1	33.8	21.0	7.4
05/06/02	60 - 90	7	r	s	29.41	27.99	4.83	7.56	1.3	27.0	24.1	6.1	5.5
05/06/02	0 - 15	4	f	s	28.95	27.42	5.28	7.98	0.6	11.0	8.9	1.3	1.1
05/06/02	15 - 30	4	f	s	29.49	27.77	5.83	9.23	0.4	7.1	10.0	1.0	1.4
05/06/02	30 - 60	4	f	s	28.92	27.31	5.57	8.78	0.2	4.4	33.5	1.2	8.8

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
05/06/02	60 - 90	4	f	s	28.91	27.37	5.33	8.38	0.2	4.6	27.3	1.2	6.9
05/06/02	0 - 15	4	r	s	29.28	27.95	4.54	6.80	1.0	22.6	89.6	2.3	9.1
05/06/02	15 - 30	4	r	s	29.00	27.47	5.28	8.30	0.7	14.2	154.1	1.8	19.2
05/06/02	30 - 60	4	r	s	29.57	27.90	5.65	8.92	0.9	16.2	55.6	4.3	14.9
05/06/02	60 - 90	4	r	s	29.17	27.46	5.86	9.28	0.8	13.7	49.6	3.8	13.8
05/15/02	0 - 15	8	f	n	29.36	27.78	5.38	8.13	2.0	37.8	37.8	4.6	4.6
05/15/02	15 - 30	8	f	n	29.12	27.51	5.53	8.72	2.6	47.7	58.9	6.2	7.7
05/15/02	30 - 60	8	f	n	29.18	27.73	4.97	7.79	0.5	10.3	32.8	2.4	7.7
05/15/02	60 - 90	8	f	n	29.30	28.01	4.40	6.86	0.5	10.4	44.9	2.1	9.3
05/15/02	0 - 15	8	r	n	29.18	27.88	4.46	6.67	3.6	81.2	96.5	8.1	9.7
05/15/02	15 - 30	8	r	n	29.70	28.80	3.03	4.66	2.0	65.4	118.9	4.6	8.3
05/15/02	30 - 60	8	r	n	29.13	27.96	4.02	6.23	1.0	24.9	86.8	4.7	16.2
05/15/02	60 - 90	8	r	n	29.81	28.55	4.23	6.58	1.5	36.6	61.9	7.2	12.2
05/15/02	0 - 15	9	f	n	29.34	27.83	5.15	7.76	1.8	35.3	72.3	4.1	8.4
05/15/02	15 - 30	9	f	n	29.06	27.49	5.40	8.51	0.8	15.5	53.8	2.0	6.9
05/15/02	30 - 60	9	f	n	29.11	27.87	4.26	6.63	0.5	12.0	51.9	2.4	10.3
05/15/02	60 - 90	9	f	n	29.11	27.98	3.88	6.02	0.5	13.2	101.8	2.4	18.4
05/15/02	0 - 15	9	r	n	29.15	28.10	3.60	5.34	4.0	111.0	116.2	8.9	9.3
05/15/02	15 - 30	9	r	n	29.04	28.20	2.89	4.44	2.3	77.9	132.6	5.2	8.8
05/15/02	30 - 60	9	r	n	29.28	28.13	3.93	6.09	3.9	99.0	118.4	18.1	21.6
05/15/02	60 - 90	9	r	n	29.39	28.22	3.98	6.18	4.8	119.6	118.2	22.2	21.9
05/15/02	0 - 15	10	f	n	29.26	27.83	4.89	7.35	3.7	75.1	175.9	8.3	19.4
05/15/02	15 - 30	10	f	n	29.09	27.42	5.74	9.07	0.9	15.5	73.9	2.1	10.1
05/15/02	30 - 60	10	f	n	29.21	27.81	4.79	7.50	0.6	12.9	70.4	2.9	15.8
05/15/02	60 - 90	10	f	n	29.16	27.96	4.12	6.39	0.4	9.8	48.1	1.9	9.2
05/15/02	0 - 15	10	r	n	28.85	27.94	3.15	4.66	10.4	330.7	48.0	23.1	3.4
05/15/02	15 - 30	10	r	n	28.90	27.93	3.36	5.17	70.5	2100.8	183.5	163.1	14.2
05/15/02	30 - 60	10	r	n	29.02	27.87	3.96	6.15	20.5	518.3	82.2	95.6	15.2
05/15/02	60 - 90	10	r	n	29.30	28.01	4.40	6.86	7.9	180.0	55.5	37.0	11.4
05/15/02	0 - 15	11	f	n	29.60	28.01	5.37	8.12	1.2	22.7	36.8	2.8	4.5
05/15/02	15 - 30	11	f	n	29.29	27.89	4.78	7.48	0.5	10.7	98.5	1.2	11.0
05/15/02	30 - 60	11	f	n	29.57	28.19	4.67	7.29	0.4	8.6	107.1	1.9	23.4
05/15/02	60 - 90	11	f	n	29.05	27.77	4.41	6.87	0.3	6.6	73.9	1.4	15.2
05/15/02	0 - 15	11	r	n	28.99	27.91	3.73	5.53	1.9	51.7	176.2	4.3	14.6
05/15/02	15 - 30	11	r	n	29.85	28.94	3.05	4.69	3.9	127.6	103.0	9.0	7.2
05/15/02	30 - 60	11	r	n	29.55	28.26	4.37	6.80	2.9	66.6	42.7	13.6	8.7
05/15/02	60 - 90	11	r	n	29.02	27.77	4.31	6.71	5.0	115.6	67.5	23.3	13.6
05/15/02	0 - 15	3	f	n	29.21	27.61	5.48	8.29	0.8	14.3	81.7	1.8	10.2
05/15/02	15 - 30	3	f	n	29.18	27.43	6.00	9.51	0.5	7.6	69.8	1.1	9.9
05/15/02	30 - 60	3	f	n	29.47	27.72	5.94	9.41	0.5	7.7	64.6	2.2	18.2
05/15/02	60 - 90	3	f	n	29.07	27.64	4.92	7.71	0.3	5.9	73.4	1.4	17.0
05/15/02	0 - 15	3	r	n	29.21	27.82	4.76	7.14	2.8	58.8	52.6	6.3	5.6
05/15/02	15 - 30	3	r	n	28.89	27.68	4.19	6.51	1.2	29.1	51.4	2.8	5.0
05/15/02	30 - 60	3	r	n	29.33	27.73	5.46	8.60	0.3	5.4	38.4	1.4	9.9
05/15/02	60 - 90	3	r	n	29.98	28.41	5.24	8.23	0.3	5.6	36.7	1.4	9.1
05/22/02	0 - 15	12	f	s	29.43	27.90	5.20	7.84	2.7	51.8	58.2	6.1	6.8
05/22/02	15 - 30	12	f	s	29.55	28.03	5.14	8.08	2.4	46.0	110.7	5.6	13.4
05/22/02	30 - 60	12	f	s	29.59	28.19	4.73	7.40	0.7	15.4	70.0	3.4	15.5
05/22/02	60 - 90	12	f	s	29.66	28.24	4.79	7.49	0.4	8.4	53.5	1.9	12.0
05/22/02	0 - 15	12	r	s	29.59	28.84	2.53	3.72	5.8	228.7	155.9	12.8	8.7
05/22/02	15 - 30	12	r	s	29.53	28.92	2.07	3.14	19.4	941.5	798.6	44.4	37.6
05/22/02	30 - 60	12	r	s	29.11	28.06	3.61	5.58	15.4	425.9	220.6	71.2	36.9
05/22/02	60 - 90	12	r	s	29.45	28.41	3.53	5.45	3.2	91.6	49.5	15.0	8.1
05/22/02	0 - 15	13	f	s	29.38	27.31	7.05	10.84	3.4	48.2	38.8	7.8	6.3
05/22/02	15 - 30	13	f	s	29.05	27.07	6.82	10.90	4.3	63.5	384.0	10.4	62.8
05/22/02	30 - 60	13	f	s	29.16	27.71	4.97	7.80	0.7	14.7	46.8	3.4	10.9
05/22/02	60 - 90	13	f	s	29.86	28.48	4.62	7.22	0.4	8.7	36.5	1.9	7.9
05/22/02	0 - 15	13	r	s	29.96	28.00	6.54	10.01	2.4	37.0	40.0	5.6	6.0
05/22/02	15 - 30	13	r	s	29.32	28.17	3.92	6.08	14.0	356.9	65.2	32.6	6.0

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
05/22/02	30 - 60	13	r	s	29.03	27.52	5.20	8.18	5.5	106.2	49.2	26.1	12.1
05/22/02	60 - 90	13	r	s	29.09	27.63	5.02	7.87	1.5	29.7	39.4	7.0	9.3
05/22/02	0 - 15	6	f	s	29.33	27.42	6.51	9.96	1.6	24.6	38.4	3.7	5.7
05/22/02	15 - 30	6	f	s	29.95	28.23	5.74	9.08	1.5	26.0	70.8	3.5	9.6
05/22/02	30 - 60	6	f	s	29.39	27.78	5.48	8.64	0.5	9.3	84.9	2.4	22.0
05/22/02	60 - 90	6	f	s	29.91	28.79	3.74	5.80	0.3	7.8	74.5	1.4	13.0
05/22/02	0 - 15	6	r	s	29.29	28.04	4.27	6.37	3.0	70.7	96.7	6.8	9.2
05/22/02	15 - 30	6	r	s	29.58	28.57	3.41	5.27	13.5	394.0	105.6	31.1	8.3
05/22/02	30 - 60	6	r	s	29.44	28.20	4.21	6.55	2.1	50.9	63.5	10.0	12.5
05/22/02	60 - 90	6	r	s	29.02	27.69	4.58	7.16	1.5	32.5	55.8	7.0	12.0
05/22/02	0 - 15	7	f	s	29.47	27.76	5.80	8.81	1.8	30.4	46.1	4.0	6.1
05/22/02	15 - 30	7	f	s	29.56	27.92	5.55	8.75	1.0	18.0	47.2	2.4	6.2
05/22/02	30 - 60	7	f	s	29.68	28.58	3.71	5.73	0.4	10.8	145.8	1.9	25.1
05/22/02	60 - 90	7	f	s	29.82	28.51	4.39	6.85	0.3	7.9	82.0	1.6	16.9
05/22/02	0 - 15	7	r	s	29.90	28.88	3.41	5.05	6.6	193.9	134.6	14.7	10.2
05/22/02	15 - 30	7	r	s	29.40	28.52	2.99	4.60	18.9	631.6	285.3	43.6	19.7
05/22/02	30 - 60	7	r	s	29.62	28.50	3.78	5.86	4.4	115.8	44.7	20.3	7.8
05/22/02	60 - 90	7	r	s	29.96	28.76	4.01	6.22	3.9	97.1	90.0	18.1	16.8
05/22/02	0 - 15	4	f	s	29.78	28.16	5.44	8.23	2.7	50.5	51.3	6.2	6.3
05/22/02	15 - 30	4	f	s	29.73	28.19	5.18	8.14	1.9	36.2	52.8	4.4	6.4
05/22/02	30 - 60	4	f	s	29.11	27.83	4.40	6.85	0.5	11.6	50.3	2.4	10.3
05/22/02	60 - 90	4	f	s	29.63	28.36	4.29	6.67	0.5	10.6	97.6	2.1	19.5
05/22/02	0 - 15	4	r	s	29.35	28.67	2.32	3.39	6.6	285.5	125.5	14.5	6.4
05/22/02	15 - 30	4	r	s	29.36	28.67	2.35	3.59	12.9	549.3	148.4	29.5	8.0
05/22/02	30 - 60	4	r	s	29.94	28.98	3.21	4.94	6.0	185.9	61.7	27.5	9.1
05/22/02	60 - 90	4	r	s	29.07	27.92	3.96	6.14	5.5	138.3	58.8	25.5	10.8
05/29/02	0 - 15	8	f	n	29.28	27.99	4.41	6.59	1.1	24.8	56.8	2.5	5.6
05/29/02	15 - 30	8	f	n	29.06	27.75	4.51	7.03	0.5	12.0	80.0	1.3	8.4
05/29/02	30 - 60	8	f	n	29.62	28.44	3.98	6.18	0.9	21.9	115.2	4.1	21.4
05/29/02	60 - 90	8	f	n	28.84	27.48	4.72	7.37	0.5	11.5	71.5	2.5	15.8
05/29/02	0 - 15	8	r	n	28.93	27.88	3.63	5.39	5.1	141.7	70.5	11.4	5.7
05/29/02	15 - 30	8	r	n	29.71	29.23	1.62	2.45	7.6	469.4	870.2	17.2	31.9
05/29/02	30 - 60	8	r	n	29.58	28.59	3.35	5.16	4.0	120.5	97.3	18.7	15.1
05/29/02	60 - 90	8	r	n	28.91	27.53	4.77	7.47	13.0	271.5	75.5	60.8	16.9
05/29/02	0 - 15	9	f	n	29.80	28.58	4.09	6.10	0.9	22.7	61.1	2.1	5.6
05/29/02	15 - 30	9	f	n	29.74	28.70	3.50	5.40	1.2	32.9	103.1	2.7	8.3
05/29/02	30 - 60	9	f	n	29.46	28.44	3.46	5.34	0.8	22.0	260.0	3.5	41.7
05/29/02	60 - 90	9	f	n	29.57	28.42	3.89	6.03	0.3	8.2	53.9	1.5	9.7
05/29/02	0 - 15	9	r	n	29.61	28.76	2.87	4.23	4.6	161.8	73.0	10.3	4.6
05/29/02	15 - 30	9	r	n	29.35	28.61	2.52	3.85	4.2	166.6	92.3	9.6	5.3
05/29/02	30 - 60	9	r	n	29.19	28.08	3.80	5.89	2.6	68.2	45.9	12.0	8.1
05/29/02	60 - 90	9	r	n	29.06	27.84	4.20	6.53	1.3	31.4	69.3	6.1	13.6
05/29/02	0 - 15	10	f	n	29.05	27.85	4.13	6.16	2.4	57.4	98.5	5.3	9.1
05/29/02	15 - 30	10	f	n	29.19	28.19	3.43	5.29	2.9	83.8	120.5	6.6	9.6
05/29/02	30 - 60	10	f	n	28.92	27.70	4.22	6.56	1.0	24.6	82.7	4.9	16.3
05/29/02	60 - 90	10	f	n	29.52	28.26	4.27	6.64	0.9	20.5	85.8	4.1	17.1
05/29/02	0 - 15	10	r	n	29.08	27.29	6.16	9.38	19.1	309.7	317.1	43.6	44.6
05/29/02	15 - 30	10	r	n	29.05	28.24	2.79	4.27	18.2	653.9	272.9	41.9	17.5
05/29/02	30 - 60	10	r	n	29.10	28.17	3.20	4.92	10.2	318.4	163.6	47.0	24.1
05/29/02	60 - 90	10	r	n	29.39	28.22	3.98	6.18	4.8	119.5	118.2	22.1	21.9
05/29/02	0 - 15	11	f	n	29.29	28.11	4.03	6.00	11.7	291.2	150.0	26.2	13.5
05/29/02	15 - 30	11	f	n	29.78	28.83	3.19	4.91	3.6	114.3	214.9	8.4	15.8
05/29/02	30 - 60	11	f	n	29.55	28.58	3.28	5.06	1.6	50.2	102.7	7.6	15.6
05/29/02	60 - 90	11	f	n	29.60	28.46	3.85	5.97	0.5	14.0	40.8	2.5	7.3
05/29/02	0 - 15	11	r	n	29.48	28.47	3.43	5.07	6.5	190.6	117.1	14.5	8.9
05/29/02	15 - 30	11	r	n	29.25	28.16	3.73	5.77	8.7	233.3	93.6	20.2	8.1
05/29/02	30 - 60	11	r	n	29.32	28.29	3.51	5.42	18.2	519.0	109.2	84.5	17.8
05/29/02	60 - 90	11	r	n	29.44	28.29	3.91	6.06	3.7	94.8	53.6	17.2	9.7
05/29/02	0 - 15	3	f	n	29.67	28.32	4.55	6.82	1.1	24.1	38.4	2.5	3.9

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
05/29/02	15 - 30	3	f	n	29.41	28.28	3.84	5.95	1.0	25.6	33.4	2.3	3.0
05/29/02	30 - 60	3	f	n	29.52	28.32	4.07	6.31	0.6	14.7	37.2	2.8	7.1
05/29/02	60 - 90	3	f	n	29.74	28.59	3.87	5.99	0.5	12.5	57.2	2.3	10.3
05/29/02	0 - 15	3	r	n	29.54	28.36	3.99	5.95	1.9	46.8	58.3	4.2	5.2
05/29/02	15 - 30	3	r	n	29.34	28.54	2.73	4.18	2.2	80.8	115.2	5.1	7.2
05/29/02	30 - 60	3	r	n	29.53	28.42	3.76	5.82	1.0	27.7	60.4	4.8	10.5
05/29/02	60 - 90	3	r	n	29.85	28.63	4.09	6.35	0.5	11.9	135.1	2.3	25.7
06/05/02	0 - 15	12	f	s	29.22	27.78	4.93	7.41	6.0	122.2	60.1	13.6	6.7
06/05/02	15 - 30	12	f	s	29.24	27.75	5.10	8.00	2.3	45.4	55.8	5.4	6.7
06/05/02	30 - 60	12	f	s	29.80	28.36	4.83	7.57	0.8	16.9	78.0	3.8	17.7
06/05/02	60 - 90	12	f	s	29.37	28.21	3.95	6.13	0.7	16.5	36.9	3.0	6.8
06/05/02	0 - 15	12	r	s	29.20	28.39	2.77	4.08	9.9	358.5	148.4	21.9	9.1
06/05/02	15 - 30	12	r	s	29.54	28.54	3.39	5.22	9.5	280.7	373.0	22.0	29.2
06/05/02	30 - 60	12	r	s	29.54	28.17	4.64	7.25	9.7	209.6	66.3	45.6	14.4
06/05/02	60 - 90	12	r	s	29.57	28.21	4.60	7.18	5.1	110.5	34.2	23.8	7.4
06/05/02	0 - 15	13	f	s	29.18	27.81	4.69	7.04	6.5	138.9	58.1	14.7	6.1
06/05/02	15 - 30	13	f	s	28.96	27.63	4.59	7.17	2.2	48.0	64.5	5.2	6.9
06/05/02	30 - 60	13	f	s	29.00	27.81	4.10	6.38	0.8	20.0	53.8	3.8	10.3
06/05/02	60 - 90	13	f	s	29.46	28.32	3.87	6.00	0.8	19.7	58.6	3.5	10.5
06/05/02	0 - 15	13	r	s	29.47	28.60	2.95	4.35	11.5	389.9	206.0	25.4	13.4
06/05/02	15 - 30	13	r	s	29.35	28.44	3.10	4.77	8.7	281.9	173.8	20.2	12.4
06/05/02	30 - 60	13	r	s	29.12	27.89	4.22	6.57	3.5	83.6	50.9	16.5	10.0
06/05/02	60 - 90	13	r	s	29.80	28.62	3.96	6.14	3.3	83.6	42.6	15.4	7.9
06/05/02	0 - 15	6	f	s	28.92	27.62	4.50	6.73	4.1	92.1	50.4	9.3	5.1
06/05/02	15 - 30	6	f	s	29.16	27.97	4.08	6.34	2.3	56.7	45.6	5.4	4.3
06/05/02	30 - 60	6	f	s	29.65	28.49	3.91	6.07	0.9	22.3	55.0	4.1	10.0
06/05/02	60 - 90	6	f	s	29.10	28.05	3.61	5.58	0.7	19.6	94.9	3.3	15.9
06/05/02	0 - 15	6	r	s	29.18	28.58	2.06	3.00	9.3	454.6	228.3	20.5	10.3
06/05/02	15 - 30	6	r	s	29.01	28.24	2.65	4.06	8.9	335.4	218.2	20.4	13.3
06/05/02	30 - 60	6	r	s	29.49	28.57	3.12	4.80	4.5	145.2	65.2	20.9	9.4
06/05/02	60 - 90	6	r	s	29.59	28.51	3.65	5.64	2.9	78.6	41.5	13.3	7.0
06/05/02	0 - 15	7	f	s	28.96	27.67	4.45	6.67	3.4	76.8	162.5	7.7	16.2
06/05/02	15 - 30	7	f	s	29.08	27.85	4.23	6.58	1.5	36.4	82.3	3.6	8.1
06/05/02	30 - 60	7	f	s	29.06	27.85	4.16	6.47	0.7	15.7	93.3	3.0	18.1
06/05/02	60 - 90	7	f	s	29.17	28.03	3.91	6.06	0.5	13.9	29.9	2.5	5.4
06/05/02	0 - 15	7	r	s	29.17	28.63	1.85	2.70	14.3	771.3	528.4	31.2	21.4
06/05/02	15 - 30	7	r	s	29.00	27.44	5.38	8.47	17.6	327.2	226.1	41.6	28.7
06/05/02	30 - 60	7	r	s	29.59	28.59	3.38	5.21	17.6	520.8	294.6	81.4	46.1
06/05/02	60 - 90	7	r	s	29.78	28.74	3.49	5.39	3.6	104.3	78.1	16.9	12.6
06/05/02	0 - 15	4	f	s	29.00	27.40	5.52	8.35	5.0	90.1	31.7	11.3	4.0
06/05/02	15 - 30	4	f	s	28.99	27.00	6.86	10.98	3.6	53.1	24.6	8.7	4.1
06/05/02	30 - 60	4	f	s	29.04	27.45	5.48	8.63	1.4	26.1	64.6	6.8	16.7
06/05/02	60 - 90	4	f	s	29.14	27.68	5.01	7.86	1.1	21.9	42.9	5.2	10.1
06/05/02	0 - 15	4	r	s	29.40	28.67	2.48	3.64	10.5	422.8	170.4	23.1	9.3
06/05/02	15 - 30	4	r	s	29.49	28.40	3.70	5.72	4.2	113.2	61.3	9.7	5.3
06/05/02	30 - 60	4	r	s	28.99	27.61	4.76	7.45	7.4	155.6	57.3	34.8	12.8
06/05/02	60 - 90	4	r	s	29.20	27.99	4.14	6.44	5.4	130.7	77.0	25.3	14.9
06/12/02	0 - 15	8	r	n	29.04	27.27	6.10	9.28	17.6	288.8	37.2	40.2	5.2
06/12/02	15 - 30	8	r	n	29.01	27.52	5.14	8.07	8.9	173.4	52.0	21.0	6.3
06/12/02	30 - 60	8	r	n	29.33	27.80	5.22	8.20	3.1	59.2	18.0	14.6	4.4
06/12/02	60 - 90	8	r	n	28.95	27.52	4.94	7.74	5.2	105.1	50.6	24.4	11.7
06/12/02	0 - 15	9	r	n	29.75	28.08	5.61	8.50	9.6	171.4	65.1	21.9	8.3
06/12/02	15 - 30	9	r	n	29.06	27.39	5.75	9.08	3.8	65.3	45.5	8.9	6.2
06/12/02	30 - 60	9	r	n	29.62	27.98	5.54	8.73	2.2	39.8	42.0	10.4	11.0
06/12/02	60 - 90	9	r	n	29.71	28.14	5.28	8.31	1.0	18.6	37.4	4.6	9.3
06/12/02	0 - 15	10	r	n	29.12	27.01	7.25	11.17	14.8	204.7	75.1	34.3	12.6
06/12/02	15 - 30	10	r	n	29.18	27.68	5.14	8.07	6.9	133.3	43.0	16.2	5.2
06/12/02	30 - 60	10	r	n	29.02	27.41	5.55	8.75	3.0	54.7	36.7	14.4	9.6
06/12/02	60 - 90	10	r	n	29.42	27.94	5.03	7.89	5.7	113.1	32.4	26.8	7.7

