SCREENING METHODS FOR GROUNDWATER POLLUTION POTENTIAL FROM PESTICIDE USE IN COLORADO AGRICULTURE

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DISCLAIMER

The opinions expressed in this report are solely those of the authors. The report has not been reviewed by the Colorado Department of Health or any other state or federal agency. When trade names are used, no endorsement is intended.

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ABSTRACT

The project reported here evaluates the use of two models for predicting groundwater pollution potential under conditions typical of Colorado agriculture. The project is in response to the pesticide strategy proposed by the U.S. Environmental Protection Agency (EPA, 1987) that includes a differential approach based on, in part, vulnerability of the groundwater. The use of chemical transport models and pollution indices for the purpose of screening or predicting chemical fate are potentially major tools that will be used for the management and, perhaps, regulation of agricultural chemicals.

The two models evaluated in this project are a solute transport model called CMLS (Nofziger and Hornsby, 1986) and a hydrologic index for ranking relative pollution potential called DRASTIC (Aller et al., 1987). The models were used to determine which pesticides had the highest potential for leaching to the groundwater and which areas had the greatest likelihood for groundwater contamination. Results were also used to assess the relative importance of hydrogeologic factors, agricultural management factors and the characteristics of the individual pesticides in determining pollution potential.

The San Luis Valley, located in south-central Colorado, was used as a case study for this project. A shallow unconfined aquifer underlying the Valley serves as the primary drinking water source for most of the Valley's population. Heavy use of agricultural chemicals and sandy soils create regions where the groundwater is vulnerable to pollution.

The results obtained using the solute transport model and the hydrologic index were compared with results from a direct sampling program completed in the San Luis Valley in conjunction with the Colorado Department of Health. The objective of the sampling program was to determine the water quality of the shallow unconfined aquifer. Thirty-four irrigation wells were sampled at the beginning and again at the end of the 1990 growing season. Samples were analyzed for inorganics and sixteen pesticides.

The direct sampling program completed during the summer of 1990 indicates that the groundwater of the San Luis Valley has high nitrate levels in some areas and <u>may</u> contain low levels of pesticides. Nitrate levels above the drinking water standard were found in 38% of the water samples tested. Pesticides were found in fifteen of the sixty-eight water samples collected from the irrigation wells. Detectable levels of Sencor, Eptam, Bravo and 2-4,D were found in the sampling program. However, in some cases, sample contamination or well bore contamination may have

occurred. Therefore, data obtained with different sampling techniques are needed to accurately assess the general aquifer quality with regard to pesticide contamination.

The DRASTIC map developed in this study indicates that the San Luis Valley is highly vulnerable to groundwater contamination by pesticides compared to other areas in Colorado. However, because of the homogeneity of the Valley's hydrogeology, the model cannot differentiate between the areas within the Valley with regard to pollution potential.

The CMLS model was found to be more useful than DRASTIC for determining pollution potential. CMLS predicted Temik, Sencor, 2-4,D and Rhomene would reach a five foot water table depth within the five year simulation period. Sencor and 2-4,D were found during the sampling program. Temik and Rhomene were not analyzed for by the Organics Laboratory. Eptam and Bravo were also found during the sampling program. These pesticides are widely used in the Valley. Eptam and Bravo were determined by CMLS to have a moderate leaching potential. This may indicate that any pesticide used heavily in the Valley should be considered a potential leacher if it has moderate or high leaching potential.

The results of this project indicate that, in the San Luis Valley, both management practices and the specific pesticide properties are both important in assessing pollution potential. Pesticide properties can be used to rank each pesticide but the pesticides that are most heavily used should be considered potential contaminants regardless of their relative ranking.

CHAPTER 1

PROJECT OBJECTIVES AND BACKGROUND

1.1 PROJECT OBJECTIVES

The goals of this project were to:

1) Evaluate pesticide contamination of the groundwater in the San Luis Valley through direct sampling.

2) Evaluate screening models for their ability to predict **which pesticides** would contaminate the groundwater, predict **which areas** would have the highest risk of contamination, and predict **what levels** of contamination would occur.

3) Determine the relative importance of different factors with respect to groundwater contamination by pesticides. The relative importance of hydrogeologic factors, agricultural management factors, and the characteristics of the individual pesticides were assessed.

Two different models were used in this project. The solute transport model CMLS (Chemical Movement though Layered Soils) was used to evaluate the individual pesticides for their potential to reach the groundwater and to determine what concentrations were likely to occur. A hydrologic index model DRASTIC was used to determine which areas of the San Luis Valley have the greatest risk of contamination.

1.2 PROJECT SETTING

The San Luis Valley is located in south-central Colorado. It is a high, arid intermontane valley about 3,200 mi^2 in area. The San Luis Valley is surrounded by the Sangre de Cristo Mountains on the east and the San Juan Mountains on the west. The San Luis Valley is part of the Rio Grande basin, and is bisected by the Rio Grande River. The valley has an average altitude of 7,700 feet above sea level. The valley floor is relatively flat with an average slope of six feet per mile.

1.2.1 Soils

A cross section of the San Luis Valley is shown in Figure 1. The valley floor is underlain by valley-fill deposits that consist of unconsolidated clay, silt, sand and gravel, and interbedded volcanic layers. The alluvial deposits are coarse and permeable near the mountains and become finer grained and less permeable toward the center of the valley. The soils on the floor surface are primarily loam, sandy loam, and loamy sand. Soil particles become increasingly sandy toward the east side of the valley, due to aeolian deposits formed by the action of strong south-west winds.

