# Pesticide and Water Management Alternatives to Mitigate Potential Ground-Water Contamination for Selected Counties in Utah

Majid Ehteshami
Antonio M. Requena
Richard C. Peralta
Howard M. Deer
Robert W. Hill
Ahmad Yar Ranjha

(This material is based upon work supported by the Utah State University Extension Service, U. S. Department of Agriculture, under special project No. 89-EWQI-1-9195.)

Agricultural and Irrigation Engineering Department
and Cooperative Extension Service
Utah State University
Logan, Utah
May 1990

# TABLE OF CONVERSIONS

| To convert | Into | Multiply by |
|---|---|---|
| m | ft | 3.2808 |
| | yd | 1.0936 |
| | mm | 1000 |
| mm | in | 0.0394 |
| | ft | 0.0033 |
| ha | ac | 2.4710 |
| | $m^2$ | 10000 |
| l | gal | 0.2642 |
| | qt | 1.0567 |
| | ml | 1000 |
| $m^3$ | $ft^3$ | 35.3147 |
| | l | 1000 |
| Kg | lb | 2.2046 |
| | Oz | 35.2740 |
| | g | 1000 |
| g | lb | 0.0022 |
| | mg | 1000 |
| | μg | 1000000 |
| Kg/ha | lb/ac | 0.8922 |

Abbreviation:

ac = acre
ft = foot
$ft^3$ = cubic foot
g = gram
μm = microgram
mg = milligram
ha = hectare
in = inch
Kg = kilogram
l = liter

lb = pound
m = meter
$m^2$ = square meter
$m^3$ = cubic meter
gal = gallon
ml = milliliter
mm = millimeter
Oz = once
qt = quart
yd = yard

# Pesticide and Water Management Alternatives to Mitigate Potential Ground-Water Contamination for Selected Counties in Utah

BY

Majid Ehteshami
Antonio M. Requena
Richard C. Peralta
Howard M. Deer
Robert W. Hill
Ahmad Yar Ranjha

AGRICULTURAL AND IRRIGATION ENGINEERING DEPT.
AND COOPERATIVE EXTENSION SERVICE
UTAH STATE UNIVERSITY
LOGAN, UTAH
MAY 1990

## ACKNOWLEDGMENTS

We gratefully acknowledge the funding support of the Utah Department of Agriculture and the following offices at Utah State University: The Department of Agricultural and Irrigation Engineering, the International Irrigation Center, the Department of Animal, Dairy and Veterinary Sciences, the Department of Soil Science and Biometerology, and the University Extension Service.

We appreciate the cooperation of Jim Paraskeva and Ken Wyatt of the Utah Department of Agriculture, the compilation by county extension agents of information on pesticide use and cropping areas. We are grateful for the help of the Soil Conservation Service and the U.S. Geological Survey in providing us with soil survey and hydrogeologic information. We acknowledge the software support and advice of Art Hornsby (University of Florida) and Bob Carsel (USEPA). We appreciate the guidance given by Dr. Robert W. Hill and L. Niel Allen in the calculation of crop water requirements and the review of Dr. Richard G. Allen. Valuable help was also provided by Ricardo Melamed with data preparation, with graphic support coming from Grant Johnson, and secretarial support from Jill Hunsaker, Sheridyn Stokes, Cheryl Johnson, and Tammy Griffeth.

## TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS.................................... ii

LIST OF TABLES...................................... v

LIST OF FIGURES..................................... vii

LIST OF SYMBOLS..................................... x

ABSTRACT............................................ xiii

CHAPTER

I. INTRODUCTION..................................... 1

Statement of the Problem.................. 1
Objectives................................ 5
Scope of the Study........................ 6

II. LITERATURE REVIEW............................... 7

Factors Affecting Pesticide Movement....... 7

Soil Properties....................... 7
Pesticide Characteristics............. 13
Agricultural Practices................ 16

Pesticide Leaching........................ 17
Simulation of Pesticide Movement in Soils.. 18

III. PROCEDURE...................................... 21

Site Identification....................... 21
Soil Data................................. 24
Pesticide Data............................ 24
Crop Data................................. 26
Evapotranspiration Data................... 27
Average Infiltrated Water Depth........... 31
CMLS Model................................ 42
Potential Pesticide Concentration in Ground Water....................... 48
Pesticide Simulations..................... 49

## TABLE OF CONTENTS

Page

IV. RESULTS AND DISCUSSION........................ 50

Management Practices to Reduce Potential Ground-Water Contamination............. 50

Alternative Pesticides................ 50
Alternative Application Dates......... 57
Alternative Water Management Practices......................... 59
Alternative Irrigation Systems........ 62

Sensitivity Analyses...................... 67

Soil.................................. 67
Sprinkler Irrigation.................. 70
Furrow Irrigation..................... 73

V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS......... 75

Summary and Conclusions................... 75
Recommendations........................... 77

REFERENCES..................................... 78

APPENDICES..................................... 83

Appendix A: CMLS Simulations.................. 84
Appendix B: Pesticide Library ................ 93
Appendix C: Soil Library ..................... 104
Appendix D: Irrigation Schedules.............. 108
Appendix E: Seasonal Soil-Water Budget......... 115
Appendix F: BMSs Graphical Outputs............ 118
Appendix G: CMLS Analysis..................... 145

## LIST OF TABLES

Table Page

1. Toxic Organic Chemicals Found in Ground Water Collected in the U.S............................ 4

2. Cation Exchange Capacity (CEC) and Surface Area for Different Soil Constituents............ 11

3. Chemodynamic Properties for Several Pesticides.. 14

4. Example of Soil Data............................ 25

5. Example of Pesticide Data....................... 25

6. Rooting Depths of Various Crops Used in this Study.................................... 26

7. Zone, County and Weather Station Assignments.... 28

8. Crop Coefficients............................... 30

9. Furrow Simulation Data.......................... 35

10. Distribution Coefficient ($H_a$) Values Based on a Normal Distribution........................ 40

11. Example of Pesticide Movement to Selected Depths................................ 48

12. Pesticide Movement Comparison Under Sprinkler Irrigation............................ 72

13. Pesticide Movement Comparison Under Surface Irrigation.............................. 74

14. CMLS Simulations: Alternatives Pesticides....... 85

15. CMLS Simulations: Furrow Irrigation............. 87

16. CMLS Simulations: Sprinkler Irrigation.......... 91

17. Irrigation Schedules: Alternative Pesticides.... 109

## LIST OF TABLES

Table Page

18. Irrigation Schedule: Furrow and Sprinkler Irrigation........................................ 112

19. Seasonal Soil Water Budget...................... 116

20. Estimated and Simulated Hydrological Data....... 148

21. Pesticide Data Used in Simulations............. 148

22. Soil Properties Used in Simulations............ 148

23. CMLS Analysis: Preferential Flow................ 156

## LIST OF FIGURES

Figure Page

1. Schematic Representation of Processes Influencing Pesticide Movement.................. 8

2. Schematic Representation of the Procedure to Estimate Potential Pesticide Concentration in Ground Water.................................. 23

3. Relation Between Required Water Application and Actual Moisture Distribution for Three Typical Irrigation Regimes...................... 33

4. Effect of Various Furrow Inflow Rates and Furrow Lengths on Storage Efficiency (furrow slope = 0.002 m/m).............................. 36

5. Effect of Various Furrow Inflow Rates and Furrow Lengths on Storage Efficiency (furrow slope = 0.006 m/m).............................. 37

6. Relation Between Fraction of Area Adequately Irrigated and $H_a$ for a UC of 84%................ 41

7. Alternative Alfalfa Herbicides and Their Relative Amounts Remaining in the Soil When Pesticides Reach a Depth of 1 m in Utah County.. 53

8. Alternative Alfalfa Insecticides and Their Relative Amounts Remaining in the Soil When Pesticides Reach a Depth of 1 m in Utah County.. 54

9. Alternative Corn Insecticides and Their Relative Amounts Remaining in the Soil When Pesticides Reach a Depth of 1 m in Utah County.. 55

10. Alternative Small Grains Herbicides and Their Relative Amounts Remaining in the Soil When Pesticides Reach a Depth of 1 m in Utah County.. 56

11. Effect on Relative Amount of Pesticides Remaining in the Soil When They Reach a Depth of 2 m for Two Pesticide Application Dates. Assumes 50% Irrigation Efficiency....... 58

## LIST OF FIGURES

Figure Page

12. Effect on Relative Amount of Atrazine Remaining in the Soil When the Herbicide Reaches a Depth of 2 m for Various Water-Storage Efficiencies.................................... 60

13. Effect on Relative Amount of Pesticides Remaining in the Soil When They Reach a Depth of 2 m for Various Surface Irrigation Efficiencies......................... 61

14. Effect of Furrow Lengths on Relative Amount of Pesticides Remaining in the Soil When They Reach a Depth of 2 m........................... 64

15. Effect on Relative Amount of Pesticides Remaining in the Soil When They Reach a Depth of 2 m for Various Inflow Rates ($Q_{in}$) to the Furrow Head...................... 65

16. Effects of Various Uniformity Coefficients on Relative Amount of Pesticides Remaining in the Soil When They Reach a Depth of 2 m Under a Sprinkler Irrigation System............ 66

17. Effect of Various Soil Textures on Relative Amount of Aldicarb Remaining in the Soil When It Reaches a Depth of 2 m...................... 68

18. Effect of Various Soil Textures on Relative Amount of Carbofuran Remaining in the Soil When It Reaches a Depth of 2 m................. 69

19. Effect of Various Infiltrated Water Depths on Relative Amount of Aldicarb Remaining in the Soil When It Reaches a Depth of 2 m............ 71

20. Rainfall, Irrigation and Chemical Depth as a Function of Time............................ 149

21. Estimated Daily Grass Evapotranspiration for Tifton, Georgia................................ 150

## LIST OF FIGURES

Figure Page

22. Total Mass of Atrazine in the Saturate Zone..... 151

23. Simulated and Observed Peak Concentrations of Atrazine on Different Dates.................... 152

24. Simulated and Observed Depths to Peak Concentration of Atrazine on Different Dates.... 153

25. Simulated and Observed Concentrations of Alachlor on Different Dates.................... 154

26. Simulated and Observed Depths to Peak Concentration of Alachlor on Different Dates.... 155

## LIST OF SYMBOLS

| Symbol | Definition | Units |
|---|---|---|
| $\theta(j)$ | Volumetric water content of layer j | - |
| $\theta'(j)$ | Volumetric water content of layer j prior to adjustment | - |
| $\theta_{fc}$ | Volumetric water content at field capacity | - |
| $\theta_{fc}(j)$ | Volumetric water content at field capacity of layer j | - |
| $\theta_{pwp}$ | Volumetric water content at permanent wilting point | - |
| $\theta_{pwp}(j)$ | Volumetric water content at permanent wilting point of layer j | - |
| $\tau$ | Infiltration opportunity time | min |
| a | Empirical fitting parameter | - |
| AC | Air-filled porosity | - |
| AW(j) | Available water in the layer j | mm |
| $AW_{total}$ | Total available water in the root zone | mm |
| BD | Bulk density | $g/cm^3$ |
| CEC | Cation exchange capacity | m.e./100 g |
| $C_s$ | Concentration of pesticide in the solid phase | $\mu g/g$ |
| $C_w$ | Concentration of pesticide in the solution phase | $\mu g/ml$ |
| d | Infiltrated water depth | mm |
| $d_{ave}$ | Average infiltrated depth | mm |
| $d_{max}$ | Maximum infiltrated depth | mm |
| $d_{min}$ | Minimum infiltrated depth | mm |
| $d_s$ | Solute front depth | mm |

# LIST OF SYMBOLS

| Symbol | Definition | Units |
|---|---|---|
| $d_s'$ | Solute front prior to adjustment | mm |
| $E_a$ | On-farm application efficiency | - |
| $E_s$ | Water storage efficiency | - |
| $ET_0$ | Grass reference evapotranspiration | mm/day |
| $ET_{crop}$ | Crop evapotranspiration | mm/day |
| $f_0$ | Basic intake rate | $m^3/m$ min |
| $H_a$ | Distribution coefficient | - |
| I(j) | Infiltrating amount into layer j | mm |
| k | Empirical fitting parameter | $m^3/m\ min^a$ |
| $K_c$ | Crop coefficient | - |
| $K_d$ | Partition coefficient of the chemical in soil | ml/g soil |
| $K_h$ | Henry's constant | - |
| $K_{oc}$ | Organic carbon partition coefficient | ml/g OC |
| L | Distance from soil surface to ground water | m |
| m | Mean application | mm |
| n | Number of observations | - |
| OC | Organic carbon content | - |
| q | Net recharge | m/day |
| $Q_{in}$ | Flow discharge at the furrow head | l/s |
| RF | Retardation factor | - |
| RA | Relative amount of pesticide remaining in the soil profile when the chemical reaches a prefixed depth | - |
| Ra | Extraterrestrial radiation | mm/day |

# LIST OF SYMBOLS

| Symbol | Definition | Units |
|---|---|---|
| S | Water solubility | mg/l |
| swd(j) | Soil-water deficit of layer j | mm |
| t(j) | Thickness of the layer j | mm |
| $t_{1/2}$ | Degradation half-life | days |
| TC | Average daily temperature | °C |
| $T_{co}$ | Time of cutoff | min |
| TD | Temperature difference | °C |
| tr | Travel time | days |
| UC | Christiansen uniformity coefficient | % |
| $V_a$ | Total depth applied | mm |
| $V_i$ | Total depth infiltrated into the soil | mm |
| $V_p$ | Vapor pressure | Pa |
| $V_s$ | Total depth storage in root zone | mm |
| $W_p$ | Amount of water passing the depth $d_s$ | mm |
| X | Absolute deviation of individual observation from the mean | mm |
| Z | Accumulated infiltrated depth per meter of furrow length | m3/m |
| z | Individual depth of catch observation from uniformity test | mm |
| $Z_{req}$ | Required application depth at the end of the furrow | $m^3/m$ |

# ABSTRACT

## Effects of Alternative Irrigation Practices on Pesticide Movement in Cropped Areas

Production of adequate supplies of food and fiber currently requires that pesticides be used to limit crop losses from insects, pathogens, weeds and other pests. Although pesticides are necessary in today's agriculture, they can be a serious problem if they reach and contaminate ground water, especially in places where drinking water needs are supplied from ground water.

The relative reduction of potential ground-water contamination due to agricultural use of pesticides was analyzed for particular sites in Utah. The potential reduction of pesticides in ground water was considered by utilizing alternative irrigation systems, water management practices and pesticides.

A one-dimensional simulation model, CMLS (Chemical Movement in Layered Soils), was utilized to simulate the movement of pesticides through soils. A hydraulic irrigation model (Kinematic-wave) was used to estimate water infiltrating through the soil profile for alternative furrow irrigation system designs and water management practices.

The study indicates that a reduction in the likelihood of ground-water contamination due to agricultural use of pesticides can be achieved with careful use of pesticides, appropriate irrigation system design and water management techniques. (170 pages)

# CHAPTER I

# INTRODUCTION

## 1.1 Statement of the Problem

Production of adequate supplies of food and fiber currently requires that pesticides be used to limit crop losses from insects, pathogens, weeds and other pests. The term pesticide refers to a large number of chemical compounds. Pesticides include acaricides, fungicides, herbicides, insecticides, nematicides, algicides, antiseptics, arboricides and zoocides (Burnside, 1974).

The Environmental Protection Agency (USEPA, 1987) reported that more than 45,000 registered products, manufactured from one or more of 1,400 chemical compounds, are used against weeds, plant diseases and pests attacking wildlife and food crops. Comparing these with earlier numbers, 34,500 registered products were from 900 chemical compounds (USEPA 1972), we see the extraordinary growth of activity in this area.

Pimentel and Levitan (1986) reported that use of pesticides, primarily synthetic organic pesticides, reaches almost 500 million kg in the United States each year. Of the total pesticides used, approximately 60 percent are herbicides, 24 percent insecticides and 16 percent fungicides. About 341 million kg of pesticides are used on agricultural land, 55 million kg on government and industrial lands, 4 million kg on forest lands and 55 million kg on household lands.

Pesticides are an integral and indispensable part of today's agriculture. Pimentel and Levitan (1986) concluded that for every $3 billion invested in the United States in controlling pests with pesticides about $12 billion is returned.

The benefits of proper use of pesticides are enormous; however, there are significant risks associated with their widespread and intensive use. Pesticides can be a serious problem if they reach and contaminate ground water. Pimentel and Levitan (1986) reported that the amount of pesticide reaching the target pest is generally very small in relation to the total amount applied. The rest of the pesticide impacts the environment by contaminating soil and water and perhaps affecting nontarget organisms. Zaki et al. (1982) found aldicarb, a carbamate pesticide, in ground water in Suffolk County, New York, in August 1979. The study showed that 13.5 percent of the 8,404 tested wells exceeded the state-recommended guidelines. Sum (1986) reported a USEPA finding that 17 pesticides have been detected in the ground water of 23 states. Concentrations range from a mere trace to several hundred parts per million. Lau and Mink (1987) reported that several essential wells were taken out of service on Oahu, Hawaii because of ground-water contamination by pesticides used in pineapple production and aviation fuels.

Oki and Giambelluca (1987) concluded that the contamination of ground water by pesticides on Oahu is derived from nonpoint and/or point sources related to nematicide use in pineapple cultivation. Pionke et al. (1988) found atrazine contamination at extremely low concentrations in 14 of 20 wells tested in the Mahantango Creek watershed, Pennsylvania.

Table 1 shows toxic organic compounds found at various places in the United States (Rao et al., 1985). Nematicides, herbicides and industrial solvents dominate the list. This fact has brought attention to the environmental hazard associated with pesticide use in crop production and in land disposal of hazardous organic wastes.

Ground-water contamination by pesticides, fertilizers or other organic or inorganic materials can be of great importance, especially in places where an important amount of the drinking water needs are supplied from ground water. Leonard et al. (1988) reported that ground water supplies drinking water for about 50 percent of the U.S. population. Waddell (1987) reported that 63 percent of Utah's population depends on ground water for drinking water supplies. Rural areas are almost totally dependent on ground water for domestic supply.

The risk of potential contamination of ground water by pesticides depends on different factors. Pesticide properties, soil, agricultural practices, plant uptake, hydrology, geology, climate and topography are important

TABLE 1. Toxic Organic Chemicals Found in Ground Water Collected in the U.S.

| Chemical | State(s) | Concentration range (ppb) |
|---|---|---|
| Acetone | NJ | 3,000 |
| Alachlor | NB | 0.04 |
| Aldicarb | AZ,CA,FL,ME,MO,NC,NJ<br>NY,OR,TX,VA,WA,WI | 1-50 |
| Atrazine | IA,NB,WI | 0.3-3.0 |
| $\alpha$-BHC | CA | 6 |
| $\beta$-BHC | CA | 4 |
| $\delta$-BHC (Lindane) | CA | 22 |
| Benzene | CT,NJ,NY | 30-330 |
| Bromacil | FL | 300 |
| Bromoform | DE | 20 |
| Butybenzylphthalate | NY | 38 |
| Carbofuran | NY,WI | 1-5 |
| Carbontetrachloride | NJ,NY | 235-400 |
| Chloroform | NJ,NY | 67-490 |
| Chloromethane | MA | 44 |
| Cyclohexane | NY | 540 |
| Dibromochloromethane | DE,NY | 20-55 |
| DBCP | AZ,CA,HI,MD,SC | 0.02-137 |
| Di-(n)-butylphthalate | NY | 470 |
| 1,1-Dichloroethane | NJ | 7 |
| 1,1-Dichloroethylene | MA,ME,NJ | 70-280 |
| 1-2-Dichloroethylene | MA,NY | 91-323 |
| 1,2-Dichloropropene | CA,MD,NY | 1-50 |
| Dinoseb | NY | 1-5 |
| Dioxane | MA | 2,100 |
| Ethylbenzene | NJ | 2,000 |
| EDB | CA,FL,HI,GA,SC | 0.05-300 |
| Isopropylbenzene | NY | 290 |
| Methylene chloride | NJ,NY | 47-3,000 |
| Oxamyl | NY | 5-65 |
| Parathion | CA | 4-6 |
| Simazine | CA | 1-2 |
| Tetrachloroethylene | CT,NJ,NY | 717-1,500 |
| Toluene | NJ | 55-5,440 |
| 1,1,1-Trichloroethane | CT,ME,NJ,NY | 965-5,440 |
| 1,1,2-Trichloroethane | NY | 20 |
| Trichloroethylene(TCE) | NJ,NY,PA | 1,530-27,300 |
| Trifluorochloroethane | NY | 35-135 |
| Xylene | NJ,NY | 59-300 |

Source: Rao et al. (1985). Adapted from Brumaster, D.E. (1981) and Cohen et al. (1984).

factors affecting pesticide movement and eventually ground-water contamination.

## 1.2 Objectives

The major objective of this study is to determine the relative reduction of potential ground-water contamination due to agricultural use of pesticides that is achievable for selected sites in Utah. The reduction of pesticides in ground water can be achieved by utilizing alternative pesticides and water management techniques. Considered are the uses of alternative irrigation systems, water management practices and pesticides.

By comparing the potential contamination results from the above, "best management systems" (BMSs) can be selected. If best management systems are implemented, the likelihood of ground-water contamination can be reduced.

### 1.3 Scope of the Study

The results of the simulation study will allow the relative comparison of potential pesticide contamination of ground water at different sites, pesticides and water management practices. The simulation sites were selected based on the study done by Eisele et al. (1989). These sites have a high risk of ground-water contamination, although contamination does not necessarily have to occur in these areas. The potential for contamination depends on the agricultural practices, pesticide characteristics and application time.

The study does not consider contamination resulting from misuse (application at higher than recommended rates), accidental spill, pesticide contamination of surface water, mixing of surface contaminated water with ground water, or degradation of pesticides to intermediate compounds that are more toxic or more mobile than the parent compound. Other limitations on the scope of this study include the assumptions of the utilized simulation models.

# CHAPTER II

# LITERATURE REVIEW

## 2.1 Factors Affecting Pesticide Movement

Many factors influence the transport of agricultural chemicals in soils (Fig. 1). Knowledge of factors that affect the behavior of pesticides after their contact with the soil surface is important in predicting the risk of ground-water contamination. Physical-chemical properties of the pesticide, soil properties, agricultural practices, plant uptake, hydrogeology, climate and topography can affect the movement of pesticides.

Of primary consideration in this study are soil properties, pesticide characteristics and agricultural practices.

### 2.1.1 Soil Properties

An important physico-chemical process related to pesticide movement in soils is sorption. The sorption process, including adsorption and desorption, is the major retention mechanism for many organic compounds and is actually not totally understood. Adsorption refers to the adherence of pesticide molecules to soil particles. Desorption is related to the separation of molecules from the soil particles.

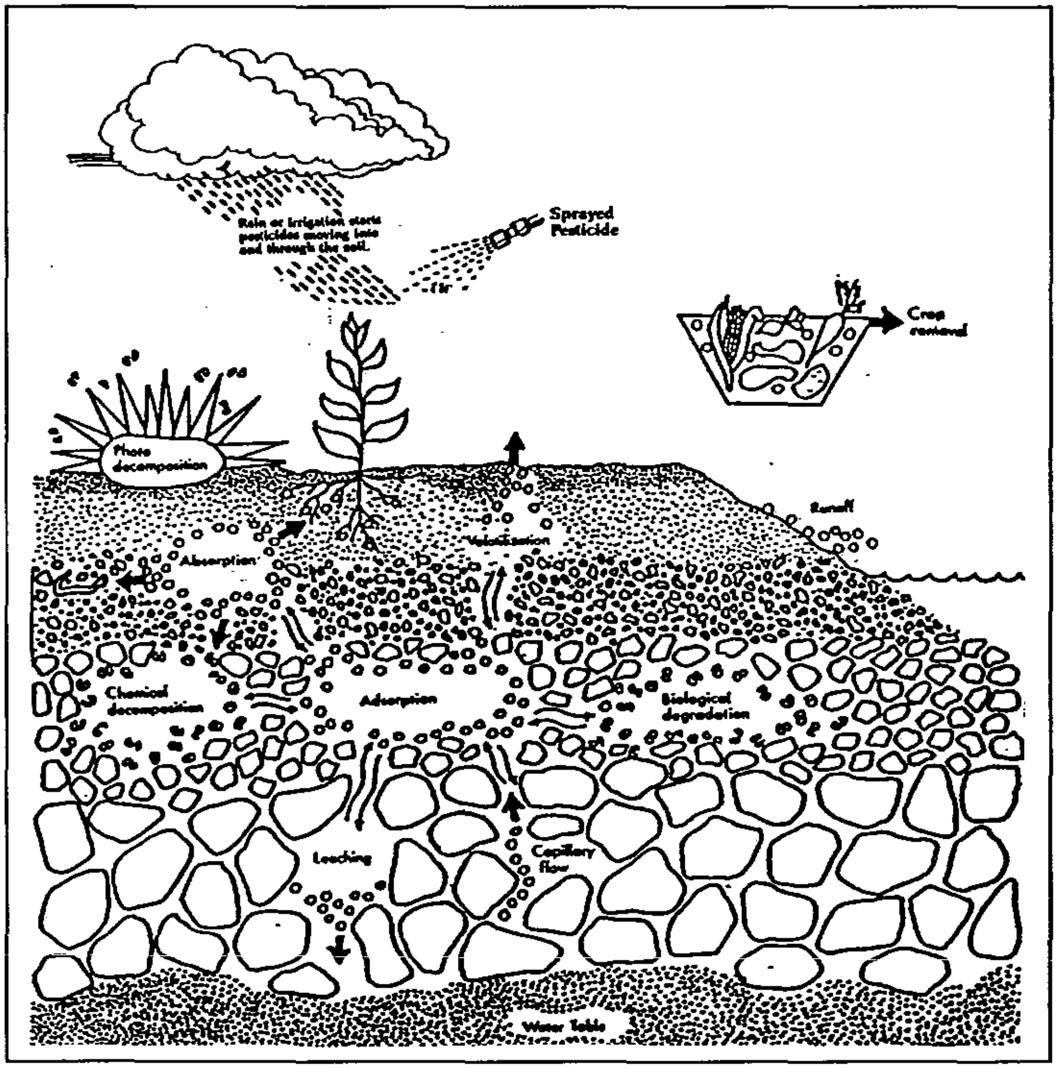


Figure 1. Schematic Representation of Processes Influencing Pesticide Movement.

Source: Adapted from Rao et al. (1983).

Adsorbed compounds are in equilibrium with the soil solution and are capable of desorption (Bonazountas and Wagner, 1981).

An equation commonly used for describing pesticide distribution between the solution phase and the soil phase is

$$K_d = C_s / C_w \qquad (1)$$

where $K_d$ is the partition coefficient of chemical in soil (ml/g soil), $C_s$ is the concentration of the pesticide in the soil or solid phase ($\mu$g/g) and $C_w$ is the concentration of the pesticide in the solution phase ($\mu$g/ml).

The soil partition coefficient, $K_d$, depends on pesticide characteristics and soil organic carbon content, among other factors. Karickhoff (1981) has shown that $K_d$ for a particular organic chemical in a soil divided by the organic-carbon content of that soil is nearly constant for a wide range of soils:

$$K_d = K_{oc} * OC \qquad (2)$$

where $K_{oc}$ (ml/g OC) is the organic partition coefficient and OC the organic carbon content of the soil.

Organic matter content, clay content, bulk density, texture, pH, moisture content and temperature are soil properties that can affect the sorption process and, therefore, the mobility of pesticides in soil.

**Organic Matter and Clay**. Many researchers consider soil organic matter, principally humus, to be the major soil constituent reducing pesticide movement (Walker and Crawford, 1968; Karickhoff et al., 1979; Nkedi-Kizza et al., 1983). Soil organic matter is a complex mixture consisting of humic and nonhumic fractions. The humic fraction is the transformed component of plants, animals and microorganisms, while the nonhumic fraction is the unaltered fraction.

Walker and Crawford (1968) found a high correlation between adsorption and percent of organic carbon content (OC) in 36 different soils. Adsorption is strongly influenced by the ionization of pesticides. Mono-cations and di-cations are strongly adsorbed by negatively charged clay in soil. Organic matter and clay tend to have the highest cation exchange capacity (CEC) in natural soils (Table 2). CEC is usually defined as the number of milliequivalents of ions that can be exchanged per 100 g dry weight of soil. CEC is pH dependent.

The size of soil particles also seems to be important in the adsorption process. Particles with small diameters, such as clay, provide a high surface area for the interaction between soil and pesticide. Organic matter and clay tend to have the highest surface area in soils (Table 2). Clays are especially effective in immobilizing cationic compounds. Weber et al. (1986), working with the herbicide fluridone in 18 soils of different textures and organic matter content, found that adsorption of the herbicide was highly correlated

TABLE 2. Cation Exchange Capacity (CEC) and Surface Area for Different Soil Constituents.

| SOIL CONSTITUENT | CEC (m.e./100g) | SURFACE AREA ($m^2/g$) |
|---|---|---|
| Organic Matter | 200-400 | 500-800 |
| Vermiculite | 100-150 | 600-800 |
| Montmorillonite | 80-150 | 600-800 |
| Illite | 10-40 | 65-100 |
| Kaolinite | 3-5 | 7-30 |

Source: Adapted from Bailey and White, 1970

with montmorillonite clay, but the highest correlation (0.92) was obtained taking into account both organic matter and montmorillonite clay.

**pH**. The increase of adsorption with decreasing pH values is reported for different pesticide and soil interactions (Frissel and Bolt, 1962; Weber et al., 1986; Lemley et al., 1988; Nicholls, 1988). Frissel and Bolt (1962), working with clay minerals, found that the main variables in the adsorption of several organic acidic and basic herbicides were pH and electrolyte concentration of the system. They found that the adsorption of studied compounds increases with increasing electrolyte concentration and with decreasing pH values ranging from 8 to 4. Lemley et al. (1988), working with aldicarb in a sandy loam soil, found that the sorption of the pesticide increased slightly with decreasing pH values ranging from 8 to 5.

**Depth.** Soil organic matter content and the resulting effect on adsorption usually decreases with depth. However, the effect of clay surface on adsorption may become more important with increasing depth (Nicholls, 1988).

Biodegradation is an important process in breaking organic compounds. Microorganisms, principally bacteria and fungi, are the most significant organisms related to biodegradation. Bonazountas and Wagner (1981) reported that pH, temperature, soil oxygen content, soil moisture content and nutrient concentration among other parameters affect biodegradation. Microbiological activity decreases with increasing depth. However, data for estimating degradation rates below the root zone are very scarce (Rao et al., 1985).

### 2.1.2 Pesticide Characteristics

Water solubility (S), vapor pressure ($V_p$), Henry's constant ($K_h$), sorption coefficient ($K_{oc}$) and degradation half-life ($t_{1/2}$) among others are important parameters related to the movement of pesticides in soil. Published data of these parameters are available in the literature (Rao and Davidson, 1980; Karickhoff, 1981; Jury et al., 1984). Table 3 shows chemodynamic properties for different pesticides. Because these parameters are interrelated, the value of one parameter can be estimated using values of the other by theoretical or empirical equations. Lyman et al. (1982) present a compendium of methods for estimating pesticide parameters and other organic pollutants.

Rao et al. (1985), using a simple screening procedure, suggested that pesticides with solubilities larger than 10 mg/l and half-lives exceeding 50 days seem to have the highest potential to contaminate ground water. In the cited research, a total of 41 pesticides were ranked. Some nematicides and herbicides in use were found to have high potential for contaminating ground water. The same authors recommended careful use of such pesticides, especially in ground water recharge areas having permeable sandy soils.

TABLE 3. Chemodynamic Properties for Several Pesticides.

| Pesticide | S (mg/l) | $K_{oc}$ (ml/g) | $K_h$ | $V_p$ (Pa) | $t_{1/2}$ (days) |
|---|---|---|---|---|---|
| Alachlor | 2.42E+02[1] | 1.90E+02 | 1.30E-06 | 2.90E-03 | 7 |
| Aldicarb | 9.00E+03 | 1.00E+01 | 1.00E-04 | 1.30E-02 | 28 |
| Atrazine | 3.20E+01 | 1.60E+02 | 2.50E-07 | 4.00E-05 | 71 |
| Bromacil | 8.20E+02 | 7.20E+01 | 3.70E-08 | 3.30E-05 | 350 |
| Captan | 3.30E+00 | 3.30E+01 | 4.90E-05 | 1.30E-03 | 3 |
| Carbaryl | 4.00E+01 | 2.29E+02 | 1.40E-03 | 6.70E-01 | 22 |
| Carbofuran | 3.20E+02 | 2.80E+01 | 3.10E-07 | 2.70E-03 | 40 |
| Chlordane | 1.00E+00 | 3.80E+04 | 2.20E-04 | 1.30E-03 | 3500 |
| Chorpyrifos | 2.00E+00 | 6.07E+03 | 1.80E-04 | 2.50E-03 | 63 |
| Cyanazine | 1.71E+02 | 1.68E+02 | 1.20E-04 | 2.00E-01 | 108 |
| 2,4-D | 9.00E+02 | 2.00E+01 | 5.60E-09 | 5.30E+01 | 15 |
| DBCP | 1.00E+03 | 7.00E+01 | 1.70E-02 | 1.06E+02 | 180 |
| DDT | 3.00E-03 | 2.40E+01 | 2.00E-03 | 2.50E-05 | 3837 |
| Diazinon | 4.00E+01 | 8.50E+01 | 5.00E-05 | 9.70E-05 | 32 |
| Dieldrin | 1.50E-01 | 1.20E+04 | 6.70E-04 | 4.00E-02 | 868 |
| Disulfoton | 2.50E+01 | 1.60E+03 | 1.10E-04 | 2.40E-02 | 5 |
| Diuron | 3.70E+01 | 3.80E+02 | 5.40E-08 | 4.10E-04 | 328 |
| EDB | 3.40E+03 | 4.40E+01 | 3.50E-02 | 1.50E+03 | 3650 |
| EPTC | 3.70E+02 | 2.80E+02 | 5.90E-04 | 4.50E+00 | 30 |
| Fenamiphos | 7.00E+02 | 1.71E+02 | 2.40E-08 | 1.33E-04 | 10 |
| Fonofos | 1.30E+01 | 6.80E+01 | 2.20E-04 | 2.80E-02 | 60 |
| Heptachlor | 5.60E+02 | 2.40E+04 | 1.45E-01 | 5.30E-02 | 2000 |
| Lindane | 7.50E+02 | 1.30E+03 | 1.30E+04 | 5.60E-03 | 266 |
| Linuron | 8.10E+01 | 8.60E+02 | 2.50E-06 | 2.00E-03 | 75 |
| Malathion | 1.45E+02 | 1.80E+03 | 5.00E-06 | 5.30E-03 | 1 |
| Methyl-Bromide | 1.30E+04 | 2.20E+01 | 1.50E+00 | 5.20E-05 | 55 |
| Methyl-Parathion | 5.70E+01 | 5.10E+03 | 4.40E-06 | 1.30E-03 | 15 |
| Monuron | 2.60E+02 | 1.80E+02 | 7.60E-09 | 6.70E-05 | 166 |
| Napropamide | 7.30E+01 | 3.00E+02 | 7.90E-07 | 5.30E-04 | 70 |
| Oxamyl | 2.80E+05 | 6.00E+00 | 9.90E-09 | 3.10E-02 | 6 |
| Parathion | 2.40E+02 | 1.10E+04 | 6.10E-06 | 5.00E-03 | 18 |
| Phorate | 5.00E+01 | 6.60E+04 | 3.10E-04 | 8.50E-05 | 82 |
| Picloram | 4.20E+02 | 2.60E+01 | 1.90E-08 | 8.20E-05 | 138 |
| Prometryne | 4.80E+01 | 6.10E+02 | 5.60E-07 | 1.30E-04 | 60 |
| Propachlor | 6.10E+02 | 4.20E+02 | 4.40E-06 | 3.10E-02 | 7 |
| Simazine | 5.00E+00 | 1.40E+02 | 3.40E-08 | 8.10E-07 | 75 |
| Terbacil | 7.10E+02 | 4.60E+01 | 8.20E-09 | 6.50E-05 | 50 |
| Triallate | 4.00E+00 | 3.60E+03 | 7.90E-04 | 1.60E-02 | 100 |
| Trifluralin | 3.00E-01 | 7.30E+03 | 6.70E-03 | 1.40E-02 | 132 |

Source: Rao et al. (1985): Adapted from Jury et al. (1984).

[1] $2.42E+02 = 2.42 * 10^2 = 242$

vapor and liquid phases. Equation 4 shows that for non-volatile ($K_h$ = 0) and non-adsorbed pesticides ($K_{oc}$ = 0), the retardation factor is equal to 1. A retardation factor equal to 1 means that the chemical will move without retardation at the same velocity as the water. Pesticides with large values of $K_{oc}$ or $K_h$ have greater RF values and need greater travel times to reach ground water than pesticides with small $K_{oc}$ or $K_h$.

The travel time determines the time available for pesticide degradation via chemical and biological processes. Assuming a constant biological degradation with time and depth, the fraction of surface-applied pesticide reaching ground water can be estimated by

$$RA = \exp(-\ 0.693\ tr\ /\ t_{1/2}) \qquad (5)$$

where RA is the relative amount of pesticide remaining in the soil and tr the total travel time (days). The half-life ($t_{1/2}$) is the length of time (days) required for one-half of the present pesticide concentration to be degraded.

### 2.1.3 Agricultural Practices

Appropriate soil moisture management can decrease the movement of pesticides in soils, allowing microorganisms to increase biological degradation (Mahmood, 1988). Thus, irrigation can influence pesticide movement. Improving irrigation efficiency can reduce the risk of ground-water contamination by pesticides. If deep percolation of water is minimized in irrigated areas, the risk of ground-water contamination by pesticides, fertilizers and other substances dissolved in the water will also be minimized. However, deep percolation water will commonly exist in an irrigated area for two reasons:

1. To leach soluble salts out of the root zone.
2. To provide enough water at those areas of the field that are less permeable or farthest from the source, consequently over-watering the rest of the field (Holden, 1986).

Addition of organic material to soil can increase the sorption capacity of the soil. This effect is particularly important in soils with low organic carbon content, such as sandy soils. Walker and Crawford (1968) reported that the addition of straw to different soils increased adsorption of four herbicides (atrazine, propazine, prometone and prometryne). Very small movement of herbicides was observed when the organic matter content of the soil reached 2.5 percent.

## 2.2 Pesticide Leaching

Water is important for the movement of pesticides. Capillary flow, leaching and runoff are the major types of water movement. Water moves through soils by essentially two processes, mass flow and capillary flow. The downward movement of water through the soil profile occurs mainly through medium to large soil pores. However, fast movement of water can occur through cracks in the root zone or subsoil, permitting dissolved substances to reach ground water in a shorter time.

Downward pesticide movement can be quite significant in some soils. Merkle et al. (1967) found that leaching was an important means of moving herbicide in light soils; the greatest herbicide concentrations generally were found at the deepest sampling depth. Davidson et al. (1968) found that the rate at which fluometuron and diuron (two substituted urea herbicides) move through uniformly packed soil columns depends upon water flux. Nicholls (1988) reported that leaching of pesticides depends on soil properties, characteristics of the pesticide and the weather.

## 2.3 Simulation of Pesticide Movement in Soils

A number of computer simulation models are available for the simulation of pesticide behavior in the root zone (Carsel et al., 1984; Nofziger and Hornsby, 1986, 1988; Grenney et al. 1987). Such models usually require a large number of soil, environmental, crop and pesticide parameters.

Carsel et al. (1984) developed the pesticide root zone model (PRZM) used in USEPA's pesticide regulation programs. The model, using a complex mathematical solution, predicts the pesticide concentration distribution in the soil profile and the pesticide loss below the root zone. PRZM simulates runoff, erosion, plant uptake, foliar washoff, pesticide leaching, decay and volatilization. The model has been tested in different states (New York, Wisconsin, Florida and Georgia). PRZM requires much data and needs a long computer solution time.

For USDA, Leonard et al. (1987) developed a model for ground loading and erosion from agricultural and management systems (GLEAMS). GLEAMS, an extension of the CREAMS model, evaluates effects of agricultural management systems on the movement of agricultural chemicals within and through the plant root zone.

Simple models and indices have been proposed for screening and ranking pesticides in terms of their potential for ground-water contamination (Leistra, 1986; Leonard et al., 1988; Aller et al., 1985; Rao et al., 1985; and Ramzi and Sims, 1986). These models or indices require a less intensive set of data and are useful as screening approaches for assessing the relative potential of various pesticides to leach beyond the crop root zone and contaminate ground water.

Aller et al. (1985) proposed a numerical ranking scheme, DRASTIC. Developed by the National Water Well Association, DRASTIC is a standard system for evaluating the potential for ground-water pollution. DRASTIC includes summing the products of relative ratings and weights of site-specific hydrogeologic factors. These products relate to such major hydrogeologic factors as depth to ground water, net recharge, aquifer media, soil media, topography, impact of the vadose zone and hydraulic conductivity--which form the acronym DRASTIC. The total sum is an index, the DRASTIC index, that shows the relative potential risk that a particular site could have in relation to other locations. The DRASTIC index is used to set priorities for various areas with respect to their vulnerability to ground-water contamination. The DRASTIC index does not include consideration of pesticide characteristics.

# CHAPTER III

# PROCEDURE

## 3.1 Site Identification

Eisele et al. (1989) identified and ranked sites with different potential hazards for ground-water contamination for all 29 counties in the state of Utah. They initially used a rapid screening procedure, DRASTIC (Aller et al., 1985), for ranking places that show a high risk for ground-water contamination by chemicals. Eisele et al. (1989) subsequently used a one-dimensional simulation model, CMLS (Nofziger and Hornsby, 1986, 1988), to simulate the movement of pesticides in unsaturated soils in locations of higher risk.

From the named study, six areas located in different counties were chosen. The selected counties are

- Cache
- Davis
- Sevier
- Utah
- Washington
- Weber

Selected areas have greater risk of significant ground-water contamination than other areas studied by Eisele et al. (1989); however, contamination does not necessarily have to occur in these areas. The potential for contamination depends on agricultural practices, pesticide characteristics and time of application, as well as soil profile characteristics. Thus, necessary data were obtained and computer simulations made for alternative water management practices, pesticides and crops for one location in each of these counties. Results were compared based on potentials for ground-water contamination. The schematic representation of the procedure to estimate the potential existence of pesticides in ground water is shown in Fig. 2. The importance of the estimated parameter values is also summarized.