Table A-1. Continued

Date	Depth (cm)	Well	Furrow-Row	Half	wet wt	dry wt	%θ (mass)	%q (vol)	ug NO3-N/gm wet soil	mg NO3-N/L	mg NH4-N/L	kg N/ha-NO3	kg N/ha-NH4
06/12/02	0 - 15	11	r	n	29.39	27.54	6.29	9.61	10.4	165.2	46.1	23.8	6.6
06/12/02	15 - 30	11	r	n	29.72	28.01	5.75	9.10	4.8	83.5	35.4	11.4	4.8
06/12/02	30 - 60	11	r	n	29.76	28.08	5.65	8.91	2.2	39.0	43.2	10.4	11.6
06/12/02	60 - 90	11	r	n	29.04	27.56	5.10	8.00	1.2	23.7	34.3	5.7	8.2
06/12/02	0 - 15	3	r	n	29.76	27.97	6.01	9.15	10.5	173.8	36.7	23.9	5.0
06/12/02	15 - 30	3	r	n	29.39	27.83	5.31	8.35	3.5	66.5	41.6	8.3	5.2
06/12/02	30 - 60	3	r	n	29.61	27.99	5.47	8.62	1.4	25.1	34.1	6.5	8.8
06/12/02	60 - 90	3	r	n	29.61	28.16	4.90	7.67	1.0	20.1	40.4	4.6	9.3

APPENDIX B
PLANT SAMPLE ANALYSIS RESULTS

Table B-1. Potato crop analysis results (2001)

Date	DAP	Location	Tissue Type	LA	Total Fresh Weight	Total Dry Weight	Moisture Content	TKN	N Mass per sample	Plant N per area
				cm^2	g/area sampled	g/plant	%	mg/kg	mg/plant	kg N/ha
03/24/01	37	Well 10	Leaves	873.70	32.37	4.58	0.859	58400	267.472	9.64
03/24/01	37	Well 10	Stems		38.69	2.87	0.926	38200	109.634	
03/24/01	37	Well 10	Tubers		3.9	0.5	0.872	36000	18	
03/24/01	37	Well 10	Leaves	525.51	16.78	2.32	0.862	67300	156.136	5.88
03/24/01	37	Well 10	Stems		22.43	2.16	0.904	38400	82.944	
03/24/01	37	Well 10	Tubers		0.69	0.06	0.913	37000	2.22	
03/24/01	37	Well 8	Leaves	935.61	30.03	3.91	0.870	52000	203.32	7.80
03/24/01	37	Well 8	Stems		46.62	3.06	0.934	35600	108.936	
03/24/01	37	Well 8	Tubers		1.81	0.21	0.884	36000	7.56	
03/24/01	37	Well 8	Leaves	641.08	20.09	2.76	0.863	70200	193.752	7.51
03/24/01	37	Well 8	Stems		36.66	2.99	0.918	37400	111.826	
03/24/01	37	Well 8	Tubers		0.45	0.06	0.867	38300	2.298	
03/24/01	37	Well 6	Leaves	592.50	19.55	2.52	0.871	64500	162.54	5.66
03/24/01	37	Well 6	Stems		28.11	1.78	0.937	38000	67.64	
03/24/01	37	Well 6	Tubers		0.45	0.04	0.911	46800	1.872	
03/24/01	37	Well6	Leaves	1039.92	36.28	4.59	0.873	56600	259.794	8.65
03/24/01	37	Well6	Stems		54.53	3.26	0.940	27400	89.324	
03/24/01	37	Well6	Tubers		2.26	0.26	0.885	20800	5.408	
03/24/01	37	SE corner	Leaves	725.96	23.13	2.75	0.881	64700	177.925	6.13
03/24/01	37	SE corner	Stems		32.34	1.93	0.940	37200	71.796	
03/24/01	37	SE corner	Tubers		1.23	0.13	0.894	11200	1.456	
03/24/01	37	SE corner	Leaves	618.52	17.31	2.4	0.861	66600	159.84	7.06
03/24/01	37	SE corner	Stems		41.82	3.54	0.915	36000	127.44	
03/24/01	37	SE corner	Tubers		0.61	0.06	0.902	39700	2.382	
03/27/01	40	Well 4	Leaves	846.70	26.03	5.32	0.796	44800	238.336	8.31
03/27/01	40	Well 4	Stems		43.47	3.96	0.909	20700	81.972	
03/27/01	40	Well 4	Tubers		4.16	0.84	0.798	24200	20.328	
03/27/01	40	Well 4	Leaves	804.50	24.9	4.38	0.824	51400	225.132	8.56
03/27/01	40	Well 4	Stems		41.18	3.5	0.915	26000	91	
03/27/01	40	Well 4	Tubers		6.97	1.56	0.776	22400	34.944	
04/03/01	47	Well 8	Leaves	2056.17	74.92	7.46	0.900	57200	426.712	16.93
04/03/01	47	Well 8	Stems		79.7	4.33	0.946	28900	125.137	
04/03/01	47	Well 8	Tubers		39.41	5.47	0.861	26000	142.22	
04/03/01	47	Well 6	Leaves	1200.33	39.99	4.21	0.895	57600	242.496	9.90
04/03/01	47	Well 6	Stems		50.72	3.15	0.938	31200	98.28	
04/03/01	47	Well 6	Tubers		18.98	2.78	0.854	23400	65.052	
04/03/01	47	Well 8	Leaves	979.91	34.22	4.25	0.876	59200	251.6	9.68
04/03/01	47	Well 8	Stems		49.69	3	0.940	33400	100.2	
04/03/01	47	Well 8	Tubers		11.19	1.75	0.844	25800	45.15	
04/03/01	47	Well 6	Leaves	2416.31	88.93	9.27	0.896	50000	463.5	18.64
04/03/01	47	Well 6	Stems		74.87	4.33	0.942	25200	109.116	
04/03/01	47	Well 6	Tubers		58.93	8.64	0.853	22200	191.808	
04/03/01	47	near W12	Leaves	1153.75	38.86	4.43	0.886	49100	217.513	9.41
04/03/01	47	near W12	Stems		37.41	2.29	0.939	29200	66.868	
04/03/01	47	near W12	Tubers		31.9	4.98	0.844	20400	101.592	
04/03/01	47	near W12	Leaves	1864.10	66.66	7.94	0.881	53200	422.408	15.76
04/03/01	47	near W12	Stems		75.2	5.12	0.932	29200	149.504	
04/03/01	47	near W12	Tubers		19.98	2.93	0.853	25400	74.422	
04/03/01	47	Well 10	Leaves	1384.06	45.15	5.32	0.882	58400	310.688	11.60
04/03/01	47	Well 10	Stems		53.47	3.35	0.937	27800	93.13	
04/03/01	47	Well 10	Tubers		21.11	3.35	0.841	21400	71.69	
04/03/01	47	Well 10	Leaves	2118.64	70.5	2.94	0.958	48000	141.12	11.69
04/03/01	47	Well 10	Stems		88.32	5.03	0.943	30200	151.906	
04/03/01	47	Well 10	Tubers		20.05	7.77	0.612	24000	186.48	
05/04/01	78	Well 8	Leaves	5447.30	204.22	26.34	0.871	24300	640.062	52.59
05/04/01	78	Well 8	Stems		105.76	7.98	0.925	18600	148.428	
05/04/01	78	Well 8	Tubers		620.04	113.99	0.816	12000	1367.88	

Table B-1. Continued

Date	DAP	Location	Tissue Type	LA	Total Fresh Weight	Total Dry Weight	Moisture Content	TKN	N Mass per sample	Plant N per area
				cm^2	g/area sampled	g/plant	%	mg/kg	mg/plant	kg N/ha
05/04/01	78	Well 6	Leaves	2461.60	83.92	8.72	0.896	35600	310.432	25.87
05/04/01	78	Well 6	Stems		77.25	4.18	0.946	16400	68.552	
05/04/01	78	Well 6	Tubers		287.22	49.76	0.827	13700	681.712	
05/04/01	78	Well 11	Leaves	6561.84	244.21	37.6	0.846	35800	1346.08	80.27
05/04/01	78	Well 11	Stems		158.98	11.88	0.925	20000	237.6	
05/04/01	78	Well 11	Tubers		874.03	161.1	0.816	10600	1707.66	
05/04/01	78	Well 10	Leaves	7138.00	272.2	37.62	0.862	23800	895.356	59.73
05/04/01	78	Well 10	Stems		266.35	15.82	0.941	17800	281.596	
05/04/01	78	Well 10	Tubers		730.88	124.72	0.829	10200	1272.144	
05/04/01	78	Well 7	Leaves	2109.90	72.95	7.57	0.896	46300	350.491	24.88
05/04/01	78	Well 7	Stems		37.18	2.66	0.928	21600	57.456	
05/04/01	78	Well 7	Tubers		271.4	46.38	0.829	13200	612.216	
05/04/01	78	Well 4	Leaves	2310.60	75.88	10.75	0.858	45400	488.05	30.28
05/04/01	78	Well 4	Stems		65.4	5.45	0.917	19900	108.455	
05/04/01	78	Well 4	Tubers		306.3	49.64	0.838	13000	645.32	
05/04/01	78	Well 12	Leaves	4185.80	155.22	19.42	0.875	31800	617.556	53.52
05/04/01	78	Well 12	Stems		109.6	7.52	0.931	20000	150.4	
05/04/01	78	Well 12	Tubers		573.6	104.89	0.817	13600	1426.504	
05/04/01	78	Well 9	Leaves	1554.80	58.77	6.62	0.887	38700	256.194	19.48
05/04/01	78	Well 9	Stems		55.7	3.81	0.932	20700	78.867	
05/04/01	78	Well 9	Tubers		213.08	38.63	0.819	12000	463.56	

Table B-2. Potato crop analysis results (2002)

Date	DAP	Well	Half	Tissue Type	Area Sampled	LA	Total Fresh Weight	Moisture Content	Total Dry Weight	TKN	N Mass per sample	Plant N per area
					cm^2	cm^2	g/area sampled	%	g/area sampled	mg/kg	mg/area sampled	kg N/ha
4/3/2002	47	11	N	stem	1 plant		120.0	0.95	6.50	41300	268.5	24.75
4/3/2002	47	11	N	tuber	1 plant		12.7	0.85	1.90	21000	39.9	
4/3/2002	47	11	N	leaves	1 plant	2336	82.5	0.87	10.40	67950	706.7	
4/3/2002	47	3	N	tuber	1 plant		12.0	0.83	2.00	23050	46.1	21.64
4/3/2002	47	3	N	tuber	1 plant		8.6	0.85	1.30	22050	28.7	
4/3/2002	47	3	N	leaves	1 plant	2186	71.9	0.87	9.50	60700	576.7	
4/3/2002	47	3	N	leaves	1 plant	2636	86.2	0.85	12.70	60650	770.3	26.23
4/3/2002	47	3	N	stem	1 plant		97.6	0.93	6.60	40100	264.7	
4/3/2002	47	3	N	stem	1 plant		105.6	0.93	7.00	39500	276.5	
4/3/2002	47	8	N	leaves	1 plant	1830	64.2	0.82	11.40	64150	731.3	22.19
4/3/2002	47	8	N	leaves	1 plant	2109	78.1	0.82	13.80	64150	885.3	
4/3/2002	47	8	N	stem	1 plant		55.0	0.92	4.20	36700	154.1	
4/3/2002	47	8	N	stem	1 plant		81.7	0.92	6.30	31350	197.5	26.41
4/3/2002	47	8	N	tuber	1 plant		6.3	0.87	0.80	30500	24.4	
4/3/2002	47	9	N	leaves	1 plant	2123	80.1	0.86	11.20	63950	716.2	21.85
4/3/2002	47	9	N	leaves	1 plant	1491	50.2	0.87	6.70	66150	443.2	
4/3/2002	47	9	N	stem	1 plant		63.6	0.94	4.10	39350	161.3	
4/3/2002	47	9	N	stem	1 plant		87.9	0.94	5.70	36550	208.3	16.21
4/3/2002	47	9	N	tuber	1 plant		4.8	0.86	0.70	26150	18.3	
4/3/2002	47	9	N	tuber	1 plant		3.7	0.86	0.50	26150	13.1	
4/12/2002	56	4	S	leaves	90x90	1225	275.1	0.86	37.62	43540	1637.9	27.55
4/12/2002	56	4	S	stem	90x90		253.3	0.92	20.36	14600	297.3	
4/12/2002	56	4	S	tuber	90x90		260.4	0.91	23.72	12500	296.6	
4/12/2002	56	13	S	leaves	90x90	1240	645.2	0.86	89.95	58600	5270.8	79.28
4/12/2002	56	13	S	stem	90x90		717.7	0.96	32.07	26600	853.1	
4/12/2002	56	13	S	tuber	90x90		241.0	0.94	14.03	21200	297.4	
4/24/2002	68	7	S	leaves	45x90	2031	483.4	0.88	57.48	54450	3129.7	142.06
4/24/2002	68	7	S	stem	45x90		502.2	0.93	35.02	23800	833.4	
4/24/2002	68	7	S	tuber	45x90		923.7	0.87	120.15	14900	1790.2	

Table B-2. Continued

Date	DAP	Well	Half	Tissue Type	Area Sampled	LA	Total Fresh Weight	Moisture Content	Total Dry Weight	TKN	N Mass per sample	Plant N per area
					cm^2	cm^2	g/area sampled	%	g/area sampled	mg/kg	mg/area sampled	kg N/ha
4/24/2002	68	11	N	leaves	45x90		425.1	0.82	77.99	45550	3552.5	213.43
4/24/2002	68	11	N	stem	45x90		466.7	0.93	30.67	26100	800.5	
4/24/2002	68	11	N	tuber	45x90		1056.5	0.85	160.21	14150	2266.9	
4/24/2002	68	11	N	leaves	45x90		447.6	0.86	64.46	44650	2878.2	198.30
4/24/2002	68	11	N	stem	45x90		554.1	0.95	27.71	23550	652.5	
4/24/2002	68	11	N	tuber	45x90		1007.5	0.85	153.60	14250	2188.8	
4/24/2002	68	4	S	leaves	45x90		658.0	0.83	111.78	36700	4102.2	166.50
4/24/2002	68	4	S	stem	45x90		668.9	0.92	52.40	22200	1163.3	
4/24/2002	68	4	S	tuber	45x90		1224.4	0.85	183.08	15500	2837.8	
5/6/2002	80	6	S	leaves	90x90		1084.0	0.88	128.29	37350	4791.5	146.10
5/6/2002	80	6	S	stem	90x90		931.0	0.93	65.34	16950	1107.6	
5/6/2002	80	6	S	tuber	90x90		2881.7	0.85	435.86	13600	5927.6	
5/6/2002	80	7	S	leaves	90x90		633.9	0.85	95.57	31600	3019.9	163.46
5/6/2002	80	7	S	stem	90x90		609.4	0.92	46.28	17000	786.8	
5/6/2002	80	7	S	tuber	90x90		1912.6	0.84	297.52	12100	3599.9	
5/6/2002	80	12	S	leaves	90x90		862.1	0.87	112.19	30600	3433.0	141.22
5/6/2002	80	12	S	stem	90x90		872.1	0.93	58.08	17300	1004.7	
5/6/2002	80	12	S	tuber	90x90		2768.0	0.85	417.13	13550	5652.1	
5/6/2002	80	8	N	leaves	45x90		470.7	0.81	87.20	28650	2498.3	200.08
5/6/2002	80	8	N	stem	45x90		579.9	0.93	43.49	22050	959.0	
5/6/2002	80	8	N	tuber	45x90		2111.1	0.83	355.26	14900	5293.4	
5/6/2002	80	8	N	leaves	45x90		411.6	0.86	58.54	30450	1782.5	153.25
5/6/2002	80	8	N	stem	45x90		402.9	0.93	29.75	22950	682.8	
5/6/2002	80	8	N	tuber	45x90		1346.3	0.83	222.15	14650	3254.6	
5/6/2002	80	4	S	leaves	45x90		418.5	0.87	53.97	26550	1432.9	98.14
5/6/2002	80	4	S	stem	45x90		375.7	0.91	33.85	14100	477.3	
5/6/2002	80	4	S	tuber	45x90		1405.8	0.83	246.00	9250	2275.5	
5/6/2002	80	3	N	leaves	45x90		207.1	0.88	24.78	33100	820.2	137.67
5/6/2002	80	3	N	stem	45x90		203.1	0.92	16.47	22500	370.5	
5/6/2002	80	3	N	tuber	45x90		682.4	0.80	134.19	14775	1982.6	
5/6/2002	80	10	N	leaves	45x90		454.8	0.90	45.12	32717	1476.2	229.41
5/6/2002	80	10	N	stem	45x90		481.5	0.94	28.97	22500	651.9	
5/6/2002	80	10	N	tuber	45x90		1428.9	0.85	207.59	14775	3067.2	