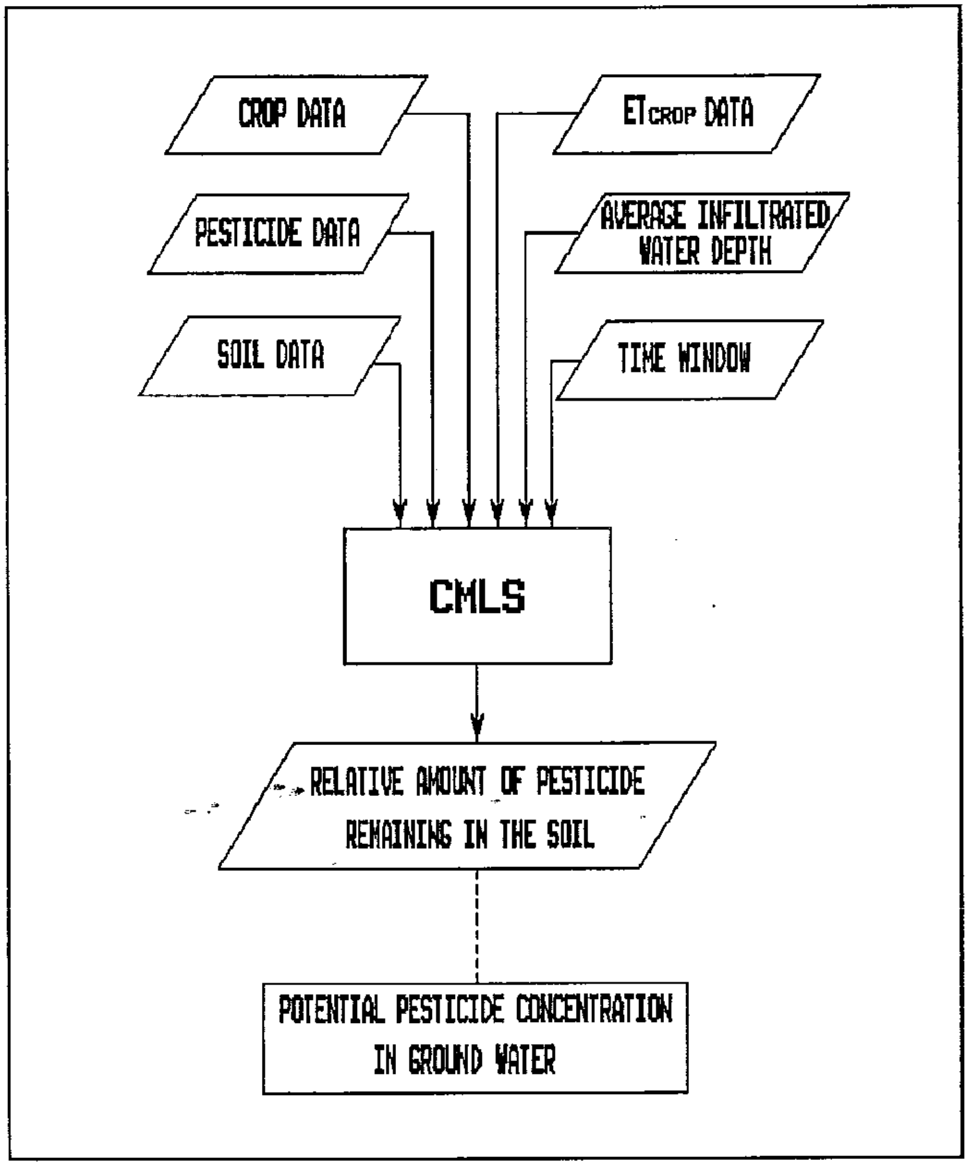


Figure 2. Schematic Representation of the Procedure to Estimate Potential Pesticide Concentration in Ground Water.

### 3.2 Soil Data

Soil characteristics influence adsorption and water movement processes. The presence of organic carbon in the soil profile affects adsorption. Volumetric water content at field capacity and wilting point, and bulk density affect water movement. Generally, soil characteristics vary with the soil layer. Table 4 shows an example of soil data used in this study. A complete listing of bulk density, percent organic carbon values and water retention at field capacity and wilting point for each horizon depth and tested sites is given in Appendix C.

### 3.3 Pesticide Data

Two pesticide descriptors related to pesticide movement and degradation in soil are the organic carbon partition coefficient ($K_{oc}$), used to predict adsorption processes, and the half-life time ($t_{1/2}$), used to calculate degradation processes. Appendix B gives $K_{oc}$, $t_{1/2}$ and Health Advisory Level of all pesticides analyzed in this study. The Health Advisory Level for a particular pesticide is set by USEPA, based on the exposure level that presents a one in a million risk of cancer in the lifetime exposed population. USEPA has not set levels for all pesticides.

Table 5 shows a sample of pesticide data. Pesticide data used in this study are based on Wauchope (1988). Note that other citations might report $K_{oc}$ and $t_{1/2}$ values different than reported by Wauchope for the same pesticide.

TABLE 4. Example of Soil Data.

Soil Name : KIDMAN Identifier : UT0395
Soil Texture: fine sandy loam

| Horizon | Depth (m) | Organic Carbon (%) | Bulk Density (Mg/cu meter) | Volumetric Water Content, (%) at -0.01 MPa | -1.5 MPa |
|---|---|---|---|---|---|
| 1 | 0.28 | 1.20 | 1.52 | 18.0 | 6.4 |
| 2 | 0.43 | 0.70 | 1.52 | 18.5 | 6.4 |
| 3 | 0.53 | 0.80 | 1.53 | 20.0 | 6.9 |
| 4 | 0.69 | 0.40 | 1.54 | 22.0 | 7.0 |
| 5 | 0.94 | 0.20 | 1.40 | 21.5 | 5.3 |
| 6 | 1.24 | 0.20 | 1.45 | 21.5 | 5.7 |
| 7 | 1.47 | 0.10 | 1.42 | 18.0 | 4.4 |

TABLE 5. Example of Pesticide Data.

| Pesticide Library | | Type | Health Advisory Level (ppb) |
|---|---|---|---|
| Common Name | :ALACHLOR | H | 1.5 |
| Partition Coefficient | :170 ml/g OC | | |
| Half-Life | :15 days | | |
| Trade Name | :ALANEX | | |
| Trade Name | :PILLARZO | | |
| Trade Name | :LASSO | | |
| Trade Name | :. | | |

Certain pesticides need to be incorporated (applied below the top layer of the soil) in order to reach their target. Incorporation depth, date and amount of commonly used pesticides in each selected county were obtained from the original survey (Eisele et al., 1989).

### 3.4 Crop data

An important factor related to the movement of pesticides in soils is the rooting system of the crop. Through their roots, crops extract water and pesticide from the soil profile and reduce downward movement of the chemical. Rooting depths depend on many factors. They may be site specific and vary from season to season. However, in this study, rooting depth is treated as a site-independent, constant value. The principal crops in each site were known by survey (Eisele et al., 1989). Table 6 illustrates rooting depths utilized for those crops.

TABLE 6. Rooting Depths of Various Crops Used in this Study

| Crop | Rooting Depth in Meters |
|---|---|
| Alfalfa | 1.50 |
| Corn | 0.90 |
| Small Grains | 1.10 |
| Potatoes | 0.80 |
| Vegetables | 0.60 |
| Orchards | 1.20 |

### 3.5 Evapotranspiration Data

The amount of water used by vegetative growth in respiration and building of plant tissue, together with evaporation from soil and plant surface in a specified time period, is defined as evapotranspiration, or ET (Hill et al., 1983). The potential evapotranspiration of a reference crop, $ET_o$, is the ET of a crop, commonly alfalfa or grass, that fully shades the ground. The reference crop is clipped to specified height and adequately irrigated so that transpiration is not limited by available soil moisture.

Extensive research has been conducted in the field of evapotranspiration, and numerous equations for calculating evapotranspiration are presented in the literature (Doorenbos and Pruitt, 1977; Hill et al., 1983). Hargreaves and Samani (1985) developed an approach that requires only data on minimum and maximum temperature and information on the latitude of the location.

The Hargreaves-Samani equation for daily $ET_o$ calculations is

$$ET_o = 0.0023 * Ra * TD^{0.5} * (TC + 17.8) \tag{6}$$

where $ET_o$ is the reference ET of well-watered grass (mm/day), Ra is the extraterrestrial radiation (mm/day), TD is the temperature difference $T_{max} - T_{min}$ (°C) and TC is average daily temperature (°C). In solving the above expression, extraterrestrial radiation can be found as a function of latitude. The same authors conclude:

> Considering the problems associated with the availability and reliability of climatological data in the world and possible errors in the more sophisticated methods for estimating crop water requirements, the temperature method herein presented is recommended as the most simple and practical method for estimating reference crop evapotranspiration. (p. 98)

**$ET_{crop}$ Data**. The Hargreaves-Samani equation was used to estimate daily $ET_o$ values for three zones of roughly uniform climate in Utah. Table 7 gives an overview of zones, counties and representative weather stations of this study. A weather station was selected in each zone and it was assumed that this station provides representative data for the entire zone.

Table 7. Zone, County and Weather Station Assignments.

| Zone | County | Weather Station |
|---|---|---|
| North Central | Cache<br>Davis<br>Utah<br>Weber | Ogden Sugar Factory |
| South Central | Sevier | Richfield Radio KSVC |
| Dixie | Washington | St. George |

The evapotranspiration of a crop, $ET_{crop}$ was estimated by

$$ET_{crop} = K_c * ET_o \tag{7}$$

where $ET_{crop}$ is the evapotranspiration of a given crop (mm/day) and $K_c$ is a Crop coefficient.

Hill et al. (1987) calculated $K_c$ values for the Bear River drainage basin in Utah, Wyoming and Idaho. Based on their results, the $K_c$ values indicated in Table 8 were used throughout the entire study areas. The application of $K_c$ values developed for northern Utah to zones in southern Utah can be questionable; however, to our knowledge, the data in Table 8 was the best available. Seasonal $ET_{crop}$ values for each crop are given in Appendix E.

TABLE 8. Crop Coefficients.

| Crop | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alfalfa | 0.00 | 0.00 | 0.27 | 0.60 | 1.03 | 1.03 | 0.83 | 0.89 | 0.92 | 0.36 | 0.00 | 0.00 |
| Small Grains | 0.00 | 0.00 | 0.27 | 0.66 | 1.19 | 1.20 | 0.40 | 0.12 | 0.12 | 0.12 | 0.00 | 0.00 |
| Corn | 0.00 | 0.00 | 0.18 | 0.25 | 0.24 | 0.43 | 0.95 | 1.12 | 0.71 | 0.30 | 0.00 | 0.00 |
| Vegetables | 0.00 | 0.00 | 0.18 | 0.25 | 0.26 | 0.79 | 1.14 | 1.09 | 0.60 | 0.12 | 0.00 | 0.00 |
| Potatoes | 0.00 | 0.00 | 0.18 | 0.25 | 0.24 | 0.69 | 0.88 | 0.81 | 0.40 | 0.24 | 0.00 | 0.00 |
| Orchards | 0.00 | 0.00 | 0.25 | 0.37 | 0.71 | 0.97 | 1.02 | 1.08 | 0.97 | 0.87 | 0.00 | 0.00 |

Source : Adapted from Hill et al. (1987)

### 3.6 Average Infiltrated Water Depth

**Water-Storage Efficiency**. Irrigation plays an important role in Utah's agriculture. Part of the irrigation water is lost to deep percolation and can contribute significantly to pesticide movement. Deep percolation and surface runoff loss are included in the on-farm application efficiency values, which may be defined for a single irrigation event as

$$E_a = V_s / V_a \tag{8}$$

where $E_a$ is on-farm application efficiency, $V_s$ is the total depth stored in root zone (mm) and $V_a$ is the total depth applied (infiltration + runoff). Water-storage efficiency, used in this work, can be defined by

$$E_s = V_s / V_i \tag{9}$$

where $E_s$ is water-storage efficiency, $V_s$ is the total depth of water stored in root zone (mm) and $V_i$ is the total depth of water infiltrated into the soil (mm). $E_s$ tends to have higher values than $E_a$ because the runoff component is not considered in $E_s$.

Reduction in potential pesticide contamination can be achieved by efficient application of water. Efficiency, in turn, can be improved in different ways. Increased efficiency can be obtained by adequate land leveling (especially important in surface irrigation systems), by changing furrow inflow rates or furrow lengths and by changing to more sophisticated irrigation systems. Efficient control of time of irrigation and adequate scheduling will increase efficiency in most of irrigation systems.

**Surface Irrigation**. Even though surface irrigation is the oldest and most common method of irrigation, this method is least likely to provide consistently high levels of performance. Fig. 3 shows the relation between required water application and actual moisture distribution for different irrigation regimes (Walker and Skogerboe, 1987).

Inefficiency is frequently the result of variability in soil infiltration rates and other factors. The rate at which water will be absorbed through the soil surface is a nonlinear process that varies both temporally and spatially and commonly is described by empirical equations.

The Kostiakov-Lewis equation, one such expression, is

$$Z = k\,\tau^{a} + f_0\,\tau \qquad (10)$$

where Z is the accumulated infiltrated depth per meter of furrow length ($m^3/m$), $\tau$ is the infiltration opportunity time (min), $f_0$ is the basic intake rate ($m^3/m$ min) and k ($m^3/m$ $min^a$) and a are empirical fitting parameters.

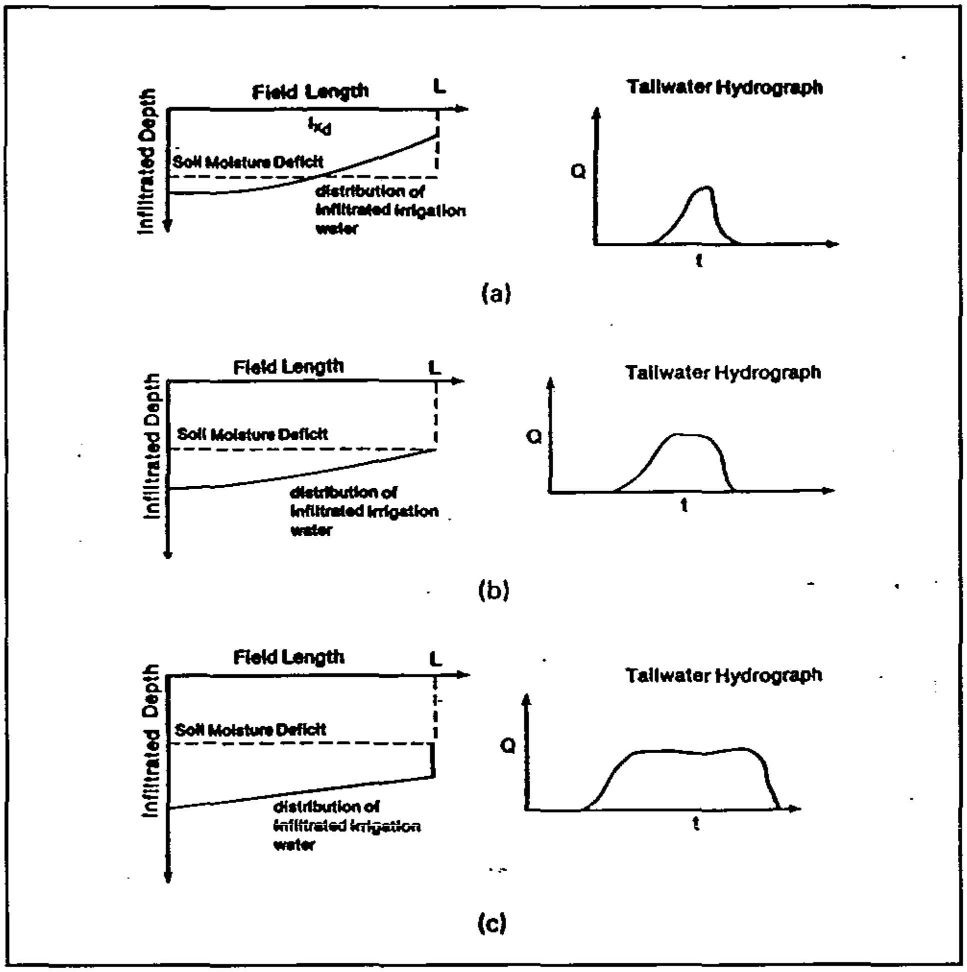


Figure 3. Relation Between Required Water Application and Actual Moisture Distribution for Three Typical Irrigation Regimes.

a. Under-irrigation.
b. Complete-irrigation.
c. Over-irrigation.

Source: Walker and Skogerboe, 1987

Walker and Humpherys (1983) developed a kinematic-wave model for simulating furrow irrigation under continuous and surge flow conditions. The kinematic-wave model solves the continuity equation utilizing a numerical procedure. The accuracy of the model was demonstrated with data of relatively wide range of field and soil conditions taken from different states (Elliott and Walker, 1982).

In the current study, the kinematic-wave model (Walker and Humpherys, 1983) was used to estimate the average quantity of water infiltrated in a soil profile along the length of furrows for different inlet discharges (1, 1.25, 1.5, 1.75, 2 and 2.5 l/s) and furrow lengths (80, 100 and 125 m). Two furrow slopes (0.006 and 0.002 m/m) were assumed. These limits of soil slopes were assumed to avoid soil erosion and to ensure applicability of the kinematic-wave model, respectively. A Kostiakov-Lewis infiltration function for an average sandy soil was assumed because all six selected soils have sandy characteristics. The required application depth, $Z_{req}$, at the end of the furrow was assumed 0.045 $m^3/m$ (45 mm) for all simulations. By using this assumption (rather than by preparing detailed values for crop and soil characteristics of each of the six sites), the number of simulations (using both kinematic-wave and CMLS models) could be drastically reduced. Input and output data of these simulations are shown on Table 9. Figs. 4 and 5 graphically represent water-storage efficiency ($Z_{req}$ / $d_{ave}$) versus furrow length.

TABLE 9. Furrow Simulation Data.

| Slope m/m | Length m | $Q_{in}$ l/s | $d_{ave}$ mm | $d_{max}$ mm | $d_{min}$ mm | $d_{run}$ mm | $T_{co}$ min |
|---|---|---|---|---|---|---|---|
| 0.006 | 80 | 1.00 | 132 | 152 | 49 | 2 | 178 |
| 0.006 | 80 | 1.25 | 87 | 97 | 49 | 4 | 97 |
| 0.006 | 80 | 1.50 | 71 | 76 | 50 | 8 | 70 |
| 0.006 | 80 | 1.75 | 63 | 67 | 53 | 12 | 57 |
| 0.006 | 100 | 1.00 | 254 | 295 | 52 | 1 | 424 |
| 0.006 | 100 | 1.25 | 134 | 154 | 53 | 2 | 181 |
| 0.006 | 100 | 1.50 | 95 | 105 | 53 | 4 | 109 |
| 0.006 | 100 | 1.75 | 77 | 83 | 52 | 6 | 79 |
| 0.006 | 125 | 1.00 | 654 | 755 | 53 | 0 | 1363 |
| 0.006 | 125 | 1.25 | 256 | 297 | 53 | 1 | 428 |
| 0.006 | 125 | 1.50 | 148 | 171 | 52 | 1 | 207 |
| 0.006 | 125 | 1.75 | 106 | 120 | 52 | 3 | 130 |
| 0.002 | 80 | 1.25 | 89 | 99 | 49 | 4 | 99 |
| 0.002 | 80 | 1.50 | 74 | 79 | 53 | 8 | 72 |
| 0.002 | 80 | 2.00 | 55 | 57 | 47 | 13 | 45 |
| 0.002 | 80 | 2.50 | 49 | 49 | 45 | 19 | 36 |
| 0.002 | 100 | 1.25 | 138 | 157 | 53 | 2 | 187 |
| 0.002 | 100 | 1.50 | 99 | 110 | 54 | 4 | 114 |
| 0.002 | 100 | 2.00 | 68 | 72 | 49 | 8 | 63 |
| 0.002 | 100 | 2.50 | 58 | 59 | 48 | 14 | 48 |
| 0.002 | 125 | 1.25 | 259 | 302 | 55 | 1 | 433 |
| 0.002 | 125 | 1.50 | 154 | 176 | 56 | 2 | 216 |
| 0.002 | 125 | 2.00 | 90 | 99 | 54 | 5 | 99 |
| 0.002 | 125 | 2.50 | 73 | 76 | 54 | 10 | 69 |

Common input data for all the simulations are:

$Z_{req}$ = 0.045 $m^3/m$
k = 0.00361 $m^3/m\ min^a$
a = 0.642
$f_0$ = 0.00028 $m^3/m$ min

---

Abbreviations: $Q_{in}$ = flow discharge at the furrow head; $d_{ave}$ = average infiltrated depth; $d_{max}$ = maximum infiltrated depth; $d_{min}$ = minimum depth; $d_{run}$ = runoff volume / furrow area $T_{co}$ = time of cutoff.

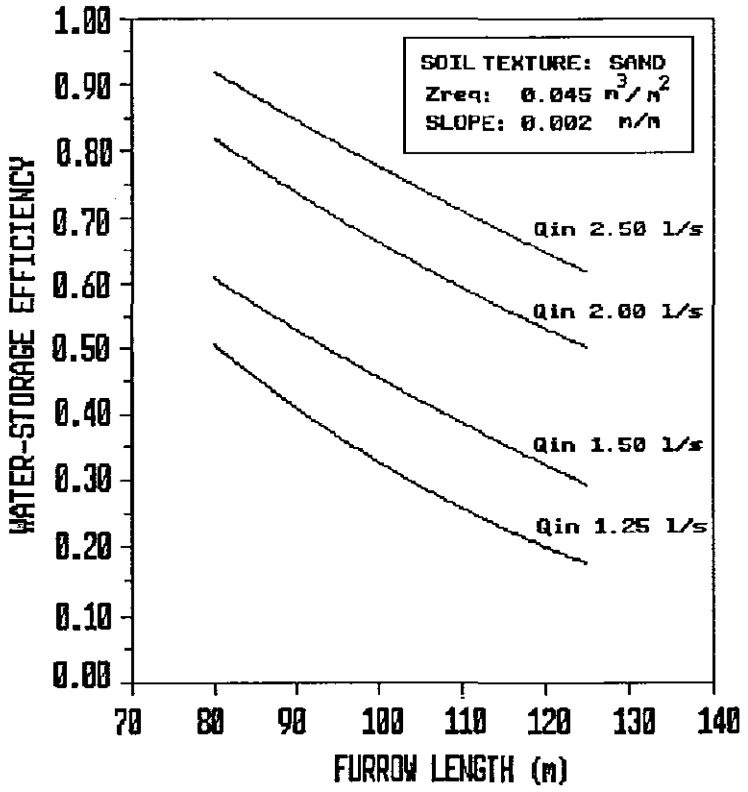


Figure 4. Effect of Various Furrow Inflow Rates and Furrow Lengths on Storage Efficiency (furrow slope = 0.002 m/m).

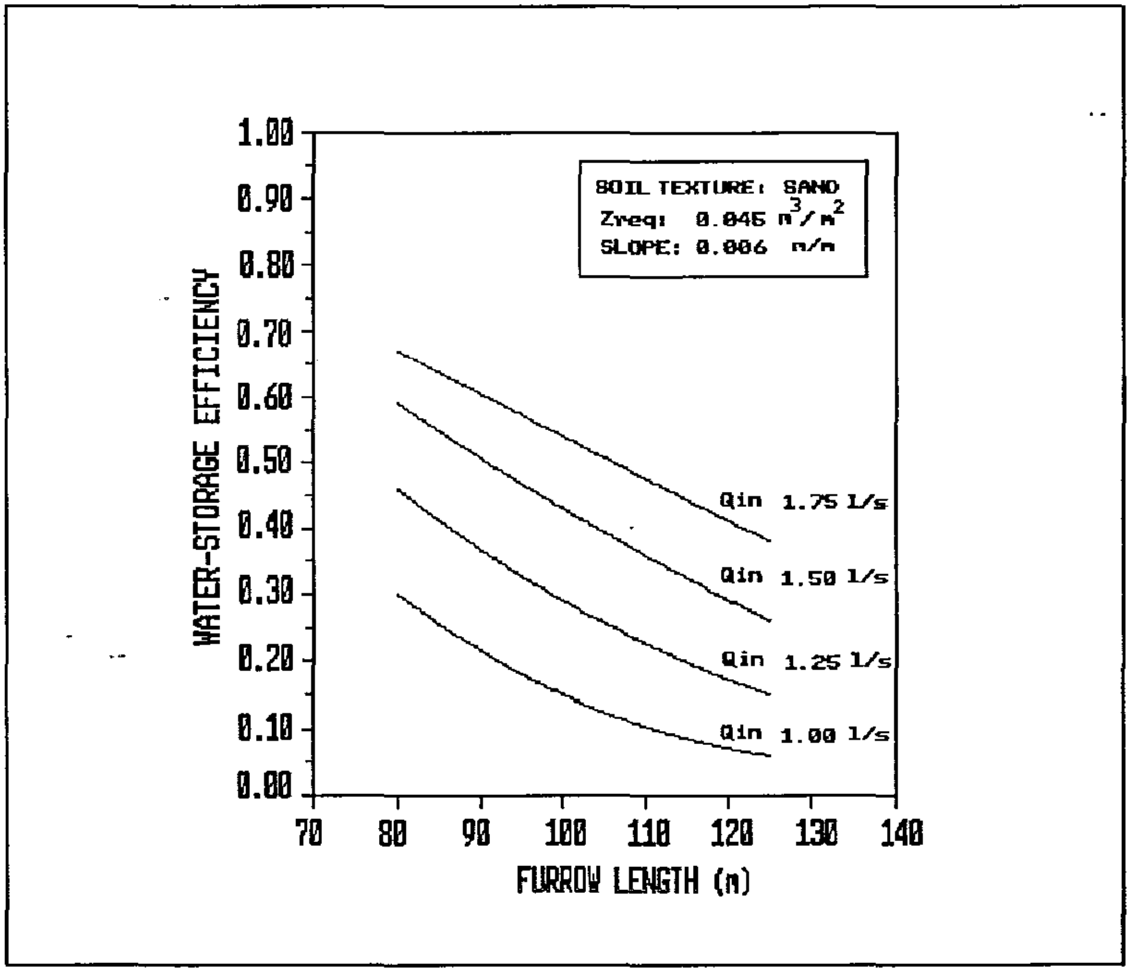


Figure 5. Effect of Various Furrow Inflow Rates and Furrow Lengths on Storage Efficiency (furrow slope = 0.006 m/m).

Dates for irrigation were estimated using a daily soil moisture balance approach (irrigation + rainfall - ETcrop - deep percolation), assuming soil at field capacity at the beginning of the irrigation schedule. Depth of water application was the same for each irrigation, although intervals between irrigation varied depending on ET.

The average depths estimated via the kinematic-wave model were then used as input to the CMLS model. Computer programs were created to automatically prepare the input files.

**Sprinkler Irrigation**. Sprinkler irrigation is an alternative to surface irrigation. This technique can be used on land of irregular topography that is difficult to irrigate by surface methods. Sprinklers are specially adapted to shallow, coarse-textured and highly permeable soils of low available water capacity that require frequent and light applications. However, sprinkler systems generally cost more than surface irrigation methods (Hansen et al., 1980).

Application efficiencies are generally higher for sprinkler systems than for surface systems. However, the uniformity of distribution of water from sprinkler systems varies greatly, depending upon pressure, wind, rotation of sprinkler, spacing and many others factors. One common method of describing the distribution of water uses Christiansen's uniformity coefficient (UC)

$$UC = 100 * (1.0 - \Sigma X / nm) \tag{11}$$

or

$$UC = 100 * (1.0 - \Sigma|z-m| / \Sigma z) \tag{12}$$

where UC is Christiansen uniformity coefficient (%), z is the individual depth of catch observation from uniformity test (mm), X is the absolute deviation of the individual observation from the mean (mm), m is the mean depth of observations (mm) and n is the number of observations.

Hart and Reynolds (1965), assuming that the distribution of values in an overlapped sprinkler pattern approximates the normal distribution, proposed a method for estimating the distribution of water on a specified area. They relate to the UC, the distribution coefficient ($H_a$) or fraction of the mean application that exceeds or equals the mean application over a specific area. Table 10 gives UC and $H_a$ values for distributions with a mean application of one. As an example, if a sprinkler system has an UC of 84 percent and a mean application depth of 45 mm, 80 percent of the area has an infiltrated depth of 37.39 mm (45 * 0.831 = 37.39) or more (Fig. 6). If the mean application is 54.15 (45 / 0.831) for the same UC, then 80 percent of the area has an infiltrated depth of 45 mm or more.

Table 10. Distribution Coefficient ($H_a$) Values Based on a Normal Distribution.

| | Fraction of Area Adequately Irrigated (%) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UC (%) | 99.9 | 95 | 90 | 85 | 80 | 75 | 70 | 65 | 60 | 55 | 50 |
| 96 | 0.845 | 0.917 | 0.936 | 0.948 | 0.958 | 0.966 | 0.974 | 0.981 | 0.987 | 0.994 | 1.000 |
| 92 | 0.690 | 0.835 | 0.871 | 0.869 | 0.915 | 0.932 | 0.947 | 0.961 | 0.975 | 0.987 | 1.000 |
| 88 | 0.535 | 0.753 | 0.807 | 0.844 | 0.873 | 0.899 | 0.921 | 0.942 | 0.962 | 0.981 | 1.000 |
| 84 | 0.380 | 0.670 | 0.743 | 0.792 | 0.831 | 0.865 | 0.895 | 0.923 | 0.949 | 0.975 | 1.000 |
| 80 | 0.225 | 0.588 | 0.670 | 0.740 | 0.789 | 0.831 | 0.860 | 0.903 | 0.937 | 0.968 | 1.000 |
| 76 | 0.071 | 0.505 | 0.614 | 0.688 | 0.747 | 0.797 | 0.842 | 0.884 | 0.924 | 0.969 | 1.000 |
| 72 | | 0.423 | 0.550 | 0.636 | 0.704 | 0.763 | 0.816 | 0.865 | 0.911 | 0.956 | 1.000 |
| 68 | | 0.340 | 0.486 | 0.535 | 0.662 | 0.730 | 0.790 | 0.845 | 0.899 | 0.949 | 1.000 |
| 64 | | 0.258 | 0.421 | 0.533 | 0.620 | 0.696 | 0.763 | 0.826 | 0.886 | 0.943 | 1.000 |
| 60 | | | 0.357 | 0.401 | 0.578 | 0.662 | 0.737 | 0.807 | 0.873 | 0.937 | 1.000 |

Source: Adapted from Hart and Reynolds, 1965

In this study, $H_a$ values were used to estimate average depth of water infiltrated in the soil profile, assuming 80 percent of area adequately irrigated and UC values of 60, 72 and 84 percent. The following equation was used to estimate average infiltrated depth

$$V_i = Z_{req} / H_a \tag{13}$$

where $V_i$ is the depth of water infiltrated into the soil (mm), $Z_{req}$ is the required depth of application at the irrigation date (mm) and $H_a$ is the distribution coefficient.

Values of average infiltrated depths of water in the soil for different uniformity coefficients were incorporated in irrigation schedules, as was done in surface irrigation systems.

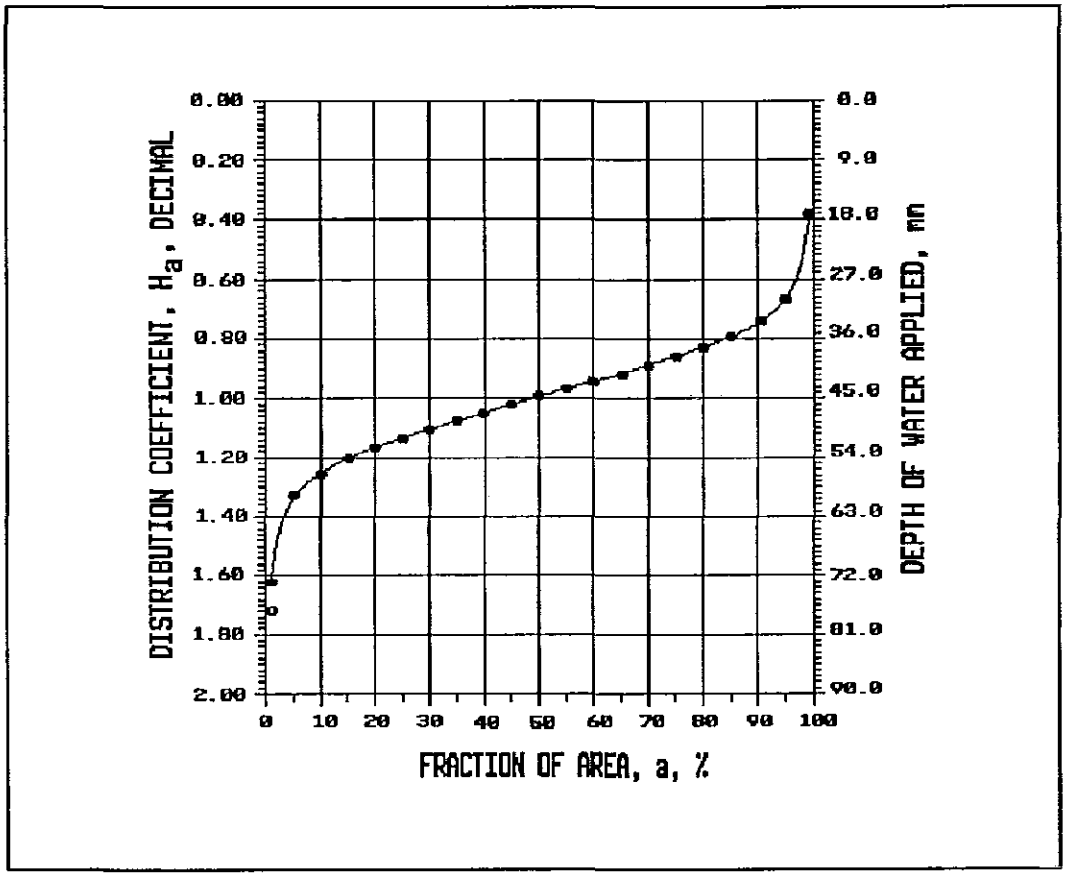


Figure 6. Relation Between Fraction of Area Adequately Irrigated and $H_a$ for a UC of 84%.

Source: Adapted from Hart and Reynolds (1965).

## 3.8 CMLS MODEL

The CMLS model was considered the most appropriate pesticide transport model for this study in terms of accuracy, simulation time, input data requirements and output data presentation (Eisele et al., 1989). A comparison of CMLS with data observed and simulated by Smith et al. (1989) is given in Appendix G. Pesticide movement predictions given by the CMLS model are based on the following assumptions (Nofziger and Hornsby, 1986, 1988):

1. All soil water residing in pore spaces participates in the transportation process. If this assumption is not valid and a preferential flow is present, a portion of the soil water will be bypassed during flow, and the model will underestimate the depth of the chemical front. An example of this aspect is shown in Appendix G.
2. Water entering the soil redistributes instantaneously to field capacity. This assumption is approached for coarse-textured soils.
3. Water is removed by evapotranspiration from each layer in the root zone in proportion to the relative amount of water available in that layer. A uniform root distribution is assumed. This assumption will not be strictly valid for many situations. More precise schemes for dealing with evapotranspiration would require information about the root distribution and the soil hydraulic properties.
4. Upward movement of soil water does not occur anywhere in the soil profile. Water is lost from the root zone by evapotranspiration and is not replenished from below.
5. The adsorption process can be described by a linear, reversible equilibrium model. If the sorption coefficient is described by non-linear isotherm, the partition coefficient decreases with increasing concentration of the chemical. Thus the depth to which the chemical will be leached will depend upon the concentration. This aspect is probably not

significant for the concentration range of interest in most agricultural applications. When adsorption equilibrium is not instantaneous, the chemical will be leached to a greater depth than predicted here. Irreversible sorption would result in less leaching.

6. The half-life time for biological degradation of the chemical is constant with time and soil depth. Degradation rate coefficients are dependent upon a variety of environmental factors, primarily temperature and soil-water content. Hence, seasonal changes in rate coefficients can be expected. Also, with decreasing microbial activity at greater soil depths, the degradation rate coefficient may decrease with depth. Sufficient data are not available to formulate mathematical relationships to describe these effects.

CMLS considers two processes: (a) the movement of the chemical and (b) the degradation of the chemical. In this model, chemicals move only in the liquid phase in response to soil-water movement. Water movement is calculated using a volume balance approach. It is assumed that at the beginning of the simulation, each layer in the soil profile is at field capacity. Water is considered available for plants if the water content in any layer of the root zone is above permanent wilting point as expressed by the following relationship

$$AW(j) = t(j) * [(\theta(j) - \theta_{pwp}(j)] \tag{14}$$

where AW(j) is the available water in the layer j (mm), t(j) is the thickness of the layer j (mm), $\theta(j)$ is the volumetric water content of layer j and $\theta_{pwp}(j)$ is the volumetric water content at permanent wilting point of layer j. The total available water, $AW_{total}$, in the root zone is the sum of the amounts of water available in each layer. If $AW_{total}$ is greater than the evapotranspiration ($ET_{crop}$) for a day, the water content of each layer in the root zone is depleted in proportion to the amount of water available in that layer as expressed by the following equation

$$\theta(j) = \theta'(j) - [ET_{crop} * AW(j)] / [AW_{total} * t(j)] \qquad (15)$$

where $\theta'(j)$ is the volumetric water content of the layer j prior to adjustment. If the total available water is less than the evapotranspiration demand all the layers in the root zone are assumed equal to

$$\theta(j) = \theta_{pwp}(j) \qquad (16)$$

Equation 16 assumes no effect of soil water content on ET when the volumetric water content of the soil is approaching wilting point. However, ET will decrease due to stress long before $\theta_{pwp}$ is reached.

When an infiltration event occurs, the water content of each layer is adjusted, starting with the layer closest to the surface (j=1). The soil-water deficit for that layer is determined using the equation

$$swd(j) = t(j) * [\theta_{fc}(j) - \theta(j)] \qquad (17)$$

where swd(j) is the soil-water deficit of the layer j (mm) and $\theta_{fc}(j)$ is the volumetric water content of the layer j at field capacity. If the infiltrating amount, I(j), is greater than swd(j), then

$$\theta(j) = \theta_{fc}(j) \tag{18}$$

$$I(j + 1) = I(j) - swd(j) \tag{19}$$

If I(j) is less than swd(j), then

$$\theta(j) = \theta'(j) + I(j) / t(j) \tag{20}$$

$$I(j + 1) = 0 \tag{21}$$

Chemicals are exposed to adsorption processes and therefore advance less far in depth than water. A linear and reversible equilibrium adsorption model simulates the retardation of the chemical movement.

The following equations are used to predict chemical movement

$$\text{if } W_p > 0, \qquad d_s - d'_s = W_p / (RF * \theta_{fc}) \tag{22}$$

$$\text{if } W_p \leq 0, \qquad d_s - d'_s = 0 \tag{23}$$

$$RF = 1 + BD * K_d / \theta_{fc} \tag{24}$$

$$K_d = K_{oc} * OC \tag{25}$$

where $W_p$ is the amount of water passing the depth $d_s$ (mm), $d_s$

is solute front depth (mm), $d'_s$ is the solute front depth prior to the adjustment (mm), RF is the retardation factor, $\theta_{fc}$ is the soil-water content on a volume basis at field capacity, BD is soil bulk density (g/cm$^3$), $K_d$ is the partition coefficient of the chemical in soil (ml/g soil), $K_{oc}$ is the organic carbon partition coefficient (ml/g OC) and OC is the organic carbon content of the soil (OC fraction).

Chemicals are exposed to degradation processes. The model predicts the fraction RA of the applied chemical remaining in the entire soil profile as

$$RA = \exp[-tr * \ln (2) / t_{1/2}] \qquad (26)$$

where tr is the travel time since the chemical was applied (days) and $t_{1/2}$ is the biological degradation half-life of the chemical (days).

**Relative Amount Remaining in the Soil**. The inputs to the CMLS model are soil properties (bulk density, water content at field capacity and permanent wilting point and soil organic carbon content); chemical properties of the pesticide (partition coefficient and degradation half-life); climatic and cultural factors (plant root depth, daily rainfall + irrigation and daily evapotranspiration amounts).

Model outputs include, among others, travel times for chemicals to move to selected depths and relative amount of pesticide remaining in the soil profile at those times. A sample analysis is demonstrated for the herbicide atrazine applied in April to corn on Vineyard sandy loam soil. Using data from Table 11 and the pesticide library (Appendix B), the relative amount remaining in the soil profile when the chemical front arrives at 2 m can be calculated by

$$RA = \exp\,[-\ tr * \ln 2\ /\ t_{1/2}]$$

$$= \exp\,[-\ 412\ \text{days} * 0.6931\ /\ 60\ \text{days}] = 0.0086$$

TABLE 11. Example of Pesticide Movement to Selected Depths.

| Chemical | ATRAZINE |
|---|---|
| Partition Coefficient, Koc, (ml/g OC) | 100 |
| Application date, (month/day/year) | 4/4/1980 |
| Ending date, (month/day/year) | 12/31/85 |
| Pesticide application depth, (m) | 0.00 |
| Rooting depth for corn, (m) | 0.90 |
| Time (days) to 1.00 m | 119 |
| Relative Amount Remaining | 0.2529 |
| Time (days) to 1.50 m | 164 |
| Relative Amount Remaining | 0.1504 |
| Time (days) to 2.00 m | 412 |
| Relative Amount Remaining | 0.0086 |
| Time (days) to 3.00 m | 467 |
| Relative Amount Remaining | 0.0045 |

## 3.9 Potential Pesticide Concentration in Ground Water

The amount of pesticide remaining in the soil profile when the pesticide front arrives at a 2-m depth is calculated as the relative amount remaining in the soil profile times the amount of pesticide applied. The amount of pesticide in the soil is subsequently converted into a hypothetical pesticide concentration by assuming a mixing water volume of 500 l. The resulting concentrations are divided by the Health Advisory Level to yield a ratio. The higher the ratio, the more hazardous is the pesticide. The calculated values of pesticide concentration generally overestimate possible pesticide concentrations in ground water because such calculations do not consider the degradation and dilution of pesticide in ground water with time. Thus, a ratio greater than one does not necessarily mean that a hazardous situation exists. However, a pesticide having a high ratio is more hazardous than one having a low ratio.

### 3.10 Pesticide Simulations

Simulations were performed to compare alternative water management practices, pesticides and irrigation systems. Simulations were performed for the following:

- Fifty-six pesticides commonly used in Utah were compared based on RA values. Considered were crop and pesticide combinations.
- Potential pesticide contamination from furrow irrigation systems were compared. Considered were 3 furrow lengths, 6 inlet discharges, 2 slopes, 41 pesticides, 6 crops and 6 soils.
- Potential pesticide contamination from sprinkler irrigation systems were compared. Considered were 3 Christiansen uniformity coefficients, 41 pesticides, 6 crops and 6 soils.
- Soil characteristics and average infiltrated water depth using furrow and sprinkler irrigation were treated as variables for sensitivity analyses.

A summary of the output results for the different case studies is given in Appendices A and F.

# CHAPTER IV

# RESULTS AND DISCUSSION

## 4.1 Management Practices to Reduce Potential Ground-Water Contamination

The use of pesticides is considered necessary for economically successful agricultural systems; however there is increasing concern about unacceptable environmental pollution by pesticides. To prevent this, best-management systems (BMSs) are being developed. By retaining pesticides in their target site as much as possible, BMSs will accomplish both pest control and water quality goals. To illustrate differences of pesticide movement, alternative pesticides, application dates, water management practices and irrigation systems were compared.

### 4.1.1 Alternative Pesticides.

Frequently, several pesticides can be used to control the same problem. Use of less toxic, less mobile, less persistent and more selective pesticides to meet pest control objectives is important for reducing undesired environmental impact.

Pesticides may only be legally applied to sites of crops or animals that are listed on the label. Site restrictions that relate to protecting ground water from potential contamination by pesticides are present on some labels and will probably appear on many more during the next few years.

Some pesticides, such as the herbicides cyanazine and picloram, are classified by the USEPA as restricted-use pesticides because of their potential to contaminate surface and/or ground water. For the same reason, more pesticides will probably be classified as restricted-use pesticides during the next few years.

When growers consider the potential for ground-water contamination of alternative pesticides, they need information on each potential choice. This information should include the pesticide's leachability, persistence and adsorptivity to soil particles. Often this information is not readily available to growers and at this time does not have to be included on the pesticide's label. Even if this information were available, growers might have difficulty in interpreting the information or in comparing the information of one pesticide with that of another.

This study, utilizing available information, compared 56 pesticides commonly used in six crops in the State of Utah. Figs. 7-10 display in bar graph form the relative comparison of registered pesticides for specific crops and types of pesticide in Utah County. These bar graphs compare the relative amount of pesticide remaining in the soil (RA) when it has reached a depth of 1 m. One-meter depth was chosen because differences in RA values among pesticides are significant at this depth. All other variables such as time since application, climate, soil characteristics and irrigation, among others, were constant for the compared simulations.

The bar graphs provide a rapid and easy visual comparison between registered alternatives and do not require in-depth analysis or examination. Fig. 7 shows a notable difference in RA for alfalfa herbicides. Terbacil and hexazinone have the greatest potential for being detected at a depth of 1 m when compared to other alfalfa herbicides, with other conditions being constant. Both of these herbicides are more mobile than the other alternatives and, thus, have the greatest potential for ground-water contamination when used on alfalfa at the tested location in Utah County. The difference in mobility shown in these graphs is principally based on the organic partition coefficient and the degradation. Pesticides with organic partition coefficients smaller than 200 ml/g and degradation half-lives equal or greater than 10 days show the biggest RA values for the case study, offering more risk for potential ground-water contamination.

Similar easy and obvious comparisons can be made from other figures or simulation results for other counties (Appendix F). This can help growers in selecting pesticides based on ground-water contamination potential.

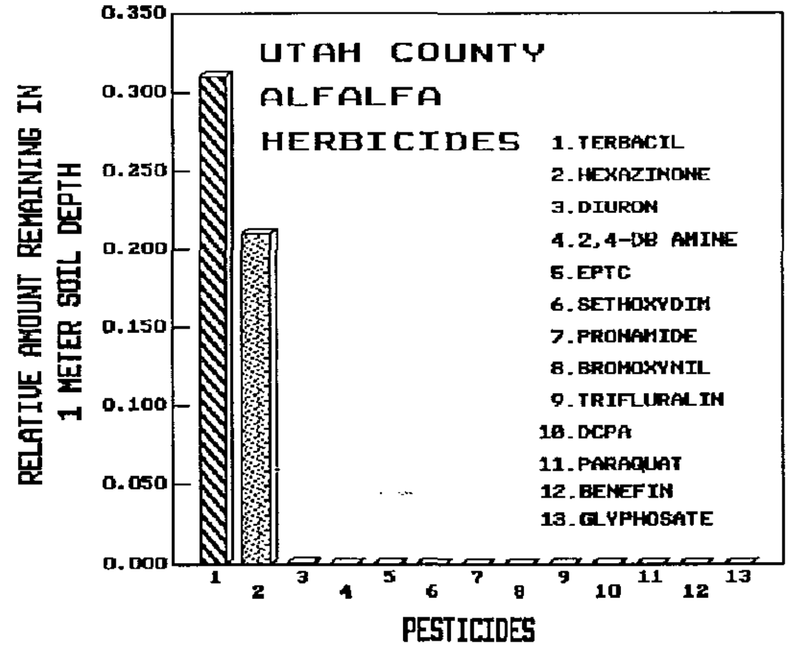


Figure 7. Alternative Alfalfa Herbicides and Their Relative Amounts Remaining in the Soil When Pesticides Reach a Depth of 1 m in Utah County.

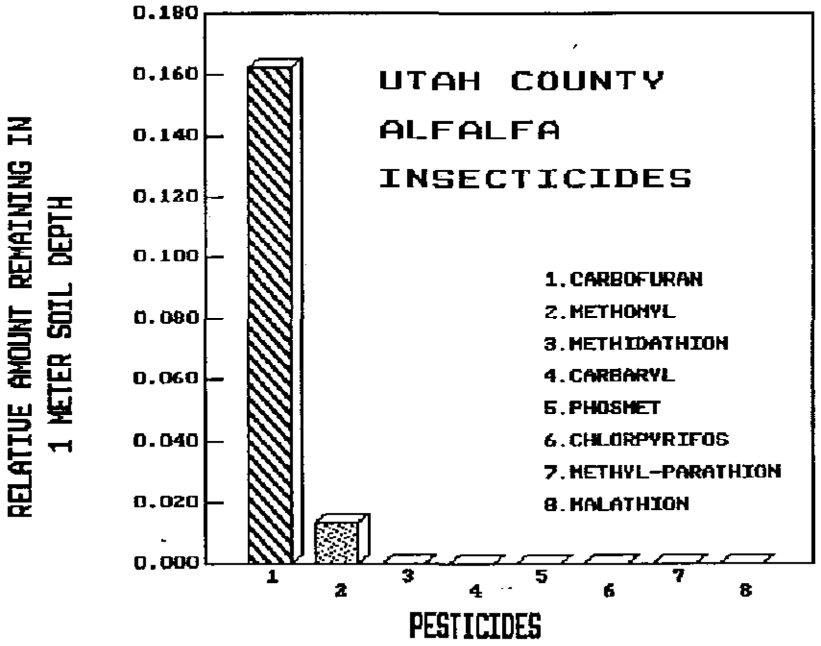


Figure 8. Alternative Alfalfa Insecticides and Their Relative Amounts Remaining in the Soil When Pesticides Reach a Depth of 1 m in Utah County.

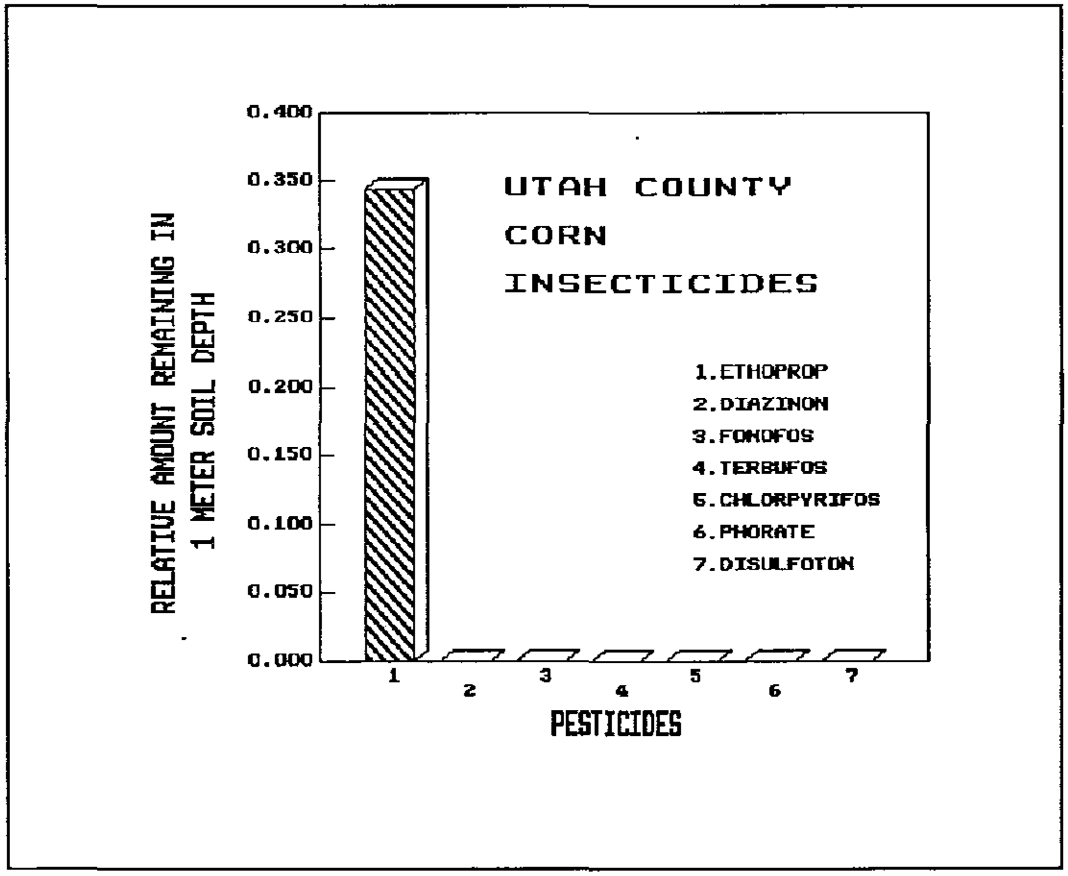


Figure 9. Alternative Corn Insecticides and Their Relative Amounts Remaining in the Soil When Pesticides Reach a Depth of 1 m in Utah County.

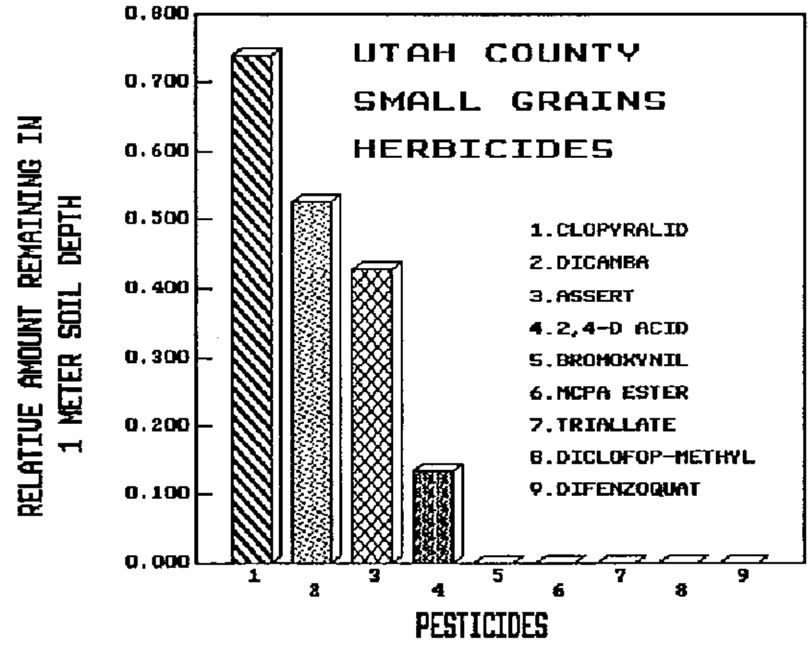


Figure 10. Alternative Small Grains Herbicides and Their Relative Amounts Remaining in the Soil When Pesticides Reach a Depth of 1 m in Utah County.

### **4.1.2 Alternative Application Dates.**

The timing and the amount of pesticide applied during the irrigation season affects pesticide transport and potential ground-water contamination. As an example, hexazinone and metribuzin can be applied in either fall or spring for efficient weed control. However, the risk of contaminating ground water with spring pesticide application can be greater than with fall application (Fig. 11). Fig. 11 shows that hexazinone reaches a depth of 2 m in 114 days when applied in spring. The same pesticide reaches a depth of 2 m in 315 days when applied in fall. Thus, hexazinone has less time available for pesticide degradation via chemical and biological processes when applied in spring. The principal factor causing this difference is the irrigation period that follows spring application.

Values of the relative amount of pesticide remaining in the soil (RA) are a function of travel time and degradation half-life (Equation 26). However, simulated RA values resulting from fall pesticide application can be underestimated because degradation rate is smaller in winter than spring, and this aspect is not accounted for in the model.

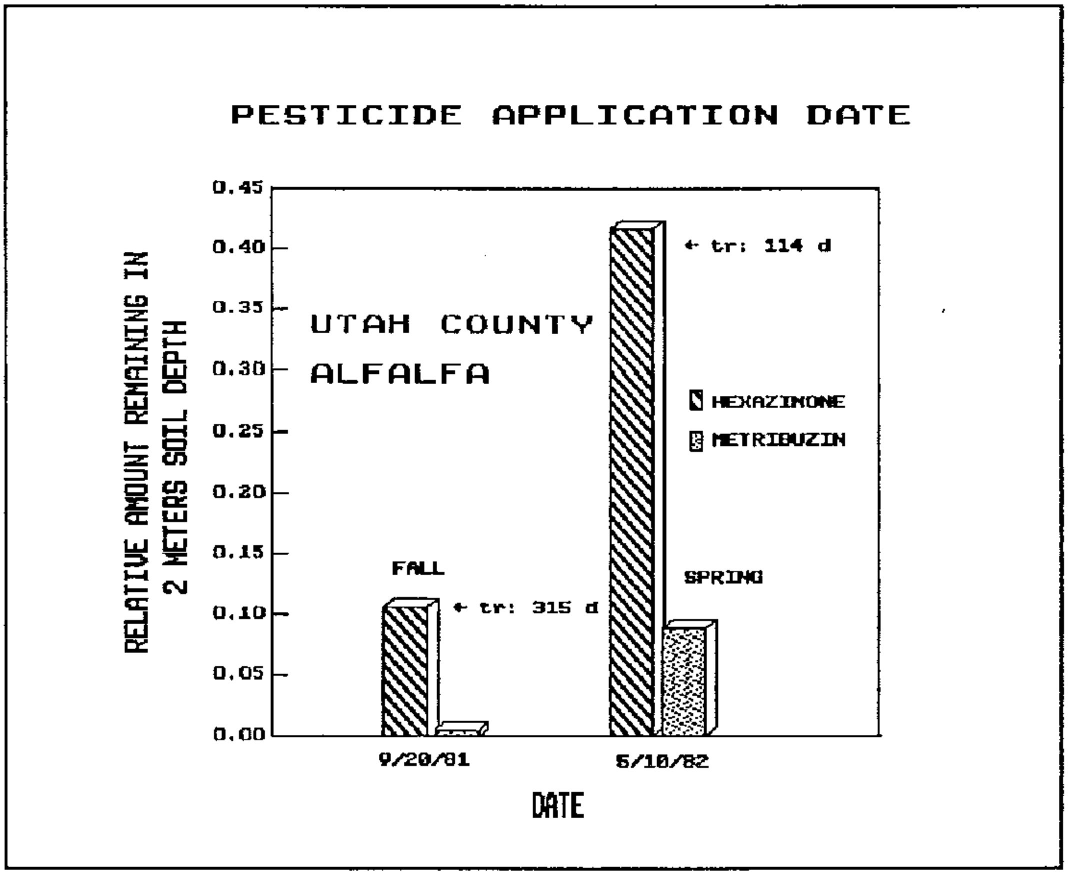


Figure 11. Effect on Relative Amount of Pesticides Remaining in the Soil When They Reach a Depth of 2 m for Two Pesticide Application Dates. Assumes 50% Irrigation Efficiency.

### 4.1.3 Alternative Water Management Practices.

Reduction in potential pesticide contamination can be achieved by improving the efficiency of water application in different ways. Increased efficiency can be obtained by adequate land leveling (especially important in surface irrigation systems), by changing furrow inflow rates or furrow lengths in surface irrigation systems and by increasing the uniformity coefficient (UC) in sprinkler irrigation systems. Efficient control of the time of irrigation and an adequate irrigation schedule will increase efficiency in most systems. Figs. 12 and 13 indicate the influence of the irrigation water-storage efficiency on the relative amount of selected pesticides remaining in the soil profile.

Fig. 12 shows an abrupt effect of water-storage efficiency on relative amounts of atrazine remaining in the soil (RA) when water-storage efficiency changes from 40 to 30 percent. This effect is related mainly to pesticide and soil characteristics.

Fig. 13 shows that low values of water-storage irrigation efficiency influence more pesticides with the small $K_{oc}$ values (metribuzin: $K_{oc} = 41$ ml/g OC) than pesticides with large $K_{oc}$ values (chlorpyrifos: $K_{oc} = 6070$ ml/g OC) for the same degradation half-lives ($t_{1/2} = 30$ days).

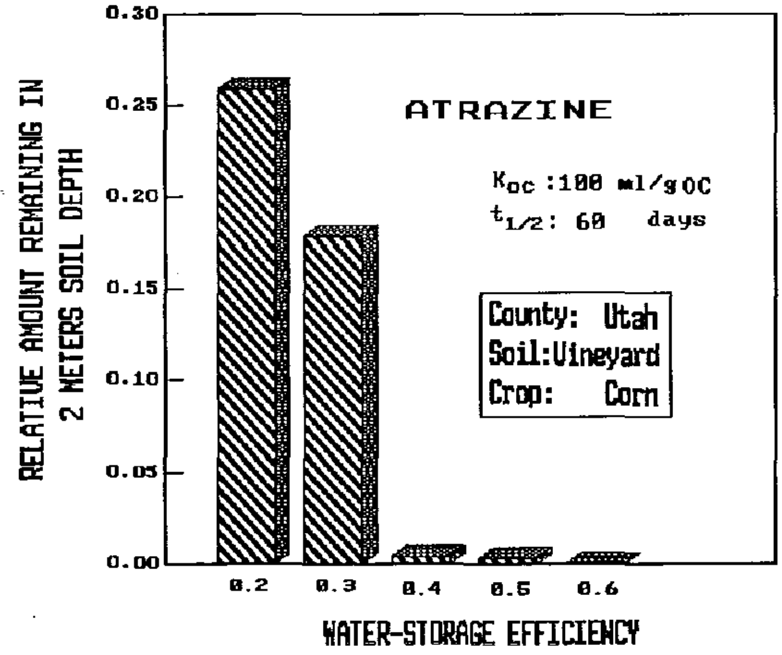


Figure 12. Effect on Relative Amount of Atrazine Remaining in the Soil When the Herbicide Reaches a Depth of 2 m for Various Water-Storage Efficiencies.

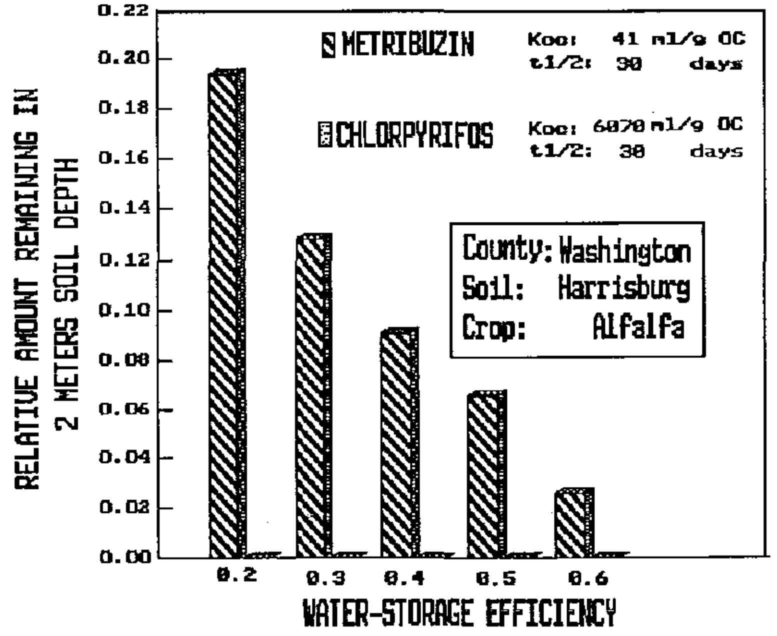


Figure 13. Effect on Relative Amount of Pesticides Remaining in the Soil When They Reach a Depth of 2 m for Various Surface Irrigation Efficiencies.

### 4.1.4 Alternative Irrigation Systems.

Irrigation system design can be critical in determining the amount of pesticide leaching in agricultural areas. With appropriate furrow system design, pesticide leaching can be reduced appreciably in relation to pesticides and sites characteristics. For example, Figs. 14 and 15 show a range of reduction between 10 to 90 percent in RA values. Fig. 14 shows decreasing RA values of carbofuran and hexazinone with decreasing furrow lengths. If the length of the furrow cannot be decreased, an important reduction in RA values for these pesticides and site characteristics can be obtained by increased flow rates at the head of the furrow (Fig. 15). Furrows that are too long or are irrigated with small inflow rates will increase leaching of pesticide, particularly for the coarse textured soils considered in this study.

When there is a limited number of alternative pesticides or leaching losses are significant (for example, irrigation of shallow rooted crops on sandy soils) the selection of improved irrigation systems such as sprinkler irrigation can be especially important. Fig. 16 indicates the effects of three uniformity coefficients on the relative amounts of pesticides remaining in the soil profile when the pesticide front reaches 2-m in depth under a sprinkler irrigation system. Comparing Figs. 16 with 14 and 15 shows that even with very small uniformity coefficients, sprinkler irrigation is less likely to contaminate ground water than is surface irrigation for the pesticides and site considered. Acceptable water-storage efficiencies can be obtained in well-designed and well-operated surface irrigation systems. However, high efficiencies are difficult to maintain in these systems because they depend on human factors, and the site characteristics change with space and time.

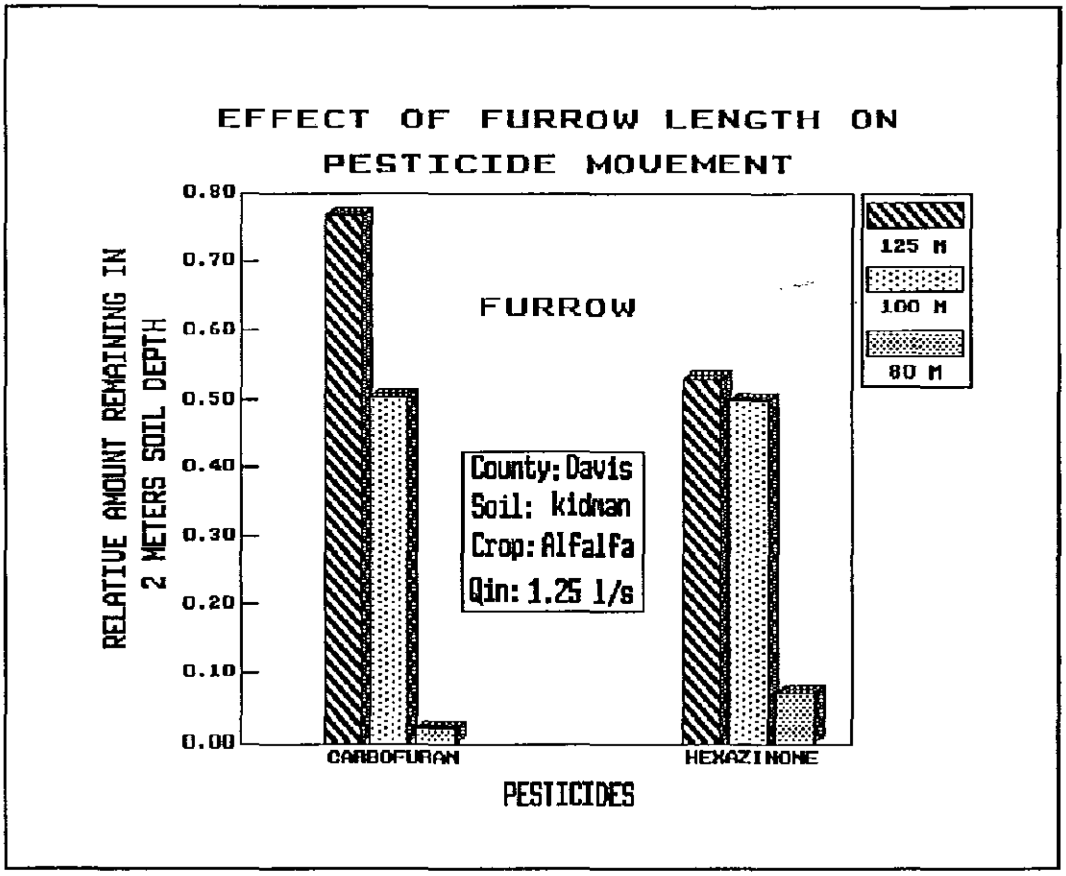


Figure 14. Effect of Furrow Lengths on Relative Amount of Pesticides Remaining in the Soil When They Reach a Depth of 2 m.

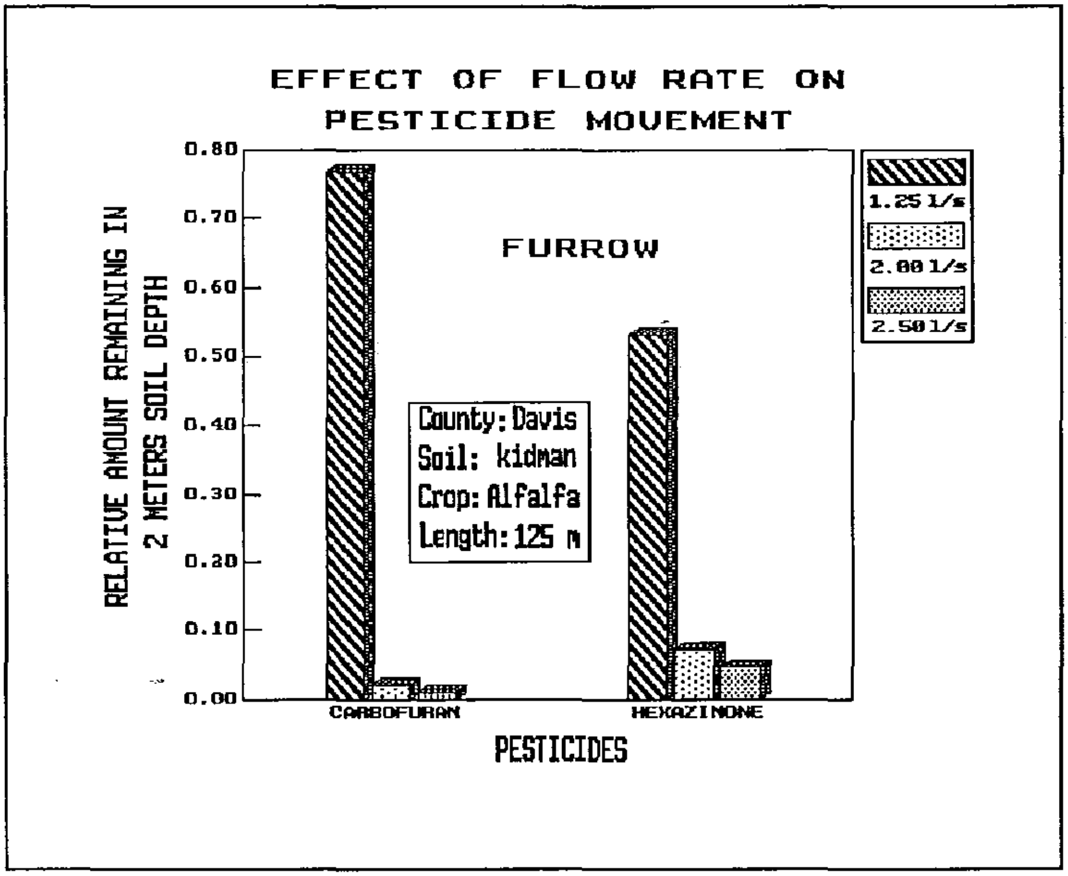


Figure 15. Effect on Relative Amount of Pesticides Remaining in the Soil When They Reach a Depth of 2 m for Various Inflows Rates ($Q_{in}$) to the Furrow Head.

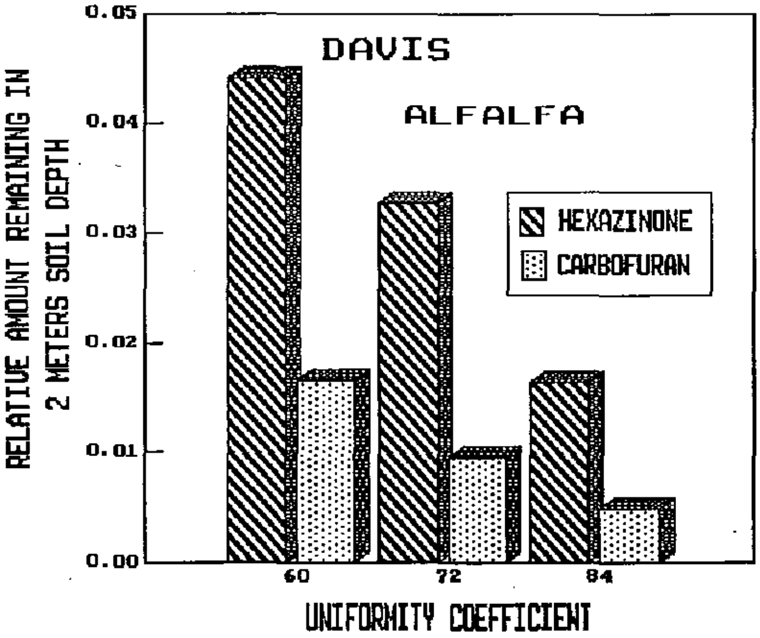


Figure 16. Effects of Various Uniformity Coefficients on Relative Amount of Pesticides Remaining in the Soil When They Reach a Depth of 2 m Under a Sprinkler Irrigation System.

## 4.2 Sensitivity Analyses

Physical properties of soils and irrigation design parameters were treated as variables for a sensitivity analysis. Some of the resulting graphs from this analysis are shown in the following pages.

### 4.2.1 Soil.

Soils with high clay and organic carbon content have a tendency to adsorb pesticides, minimizing the risk of groundwater contamination. Pesticides require more travel time when moving through soils of high water content at field capacity values, as clay soils, than through lighter soils of small water content at field capacity values (equation 3). The travel time, in turn, determines the time available for pesticide attenuation via chemical and biological processes. Figs. 17 and 18 clearly indicate the change in RA resulting from different soil textures. Fig. 17 shows approximately 80 percent reduction in RA values when a silty clay soil is compared to a sandy soil. Differences in organic carbon and water contents are the principal contributors to this contrast. Soils used for the simulations are given in Appendix C.

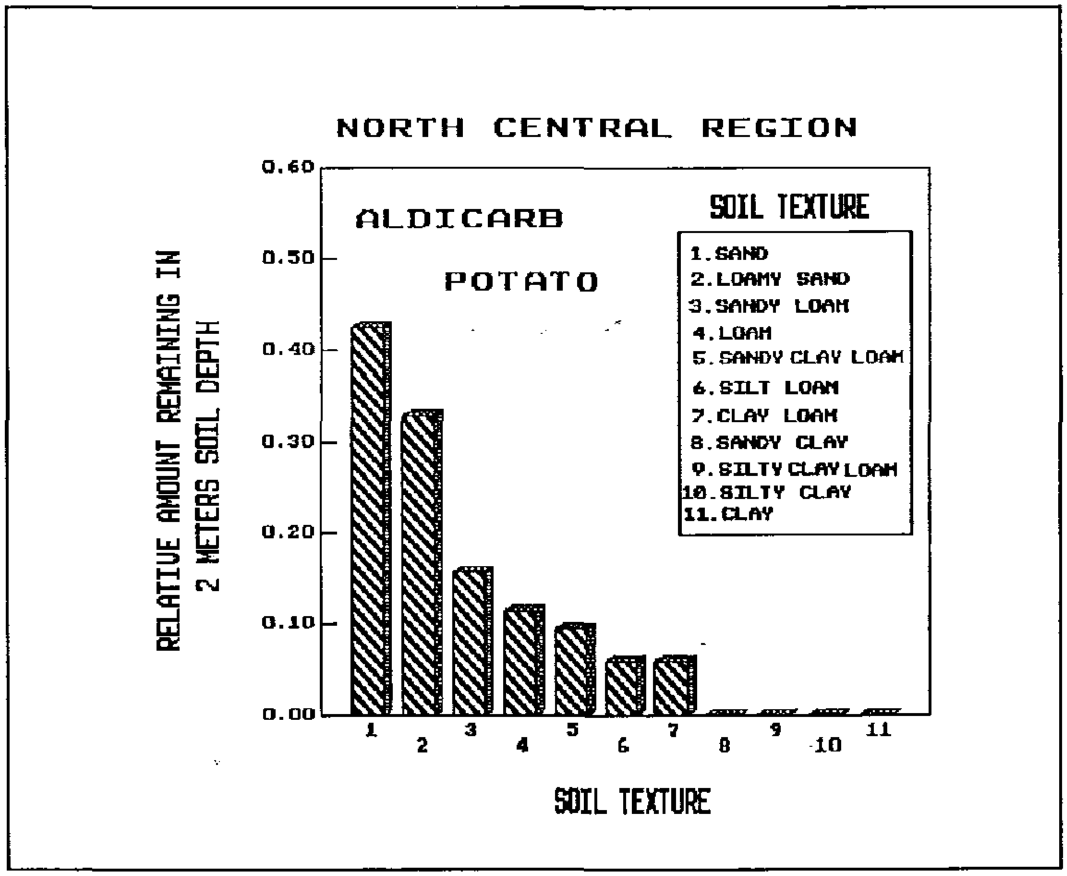


Figure 17. Effect of Various Soil Textures on Relative Amount of Aldicarb Remaining in the Soil When It Reaches a Depth of 2 m.

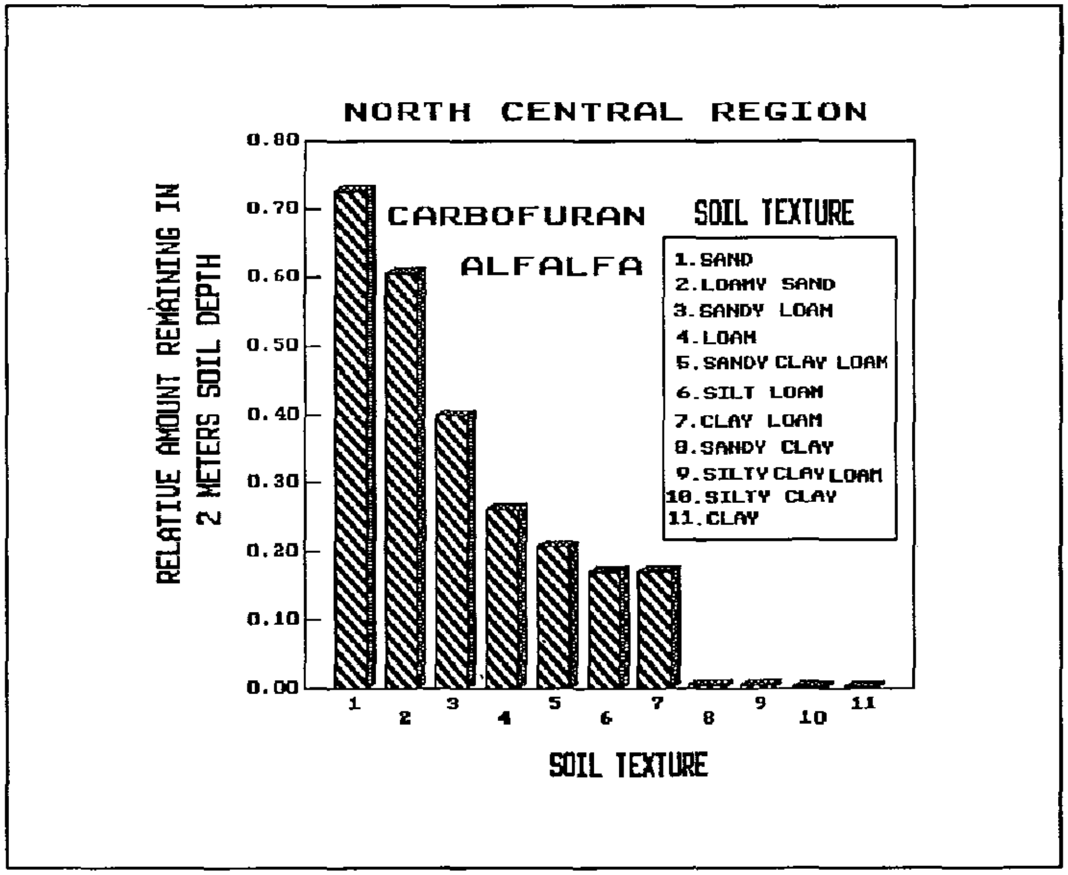


Figure 18. Effect of Various Soil Textures on Relative Amount of Carbofuran Remaining in the Soil When It Reaches a Depth of 2 m.

### 4.2.2 Sprinkler Irrigation.

The depth of water infiltrated in the soil in each 10 percent increment of field area was estimated as described in the Procedure section. Assumed were a uniformity coefficient of 60 percent and 80 percent of the area adequately irrigated. A uniformity coefficient of 60 percent was selected because it demonstrates the greatest difference between RA values for the average depth of infiltrated water.

Estimated depths of infiltrated water for each increment of area were input in each of 10 runs of CMLS. Aldicarb, one of the most mobile and commonly found pesticides in ground water (Table 1), was used. Fig. 19 shows the influence of different irrigation depths in the movement of the pesticide. The first 10 rows of Table 12 numerically illustrate the results of these simulations. Averaging these 10 rows yields a field average of these detailed simulations. It is useful to compare that average with what is computed if only a single average infiltration value is used for an entire field (bottom row). The results are very similar down to a depth of 1.5 m.

TABLE 12. Pesticide Movement Comparison Under Sprinkler Irrigation.

| No | PESTICIDE NAME | AREA % | d (mm) | RELATIVE AMOUNT REMAINING 1.0 m | 1.5 m | 2.0 m | 3.0 m |
|---|---|---|---|---|---|---|---|
| 1 | ALDICARB | 10 | 16 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2 | ALDICARB | 10 | 37 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 3 | ALDICARB | 10 | 51 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| 4 | ALDICARB | 10 | 63 | 0.0905 | 0.0001 | 0.0000 | 0.0000 |
| 5 | ALDICARB | 10 | 73 | 0.1649 | 0.0001 | 0.0001 | 0.0000 |
| 6 | ALDICARB | 10 | 83 | 0.1984 | 0.0905 | 0.0001 | 0.0000 |
| 7 | ALDICARB | 10 | 93 | 0.1984 | 0.1371 | 0.0686 | 0.0001 |
| 8 | ALDICARB | 10 | 104 | 0.2679 | 0.1649 | 0.1114 | 0.0001 |
| 9 | ALDICARB | 10 | 118 | 0.2679 | 0.1984 | 0.1371 | 0.0686 |
| 10 | ALDICARB | 10 | 140 | 0.3455 | 0.1984 | 0.1649 | 0.1114 |
| 10 | SUBAREAS AVERAGE | | 78 | 0.1534 | 0.0790 | 0.0482 | 0.0180 |
| | ALDICARB | 100 | 78 | 0.1649 | 0.0686 | 0.0001 | 0.0000 |

However, we do see appreciable difference in relatively insignificant RA values for depths greater than 1.5 m because applied depth of water in each 10 percent area is not uniform (16 to 140 mm). This nonuniformity produces some areas with practically no deep percolation and pesticide movement and other areas with high deep percolation and pesticide movement. Results from the sprinkler simulation can underestimate real RA values in 2-m soil depth. This underestimation can be more important if preferential flow, not accounted for in the model, is present, and a portion of the soil water is bypassed during flow.

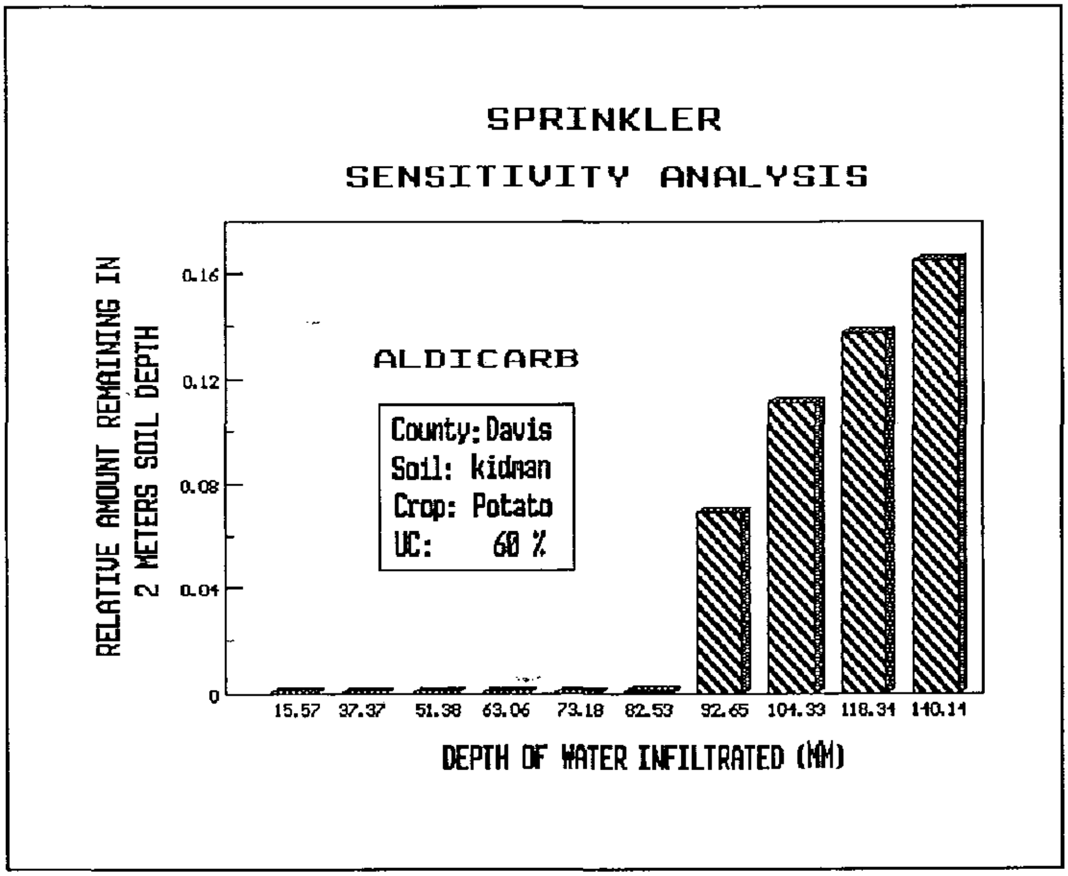


Figure 19. Effect of Various Infiltrated Water Depths on Relative Amount of Aldicarb Remaining in the Soil When It Reaches a Depth of 2 m.