APPENDIX C
SUBSTOR/DSSAT INPUT FILES

SUBSTOR Input File Created from DSSAT FILEX

```
*MODEL INPUT FILE           I     1     5     1     3     0
*FILES
MODEL          PTSUB980.EXE
FILEX          REDLASOD.PTX
FILEA          REDLASOD.PTA
FILET          REDLASOD.PTT
SPECIES        PTSUB980.SPE C:\DSSAT35\GENOTYPE\
ECOTYPE        □□□□
```

```
*IRRIGATION
    .900   60.   50.  100. GS000 IR001  10.0
    1007 IR004   5.0     0
    1012 IR004   3.0     0
    1013 IR004   5.0     0
    1037 IR004   3.0     0
    1043 IR004   7.0     0
    1048 IR004   6.0     0
    1051 IR004   5.0     0
    1053 IR004   7.0     0
    1055 IR004   9.0     0
    1060 IR004   8.0     0
    1066 IR004   4.0     0
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    1092 IR004   9.0     0
    1093 IR004   8.0     0
    1094 IR004   9.0     0
    1095 IR004   8.0     0
    1096 IR004   9.0     0
    1097 IR004   8.0     0
    1098 IR004   9.0     0
    1099 IR004   8.0     0
    1100 IR004   9.0     0
    1101 IR004   8.0     0
    1102 IR004   9.0     0
    1103 IR004   8.0     0
    1104 IR004   9.0     0
    1105 IR004   8.0     0
    1106 IR004   9.0     0
    1107 IR004   8.0     0
    1108 IR004   9.0     0
    1109 IR004   8.0     0
    1110 IR004   9.0     0
    1111 IR004   8.0     0
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    1113 IR004   8.0     0
    1114 IR004   9.0     0
    1115 IR004   8.0     0
    1116 IR004   9.0     0
    1117 IR004   8.0     0
    1118 IR004   9.0     0
    1119 IR004   8.0     0
    1120 IR004   9.0     0
    1121 IR004   8.0     0
```

```
    1122 IR004   9.0     0
    1123 IR004   8.0     0
    1124 IR004   9.0     0
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    1127 IR004   8.0     0
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    1135 IR004   8.0     0
    1136 IR004   9.0     0
    1137 IR004   8.0     0
    1138 IR004   9.0     0
    1139 IR004   8.0     0
    1140 IR004   9.0     0
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    1012 FE001 AP005    0.    1.    0.    0.    0.    0.
    1013 FE001 AP005    0.    1.    0.    0.    0.    0.
    1018 FE001 AP009   15.   38.    0.    0.    0.    0.
    1037 FE001 AP005    0.    1.    0.    0.    0.    0.
    1043 FE001 AP005    0.    1.    0.    0.    0.    0.
    1046 FE001 AP004   15.   17.    0.    0.    0.    0.
    1048 FE001 AP005    0.    1.    0.    0.    0.    0.
    1051 FE001 AP005    0.    1.    0.    0.    0.    0.
    1053 FE001 AP005    0.    1.    0.    0.    0.    0.
    1055 FE001 AP005    0.    2.    0.    0.    0.    0.
    1060 FE001 AP005    0.    2.    0.    0.    0.    0.
    1064 FE001 AP009   15.  112.    0.    0.    0.    0.
    1066 FE001 AP005    0.    1.    0.    0.    0.    0.
    1071 FE001 AP005    0.    1.    0.    0.    0.    0.
    1083 FE001 AP005    0.    2.    0.    0.    0.    0.
    1084 FE001 AP009   15.  112.    0.    0.    0.    0.
    1091 FE001 AP005    0.    2.    0.    0.    0.    0.
    1092 FE001 AP005    0.    2.    0.    0.    0.    0.
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    1094 FE001 AP005    0.    2.    0.    0.    0.    0.
    1095 FE001 AP005    0.    2.    0.    0.    0.    0.
    1096 FE001 AP005    0.    2.    0.    0.    0.    0.
    1097 FE001 AP005    0.    2.    0.    0.    0.    0.
    1098 FE001 AP005    0.    2.    0.    0.    0.    0.
    1099 FE001 AP005    0.    2.    0.    0.    0.    0.
    1100 FE001 AP005    0.    2.    0.    0.    0.    0.
```

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    1101 FE001 AP005    0.    2.    0.    0.    0.    0.
    1102 FE001 AP005    0.    2.    0.    0.    0.    0.
    1103 FE001 AP005    0.    2.    0.    0.    0.    0.
    1104 FE001 AP005    0.    2.    0.    0.    0.    0.
    1105 FE001 AP005    0.    2.    0.    0.    0.    0.
    1106 FE001 AP005    0.    2.    0.    0.    0.    0.
    1107 FE001 AP005    0.    2.    0.    0.    0.    0.
    1108 FE001 AP005    0.    2.    0.    0.    0.    0.
    1109 FE001 AP005    0.    2.    0.    0.    0.    0.
    1110 FE001 AP005    0.    2.    0.    0.    0.    0.
    1111 FE001 AP005    0.    2.    0.    0.    0.    0.
    1112 FE001 AP005    0.    2.    0.    0.    0.    0.
    1113 FE001 AP005    0.   34.    0.    0.    0.    0.
    1114 FE001 AP005    0.    2.    0     0     0     0
    1115 FE001 AP005    0.    2.    0.    0.    0.    0.
    1116 FE001 AP005    0.    2.    0     0     0     0
    1117 FE001 AP005    0.    2.    0.    0.    0.    0.
    1118 FE001 AP005    0.    2.    0     0     0     0
    1119 FE001 AP005    0.    2.    0.    0.    0.    0.
    1120 FE001 AP005    0.    2.    0     0     0     0
    1121 FE001 AP005    0.    2.    0.    0.    0.    0.
    1122 FE001 AP005    0.    2.    0     0     0     0
    1123 FE001 AP005    0.    2.    0.    0.    0.    0.
    1124 FE001 AP005    0.    2.    0     0     0     0
    1125 FE001 AP005    0.    2.    0.    0.    0.    0.
    1126 FE001 AP005    0.    2.    0     0     0     0
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    1128 FE001 AP005    0.    2.    0     0     0     0
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    1131 FE001 AP005    0.    2.    0.    0.    0.    0.
    1132 FE001 AP005    0.    2.    0     0     0     0
    1133 FE001 AP005    0.    2.    0.    0.    0.    0.
    1134 FE001 AP005    0.    2.    0     0     0     0
    1135 FE001 AP005    0.    2.    0.    0.    0.    0.
    1136 FE001 AP005    0.    2.    0     0     0     0
    1137 FE001 AP005    0.    2.    0.    0.    0.    0.
    1138 FE001 AP005    0.    2.    0     0     0     0
    1139 FE001 AP005    0.    2.    0.    0.    0.    0.
    1140 FE001 AP005    0.    2.    0     0     0     0
*RESIDUES
*CHEMICALS
*TILLAGE
*ENVIRONMENT
*HARVEST
    1141 GS000 L     A      100.    0.
*SOIL
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 TEMPLATE       USA      -82.000  24.000 00 GROSSARENIC PALEUDULTS
 G       .13   5.6   .50   75.  1.00  1.00 IB001 IB001 IB001
    5.        .017  .097  .388  .750 188.0  1.48   .90   1.7   2.5   1.4 -9.00   5.2   4.3   4.0    .0
   15.        .017  .097  .388  .750 188.0  1.48   .90   1.7   2.5   1.4 -9.00   5.2   4.3   4.0    .0
   30.        .017  .097  .388  .500 188.0  1.48   .02   1.2   3.7   1.1 -9.00   5.3   4.8   4.0    .0
   45.        .019  .080  .388  .150 156.6  1.56   .01   1.0   3.9   1.4 -9.00   5.3   4.8   4.0    .0
   60.        .019  .080  .388  .150 156.6  1.56   .01   1.0   3.9   1.4 -9.00   5.3   4.8   4.0    .0
   90.        .019  .080  .388  .150 156.6  1.56   .01   1.0   3.9   1.4 -9.00   5.3   4.8   4.0    .0

    5.    .0    .0    .0    .0    .0    .0    .0    .0
   15.    .0    .0    .0    .0    .0    .0    .0    .0
   30.    .0    .0    .0    .0    .0    .0    .0    .0
   45.    .0    .0    .0    .0    .0    .0    .0    .0
   60.    .0    .0    .0    .0    .0    .0    .0    .0
   90.    .0    .0    .0    .0    .0    .0    .0    .0
*CULTIVAR
UF0001 RED LASODA       IB0001  2000.  22.0   .20    .7    .4  19.0
```

Cultivar File

```
*POTATO GENOTYPE COEFFICIENTS - PTSUB980 MODEL

! COEFF       DEFINITIONS
! ========    ===========
! VAR#        Identification code or number for a specific cultivar
! VAR-NAME    Name of cultivar
! ECO#        Ecotype code or this cultivar, points to the Ecotype in the
!             ECO file (currently not used).
! G2          Leaf area expansion rate in degree days
! G3          Potential tuber growth rate
! G4          Currently not used in the model
! PD          Index that supresses tuber growth during the period
!             that immediately follows tuber induction
! P2          Index that relates photoperiod response to tuber initiation
! TC          Upper critical temperature for tuber intitiation

@VAR#  VAR-NAME........   ECO#    G2    G3    G4    PD    P2    TC
SW0001 REDLASOD         IB0001 2000.  25.0  0.20   0.7   0.6  19.0
```

Soil File

```
*POTATO GENOTYPE COEFFICIENTS - PTSUB980 MODEL

! COEFF       DEFINITIONS
! ========    ===========
! VAR#        Identification code or number for a specific cultivar
! VAR-NAME    Name of cultivar
! ECO#        Ecotype code or this cultivar, points to the Ecotype in the
!             ECO file (currently not used).
! G2          Leaf area expansion rate in degree days
! G3          Potential tuber growth rate
! G4          Currently not used in the model
! PD          Index that supresses tuber growth during the period
!             that immediately follows tuber induction
! P2          Index that relates photoperiod response to tuber initiation
! TC          Upper critical temperature for tuber intitiation

@VAR#  VAR-NAME........   ECO#    G2    G3    G4    PD    P2    TC
SW0001 REDLASOD         IB0001 2000.  25.0  0.20   0.7   0.6  19.0
```

2001 Weather File

```
*WEATHER DATA : SuwanneFarms,FL

@ INSI      LAT     LONG  ELEV   TAV   AMP REFHT WNDHT
  UFSU   29.000  -82.000    10  21.2   5.8   2.0   3.0
@DATE  SRAD  TMAX  TMIN  RAIN
01001  12.6   9.8  -4.9   0.0
01002  10.6   7.6  -3.4   0.0
01003  12.9   8.6  -6.3   0.0
01004  14.9  10.0  -5.9   0.9
01005  14.1  15.5  -5.2   0.0
01006  15.5  16.8   0.7   0.0
01007  14.7  18.9  -2.3   0.0
01008  10.2  19.3   7.7   2.9
01009  13.4   8.3  -2.4   0.0
01010  15.2  13.6  -5.7   0.0
01011  12.2  18.6  -1.4   4.4
01012   5.2  15.9   5.5   1.5
01013  13.2  17.2   2.4   0.0
```

01014	11.1	20.5	6.6	0.0
01015	9.7	23.6	5.6	0.1
01016	9.8	23.7	7.8	0.0
01017	8.8	23.8	11.6	0.0
01018	9.7	24.4	14.7	0.0
01019	10.4	25.5	15.1	4.3
01020	5.8	19.3	2.0	6.6
01021	15.0	10.6	-2.7	0.0
01022	14.1	12.7	-1.7	0.0
01023	15.3	15.0	1.2	0.1
01024	15.5	16.3	-0.3	0.0
01025	15.0	14.6	0.5	0.0
01026	16.5	15.6	-2.2	0.0
01027	12.4	20.8	0.4	0.0
01028	15.6	23.5	6.7	0.1
01029	12.3	21.6	8.0	0.1
01030	3.5	19.2	14.3	2.0
01031	2.0	15.7	12.4	8.7
01032	5.2	16.6	12.6	1.8
01033	4.8	12.8	8.9	1.2
01034	10.9	14.4	7.4	0.1
01035	8.6	14.4	6.2	5.0
01036	17.6	18.1	5.0	0.1
01037	17.5	21.4	0.4	0.1
01038	17.3	24.0	2.1	0.2
01039	17.5	25.8	6.2	0.0
01040	17.1	26.5	10.6	0.1
01041	6.1	22.4	11.5	0.9
01042	12.2	21.5	12.4	0.0
01043	12.0	21.6	11.6	0.0
01044	13.2	26.4	11.6	0.0
01045	13.5	26.2	14.1	0.0
01046	12.1	25.1	12.9	0.2
01047	11.8	25.5	14.9	0.2
01048	17.0	21.7	9.6	1.1
01049	19.7	20.4	4.4	0.0
01050	19.4	24.2	5.1	0.0
01051	11.0	24.5	10.0	0.0
01052	14.4	26.3	10.3	0.0
01053	15.3	25.0	12.1	0.8
01054	10.1	19.1	13.5	0.0
01055	12.7	26.7	11.4	0.0
01056	15.9	26.8	19.3	0.0
01057	14.7	26.3	18.4	0.0
01058	19.4	28.7	11.3	0.0
01059	17.3	26.6	13.1	1.6
01060	10.3	23.0	17.3	10.0
01061	14.3	26.4	19.0	0.0
01062	15.2	27.2	19.2	0.0
01063	12.0	23.5	14.3	16.4
01064	22.4	18.3	8.0	0.0
01065	22.9	15.5	5.1	0.0
01066	22.7	17.5	2.2	0.0
01067	22.7	19.3	0.2	0.0
01068	11.3	19.9	3.7	13.5
01069	22.2	20.3	7.6	0.0
01070	17.7	25.3	8.1	0.0

01071	16.7	27.5	12.7	0.0
01072	15.6	26.8	16.0	9.3
01073	17.9	24.7	12.3	0.8
01074	3.5	23.6	15.1	15.3
01075	19.9	25.3	13.0	6.4
01076	4.9	14.9	10.7	4.1
01077	3.5	12.2	9.6	19.1
01078	3.1	16.7	10.5	8.4
01079	14.6	17.5	8.2	8.4
01080	7.3	10.7	5.4	0.0
01081	24.9	21.4	5.7	0.0
01082	24.5	23.5	6.3	0.0
01083	24.2	25.4	6.5	0.0
01084	5.4	18.2	12.0	8.9
01085	25.4	18.0	6.6	0.1
01086	24.2	17.2	4.8	0.0
01087	20.6	21.3	4.8	0.0
01088	10.7	22.1	13.8	21.1
01089	12.6	23.8	15.7	1.2
01090	19.6	25.0	11.5	0.2
01091	25.6	24.2	9.5	0.0
01092	26.9	25.1	4.3	0.0
01093	22.9	25.4	9.8	0.0
01094	13.9	25.9	17.3	0.1
01095	20.4	26.2	15.8	0.0
01096	24.7	28.3	13.2	0.0
01097	22.4	28.7	14.8	0.0
01098	21.5	28.8	15.5	0.0
01099	22.4	28.5	17.2	0.1
01100	24.9	30.5	16.0	0.0
01101	19.8	28.6	17.0	0.0
01102	20.3	28.4	15.3	0.1
01103	22.3	28.0	17.3	0.1
01104	12.8	28.8	20.4	3.2
01105	23.9	28.4	20.6	5.9
01106	27.5	25.6	14.2	0.1
01107	26.4	24.1	10.5	0.0
01108	28.5	18.3	5.6	0.0
01109	27.7	22.7	3.2	0.0
01110	26.7	26.2	9.0	0.0
01111	25.7	27.7	12.8	0.0
01112	23.7	28.7	14.3	0.0
01113	26.0	29.3	15.1	0.0
01114	23.1	28.2	16.9	0.0
01115	10.4	22.3	15.5	5.6
01116	28.4	23.1	12.8	0.0
01117	28.9	26.6	6.6	0.0
01118	26.8	28.3	8.7	0.0
01119	25.8	27.7	12.4	0.0
01120	20.5	24.9	17.2	0.0
01121	24.4	27.7	14.2	0.0
01122	22.8	27.8	14.1	0.0
01123	24.2	28.1	16.5	0.0
01124	24.9	28.7	15.0	0.0
01125	25.7	29.9	14.0	0.0
01126	28.4	30.9	12.4	0.0
01127	12.8	23.7	16.6	1.8

01128	24.3	27.6	17.7	0.0
01129	18.1	27.8	13.0	2.6
01130	23.1	29.0	13.8	0.0
01131	27.0	30.1	13.4	0.0
01132	21.8	29.0	16.8	0.0
01133	26.1	29.9	16.6	0.0
01134	24.9	31.1	13.7	0.0
01135	24.0	30.5	18.0	0.0
01136	27.2	33.3	15.8	0.0
01137	26.6	33.3	18.1	0.0
01138	27.6	32.1	17.6	0.0
01139	28.5	31.7	14.7	0.0
01140	18.1	29.0	19.0	0.0
01141	28.7	31.8	17.8	0.0
01142	26.3	32.9	17.6	0.0
01143	27.0	28.6	16.1	0.0
01144	27.8	32.9	10.8	0.0
01145	12.2	31.9	18.3	0.0
01146	28.0	31.8	18.2	0.0
01147	26.8	32.6	15.8	0.0
01148	23.7	31.5	18.0	0.0
01149	15.6	28.4	20.4	0.0
01150	20.8	31.2	22.4	0.0
01151	25.3	33.5	19.7	0.0
01152	8.0	25.1	20.2	0.1
01153	26.2	30.5	19.9	0.1
01154	28.3	32.3	21.6	0.0
01155	24.6	34.7	22.1	0.0
01156	22.7	33.7	20.1	15.9
01157	20.0	30.3	20.2	0.0
01158	25.7	33.0	21.4	2.2
01159	14.7	30.1	22.7	5.0
01160	14.4	29.4	22.1	12.7
01161	8.2	25.8	22.0	0.7
01162	12.3	29.7	21.4	31.4
01163	12.8	28.3	23.3	25.4
01164	19.0	30.6	21.7	7.4
01165	18.7	31.0	21.1	0.0
01166	24.4	33.1	20.4	4.0
01167	16.2	32.1	21.9	0.0
01168	25.4	32.4	20.3	25.9
01169	15.1	30.7	21.4	8.9
01170	27.6	32.7	19.8	3.9
01171	22.7	32.1	20.1	10.7
01172	23.6	32.1	21.0	13.2
01173	19.1	29.8	20.9	22.7
01174	15.0	27.8	20.2	0.0
01175	28.8	30.6	19.7	0.0
01176	28.0	31.9	16.9	0.0
01177	28.6	33.5	18.0	0.3
01178	21.7	33.4	20.9	0.5
01179	18.5	30.8	21.2	30.7
01180	10.7	29.5	20.6	40.3
01181	22.6	31.8	20.2	58.0
01182	17.7	31.6	21.2	0.0
01183	17.2	31.2	21.6	0.0
01184	26.6	32.9	21.7	1.0

01185	16.0	31.2	22.6	1.1
01186	27.3	33.4	22.0	2.2
01187	20.9	31.1	21.6	0.0
01188	28.5	34.3	21.3	2.1
01189	22.9	34.2	24.6	0.0
01190	23.2	34.2	23.8	13.1
01191	17.7	32.6	23.9	28.1
01192	11.2	30.5	23.6	28.1
01193	20.4	30.7	23.9	0.5
01194	20.5	32.1	22.4	22.1
01195	21.3	30.2	22.8	1.2
01196	24.0	30.6	20.2	0.0
01197	21.6	31.1	19.3	0.0
01198	23.7	32.3	20.8	1.0
01199	20.3	31.5	21.8	0.3
01200	25.1	34.0	22.3	0.0
01201	17.0	34.4	22.6	0.0
01202	16.4	29.8	21.9	0.0
01203	21.8	31.3	23.4	0.0
01204	23.3	31.4	23.0	0.0
01205	7.6	26.5	22.4	0.0
01206	24.3	32.4	21.6	0.0
01207	26.5	30.7	21.8	3.4
01208	16.2	31.3	22.3	4.6
01209	27.2	33.0	21.0	0.0
01210	22.8	32.3	22.8	0.0
01211	20.7	32.8	22.8	13.8
01212	12.9	28.3	23.5	0.1
01213	18.0	30.7	22.0	5.3
01214	19.7	29.6	21.4	0.1
01215	21.6	30.1	20.8	0.9
01216	19.5	30.6	21.7	0.1
01217	8.1	27.1	22.1	13.1
01218	15.3	30.0	22.1	0.0
01219	19.0	32.7	23.1	0.0
01220	25.3	33.1	21.8	0.0
01221	25.9	33.1	21.6	0.3
01222	22.8	32.1	23.3	0.0
01223	14.6	30.7	21.8	9.8
01224	26.5	32.4	21.9	0.0
01225	23.2	32.5	21.9	0.0
01226	17.7	30.5	21.5	2.8
01227	21.1	33.0	23.5	0.1
01228	22.7	33.7	23.0	0.0
01229	18.7	33.8	24.1	1.5
01230	23.1	32.9	23.8	0.0
01231	13.9	30.0	23.4	2.8
01232	25.9	33.9	22.7	0.0
01233	23.8	33.6	21.2	0.0
01234	23.7	33.9	20.1	0.0
01235	20.8	33.4	20.8	0.0
01236	23.8	33.6	19.3	0.0
01237	17.4	34.5	20.8	0.0
01238	23.0	34.3	21.0	0.0
01239	20.9	33.1	21.1	0.0
01240	22.2	33.1	20.8	0.0
01241	23.2	34.5	20.3	0.0

01242	20.3	34.7	21.7	0.0
01243	18.3	33.7	21.0	7.5
01244	13.7	30.3	22.4	10.0
01245	17.0	31.4	22.2	4.4
01246	13.1	31.2	21.3	32.0
01247	18.8	31.4	21.2	0.1
01248	21.5	32.8	20.9	0.0
01249	21.0	32.2	22.0	3.3
01250	17.5	31.3	21.6	0.3
01251	20.5	32.3	21.5	0.1
01252	17.7	31.8	21.7	0.0
01253	14.5	31.4	22.3	14.7
01254	13.2	29.9	22.2	3.2
01255	21.3	30.4	21.8	0.1
01256	13.7	28.4	21.7	1.6
01257	3.1	23.5	20.7	10.7
01258	20.6	25.9	19.8	0.0
01259	24.4	28.0	14.7	0.0
01260	21.7	28.7	14.1	0.0
01261	20.3	30.4	16.8	0.0
01262	21.8	30.9	19.5	0.0
01263	16.3	30.9	20.2	0.0
01264	15.6	30.2	20.2	5.3
01265	19.2	31.7	20.7	0.5
01266	17.1	31.3	20.6	5.4
01267	9.1	27.4	21.0	3.7
01268	17.0	25.4	15.5	1.1
01269	15.4	24.1	12.5	0.0
01270	17.5	27.7	13.7	0.0
01271	21.0	27.9	15.3	0.1
01272	19.4	24.0	15.2	0.0
01273	22.2	23.8	11.5	0.0
01274	22.3	23.7	7.0	0.0
01275	22.4	27.4	6.4	0.0
01276	21.9	28.3	7.1	0.0
01277	20.4	29.3	12.0	0.0
01278	15.2	29.4	17.6	0.0
01279	14.4	29.6	19.9	0.0
01280	12.1	22.8	16.2	0.0
01281	14.4	25.2	14.7	0.0
01282	17.6	27.4	14.9	0.0
01283	13.9	27.3	15.9	0.0
01284	17.0	29.9	18.8	0.0
01285	13.1	27.7	18.4	0.0
01286	15.7	29.7	19.4	0.0
01287	8.9	28.5	17.9	0.0
01288	20.0	27.9	14.2	0.1
01289	17.1	26.8	12.9	0.0
01290	19.9	19.5	6.9	0.0
01291	19.2	24.3	3.1	0.0
01292	14.6	27.6	13.5	0.0
01293	17.9	29.6	16.3	0.0
01294	16.3	30.1	15.8	0.0
01295	14.6	30.0	18.5	0.0
01296	13.4	30.3	19.0	0.1
01297	10.6	29.1	18.5	1.3
01298	17.0	30.8	18.1	3.9

01299	18.9	23.7	7.2	0.0
01300	17.5	17.9	3.7	0.0
01301	19.1	17.1	1.9	0.0
01302	17.4	22.1	6.2	0.0
01303	18.1	23.9	4.5	0.0
01304	11.9	26.4	9.7	0.0
01305	16.4	29.0	15.1	0.0
01306	13.6	28.6	16.5	0.0
01307	14.1	28.8	18.2	0.0
01308	12.4	27.3	17.3	0.0
01309	10.1	21.2	8.0	0.0
01310	17.5	22.4	3.7	0.0
01311	17.3	24.1	0.0	0.0
01312	16.5	25.2	3.0	0.0
01313	16.1	25.9	6.2	0.0
01314	15.6	25.6	4.4	0.0
01315	15.0	25.8	6.3	0.0
01316	15.1	25.4	7.2	0.0
01317	6.5	21.8	12.1	0.0
01318	6.5	19.6	13.2	6.4
01319	11.7	22.8	14.6	0.0
01320	14.9	24.8	11.5	0.0
01321	15.2	25.9	7.3	0.0
01322	13.9	26.2	10.0	0.0
01323	14.4	26.2	10.2	0.0
01324	11.4	24.4	9.8	0.0
01325	14.5	22.9	8.3	0.0
01326	9.5	23.2	9.1	0.1
01327	4.6	23.2	15.9	11.4
01328	11.9	25.8	14.0	0.1
01329	8.4	26.0	16.5	0.7
01330	13.8	28.1	16.3	0.0
01331	13.3	27.1	14.9	0.0
01332	13.7	26.8	12.9	0.0
01333	12.2	26.5	14.6	0.1
01334	8.4	26.2	16.1	0.0
01335	6.0	24.8	17.7	0.1
01336	12.3	25.1	12.9	0.0
01337	9.6	21.8	7.5	0.0
01338	12.8	23.9	11.5	0.1
01339	10.2	26.5	15.0	0.0
01340	10.7	26.5	14.7	0.0
01341	12.6	27.8	13.6	0.0
01342	5.3	25.0	17.0	5.2
01343	4.2	23.1	19.0	0.2
01344	5.0	23.7	17.9	0.7
01345	7.7	24.5	16.7	0.2
01346	7.8	26.1	16.6	0.0
01347	9.0	26.3	17.2	0.0
01348	6.4	25.3	16.0	3.2
01349	8.0	26.8	19.0	0.3
01350	10.1	26.4	15.5	0.0
01351	10.3	26.6	15.8	4.1
01352	13.7	21.0	8.7	0.1
01353	12.9	20.7	4.2	0.0
01354	13.9	17.8	3.5	0.1
01355	13.9	18.9	-2.0	0.0

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01356  13.7  22.1  -1.3   0.0
01357   6.2  21.8   6.4  11.8
01358  13.4  17.1   6.1   9.1
01359   2.4   7.6   5.6   0.0
01360  14.0  10.9  -1.5   0.0
01361   8.1  12.6  -4.0   0.0
01362  10.7  18.7  -1.8   0.0
01363  11.9  22.2   8.4   0.0
01364  11.4  15.8   2.6   0.1
01365   4.6   9.9  -1.2   0.0
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2002 Weather File

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*WEATHER DATA : SuwanneFarms,FL

@ INSI      LAT     LONG  ELEV   TAV   AMP REFHT WNDHT
  UFSU   29.000  -82.000    10  21.2   5.8  2.00  3.00
@DATE  SRAD  TMAX  TMIN  RAIN
02001  10.5  13.1  -2.5   2.3
02002   0.9   7.5   1.8  15.7
02003   7.7   5.4   0.8   0.1
02004  14.2  10.0  -4.2   0.0
02005  12.3  14.4  -6.9   0.1
02006  11.8  18.1   7.0   5.9
02007  12.2  11.2   1.3   0.0
02008  14.4  10.8  -3.8   0.0
02009  14.0  17.9  -5.7   0.0
02010  14.2  21.9   2.1   0.2
02011   9.2  20.9   5.7   0.1
02012   4.0  18.7  10.2  10.1
02013  13.9  16.4   3.0   8.2
02014   1.3  11.5   6.3  48.8
02015  12.4  17.6   5.2   0.3
02016  14.3  18.8  -0.4   0.1
02017  12.7  20.3  -0.2   0.0
02018  12.6  24.3   2.1   0.0
02019  12.7  25.3   9.0   1.7
02020  11.6  22.0  10.1   1.6
02021   3.6  21.1  15.0  46.7
02022   4.6  17.9  15.2   0.1
02023  11.7  26.1  12.6   0.0
02024  10.2  24.7  15.7   0.0
02025   2.5  20.9  16.0  17.0
02026   3.5  15.6  13.2   0.1
02027   4.2  18.4  13.4   0.8
02028  10.4  26.4  15.4  11.4
02029  12.1  26.9  17.7   0.1
02030  10.2  27.0  18.5   0.0
02031  14.1  27.9  18.1   0.0
02032  15.4  27.8  14.6   0.0
02033  14.3  20.6  10.0   0.0
02034  13.5  20.7   4.7   0.0
02035  15.2  15.6   4.5   0.0
02036   6.9  10.6   3.0   0.0
02037   7.5  22.4   6.7   0.7
02038   4.6  19.5   3.9   7.1
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02039	16.1	17.6	0.4	0.0
02040	14.4	23.0	3.3	0.0
02041	9.6	22.2	13.7	0.0
02042	16.2	18.6	6.5	0.0
02043	15.0	19.4	1.9	0.0
02044	5.0	13.4	3.6	0.5
02045	17.0	19.6	4.9	0.0
02046	13.2	22.4	7.9	0.0
02047	14.0	23.0	10.9	0.0
02048	18.4	20.8	1.8	0.0
02049	18.1	18.0	0.2	0.0
02050	18.6	23.1	1.2	0.0
02051	8.9	23.4	8.1	3.5
02052	12.1	23.9	15.8	0.0
02053	5.9	19.5	12.9	0.0
02054	2.2	15.6	7.7	8.4
02055	17.0	18.8	1.1	0.0
02056	17.0	22.2	2.2	0.0
02057	16.8	23.0	3.2	0.0
02058	18.1	16.0	-1.6	0.0
02059	18.5	11.3	-6.3	0.0
02060	14.0	19.0	-4.4	0.0
02061	2.1	20.5	14.7	69.8
02062	2.3	21.3	11.2	63.8
02063	9.5	10.5	-0.5	0.0
02064	19.6	15.4	-4.3	0.0
02065	18.7	21.7	-0.4	0.0
02066	18.4	23.5	7.6	0.0
02067	16.9	26.9	10.5	0.0
02068	19.2	28.3	15.4	0.0
02069	21.5	23.0	11.8	0.0
02070	20.4	25.5	4.6	0.0
02071	11.9	26.0	13.7	5.7
02072	17.5	23.4	13.2	3.0
02073	21.2	24.5	8.5	0.2
02074	19.1	28.7	10.2	0.0
02075	17.1	30.1	15.1	0.0
02076	17.2	31.3	16.7	0.0
02077	20.1	31.0	17.2	0.0
02078	20.5	30.7	13.1	0.1
02079	18.2	27.6	15.9	0.0
02080	9.1	24.7	16.7	3.7
02081	18.7	18.9	8.6	0.0
02082	21.5	21.2	3.4	0.0
02083	19.8	27.1	6.8	0.0
02084	18.0	29.2	13.8	0.0
02085	17.6	28.5	15.3	0.0
02086	18.0	25.5	13.2	0.0
02087	23.3	27.2	7.7	0.0
02088	20.8	27.1	8.6	0.0
02089	20.4	28.9	13.5	0.1
02090	18.6	28.1	18.3	16.2
02091	20.2	26.4	17.9	0.1
02092	17.8	28.0	15.6	0.0
02093	13.8	26.1	18.0	1.8
02094	17.8	27.5	18.0	0.0
02095	18.6	22.7	10.9	0.0

02096	24.4	24.0	8.5	0.0
02097	20.3	24.3	10.6	0.0
02098	20.3	26.2	13.8	0.0
02099	18.9	27.5	17.2	0.0
02100	11.2	25.4	18.3	18.8
02101	7.4	24.7	18.7	20.9
02102	17.0	26.1	17.0	1.1
02103	10.9	23.5	18.3	3.5
02104	19.9	27.0	17.7	0.0
02105	19.4	28.3	14.8	0.1
02106	23.1	30.4	16.4	29.6
02107	22.7	30.1	18.3	0.1
02108	20.0	29.0	18.2	0.0
02109	25.9	31.9	19.1	0.2
02110	23.2	31.7	17.9	0.0
02111	24.5	31.7	17.5	0.0
02112	22.3	31.3	17.9	0.0
02113	22.3	29.4	16.8	0.0
02114	24.8	30.2	14.8	0.0
02115	22.5	29.8	20.9	0.0
02116	22.4	30.0	17.8	0.0
02117	20.4	30.3	17.9	0.0
02118	22.2	28.9	17.8	0.0
02119	17.0	29.8	19.2	0.0
02120	19.4	30.1	18.4	0.0
02121	23.4	29.6	19.5	0.1
02122	22.5	29.9	19.2	0.0
02123	24.2	31.7	20.4	0.1
02124	23.2	33.2	20.2	0.1
02125	19.9	30.7	19.7	0.1
02126	21.3	30.3	18.8	0.0
02127	22.3	31.4	18.6	0.0
02128	23.5	33.5	18.7	0.0
02129	22.3	33.7	19.1	0.0
02130	24.5	34.8	20.1	0.0
02131	25.0	33.6	19.9	0.0
02132	24.9	33.8	19.0	0.0
02133	22.7	31.0	21.2	0.0
02134	26.3	28.1	16.5	2.2
02135	24.7	29.1	9.4	0.0
02136	26.0	32.0	14.4	0.0
02137	21.9	31.7	19.0	0.0
02138	11.3	27.8	20.6	8.1

APPENDIX D
HYDRUS INPUT FILES

Flat Surface Input Files

BOUNDARY.IN

```
Pcp_File_Version=2
*** BLOCK ?: BOUNDARY INFORMATION *********************************************
    NumBP     NObs  SeepF  FreeD DrainF  qQWLF
       62        0      f      t      f      f
Node Number Array
      1      30      31      32      33      34      35      36      37      38
     39      40      41      42      43      44      45      46      47      48
     49      50      51      52      53      54      55      56      57      58
     59      60      90      91      92      93      94      95      96      97
     98      99     100     101     102     103     104     105     106     107
    108     109     110     111     112     113     114     115     116     117
    118     119
Width Array
    1.5     1.5       3       3       3       3       3       3       3       3
      3       3       3       3       3       3       3       3       3       3
      3       3       3       3       3       3       3       3       3       3
      3     1.5     1.5       3       3       3       3       3       3       3
      3       3       3       3       3       3       3       3       3       3
      3       3       3       3       3       3       3       3       3       3
      3       3
Length of soil surface associated with transpiration
            90
*** BLOCK ?: Solute transport boundary conditions *****************************
KodCB(1),KodCB(2),.....,KodCB(NumBP)
 -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
 -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
 -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
 -1  -1
*** End of input file 'BOUNDARY.IN' ****************************************
```

DIMENSIO.IN

```
Pcp_File_Version=2
  NumNPD  NumElD  NumBPD  MBandD  NSeepD  NumSPD    NDrD  NElDrD   NMatD   NObsD     NSD
     206     291      62      15       1       1       1      20       4       1       3
```

ATMOSPH.IN