### 4.2.3 Furrow Irrigation.

Values of depth of infiltrated water in every 10 percent increment of furrow length were obtained from the kinematic-wave model. The greatest depth of applied water (259 mm) was considered because it gives the biggest nonuniformity in the distribution of water and the highest variation among RA values. This water depth is a kinematic-wave output for a 125-m long furrow on sandy soil with an inflow discharge of 1.25 l/s at the furrow head.

Table 13 shows the CMLS results of these 10 infiltration depths and the average RA values. Table 13 also shows the RA values computed if only an average infiltration depth is used. Comparison shows that using average infiltration in this case is quite reasonable.

Selection of inflow rate and furrow length depends on site-specific water management practices. In the selection process, it is helpful to consider an efficiency criteria (such as that discussed in the Procedure section) that quantifies hydraulic performances. It is also beneficial if, in the selection process, the environmental results of using a particular irrigation water management alternative are estimated. Knowing that efficient water management practice greatly reduces pesticide leaching beyond the root zone, the farmer may decide to use a combination of improved irrigation management and alternative pesticides that have less hazardous environmental effects.

TABLE 13. Pesticide Movement Comparison Under Surface Irrigation.

| No | PESTICIDE NAME | AREA % | d (mm) | RELATIVE AMOUNT REMAINING 1.0 m | 1.5 m | 2.0 m | 3.0 m |
|---|---|---|---|---|---|---|---|
| 1 | ALDICARB | 10 | 302 | 0.3455 | 0.3455 | 0.2679 | 0.2679 |
| 2 | ALDICARB | 10 | 302 | 0.3455 | 0.2679 | 0.2679 | 0.2679 |
| 3 | ALDICARB | 10 | 302 | 0.3455 | 0.3455 | 0.2679 | 0.2679 |
| 4 | ALDICARB | 10 | 299 | 0.3455 | 0.3455 | 0.2679 | 0.2679 |
| 5 | ALDICARB | 10 | 292 | 0.3455 | 0.3455 | 0.2679 | 0.1984 |
| 6 | ALDICARB | 10 | 283 | 0.3455 | 0.3455 | 0.2679 | 0.1984 |
| 7 | ALDICARB | 10 | 267 | 0.3455 | 0.3455 | 0.2679 | 0.1984 |
| 8 | ALDICARB | 10 | 239 | 0.3455 | 0.2679 | 0.2679 | 0.1984 |
| 9 | ALDICARB | 10 | 193 | 0.3455 | 0.2679 | 0.1984 | 0.1649 |
| 10 | ALDICARB | 10 | 111 | 0.2679 | 0.1649 | 0.1371 | 0.0005 |
| 10 | SUBAREAS AVERAGE |  | 259 | 0.3377 | 0.3042 | 0.2479 | 0.1763 |
|  | ALDICARB | 100 | 259 | 0.3455 | 0.3455 | 0.2679 | 0.1984 |

# CHAPTER V

# SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Summary and Conclusions

The principal objective of this study was to develop guidelines to help in reducing potential hazardous effects of agricultural pesticides. Different irrigation water management approaches (stream size and length of furrows in surface irrigation systems, uniformity coefficients in sprinkler systems), alternative pesticides and timing of pesticide applications were considered to evaluate water management and pesticide transport interactions.

It was determined that pesticide application near to an infiltration event, rain or irrigation, is not advisable because of potential ground-water contamination.

Water-storage efficiency is an important factor in the movement of pesticides. Water-storage efficiencies do not affect the movement of pesticides in the same way. Pesticides with $K_{oc}$ smaller than 200 ml/g and half-life equal or greater than 10 days present the greatest risk for potential ground-water contamination when water-storage efficiency values are smaller than 50 percent. Increasing flow rates at the head of the furrow or decreasing furrow length decreases the leaching of pesticides and the risk of potential ground-water contamination. Sprinkler irrigation systems present less potential risk for ground-water contamination than surface irrigation systems. Using an average estimate of infiltration within a pesticide transport model is very appropriate for furrow irrigation systems and almost as appropriate for sprinkler irrigation systems.

Environmental consequences should be considered when selecting from alternative pesticides to prevent ground-water contamination and unnecessary losses of pesticides. Chemicals removed by run-off and leaching are not available for pest control. Use of pesticide conservation practices will have both short-term and long-term economic benefits. Voluntary adoption, cost-sharing and selection of sound chemical management are superior alternatives to forced regulation. The implementation of sound pesticide management practices will provide water quality, crop production and economic benefits.

## 5.2 Recommendations

As a result of the study conducted the following topics are considered important for further investigation:

1. Further comparison of the CMLS model with alternative simulation models and field measurement is desirable. A complete set of field data should be obtained for using in these comparisons. This will allow the improvement of the CMLS model and a better knowledge of the importance of its assumptions.

2. A stochastic procedure (random generation of a statistical population) for determining the weather input data to the model is recommended. Probability distribution functions can help in developing generalizations for the selection of pesticides.

3. Improving and linking the CMLS model with an expert system may be a useful tool in pesticide decision-making for different pesticide and site characteristics.

4. Economic consideration of the relationships between irrigation system designs and potential ground-water contamination is recommended.

## REFERENCES

Aller, L., Truman, B., Lehr, J.H., and Petty, R.J. 1985. "DRASTIC: A standardized system for evaluating ground water pollution potential using hydrogeologic settings," USEPA/600/2-85/018 U.S. Environmental Protection Agency, Washington, DC.

Bailey, G.W., and White, J.L. 1970. "Factors influencing the adsorption, desorption, and movement of pesticide in soils," Residue Reviews 32: 29-93.

Bonazountas, M., and Wagner, J. 1981. SESOIL- "A seasonal soil compartment model". Arthur D. Little., Inc., Cambridge, Mass. Prepared for USEPA Office of Toxic Substances, Wash., DC.

Burnside, O.C. 1974. "Prevention and detoxification of pesticide residues in soils," Pesticides in soil and water, W.D. Guenzi, ed., Society of America, Soil Science, Madison, Wisconsin, pp. 387-412.

Carsel, R.F., Smith, C.N., Mulkey, L.A., Dean, J.D., and Jowsie, P. 1984. "Pesticide root zone model (PRZM): Release 1," USEPA-600/3-84-109, Environmental Protection Agency, Athens, GA.

Davidson, J.M., Rieck, C.E., and Santelmann, P.W. 1968. "Influence of water flux and porous material on movement of selected herbicides," Proceedings, Soil Science Society of America, Vol. 32, pp. 629-633.

Doorenbos, J., and Pruitt, W.O. 1977. "Crop water requirements," FAO Irrigation and Drainage Paper 24, Food and Agriculture Organization of the United Nations, Rome, p. 156.

Eisele, H., Ehteshami, M., Peralta, R.C., Deer, H.M., and Tindall, T. 1989. "Agricultural pesticide hazard to ground water in Utah," IIC-89/1A, Agricultural and Irrigation Engineering Department, Vols. I-II, Utah State University, Logan, Utah.

Elliot, R.L., and Walker, W.R. 1982. "Field evaluation of furrow infiltration and advance functions," Transactions, ASAE, 25(2): 396-400.

Frissel, M.J., and Bolt, G.H. 1962. "Interaction between certain ionizable organic compounds (herbicides) and clay minerals," Soil Science 94: 284-291.

Grenney, W.J., Caupp, C.L., Sims, R.C., and Short, T. 1987. "A mathematical model for the fate of hazardous substances in soil: Model description and experimental results," Hazardous Waste & Hazardous Material 4(3): 223-239.

Hansen, V.E., Israelsen, O.W., and Stringham, G.E. 1980. Irrigation principles and practices, John Wiley and Sons, New York.

Hargreaves, G.H., and Samani, Z.A. 1985. "Reference crop evapotranspiration from ambient air temperature," presented at December 12-13 ASCE winter meeting of the ASAE, held at Chicago, IL.

Hart, W.E., and Reynolds, W.N. 1965. "Analytical Design of Sprinkler Systems," Transactions, ASAE 8(2): 83-89.

Hedden, K.F. 1986. "Example field testing of soil fate and transport model, PRZM, Dougherty Plain, Georgia," in Vadose Zone Modeling of Organic Pollutants. S.C. Hern and S.M. Melancon, eds., Lewis Publishers, Inc. Chelsea, MI., pp. 81-101. (Cited by Smith et al., 1989)

Hill, R.W., Brockway, C.E., Burman, R.W., Allen, L.N., Robison, C.W. 1987. "Field verification of empirical method for estimating depletion," Research Report 125, Appendices F and G, Utah Agricultural Experiment Station, Utah State University, Logan, Utah.

Hill, R.W., Johns, E.L., and Frevert, D.K. 1983. "Comparison of equations used for estimating agricultural crop evapotranspiration with field research," Bureau of Reclamation, Engineering and Research Center, Denver, CO.

Holden, P.W. 1986. "Pesticides and ground water quality," National Academy Press, Washington, DC.

Jury, W.A., Spencer, W.F., and Farmer, W.J. 1984. "Behavior assessment model for trace organics in soil: III. Application of screening model," Journal of Environmental Quality. 13: 573-579. (Cited by Rao et al., 1985)

Karickhoff, S.A. 1981. "Semi-empirical estimation of sorption of hydrophobic pollutants on natural sediments and soils," Chemosphere 10: 833-846.

Karickhoff, S.A., Brown, D.S., and Scott, T.A. 1979. "Sorption of hydrophobic pollutant on natural sediments," Water Resources 13: 245-248.

Lau, L.S., and Mink, J.F. 1987. "Organic contamination of ground water: A learning experience," Journal of American

Water Works Association, 79(8): 37-42.

Leistra, M. 1986. "Modelling the behavior of organic chemical in soil and ground water," Pesticide Science, 17: 256-264.

Lemley, A.T., Wagenet, R.J., and Zhong, W.Z. 1988. "Sorption and degradation of aldicarb and its oxidation products in soil water flow system as a function of pH and temperature," Journal of Environmental Quality, 17: 408-414.

Leonard, R.A., Knisel, W.G., and Still, D.A. 1987. "GLEAMS: Ground water loading effects of agricultural management systems," Transactions, ASAE 30(5): 1403-1418

Leonard, R.A., Shirmohammadi, A., Johnson, A.W., and Marti, L.R. 1988. "Pesticides transport in shallow ground water," Transactions of American Society of Agricultural Engineers 31(3): 776-788.

Lyman, W.J., Rheel, W.F., and Rosenblatt, D.H. 1982. "Handbook of chemical property estimation methods: Environmental behavior of organic compounds," McGraw-Hill Book Co., New York, NY.

Mahmood, J.R. 1988. "Evaluation of enhanced mobility of polynuclear aromatic compounds in soil systems," dissertation presented to Utah State University at Logan, Utah.

Merkle, M.G., Bovey, R.W., and Davis, F.S. 1967. "Factors affecting the persistence of picloram in soil," Agronomy Journal 59: 413-415.

Nicholls, P.H. 1988. "Factors influencing entry of pesticides into soil water," Pesticide Science 22: 123-137.

Nkedi-Kizza, P.R., Rao, S. C., and Johnson, J.W. 1983. "Adsorption of Diuron and 2,4,5-T on soil particle separates," Journal of Environmental Quality 12: 195-197.

Nofziger, D.L., and Hornsby, A.G. 1986. "A microcomputer-based management tool for chemical movement in soil," Applied Agricultural Research, Vol.1, No.1, pp. 50-56.

Nofziger, D.L., and Hornsby, A.G. 1988. "Chemical movement in layered soils: User's Manual," Agricultural Experiment Station, Division of Agriculture, Oklahoma State University, Stillwater, OK.

Oki, D.S., and Giambelluca, T.W. 1987. "DBCP, EDB, and TCP contamination of ground water in Hawaii," Ground Water 25(6): 693-702.

Pimentel, D., and Levitan, L. 1986. "Pesticides: Amounts applied and amounts reaching pest," BioScience 36: 86-91.

Pionke, H.B., Glotfelty, D.E., Lucas, A.D., and Urban, J.B. 1988. "Pesticide contamination of ground water in the Mahantango Creek Watershed," Journal of Environmental Quality 17: 76-84.

Ramzi, J.M., and Sims, R.C. 1986. "Mobility of organics in land treatment systems," Journal of Environmental Engineering 112(2): 236-245.

Rao, P.S.C., and Davidson, J.M. 1980. "Estimation of pesticide retention and transformation parameters required in nonpoint source pollution models," in Environmental impact of nonpoint source pollution, M.R. Overcash and J.M. Davidson eds., Ann Arbor Publishers, Ann Arbor, MI, pp: 2-67.

Rao, P.S.C., Hornsby, A.C., and Jessup, R.E. 1985. "Indices for ranking the potential for pesticide contamination of ground water," Proceedings, Soil Crop Science Society of Florida, 44, pp. 1-8

Rao, P.S.C., Mansell, R.S., Baldwin, L.B., and Laurent, M.F. 1983. "Pesticides and their behavior in soil and water," Soil Science Fact Sheet, Sept. 1983, Florida Cooperative Extension Service, Univ. of Florida, Gainesville, FL.

Smith, M.C., Campbell, K.L., Bottcher, A.B., and Thomas, D.L. 1989. "Field testing and comparison of the PRZM and GLEAMS models," presented at June 25-28 ASAE and CSAE, St. Joseph, MI., Paper No. 89-2072, 29 pp.

Sum, M. 1986. "Ground water: Many diagnoses, few remedies," Science, 232: 1490-1493.

USEPA. 1972. "Pesticides," in Environmental Protection Agency progress report, Environmental Protection Agency, Washington, DC, pp. 34-37.

USEPA. 1987. "Agricultural chemicals in ground water: Proposed strategy," U.S. Environmental Protection Agency, Office of Pesticide and Toxic Substances, Washington, DC.

Waddell, K.M. 1987. "Utah ground water quality," U.S. Geological Survey, Open-File 87-0757.

Walker, A., and Crawford, D.V. 1968. "The role of organic matter in adsorption of the triazine herbicides by soils," Proceedings, Second Symposium at International Atomic Energy Agency, Vienna, July 20-28, pp. 91-108.

Walker, W.R., and Humpherys, A.S. 1983. "Kinematic-wave furrow irrigation model," Journal of Irrigation and Drainage Division, ASCE, 109(IR4): 377-392.

Walker, W.R., and Skogerboe, G.V. 1987. "Surface irrigation: Theory and Practice," Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Wauchope, R.D. 1988. "USDA-ARS interim pesticide properties database, version 1.9," Office of Pesticide Programs, U.S. Environmental Protection Agency, Washington, DC.

Weber, J.B., Shea, P.H., and Weed, S.B. 1986. "Fluridone retention and release in soils," Journal of Soil Science Society of America 50: 582-588.

Zaki, M.H., Morgan, D., and Harris, D. 1982. "Pesticides in ground water: The aldicarb story in Suffolk County, NY," American Public Health 72: 1391-1395.

# APPENDICES

# Appendix A. CMLS Simulations

# Table 14. CMLS Simulations: Alternatives Pesticides

| COUNTY | CROP | Type | PESTICIDE NAME | Koc ml/g | t1/2 days | RA 1 m | RA 1.5 m | RA 2 m | RA 3 m |
|---|---|---|---|---|---|---|---|---|---|
| UTA | ALF | I | CARBOFURAN | 22 | 50 | 0.1627 | 0.1416 | 0.1001 | 0.0034 |
| UTA | ALF | H | 2,4-DB AMINE | 109 | 10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | H | BENEFIN | 9000 | 40 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | H | BROMOXYNIL | 190 | 5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | H | DCPA | 5000 | 100 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | H | DIURON | 480 | 90 | 0.0009 | 0.0001 | 0.0000 | 0.0000 |
| UTA | ALF | H | EPTC | 280 | 30 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | H | GLYPHOSATE | 24000 | 47 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | H | HEXAZINONE | 54 | 90 | 0.2094 | 0.1166 | 0.0296 | 0.0166 |
| UTA | ALF | H | PARAQUAT | 100000 | 500 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | H | PRONAMIDE | 990 | 60 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | H | SETHOXYDIM | 50 | 10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | H | TERBACIL | 55 | 120 | 0.3096 | 0.1984 | 0.0658 | 0.0463 |
| UTA | ALF | H | TRIFLURALIN | 7000 | 60 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | I | CARBARYL | 200 | 10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | I | CHLORPYRIFOS | 6070 | 30 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | I | MALATHION | 1800 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | I | METHIDATHION | 400 | 21 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | I | METHOMYL | 72 | 33 | 0.0132 | 0.0002 | 0.0001 | 0.0000 |
| UTA | ALF | I | METHYL-PARATHION | 5100 | 5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ALF | I | PHOSMET | 612 | 12 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | H | ALACHLOR | 170 | 15 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | H | ATRAZINE | 100 | 60 | 0.2529 | 0.1504 | 0.0086 | 0.0045 |
| UTA | COR | H | BENTAZON | 35 | 20 | 0.1340 | 0.0825 | 0.0474 | 0.0055 |
| UTA | COR | H | BROMOXYNIL | 190 | 5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | H | BUTYLATE | 126 | 12 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | H | CYANAZINE | 190 | 14 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | H | EPTC | 280 | 30 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | H | GLYPHOSATE | 24000 | 47 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | H | PARAQUAT | 100000 | 500 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | H | PENDIMETHALIN | 24300 | 90 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | H | SIMAZINE | 138 | 75 | 0.2197 | 0.0222 | 0.0176 | 0.0030 |
| UTA | COR | H | TRIDIPHANE | 5600 | 31 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | H | VERNOLATE | 330 | 12 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | I | CHLORPYRIFOS | 6070 | 30 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | I | DIAZINON | 500 | 40 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | I | DISULFONTON | 1600 | 5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | I | ETHOPROP | 70 | 50 | 0.3439 | 0.0154 | 0.0073 | 0.0041 |
| UTA | COR | I | FONOFOS | 532 | 45 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | I | PHORATE | 2000 | 90 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | COR | I | TERBUFOS | 3000 | 5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ORC | I | AZINPHOS-METHYL | 1000 | 40 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ORC | I | CARBARYL | 200 | 10 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ORC | I | DIAZINON | 500 | 40 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ORC | I | DIMETHOATE | 8 | 7 | 0.2500 | 0.0464 | 0.0421 | 0.0001 |
| UTA | ORC | I | FENVALERATE | 5300 | 35 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ORC | I | MALATHION | 1800 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | ORC | I | PARATHION | 5000 | 14 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | H | EPTC | 280 | 30 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | H | GLYPHOSATE | 24000 | 47 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | H | METRIBUZIN | 41 | 30 | 0.0702 | 0.0597 | 0.0313 | 0.0001 |
| UTA | POT | H | PARAQUAT | 100000 | 500 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | H | PENDIMETHALIN | 24300 | 90 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | H | TRIFLURALIN | 7000 | 60 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | I | ALDICARB | 10 | 30 | 0.5743 | 0.4774 | 0.4353 | 0.1649 |
| UTA | POT | I | DIMETHOATE | 8 | 7 | 0.1132 | 0.0464 | 0.0283 | 0.0009 |
| UTA | POT | I | DISULFOTON | 1600 | 5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | I | ENDOSULFAN | 2040 | 120 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | I | ESFENVALERATE | 5300 | 35 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | I | FENVALERATE | 5300 | 35 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | I | MALATHION | 1800 | 1 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | I | METHAMIDOPHOS | 1 | 6 | 0.1575 | 0.0351 | 0.0248 | 0.0014 |
| UTA | POT | I | METHOMYL | 72 | 33 | 0.1677 | 0.0694 | 0.0003 | 0.0001 |

Abbreviations: A = acaricide; H = herbicide; I = insecticide; N = nematicide; ALF = alfalfa; COR = corn ORC = orchards; POT = potato; SGR = Small grains; VEG = Vetables; UTA = Utah; $K_{oc}$ = organic carbon partition coefficient; $t_{1/2}$ = degradation half-life; RA = Relative Amount of Pesticide Remaining in the soil when the chemical front arrives at a given depth. Assumed water-storage efficiency 50 percent.

Table 14. CMLS Simulations: Alternatives Pesticides (cont.)

| COUNTY | CROP | Type | PESTICIDE NAME | Koc ml/g | t1/2 days | RA 1 m | RA 1.5 m | RA 2 m | RA 3 m |
|---|---|---|---|---|---|---|---|---|---|
| UTA | POT | I | OXAMYL | 25 | 4 | 0.0039 | 0.0006 | 0.0000 | 0.0000 |
| UTA | POT | I | PARATHION | 5000 | 14 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | I | PERMETHRIN | 86000 | 32 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | I | PHORATE | 2000 | 90 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | POT | I | PHOSPHAMIDON | 1 | 17 | 0.5208 | 0.3065 | 0.2712 | 0.0979 |
| UTA | VEG | H | BENTAZON | 35 | 20 | 0.4353 | 0.3536 | 0.2500 | 0.1487 |
| UTA | VEG | H | DCPA | 5000 | 100 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | VEG | H | EPTC | 280 | 30 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| UTA | VEG | H | PENDIMETHALIN | 24300 | 90 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | VEG | H | TRIFLURALIN | 7000 | 60 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | SGR | H | 2,4-D ACID | 20 | 10 | 0.1340 | 0.0508 | 0.0000 | 0.0000 |
| UTA | SGR | H | ASSERT | 35 | 35 | 0.4267 | 0.0009 | 0.0006 | 0.0000 |
| UTA | SGR | H | BROMOXYNIL | 190 | 5 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | SGR | H | CLOPYRALID | 1 | 30 | 0.7405 | 0.5117 | 0.3703 | 0.0003 |
| UTA | SGR | H | DICAMBA | 2 | 14 | 0.5254 | 0.2379 | 0.1190 | 0.0000 |
| UTA | SGR | H | DICLOFOP-METHYL | 48500 | 2 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | SGR | H | DIFENZOQUAT | 54500 | 100 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | SGR | H | MCPA ESTER | 1000 | 14 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UTA | SGR | H | TRIALLATE | 2400 | 82 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

Table 15. CMLS Simulations: Furrow Irrigation

| COUNTY | CROP | Type | PESTICIDE NAME | d (mm) | Es | t(days) 2 m | RA 2 m | C(ppb) 2 m | RATIO 2 m |
|---|---|---|---|---|---|---|---|---|---|
| CAC | ALF | H | HEXAZINONE | 259 | 0.2 | 63 | 0.6156 | 184.670 | 0.880 |
| CAC | ALF | H | HEXAZINONE | 148 | 0.3 | 78 | 0.5484 | 164.520 | 0.780 |
| CAC | ALF | H | HEXAZINONE | 106 | 0.4 | 99 | 0.4665 | 139.950 | 0.670 |
| CAC | ALF | H | HEXAZINONE | 89 | 0.5 | 116 | 0.4093 | 122.780 | 0.580 |
| CAC | ALF | H | HEXAZINONE | 71 | 0.6 | 296 | 0.1023 | 30.690 | 0.150 |
| CAC | ALF | H | METRIBUZIN | 259 | 0.2 | 63 | 0.2333 | 39.190 | 0.220 |
| CAC | ALF | H | METRIBUZIN | 148 | 0.3 | 71 | 0.1939 | 32.570 | 0.190 |
| CAC | ALF | H | METRIBUZIN | 106 | 0.4 | 90 | 0.1250 | 21.000 | 0.120 |
| CAC | ALF | H | METRIBUZIN | 89 | 0.5 | 107 | 0.0844 | 14.180 | 0.080 |
| CAC | ALF | H | METRIBUZIN | 71 | 0.6 | 146 | 0.0343 | 5.760 | 0.030 |
| CAC | ALF | I | MALATHION | 259 | 0.2 | 1135 | 0.0000 | 0.000 | 0.000 |
| CAC | ALF | I | MALATHION | 148 | 0.3 | 2020 | 0.0000 | 0.000 | 0.000 |
| CAC | ALF | I | PARATHION | 259 | 0.2 | 2046 | 0.0000 | 0.000 | 0.000 |
| CAC | ALF | I,A,N | CARBOFURAN | 259 | 0.2 | 41 | 0.5664 | 126.880 | 3.520 |
| CAC | ALF | I,A,N | CARBOFURAN | 148 | 0.3 | 48 | 0.5141 | 115.150 | 3.200 |
| CAC | ALF | I,A,N | CARBOFURAN | 106 | 0.4 | 60 | 0.4353 | 97.500 | 2.710 |
| CAC | ALF | I,A,N | CARBOFURAN | 89 | 0.5 | 77 | 0.3439 | 77.030 | 2.140 |
| CAC | ALF | I,A,N | CARBOFURAN | 71 | 0.6 | 105 | 0.2333 | 52.250 | 1.450 |
| CAC | COR | H | ALACHLOR | 259 | 0.2 | 106 | 0.0075 | 5.010 | 3.340 |
| CAC | COR | H | ALACHLOR | 148 | 0.3 | 434 | 0.0000 | 0.000 | 0.000 |
| CAC | COR | H | ALACHLOR | 106 | 0.4 | 480 | 0.0000 | 0.000 | 0.000 |
| CAC | COR | H | ALACHLOR | 89 | 0.5 | 615 | 0.0000 | 0.000 | 0.000 |
| CAC | COR | H | ALACHLOR | 71 | 0.6 | 1109 | 0.0000 | 0.000 | 0.000 |
| CAC | COR | H | ATRAZINE | 259 | 0.2 | 99 | 0.3186 | 142.750 | 47.580 |
| CAC | COR | H | ATRAZINE | 148 | 0.3 | 119 | 0.2529 | 113.300 | 37.770 |
| CAC | COR | H | ATRAZINE | 106 | 0.4 | 434 | 0.0066 | 2.980 | 0.990 |
| CAC | COR | H | ATRAZINE | 89 | 0.5 | 460 | 0.0049 | 2.200 | 0.730 |
| CAC | COR | H | ATRAZINE | 71 | 0.6 | 616 | 0.0008 | 0.360 | 0.120 |
| CAC | COR | H | CYANAZINE | 259 | 0.2 | 113 | 0.0037 | 1.670 | 0.190 |
| CAC | COR | H | CYANAZINE | 148 | 0.3 | 445 | 0.0000 | 0.000 | 0.000 |
| CAC | COR | H | CYANAZINE | 106 | 0.4 | 488 | 0.0000 | 0.000 | 0.000 |
| CAC | COR | H | CYANAZINE | 89 | 0.5 | 699 | 0.0000 | 0.000 | 0.000 |
| CAC | COR | H | CYANAZINE | 71 | 0.6 | 860 | 0.0000 | 0.000 | 0.000 |
| CAC | COR | H | EPTC | 259 | 0.2 | 93 | 0.1166 | 104.500 | |
| CAC | COR | H | EPTC | 148 | 0.3 | 375 | 0.0002 | 0.150 | |
| CAC | COR | H | EPTC | 106 | 0.4 | 458 | 0.0000 | 0.020 | |
| CAC | COR | H | METOLACHLOR | 259 | 0.2 | 57 | 0.1387 | 93.200 | 9.320 |
| CAC | COR | H | METOLACHLOR | 148 | 0.3 | 88 | 0.0474 | 31.830 | 3.180 |
| CAC | COR | H | METOLACHLOR | 106 | 0.4 | 93 | 0.0398 | 26.770 | 2.680 |
| CAC | COR | H | METOLACHLOR | 89 | 0.5 | 432 | 0.0000 | 0.000 | 0.000 |
| CAC | COR | H | METOLACHLOR | 71 | 0.6 | 683 | 0.0000 | 0.000 | 0.000 |
| CAC | ORC | H | PHOSALONE | 259 | 0.2 | 1225 | 0.0000 | 0.000 | |
| CAC | ORC | M | PROPARGITE | 259 | 0.2 | 2066 | 0.0000 | 0.000 | 0.000 |
| CAC | ORC | M | PROPARGITE | 148 | 0.3 | 2066 | 0.0000 | 0.000 | 0.000 |
| CAC | VEG | H | TRIFLURALIN | 259 | 0.2 | 2066 | 0.0000 | 0.000 | 0.000 |
| CAC | SGR | H | 2,4-D ACID | 259 | 0.2 | 44 | 0.0474 | 10.610 | 0.150 |
| CAC | SGR | H | 2,4-D ACID | 148 | 0.3 | 50 | 0.0313 | 7.000 | 0.100 |
| CAC | SGR | H | 2,4-D ACID | 106 | 0.4 | 56 | 0.0206 | 4.620 | 0.070 |
| CAC | SGR | H | 2,4-D ACID | 89 | 0.5 | 355 | 0.0000 | 0.000 | 0.000 |
| CAC | SGR | H | 2,4-D ACID | 71 | 0.6 | 381 | 0.0000 | 0.000 | 0.000 |
| CAC | SGR | H | 2,4-D ACID | 49 | 0.9 | 626 | 0.0000 | 0.000 | 0.000 |
| CAC | SGR | H | CHLORSULFURON | 259 | 0.2 | 50 | 0.8052 | 4.350 | |
| CAC | SGR | H | CHLORSULFURON | 148 | 0.3 | 58 | 0.7778 | 4.200 | |
| CAC | SGR | H | CHLORSULFURON | 106 | 0.4 | 65 | 0.7546 | 4.070 | |
| CAC | SGR | H | CHLORSULFURON | 89 | 0.5 | 71 | 0.7352 | 3.970 | |
| CAC | SGR | H | CHLORSULFURON | 71 | 0.6 | 376 | 0.1961 | 1.060 | |
| CAC | SGR | H | DICAMBA | 259 | 0.2 | 22 | 0.3365 | 9.420 | 1.050 |
| CAC | SGR | H | DICAMBA | 148 | 0.3 | 29 | 0.2379 | 6.660 | 0.740 |
| CAC | SGR | H | DICAMBA | 106 | 0.4 | 41 | 0.1313 | 3.680 | 0.410 |
| CAC | SGR | H | DICAMBA | 89 | 0.5 | 42 | 0.1250 | 3.500 | 0.390 |
| CAC | SGR | H | DICAMBA | 71 | 0.6 | 364 | 0.0000 | 0.000 | 0.000 |

Abbreviations: A = acaricide; H = herbicide; I = insecticide; N = nematicide; ALF = alfalfa; COR = corn ORC = orchards; POT = potato; SGR = Small grains; VEG = Vegetables; CAC = Cache county; DAV = Davis county; SEV = Sevier county; UTA = Utah county; WAS = Washington county; WEB = Weber county; t = travel time; RA = Relative Amount of Pesticide Remaining in the soil when the chemical front arrives at a given depth; d = average depth of water infiltrated in the soil; Es = water-storage efficiency; C = potential pesticide concentration in water table assuming a mixing volume of 500 liters of water; RATIO = C / h.a.l.

Table 15. CMLS Simulations: Furrow Irrigation (cont.)

| COUNTY | CROP | Type | PESTICIDE NAME | d (mm) | Es | t(days) 2 m | RA 2 m | C(ppb) 2 m | RATIO 2 m |
|---|---|---|---|---|---|---|---|---|---|
| CAC | SGR | H | METSULFURON | 259 | 0.2 | 65 | 0.6870 | 0.550 | |
| CAC | SGR | H | METSULFURON | 148 | 0.3 | 77 | 0.6410 | 0.510 | |
| CAC | SGR | H | METSULFURON | 106 | 0.4 | 387 | 0.1069 | 0.090 | |
| CAC | SGR | H | METSULFURON | 89 | 0.5 | 402 | 0.0981 | 0.080 | |
| CAC | SGR | H | METSULFURON | 71 | 0.6 | 436 | 0.0806 | 0.060 | |
| DAV | ALF | H | HEXAZINONE | 259 | 0.2 | 82 | 0.5318 | 159.530 | 0.760 |
| DAV | ALF | H | HEXAZINONE | 148 | 0.3 | 82 | 0.5318 | 159.530 | 0.760 |
| DAV | ALF | H | HEXAZINONE | 106 | 0.4 | 121 | 0.3938 | 118.140 | 0.560 |
| DAV | ALF | H | HEXAZINONE | 89 | 0.5 | 342 | 0.0718 | 21.540 | 0.100 |
| DAV | ALF | H | HEXAZINONE | 71 | 0.6 | 397 | 0.0470 | 14.100 | 0.070 |
| DAV | ALF | H | SETHOXYDIM | 259 | 0.2 | 58 | 0.0179 | 0.000 | |
| DAV | ALF | H | SETHOXYDIM | 148 | 0.3 | 87 | 0.0024 | 0.000 | |
| DAV | ALF | H | SETHOXYDIM | 106 | 0.4 | 115 | 0.0003 | 0.000 | |
| DAV | ALF | H | SETHOXYDIM | 89 | 0.5 | 334 | 0.0000 | 0.000 | |
| DAV | ALF | H | SETHOXYDIM | 71 | 0.6 | 391 | 0.0000 | 0.000 | |
| DAV | ALF | I,A,N | CARBOFURAN | 259 | 0.2 | 19 | 0.7684 | 172.130 | 4.780 |
| DAV | ALF | I,A,N | CARBOFURAN | 148 | 0.3 | 45 | 0.5359 | 120.040 | 3.330 |
| DAV | ALF | I,A,N | CARBOFURAN | 106 | 0.4 | 64 | 0.4118 | 92.240 | 2.560 |
| DAV | ALF | I,A,N | CARBOFURAN | 89 | 0.5 | 280 | 0.0206 | 4.620 | 0.130 |
| DAV | ALF | I,A,N | CARBOFURAN | 71 | 0.6 | 328 | 0.0106 | 2.370 | 0.070 |
| DAV | COR | H | ALACHLOR | 259 | 0.2 | 414 | 0.0000 | 0.000 | 0.000 |
| DAV | COR | H | ALACHLOR | 148 | 0.3 | 468 | 0.0000 | 0.000 | 0.000 |
| DAV | COR | H | METOLACHLOR | 259 | 0.2 | 425 | 0.0000 | 0.000 | 0.000 |
| DAV | COR | H | METOLACHLOR | 148 | 0.3 | 626 | 0.0000 | 0.000 | 0.000 |
| DAV | POT | H | METOLACHLOR | 106 | 0.4 | 423 | 0.0000 | 0.000 | 0.000 |
| DAV | POT | H | METRIBUZIN | 259 | 0.2 | 66 | 0.2176 | 24.380 | 0.140 |
| DAV | POT | H | METRIBUZIN | 148 | 0.3 | 100 | 0.0992 | 11.110 | 0.060 |
| DAV | POT | H | METRIBUZIN | 106 | 0.4 | 400 | 0.0001 | 0.010 | 0.000 |
| DAV | POT | H | METRIBUZIN | 89 | 0.5 | 431 | 0.0000 | 0.010 | 0.000 |
| DAV | POT | H | METRIBUZIN | 71 | 0.6 | 527 | 0.0000 | 0.000 | 0.000 |
| DAV | POT | I | AZINPHOS-METHYL | 259 | 0.2 | 1849 | 0.0000 | 0.000 | |
| DAV | POT | I,N | ALDICARB | 259 | 0.2 | 63 | 0.2333 | 104.500 | 10.450 |
| DAV | POT | I,N | ALDICARB | 148 | 0.3 | 76 | 0.1727 | 77.390 | 7.740 |
| DAV | POT | I,N | ALDICARB | 106 | 0.4 | 101 | 0.0969 | 43.430 | 4.340 |
| DAV | POT | I,N | ALDICARB | 89 | 0.5 | 122 | 0.0597 | 26.740 | 2.670 |
| DAV | POT | I,N | ALDICARB | 71 | 0.6 | 433 | 0.0000 | 0.020 | 0.000 |
| DAV | VEG | H | BENTAZON | 259 | 0.2 | 6 | 0.8123 | 181.940 | |
| DAV | VEG | H | BENTAZON | 148 | 0.3 | 49 | 0.1830 | 40.990 | |
| DAV | VEG | H | BENTAZON | 106 | 0.4 | 376 | 0.0000 | 0.000 | |
| DAV | VEG | H | BENTAZON | 89 | 0.5 | 412 | 0.0000 | 0.000 | |
| DAV | VEG | H | TRIFLURALIN | 259 | 0.2 | 2091 | 0.0000 | 0.000 | 0.000 |
| DAV | VEG | I | MALATHION | 259 | 0.2 | 2091 | 0.0000 | 0.000 | 0.000 |
| DAV | SGR | H | 2,4-D ACID | 259 | 0.2 | 45 | 0.0442 | 9.900 | 0.140 |
| DAV | SGR | H | 2,4-D ACID | 148 | 0.3 | 350 | 0.0000 | 0.000 | 0.000 |
| DAV | SGR | H | 2,4-D ACID | 106 | 0.4 | 374 | 0.0000 | 0.000 | 0.000 |
| DAV | SGR | I | CARBARYL | 259 | 0.2 | 384 | 0.0000 | 0.000 | 0.000 |
| DAV | SGR | I | CARBARYL | 148 | 0.3 | 741 | 0.0000 | 0.000 | 0.000 |
| DAV | SGR | I | CARBARYL | 106 | 0.4 | 1105 | 0.0000 | 0.000 | 0.000 |
| SEV | ALF | H | HEXAZINONE | 259 | 0.2 | 91 | 0.4962 | 148.850 | 0.710 |
| SEV | ALF | H | HEXAZINONE | 148 | 0.3 | 114 | 0.4156 | 124.690 | 0.590 |
| SEV | ALF | H | HEXAZINONE | 106 | 0.4 | 149 | 0.3174 | 95.220 | 0.450 |
| SEV | ALF | H | HEXAZINONE | 89 | 0.5 | 177 | 0.2558 | 76.750 | 0.370 |
| SEV | ALF | H | HEXAZINONE | 71 | 0.6 | 498 | 0.0216 | 6.480 | 0.030 |
| SEV | ALF | H | METRIBUZIN | 259 | 0.2 | 91 | 0.1221 | 20.520 | 0.120 |
| SEV | ALF | H | METRIBUZIN | 148 | 0.3 | 114 | 0.0718 | 12.060 | 0.070 |
| SEV | ALF | H | METRIBUZIN | 106 | 0.4 | 140 | 0.0394 | 6.610 | 0.040 |
| SEV | ALF | H | METRIBUZIN | 89 | 0.5 | 158 | 0.0260 | 4.360 | 0.020 |
| SEV | ALF | H | METRIBUZIN | 71 | 0.6 | 480 | 0.0000 | 0.000 | 0.000 |
| SEV | ALF | I | PARATHION | 259 | 0.2 | 2048 | 0.0000 | 0.000 | 0.000 |
| SEV | ALF | I,A,N | CARBOFURAN | 259 | 0.2 | 26 | 0.6974 | 156.210 | 4.340 |
| SEV | ALF | I,A,N | CARBOFURAN | 148 | 0.3 | 42 | 0.5586 | 125.140 | 3.480 |
| SEV | ALF | I,A,N | CARBOFURAN | 106 | 0.4 | 68 | 0.3896 | 87.270 | 2.420 |
| SEV | ALF | I,A,N | CARBOFURAN | 89 | 0.5 | 86 | 0.3035 | 67.990 | 1.890 |
| SEV | ALF | I,A,N | CARBOFURAN | 71 | 0.6 | 399 | 0.0040 | 0.890 | 0.020 |
| SEV | COR | H | ATRAZINE | 259 | 0.2 | 87 | 0.3660 | 163.980 | 54.660 |
| SEV | COR | H | ATRAZINE | 148 | 0.3 | 116 | 0.2618 | 117.300 | 39.100 |
| SEV | COR | H | ATRAZINE | 106 | 0.4 | 452 | 0.0054 | 2.420 | 0.810 |
| SEV | COR | H | ATRAZINE | 89 | 0.5 | 491 | 0.0034 | 1.540 | 0.510 |

Table 15. CMLS Simulations: Furrow Irrigation (cont.)

| COUNTY | CROP | Type | PESTICIDE NAME | d (mm) | Es | t(days) 2 m | RA 2 m | C(ppb) 2 m | RATIO 2 m |
|---|---|---|---|---|---|---|---|---|---|
| SEV | COR | H | ATRAZINE | 71 | 0.6 | 1211 | 0.0000 | 0.000 | 0.000 |
| SEV | COR | H | DICAMBA | 259 | 0.2 | 49 | 0.0884 | 9.900 | 1.100 |
| SEV | COR | H | DICAMBA | 148 | 0.3 | 65 | 0.0400 | 4.480 | 0.500 |
| SEV | COR | H | DICAMBA | 106 | 0.4 | 86 | 0.0142 | 1.590 | 0.180 |
| SEV | COR | H | DICAMBA | 89 | 0.5 | 101 | 0.0067 | 0.750 | 0.080 |
| SEV | COR | H | DICAMBA | 71 | 0.6 | 437 | 0.0000 | 0.000 | 0.000 |
| SEV | COR | I | FONOFOS | 259 | 0.2 | 1186 | 0.0000 | 0.000 | 0.000 |
| SEV | COR | I | PHORATE | 259 | 0.2 | 2068 | 0.0000 | 0.000 |  |
| SEV | COR | I | TRIMETHACARB | 259 | 0.2 | 449 | 0.0000 | 0.000 |  |
| SEV | COR | I,A,N | CARBOFURAN | 259 | 0.2 | 69 | 0.3842 | 172.130 | 4.780 |
| SEV | COR | I,A,N | CARBOFURAN | 148 | 0.3 | 84 | 0.3121 | 139.810 | 3.880 |
| SEV | COR | I,A,N | CARBOFURAN | 106 | 0.4 | 105 | 0.2333 | 104.500 | 2.900 |
| SEV | COR | I,A,N | CARBOFURAN | 89 | 0.5 | 128 | 0.1696 | 75.970 | 2.110 |
| SEV | COR | I,A,N | CARBOFURAN | 71 | 0.6 | 470 | 0.0015 | 0.660 | 0.020 |
| SEV | ORC | I | AZINPHOS-METHYL | 259 | 0.2 | 454 | 0.0004 | 0.130 |  |
| SEV | ORC | I | PHOSMET | 259 | 0.2 | 369 | 0.0000 | 0.000 |  |
| SEV | SGR | H | 2,4-D ACID | 259 | 0.2 | 16 | 0.3299 | 73.890 | 1.060 |
| SEV | SGR | H | 2,4-D ACID | 148 | 0.3 | 28 | 0.1436 | 32.160 | 0.460 |
| SEV | SGR | H | 2,4-D ACID | 106 | 0.4 | 380 | 0.0000 | 0.000 | 0.000 |
| SEV | SGR | H | 2,4-D ACID | 89 | 0.5 | 397 | 0.0000 | 0.000 | 0.000 |
| SEV | SGR | H | DICLOFOP-METHYL | 259 | 0.2 | 2071 | 0.0000 | 0.000 |  |
| SEV | SGR | H | DIFENZOQUAT | 259 | 0.2 | 2068 | 0.0000 | 0.000 |  |
| SEV | SGR | H | TRIALLATE | 259 | 0.2 | 2098 | 0.0000 | 0.000 |  |
| SEV | SGR | I | BARBAN | 259 | 0.2 | 41 | 0.3878 | 32.570 |  |
| SEV | SGR | I | BARBAN | 148 | 0.3 | 53 | 0.2939 | 24.690 |  |
| SEV | SGR | I | BARBAN | 106 | 0.4 | 405 | 0.0001 | 0.010 |  |
| SEV | SGR | I | BARBAN | 89 | 0.5 | 422 | 0.0001 | 0.000 |  |
| UTA | ALF | H | GLYPHOSATE | 259 | 0.2 | 2096 | 0.0000 | 0.000 | 0.000 |
| UTA | COR | H | 2,4-D ACID | 259 | 0.2 | 100 | 0.0010 | 0.220 | 0.000 |
| UTA | COR | H | 2,4-D ACID | 148 | 0.3 | 107 | 0.0006 | 0.130 | 0.000 |
| UTA | COR | H | 2,4-D ACID | 106 | 0.4 | 122 | 0.0002 | 0.050 | 0.000 |
| UTA | COR | H | 2,4-D ACID | 89 | 0.5 | 135 | 0.0001 | 0.020 | 0.000 |
| UTA | COR | H | 2,4-D ACID | 71 | 0.6 | 468 | 0.0000 | 0.000 | 0.000 |
| UTA | COR | H | ATRAZINE | 259 | 0.2 | 117 | 0.2588 | 115.950 | 38.650 |
| UTA | COR | H | ATRAZINE | 148 | 0.3 | 149 | 0.1788 | 80.120 | 26.710 |
| UTA | COR | H | ATRAZINE | 106 | 0.4 | 478 | 0.0040 | 1.790 | 0.600 |
| UTA | COR | H | ATRAZINE | 89 | 0.5 | 514 | 0.0026 | 1.180 | 0.390 |
| UTA | COR | H | ATRAZINE | 71 | 0.6 | 839 | 0.0001 | 0.030 | 0.010 |
| UTA | COR | I | DIAZINON | 259 | 0.2 | 2097 | 0.0000 | 0.000 | 0.000 |
| UTA | COR | I | DIAZINON | 148 | 0.3 | 2097 | 0.0000 | 0.000 | 0.000 |
| UTA | SGR | H | 2,4-D ACID | 259 | 0.2 | 34 | 0.0947 | 21.220 | 0.300 |
| UTA | SGR | H | 2,4-D ACID | 148 | 0.3 | 46 | 0.0412 | 9.240 | 0.130 |
| UTA | SGR | H | 2,4-D ACID | 106 | 0.4 | 356 | 0.0000 | 0.000 | 0.000 |
| UTA | SGR | H | 2,4-D ACID | 89 | 0.5 | 371 | 0.0000 | 0.000 | 0.000 |
| UTA | SGR | H | 2,4-D ACID | 71 | 0.6 | 412 | 0.0000 | 0.000 | 0.000 |
| UTA | SGR | H | 2,4-D ACID | 49 | 0.9 | 864 | 0.0000 | 0.000 | 0.000 |
| UTA | SGR | H | DICAMBA | 259 | 0.2 | 34 | 0.1857 | 5.200 | 0.580 |
| UTA | SGR | H | DICAMBA | 148 | 0.3 | 40 | 0.1380 | 3.860 | 0.430 |
| UTA | SGR | H | DICAMBA | 106 | 0.4 | 47 | 0.0976 | 2.730 | 0.300 |
| UTA | SGR | H | DICAMBA | 89 | 0.5 | 356 | 0.0000 | 0.000 | 0.000 |
| UTA | SGR | H | DICAMBA | 71 | 0.6 | 383 | 0.0000 | 0.000 | 0.000 |
| UTA | SGR | H | DIFENZOQUAT | 259 | 0.2 | 2056 | 0.0000 | 0.000 |  |
| WAS | ALF | H | HEXAZINONE | 259 | 0.2 | 71 | 0.5788 | 173.640 | 0.830 |
| WAS | ALF | H | HEXAZINONE | 148 | 0.3 | 89 | 0.5039 | 151.160 | 0.720 |
| WAS | ALF | H | HEXAZINONE | 106 | 0.4 | 104 | 0.4489 | 134.670 | 0.640 |
| WAS | ALF | H | HEXAZINONE | 89 | 0.5 | 124 | 0.3848 | 115.440 | 0.550 |
| WAS | ALF | H | HEXAZINONE | 71 | 0.6 | 165 | 0.2806 | 84.180 | 0.400 |
| WAS | ALF | H | METRIBUZIN | 259 | 0.2 | 71 | 0.1939 | 32.570 | 0.190 |
| WAS | ALF | H | METRIBUZIN | 148 | 0.3 | 89 | 0.1279 | 21.490 | 0.120 |
| WAS | ALF | H | METRIBUZIN | 106 | 0.4 | 104 | 0.0905 | 15.200 | 0.090 |
| WAS | ALF | H | METRIBUZIN | 89 | 0.5 | 118 | 0.0655 | 11.000 | 0.060 |
| WAS | ALF | H | METRIBUZIN | 71 | 0.6 | 158 | 0.0260 | 4.360 | 0.020 |
| WAS | ALF | I | CHLORPYRIFOS | 259 | 0.2 | 1878 | 0.0000 | 0.000 |  |
| WAS | ALF | I | PARATHION | 259 | 0.2 | 1535 | 0.0000 | 0.000 | 0.000 |
| WAS | ORC | I | AZINPHOS-METHYL | 259 | 0.2 | 339 | 0.0028 | 1.260 |  |
| WAS | ORC | I | AZINPHOS-METHYL | 148 | 0.3 | 475 | 0.0003 | 0.120 |  |
| WAS | ORC | I | AZINPHOS-METHYL | 106 | 0.4 | 1082 | 0.0000 | 0.000 |  |

Table 15. CMLS Simulations: Furrow Irrigation (cont.)

| COUNTY | CROP | Type | PESTICIDE NAME | d (mm) | Es | t(days) 2 m | RA 2 m | C(ppb) 2 m | RATIO 2 m |
|---|---|---|---|---|---|---|---|---|---|
| WEB | ALF | H | HEXAZINONE | 259 | 0.2 | 26 | 0.8185 | 245.560 | 1.170 |
| WEB | ALF | H | HEXAZINONE | 148 | 0.3 | 43 | 0.7181 | 215.420 | 1.030 |
| WEB | ALF | H | HEXAZINONE | 106 | 0.4 | 60 | 0.6300 | 188.990 | 0.900 |
| WEB | ALF | H | HEXAZINONE | 89 | 0.5 | 82 | 0.5318 | 159.530 | 0.760 |
| WEB | ALF | H | HEXAZINONE | 71 | 0.6 | 303 | 0.0969 | 29.080 | 0.140 |
| WEB | ALF | H | METRIBUZIN | 259 | 0.2 | 105 | 0.0884 | 14.850 | 0.080 |
| WEB | ALF | H | METRIBUZIN | 148 | 0.3 | 113 | 0.0735 | 12.340 | 0.070 |
| WEB | ALF | H | METRIBUZIN | 106 | 0.4 | 120 | 0.0625 | 10.500 | 0.060 |
| WEB | ALF | H | METRIBUZIN | 89 | 0.5 | 132 | 0.0474 | 7.960 | 0.050 |
| WEB | ALF | H | METRIBUZIN | 71 | 0.6 | 158 | 0.0260 | 4.360 | 0.020 |
| WEB | ALF | I | PARATHION | 259 | 0.2 | 2027 | 0.0000 | 0.000 | 0.000 |
| WEB | ALF | I,A,N | CARBOFURAN | 259 | 0.2 | 14 | 0.8236 | 184.480 | 5.120 |
| WEB | ALF | I,A,N | CARBOFURAN | 148 | 0.3 | 26 | 0.6974 | 156.210 | 4.340 |
| WEB | ALF | I,A,N | CARBOFURAN | 106 | 0.4 | 43 | 0.5510 | 123.410 | 3.430 |
| WEB | ALF | I,A,N | CARBOFURAN | 89 | 0.5 | 52 | 0.4863 | 108.940 | 3.030 |
| WEB | ALF | I,A,N | CARBOFURAN | 71 | 0.6 | 82 | 0.3209 | 71.870 | 2.000 |
| WEB | COR | H | METOLACHLOR | 259 | 0.2 | 103 | 0.0282 | 18.930 | 1.890 |
| WEB | COR | H | METOLACHLOR | 148 | 0.3 | 435 | 0.0000 | 0.000 | 0.000 |
| WEB | COR | H | METOLACHLOR | 106 | 0.4 | 485 | 0.0000 | 0.000 | 0.000 |
| WEB | COR | I | FONOFOS | 259 | 0.2 | 454 | 0.0009 | 0.210 | 0.010 |
| WEB | COR | I | FONOFOS | 148 | 0.3 | 840 | 0.0000 | 0.000 | 0.000 |
| WEB | COR | I | FONOFOS | 106 | 0.4 | 1193 | 0.0000 | 0.000 | 0.000 |
| WEB | ORC | F | BENOMYL | 259 | 0.2 | 268 | 0.4612 | 51.650 | |
| WEB | ORC | F | BENOMYL | 148 | 0.3 | 326 | 0.3900 | 43.680 | |
| WEB | ORC | F | BENOMYL | 106 | 0.4 | 357 | 0.3566 | 39.940 | |
| WEB | ORC | F | BENOMYL | 89 | 0.5 | 390 | 0.3242 | 36.310 | |
| WEB | ORC | F | BENOMYL | 71 | 0.6 | 668 | 0.1453 | 16.270 | |
| WEB | ORC | F | CHLOROTHALONIL | 259 | 0.2 | 995 | 0.0000 | 0.000 | 0.000 |
| WEB | ORC | I | AZINPHOS-METHYL | 259 | 0.2 | 661 | 0.0000 | 0.000 | |
| WEB | ORC | I | AZINPHOS-METHYL | 148 | 0.3 | 1311 | 0.0000 | 0.000 | |
| WEB | ORC | I | AZINPHOS-METHYL | 106 | 0.4 | 1738 | 0.0000 | 0.000 | |
| WEB | ORC | I | CHLORPYRIFOS | 259 | 0.2 | 1670 | 0.0000 | 0.000 | |
| WEB | ORC | I | ENDOSULFAN | 259 | 0.2 | 2049 | 0.0000 | 0.000 | |
| WEB | ORC | I | ENDOSULFAN | 148 | 0.3 | 2049 | 0.0000 | 0.000 | |
| WEB | ORC | I | ENDOSULFAN | 106 | 0.4 | 2049 | 0.0000 | 0.000 | |
| WEB | ORC | I | METHIDATHION | 259 | 0.2 | 152 | 0.0066 | 1.480 | |
| WEB | VEG | H | BENTAZON | 259 | 0.2 | 320 | 0.0000 | 0.000 | |
| WEB | VEG | H | BENTAZON | 148 | 0.3 | 329 | 0.0000 | 0.000 | |
| WEB | VEG | H | BENTAZON | 106 | 0.4 | 336 | 0.0000 | 0.000 | |
| WEB | VEG | H | EPTC | 259 | 0.2 | 407 | 0.0001 | 0.060 | |
| WEB | VEG | H | EPTC | 148 | 0.3 | 754 | 0.0000 | 0.000 | |
| WEB | VEG | H | EPTC | 106 | 0.4 | 894 | 0.0000 | 0.000 | |
| WEB | VEG | H | TRIFLURALIN | 259 | 0.2 | 2056 | 0.0000 | 0.000 | 0.000 |
| WEB | VEG | I | MALATHION | 259 | 0.2 | 2006 | 0.0000 | 0.000 | 0.000 |
| WEB | SGR | H | 2,4-D ACID | 259 | 0.2 | 32 | 0.1088 | 24.380 | 0.350 |
| WEB | SGR | H | 2,4-D ACID | 148 | 0.3 | 39 | 0.0670 | 15.000 | 0.210 |
| WEB | SGR | H | 2,4-D ACID | 106 | 0.4 | 45 | 0.0442 | 9.900 | 0.140 |
| WEB | SGR | H | 2,4-D ACID | 89 | 0.5 | 52 | 0.0272 | 6.090 | 0.090 |
| WEB | SGR | H | 2,4-D ACID | 71 | 0.6 | 375 | 0.0000 | 0.000 | 0.000 |

Table 16. CMLS Simulations: Sprinkler Irrigation

| COUNTY | CROP | Type | PESTICIDE NAME | UC | t(days) 2 m | RA 2 m | C(ppb) 2 m | RATIO 2 m |
|---|---|---|---|---|---|---|---|---|
| CAC | ALF | H | HEXAZINONE | 60 | 146 | 0.3248 | 97.50 | 0.464 |
| CAC | ALF | H | HEXAZINONE | 72 | 367 | 0.0592 | 17.80 | 0.085 |
| CAC | ALF | H | HEXAZINONE | 84 | 406 | 0.0439 | 13.20 | 0.063 |
| CAC | ALF | H | METRIBUZIN | 60 | 124 | 0.0570 | 9.60 | 0.055 |
| CAC | ALF | H | METRIBUZIN | 72 | 351 | 0.0003 | 0.10 | 0.000 |
| CAC | ALF | H | METRIBUZIN | 84 | 399 | 0.0001 | 0.00 | 0.000 |
| CAC | ALF | I,A,N | CARBOFURAN | 60 | 94 | 0.2717 | 60.90 | 1.690 |
| CAC | ALF | I,A,N | CARBOFURAN | 72 | 135 | 0.1539 | 34.50 | 0.958 |
| CAC | ALF | I,A,N | CARBOFURAN | 84 | 337 | 0.0094 | 2.10 | 0.058 |
| CAC | COR | H | ALACHLOR | 60 | 699 | 0.0000 | 0.00 | 0.000 |
| CAC | COR | H | ALACHLOR | 72 | 839 | 0.0000 | 0.00 | 0.000 |
| CAC | COR | H | ALACHLOR | 84 | 899 | 0.0000 | 0.00 | 0.000 |
| CAC | COR | H | ATRAZINE | 60 | 480 | 0.0039 | 1.80 | 0.583 |
| CAC | COR | H | ATRAZINE | 72 | 646 | 0.0006 | 0.30 | 0.086 |
| CAC | COR | H | ATRAZINE | 84 | 717 | 0.0003 | 0.10 | 0.038 |
| CAC | COR | H | CYANAZINE | 60 | 790 | 0.0000 | 0.00 | 0.000 |
| CAC | COR | H | CYANAZINE | 72 | 871 | 0.0000 | 0.00 | 0.000 |
| CAC | COR | H | CYANAZINE | 84 | 960 | 0.0000 | 0.00 | 0.000 |
| CAC | COR | H | METOLACHLOR | 60 | 800 | 0.0000 | 0.00 | 0.000 |
| CAC | COR | H | METOLACHLOR | 72 | 874 | 0.0000 | 0.00 | 0.000 |
| CAC | COR | H | METOLACHLOR | 84 | 1015 | 0.0000 | 0.00 | 0.000 |
| CAC | SGR | H | 2,4-D ACID | 60 | 379 | 0.0000 | 0.00 | 0.000 |
| CAC | SGR | H | 2,4-D ACID | 72 | 394 | 0.0000 | 0.00 | 0.000 |
| CAC | SGR | H | 2,4-D ACID | 84 | 529 | 0.0000 | 0.00 | 0.000 |
| CAC | SGR | H | DICAMBA | 60 | 351 | 0.0000 | 0.00 | 0.000 |
| CAC | SGR | H | DICAMBA | 72 | 366 | 0.0000 | 0.00 | 0.000 |
| CAC | SGR | H | DICAMBA | 84 | 394 | 0.0000 | 0.00 | 0.000 |
| CAC | SGR | H | METSULFURON | 60 | 430 | 0.0834 | 0.10 | |
| CAC | SGR | H | METSULFURON | 72 | 614 | 0.0288 | 0.00 | |
| CAC | SGR | H | METSULFURON | 84 | 673 | 0.0205 | 0.00 | |
| DAV | ALF | H | HEXAZINONE | 60 | 405 | 0.0442 | 13.30 | 0.063 |
| DAV | ALF | H | HEXAZINONE | 72 | 444 | 0.0327 | 9.80 | 0.047 |
| DAV | ALF | H | HEXAZINONE | 84 | 534 | 0.0164 | 4.90 | 0.023 |
| DAV | ALF | H | SETHOXYDIM | 60 | 379 | 0.0000 | | |
| DAV | ALF | H | SETHOXYDIM | 72 | 419 | 0.0000 | | |
| DAV | ALF | H | SETHOXYDIM | 84 | 498 | 0.0000 | | |
| DAV | ALF | I,A,N | CARBOFURAN | 60 | 296 | 0.0165 | 3.70 | 0.103 |
| DAV | ALF | I,A,N | CARBOFURAN | 72 | 335 | 0.0096 | 2.20 | 0.060 |
| DAV | ALF | I,A,N | CARBOFURAN | 84 | 384 | 0.0049 | 1.10 | 0.030 |
| DAV | COR | H | ALACHLOR | 60 | 1081 | 0.0000 | 0.00 | 0.000 |
| DAV | COR | H | ALACHLOR | 72 | 1179 | 0.0000 | 0.00 | 0.000 |
| DAV | COR | H | ALACHLOR | 84 | 1305 | 0.0000 | 0.00 | 0.000 |
| DAV | COR | H | METOLACHLOR | 60 | 1169 | 0.0000 | 0.00 | 0.000 |
| DAV | COR | H | METOLACHLOR | 72 | 1305 | 0.0000 | 0.00 | 0.000 |
| DAV | COR | H | METOLACHLOR | 84 | 1428 | 0.0000 | 0.00 | 0.000 |
| DAV | POT | H | METOLACHLOR | 60 | 1187 | 0.0000 | 0.00 | 0.000 |
| DAV | POT | H | METOLACHLOR | 72 | 1305 | 0.0000 | 0.00 | 0.000 |
| DAV | POT | H | METOLACHLOR | 84 | 1445 | 0.0000 | 0.00 | 0.000 |
| DAV | POT | H | METRIBUZIN | 60 | 455 | 0.0000 | 0.00 | 0.000 |
| DAV | POT | H | METRIBUZIN | 72 | 599 | 0.0000 | 0.00 | 0.000 |
| DAV | POT | H | METRIBUZIN | 84 | 680 | 0.0000 | 0.00 | 0.000 |
| DAV | POT | I,N | ALDICARB | 60 | 410 | 0.0001 | 0.00 | 0.003 |
| DAV | POT | I,N | ALDICARB | 72 | 449 | 0.0000 | 0.00 | 0.001 |
| DAV | POT | I,N | ALDICARB | 84 | 539 | 0.0000 | 0.00 | 0.000 |
| DAV | VEG | H | BENTAZON | 60 | 489 | 0.0000 | 0.00 | |
| DAV | SGR | H | 2,4-D ACID | 60 | 410 | 0.0000 | 0.00 | 0.000 |
| DAV | SGR | H | 2,4-D ACID | 72 | 670 | 0.0000 | 0.00 | 0.000 |
| DAV | SGR | H | 2,4-D ACID | 84 | 678 | 0.0000 | 0.00 | 0.000 |

Abbreviations: A = acaricide; H = herbicide; I = insecticide; N = nematicide; ALF = alfalfa; COR = corn ORC = orchards; POT = potato; SGR = Small grains; VEG = Vegetables; CAC = Cache county; DAV = Davis county; SEV = Sevier county; UTA = Utah county; WAS = Washington county; WEB = Weber county; t = travel time; RA = Relative Amount of Pesticide Remaining in the soil when the chemical front arrives at a given depth; d = average depth of water infiltrated in the soil; UC = uniformity coefficient; C = potential pesticide concentration in water table assuming a mixing volume of 500 liters of water; RATIO = C / h.a.l.

Table 16. CMLS Simulations: Sprinkler Irrigation (cont.)

| COUNTY | CROP | Type | PESTICIDE NAME | UC | t(days) 2 m | RA 2 m | C(ppb) 2 m | RATIO 2 m |
|---|---|---|---|---|---|---|---|---|
| SEV | ALF | H | HEXAZINONE | 60 | 466 | 0.0276 | 8.30 | 0.040 |
| SEV | ALF | H | HEXAZINONE | 72 | 532 | 0.0166 | 5.00 | 0.024 |
| SEV | ALF | H | HEXAZINONE | 84 | 1006 | 0.0004 | 0.10 | 0.001 |
| SEV | ALF | H | METRIBUZIN | 60 | 191 | 0.0121 | 2.00 | 0.012 |
| SEV | ALF | H | METRIBUZIN | 72 | 514 | 0.0000 | 0.00 | 0.000 |
| SEV | ALF | H | METRIBUZIN | 84 | 917 | 0.0000 | 0.00 | 0.000 |
| SEV | ALF | I,A,N | CARBOFURAN | 60 | 124 | 0.1792 | 40.20 | 1.115 |
| SEV | ALF | I,A,N | CARBOFURAN | 72 | 425 | 0.0028 | 0.60 | 0.017 |
| SEV | ALF | I,A,N | CARBOFURAN | 84 | 824 | 0.0000 | 0.00 | 0.000 |
| SEV | COR | H | ATRAZINE | 60 | 845 | 0.0001 | 0.00 | 0.009 |
| SEV | COR | H | ATRAZINE | 72 | 1887 | 0.0000 | 0.00 | 0.000 |
| SEV | COR | H | ATRAZINE | 84 | 2071 | 0.0000 | 0.00 | 0.000 |
| SEV | COR | H | DICAMBA | 60 | 414 | 0.0000 | 0.00 | 0.000 |
| SEV | COR | H | DICAMBA | 72 | 467 | 0.0000 | 0.00 | 0.000 |
| SEV | COR | H | DICAMBA | 84 | 1877 | 0.0000 | 0.00 | 0.000 |
| SEV | COR | I | FONOFOS | 60 | 2068 | 0.0000 | 0.00 | 0.000 |
| SEV | COR | I | FONOFOS | 72 | 2068 | 0.0000 | 0.00 | 0.000 |
| SEV | COR | I | FONOFOS | 84 | 2068 | 0.0000 | 0.00 | 0.000 |
| SEV | COR | I,A,N | CARBOFURAN | 60 | 449 | 0.0020 | 0.90 | 0.025 |
| SEV | COR | I,A,N | CARBOFURAN | 72 | 803 | 0.0000 | 0.00 | 0.000 |
| SEV | COR | I,A,N | CARBOFURAN | 84 | 1943 | 0.0000 | 0.00 | 0.000 |
| SEV | SGR | H | 2,4-D ACID | 60 | 730 | 0.0000 | 0.00 | 0.000 |
| SEV | SGR | H | 2,4-D ACID | 72 | 1096 | 0.0000 | 0.00 | 0.000 |
| SEV | SGR | H | 2,4-D ACID | 84 | 2046 | 0.0000 | 0.00 | 0.000 |
| SEV | SGR | I | BARBAN | 60 | 746 | 0.0000 | 0.00 | |
| SEV | SGR | I | BARBAN | 72 | 1128 | 0.0000 | 0.00 | |
| SEV | SGR | I | BARBAN | 84 | 2071 | 0.0000 | 0.00 | |
| UTA | COR | H | 2,4-D ACID | 60 | 422 | 0.0000 | 0.00 | 0.000 |
| UTA | COR | H | 2,4-D ACID | 72 | 490 | 0.0000 | 0.00 | 0.000 |
| UTA | COR | H | 2,4-D ACID | 84 | 662 | 0.0000 | 0.00 | 0.000 |
| UTA | COR | H | ATRAZINE | 60 | 728 | 0.0002 | 0.10 | 0.033 |
| UTA | COR | H | ATRAZINE | 72 | 871 | 0.0000 | 0.00 | 0.006 |
| UTA | COR | H | ATRAZINE | 84 | 971 | 0.0000 | 0.00 | 0.002 |
| UTA | SGR | H | 2,4-D ACID | 60 | 390 | 0.0000 | 0.00 | 0.000 |
| UTA | SGR | H | 2,4-D ACID | 72 | 601 | 0.0000 | 0.00 | 0.000 |
| UTA | SGR | H | 2,4-D ACID | 84 | 654 | 0.0000 | 0.00 | 0.000 |
| UTA | SGR | H | DICAMBA | 60 | 371 | 0.0000 | 0.00 | 0.000 |
| UTA | SGR | H | DICAMBA | 72 | 399 | 0.0000 | 0.00 | 0.000 |
| UTA | SGR | H | DICAMBA | 84 | 616 | 0.0000 | 0.00 | 0.000 |
| WAS | ALF | H | HEXAZINONE | 60 | 143 | 0.3324 | 99.70 | 0.475 |
| WAS | ALF | H | HEXAZINONE | 72 | 184 | 0.2424 | 72.70 | 0.346 |
| WAS | ALF | H | HEXAZINONE | 84 | 487 | 0.0235 | 7.10 | 0.034 |
| WAS | ALF | H | METRIBUZIN | 60 | 136 | 0.0432 | 7.30 | 0.042 |
| WAS | ALF | H | METRIBUZIN | 72 | 166 | 0.0216 | 3.60 | 0.021 |
| WAS | ALF | H | METRIBUZIN | 84 | 469 | 0.0000 | 0.00 | 0.000 |
| WEB | ALF | H | HEXAZINONE | 60 | 303 | 0.0969 | 29.10 | 0.139 |
| WEB | ALF | H | HEXAZINONE | 72 | 335 | 0.0758 | 22.70 | 0.108 |
| WEB | ALF | H | HEXAZINONE | 84 | 358 | 0.0635 | 19.00 | 0.091 |
| WEB | ALF | H | METRIBUZIN | 60 | 149 | 0.0320 | 5.40 | 0.031 |
| WEB | ALF | H | METRIBUZIN | 72 | 177 | 0.0167 | 2.80 | 0.016 |
| WEB | ALF | H | METRIBUZIN | 84 | 409 | 0.0001 | 0.00 | 0.000 |
| WEB | ALF | I,A,N | CARBOFURAN | 60 | 60 | 0.4353 | 97.50 | 2.708 |
| WEB | ALF | I,A,N | CARBOFURAN | 72 | 101 | 0.2466 | 55.20 | 1.534 |
| WEB | ALF | I,A,N | CARBOFURAN | 84 | 303 | 0.0150 | 3.40 | 0.093 |
| WEB | COR | H | METOLACHLOR | 60 | 818 | 0.0000 | 0.00 | 0.000 |
| WEB | COR | H | METOLACHLOR | 72 | 888 | 0.0000 | 0.00 | 0.000 |
| WEB | COR | H | METOLACHLOR | 84 | 1056 | 0.0000 | 0.00 | 0.000 |
| WEB | COR | I | FONOFOS | 60 | 1665 | 0.0000 | 0.00 | 0.000 |
| WEB | COR | I | FONOFOS | 72 | 2066 | 0.0000 | 0.00 | 0.000 |
| WEB | COR | I | FONOFOS | 84 | 2066 | 0.0000 | 0.00 | 0.000 |
| WEB | SGR | H | 2,4-D ACID | 60 | 374 | 0.0000 | 0.00 | 0.000 |
| WEB | SGR | H | 2,4-D ACID | 72 | 388 | 0.0000 | 0.00 | 0.000 |
| WEB | SGR | H | 2,4-D ACID | 84 | 524 | 0.0000 | 0.00 | 0.000 |

# Appendix B. Pesticide Library

| | | Type[1] | Health Advisory (ppb) |
|---|---|---|---|
| Common Name | :2,4-D ACID | H | 70 |
| Partition Coefficient | :20 ml/g OC | | |
| Half-Life | :10 days | | |
| Trade Name | :DACAMINE | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :2,4-D ESTER | H | 70 |
| Partition Coefficient | :1000 ml/g OC | | |
| Half-Life | :10 days | | |
| Trade Name | :AQUA KLEEN | | |
| Trade Name | :WEEDONE | | |
| Trade Name | :EMULSAMINE | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :2,4-D AMINE SALT | H | 70 |
| Partition Coefficient | :109 ml/g OC | | |
| Half-Life | :10 days | | |
| Trade Name | :WEEDAR | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :2,4-DB ESTER | H | 70 |
| Partition Coefficient | :1000 ml/g OC | | |
| Half-Life | :10 days | | |
| Trade Name | :BUTYRAC ESTER | | |
| Trade Name | :BUTOXONE | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :2,4-DB AMINE | H | 70 |
| Partition Coefficient | :20 ml/g OC | | |
| Half-Life | :10 days | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :ALACHLOR | H | 1.5 |
| Partition Coefficient | :170 ml/g OC | | |
| Half-Life | :15 days | | |
| Trade Name | :ALANEX | | |
| Trade Name | :PILLARZO | | |
| Trade Name | :LASSO | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :ALDICARB | I | 10 |
| Partition Coefficient | :10 ml/g OC | | |
| Half-Life | :30 days | | |
| Trade Name | :TEMIK | | |
| Trade Name | :TEMIK15G | | |
| Trade Name | :OMS 771 | | |
| Trade Name | :UC21149 | | |
| | | | |
| Common Name | :ASSERT | H | |
| Partition Coefficient | :35 ml/g OC | | |
| Half-Life | :35 days | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :ATRAZINE | H | 3 |
| Partition Coefficient | :100 ml/g OC | | |
| Half-Life | :60 days | | |
| Trade Name | :AATREX | | |
| Trade Name | :GRIFFEX | | |
| Trade Name | :ATRANEX | | |
| Trade Name | :VECTAL SC | | |

---

[1] I-Insecticide; H-Herbicide; F-Fungicide; G-Growth Regulator; M-Miticide

```
                                                 Type      Health Advisory (ppb)

Common Name           :AZINPHOS-METHYL             I
Partition Coefficient :1000 ml/g OC
Half-Life             :40 days
Trade Name            :GUTHION
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :BARBAN                      I
Partition Coefficient :30 ml/g OC
Half-Life             :30 days
Trade Name            :CARBYNE
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :BENEFIN                     H
Partition Coefficient :9000 ml/g OC
Half-Life             :40 days
Trade Name            :BATAN
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :BENOMYL                     F
Partition Coefficient :190 ml/g OC
Half-Life             :240 days
Trade Name            :BENLATE
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :BENSULIDE                   H
Partition Coefficient :10000 ml/g OC
Half-Life             :120 days
Trade Name            :PREFAR
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :BENTAZON                    H
Partition Coefficient :35 ml/g OC
Half-Life             :20 days
Trade Name            :BASAGRAN
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :BROMACIL ACID               H
Partition Coefficient :32 ml/g OC
Half-Life             :60 days
Trade Name            :HYVAR XL
Trade Name            :BOROCIL
Trade Name            :UREABOR
Trade Name            :HYVAR X

Common Name           :BROMOXYNIL                  H
Partition Coefficient :190 ml/g OC
Half-Life             :5 days
Trade Name            :BROMINAL
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :BUTYLATE                    H
Partition Coefficient :126 ml/g OC
Half-Life             :12 days
Trade Name            :SUTAN PLUS
Trade Name            :.
Trade Name            :.
Trade Name            :.
```

| | | Type | Health Advisory (ppb) |
|---|---|---|---|
| Common Name | :CAPTAN | F | |
| Partition Coefficient | :100 ml/g OC | | |
| Half-Life | :3 days | | |
| Trade Name | :CAPTAN | | |
| Trade Name | :ORTHOCIDE | | |
| Trade Name | :PILLARCAP | | |
| Trade Name | :VONDCAPTAN | | |
| Common Name | :CARBARYL | I | 700 |
| Partition Coefficient | :200 ml/g OC | | |
| Half-Life | :10 days | | |
| Trade Name | :SEVIN | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Common Name | :CARBOFURAN | I | 36 |
| Partition Coefficient | :22 ml/g OC | | |
| Half-Life | :50 days | | |
| Trade Name | :FURADAN | | |
| Trade Name | :BAY 70143 | | |
| Trade Name | :YALTOX | | |
| Trade Name | :CURATERR | | |
| Common Name | :CHLORDANE | I | |
| Partition Coefficient | :38000 ml/g OC | | |
| Half-Life | :3500 days | | |
| Trade Name | :CHLORDAN | | |
| Trade Name | :ORTHO-KLOR | | |
| Trade Name | :BELT | | |
| Trade Name | :. | | |
| Common Name | :CHLOROTHALONIL | F | 1.5 |
| Partition Coefficient | :1380 ml/g OC | | |
| Half-Life | :30 days | | |
| Trade Name | :BRAVO | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Common Name | :CHLORPYRIFOS | I | |
| Partition Coefficient | :6070 ml/g OC | | |
| Half-Life | :30 days | | |
| Trade Name | :LORSBAN | | |
| Trade Name | :BRODAN | | |
| Trade Name | :DURSBAN | | |
| Trade Name | :ERADEX | | |
| Common Name | :CHLORSULFURON | H | |
| Partition Coefficient | :1 ml/g OC | | |
| Half-Life | :160 days | | |
| Trade Name | :GLEAN | | |
| Trade Name | :TELAR | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Common Name | :CLOPYRALID | H | |
| Partition Coefficient | :1 ml/g OC | | |
| Half-Life | :30 days | | |
| Trade Name | :STRINGER | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Common Name | :CYANAZINE | H | 9 |
| Partition Coefficient | :190 ml/g OC | | |
| Half-Life | :14 days | | |
| Trade Name | :BLADEX | | |
| Trade Name | :FORTROL | | |
| Trade Name | :SD 15418 | | |
| Trade Name | :WL 19805 | | |

```
                                                   Type      Health Advisory (ppb)


Common Name            :DAMINOZIDE                  G
Partition Coefficient  :10 ml/g OC
Half-Life              :7 days
Trade Name             :ALAR
Trade Name             :ALAR
Trade Name             :.
Trade Name             :.

Common Name            :DCPA                        H                 3500
Partition Coefficient  :5000 ml/g OC
Half-Life              :100 days
Trade Name             :DACTHAL
Trade Name             :.
Trade Name             :.
Trade Name             :.

Common Name            :DEMENTON                    I                 35
Partition Coefficient  :51 ml/g OC
Half-Life              :30 days
Trade Name             :METASYSTOX
Trade Name             :.
Trade Name             :.
Trade Name             :.

Common Name            :DIAZINON                    I                 0.63
Partition Coefficient  :500 ml/g OC
Half-Life              :40 days
Trade Name             :BASUDIN
Trade Name             :DIANON
Trade Name             :SPECTRACIDE
Trade Name             :.

Common Name            :DICAMBA                     H                 9
Partition Coefficient  :2 ml/g OC
Half-Life              :14 days
Trade Name             :BANVEL D
Trade Name             :BANEX
Trade Name             :DIANAT
Trade Name             :WEEDMASTER

Common Name            :DICLOFOP-METHYL             H
Partition Coefficient  :48500 ml/g OC
Half-Life              :2 days
Trade Name             :HOELON
Trade Name             :.
Trade Name             :.
Trade Name             :.

Common Name            :DIELDRIN                    I
Partition Coefficient  :8400 ml/g OC
Half-Life              :1000 days
Trade Name             :ALVIT
Trade Name             :DIELDREX
Trade Name             :DIELDRITE
Trade Name             :OCTALOX

Common Name            :DIFENZOQUAT                 H
Partition Coefficient  :54500 ml/g OC
Half-Life              :100 days
Trade Name             :AVENGE
Trade Name             :.
Trade Name             :.
Trade Name             :.

Common Name            :DIMETHOATE                  I
Partition Coefficient  :8 ml/g OC
Half-Life              :7 days
Trade Name             :CYGON
Trade Name             :.
Trade Name             :.
Trade Name             :.
```

| | | Type | Health Advisory (ppb) |
|---|---|---|---|
| Common Name | :DINOSEB | I | |
| Partition Coefficient | :120 ml/g OC | | |
| Half-Life | :30 days | | |
| Trade Name | :DNBP | | |
| Trade Name | :BASANITE | | |
| Trade Name | :KILOSEB | | |
| Trade Name | :CHEMOX | | |
| Common Name | :DISULFOTON | I | 0.3 |
| Partition Coefficient | :1600 ml/g OC | | |
| Half-Life | :5 days | | |
| Trade Name | :DISYSTON | | |
| Trade Name | :DITHIOSYSTOX | | |
| Trade Name | :THIODEMETON | | |
| Trade Name | :DITHIODEMETON | | |
| Common Name | :DIURON | H | |
| Partition Coefficient | :480 ml/g OC | | |
| Half-Life | :90 days | | |
| Trade Name | :KARMEX | | |
| Trade Name | :UROX D | | |
| Trade Name | :DIREX 4L | | |
| Trade Name | :DIUROL | | |
| Common Name | :ENDOSULFAN | I | |
| Partition Coefficient | :2040 ml/g OC | | |
| Half-Life | :120 days | | |
| Trade Name | :THIODAN | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Common Name | :ENDRIN | I | |
| Partition Coefficient | :8100 ml/g OC | | |
| Half-Life | :4300 days | | |
| Trade Name | :ENDREX | | |
| Trade Name | :HEXADRIN | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Common Name | :EPTC | H | |
| Partition Coefficient | :280 ml/g OC | | |
| Half-Life | :30 days | | |
| Trade Name | :EPTAM | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Common Name | :ESFENVALERATE | I | |
| Partition Coefficient | :5300 ml/g OC | | |
| Half-Life | :35 days | | |
| Trade Name | :ASANA | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Common Name | :ETHOPROP | I | |
| Partition Coefficient | :70 ml/g OC | | |
| Half-Life | :50 days | | |
| Trade Name | :MOCAP | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Common Name | :FENVALERATE | I | |
| Partition Coefficient | :5300 ml/g OC | | |
| Half-Life | :35 days | | |
| Trade Name | :PYDRIN | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |

```
                                                Type       Health Advisory (ppb)


Common Name           :FLUAZIFOP-P-BUTYL           H
Partition Coefficient :3000 ml/g OC
Half-Life             :20 days
Trade Name            :FUSILADE
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :FONOFOS                     I               14
Partition Coefficient :532 ml/g OC
Half-Life             :45 days
Trade Name            :DYFONATE
Trade Name            :N-2790
Trade Name            :.
Trade Name            :.

Common Name           :GLYPHOSATE                  H               700
Partition Coefficient :24000 ml/g OC
Half-Life             :47 days
Trade Name            :ROUNDUP
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :HEPTACHLOR                  I
Partition Coefficient :24000 ml/g OC
Half-Life             :2000 days
Trade Name            :DRINOX
Trade Name            :HEPTOX
Trade Name            :HEPTAMUL
Trade Name            :.

Common Name           :HEXAZINONE                  H               210
Partition Coefficient :54 ml/g OC
Half-Life             :90 days
Trade Name            :VELPAR
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :LINDANE                     I
Partition Coefficient :1100 ml/g OC
Half-Life             :400 days
Trade Name            :GAMMA BHC
Trade Name            :ISOTOX
Trade Name            :LINTOX
Trade Name            :SILVANOL

Common Name           :LINURON                     H
Partition Coefficient :370 ml/g OC
Half-Life             :60 days
Trade Name            :AFALON
Trade Name            :HOE 2810
Trade Name            :LOROX L
Trade Name            :LINUREX

Common Name           :MALATHION                   I               140
Partition Coefficient :1800 ml/g OC
Half-Life             :1 days
Trade Name            :MERCAPTOTHION
Trade Name            :CALMATHION
Trade Name            :CARBOFOS
Trade Name            :CYTHION

Common Name           :MANEB                       F
Partition Coefficient :1000 ml/g OC
Half-Life             :60 days
Trade Name            :DITHANE
Trade Name            :MANEB
Trade Name            :.
Trade Name            :.
```

```
                                                  Type       Health Advisory (ppb)

Common Name           :MCPA ESTER                  H                 3.6
Partition Coefficient :1000 ml/g OC
Half-Life             :14 days
Trade Name            :WEEDONE
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :METHAMIDOPHOS               I
Partition Coefficient :1 ml/g OC
Half-Life             :6 days
Trade Name            :MONITOR
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :METHIDATHION                I
Partition Coefficient :400 ml/g OC
Half-Life             :21 days
Trade Name            :SUPRACIDE
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :METHYL PARATHION            I                 2
Partition Coefficient :5100 ml/g OC
Half-Life             :5 days
Trade Name            :METAFOS
Trade Name            :PARATHION-METHYL
Trade Name            :DEVITHION
Trade Name            :NITROX 80

Common Name           :METOLACHLOR                 H                 10
Partition Coefficient :200 ml/g OC
Half-Life             :20 days
Trade Name            :DUAL
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :METHOMIL                    I
Partition Coefficient :72 ml/g OC
Half-Life             :33 days
Trade Name            :LANNATE
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :METRIBUZIN                  H                 175
Partition Coefficient :41 ml/g OC
Half-Life             :30 days
Trade Name            :LEXONE
Trade Name            :SENCOR
Trade Name            :.
Trade Name            :.

Common Name           :METSULFURON                 H
Partition Coefficient :61 ml/g OC
Half-Life             :120 days
Trade Name            :ALLY
Trade Name            :ESCORT
Trade Name            :.
Trade Name            :.

Common Name           :MEVINPHOS                   I
Partition Coefficient :1 ml/g OC
Half-Life             :3 days
Trade Name            :PHOSDRIN
Trade Name            :.
Trade Name            :.
Trade Name            :.
```

| | | Type | Health Advisory (ppb) |
|---|---|---|---|
| Common Name | :NAPTALAM | H | |
| Partition Coefficient | :30 ml/g OC | | |
| Half-Life | :14 days | | |
| Trade Name | :ALANAP | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :OXAMYL | I | |
| Partition Coefficient | :25 ml/g OC | | |
| Half-Life | :4 days | | |
| Trade Name | :VYDATE | | |
| Trade Name | :VYDATE L | | |
| Trade Name | :VYDATE G | | |
| Trade Name | :HA-2214 | | |
| | | | |
| Common Name | :OXYDEMETON-METHYL | I | |
| Partition Coefficient | :1 ml/g OC | | |
| Half-Life | :10 days | | |
| Trade Name | :MSR | | |
| Trade Name | :METASYSTOX | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :OXYFLUORFEN | H | |
| Partition Coefficient | :100000 ml/g OC | | |
| Half-Life | :35 days | | |
| Trade Name | :GOAL | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :PARAQUAT | H | |
| Partition Coefficient | :100000 ml/g OC | | |
| Half-Life | :500 days | | |
| Trade Name | :GRAMOXONE | | |
| Trade Name | :GRAMOXONE | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :PARATHION | H | 35 |
| Partition Coefficient | :5000 ml/g OC | | |
| Half-Life | :14 days | | |
| Trade Name | :THIOPHOS | | |
| Trade Name | :BLADAN | | |
| Trade Name | :ORTHOPHOS | | |
| Trade Name | :PANTHION | | |
| | | | |
| Common Name | :PENDIMETHALIN | H | |
| Partition Coefficient | :24300 ml/g OC | | |
| Half-Life | :90 days | | |
| Trade Name | :PROWL | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :PERMETHRIN | I | |
| Partition Coefficient | :86000 ml/g OC | | |
| Half-Life | :32 days | | |
| Trade Name | :POUNCE | | |
| Trade Name | :AMBUSH | | |
| Trade Name | :. | | |
| Trade Name | :. | | |
| | | | |
| Common Name | :PHORATE | I | |
| Partition Coefficient | :2000 ml/g OC | | |
| Half-Life | :90 days | | |
| Trade Name | :THIMET | | |
| Trade Name | :RAMPART | | |
| Trade Name | :AGRIMET | | |
| Trade Name | :GEOMET | | |

```
                                                   Type      Health Advisory (ppb)


Common Name           :PHOSPHAMIDON                  I
Partition Coefficient :1 ml/g OC
Half-Life             :17 days
Trade Name            :SWAT
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :PHOSMET                       I
Partition Coefficient :612 ml/g OC
Half-Life             :12 days
Trade Name            :IMIDAN
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :PICLORAM                      H
Partition Coefficient :16 ml/g OC
Half-Life             :908 days
Trade Name            :TORDON
Trade Name            :TORDON 22K
Trade Name            :AMDON
Trade Name            :GRAZON

Common Name           :PROMETON                      H                100
Partition Coefficient :300 ml/g OC
Half-Life             :120 days
Trade Name            :PRAMITOL
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :PRONAMID                      H                52
Partition Coefficient :990 ml/g OC
Half-Life             :60 days
Trade Name            :KERB
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :PROPARGITE                    M
Partition Coefficient :8000 ml/g OC
Half-Life             :56 days
Trade Name            :COMITE
Trade Name            :OMITE
Trade Name            :.
Trade Name            :.

Common Name           :SETHOXYDIM                    H
Partition Coefficient :50 ml/g OC
Half-Life             :10 days
Trade Name            :POAST
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :SIMAZINE                      H                35
Partition Coefficient :138 ml/g OC
Half-Life             :75 days
Trade Name            :AQUAZINE
Trade Name            :PRINCEP
Trade Name            :SIMADEX
Trade Name            :SIM-TROL

Common Name           :TERBACIL                      H
Partition Coefficient :55 ml/g OC
Half-Life             :120 days
Trade Name            :SINBAR
Trade Name            :.
Trade Name            :.
Trade Name            :.
```

```
                                                 Type       Health Advisory (ppb)


Common Name           :TERBUFOS                    I                 0.18
Partition Coefficient :3000 ml/g OC
Half-Life             :5 days
Trade Name            :COUNTER
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :TRIALLATE                   H
Partition Coefficient :2400 ml/g OC
Half-Life             :82 days
Trade Name            :FARGO
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :TRIADIMEFON                 F
Partition Coefficient :273 ml/g OC
Half-Life             :21 days
Trade Name            :BAYLETON
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :TRIFLURALIN                 H                 2
Partition Coefficient :7000 ml/g OC
Half-Life             :60 days
Trade Name            :ELANCOLAN
Trade Name            :TREFANOCIDE
Trade Name            :TREFLAN
Trade Name            :TRIM

Common Name           :TRIMETHACARB                I
Partition Coefficient :200 ml/g OC
Half-Life             :10 days
Trade Name            :BROOT
Trade Name            :.
Trade Name            :.
Trade Name            :.

Common Name           :VERNOLATE                   H
Partition Coefficient :330 ml/g OC
Half-Life             :12 days
Trade Name            :SAFER
Trade Name            :SURPASS
```