```
Pcp_File_Version=2
*** BLOCK I: ATMOSPHERIC INFORMATION  *********************************
   MaxAL                    (MaxAL = number of atmospheric data-records)
    130
 hCritS                 (max. allowed pressure head at the soil surface)
      0
       tAtm        Prec       rSoil       rRoot      hCritA          rt          ht      cValue1     cValue2     cValue3
          1           0       0.249           0       10000           0           0           0           0           0           0
0           0           0           0           0
          2       0.001       0.289           0       10000           0           0     180.399           0           0           0
0           0      639.58           0           0
          3           0       0.191           0       10000           0           0           0           0           0           0
0           0           0           0           0
          4         1.1       0.084           0       10000           0           0           0           0           0           0
0           0           0           0           0
          5         0.8       0.264           0       10000           0           0           0           0           0           0
0           0           0           0           0
          6         4.9       0.024           0       10000           0           0           0           0           0           0
0           0           0           0           0
          7       0.001       0.245           0       10000           0           0        62.7           0           0           0
0           0       222.3           0           0
          8           0       0.272           0       10000           0           0           0           0           0           0
0           0           0           0           0
          9           0       0.248           0       10000           0           0           0           0           0           0
0           0           0           0           0
         10           0       0.265           0       10000           0           0           0           0           0           0
0           0           0           0           0
         11         0.2       0.288           0       10000           0           0           0           0           0           0
0           0           0           0           0
         12         0.1       0.254           0       10000           0           0           0           0           0           0
0           0           0           0           0
         13         4.7       0.081           0       10000           0           0           0           0           0           0
0           0           0           0           0
         14           0         0.1           0       10000           0           0           0           0           0           0
0           0           0           0           0
         15           0       0.276           0       10000           0           0           0           0           0           0
0           0           0           0           0
         16           0       0.242           0       10000           0           0           0           0           0           0
0           0           0           0           0
         17         1.7       0.057           0       10000           0           0           0           0           0           0
0           0           0           0           0
         18           0       0.072           0       10000           0           0           0           0           0           0
0           0           0           0           0
```

19	0.1	0.09	0	10000	0	0	0	0	0	0	0	0
20	1.1	0.252	0	10000	0	0	0	0	0	0	0	0
21	0	0.3	0	10000	0	0	0	0	0	0	0	0
22	0	0.254	0	10000	0	0	0	0	0	0	0	0
23	0	0.354	0	10000	0	0	0	0	0	0	0	0
24	0	0.376	0	10000	0	0	0	0	0	0	0	0
25	0	0.308	0	10000	0	0	0	0	0	0	0	0
26	0	0.277	0	10000	0	0	0	0	0	0	0	0
27	0	0.289	0	10000	0	0	0	0	0	0	0	0
28	0	0.12	0	10000	0	0	0	0	0	0	0	0
29	0.1	0.16	0	10000	0	0	0	0	0	0	0	0
30	0.7	0.092	0	10000	0	0	0	0	0	0	0	0
31	0	0.303	0	10000	0	0	0	0	0	0	0	0
32	0	0.301	0	10000	0	0	0	0	0	0	0	0
33	0	0.218	0	10000	0	0	0	0	0	0	0	0
34	0	0.329	0	10000	0	0	0	0	0	0	0	0
35	0	0.294	0	10000	0	0	0	0	0	0	0	0
36	0.1	0.091	0	10000	0	0	0.374	0	0	0	0	0
37	1.326	0.344	0	10000	0	0	0	0	0	0	0	0
38	0	0.285	0	10000	0	0	0	0	0	0	0	0
39	0	0.313	0	10000	0	0	0	0	0	0	0	0
40	0	0.368	0	10000	0	0	0	0	0	0	0	0
41	0	0.342	0	10000	0	0	0	0	0	0	0	0

42	0	0.382	0	10000	0	0	0	0	0	0	0	0	0
43	0.3	0.195	0	10000	0	0	0	0	0	0	0	0	0
44	0	0.285	0	10000	0	0	0	0	0	0	0	0	0
45	0	0.128	0	10000	0	0	0	0	0	0	0	0	0
46	0.9	0.043	0	10000	0	0	0	0	0	0	0	0	0
47	0	0.328	0	10000	0	0	0	0	0	0	0	0	0
48	0	0.348	0	10000	0	0	0	0	0	0	0	0	0
49	0	0.351	0	10000	0	0	0	0	0	0	0	0	0
50	0	0.326	0	10000	0	0	0	0	0	0	0	0	0
51	0.6	0.292	0	10000	0	0	0	0	0	0	0	0	0
52	0	0.257	0	10000	0	0	0	0	0	0	0	0	0
53	6.9	0.047	0	10000	0	0	0	0	0	0	0	0	0
54	6.4	0.05	0	10000	0	0	0	0	0	0	0	0	0
55	0	0.158	0	10000	0	0	0	0	0	0	0	0	0
56	0	0.339	0	10000	0	0	0	0	0	0	0	0	0
57	0	0.371	0	10000	0	0	0	0	0	0	0	0	0
58	0	0.403	0	10000	0	0	0	0	0	0	0	0	0
59	0	0.395	0	10000	0	0	0	0	0	0	0	0	0
60	0	0.475	0	10000	0	0	0	0	0	0	0	0	0
61	0	0.482915	0.0020855	10000	0	0	0	0	0	0	0	0	0
62	0	0.444082	0.0019178	10000	0	0	0	0	0	0	0	0	0
63	0.6	0.280787	0.0012126	10000	0	0	0	0	0	0	0	0	0
64	0.3	0.397551	0.0034486	10000	0	0	0	1599.27	0	0	0	0.744335	0

65	0.8	0.466898	0.0061017	10000	0	0	0	0	0	0	0	0
66	0	0.444239	0.009761	10000	0	0	0	0	0	0	0	0
67	0.7	0.416087	0.0129129	10000	0	0	0	0	0	0	0	0
68	0	0.424895	0.0171054	10000	0	0	0	0	0	0	0	0
69	0	0.491593	0.0244068	10000	0	0	0	0	0	0	0	0
70	0.9	0.479603	0.0283972	10000	0	0	0	0	0	0	0	0
71	0	0.413453	0.0305472	10000	0	0	0	0	0	0	0	0
72	0.4	0.199283	0.0157165	10000	0	0	0	0	0	0	0	0
73	0	0.350062	0.032938	10000	0	0	0	0	0	0	0	0
74	0.9	0.388314	0.0446856	10000	0	0	0	0	0	0	0	0
75	0.9	0.389663	0.0533372	10000	0	0	0	0	0	0	0	0
76	0.5	0.374132	0.0618684	10000	0	0	8.36816	0	0	0	0	0
77	0.9	0.35456	0.0714402	10000	0	0	0	0	0	0	0	0
78	0.9	0.332278	0.079722	10000	0	0	0	0	0	0	0	0
79	0.9	0.396257	0.122744	10000	0	0	0	0	0	0	0	0
80	0.9	0.334312	0.129688	10000	0	0	0	0	0	0	0	0
81	0.9	0.323809	0.157191	10000	0	0	0	0	0	0	0	0
82	2.5	0.278477	0.169523	10000	0	0	0	0	0	0	0	0
83	0.9	0.284262	0.189738	10000	0	0	0	0	0	0	0	0
84	0	0.232518	0.182482	10000	0	0	0	0	0	0	0	0
85	0.2	0.172411	0.146589	10000	0	0	0	0	0	0	0	0
86	1	0.215676	0.201324	10000	0	0	0	0	0	0	0	0
87	0.9	0.193082	0.193918	10000	0	0	0	0	0	0	0	0

88	0.9	0.237761	0.266239	10000	0	0	0	0	0	0	0	0
89	0.9	0.191996	0.235004	10000	0	0	0	0	0	0	0	0
90	0.9	0.194315	0.253685	10000	0	0	0	0	0	0	0	0
91	0.9	0.182315	0.251685	10000	0	0	0	0	0	0	0	0
92	1.9	0.104176	0.148824	10000	0	0	0	0	0	0	0	0
93	2.1	0.0683525	0.0976475	10000	0	0	0	0	0	0	0	0
94	0.1	0.157923	0.224077	10000	0	0	0	0	0	0	0	0
95	0.3	0.0996166	0.140383	10000	0	0	0	0	0	0	0	0
96	0	0.189613	0.265387	10000	0	0	0	0	0	0	0	0
97	1	0.184097	0.255903	10000	0	0	0	0	0	0	0	0
98	3.6	0.228103	0.314897	10000	0	0	0	0	0	0	0	0
99	0.9	0.227752	0.312248	10000	0	0	0	0	0	0	0	0
100	0.5	0.199023	0.270977	10000	0	0	0	0	0	0	0	0
101	0.7	0.268696	0.363304	10000	0	0	0	0	0	0	0	0
102	0.7	0.239997	0.320003	10000	0	0	0	0	0	0	0	0
103	0.7	0.253867	0.336133	10000	0	0	0	0	0	0	0	0
104	0.7	0.231989	0.305011	10000	0	0	0	0	0	0	0	0
105	0.9	0.226884	0.294116	10000	0	0	0	0	0	0	0	0
106	0.9	0.251841	0.324159	10000	0	0	0	0	0	0	0	0
107	0.9	0.240201	0.304799	10000	0	0	0	0	0	0	0	0
108	0.8	0.236355	0.295645	10000	0	0	0	0	0	0	0	0
109	0.8	0.217652	0.268348	10000	0	0	0	0	0	0	0	0
110	0.8	0.235201	0.285799	10000	0	0	0	0	0	0	0	0

```
        111         0.8    0.185212    0.221788       10000           0           0           0           0           0           0
0           0           0           0           0
        112         0.8      0.2137      0.2503       10000           0           0           0           0           0           0
0           0           0           0           0
        113         0.9     0.26045     0.30055       10000           0           0           0           0           0           0
0           0           0           0           0
        114         0.8    0.253727    0.286273       10000           0           0           0           0           0           0
0           0           0           0           0
        115         0.7    0.283236    0.314764       10000           0           0           0           0           0           0
0           0           0           0           0
        116           0    0.278986    0.303014       10000           0           0           0           0           0           0
0           0           0           0           0
        117           0    0.235295    0.249705       10000           0           0           0           0           0           0
0           0           0           0           0
        118         0.6    0.252374    0.261626       10000           0           0           0           0           0           0
0           0           0           0           0
        119         0.6    0.270329    0.273671       10000           0           0           0           0           0           0
0           0           0           0           0
        120           0    0.295218    0.291782       10000           0           0           0           0           0           0
0           0           0           0           0
        121         0.4    0.286182    0.273818       10000           0           0           0           0           0           0
0           0           0           0           0
        122         0.4    0.324807    0.303193       10000           0           0           0           0           0           0
0           0           0           0           0
        123         0.4    0.332148    0.299852       10000           0           0           0           0           0           0
0           0           0           0           0
        124           0     0.33403     0.29397       10000           0           0           0           0           0           0
0           0           0           0           0
        125           0    0.306591    0.258409       10000           0           0           0           0           0           0
0           0           0           0           0
        126         0.2    0.338003    0.274997       10000           0           0           0           0           0           0
0           0           0           0           0
        127           0    0.310517    0.241483       10000           0           0           0           0           0           0
0           0           0           0           0
        128           0    0.358684    0.266316       10000           0           0           0           0           0           0
0           0           0           0           0
        129           0    0.318505    0.225495       10000           0           0           0           0           0           0
0           0           0           0           0
        130         0.8    0.159253    0.112747       10000           0           0           0           0           0           0
0           0           0           0           0
*** END OF INPUT FILE 'ATMOSPH.IN' ************************************
```

SELECTOR.IN

```
Pcp_File_Version=2
*** BLOCK A: BASIC INFORMATION ****************************************
Heading
Welcome to HYDRUS-2D
LUnit  TUnit  MUnit  (indicated units are obligatory for all input data)
cm
days
-mg
Kat (0:horizontal plane, 1:axisymmetric vertical flow, 2:vertical plane)
  2
MaxIt   TolTh   TolH InitH/W  (max. number of iterations and tolerances)
10000   0.0001    0.1     t
lWat lChem lSink Short Flux lScrn AtmIn lTemp lWTDep lEquil lExtGen lInv
 t     t     t     f     t    t     t     f     f      t      t      f
*** BLOCK B: MATERIAL INFORMATION **************************************
NMat    NLay    hTab1   hTabN
  4       5    1e-006   10000
    Model   Hysteresis
      2          0
  thr    ths   Alfa     n         Ks      l
  0.03 0.3883  0.061  0.753       4515      2
  0.03 0.3883  0.061  0.753       4515      2
  0.03 0.3526  0.053  0.754       3759      2
  0.03 0.3526  0.053  0.754       3759      2
*** BLOCK C: TIME INFORMATION *****************************************
        dt       dtMin       dtMax     DMul    DMul2  ItMin ItMax  MPL
     0.0001      1e-005      0.0001     1.5     0.1     3     7   100
      tInit        tMax
          0         130
TPrint(1),TPrint(2),...,TPrint(MPL)
          1           2           3           4           5           6
          7           8           9          10          11          12
         13          14          15          16          17          18
         19          20          21          22          23          24
         25          26          27          28          29          30
         31          32          33          34          35          36
         37          38          39          40          41          42
         43          44          45          46          47          48
         49          50          51          52          53          54
         55          56          57          58          59          60
         61          62          63          64          65          66
         67          68          69          71          73          75
         77          79          81          82          84          86
         88          90          92          94          96          98
```

```
        100         102         104         106         108         110
        112         114         116         118         120         122
        124         126         128         130
*** BLOCK G: SOLUTE TRANSPORT INFORMATION ****************************************************
 Epsi  lUpW  lArtD lTDep    cTolA    cTolR   MaxItC    PeCr  Nu.of Solutes Tortuosity
    1     f     f     f         0        0     1       1       3         t
     Bulk.d.     DisperL.      DisperT     Frac      ThImob (1..NMat)
       1.48          10           10          1           0
       1.48          10           10          1           0
       1.56          10           10          1           0
       1.56          10           10          1           0
         DifW       DifG               n-th solute
          1.2          0
          Ks          Nu        Beta       Henry       SnkL1       SnkS1       SnkG1       SnkL1'      SnkS1'      SnkG1'      SnkL0
SnkS0       SnkG0        Alfa
       0.001          0           1           0           0           0           0       0.001           0           0           0
0           0           0
       0.001          0           1           0           0           0           0       0.001           0           0           0
0           0           0
       0.001          0           1           0           0           0           0       0.001           0           0           0
0           0           0
       0.001          0           1           0           0           0           0       0.001           0           0           0
0           0           0
         DifW       DifG               n-th solute
          1.2          0
          Ks          Nu        Beta       Henry       SnkL1       SnkS1       SnkG1       SnkL1'      SnkS1'      SnkG1'      SnkL0
SnkS0       SnkG0        Alfa
           0          0           1           0           0           0           0        0.11           0           0           0
0           0           0
           0          0           1           0           0           0           0        0.11           0           0           0
0           0           0
           0          0           1           0           0           0           0        0.11           0           0           0
0           0           0
           0          0           1           0           0           0           0        0.11           0           0           0
0           0           0
         DifW       DifG               n-th solute
          1.2          0
          Ks          Nu        Beta       Henry       SnkL1       SnkS1       SnkG1       SnkL1'      SnkS1'      SnkG1'      SnkL0
SnkS0       SnkG0        Alfa
           0          0           1           0           0           0           0           0           0           0           0
0           0           0
           0          0           1           0           0           0           0           0           0           0           0
0           0           0
           0          0           1           0           0           0           0           0           0           0           0
0           0           0
           0          0           1           0           0           0           0           0           0           0           0
0           0           0
```

```
       cTop        cBot
          0           0           0           0           0           0           0           0           0
          0           0           0           0           0           0           0           0           0
          0           0           0           0           0           0           0           0           0
      tPulse
          1
*** BLOCK G: ROOT WATER UPTAKE INFORMATION *****************************
     Model  (0 - Feddes, 1 - S shape)
        0
       P0        P2H        P2L        P3          r2H         r2L
      -10       -320       -600     -6000          0.5          0.1
POptm(1),POptm(2),...,POptm(NMat)
     -25       -25       -25       -25
     Solute Reduction
        f
*** END OF INPUT FILE 'SELECTOR.IN' ***********************************
```

MESHTRIA.000

	1	206	496	291	119	
1		0	90		30	0
2		0	86.8966		62.0689	0
3	-5.42101e-020		83.7931		62.0689	0
4		0	80.6897		62.0689	0
5	6.77626e-020		77.5862		62.0689	0
6	1.35525e-020		74.4828		62.0689	0
7		0	71.3793		62.0689	0
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9	-4.06576e-020		65.1724		62.0689	0
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284	15	138	135	16	150	29	0
285	137	143	136	75	151	34	0
286	135	138	136	15	27	150	0
287	75	137	74	143	152	34	0
288	136	138	201	135	280	27	0
289	74	137	139	75	28	152	0
290	17	138	16	205	154	158	0
291	139	137	140	74	155	28	0
292	16	138	15	17	29	154	0
293	74	139	73	137	156	28	0

294	136	201	140	138	157	280	0
295	73	139	72	74	30	156	0
296	17	205	138	18	158	162	0
297	141	139	121	72	159	160	0
298	138	142	201	205	281	33	0
299	72	139	141	73	160	30	0
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301	72	141	71	139	32	160	0
302	205	20	206	19	252	256	0
303	121	141	139	188	159	254	0
304	138	205	142	17	33	158	0
305	76	143	75	148	164	39	0
306	135	136	203	138	165	27	0
307	75	143	137	76	34	164	0
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309	203	204	145	134	284	286	0
310	146	79	80	78	190	166	0
311	202	135	145	14	283	26	0
312	146	144	148	156	169	35	0
313	202	13	14	12	172	168	0
314	78	146	148	79	37	166	0
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316	148	78	146	77	37	170	0
317	14	202	13	135	172	26	0
318	148	146	144	78	169	37	0
319	145	135	203	202	285	283	0
320	77	148	76	78	174	170	0
321	136	203	135	147	165	38	0
322	76	148	143	77	39	174	0
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324	127	151	153	128	183	178	0
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326	128	151	127	7	178	19	0
327	152	157	166	154	145	43	0
328	133	149	150	106	41	176	0
329	151	9	145	8	188	44	0
330	152	150	153	166	181	179	0
331	8	151	7	9	42	44	0
332	83	154	156	84	182	208	0
333	151	153	127	204	183	287	0
334	83	156	82	154	48	182	0
335	153	204	134	151	184	287	0
336	154	152	155	157	185	43	0
337	153	134	155	204	180	184	0
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339	153	155	152	134	187	180	0
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342	156	154	155	83	189	182	0
343	151	145	204	9	46	188	0
344	146	81	156	80	47	186	0
345	155	134	144	153	147	180	0
346	156	146	81	144	47	35	0
347	154	84	165	83	202	208	0
348	133	150	166	149	193	41	0
349	157	154	165	152	192	43	0
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351	158	167	168	160	195	197	0
352	96	159	158	97	215	194	0
353	159	98	161	97	196	52	0
354	167	168	158	88	195	61	0
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359	100	164	161	101	53	56	0
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382	167	87	88	162	66	59	0
383	169	176	50	177	222	85	0
384	172	178	177	173	235	223	0
385	50	169	176	51	222	68	0
386	174	54	170	53	70	79	0
387	170	173	172	171	225	227	0
388	174	53	54	52	79	82	0
389	63	173	62	178	220	81	0
390	54	170	174	55	70	69	0
391	62	173	171	63	78	220	0
392	169	52	174	51	218	226	0
393	173	178	172	63	223	81	0
394	169	51	52	50	226	68	0
395	64	178	63	180	224	86	0
396	172	174	170	169	219	80	0
397	63	178	173	64	81	224	0
398	174	169	52	172	218	80	0
399	171	173	170	62	227	78	0
400	52	174	169	53	218	82	0
401	181	44	45	175	228	89	0
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403	44	175	43	181	83	89	0
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405	177	180	182	178	241	233	0
406	48	176	47	49	230	216	0
407	176	50	169	49	222	84	0
408	178	180	177	64	233	86	0
409	181	176	179	47	87	232	0
410	65	180	64	66	234	238	0
411	177	169	172	176	217	85	0
412	64	180	178	65	86	234	0
413	47	176	181	48	232	230	0
414	179	182	184	177	245	239	0
415	181	47	176	46	232	236	0
416	180	186	182	66	88	90	0
417	179	176	177	181	231	87	0
418	180	66	186	65	90	238	0
419	46	181	45	47	240	236	0

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423	183	181	179	175	237	244	0
424	66	186	180	67	90	246	0
425	175	181	183	44	244	89	0
426	182	184	179	186	245	242	0
427	197	183	185	175	259	91	0
428	67	188	186	68	92	250	0
429	185	190	197	189	273	93	0
430	186	67	188	66	92	246	0
431	23	206	22	196	98	270	0
432	184	186	187	182	251	242	0
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434	69	188	68	141	94	96	0
435	187	185	184	189	249	95	0
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438	186	188	187	67	253	92	0
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442	69	141	188	70	96	2	0
443	206	20	21	205	248	252	0
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446	206	196	190	23	290	270	0
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448	189	185	187	190	95	93	0
449	39	192	38	40	260	262	0
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456	192	194	191	195	265	102	0
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458	195	41	42	40	268	103	0
459	194	197	196	195	269	271	0
460	192	195	194	40	102	100	0
461	42	175	195	43	266	272	0
462	196	193	194	25	267	101	0
463	195	42	175	41	266	268	0
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466	196	23	24	206	264	270	0
467	43	175	42	44	272	83	0
468	190	196	197	206	229	290	0
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473	198	28	199	27	114	111	0
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478	36	120	35	37	117	278	0
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480	142	201	138	189	281	121	0
481	140	201	189	136	31	157	0
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485	145	203	204	135	284	285	0
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487	147	203	136	134	38	171	0
488	134	204	203	153	286	184	0
489	151	204	153	145	287	46	0
490	145	204	151	203	46	284	0
491	19	205	18	20	288	256	0
492	142	205	206	138	289	33	0
493	18	205	17	19	162	288	0
494	190	206	196	142	290	291	0
495	142	206	190	205	291	289	0
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11	118	119	126
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13	117	126	125
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15	124	132	113
16	115	125	124
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21	130	129	132
22	5	6	128
23	110	111	132
24	103	104	133
25	9	10	145
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27	135	138	136
28	74	137	139
29	15	16	138
30	72	73	139
31	140	201	189
32	71	72	141
33	138	205	142
34	137	75	143
35	144	146	156
36	10	11	145
37	78	146	148
38	136	147	203
39	143	76	148
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41	150	133	149
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43	152	154	157
44	8	9	151
45	81	82	156
46	151	145	204
47	156	146	81
48	82	83	156

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51	161	160	159
52	97	98	159
53	100	164	161
54	165	86	162
55	164	163	161
56	100	101	164
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58	166	164	133
59	162	87	167
60	94	95	158
61	88	168	167
62	91	92	168
63	88	89	168
64	92	93	168
65	93	158	168
66	87	88	167
67	89	90	91
68	50	51	169
69	54	55	170
70	174	54	170
71	55	56	170
72	56	57	170
73	61	171	59
74	57	58	171
75	58	59	171
76	59	60	61
77	171	170	57
78	62	173	171
79	53	54	174
80	172	169	174
81	63	178	173
82	52	53	174
83	43	44	175
84	49	50	176
85	177	176	169
86	64	180	178
87	181	176	179
88	180	186	182
89	181	175	44
90	180	66	186
91	183	197	175
92	67	188	186
93	185	189	190
94	68	69	188
95	187	189	185
96	69	141	188
97	142	190	189
98	22	23	206
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104	24	25	196
105	197	195	175
106	193	27	198
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108	31	32	199
109	199	29	31
110	29	30	31
111	27	28	198

112	33	34	200
113	32	33	199
114	199	198	28
115	34	35	200
116	33	200	199
117	35	36	120
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119	191	198	200
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121	142	189	201
122	129	110	132
123	132	122	130
124	4	5	131
125	123	122	125
126	111	112	132
127	122	124	125
128	112	113	132
129	126	123	125
130	3	4	123
131	2	3	126
132	106	107	149
133	149	127	150
134	6	7	128
135	128	127	130
136	107	108	149
137	127	129	130
138	149	108	129
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140	5	128	131
141	123	131	122
142	108	109	129
143	131	130	122
144	104	105	133
145	152	157	166
146	145	11	202
147	144	155	134
148	14	15	135
149	136	143	147
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152	74	75	137
153	137	136	140
154	16	17	138
155	140	139	137
156	73	74	139
157	136	201	140
158	17	205	138
159	121	141	139
160	141	72	139
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162	17	18	205
163	140	189	121
164	75	76	143
165	135	136	203
166	78	79	146
167	144	134	147
168	12	13	202
169	144	148	146
170	77	78	148
171	134	203	147
172	13	14	202
173	147	148	144
174	76	77	148

175	143	148	147
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177	127	153	150
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179	150	152	166
180	153	134	155
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182	83	154	156
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186	80	81	146
187	153	155	152
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189	155	156	154
190	79	80	146
191	144	156	155
192	157	154	165
193	150	166	133
194	96	97	159
195	168	158	167
196	159	98	161
197	160	167	158
198	98	99	161
199	167	160	162
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201	160	163	162
202	154	84	165
203	161	163	160
204	102	103	164
205	163	165	162
206	101	102	164
207	163	157	165
208	83	84	154
209	164	166	163
210	103	133	164
211	163	166	157
212	85	86	165
213	159	160	158
214	86	87	162
215	159	158	96
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218	169	52	174
219	174	170	172
220	62	63	173
221	61	62	171
222	169	176	50
223	173	178	172
224	63	64	178
225	173	172	170
226	51	52	169
227	171	173	170
228	44	45	181
229	197	190	196
230	47	48	176
231	177	179	176
232	181	47	176
233	178	180	177
234	64	65	180
235	172	178	177
236	46	47	181
237	181	179	183

238	65	66	180
239	177	182	179
240	45	46	181
241	177	180	182
242	182	186	184
243	179	184	183
244	183	175	181
245	184	179	182
246	66	67	186
247	185	183	184
248	20	21	206
249	185	184	187
250	67	68	188
251	184	186	187
252	205	20	206
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265	192	194	191
266	42	175	195
267	194	196	193
268	41	42	195
269	194	197	196
270	23	196	206
271	195	197	194
272	42	43	175
273	185	190	197
274	25	26	193
275	191	200	120
276	26	27	193
277	200	35	120
278	36	37	120
279	200	198	199
280	136	138	201
281	138	142	201
282	11	12	202
283	202	135	145
284	203	204	145
285	145	135	203
286	203	134	204
287	151	204	153
288	18	19	205
289	206	142	205
290	206	196	190
291	190	142	206

Bedded Surface Input Files

BOUNDARY.IN