## Appendix C. Soil Library

# Soil Library

Soil Name : HARRISBURG Identifier : UTU003
County : Washington Region : Dixie

| Horizon | Depth | Organic Carbon | Bulk Density | Volumetric Water Content, (%) at | | |
|---|---|---|---|---|---|---|
| | (m) | (%) | (Mg/cu meter) | -0.01 MPa | -1.5 MPa | Saturation |
| 1 | 0.05 | 0.22 | 1.70 | 13.0 | 5.5 | 40.0 |
| 2 | 0.41 | 0.14 | 1.66 | 13.5 | 6.0 | 40.0 |
| 3 | 0.66 | 0.09 | 1.69 | 13.5 | 6.0 | 40.0 |
| 4 | 0.89 | 0.21 | 1.59 | 13.5 | 6.5 | 40.0 |
| 5 | 0.99 | 0.10 | 1.59 | 13.5 | 6.5 | 40.0 |

Soil Name : KIDMAN Identifier : UT0395
County : Davis Region : North Central

| Horizon | Depth | Organic Carbon | Bulk Density | Volumetric Water Content, (%) at | | |
|---|---|---|---|---|---|---|
| | (m) | (%) | (Mg/cu meter) | -0.01 MPa | -1.5 MPa | Saturation |
| 1 | 0.28 | 1.20 | 1.52 | 18.0 | 6.4 | 40.0 |
| 2 | 0.43 | 0.70 | 1.52 | 18.5 | 6.4 | 40.0 |
| 3 | 0.53 | 0.80 | 1.53 | 20.0 | 6.9 | 40.0 |
| 4 | 0.69 | 0.40 | 1.54 | 22.0 | 7.0 | 40.0 |
| 5 | 0.94 | 0.20 | 1.40 | 21.5 | 5.3 | 40.0 |
| 6 | 1.24 | 0.20 | 1.45 | 21.5 | 5.7 | 40.0 |
| 7 | 1.47 | 0.10 | 1.42 | 18.0 | 4.4 | 40.0 |

Soil Name : LAYTON Identifier : UT0338
County : Weber Region : North Central

| Horizon | Depth | Organic Carbon | Bulk Density | Volumetric Water Content, (%) at | | |
|---|---|---|---|---|---|---|
| | (m) | (%) | (Mg/cu meter) | -0.01 MPa | -1.5 MPa | Saturation |
| 1 | 0.18 | 0.70 | 1.55 | 12.5 | 3.7 | 40.0 |
| 2 | 0.38 | 0.50 | 1.55 | 13.0 | 4.0 | 40.0 |
| 3 | 0.58 | 0.20 | 1.55 | 14.0 | 4.5 | 40.0 |
| 4 | 0.74 | 0.20 | 1.55 | 12.5 | 4.0 | 40.0 |
| 5 | 1.04 | 0.10 | 1.54 | 12.0 | 3.3 | 40.0 |
| 6 | 1.68 | 0.10 | 1.52 | 8.0 | 1.7 | 42.0 |

Soil Name : LEWISTON Identifier : UT0546
County : Cache Region : North Central

| Horizon | Depth | Organic Carbon | Bulk Density | Volumetric Water Content, (%) at | | |
|---|---|---|---|---|---|---|
| | (m) | (%) | (Mg/cu meter) | -0.01 MPa | -1.5 MPa | Saturation |
| 1 | 0.25 | 0.60 | 1.55 | 14.0 | 7.0 | 41.0 |
| 2 | 0.33 | 0.42 | 1.66 | 16.0 | 11.0 | 41.0 |
| 3 | 0.56 | 0.39 | 1.59 | 22.0 | 14.0 | 41.0 |
| 4 | 0.81 | 0.16 | 1.64 | 18.0 | 12.0 | 41.0 |
| 5 | 1.52 | 0.08 | 1.58 | 12.0 | 6.0 | 41.0 |

Soil Name : SEVIER Identifier : SE1
County : Sevier Region : South Central

| Horizon | Depth | Organic Carbon | Bulk Density | Volumetric Water Content, (%) at | | |
|---|---|---|---|---|---|---|
| | (m) | (%) | (Mg/cu meter) | -0.01 MPa | -1.5 MPa | Saturation |
| 1 | 0.15 | 1.00 | 1.35 | 20.0 | 10.0 | 43.0 |
| 2 | 0.30 | 0.70 | 1.35 | 20.0 | 10.0 | 43.0 |
| 3 | 0.60 | 0.30 | 1.35 | 20.0 | 8.0 | 43.0 |
| 4 | 0.90 | 0.20 | 1.35 | 20.0 | 10.0 | 43.0 |
| 5 | 1.00 | 0.10 | 1.35 | 20.0 | 10.0 | 43.0 |

```
Soil Name : VINEYARD                 Identifier : UT0350
County    : Utah                     Region     : North Central
Horizon  Depth  Organic Carbon  Bulk Density  Volumetric Water Content, (%) at
          (m)         (%)       (Mg/cu meter)  -0.01 MPa  -1.5 MPa  Saturation
   1     0.18        0.81          1.70          16.0       8.0        40.0
   2     0.33        0.47          1.70          16.0       8.0        40.0
   3     0.61        0.31          1.70          17.0       9.0        40.0
   4     0.89        0.21          1.70          18.0       9.0        40.0
   5     1.07        0.21          1.70          19.0      10.0        40.0
   6     1.52        0.12          1.70          16.0       8.0        40.0


Soil Name : SAND                     Identifier : SAND
Horizon  Depth  Organic Carbon  Bulk Density  Volumetric Water Content, (%) at
          (m)         (%)       (Mg/cu meter)  -0.01 MPa  -1.5 MPa  Saturation
   1     0.25        1.00          1.60           9.1       3.3        39.6
   2     1.50        0.10          1.60           9.1       3.3        39.6


Soil Name : LOAMY SAND               Identifier : LOAMY SAND
Horizon  Depth  Organic Carbon  Bulk Density  Volumetric Water Content, (%) at
          (m)         (%)       (Mg/cu meter)  -0.01 MPa  -1.5 MPa  Saturation
   1     0.25        1.20          1.50          12.5       5.5        43.4
   2     1.50        0.11          1.50          12.5       5.5        43.4


Soil Name : SANDY LOAM               Identifier : SANDY LOAM
Horizon  Depth  Organic Carbon  Bulk Density  Volumetric Water Content, (%) at
          (m)         (%)       (Mg/cu meter)  -0.01 MPa  -1.5 MPa  Saturation
   1     0.25        1.30          1.49          20.7       9.5        43.8
   2     1.50        0.12          1.49          20.7       9.5        43.8


Soil Name : LOAM                     Identifier : LOAM
Horizon  Depth  Organic Carbon  Bulk Density  Volumetric Water Content, (%) at
          (m)         (%)       (Mg/cu meter)  -0.01 MPa  -1.5 MPa  Saturation
   1     0.25        1.50          1.42          27.0      11.7        46.4
   2     1.50        0.13          1.42          27.0      11.7        46.4


Soil Name : SILT LOAM                Identifier : SILT LOAM
Horizon  Depth  Organic Carbon  Bulk Density  Volumetric Water Content, (%) at
          (m)         (%)       (Mg/cu meter)  -0.01 MPa  -1.5 MPa  Saturation
   1     0.25        2.00          1.32          33.0      13.3        50.2
   2     1.50        0.14          1.32          33.0      13.3        50.2


Soil Name : SANDY CLAY LOAM          Identifier : SANDY CLAY LOAM
Horizon  Depth  Organic Carbon  Bulk Density  Volumetric Water Content, (%) at
          (m)         (%)       (Mg/cu meter)  -0.01 MPa  -1.5 MPa  Saturation
   1     0.25        2.50          1.60          25.7      14.8        39.6
   2     1.50        0.15          1.60          25.7      14.8        39.6
```

```
Soil Name : CLAY LOAM                    Identifier : CLAY LOAM
Horizon  Depth  Organic Carbon  Bulk Density  Volumetric Water Content, (%) at
          (m)        (%)        (Mg/cu meter)  -0.01 MPa  -1.5 MPa  Saturation
   1     0.25       3.00            1.30         31.8       19.7        50.9
   2     1.50       0.16            1.30         31.8       19.7        50.9


Soil Name : SILTY CLAY LOAM              Identifier : SILTY CLAY LOAM
Horizon  Depth  Organic Carbon  Bulk Density  Volumetric Water Content, (%) at
          (m)        (%)        (Mg/cu meter)  -0.01 MPa  -1.5 MPa  Saturation
   1     0.25       3.50            1.40         36.6       20.8        47.2
   2     1.50       0.17            1.40         36.6       20.8        47.2


Soil Name : SANDY CLAY                   Identifier : SANDY CLAY
Horizon  Depth  Organic Carbon  Bulk Density  Volumetric Water Content, (%) at
          (m)        (%)        (Mg/cu meter)  -0.01 MPa  -1.5 MPa  Saturation
   1     0.25       4.00            1.55         33.9       23.9        41.5
   2     1.50       0.18            1.55         33.9       23.9        41.5


Soil Name : SILTY CLAY                   Identifier : SILTY CLAY
Horizon  Depth  Organic Carbon  Bulk Density  Volumetric Water Content, (%) at
          (m)        (%)        (Mg/cu meter)  -0.01 MPa  -1.5 MPa  Saturation
   1     0.25       4.50            1.45         38.7       25.0        45.3
   2     1.50       0.19            1.45         38.7       25.0        45.3


Soil Name : CLAY                         Identifier : CLAY
Horizon  Depth  Organic Carbon  Bulk Density  Volumetric Water Content, (%) at
          (m)        (%)        (Mg/cu meter)  -0.01 MPa  -1.5 MPa  Saturation
   1     0.25       5.00            1.30         39.6       27.2        50.9
   2     1.50       0.20            1.30         39.6       27.2        50.9
```

# Appendix D. Irrigation Schedules

Table 17. Irrigation Schedules: Alternative Pesticides

| Crop | Date | d(mm) |
|---|---|---|
| Alfalfa | | |
| | 05/15 | 75 |
| | 06/01 | 150 |
| | 06/15 | 150 |
| | 07/01 | 150 |
| | 07/15 | 150 |
| | 08/01 | 150 |
| | 08/15 | 150 |
| | 09/01 | 150 |
| | 09/15 | 75 |
| Corn | | |
| | 05/10 | 75 |
| | 05/20 | 75 |
| | 06/01 | 125 |
| | 06/15 | 125 |
| | 07/01 | 125 |
| | 07/15 | 125 |
| | 08/01 | 125 |
| | 08/15 | 125 |
| | 09/01 | 125 |
| | 09/15 | 125 |

---

Values given in tables are from Eisele et al., 1989. Values, d, represent depth of water expresed in millimeters required for different crop, assuming a 50% of irrigation efficiency.

Table 17. Irrigation Schedules: Alternative Pesticides (cont.)

| Crop | Date | d(mm) |
|---|---|---|
| Orchards | | |
| | 05/01 | 75 |
| | 05/15 | 100 |
| | 06/01 | 125 |
| | 06/15 | 125 |
| | 07/01 | 125 |
| | 07/15 | 125 |
| | 08/01 | 125 |
| | 08/15 | 125 |
| | 09/01 | 125 |
| | 09/15 | 125 |
| | 10/01 | 125 |
| | 10/15 | 100 |
| Potato | | |
| | 05/01 | 50 |
| | 05/10 | 50 |
| | 05/20 | 50 |
| | 06/10 | 75 |
| | 06/10 | 75 |
| | 06/20 | 75 |
| | 07/01 | 75 |
| | 07/10 | 75 |
| | 07/20 | 75 |
| | 08/01 | 75 |
| | 08/10 | 75 |

Table 17. Irrigation Schedules: Alternative Pesticides (cont.)

| Crop | Date | d(mm) |
|---|---|---|
| Small Grains | | |
| | 05/25 | 150 |
| | 06/05 | 150 |
| | 06/15 | 150 |
| | 07/01 | 150 |
| | 07/15 | 150 |
| Vegetables | | |
| | 05/10 | 50 |
| | 05/15 | 50 |
| | 05/20 | 50 |
| | 05/25 | 50 |
| | 05/30 | 80 |
| | 06/04 | 80 |
| | 06/09 | 80 |
| | 06/14 | 80 |
| | 06/19 | 80 |
| | 06/24 | 80 |
| | 06/29 | 80 |
| | 07/04 | 80 |
| | 07/09 | 80 |
| | 07/14 | 80 |

Table 18. Irrigation Schedule[a]: Furrow and Sprinkler Irrigation.

| Crop | North Central | South Central | Dixie |
|---|---|---|---|
| Alfalfa | | | |
| | 05/14 | 05/17 | 05/09 |
| | 05/25 | 05/27 | 05/18 |
| | 06/07 | 06/07 | 05/25 |
| | 06/17 | 06/14 | 05/31 |
| | 06/24 | 06/21 | 06/07 |
| | 07/04 | 07/03 | 06/14 |
| | 07/15 | 07/11 | 06/20 |
| | 07/24 | 07/30 | 06/26 |
| | 08/04 | 08/08 | 07/03 |
| | 08/13 | 08/17 | 07/11 |
| | 08/22 | 08/26 | 07/18 |
| | 09/04 | 09/05 | 07/28 |
| | *** | 09/22 | 08/06 |
| | *** | *** | 08/16 |
| | *** | *** | 08/27 |
| | *** | *** | 09/04 |
| | *** | *** | 09/13 |
| Corn | | | |
| | 06/23 | 06/09 | |
| | 07/08 | 06/29 | |
| | 07/15 | 07/07 | |
| | 07/23 | 07/15 | |
| | 07/30 | 07/24 | |
| | 08/06 | 08/02 | |
| | 08/12 | 08/10 | |
| | 08/22 | 08/24 | |
| | 08/31 | 09/01 | |

---

[a] Average dates of irrigation considering six years of data.

Table 18. Irrigation Schedule: Furrow and Sprinkler Irrigation (cont.)

| Crop | North Central | South Central | Dixie |
|---|---|---|---|
| Orchards | | | |
| | 06/12 | 05/07 | 05/14 |
| | 06/20 | 05/26 | 05/24 |
| | 06/27 | 06/07 | 06/03 |
| | 07/06 | 06/14 | 06/10 |
| | 07/13 | 06/21 | 06/17 |
| | 07/20 | 07/02 | 06/23 |
| | 07/26 | 07/08 | 06/29 |
| | 08/02 | 07/15 | 07/09 |
| | 08/08 | 07/31 | 07/15 |
| | 08/15 | 08/07 | 07/21 |
| | 08/24 | 08/14 | 07/27 |
| | 09/02 | 09/21 | 08/02 |
| | 09/18 | 08/28 | 08/08 |
| | 10/01 | 09/06 | 08/14 |
| | *** | 09/22 | 08/21 |
| | *** | 10/06 | 08/29 |
| | *** | *** | 09/06 |
| | *** | *** | 09/17 |
| | *** | *** | 09/27 |
| | *** | *** | 10/07 |
| Potato | | | |
| | 04/21 | | |
| | 05/08 | | |
| | 05/25 | | |
| | 06/10 | | |
| | 06/24 | | |
| | 07/09 | | |
| | 07/17 | | |
| | 07/26 | | |
| | 08/06 | | |
| | 08/16 | | |

Table 18. Irrigation Schedule: Furrow and Sprinkler Irrigation (cont.)

| Crop | North Central | South Central |
|---|---|---|
| Small grains | | |
| | 05/20 | 05/23 |
| | 05/29 | 05/30 |
| | 06/08 | 06/08 |
| | 06/16 | 06/14 |
| | 06/23 | 06/19 |
| | *** | 06/29 |
| | *** | 07/14 |
| Vegetables | | |
| | 06/10 | 06/04 |
| | 06/19 | 06/10 |
| | 06/26 | 06/16 |
| | 07/02 | 06/22 |
| | 07/08 | 06/28 |
| | 07/14 | 07/04 |
| | *** | 07/08 |
| | *** | 07/12 |

## Appendix E. Seasonal Soil-Water Budget

Table 19. Seasonal Soil-Water Budget

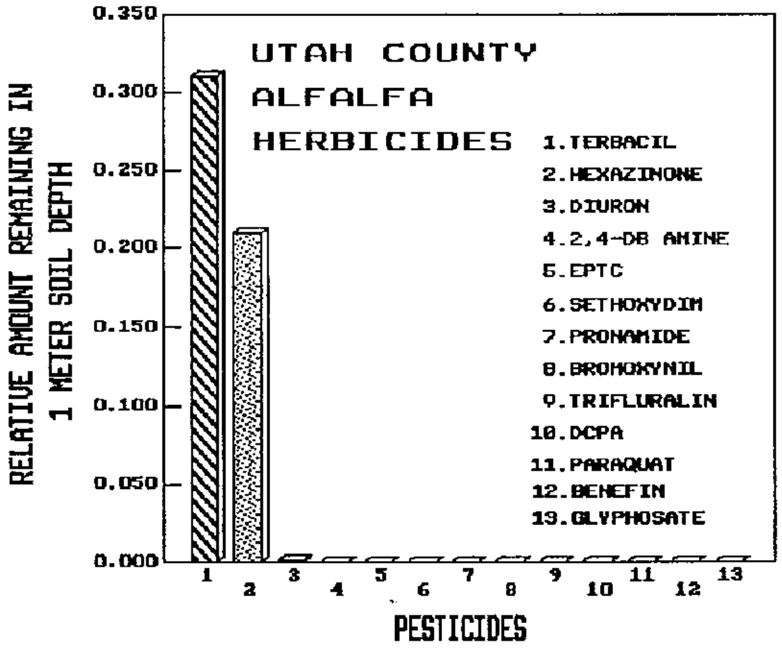
| CROP | YEAR | REGION | SEASON | ET mm | $R_{in}$ mm | d mm | $I_{num}$ | $T_{iw}$ mm | $d_r$ mm |
|---|---|---|---|---|---|---|---|---|---|
| ALFALFA | 1980 | NORTH CENTRAL | 5/8-9/22 | 729 | 242 | 89 | 11 | 979 | 492 |
| | 1981 | | | 760 | 108 | 89 | 14 | 1246 | 594 |
| | 1982 | | | 728 | 165 | 89 | 12 | 1068 | 506 |
| | 1983 | | | 704 | 218 | 89 | 10 | 890 | 404 |
| | 1984 | | | 715 | 160 | 89 | 12 | 1068 | 514 |
| | 1985 | | | 754 | 143 | 89 | 12 | 1068 | 457 |
| | AVG | | | 732 | 173 | 89 | 12 | 1053 | 494 |
| | 1980 | SOUTH CENTRAL | 5/8-9/22 | 767 | 157 | 89 | 12 | 1068 | 458 |
| | 1981 | | | 779 | 122 | 89 | 13 | 1157 | 500 |
| | 1982 | | | 740 | 154 | 89 | 12 | 1068 | 481 |
| | 1983 | | | 747 | 125 | 89 | 13 | 1157 | 535 |
| | 1984 | | | 792 | 135 | 89 | 12 | 1068 | 411 |
| | 1985 | | | 766 | 127 | 89 | 13 | 1157 | 519 |
| | AVG | | | 765 | 137 | 89 | 13 | 1113 | 484 |
| | 1980 | DIXIE | 5/8-9/22 | 899 | 55 | 89 | 16 | 1424 | 580 |
| | 1981 | | | 919 | 76 | 89 | 16 | 1424 | 580 |
| | 1982 | | | 886 | 75 | 89 | 16 | 1424 | 613 |
| | 1983 | | | 921 | 80 | 89 | 17 | 1513 | 671 |
| | 1984 | | | 944 | 47 | 89 | 17 | 1513 | 616 |
| | 1985 | | | 954 | 62 | 89 | 17 | 1513 | 620 |
| | AVG | | | 921 | 66 | 89 | 17 | 1469 | 613 |
| CORN | 1980 | NORTH CENTRAL | 5/8-9/22 | 589 | 241 | 89 | 9 | 801 | 453 |
| | 1981 | | | 616 | 107 | 89 | 10 | 890 | 381 |
| | 1982 | | | 578 | 164 | 89 | 9 | 801 | 387 |
| | 1983 | | | 562 | 217 | 89 | 7 | 623 | 278 |
| | 1984 | | | 561 | 159 | 89 | 8 | 712 | 311 |
| | 1985 | | | 596 | 142 | 89 | 9 | 801 | 347 |
| | AVG | | | 584 | 172 | 89 | 9 | 771 | 359 |
| | 1980 | SOUTH CENTRAL | 5/8-9/22 | 613 | 136 | 89 | 10 | 890 | 414 |
| | 1981 | | | 617 | 121 | 89 | 10 | 890 | 394 |
| | 1982 | | | 582 | 152 | 89 | 8 | 712 | 283 |
| | 1983 | | | 586 | 123 | 89 | 9 | 801 | 338 |
| | 1984 | | | 601 | 138 | 89 | 8 | 712 | 249 |
| | 1985 | | | 599 | 126 | 89 | 10 | 890 | 417 |
| | AVG | | | 597 | 133 | 89 | 9 | 816 | 349 |
| ORCHARDS | 1980 | NORTH CENTRAL | 4/24-10/22 | 885 | 298 | 89 | 14 | 1246 | 658 |
| | 1981 | | | 906 | 215 | 89 | 16 | 1424 | 733 |
| | 1982 | | | 855 | 273 | 89 | 13 | 1157 | 574 |
| | 1983 | | | 837 | 421 | 89 | 12 | 1068 | 652 |
| | 1984 | | | 824 | 258 | 89 | 13 | 1157 | 592 |
| | 1985 | | | 893 | 166 | 89 | 15 | 1335 | 608 |
| | AVG | | | 867 | 272 | 89 | 14 | 1231 | 636 |
| | 1980 | SOUTH CENTRAL | 4/24-10/22 | 930 | 184 | 89 | 16 | 1424 | 679 |
| | 1981 | | | 936 | 204 | 89 | 16 | 1424 | 693 |
| | 1982 | | | 881 | 186 | 89 | 14 | 1246 | 552 |
| | 1983 | | | 889 | 156 | 89 | 14 | 1246 | 513 |
| | 1984 | | | 913 | 183 | 89 | 16 | 1424 | 694 |
| | 1985 | | | 912 | 166 | 89 | 16 | 1424 | 679 |
| | AVG | | | 910 | 180 | 89 | 15 | 1365 | 635 |

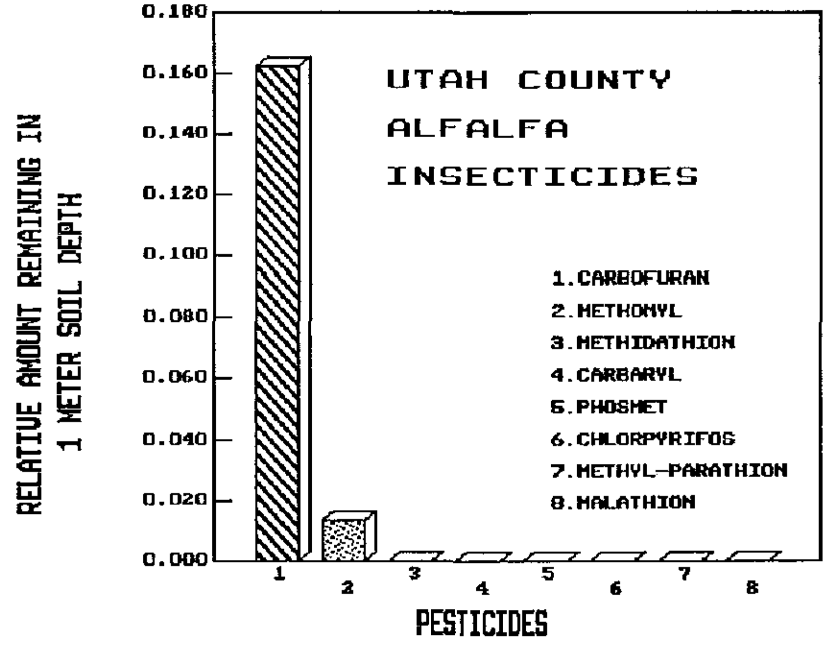
Abbreviations: ET = sesonal $ET_{crop}$; $R_{in}$ = seasonal rain fall; $I_{num}$ = number of irrigations in the season; $T_{iw}$ = total water infiltrated in the seson; d = average water depth infiltrated in each irrigation considering 0.5 water-storage efficiency; $d_r$ = seasonal drainage ($R_{in}$ + $T_{iw}$ - ET); AVG = average values.

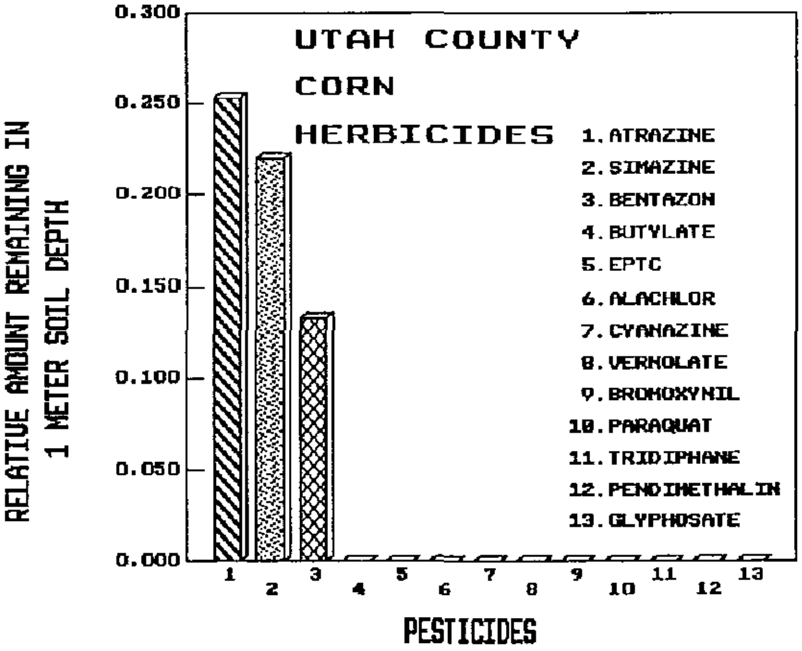
Table 19. Seasonal Soil Water Budget (cont.)

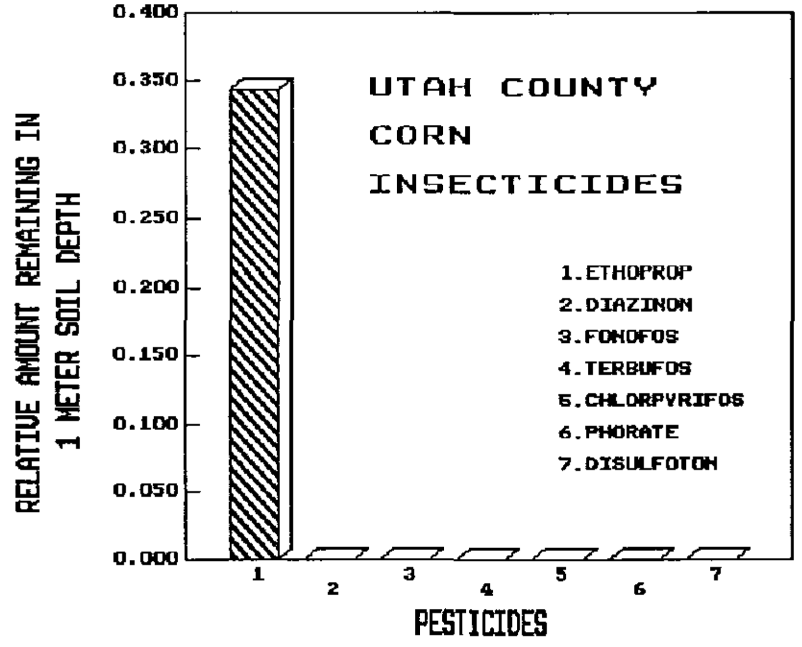
| CROP | YEAR | REGION | SEASON | ET mm | $R_{in}$ mm | d mm | $I_{num}$ | $T_{iw}$ mm | $d_r$ mm |
|---|---|---|---|---|---|---|---|---|---|
| ORCHARDS | 1980 | DIXIE | 4/24-10/22 | 1087 | 86 | 89 | 20 | 1780 | 780 |
| (Cont.) | 1981 | | | 1103 | 85 | 89 | 20 | 1780 | 762 |
| | 1982 | | | 1062 | 95 | 89 | 20 | 1780 | 813 |
| | 1983 | | | 1086 | 142 | 89 | 19 | 1691 | 747 |
| | 1984 | | | 1109 | 63 | 89 | 21 | 1869 | 823 |
| | 1985 | | | 1141 | 83 | 89 | 21 | 1869 | 811 |
| | AVG | | | 1098 | 92 | 89 | 20 | 1795 | 789 |
| POTATO | 1980 | NORTH CENTRAL | 4/14-8/17 | 447 | 243 | 89 | 10 | 890 | 419 |
| | 1981 | | | 461 | 98 | 89 | 11 | 917 | 350 |
| | 1982 | | | 434 | 98 | 89 | 10 | 890 | 286 |
| | 1983 | | | 422 | 241 | 89 | 9 | 801 | 353 |
| | 1984 | | | 413 | 148 | 89 | 9 | 801 | 270 |
| | 1985 | | | 456 | 70 | 89 | 11 | 917 | 326 |
| | AVG | | | 439 | 150 | 89 | 10 | 869 | 334 |
| SMALL GRAINS | 1980 | NORTH CENTRAL | 5/8-7/22 | 401 | 210 | 89 | 4 | 356 | 165 |
| | 1981 | | | 413 | 97 | 89 | 6 | 534 | 218 |
| | 1982 | | | 410 | 83 | 89 | 5 | 445 | 117 |
| | 1983 | | | 392 | 111 | 89 | 5 | 445 | 164 |
| | 1984 | | | 405 | 89 | 89 | 6 | 534 | 218 |
| | 1985 | | | 436 | 67 | 89 | 6 | 534 | 165 |
| | AVG | | | 409 | 109 | 89 | 5 | 475 | 175 |
| | 1980 | SOUTH CENTRAL | 5/8-7/22 | 430 | 52 | 89 | 7 | 623 | 245 |
| | 1981 | | | 443 | 72 | 89 | 6 | 534 | 163 |
| | 1982 | | | 425 | 74 | 89 | 6 | 534 | 183 |
| | 1983 | | | 420 | 52 | 89 | 7 | 623 | 255 |
| | 1984 | | | 473 | 80 | 89 | 6 | 534 | 142 |
| | 1985 | | | 448 | 105 | 89 | 7 | 623 | 280 |
| | AVG | | | 442 | 73 | 89 | 7 | 579 | 211 |
| VEGETABLE | 1980 | NORTH CENTRAL | 5/3-7/21 | 258 | 222 | 89 | 5 | 445 | 409 |
| | 1981 | | | 274 | 96 | 89 | 6 | 534 | 357 |
| | 1982 | | | 268 | 81 | 89 | 5 | 445 | 258 |
| | 1983 | | | 261 | 120 | 89 | 5 | 445 | 304 |
| | 1984 | | | 273 | 92 | 89 | 6 | 534 | 354 |
| | 1985 | | | 303 | 60 | 89 | 7 | 623 | 380 |
| | AVG | | | 273 | 112 | 89 | 6 | 504 | 344 |
| | 1980 | SOUTH CENTRAL | 5/8-7/22 | 362 | 62 | 89 | 8 | 712 | 412 |
| | 1981 | | | 367 | 83 | 89 | 7 | 623 | 339 |
| | 1982 | | | 346 | 75 | 89 | 7 | 623 | 352 |
| | 1983 | | | 349 | 55 | 89 | 8 | 712 | 418 |
| | 1984 | | | 368 | 77 | 89 | 9 | 801 | 510 |
| | 1985 | | | 364 | 93 | 89 | 8 | 712 | 441 |
| | AVG | | | 359 | 74 | 89 | 8 | 697 | 412 |

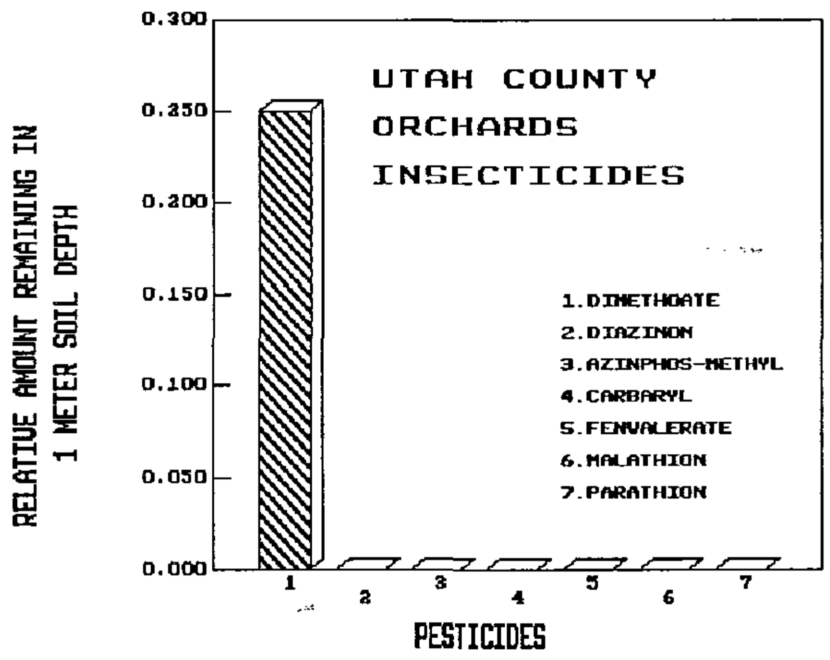
# Appendix F. BMSs Graphical Outputs

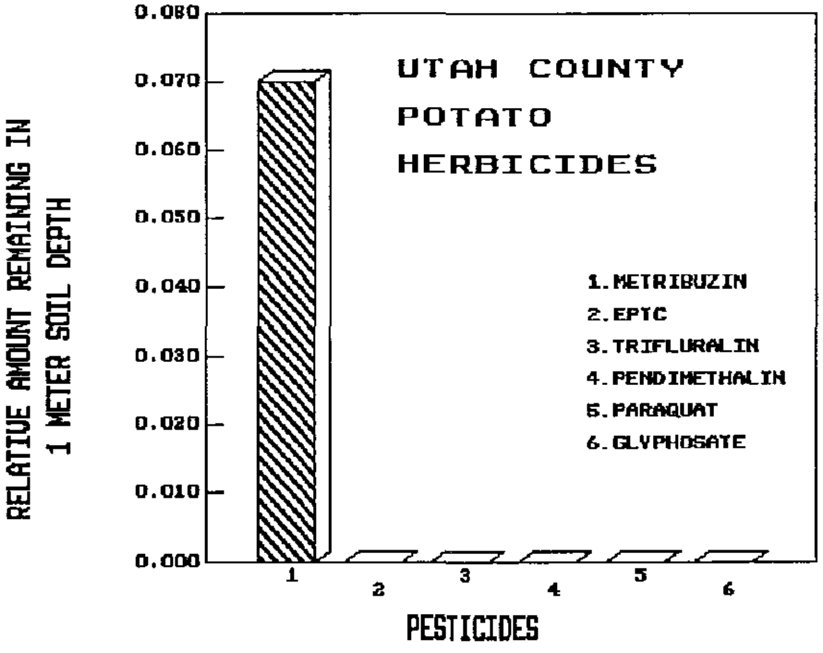

UTAH COUNTY
ALFALFA
HERBICIDES
1.TERBACIL
2.HEXAZINONE
3.DIURON
4.2,4-DB AMINE
5.EPTC
6.SETHOXYDIM
7.PRONAMIDE
8.BROMOXYNIL
9.TRIFLURALIN
10.DCPA
11.PARAQUAT
12.BENEFIN
13.GLYPHOSATE
RELATIVE AMOUNT REMAINING IN 1 METER SOIL DEPTH
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1
2
3
4
5
6
7
8
9
10
11
12
13
PESTICIDES

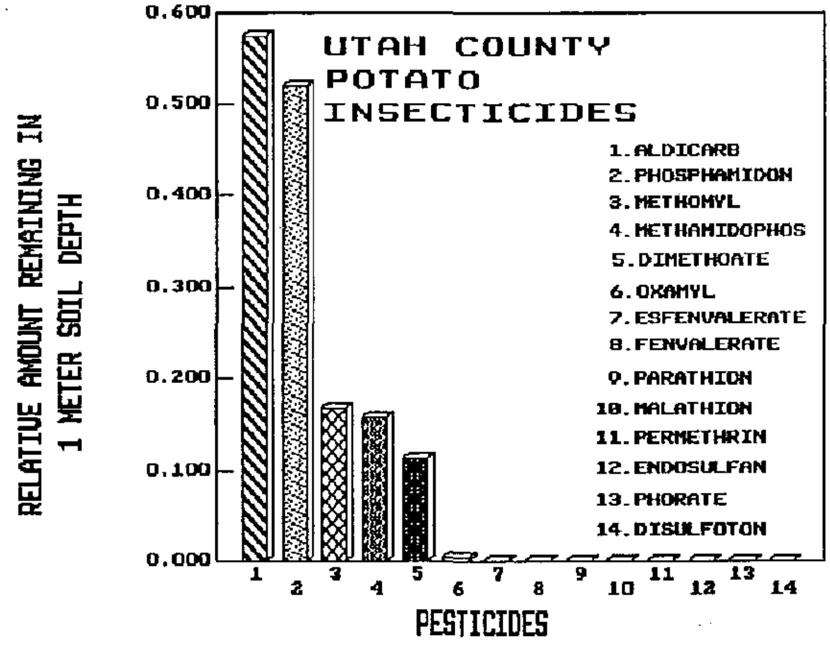

UTAH COUNTY
ALFALFA
INSECTICIDES
RELATIVE AMOUNT REMAINING IN
1 METER SOIL DEPTH
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
1.CARBOFURAN
2.METHOMYL
3.METHIDATHION
4.CARBARYL
5.PHOSMET
6.CHLORPYRIFOS
7.METHYL-PARATHION
8.MALATHION
1
2
3
4
5
6
7
8
PESTICIDES

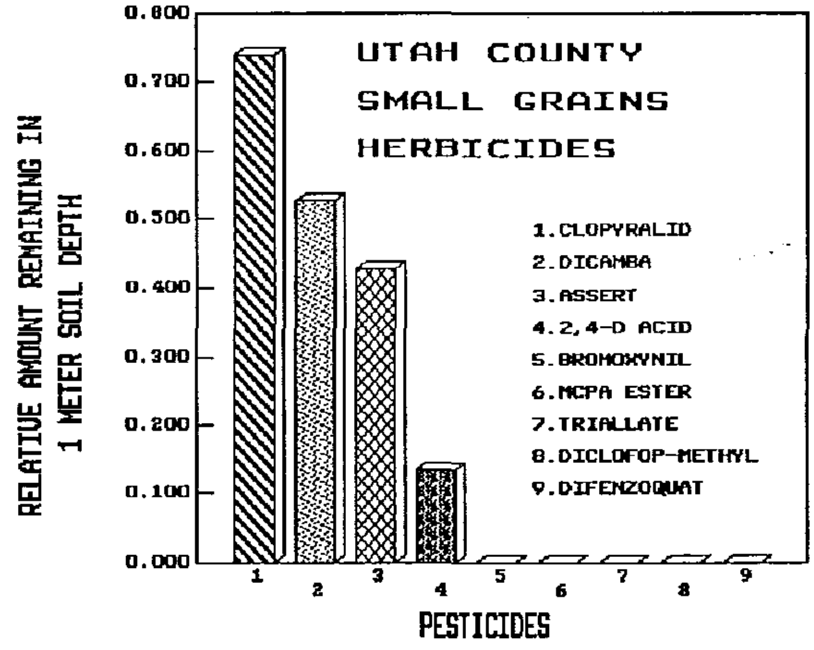

UTAH COUNTY
CORN
HERBICIDES
1. ATRAZINE
2. SIMAZINE
3. BENTAZON
4. BUTYLATE
5. EPTC
6. ALACHLOR
7. CYANAZINE
8. VERNOLATE
9. BROMOXYNIL
10. PARAQUAT
11. TRIDIPHANE
12. PENDIMETHALIN
13. GLYPHOSATE
RELATIVE AMOUNT REMAINING IN 1 METER SOIL DEPTH
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1
2
3
4
5
6
7
8
9
10
11
12
13
PESTICIDES

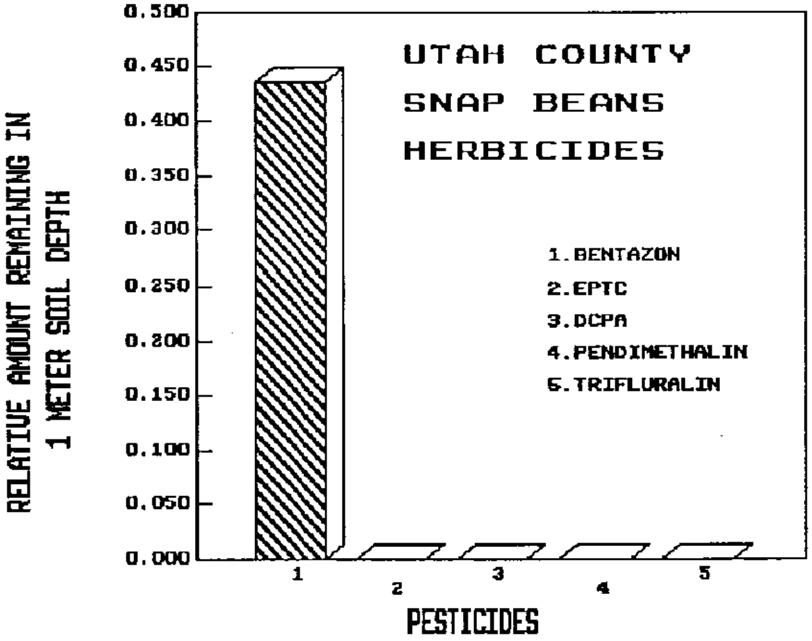

UTAH COUNTY
CORN
INSECTICIDES
RELATIVE AMOUNT REMAINING IN 1 METER SOIL DEPTH
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1
2
3
4
5
6
7
PESTICIDES
1. ETHOPROP
2. DIAZINON
3. FONOFOS
4. TERBUFOS
5. CHLORPYRIFOS
6. PHORATE
7. DISULFOTON

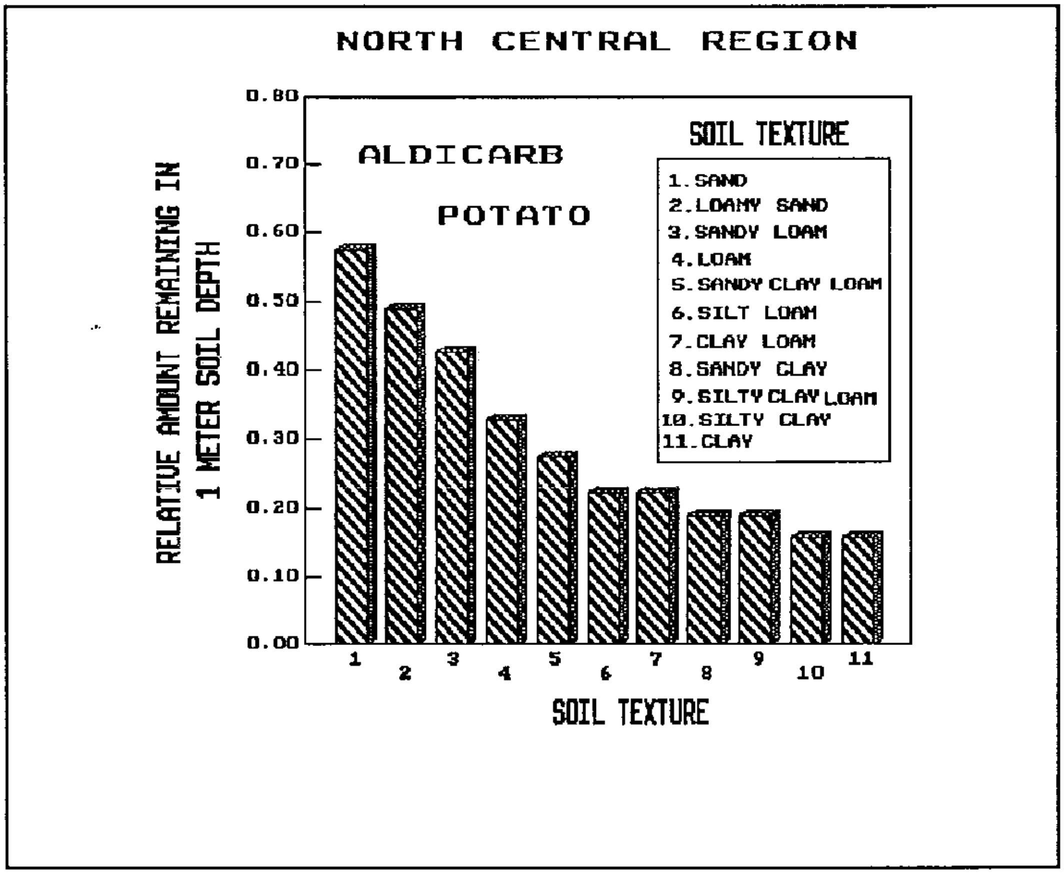

UTAH COUNTY
ORCHARDS
INSECTICIDES
RELATIVE AMOUNT REMAINING IN
1 METER SOIL DEPTH
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1
2
3
4
5
6
7
PESTICIDES
1.DIMETHOATE
2.DIAZINON
3.AZINPHOS-METHYL
4.CARBARYL
5.FENVALERATE
6.MALATHION
7.PARATHION

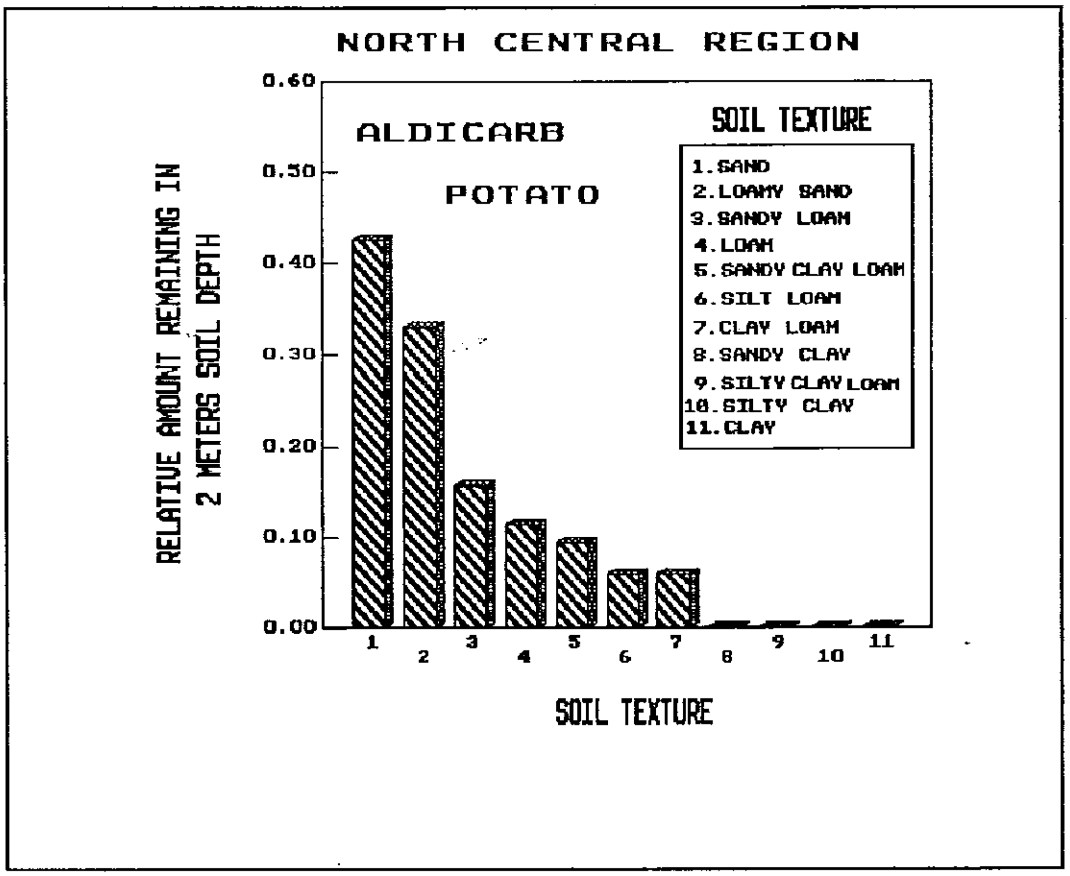

UTAH COUNTY
POTATO
HERBICIDES
RELATIVE AMOUNT REMAINING IN
1 METER SOIL DEPTH
0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
1
2
3
4
5
6
PESTICIDES
1. METRIBUZIN
2. EPTC
3. TRIFLURALIN
4. PENDIMETHALIN
5. PARAQUAT
6. GLYPHOSATE

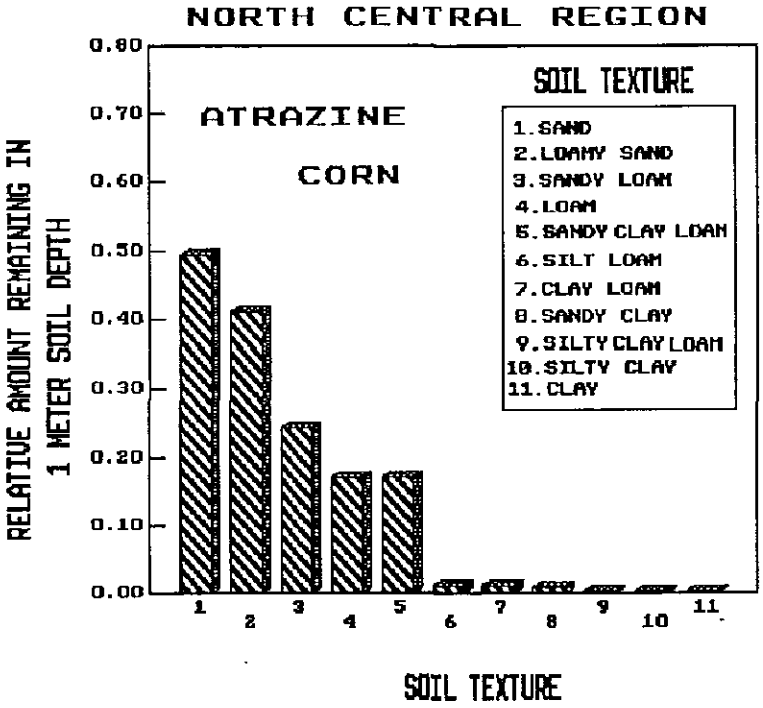

UTAH COUNTY
POTATO
INSECTICIDES
1. ALDICARB
2. PHOSPHAMIDON
3. METHOMYL
4. METHAMIDOPHOS
5. DIMETHOATE
6. OXAMYL
7. ESFENVALERATE
8. FENVALERATE
9. PARATHION
10. MALATHION
11. PERMETHRIN
12. ENDOSULFAN
13. PHORATE
14. DISULFOTON
RELATIVE AMOUNT REMAINING IN 1 METER SOIL DEPTH
0.000
0.100
0.200
0.300
0.400
0.500
0.600
1
2
3
4
5
6
7
8
9
10
11
12
13
14
PESTICIDES

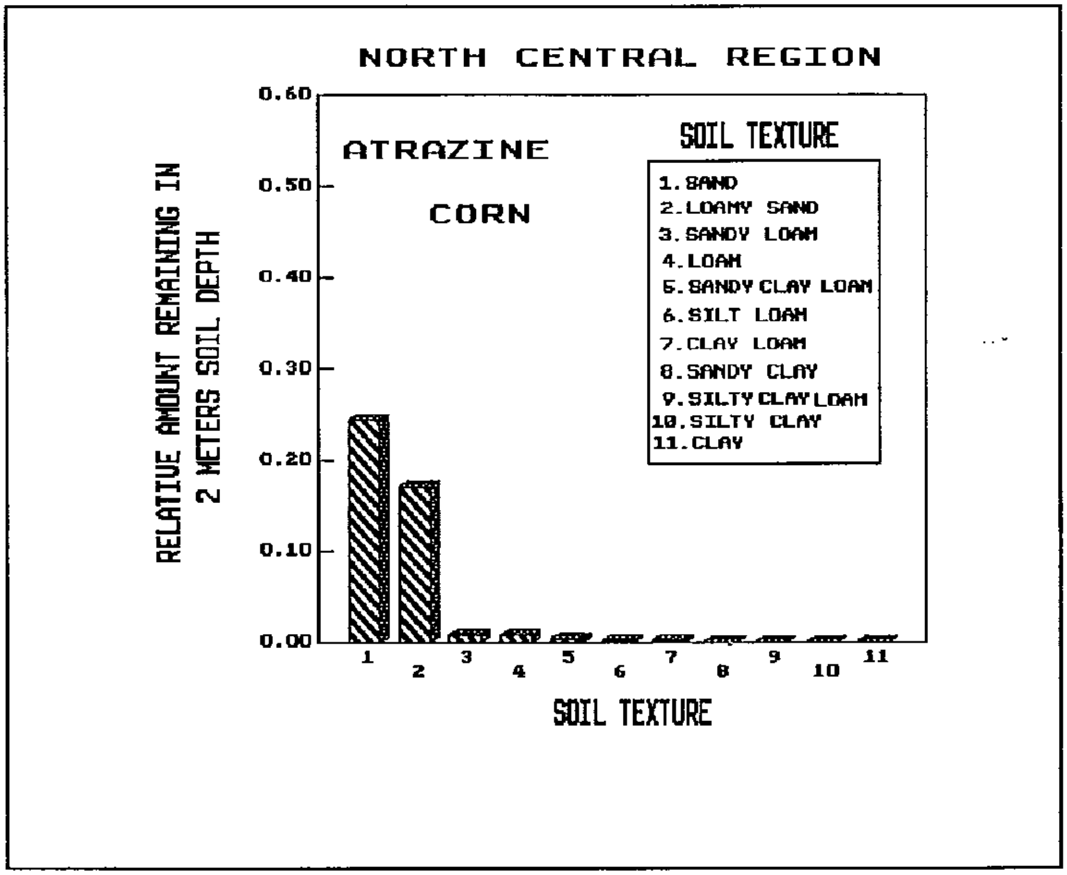

UTAH COUNTY
SMALL GRAINS
HERBICIDES
RELATIVE AMOUNT REMAINING IN 1 METER SOIL DEPTH
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
PESTICIDES
1
2
3
4
5
6
7
8
9
1. CLOPYRALID
2. DICAMBA
3. ASSERT
4. 2,4-D ACID
5. BROMOXYNIL
6. MCPA ESTER
7. TRIALLATE
8. DICLOFOP-METHYL
9. DIFENZOQUAT

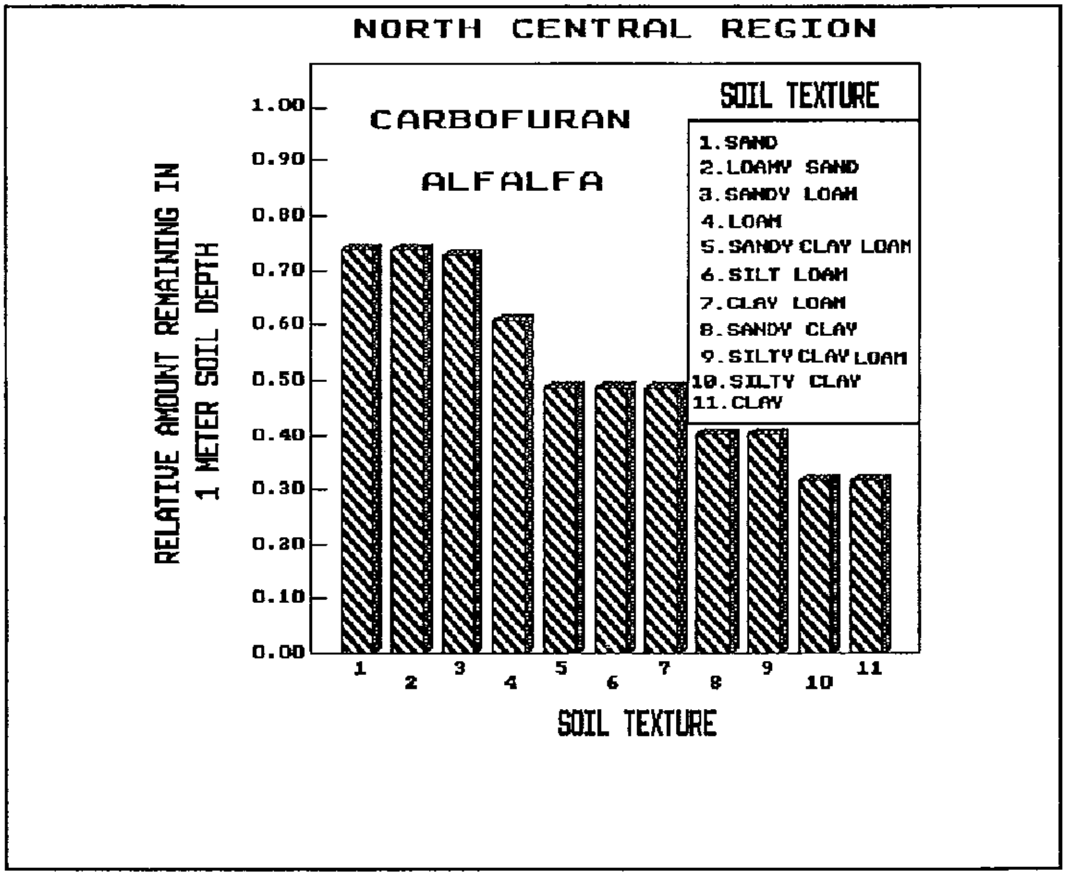

UTAH COUNTY
SNAP BEANS
HERBICIDES
1. BENTAZON
2. EPTC
3. DCPA
4. PENDIMETHALIN
5. TRIFLURALIN
RELATIVE AMOUNT REMAINING IN 1 METER SOIL DEPTH
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
1
2
3
4
5
PESTICIDES

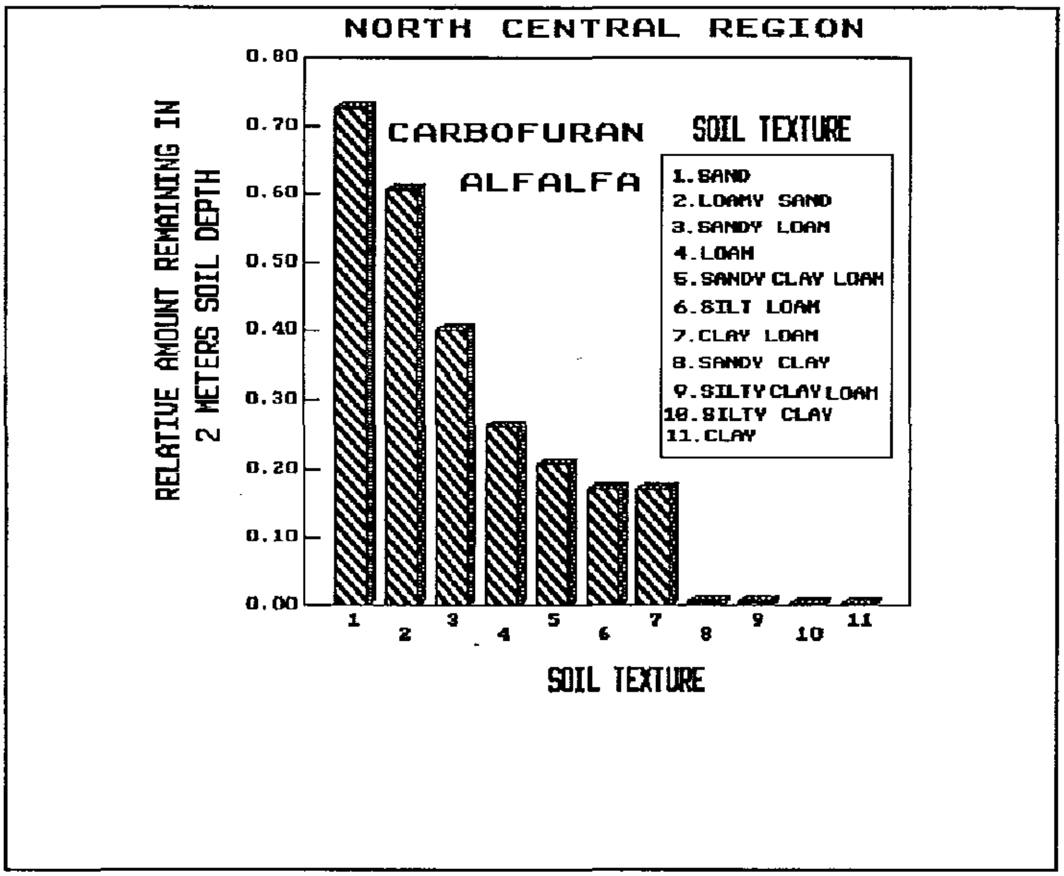

NORTH CENTRAL REGION
ALDICARB
POTATO
RELATIVE AMOUNT REMAINING IN 1 METER SOIL DEPTH
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
SOIL TEXTURE
1. SAND
2. LOAMY SAND
3. SANDY LOAM
4. LOAM
5. SANDY CLAY LOAM
6. SILT LOAM
7. CLAY LOAM
8. SANDY CLAY
9. SILTY CLAY LOAM
10. SILTY CLAY
11. CLAY
1
2
3
4
5
6
7
8
9
10
11
SOIL TEXTURE

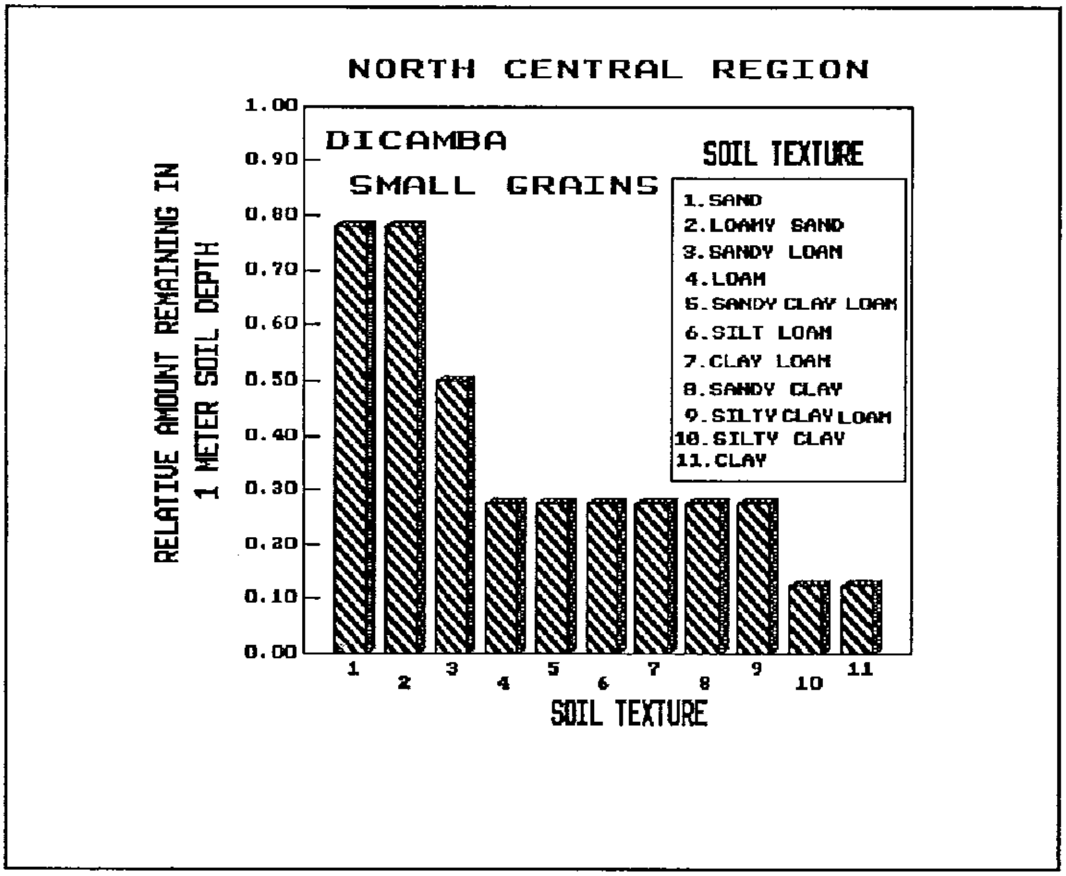

NORTH CENTRAL REGION
ALDICARB
POTATO
RELATIVE AMOUNT REMAINING IN 2 METERS SOIL DEPTH
0.00
0.10
0.20
0.30
0.40
0.50
0.60
SOIL TEXTURE
1. SAND
2. LOAMY SAND
3. SANDY LOAM
4. LOAM
5. SANDY CLAY LOAM
6. SILT LOAM
7. CLAY LOAM
8. SANDY CLAY
9. SILTY CLAY LOAM
10. SILTY CLAY
11. CLAY
1
2
3
4
5
6
7
8
9
10
11
SOIL TEXTURE

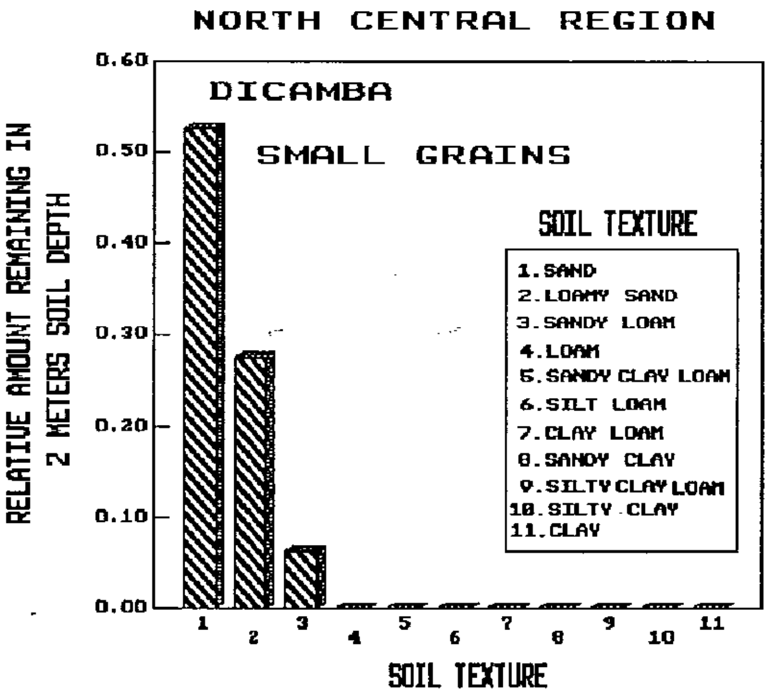

NORTH CENTRAL REGION
ATRAZINE
CORN
SOIL TEXTURE
1. SAND
2. LOAMY SAND
3. SANDY LOAM
4. LOAM
5. SANDY CLAY LOAM
6. SILT LOAM
7. CLAY LOAM
8. SANDY CLAY
9. SILTY CLAY LOAM
10. SILTY CLAY
11. CLAY
RELATIVE AMOUNT REMAINING IN 1 METER SOIL DEPTH
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
5
6
7
8
9
10
11
SOIL TEXTURE

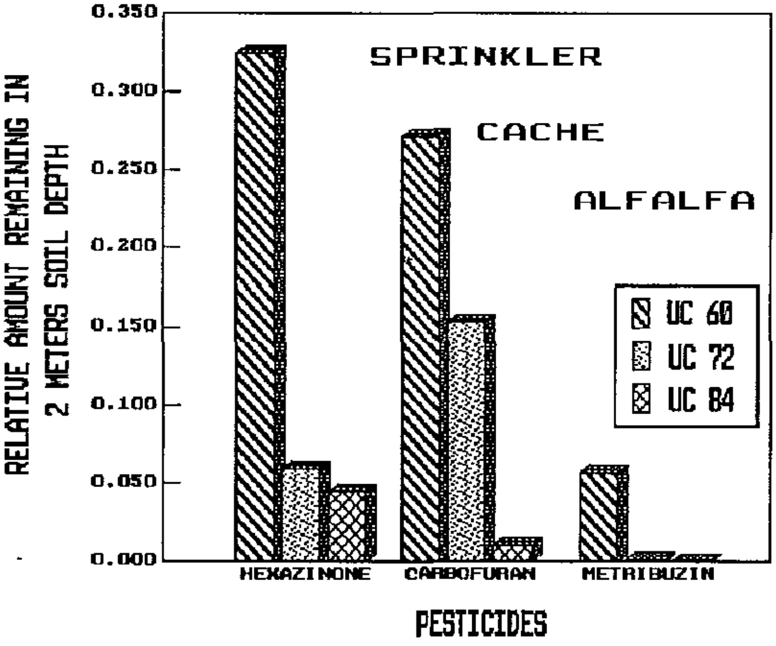

NORTH CENTRAL REGION
ATRAZINE
CORN
SOIL TEXTURE
1. SAND
2. LOAMY SAND
3. SANDY LOAM
4. LOAM
5. SANDY CLAY LOAM
6. SILT LOAM
7. CLAY LOAM
8. SANDY CLAY
9. SILTY CLAY LOAM
10. SILTY CLAY
11. CLAY
RELATIVE AMOUNT REMAINING IN 2 METERS SOIL DEPTH
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
5
6
7
8
9
10
11
SOIL TEXTURE

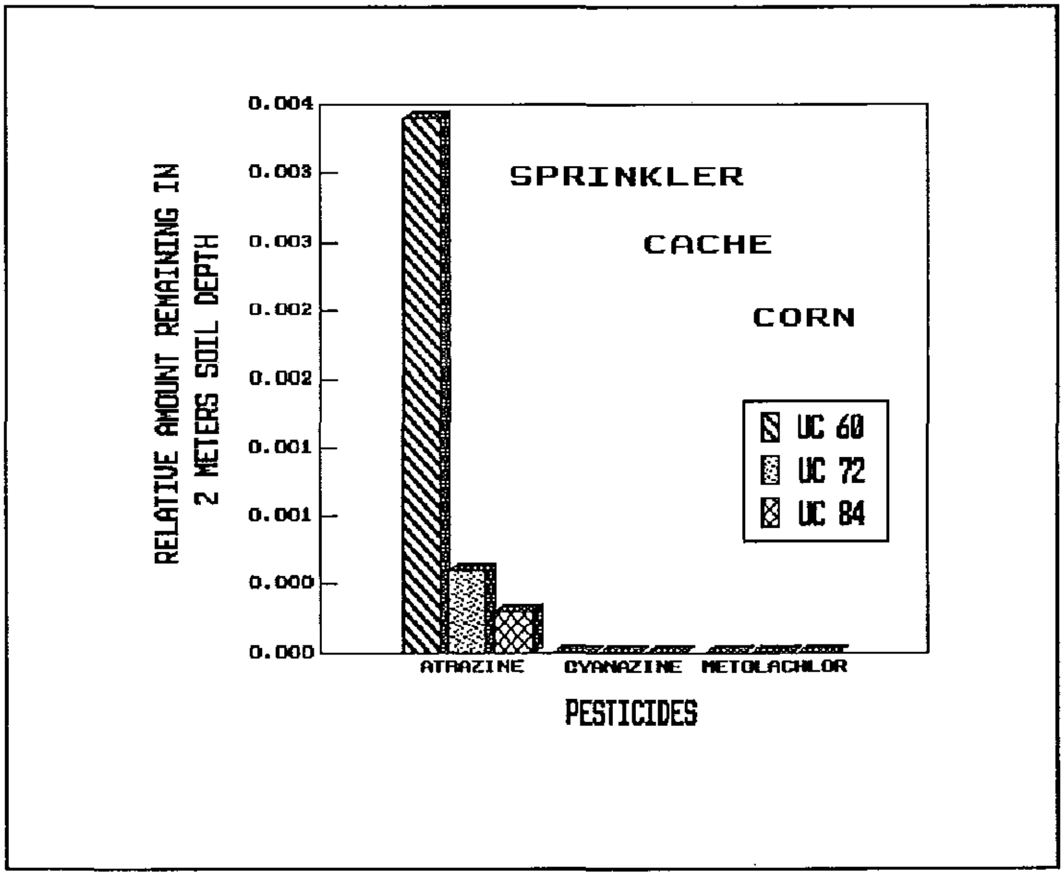

NORTH CENTRAL REGION
CARBOFURAN
ALFALFA
SOIL TEXTURE
1.SAND
2.LOAMY SAND
3.SANDY LOAM
4.LOAM
5.SANDY CLAY LOAM
6.SILT LOAM
7.CLAY LOAM
8.SANDY CLAY
9.SILTY CLAY LOAM
10.SILTY CLAY
11.CLAY
RELATIVE AMOUNT REMAINING IN 1 METER SOIL DEPTH
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
5
6
7
8
9
10
11
SOIL TEXTURE

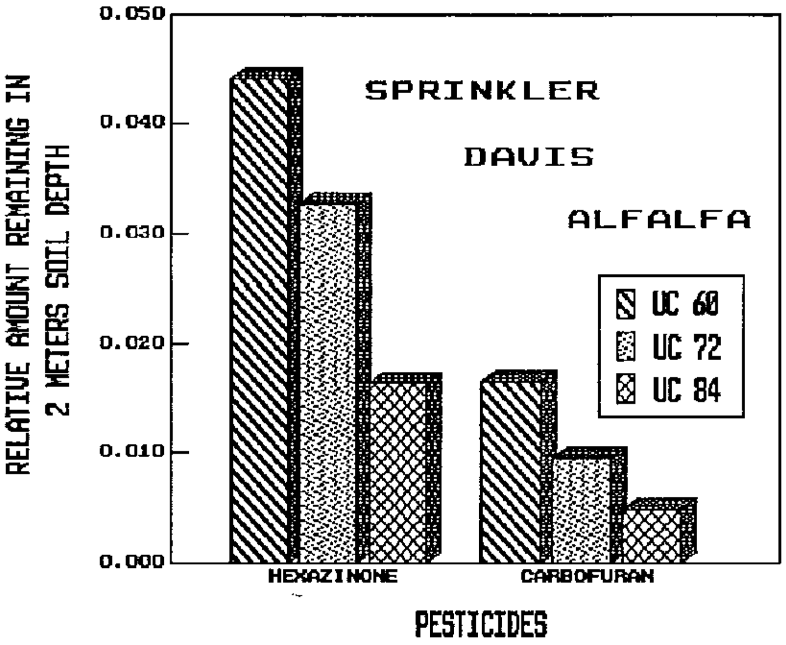

NORTH CENTRAL REGION
CARBOFURAN
ALFALFA
SOIL TEXTURE
1. SAND
2. LOAMY SAND
3. SANDY LOAM
4. LOAM
5. SANDY CLAY LOAM
6. SILT LOAM
7. CLAY LOAM
8. SANDY CLAY
9. SILTY CLAY LOAM
10. SILTY CLAY
11. CLAY
RELATIVE AMOUNT REMAINING IN 2 METERS SOIL DEPTH
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
5
6
7
8
9
10
11
SOIL TEXTURE

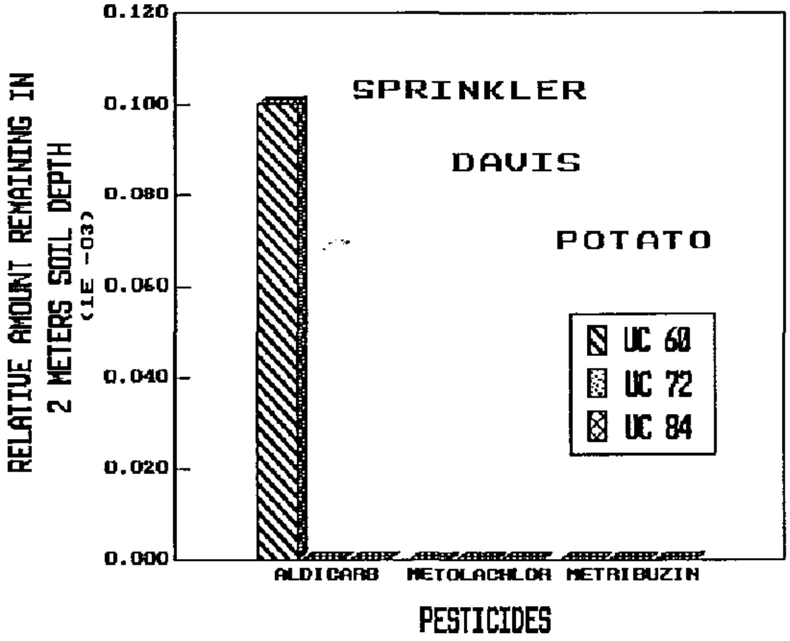

NORTH CENTRAL REGION
DICAMBA
SMALL GRAINS
SOIL TEXTURE
1. SAND
2. LOAMY SAND
3. SANDY LOAM
4. LOAM
5. SANDY CLAY LOAM
6. SILT LOAM
7. CLAY LOAM
8. SANDY CLAY
9. SILTY CLAY LOAM
10. SILTY CLAY
11. CLAY
RELATIVE AMOUNT REMAINING IN 1 METER SOIL DEPTH
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
5
6
7
8
9
10
11
SOIL TEXTURE

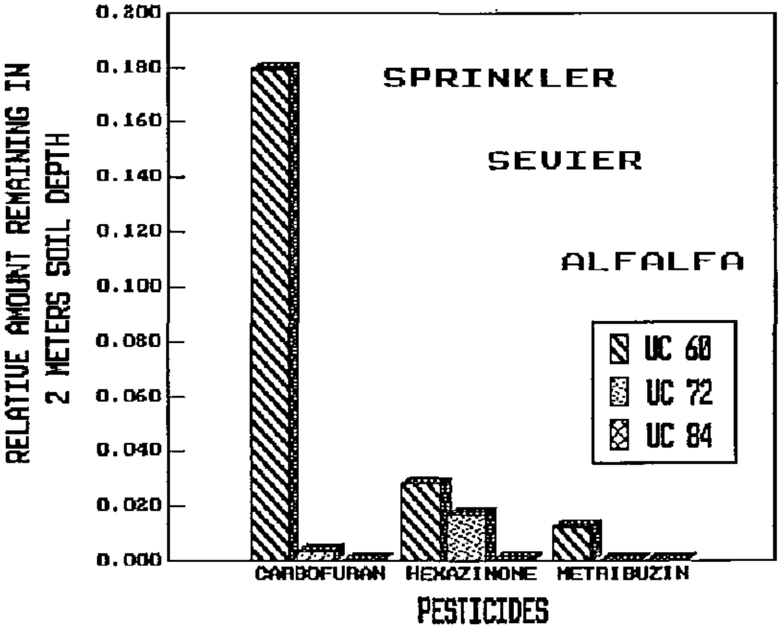

NORTH CENTRAL REGION
DICAMBA
SMALL GRAINS
RELATIVE AMOUNT REMAINING IN 2 METERS SOIL DEPTH
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
5
6
7
8
9
10
11
SOIL TEXTURE
SOIL TEXTURE
1. SAND
2. LOAMY SAND
3. SANDY LOAM
4. LOAM
5. SANDY CLAY LOAM
6. SILT LOAM
7. CLAY LOAM
8. SANDY CLAY
9. SILTY CLAY LOAM
10. SILTY CLAY
11. CLAY