```
Pcp_File_Version=2
*** BLOCK ?: BOUNDARY INFORMATION *****************************************
    NumBP     NObs  SeepF  FreeD DrainF  qQWLF
      101        0      f      t      f      f
Node Number Array
      1       2       3       4       5       6       7       8       9      10
     11      12      13      14      15      16      17      18      19      20
     21      22      23      24      25      26      27      28      29      30
     31      32      33      34      35      36      37      38      39      40
     62      63      64      65      66      67      68      69      70      71
     72      73      74      75      76      77      78      79      80      81
     82      83      84      85      86      87      88      89      90      91
     92      93      94     115     116     117     118     119     120     121
    122     123     124     125     126     127     128     129     130     131
    132     133     134     135     136     137     138     139     140     141
    142
Width Array
1.47302 2.94228 2.93131 2.91402 2.89197  2.8674 2.84329 2.82337 2.81219 2.81295
2.81892 2.81707 2.80283 2.78459 2.78353 2.81461 2.85877 2.89007 2.90095  2.8903
2.86518 2.83546 2.80658 2.78356 2.77569 2.79618 2.83817 2.87452 2.88673 2.87133
2.84174 2.81984 2.81433 2.82089 2.83461 2.85134 2.86771 2.88119 2.88997 1.44651
1.40625  2.8125  2.8125  2.8125  2.8125  2.8125  2.8125  2.8125  2.8125  2.8125
 2.8125  2.8125  2.8125  2.8125  2.8125  2.8125  2.8125  2.8125  2.8125  2.8125
 2.8125  2.8125  2.8125  2.8125  2.8125  2.8125  2.8125  2.8125  2.8125  2.8125
 2.8125  2.8125 1.40625 0.445041 0.445042 0.445043 0.445043 0.445042 0.445042 0.445042
0.445041 0.445042 0.445043 0.445043 0.445042 0.445042 0.445042 0.445041 0.445042 0.445043
0.445043 0.445042 0.445042 0.445042 0.445041 0.445042 0.445043 0.445043 0.445042 0.445042
0.445042
Length of soil surface associated with transpiration
       111.075
*** BLOCK ?: Solute transport boundary conditions ****************************
KodCB(1),KodCB(2),.....,KodCB(NumBP)
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 -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
 -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
 -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -2  -2  -2  -2  -2  -2  -2
 -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2  -2
 -2
*** End of input file 'BOUNDARY.IN' ***************************************
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DIMENSIO.IN

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Pcp_File_Version=2
  NumNPD  NumElD  NumBPD  MBandD  NSeepD  NumSPD    NDrD  NElDrD   NMatD   NObsD     NSD
     265     390     101      15       1       1       1      20       4       1       3
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ATMOSPH.IN

```
Pcp_File_Version=2
*** BLOCK I: ATMOSPHERIC INFORMATION  *********************************
   MaxAL                    (MaxAL = number of atmospheric data-records)
    130
 hCritS                 (max. allowed pressure head at the soil surface)
      0
       tAtm        Prec       rSoil       rRoot      hCritA          rt          ht      cValue1     cValue2     cValue3
          1           0       0.249           0       10000           0           0           0           0           0           0
0           0           0           0           0
          2           0       0.289           0       10000      -0.001           0           0         646           0           0
0           0           0      2290.4           0
          3           0       0.191           0       10000           0           0           0           0           0           0
0           0           0           0           0
          4         1.1       0.084           0       10000           0           0           0           0           0           0
0           0           0           0           0
          5         0.8       0.264           0       10000           0           0           0           0           0           0
0           0           0           0           0
          6         4.9       0.024           0       10000           0           0           0           0           0           0
0           0           0           0           0
          7           0       0.245           0       10000      -0.001           0           0     449.055           0           0
0           0           0     1592.11           0
          8           0       0.272           0       10000           0           0           0           0           0           0
0           0           0           0           0
          9           0       0.248           0       10000           0           0           0           0           0           0
0           0           0           0           0
         10           0       0.265           0       10000           0           0           0           0           0           0
0           0           0           0           0
         11         0.2       0.288           0       10000           0           0           0           0           0           0
0           0           0           0           0
         12         0.1       0.254           0       10000           0           0           0           0           0           0
0           0           0           0           0
         13         4.7       0.081           0       10000           0           0           0           0           0           0
0           0           0           0           0
         14           0         0.1           0       10000           0           0           0           0           0           0
0           0           0           0           0
         15           0       0.276           0       10000           0           0           0           0           0           0
0           0           0           0           0
         16           0       0.242           0       10000           0           0           0           0           0           0
0           0           0           0           0
         17         1.7       0.057           0       10000           0           0           0           0           0           0
0           0           0           0           0
         18           0       0.072           0       10000           0           0           0           0           0           0
0           0           0           0           0
```

19	0.1	0.09	0	10000	0	0	0	0	0	0	0	0
20	1.1	0.252	0	10000	0	0	0	0	0	0	0	0
21	0	0.3	0	10000	0	0	0	0	0	0	0	0
22	0	0.254	0	10000	0	0	0	0	0	0	0	0
23	0	0.354	0	10000	0	0	0	0	0	0	0	0
24	0	0.376	0	10000	0	0	0	0	0	0	0	0
25	0	0.308	0	10000	0	0	0	0	0	0	0	0
26	0	0.277	0	10000	0	0	0	0	0	0	0	0
27	0	0.289	0	10000	0	0	0	0	0	0	0	0
28	0	0.12	0	10000	0	0	0	0	0	0	0	0
29	0.1	0.16	0	10000	0	0	0	0	0	0	0	0
30	0.7	0.092	0	10000	0	0	0	0	0	0	0	0
31	0	0.303	0	10000	0	0	0	0	0	0	0	0
32	0	0.301	0	10000	0	0	0	0	0	0	0	0
33	0	0.218	0	10000	0	0	0	0	0	0	0	0
34	0	0.329	0	10000	0	0	0	0	0	0	0	0
35	0	0.294	0	10000	0	0	0	0	0	0	0	0
36	0.1	0.091	0	10000	-0.001	0	0	267.859	0	0	0	949.68
37	0	0.344	0	10000	0	0	0	0	0	0	0	0
38	0	0.285	0	10000	0	0	0	0	0	0	0	0
39	0	0.313	0	10000	0	0	0	0	0	0	0	0
40	0	0.368	0	10000	0	0	0	0	0	0	0	0
41	0	0.342	0	10000	0	0	0	0	0	0	0	0

42	0	0.382	0	10000	0	0	0	0	0	0	0	0
43	0.3	0.195	0	10000	0	0	0	0	0	0	0	0
44	0	0.285	0	10000	0	0	0	0	0	0	0	0
45	0	0.128	0	10000	0	0	0	0	0	0	0	0
46	0.9	0.043	0	10000	0	0	0	0	0	0	0	0
47	0	0.328	0	10000	0	0	0	0	0	0	0	0
48	0	0.348	0	10000	0	0	0	0	0	0	0	0
49	0	0.351	0	10000	0	0	0	0	0	0	0	0
50	0	0.326	0	10000	0	0	0	0	0	0	0	0
51	0.6	0.292	0	10000	0	0	0	0	0	0	0	0
52	0	0.257	0	10000	0	0	0	0	0	0	0	0
53	6.9	0.047	0	10000	0	0	0	0	0	0	0	0
54	6.4	0.05	0	10000	0	0	0	0	0	0	0	0
55	0	0.158	0	10000	0	0	0	0	0	0	0	0
56	0	0.339	0	10000	0	0	0	0	0	0	0	0
57	0	0.371	0	10000	0	0	0	0	0	0	0	0
58	0	0.403	0	10000	0	0	0	0	0	0	0	0
59	0	0.395	0	10000	0	0	0	0	0	0	0	0
60	0	0.475	0	10000	0	0	0	0	0	0	0	0
61	0	0.482915	0.0020855	10000	0	0	0	0	0	0	0	0
62	0	0.444082	0.0019178	10000	0	0	0	0	0	0	0	0
63	0.6	0.280787	0.0012126	10000	0	0	0	0	0	0	0	0
64	0.3	0.397551	0.0034486	10000	-0.001	0	0	1599.27	0	0	0	0
0	0	5670.15	0									

65	0.8	0.466898	0.0061017	10000	0	0	0	0	0	0	0	0
66	0	0.444239	0.009761	10000	0	0	0	0	0	0	0	0
67	0.7	0.416087	0.0129129	10000	0	0	0	0	0	0	0	0
68	0	0.424895	0.0171054	10000	0	0	0	0	0	0	0	0
69	0	0.491593	0.0244068	10000	0	0	0	0	0	0	0	0
70	0.9	0.479603	0.0283972	10000	0	0	0	0	0	0	0	0
71	0	0.413453	0.0305472	10000	0	0	0	0	0	0	0	0
72	0.4	0.199283	0.0157165	10000	0	0	0	0	0	0	0	0
73	0	0.350062	0.032938	10000	0	0	0	0	0	0	0	0
74	0.9	0.388314	0.0446856	10000	0	0	0	0	0	0	0	0
75	0.9	0.389663	0.0533372	10000	0	0	0	0	0	0	0	0
76	0.5	0.374132	0.0618684	10000	-0.001	0	0	1638.66	0	0	0	0
77	0.9	0.35456	0.0714402	10000	0	0	0	0	0	0	0	0
78	0.9	0.332278	0.079722	10000	0	0	0	0	0	0	0	0
79	0.9	0.396257	0.122744	10000	0	0	0	0	0	0	0	0
80	0.9	0.334312	0.129688	10000	0	0	0	0	0	0	0	0
81	0.9	0.323809	0.157191	10000	0	0	0	0	0	0	0	0
82	2.5	0.278477	0.169523	10000	0	0	0	0	0	0	0	0
83	0.9	0.284262	0.189738	10000	0	0	0	0	0	0	0	0
84	0	0.232518	0.182482	10000	0	0	0	0	0	0	0	0
85	0.2	0.172411	0.146589	10000	0	0	0	0	0	0	0	0
86	1	0.215676	0.201324	10000	0	0	0	0	0	0	0	0
87	0.9	0.193082	0.193918	10000	0	0	0	0	0	0	0	0

88	0.9	0.237761	0.266239	10000	0	0	0	0	0	0	0	0
89	0.9	0.191996	0.235004	10000	0	0	0	0	0	0	0	0
90	0.9	0.194315	0.253685	10000	0	0	0	0	0	0	0	0
91	0.9	0.182315	0.251685	10000	0	0	0	0	0	0	0	0
92	1.9	0.104176	0.148824	10000	0	0	0	0	0	0	0	0
93	2.1	0.0683525	0.0976475	10000	0	0	0	0	0	0	0	0
94	0.1	0.157923	0.224077	10000	0	0	0	0	0	0	0	0
95	0.3	0.0996166	0.140383	10000	0	0	0	0	0	0	0	0
96	0	0.189613	0.265387	10000	0	0	0	0	0	0	0	0
97	1	0.184097	0.255903	10000	0	0	0	0	0	0	0	0
98	3.6	0.228103	0.314897	10000	0	0	0	0	0	0	0	0
99	0.9	0.227752	0.312248	10000	0	0	0	0	0	0	0	0
100	0.5	0.199023	0.270977	10000	0	0	0	0	0	0	0	0
101	0.7	0.268696	0.363304	10000	0	0	0	0	0	0	0	0
102	0.7	0.239997	0.320003	10000	0	0	0	0	0	0	0	0
103	0.7	0.253867	0.336133	10000	0	0	0	0	0	0	0	0
104	0.7	0.231989	0.305011	10000	0	0	0	0	0	0	0	0
105	0.9	0.226884	0.294116	10000	0	0	0	0	0	0	0	0
106	0.9	0.251841	0.324159	10000	0	0	0	0	0	0	0	0
107	0.9	0.240201	0.304799	10000	0	0	0	0	0	0	0	0
108	0.8	0.236355	0.295645	10000	0	0	0	0	0	0	0	0
109	0.8	0.217652	0.268348	10000	0	0	0	0	0	0	0	0
110	0.8	0.235201	0.285799	10000	0	0	0	0	0	0	0	0

```
        111         0.8    0.185212    0.221788       10000           0           0           0           0           0           0
0           0           0           0           0
        112         0.8      0.2137      0.2503       10000           0           0           0           0           0           0
0           0           0           0           0
        113         0.9     0.26045     0.30055       10000           0           0           0           0           0           0
0           0           0           0           0
        114         0.8    0.253727    0.286273       10000           0           0           0           0           0           0
0           0           0           0           0
        115         0.7    0.283236    0.314764       10000           0           0           0           0           0           0
0           0           0           0           0
        116           0    0.278986    0.303014       10000           0           0           0           0           0           0
0           0           0           0           0
        117           0    0.235295    0.249705       10000           0           0           0           0           0           0
0           0           0           0           0
        118         0.6    0.252374    0.261626       10000           0           0           0           0           0           0
0           0           0           0           0
        119         0.6    0.270329    0.273671       10000           0           0           0           0           0           0
0           0           0           0           0
        120           0    0.295218    0.291782       10000           0           0           0           0           0           0
0           0           0           0           0
        121         0.4    0.286182    0.273818       10000           0           0           0           0           0           0
0           0           0           0           0
        122         0.4    0.324807    0.303193       10000           0           0           0           0           0           0
0           0           0           0           0
        123         0.4    0.332148    0.299852       10000           0           0           0           0           0           0
0           0           0           0           0
        124           0     0.33403     0.29397       10000           0           0           0           0           0           0
0           0           0           0           0
        125           0    0.306591    0.258409       10000           0           0           0           0           0           0
0           0           0           0           0
        126         0.2    0.338003    0.274997       10000           0           0           0           0           0           0
0           0           0           0           0
        127           0    0.310517    0.241483       10000           0           0           0           0           0           0
0           0           0           0           0
        128           0    0.358684    0.266316       10000           0           0           0           0           0           0
0           0           0           0           0
        129           0    0.318505    0.225495       10000           0           0           0           0           0           0
0           0           0           0           0
        130         0.8    0.159253    0.112747       10000           0           0           0           0           0           0
0           0           0           0           0
*** END OF INPUT FILE 'ATMOSPH.IN' ************************************
```

SELECTOR.IN

```
Pcp_File_Version=2
*** BLOCK A: BASIC INFORMATION ****************************************
Heading
Welcome to HYDRUS-2D
LUnit  TUnit  MUnit  (indicated units are obligatory for all input data)
cm
days
-mg
Kat (0:horizontal plane, 1:axisymmetric vertical flow, 2:vertical plane)
  2
MaxIt   TolTh   TolH InitH/W  (max. number of iterations and tolerances)
10000   0.0001    0.1     t
lWat lChem lSink Short Flux lScrn AtmIn lTemp lWTDep lEquil lExtGen lInv
 t     t     t     f     t    t     t     f     f      t      t      f
*** BLOCK B: MATERIAL INFORMATION **************************************
NMat    NLay    hTab1   hTabN
  4       5    1e-006   10000
    Model   Hysteresis
      2          0
  thr    ths   Alfa     n         Ks      l
  0.03 0.3883  0.061  0.753       4515      2
  0.03 0.3883  0.061  0.753       4515      2
  0.03 0.3526  0.053  0.754       3759      2
  0.03 0.3526  0.053  0.754       3759      2
*** BLOCK C: TIME INFORMATION *****************************************
        dt       dtMin       dtMax     DMul    DMul2  ItMin ItMax  MPL
      0.001      1e-005       0.001     1.7     0.7     3     7   100
      tInit        tMax
          0         130
TPrint(1),TPrint(2),...,TPrint(MPL)
          1           2           3           4           5           6
          7           8           9          10          11          12
         13          14          15          16          17          18
         19          20          21          22          23          24
         25          26          27          28          29          30
         31          32          33          34          35          36
         37          38          39          40          41          42
         43          44          45          46          47          48
         49          50          51          52          53          54
         55          56          57          58          59          60
         61          62          63          64          65          66
         67          68          69          71          73          75
         77          79          81          82          84          86
         88          90          92          94          96          98
```

```
        100         102         104         106         108         110
        112         114         116         118         120         122
        124         126         128         130
*** BLOCK G: SOLUTE TRANSPORT INFORMATION ****************************************************
 Epsi  lUpW  lArtD lTDep    cTolA    cTolR   MaxItC    PeCr  Nu.of Solutes Tortuosity
    1     f     f     f         0        0     1       1       3         t
     Bulk.d.     DisperL.      DisperT     Frac      ThImob (1..NMat)
       1.48          10          10          1           0
       1.48          10          10          1           0
       1.56          10          10          1           0
       1.56          10          10          1           0
         DifW       DifG               n-th solute
        1.2           0
         Ks          Nu        Beta       Henry       SnkL1       SnkS1       SnkG1       SnkL1'      SnkS1'      SnkG1'      SnkL0
SnkS0       SnkG0         Alfa
      0.001           0           1           0           0           0           0       0.001           0           0           0
0           0           0
      0.001           0           1           0           0           0           0       0.001           0           0           0
0           0           0
      0.001           0           1           0           0           0           0       0.001           0           0           0
0           0           0
      0.001           0           1           0           0           0           0       0.001           0           0           0
0           0           0
         DifW       DifG               n-th solute
        1.2           0
         Ks          Nu        Beta       Henry       SnkL1       SnkS1       SnkG1       SnkL1'      SnkS1'      SnkG1'      SnkL0
SnkS0       SnkG0         Alfa
         0           0           1           0           0           0           0        0.11           0           0           0
0           0           0
         0           0           1           0           0           0           0        0.11           0           0           0
0           0           0
         0           0           1           0           0           0           0        0.11           0           0           0
0           0           0
         0           0           1           0           0           0           0        0.11           0           0           0
0           0           0
         DifW       DifG               n-th solute
        1.2           0
         Ks          Nu        Beta       Henry       SnkL1       SnkS1       SnkG1       SnkL1'      SnkS1'      SnkG1'      SnkL0
SnkS0       SnkG0         Alfa
         0           0           1           0           0           0           0           0           0           0           0
0           0           0
         0           0           1           0           0           0           0           0           0           0           0
0           0           0
         0           0           1           0           0           0           0           0           0           0           0
0           0           0
         0           0           1           0           0           0           0           0           0           0           0
0           0           0
```

```
       cTop        cBot
          0           0           0           0           0           0           0           0           0
          0           0           0           0           0           0           0           0           0
          0           0           0           0           0           0           0           0           0
      tPulse
          1
*** BLOCK G: ROOT WATER UPTAKE INFORMATION *****************************
     Model  (0 - Feddes, 1 - S shape)
        0
       P0       P2H       P2L       P3          r2H        r2L
      -10      -320      -600     -6000         0.5         0.1
POptm(1),POptm(2),...,POptm(NMat)
     -25      -25      -25      -25
     Solute Reduction
        f
*** END OF INPUT FILE 'SELECTOR.IN' **********************************
```