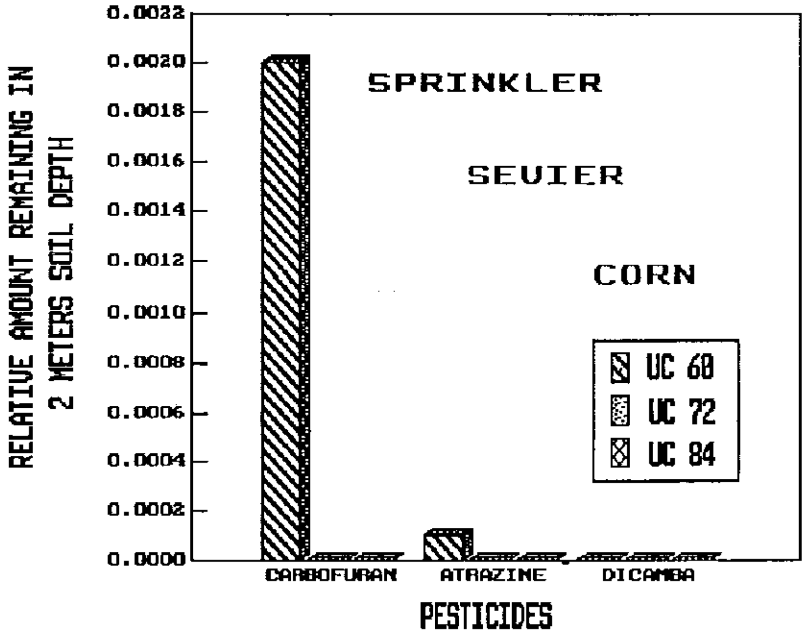

SPRINKLER
CACHE
ALFALFA
UC 60
UC 72
UC 84
RELATIVE AMOUNT REMAINING IN 2 METERS SOIL DEPTH
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
HEXAZINONE
CARBOFURAN
METRIBUZIN
PESTICIDES

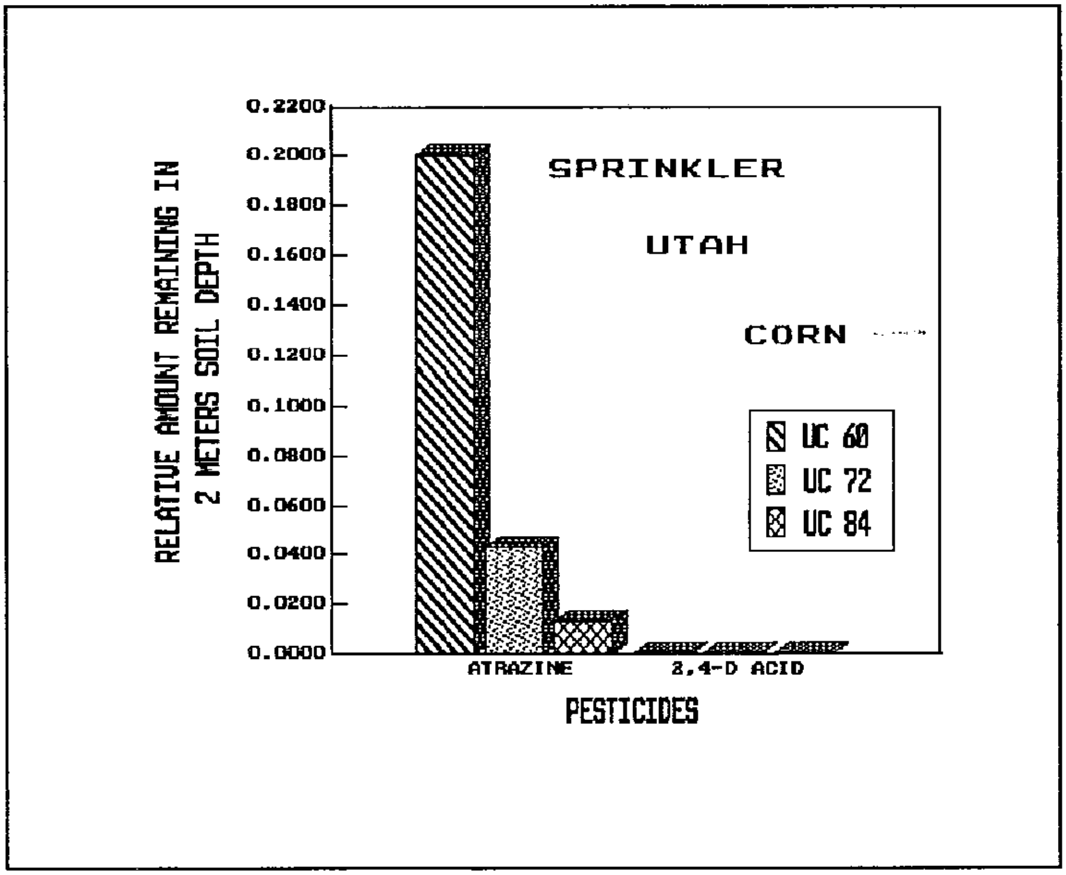

0.004
0.003
0.003
0.002
0.002
0.001
0.001
0.000
0.000
RELATIVE AMOUNT REMAINING IN
2 METERS SOIL DEPTH
SPRINKLER
CACHE
CORN
UC 60
UC 72
UC 84
ATRAZINE
CYANAZINE
METOLACHLOR
PESTICIDES

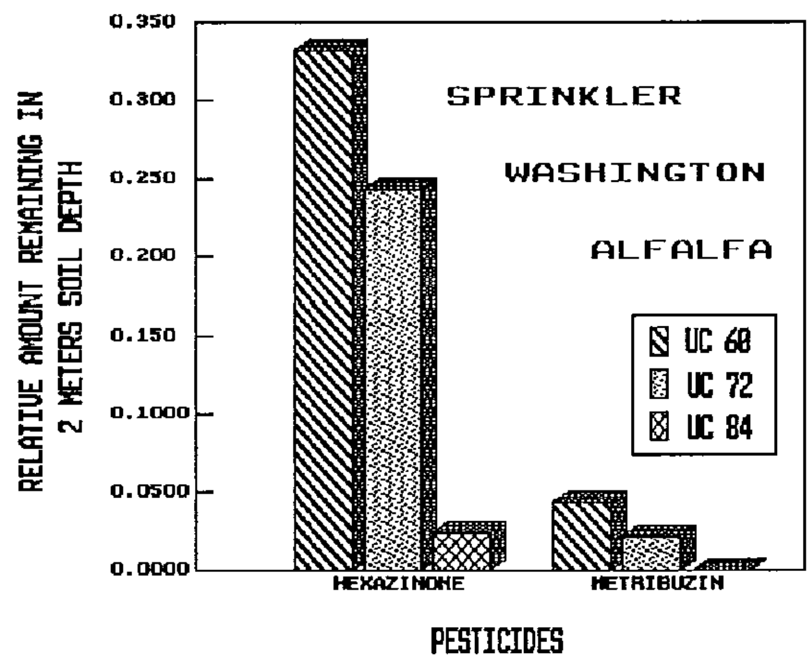

0.050
0.040
0.030
0.020
0.010
0.000
RELATIVE AMOUNT REMAINING IN
2 METERS SOIL DEPTH
SPRINKLER
DAVIS
ALFALFA
UC 60
UC 72
UC 84
HEXAZINONE
CARBOFURAN
PESTICIDES

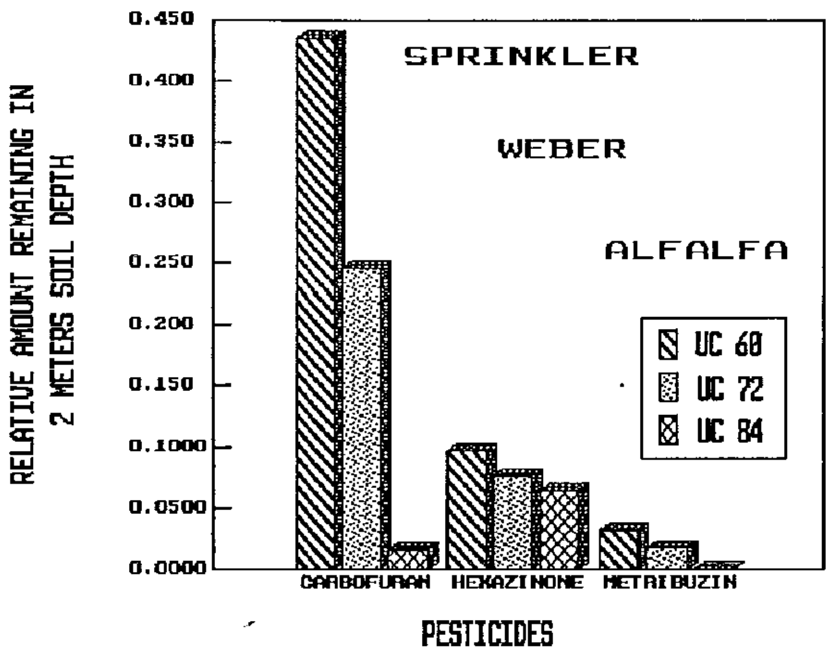

SPRINKLER
DAVIS
POTATO
RELATIVE AMOUNT REMAINING IN 2 METERS SOIL DEPTH (1E -03)
0.120
0.100
0.080
0.060
0.040
0.020
0.000
ALDICARB
METOLACHLOR
METRIBUZIN
PESTICIDES
UC 60
UC 72
UC 84


RELATIVE AMOUNT REMAINING IN 2 METERS SOIL DEPTH
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
SPRINKLER
SEVIER
ALFALFA
UC 60
UC 72
UC 84
CARBOFURAN
HEXAZINONE
METRIBUZIN
PESTICIDES


RELATIVE AMOUNT REMAINING IN
2 METERS SOIL DEPTH
0.0022
0.0020
0.0018
0.0016
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
SPRINKLER
SEVIER
CORN
UC 60
UC 72
UC 84
CARBOFURAN
ATRAZINE
DICAMBA
PESTICIDES


SPRINKLER
UTAH
CORN
UC 60
UC 72
UC 84
RELATIVE AMOUNT REMAINING IN 2 METERS SOIL DEPTH
0.2200
0.2000
0.1800
0.1600
0.1400
0.1200
0.1000
0.0800
0.0600
0.0400
0.0200
0.0000
ATRAZINE
2,4-D ACID
PESTICIDES


SPRINKLER
WASHINGTON
ALFALFA
UC 60
UC 72
UC 84
RELATIVE AMOUNT REMAINING IN 2 METERS SOIL DEPTH
0.350
0.300
0.250
0.200
0.150
0.1000
0.0500
0.0000
HEXAZINONE
METRIBUZIN
PESTICIDES


SPRINKLER
WEBER
ALFALFA
UC 60
UC 72
UC 84
RELATIVE AMOUNT REMAINING IN 2 METERS SOIL DEPTH
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.1000
0.0500
0.0000
CARBOFURAN
HEXAZINONE
METRIBUZIN
PESTICIDES

# Appendix G. CMLS Analysis

## G.1 CMLS Comparison

Many sources of error (input data, assumptions, etc.) are associated with model predictions; thus, it should not be expected that models provide accurate predictions of pesticide transport within a field. Hedden (1986) reported comments of participants of the Predictive Exposure Assessment Workshop, sponsored by USEPA in Atlanta, GA, on April 27-29, 1982. Participants agreed that for screening applications (having limited site-specific data and without the model being calibrated to the site), a model should be able to predict measured field data within an order of magnitude. This criteria seems to be quite reasonable considering all the sources of error associated with model predictions.

The purpose of this study is not the estimation of the probable pesticide concentration in groundwater but the relative comparison of different pesticides under alternative irrigation and pesticide management practices. However, in order to gain confidence in the use of the CMLS model, comparisons between simulated pesticide concentrations from three pesticide transport models and observed data from Smith et al. (1989) are presented.

Smith et al. (1989) reported data of simulated concentrations using the Pesticide Root Zone Model, PRZM version 2 (Carsel et al., 1984), Groundwater Loading Effects of Agricultural Management Systems, GLEAMS, (Leonard et al., 1988), and observed concentrations of atrazine and alachlor in the soil. Some data for the experimental site located near Tifton, Georgia, are shown in Tables 20 through 22. The same data were used as input for CMLS simulations.

Results of the comparisons are shown in Figs. 20 to 25. Fig. 20 shows that the front (presumably the peak concentration) of atrazine simulated by CMLS arrives at a depth of 121 cm between 70 and 80 days. This approximates in agreement with the arrival time of atrazine reported by Smith et al. (1989) (Fig. 22). Figs. 23 to 26 show that in all cases, CMLS-peak simulated concentrations are within one order of magnitude of the observed values. Thus, CMLS, PRZM and GLEAMS have met the criteria for acceptance suggested by Hedden (1986).

### G.2 Preferential Flow.

It is appropriate to consider the effect of preferential flow on CMLS-predicted values. Table 23 illustrates possible effects of preferential flow on RA values. If there is no preferential flow, the preferential flow factor (PF) is 1.0. This factor decreases in value as the number of preferential flow paths increase. Thus, as the PF factor decreases, contaminant movement increases.

Table 20. Estimated and Simulated Hydrological Data.

| | Year | Precipitation (mm) | ET (mm) |
|---|---|---|---|
| CMLS | 1986 | 1190 | 733 |
| | 1987 | 1431 | 704 |
| PRZM[1] | 1986 | 1190 | 630 |
| | 1987 | 1431 | 737 |
| GLEAMS[1] | 1986 | 1190 | 687 |
| | 1987 | 1431 | 831 |

Table 21. Pesticide Data Used in Simulations[1]

| | Chemical Applied | |
|---|---|---|
| | Atrazine | Alachlor |
| Application Date | 11/12/86 | 11/12/86 |
| Application Rate (kg/ha) | 4.9 | 4.9 |
| $K_{oc}$ (ml/g OC) | 163 | 190 |
| $t_{1/2}$ | 60 | 18 |

Table 22. Soil Properties Used in Simulations.

| Depth (cm) | Organic Carbon (%) | Bulk Density (g/cm$^3$) | Water Content (%) | | |
|---|---|---|---|---|---|
| | | | Effective Saturation | Field Capacity | Wilting Point |
| 0-13 | 0.55 | 1.45 | 33.0 | 10.0 | 2.1 |
| 13-20 | 0.28 | 1.60 | 33.0 | 10.0 | 2.1 |
| 20-51 | 0.08 | 1.58 | 33.3 | 10.0 | 2.1 |
| 51-102 | 0.04 | 1.59 | 33.8 | 9.0 | 2.1 |
| 102-262 | 0.03 | 1.59 | 34.0 | 9.0 | 2.1 |

---

[1] Data from Smith et al.,1989

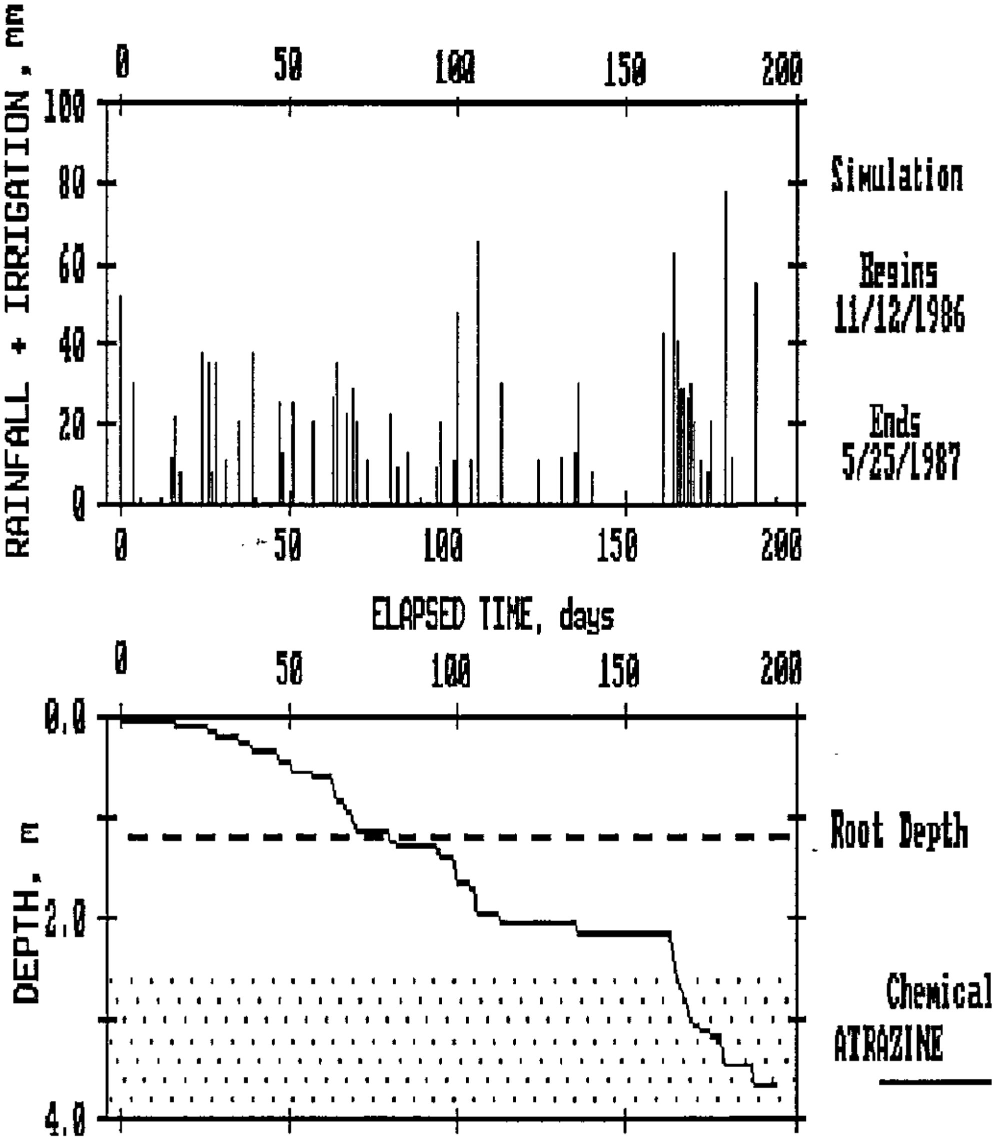


Figure 20. Rainfall, Irrigation and Chemical Depth as a Function of Time.

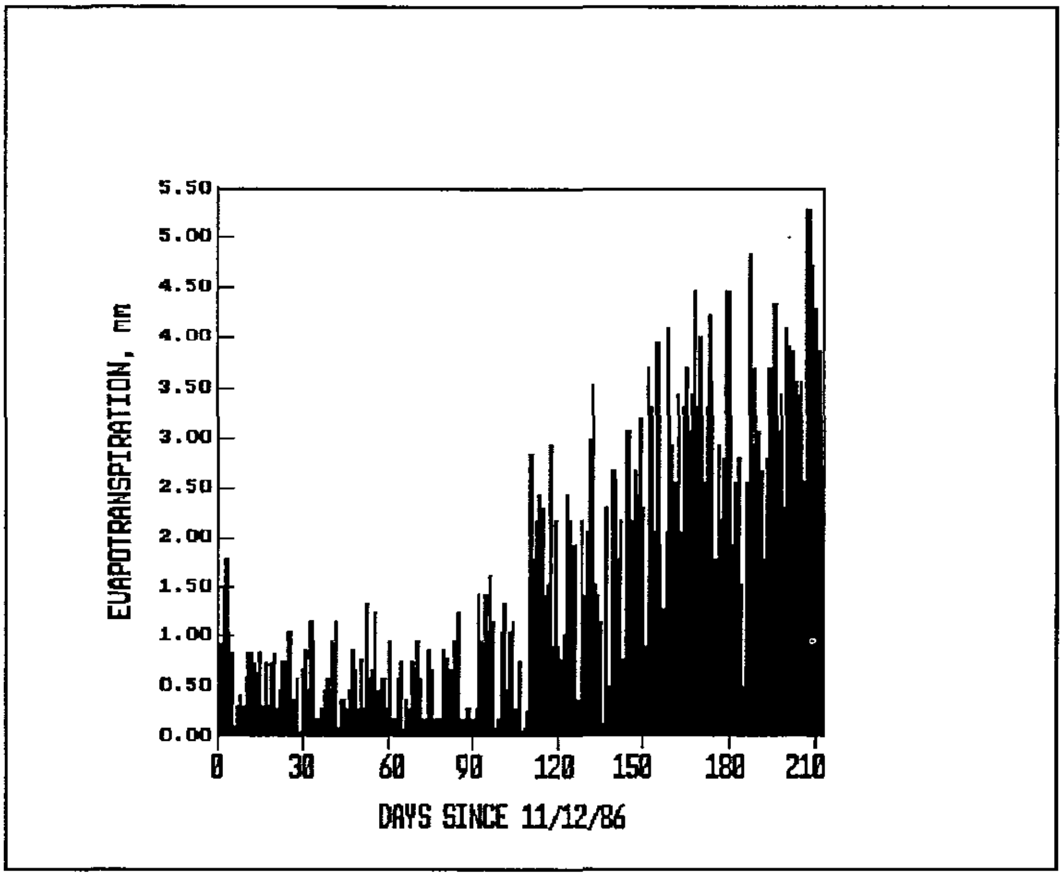


Figure 21. Estimated Daily Grass Evapotranspiration for Tifton, Georgia.

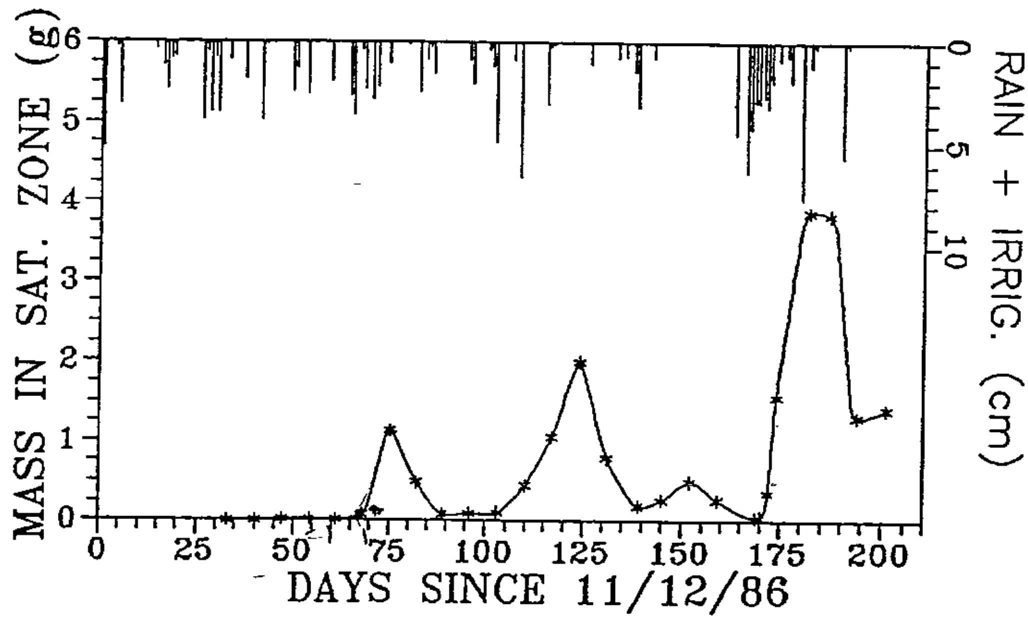


Figure 22. Total Mass of Atrazine in the Saturate Zone. Source: Smith et al., (1989).

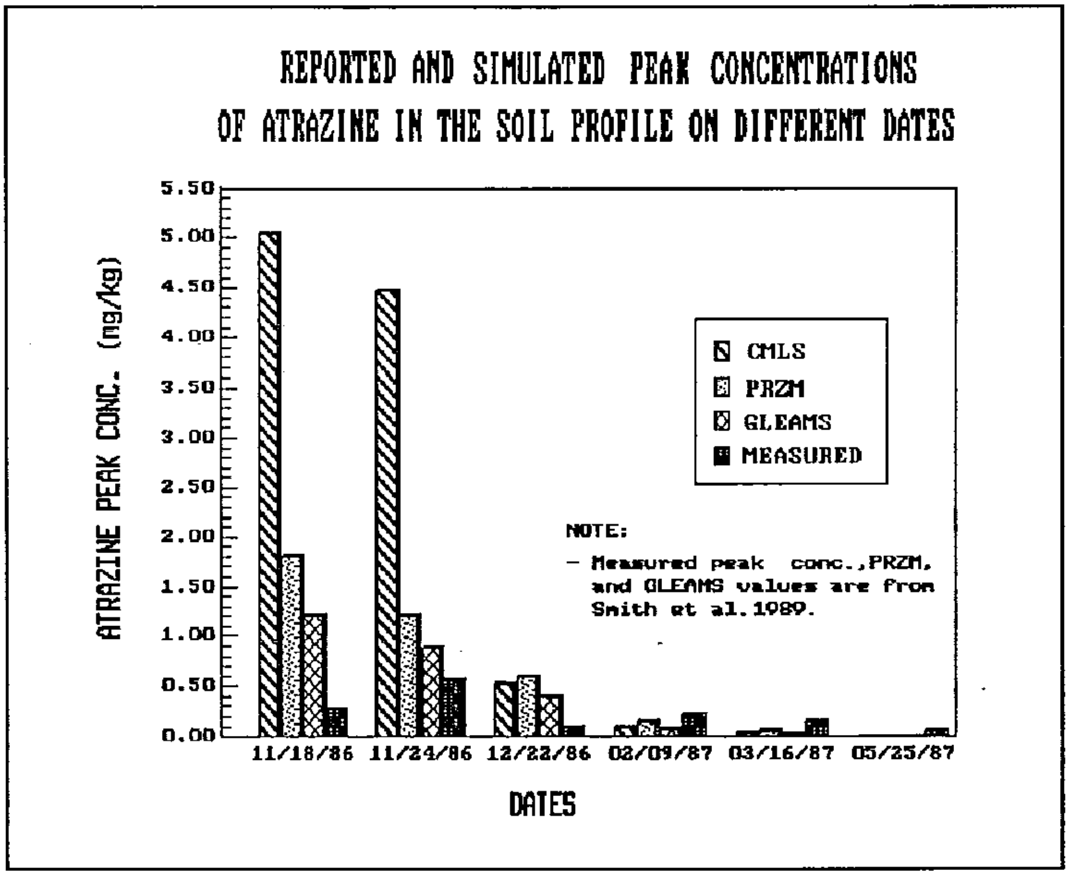


Figure 23. Simulated and Observed Peak Concentrations of Atrazine on Different Dates.

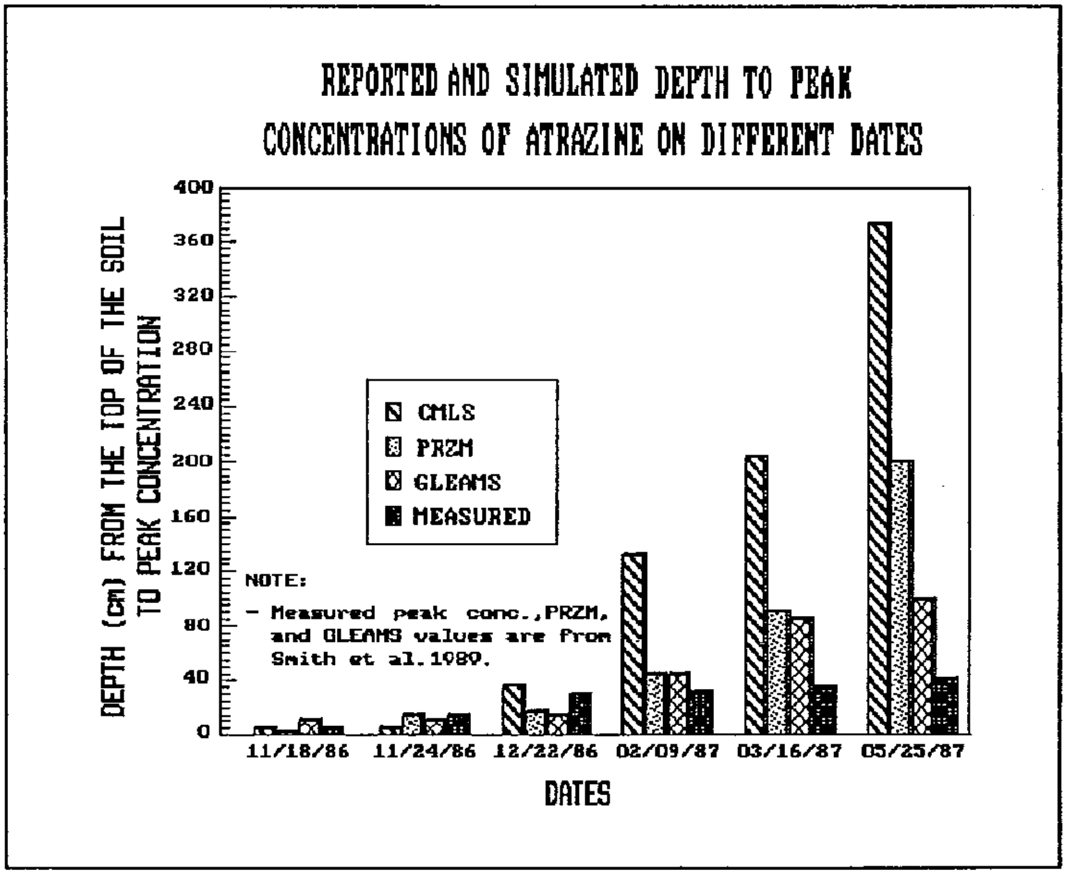


Figure 24. Simulated and Observed Depths to Peak Concentration of Atrazine on Different Dates.

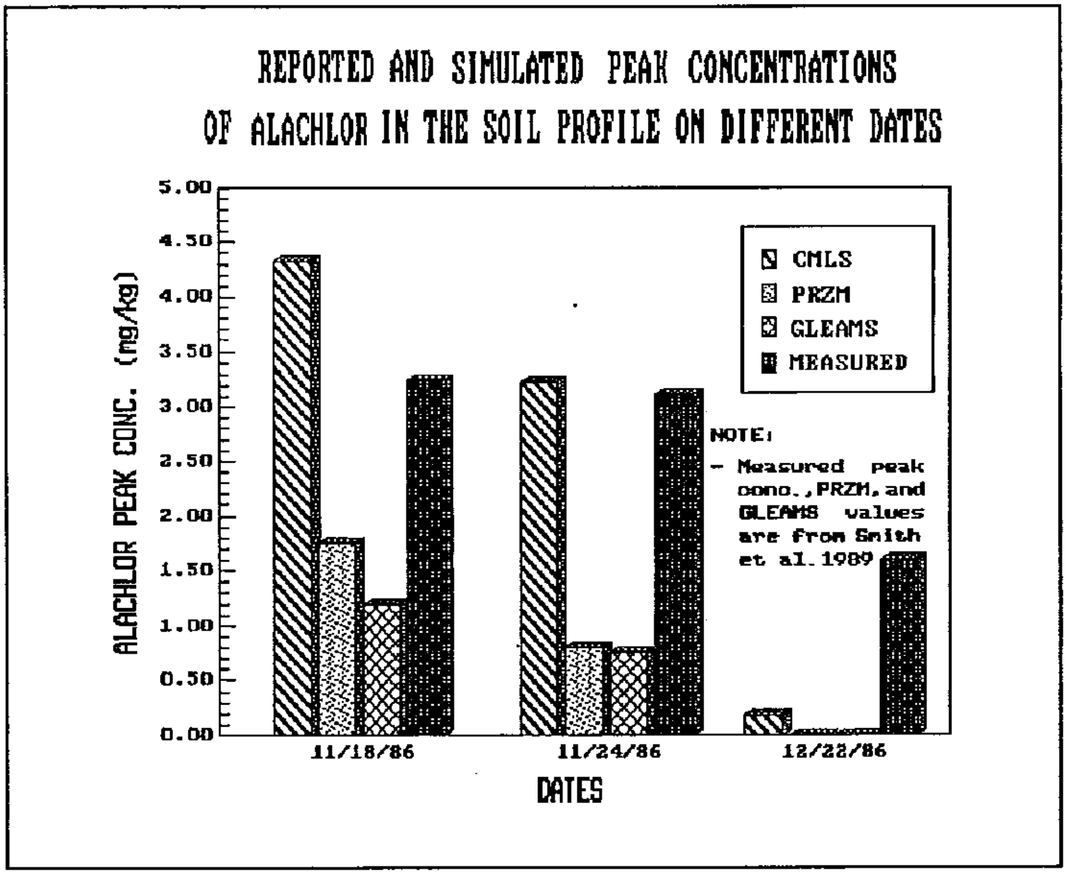


Figure 25. Simulated and Observed Concentrations of Alachlor on Different Dates.

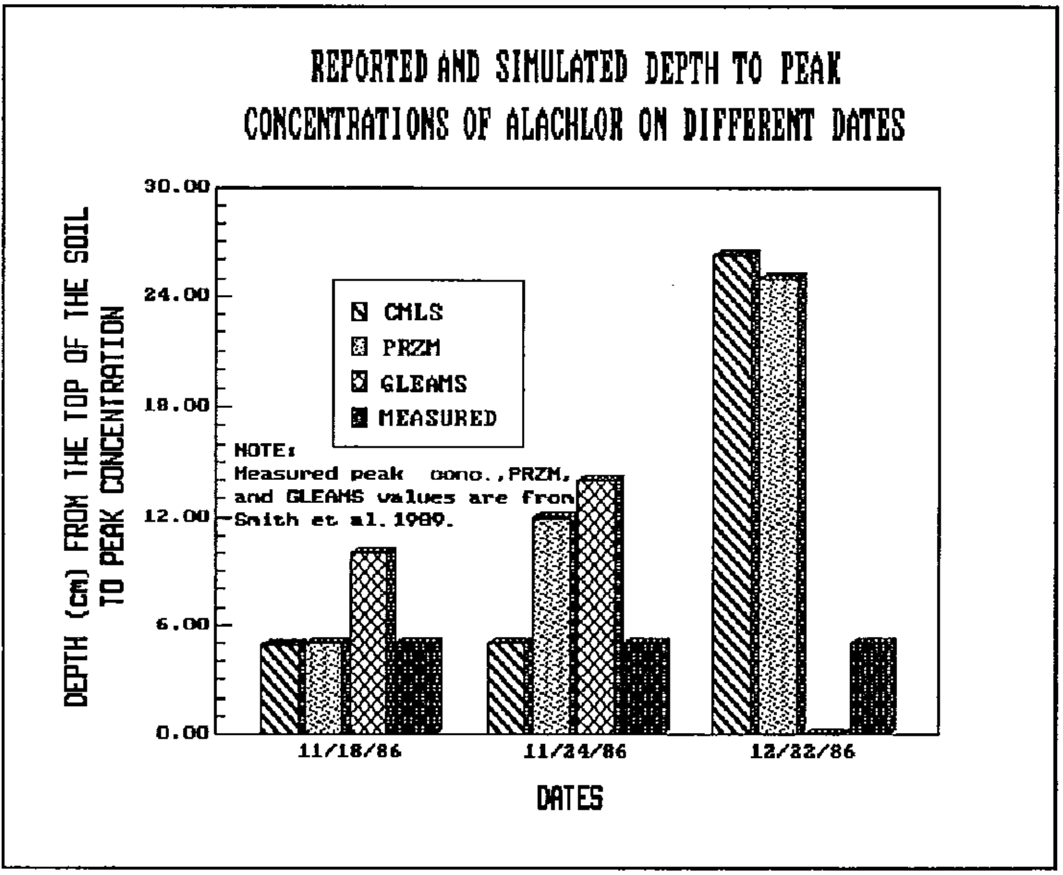


Figure 26. Simulated and Observed Depths to Peak Concentration of Alachlor on Different Dates.

# Table 23. CMLS Analysis: Preferential Flow

| COUNTY | SOIL | CROP | PESTICIDE NAME | d (mm) | PF | t(days) 2 m | RA 2 m | C(ppb) 2 m | RATIO 2 m |
|---|---|---|---|---|---|---|---|---|---|
| DAVIS | KIDMAN | COR | ATRAZINE | 89 | 1.00 | 699 | 3.11E-04 | 0.15 | 0.05 |
| DAVIS | KIDMAN | COR | ATRAZINE | 89 | 0.67 | 466 | 4.59E-03 | 2.20 | 0.73 |
| DAVIS | KIDMAN | COR | ATRAZINE | 89 | 0.50 | 350 | 1.76E-02 | 8.47 | 2.82 |
| DAVIS | KIDMAN | COR | ATRAZINE | 89 | 0.33 | 233 | 6.78E-02 | 32.53 | 10.84 |
| DAVIS | KIDMAN | COR | ATRAZINE | 89 | 0.20 | 140 | 1.99E-01 | 95.46 | 31.82 |
| DAVIS | KIDMAN | COR | ALACHLOR | 89 | 1.00 | 877 | 2.51E-18 | 0.00 | 0.00 |
| DAVIS | KIDMAN | COR | ALACHLOR | 89 | 0.67 | 585 | 1.85E-12 | 0.00 | 0.00 |
| DAVIS | KIDMAN | COR | ALACHLOR | 89 | 0.50 | 439 | 1.58E-09 | 0.00 | 0.00 |
| DAVIS | KIDMAN | COR | ALACHLOR | 89 | 0.33 | 292 | 1.36E-06 | 0.00 | 0.00 |
| DAVIS | KIDMAN | COR | ALACHLOR | 89 | 0.20 | 175 | 3.02E-04 | 0.09 | 0.06 |
| DAVIS | KIDMAN | ALF | HEXAZINONE | 89 | 1.00 | 342 | 7.18E-02 | 21.54 | 0.10 |
| DAVIS | KIDMAN | ALF | HEXAZINONE | 89 | 0.67 | 228 | 1.73E-01 | 51.82 | 0.25 |
| DAVIS | KIDMAN | ALF | HEXAZINONE | 89 | 0.50 | 171 | 2.68E-01 | 80.38 | 0.38 |
| DAVIS | KIDMAN | ALF | HEXAZINONE | 89 | 0.33 | 114 | 4.16E-01 | 124.69 | 0.59 |
| DAVIS | KIDMAN | ALF | HEXAZINONE | 89 | 0.20 | 68 | 5.90E-01 | 177.15 | 0.84 |
| DAVIS | KIDMAN | ALF | CARBOFURAN | 89 | 1.00 | 280 | 2.06E-02 | 4.62 | 0.13 |
| DAVIS | KIDMAN | ALF | CARBOFURAN | 89 | 0.67 | 187 | 7.52E-02 | 16.84 | 0.47 |
| DAVIS | KIDMAN | ALF | CARBOFURAN | 89 | 0.50 | 140 | 1.44E-01 | 32.16 | 0.89 |
| DAVIS | KIDMAN | ALF | CARBOFURAN | 89 | 0.33 | 93 | 2.74E-01 | 61.42 | 1.71 |
| DAVIS | KIDMAN | ALF | CARBOFURAN | 89 | 0.20 | 56 | 4.60E-01 | 103.06 | 2.86 |
| DAVIS | KIDMAN | SGR | DICAMBA | 89 | 1.00 | 364 | 1.49E-08 | 0.00 | 0.00 |
| DAVIS | KIDMAN | SGR | DICAMBA | 89 | 0.67 | 243 | 6.06E-06 | 0.00 | 0.00 |
| DAVIS | KIDMAN | SGR | DICAMBA | 89 | 0.50 | 182 | 1.22E-04 | 0.00 | 0.00 |
| DAVIS | KIDMAN | SGR | DICAMBA | 89 | 0.33 | 121 | 2.46E-03 | 0.07 | 0.01 |
| DAVIS | KIDMAN | SGR | DICAMBA | 89 | 0.20 | 73 | 2.72E-02 | 0.76 | 0.08 |
| DAVIS | KIDMAN | SGR | 2,4-D ACID | 89 | 1.00 | 396 | 1.20E-12 | 0.00 | 0.00 |
| DAVIS | KIDMAN | SGR | 2,4-D ACID | 89 | 0.67 | 264 | 1.13E-08 | 0.00 | 0.00 |
| DAVIS | KIDMAN | SGR | 2,4-D ACID | 89 | 0.50 | 198 | 1.10E-06 | 0.00 | 0.00 |
| DAVIS | KIDMAN | SGR | 2,4-D ACID | 89 | 0.33 | 132 | 1.06E-04 | 0.03 | 0.00 |
| DAVIS | KIDMAN | SGR | 2,4-D ACID | 89 | 0.20 | 79 | 4.13E-03 | 0.99 | 0.01 |
| DAVIS | KIDMAN | POT | ALDICARB | 89 | 1.00 | 122 | 5.97E-02 | 26.74 | 2.67 |
| DAVIS | KIDMAN | POT | ALDICARB | 89 | 0.67 | 81 | 1.53E-01 | 68.42 | 6.84 |
| DAVIS | KIDMAN | POT | ALDICARB | 89 | 0.50 | 61 | 2.44E-01 | 109.44 | 10.94 |
| DAVIS | KIDMAN | POT | ALDICARB | 89 | 0.33 | 41 | 3.91E-01 | 175.07 | 17.51 |
| DAVIS | KIDMAN | POT | ALDICARB | 89 | 0.20 | 24 | 5.69E-01 | 254.94 | 25.49 |
| DAVIS | KIDMAN | POT | METOLACHLOR | 89 | 1.00 | 1090 | 3.93E-17 | 0.00 | 0.00 |
| DAVIS | KIDMAN | POT | METOLACHLOR | 89 | 0.67 | 727 | 1.15E-11 | 0.00 | 0.00 |
| DAVIS | KIDMAN | POT | METOLACHLOR | 89 | 0.50 | 545 | 6.27E-09 | 0.00 | 0.00 |
| DAVIS | KIDMAN | POT | METOLACHLOR | 89 | 0.20 | 218 | 5.23E-04 | 0.35 | 0.04 |

---

Abbreviations: ALF = alfalfa; COR = corn; POT = potato; SRG = small grains; PF = preferential flow; RA = relative amount of pesticide remaining in the soil when the chemical front arrives at a given depth; d = average depth of water infiltrated in the soil; C = potential pesticide concentration in groundwater assuming a mixing volume of 500 liters of water; RATIO = C / health advisory level.