MESHTRIA.000

	1	265	656	390	142	
1		90	60	37.7346		0
2		87.3874	61.3614	37.7346		0
3		84.7926	62.7406	37.8704		0
4		82.2337	64.1555	38.1531		0
5		79.7284	65.6241	38.6044		0
6		77.2948	67.1642	39.255		0
7		74.9507	68.7936	40.1433		0
8		72.7139	70.5302	41.3115		0
9		70.6025	72.3919	42.8043		0
10		68.6342	74.3965	44.6627		0
11		66.8008	76.5346	46.5268		0
12		65.0353	78.7353	47.1346		0
13		63.2623	80.9189	45.6801		0
14		61.4064	83.0059	43.1991		0
15		59.3922	84.9167	40.0134		0
16		57.1456	86.5723	36.7486		0
17		54.6474	87.9198	33.8152		0
18		51.9566	88.9438	31.3613		0
19		49.1382	89.6316	29.5961		0
20		46.2572	89.9705	28.8002		0
21		43.3776	89.9489	28.8002		0
22		40.5529	89.5657	29.2684		0
23		37.8315	88.825	30.9838		0
24		35.2617	87.7314	33.7464		0
25		32.8919	86.2889	37.3344		0
26		30.7589	84.5106	41.4723		0
27		28.8222	82.4673	45.2235		0
28		27.0091	80.2541	47.833		0
29		25.2464	77.9664	48.7269		0
30		23.4613	75.6994	46.9529		0
31		21.5808	73.5483	44.3631		0
32		19.5584	71.5741	42.1071		0
33		17.4035	69.7653	40.2889		0
34		15.1326	68.1013	38.8621		0
35		12.7623	66.5615	37.7767		0
36		10.3093	65.1251	36.9822		0
37		7.78992	63.7714	36.4321		0
38		5.22089	62.4798	36.0884		0
39		2.61872	61.2296	35.9235		0
40		0	60	35.9235		0
41		-2.71051e-020	57.2727	54.5454		0
42		0	54.5455	54.5454		0
43		0	51.8182	54.5454		0
44		0	49.0909	54.5454		0
45		1.35525e-020	46.3636	54.5454		0
46		6.77626e-021	43.6364	54.5454		0
47		-2.71051e-020	40.9091	54.5454		0
48		0	38.1818	54.5454		0
49		0	35.4545	54.5454		0
50		0	32.7273	54.5454		0
51		0	30	54.5454		0
52		0	27.2727	54.5454		0
53		0	24.5455	54.5454		0
54		3.38813e-021	21.8182	54.5454		0
55		0	19.0909	54.5454		0
56		0	16.3636	54.5454		0
57		0	13.6364	54.5454		0
58		3.38813e-021	10.9091	54.5454		0
59		0	8.18182	54.5454		0
60		1.69407e-021	5.45454	54.5454		0
61		8.47033e-022	2.72727	54.5454		0
62		0	0	28.125		0
63		2.8125	-4.23516e-022	28.125		0
64		5.625	-8.47033e-022	28.125		0
65		8.4375	8.47033e-021	28.125		0
66		11.25	-1.69407e-021	28.125		0
67		14.0625	0	28.125		0

68	16.875	1.69407e-020	28.125	0
69	19.6875	1.01644e-020	28.125	0
70	22.5	-3.38813e-021	28.125	0
71	25.3125	3.38813e-020	28.125	0
72	28.125	0	28.125	0
73	30.9375	0	28.125	0
74	33.75	3.38813e-020	28.125	0
75	36.5625	0	28.125	0
76	39.375	2.03288e-020	28.125	0
77	42.1875	0	28.125	0
78	45	-6.77626e-021	28.125	0
79	47.8125	6.77626e-020	28.125	0
80	50.625	6.77626e-020	28.125	0
81	53.4375	0	28.125	0
82	56.25	0	28.125	0
83	59.0625	2.71051e-020	28.125	0
84	61.875	0	28.125	0
85	64.6875	4.06576e-020	28.125	0
86	67.5	6.77626e-020	28.125	0
87	70.3125	0	28.125	0
88	73.125	0	28.125	0
89	75.9375	-6.77626e-020	28.125	0
90	78.75	4.06576e-020	28.125	0
91	81.5625	6.77626e-020	28.125	0
92	84.375	0	28.125	0
93	87.1875	0	28.125	0
94	90	-1.35525e-020	28.125	0
95	90	2.85715	57.1426	0
96	90	5.71428	57.1426	0
97	90	8.57143	57.1429	0
98	90	11.4286	57.1429	0
99	90	14.2857	57.1426	0
100	90	17.1429	57.1426	0
101	90	20	57.1429	0
102	90	22.8571	57.1426	0
103	90	25.7143	57.1426	0
104	90	28.5714	57.1429	0
105	90	31.4286	57.1429	0
106	90	34.2857	57.1426	0
107	90	37.1429	57.1426	0
108	90	40	57.1429	0
109	90	42.8571	57.1426	0
110	90	45.7143	57.1426	0
111	90	48.5714	57.1429	0
112	90	51.4286	57.1429	0
113	90	54.2857	57.1426	0
114	90	57.1429	57.1426	0
115	53	84	8.73399	0
116	52.901	84.4339	7.49174	0
117	52.6235	84.7818	5.56711	0
118	52.2225	84.9749	4.45042	0
119	51.7775	84.9749	4.45042	0
120	51.3765	84.7818	5.56709	0
121	51.099	84.4339	7.49175	0
122	51	84	8.73399	0
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124	51.3765	83.2182	5.56711	0
125	51.7775	83.0251	4.45042	0
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127	52.6235	83.2182	5.56709	0
128	52.901	83.5661	7.49175	0
129	39	84	8.73399	0
130	38.901	84.4339	7.49174	0
131	38.6235	84.7818	5.56711	0
132	38.2225	84.9749	4.45042	0
133	37.7775	84.9749	4.45042	0
134	37.3765	84.7818	5.56709	0
135	37.099	84.4339	7.49175	0
136	37	84	8.73399	0
137	37.099	83.5661	7.49174	0
138	37.3765	83.2182	5.56711	0

139	37.7775	83.0251	4.45042	0
140	38.2225	83.0251	4.45042	0
141	38.6235	83.2182	5.56709	0
142	38.901	83.5661	7.49175	0
143	34.9967	64.7309	43.6497	3
144	6.15428	2.56221	38.1007	3
145	11.9901	2.75945	34.5996	3
146	8.80991	6.07518	43.6986	3
147	17.0279	2.4242	32.5304	3
148	16.3703	6.08173	38.9784	3
149	11.8224	10.4436	46.8659	3
150	21.9885	3.71081	33.7385	3
151	22.8169	9.09533	40.7875	3
152	17.5983	15.6777	48.3773	3
153	27.379	4.30782	33.8492	3
154	32.9092	7.74126	37.4607	3
155	30.0016	12.6089	43.0062	3
156	32.9291	3.02961	31.8187	3
157	39.1382	4.79634	33.6165	3
158	34.4721	17.9967	46.7905	3
159	64.5054	9.4017	41.4407	3
160	75.4175	2.59867	34.6928	3
161	82.6437	2.34473	38.0955	3
162	76.6206	9.21441	46.9738	3
163	63.6311	3.78364	33.8894	3
164	70.6094	5.67338	38.8199	3
165	79.8077	5.61457	44.1925	3
166	69.1224	2.16965	32.2236	3
167	41.7119	11.3933	40.6014	3
168	45.5717	5.46091	34.3129	3
169	62.8184	15.8035	46.4963	3
170	51.2946	3.73903	32.5337	3
171	53.088	10.2377	39.898	3
172	75.4268	13.7887	49.6434	3
173	57.7067	4.97426	34.5449	3
174	39.7112	52.8527	47.7586	3
175	21.1083	35.5583	52.5769	3
176	40.862	32.5913	51.7446	3
177	22.1099	29.0758	52.2823	3
178	65.5657	23.9723	51.5099	3
179	43.3603	25.2354	50.2993	3
180	76.3692	19.8059	52.4307	3
181	20.4285	22.623	51.064	3
182	50.2783	17.8132	46.1941	3
183	63.7016	31.5835	52.8908	3
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185	63.3903	49.8053	49.5349	3
186	16.6475	47.4323	51.2897	3
187	48.7549	46.1783	49.9215	3
188	24.2098	42.1662	51.5798	3
189	63.0152	41.4608	51.8864	3
190	23.586	63.8553	42.1562	3
191	17.0163	56.7748	45.6047	3
192	43.2768	59.5885	45.4941	3
193	32.2637	58.7442	45.3063	3
194	52.2151	54.0056	47.474	3
195	55.544	80.4952	32.4223	3
196	49.9368	84.7611	10.5183	3
197	42.3197	83.1486	14.8374	3
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199	51.2685	82.8358	8.78395	3
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201	50.028	83.5256	9.44729	3
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213	52.1955	72.3763	42.1631	3
214	36.7034	71.0889	42.8683	3
215	45.6926	66.3335	43.6818	3
216	48.9372	80.5721	25.0018	3
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218	33.821	81.4713	30.869	3
219	39.3826	81.8027	18.5968	3
220	36.8072	79.622	32.1287	3
221	40.2999	82.886	12.7471	3
222	44.9161	83.0865	15.9573	3
223	46.9657	82.2287	17.4995	3
224	47.7684	83.3906	13.3043	3
225	34.4614	83.1782	24.6118	3
226	36.5844	83.4169	12.6455	3
227	38.555	82.785	9.51015	3
228	37.0791	82.2458	17.0519	3
229	35.7301	84.5646	17.6077	3
230	46.707	87.3447	21.5131	3
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233	41.6551	85.907	16.2167	3
234	38.7823	86.4979	19.7139	3
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253	76.1292	46.5269	52.889	3
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233	49	175	263
234	187	248	189
235	107	108	249
236	265	188	184
237	258	190	35
238	247	42	259
239	42	43	259
240	190	193	143
241	112	256	253
242	254	259	186
243	194	192	174
244	110	111	253
245	193	174	192
246	11	12	211
247	201	198	124
248	196	240	239
249	239	237	243
250	141	221	142
251	242	222	241
252	126	250	202
253	199	124	198
254	13	14	195
255	200	198	223
256	12	13	195
257	199	198	200
258	250	126	199
259	216	250	200
260	195	14	255
261	115	203	116
262	126	202	127
263	116	203	117
264	15	16	203
265	204	117	203
266	16	17	204
267	240	119	204
268	17	18	205
269	240	205	239
270	29	212	220
271	216	223	206
272	207	34	190
273	215	252	262
274	112	113	256
275	3	4	257
276	261	257	5
277	143	214	207
278	30	214	212
279	211	216	210
280	8	9	209

281	211	210	212
282	31	207	214
283	212	213	211
284	7	8	261
285	213	212	214
286	32	33	207
287	214	215	213
288	257	261	260
289	143	215	214
290	9	10	209
291	216	206	210
292	24	25	217
293	132	217	133
294	28	220	218
295	220	219	228
296	141	227	221
297	220	228	218
298	220	212	210
299	206	221	219
300	206	197	221
301	206	222	197
302	198	201	224
303	220	206	219
304	10	11	213
305	223	222	206
306	124	199	125
307	26	27	225
308	225	226	229
309	138	228	139
310	137	226	138
311	228	227	139
312	226	225	228
313	27	218	225
314	228	219	227
315	229	134	217
316	229	217	25
317	19	20	230
318	237	239	230
319	20	21	231
320	237	231	233
321	21	22	231
322	232	233	231
323	131	235	132
324	233	232	234
325	22	23	232
326	234	235	233
327	23	24	234
328	236	233	235
329	132	235	217
330	236	235	131
331	239	243	196
332	237	230	231
333	19	230	238
334	238	239	205
335	196	120	240
336	239	238	230
337	240	204	205
338	122	201	123
339	246	236	130
340	242	241	237
341	245	122	196
342	237	244	242
343	244	233	236
344	237	241	243
345	123	201	124
346	222	242	197
347	142	246	129
348	241	224	245
349	197	246	221
350	241	222	224
351	38	39	247

352	259	191	247
353	184	248	187
354	183	248	176
355	106	107	249
356	249	253	189
357	250	199	200
358	216	195	250
359	128	251	115
360	127	202	128
361	215	192	252
362	252	194	208
363	256	185	253
364	189	253	185
365	193	190	264
366	193	254	174
367	186	188	265
368	14	15	255
369	255	251	202
370	256	257	208
371	208	185	256
372	4	5	257
373	257	260	208
374	258	38	247
375	191	258	247
376	41	42	247
377	44	186	259
378	261	209	260
379	252	260	262
380	6	7	261
381	209	261	8
382	260	209	262
383	213	262	209
384	184	188	175
385	45	46	263
386	263	175	188
387	258	191	264
388	193	264	254
389	174	265	187
390	174	254	265

APPENDIX E
DSSAT MODIFICATIONS

Changes needed in GROSUB to account for plants growing on BedWidth (cm), but with LAI draping over the entire row spacing (RowSP, in cm)

James W. Jones
8-18-02

1. Potato plants are grown as individual plants in GROSUB. The variable PLANTS is the number of plants per meter square. Thus, daily growth is computed by dividing overall growth per m^2 by the plant population. LAI is computed by multiplying the area per plant (PLA, m^2[leaf area]/plant) by PLANT (plants/m^2[soil area]). Getting biomass per m^2[soil area] also requires multiplying biomass per plant by PLANTS to get g[biomass]/(m^2[ground area]).
2. To account for plants growing only on the bed, it is best to assume that PLANTS is the plants per m^2[bed area], and thus the row spacing and plant population put in fileX are on a bed basis, not a row width basis. This will allow one to compute all soil processes as they are, and just to convert biomass values to account for the differences in row width vs. bed width. This is done as follows:
3. LAI is computed by multiplying LAI computed on a bed basis (now that this is the basic dimension of the model) by the ratio of Bed Width to Rowspacing (or, by BedWidth/RowSP). Since these variables are not in the model input file yet, I suggest that the numbers be used instead ov variables, or that these variables are declared locally in GROSUB. For example, if BedWidth = 0.5 and RowSP = 0.9, then the ratio would be 0.5/0.9. This LAI computation needs to be done in several places.
4. Daily growth (PCARB, g/(plant) per day), accounts for PLANTS, the plants per m^2 row width, but since LAI has already been adjusted (downward since BedWidth is less than RowSP), then growth is computed on a per m^2[row width] basis and this must be adjusted upward. This is done by multiplying PCARB by the ratio (RowSP / BedWidth).
5. Finally, biomass in g per m^2[bed] is computed by multiplying per plant values by PLANTS * (RowSP / BedWidth).
6. The resulting biomass values that are output will thus be for the BED WIDTH, not the entire row width, but LAI will come out as leaf area on a row width basis NOT bed width.

GROSUB

XLAI on Line 179

```
!***********************************************************************
!***********************************************************************
!     Daily rate calculations
!***********************************************************************
      ELSEIF (DYNAMIC .EQ. RATE) THEN
!-----------------------------------------------------------------------

      IF (FIRST) THEN     !Initializations from PHASEI, all Case(7),
                          ! except where noted.
        FIRST   = .FALSE.
!       XLAI    = PLA * PLANTS * 0.0001
        XLAI    = PLA * PLANTS * 0.0001 *BedWidth / RowSp  !
        LFWT    = 0.093
```

Line 274

```
  IF (DDEADLF .GE. LFWT) THEN
        DDEADLF = LFWT
      END IF
      !
      ! Senescence calculation, end
      !
      ! Update of haulm after senescence
      !
      LFWT   = LFWT   - DDEADLF
      PLA    = LFWT   * LALWR
!     XLAI   = PLA    * PLANTS * 0.0001
      XLAI   = PLA    * PLANTS * 0.0001 * BedWidth / RowSP
      TOPWT  = LFWT   + STMWT
```

Line 290 PCARB

```
      IF (ISTAGE .LT. 2) THEN
!       PCARB = 3.5*PAR/PLANTS*(1.0 - EXP(-0.55*XLAI))
        PCARB = 3.5*PAR/PLANTS*(1.0 - EXP(-0.55*XLAI)) * RowSP / BedWidth
      ELSE
!       PCARB = 4.0*PAR/PLANTS*(1.0 - EXP(-0.55*XLAI))
        PCARB = 4.0*PAR/PLANTS*(1.0 - EXP(-0.55*XLAI)) * RowSP / BedWidth
      END IF
```

Line 421 AND 423 in GROSUB

```
!
        ! Calculation of potential growth .. Set priorities for carbon
        !
!        PTUBGR  = G3*ETGT/PLANTS
        PTUBGR  = G3*ETGT/PLANTS * (RowSP / BedWidth)
       GROTUB  = PTUBGR*AMIN1 (TURFAC, AGEFAC, 1.0)*TIND
 !       PLAG    = G2*DTT/PLANTS
        PLAG    = G2*DTT/PLANTS * (RowSP / BedWidth)
        PLAG    = PLAG  *AMIN1 (TURFAC, AGEFAC, 1.0)
        GROLF   = PLAG/LALWR
        GROSTM  = GROLF*0.75
        RTPAR   = 0.2
        GRORT   = (GROLF + GROSTM)* RTPAR
        GROPLNT =  GROLF + GROSTM + GRORT
        RVCAV   = RVCHO
        CARBO   = CARBO + RVCAV
```

Lines 531 in GROSUB

```
      IF (GROTOP .LT. 0.0) THEN
        DEADLF = DEADLF - GROTOP*0.5
      END IF

      PLAG = GROLF * LALWR
      PLA  = PLA   + PLAG
!     XLAI = PLA   * PLANTS * 0.0001
      XLAI = PLA   * PLANTS * 0.0001 * (BedSP / RowWidth)
      IF (TOPWT .LE. 0.0) THEN
        TOPWT = 0.0
        XLAI  = 0.0
        TANC  = 0.0
       ELSE
        TANC  = TOPSN/TOPWT
      END IF

      BIOMAS = (LFWT + STMWT + TUBWT)*PLANTS
```

APPENDIX F
MODIFIED DSSAT/SUBSTOR INPUT FILES

Modified North Half SUBSTOR Input File (2001)

```
*MODEL INPUT FILE            I     1     5     1     3     0
*FILES
MODEL          PTSUB980.EXE
FILEX          REDLASOD.PTX
FILEA          REDLASOD.PTA
FILET          REDLASOD.PTT
SPECIES        PTSUB980.SPE C:\DSSAT35\GENOTYPE\
ECOTYPE        □□□□
```

```
*IRRIGATION
    .900   60.   50.  100. GS000 IR001  10.0
    1007 IR004   5.0     0
    1012 IR004   3.0     0
    1013 IR004   5.0     0
    1037 IR004   3.0     0
    1043 IR004   7.0     0
    1048 IR004   6.0     0
    1051 IR004   5.0     0
    1053 IR004   7.0     0
    1055 IR004   9.0     0
    1060 IR004   8.0     0
    1066 IR004   4.0     0
    1071 IR004   5.0     0
    1083 IR004   9.0     0
    1085 IR004   6.0     0
    1091 IR004   8.0     0
    1092 IR004   9.0     0
    1093 IR004   8.0     0
    1094 IR004   9.0     0
    1095 IR004   8.0     0
    1096 IR004   9.0     0
    1097 IR004   8.0     0
    1098 IR004   9.0     0
    1099 IR004   8.0     0
    1100 IR004   9.0     0
    1101 IR004   8.0     0
    1102 IR004   9.0     0
    1103 IR004   8.0     0
    1104 IR004   9.0     0
    1105 IR004   8.0     0
    1106 IR004   9.0     0
    1107 IR004   8.0     0
    1108 IR004   9.0     0
    1109 IR004   8.0     0
    1110 IR004   9.0     0
    1111 IR004   8.0     0
    1112 IR004   9.0     0
    1113 IR004   8.0     0
    1114 IR004   9.0     0
    1115 IR004   8.0     0
    1116 IR004   9.0     0
    1117 IR004   8.0     0
    1118 IR004   9.0     0
    1119 IR004   8.0     0
    1120 IR004   9.0     0
```

```
    1121 IR004   8.0     0
    1122 IR004   9.0     0
    1123 IR004   8.0     0
    1124 IR004   9.0     0
    1125 IR004   8.0     0
    1126 IR004   9.0     0
    1127 IR004   8.0     0
    1128 IR004   9.0     0
    1129 IR004   8.0     0
    1130 IR004   9.0     0
    1131 IR004   8.0     0
    1132 IR004   9.0     0
    1133 IR004   8.0     0
    1134 IR004   9.0     0
    1135 IR004   8.0     0
    1136 IR004   9.0     0
    1137 IR004   8.0     0
    1138 IR004   9.0     0
    1139 IR004   8.0     0
    1140 IR004   9.0     0
*FERTILIZERS
    1007 FE001 AP005    0.    1.    0.    0.    0.    0.
    1012 FE001 AP005    0.    1.    0.    0.    0.    0.
    1013 FE001 AP005    0.    1.    0.    0.    0.    0.
    1018 FE001 AP009   15.   76.    0.    0.    0.    0.
    1037 FE001 AP005    0.    1.    0.    0.    0.    0.
    1043 FE001 AP005    0.    1.    0.    0.    0.    0.
    1046 FE001 AP004   15.   34.    0.    0.    0.    0.
    1048 FE001 AP005    0.    1.    0.    0.    0.    0.
    1051 FE001 AP005    0.    1.    0.    0.    0.    0.
    1053 FE001 AP005    0.    1.    0.    0.    0.    0.
    1055 FE001 AP005    0.    2.    0.    0.    0.    0.
    1060 FE001 AP005    0.    2.    0.    0.    0.    0.
    1064 FE001 AP009   15.  224.    0.    0.    0.    0.
    1066 FE001 AP005    0.    1.    0.    0.    0.    0.
    1071 FE001 AP005    0.    1.    0.    0.    0.    0.
    1083 FE001 AP005    0.    2.    0.    0.    0.    0.
    1084 FE001 AP009   15.  224.    0.    0.    0.    0.
    1091 FE001 AP005    0.    2.    0.    0.    0.    0.
    1092 FE001 AP005    0.    2.    0.    0.    0.    0.
    1093 FE001 AP005    0.    2.    0.    0.    0.    0.
    1094 FE001 AP005    0.    2.    0.    0.    0.    0.
    1095 FE001 AP005    0.    2.    0.    0.    0.    0.
    1096 FE001 AP005    0.    2.    0.    0.    0.    0.
    1097 FE001 AP005    0.    2.    0.    0.    0.    0.
    1098 FE001 AP005    0.    2.    0.    0.    0.    0.
    1099 FE001 AP005    0.    2.    0.    0.    0.    0.
```

```
    1100 FE001 AP005    0.    2.    0.    0.    0.    0.
    1101 FE001 AP005    0.    2.    0.    0.    0.    0.
    1102 FE001 AP005    0.    2.    0.    0.    0.    0.
    1103 FE001 AP005    0.    2.    0.    0.    0.    0.
    1104 FE001 AP005    0.    2.    0.    0.    0.    0.
    1105 FE001 AP005    0.    2.    0.    0.    0.    0.
    1106 FE001 AP005    0.    2.    0.    0.    0.    0.
    1107 FE001 AP005    0.    2.    0.    0.    0.    0.
    1108 FE001 AP005    0.    2.    0.    0.    0.    0.
    1109 FE001 AP005    0.    2.    0.    0.    0.    0.
    1110 FE001 AP005    0.    2.    0.    0.    0.    0.
    1111 FE001 AP005    0.    2.    0.    0.    0.    0.
    1112 FE001 AP005    0.    2.    0.    0.    0.    0.
    1113 FE001 AP004    0.   34.    0.    0.    0.    0.
    1114 FE001 AP005    0.    2.    0     0     0     0
    1115 FE001 AP005    0.    2.    0.    0.    0.    0.
    1116 FE001 AP005    0.    2.    0     0     0     0
    1117 FE001 AP005    0.    2.    0.    0.    0.    0.
    1118 FE001 AP005    0.    2.    0     0     0     0
    1119 FE001 AP005    0.    2.    0.    0.    0.    0.
    1120 FE001 AP005    0.    2.    0     0     0     0
    1121 FE001 AP005    0.    2.    0.    0.    0.    0.
    1122 FE001 AP005    0.    2.    0     0     0     0
    1123 FE001 AP005    0.    2.    0.    0.    0.    0.
    1124 FE001 AP005    0.    2.    0     0     0     0
    1125 FE001 AP005    0.    2.    0.    0.    0.    0.
    1126 FE001 AP005    0.    2.    0     0     0     0
    1127 FE001 AP005    0.    2.    0.    0.    0.    0.
    1128 FE001 AP005    0.    2.    0     0     0     0
    1129 FE001 AP005    0.    2.    0.    0.    0.    0.
    1130 FE001 AP005    0.    2.    0     0     0     0
    1131 FE001 AP005    0.    2.    0.    0.    0.    0.
    1132 FE001 AP005    0.    2.    0     0     0     0
    1133 FE001 AP005    0.    2.    0.    0.    0.    0.
    1134 FE001 AP005    0.    2.    0     0     0     0
    1135 FE001 AP005    0.    2.    0.    0.    0.    0.
    1136 FE001 AP005    0.    2.    0     0     0     0
    1137 FE001 AP005    0.    2.    0.    0.    0.    0.
    1138 FE001 AP005    0.    2.    0     0     0     0
    1139 FE001 AP005    0.    2.    0.    0.    0.    0.
    1140 FE001 AP005    0.    2.    0     0     0     0
*RESIDUES
*CHEMICALS
*TILLAGE
*ENVIRONMENT
*HARVEST
    1141 GS000 L     A      100.    0.
```

```
*SOIL
 UF00850002  SCS         FSA     60. TEMPLATE
 TEMPLATE       USA      -82.000  24.000 00 GROSSARENIC PALEUDULTS
 G       .13   5.6   .50   95.  1.00  1.00 IB001 IB001 IB001
    5.        .017  .097  .388  .750 188.0  1.48   .90   1.7   2.5   1.4 -9.00   5.2   4.3   4.0    .0
   15.        .017  .097  .388  .750 188.0  1.48   .90   1.7   2.5   1.4 -9.00   5.2   4.3   4.0    .0
   30.        .017  .097  .388  .500 188.0  1.48   .02   1.2   3.7   1.1 -9.00   5.3   4.8   4.0    .0
   45.        .019  .080  .388  .150 156.6  1.56   .01   1.0   3.9   1.4 -9.00   5.3   4.8   4.0    .0
   60.        .019  .080  .388  .150 156.6  1.56   .01   1.0   3.9   1.4 -9.00   5.3   4.8   4.0    .0
   90.        .019  .080  .388  .150 156.6  1.56   .01   1.0   3.9   1.4 -9.00   5.3   4.8   4.0    .0

    5.    .0    .0    .0    .0    .0    .0    .0    .0
   15.    .0    .0    .0    .0    .0    .0    .0    .0
   30.    .0    .0    .0    .0    .0    .0    .0    .0
   45.    .0    .0    .0    .0    .0    .0    .0    .0
   60.    .0    .0    .0    .0    .0    .0    .0    .0
   90.    .0    .0    .0    .0    .0    .0    .0    .0
*CULTIVAR
UF0001 RED LASODA       IB0001  2000.  22.0   .20    .7    .4  19.0
```

Modified North Half SUBSTOR Input File (2002)

```
*MODEL INPUT FILE           I     1     4     1     2     0
*FILES
MODEL          PTSUB980.EXE
FILEX          RDLASD02.PTX
FILEA          RDLASD02.PTA
FILET          RDLASD02.PTT
SPECIES        PTSUB980.SPE C:\DSSAT35\GENOTYPE\
ECOTYPE        □□□□
```

```
                  0  2354  100.    0.
*EXP.DETAILS
  4RDLASD02 PT RDLASD02PT
*TREATMENTS
  10 0 0 NORTHHALF
*CULTIVARS
   PT UF0001 RED LASODA
*FIELDS
   UFSW0001 UFSU0201    .0    0. DR000    0.  100. 00000 FSA     60. UF00850002
         -83.04000        30.08000     13.70              99.0  995.   1.0    .0
*INITIAL CONDITIONS
   MZ     2009    1.    0.  1.00  1.00 200.0     0   .00   .00  100.   15.
      5.  .081   5.6   4.0
     15.  .081   5.6   4.0
     30.  .082   3.6   3.2
     45.  .086   3.6   2.7
     60.  .086   3.6   2.7
     90.  .081   3.2   2.1
*PLANTING DETAILS
    2043  2069   5.4   4.6     B     R   90.   45.  16.0 1500.  -99. -99.0 -99.0   5.0
*IRRIGATION
    .900   60.   50.  100. GS000 IR001  10.0
    2059 IR004   6.0     0
    2073 IR004   8.0     0
    2075 IR004   7.0     0
    2078 IR004   9.0     0
    2082 IR004   9.0     0
    2083 IR004   9.0     0
    2084 IR004   5.0     0
    2085 IR004   9.0     0
    2086 IR004   9.0     0
    2087 IR004   9.0     0
    2088 IR004   9.0     0
    2089 IR004   9.0     0
    2090 IR004   9.0     0
    2091 IR004   9.0     0
    2094 IR004  10.0     0
    2095 IR004   9.0     0
    2096 IR004   9.0     0
    2097 IR004   9.0     0
    2098 IR004   9.0     0
    2099 IR004   9.0     0
    2105 IR004   9.0     0
    2106 IR004   7.0     0
    2107 IR004   9.0     0
    2108 IR004   5.0     0
    2109 IR004   7.0     0
```

```
    2110 IR004   7.0     0
    2111 IR004   7.0     0
    2112 IR004   7.0     0
    2113 IR004   9.0     0
    2114 IR004   9.0     0
    2115 IR004   9.0     0
    2116 IR004   8.0     0
    2117 IR004   8.0     0
    2118 IR004   8.0     0
    2119 IR004   8.0     0
    2120 IR004   8.0     0
    2121 IR004   8.0     0
    2122 IR004   8.0     0
    2123 IR004   7.0     0
    2126 IR004   6.0     0
    2127 IR004   6.0     0
    2129 IR004   4.0     0
    2130 IR004   4.0     0
    2131 IR004   4.0     0
*FERTILIZERS
    2010 FE001 AP004    15    82     0     0     0     0
    2015 FE001 AP004    15    57     0     0     0     0
    2044 FE001 AP004    15    34     0     0     0     0
    2059 FE001 AP005     0    1.     0     0     0     0
    2072 FE001 AP004    15   203     0     0     0     0
    2073 FE001 AP005     0    2.     0     0     0     0
    2075 FE001 AP005     0    1.     0     0     0     0
    2078 FE001 AP005     0    2.     0     0     0     0
    2082 FE001 AP005     0    2.     0     0     0     0
    2083 FE001 AP005     0    2.     0     0     0     0
    2084 FE001 AP004    15   208     0     0     0     0
    2085 FE001 AP005     0    2.     0     0     0     0
    2086 FE001 AP005     0    2.     0     0     0     0
    2087 FE001 AP005     0    2.     0     0     0     0
    2088 FE001 AP005     0    2.     0     0     0     0
    2089 FE001 AP005     0    2.     0     0     0     0
    2090 FE001 AP005     0    2.     0     0     0     0
    2091 FE001 AP005     0    2.     0     0     0     0
    2094 FE001 AP005     0    2.     0     0     0     0
    2095 FE001 AP005     0    2.     0     0     0     0
    2096 FE001 AP005     0    2.     0     0     0     0
    2097 FE001 AP005     0    2.     0     0     0     0
    2098 FE001 AP005     0    2.     0     0     0     0
    2099 FE001 AP005     0    2.     0     0     0     0
    2105 FE001 AP005     0    2.     0     0     0     0
    2106 FE001 AP005     0    1.     0     0     0     0
    2107 FE001 AP005     0    2.     0     0     0     0
```

```
    2108 FE001 AP005     0    1.     0     0     0     0
    2109 FE001 AP005     0    1.     0     0     0     0
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    2130 FE001 AP005     0    1.     0     0     0     0
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*RESIDUES
*CHEMICALS
*TILLAGE
*ENVIRONMENT
*HARVEST
    2138 GS000 L     A      100.    0.
*SOIL
 UF00850002  SCS          FSA     60. TEMPLATE
 TEMPLATE       USA      -82.000  24.000 00 GROSSARENIC PALEUDULTS
 G       .13   5.6   .50   95.  1.00  1.00 IB001 IB001 IB001
    5.        .017  .097  .388  .750 188.0  1.48   .90   1.7   2.5   1.4 -9.00   5.2   4.3   4.0    .0
   15.        .017  .097  .388  .750 188.0  1.48   .90   1.7   2.5   1.4 -9.00   5.2   4.3   4.0    .0
   30.        .017  .097  .388  .500 188.0  1.48   .02   1.2   3.7   1.1 -9.00   5.3   4.8   4.0    .0
   45.        .019  .080  .388  .150 156.6  1.56   .01   1.0   3.9   1.4 -9.00   5.3   4.8   4.0    .0
   60.        .019  .080  .388  .150 156.6  1.56   .01   1.0   3.9   1.4 -9.00   5.3   4.8   4.0    .0
   90.        .019  .080  .388  .150 156.6  1.56   .01   1.0   3.9   1.4 -9.00   5.3   4.8   4.0    .0

    5.    .0    .0    .0    .0    .0    .0    .0    .0
   15.    .0    .0    .0    .0    .0    .0    .0    .0
   30.    .0    .0    .0    .0    .0    .0    .0    .0
   45.    .0    .0    .0    .0    .0    .0    .0    .0
   60.    .0    .0    .0    .0    .0    .0    .0    .0
   90.    .0    .0    .0    .0    .0    .0    .0    .0
*CULTIVAR
UF0001 RED LASODA       IB0001  2000.  22.0   .20    .7    .4  19.0
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Modified South Half SUBSTOR Input File (2002)

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FILEA          RDLASD02.PTA
FILET          RDLASD02.PTT
SPECIES        PTSUB980.SPE C:\DSSAT35\GENOTYPE\
ECOTYPE        □□□□
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    2075 IR004   7.0     0
    2078 IR004   9.0     0
    2082 IR004   4.0     0
    2083 IR004   4.0     0
    2084 IR004   5.0     0
    2085 IR004   4.0     0
    2086 IR004   4.0     0
    2087 IR004   4.0     0
    2088 IR004   4.0     0
    2089 IR004   4.0     0
    2090 IR004   5.0     0
    2091 IR004   5.0     0
    2094 IR004   6.0     0
    2095 IR004   7.0     0
    2096 IR004   7.0     0
    2097 IR004   7.0     0
    2098 IR004   6.0     0
    2099 IR004   7.0     0
    2106 IR004   7.0     0
    2107 IR004   7.0     0
    2108 IR004   5.0     0
    2109 IR004   7.0     0
    2110 IR004   7.0     0
    2111 IR004   7.0     0
    2112 IR004   7.0     0
    2113 IR004   9.0     0
    2114 IR004   9.0     0
    2115 IR004   9.0     0
    2116 IR004   8.0     0
    2117 IR004   8.0     0
    2118 IR004   8.0     0
    2119 IR004   8.0     0
    2120 IR004   8.0     0
    2121 IR004   8.0     0
    2122 IR004   8.0     0
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    2075 FE001 AP005    0.     1.    0.    0.    0.    0.
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    2083 FE001 AP005    0.     1.    0.    0.    0.    0.
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    2087 FE001 AP005    0.     1.    0.    0.    0.    0.
    2088 FE001 AP005    0.     1.    0.    0.    0.    0.
    2089 FE001 AP005    0.     1.    0.    0.    0.    0.
    2090 FE001 AP005    0.     1.    0.    0.    0.    0.
    2091 FE001 AP005    0.     1.    0.    0.    0.    0.
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    2116 FE001 AP005    0.     2.    0.    0.    0.    0.
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    2118 FE001 AP005    0.     2.    0.    0.    0.    0.
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    2122 FE001 AP005    0.     2.    0.    0.    0.    0.
    2123 FE001 AP005    0.     1.    0.    0.    0.    0.
    2125 FE001 AP005    0.     1.    0.    0.    0.    0.
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*RESIDUES
*CHEMICALS
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*TILLAGE
*ENVIRONMENT
*HARVEST
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*SOIL
 UF00850002  SCS          FSA     60. TEMPLATE
 TEMPLATE       USA      -82.000  24.000 00 GROSSARENIC PALEUDULTS
 G       .13   5.6   .50   95.  1.00  1.00 IB001 IB001 IB001
    5.         .017  .097  .388  .750 188.0  1.48   .90   1.7   2.5   1.4 -9.00   5.2   4.3   4.0    .0
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   45.         .019  .080  .388  .150 156.6  1.56   .01   1.0   3.9   1.4 -9.00   5.3   4.8   4.0    .0
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    5.    .0    .0    .0    .0    .0    .0    .0    .0
   15.    .0    .0    .0    .0    .0    .0    .0    .0
   30.    .0    .0    .0    .0    .0    .0    .0    .0
   45.    .0    .0    .0    .0    .0    .0    .0    .0
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BIOGRAPHICAL SKETCH

Frank Warren McKinnie was born on October 13, 1977, in Marianna, FL, and grew up in Grand Ridge, FL. After graduating from Sneads High School in 1996, he enrolled at Chipola Junior College in Marianna, FL, where he received an Associate of Arts degree in pre-engineering curriculum. In fall of 1999, he enrolled in the Electrical Engineering Department at the University of Florida. At the beginning of the semester, he changed his major to agricultural and biological engineering with emphasis in soil and water engineering because he was not content with the engineering discipline he had initially selected. On May 5, 2001, Frank graduated with his Bachelor of Science in Agricultural and Biological Engineering with highest honors. In August 2001, he enrolled at the Agricultural and Biological Engineering Department where he focused his studies on water resources, specifically subsurface contaminant transport.