1.2.2 Aquifer System

Most of the valley-fill deposits contain water. The San Luis Valley supports a complex system of aquifers that appear to be in hydrologic connection. The aquifer system is controlled by the complex structural and stratigraphic relationships which typify the hydrogeological system of the San Luis Valley.

Three distinct units form the aquifer system: 1) the unconfined unit, 2) the active confined unit, 3) the passive confined unit (Hanna, 1989). The primary producing aquifers in the San Luis Valley compose the unconfined aquifer. An active artesian layer is called the active confined aquifer. The passive confined unit is the deepest aquifer system and has few wells completed within it.

The unconfined aquifer is quite thin, ranging from 40 to 100 feet in thickness. It consists of sands and gravels of the upper Alamosa Formation. Water recharges this aquifer from the land surface. However, the primary source of water recharge comes from horst and graben faults along the valley's boundary with the surrounding mountains, and from upward leaks through discontinuous layers between the confined unit. Many wells have been completed within this unit, and the valley depends upon the unconfined aquifer as its main source of drinking water and farm irrigation water.

The active confined unit is primarily comprised of detrital sediments of the Los Pinos and upper Sante Fe Formations. It is confined by a discontinuous series of lacustrine blue clays, silty sands, and volcanic outcroppings of the upper Alamosa Formation. Water wells in the valley completed into this unit range in depth from approximately 250 to 2500 feet in depth.

A low drainage divide bisects the Rio Grande Basin. North of this divide the active unit establishes a closed basin. The closed basin is an area where the water from the confined unit surfaces. The closed basin supports a series of marshes and

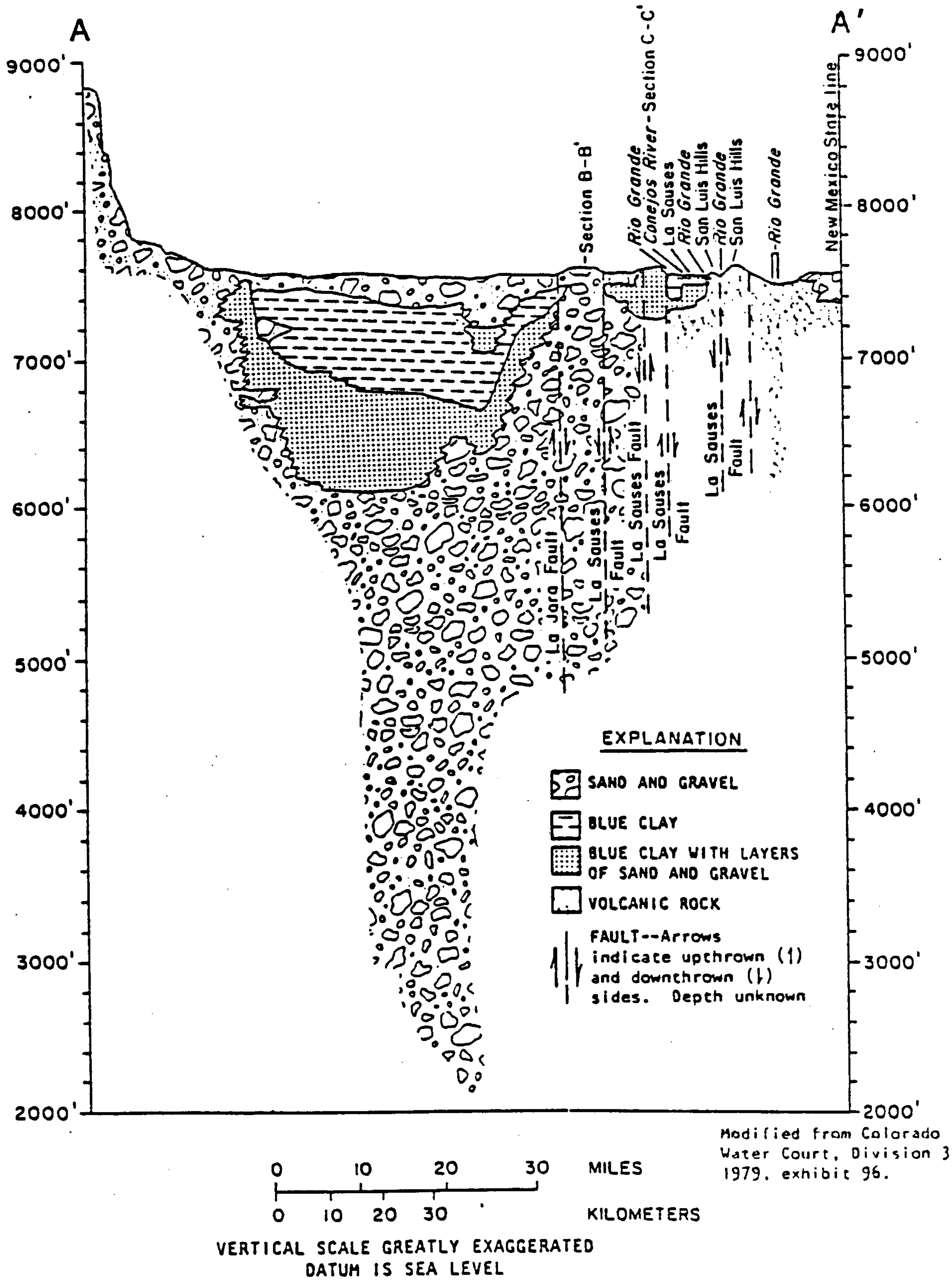


Figure 1. Geology of the San Luis Valley (Wilkins, 1986)

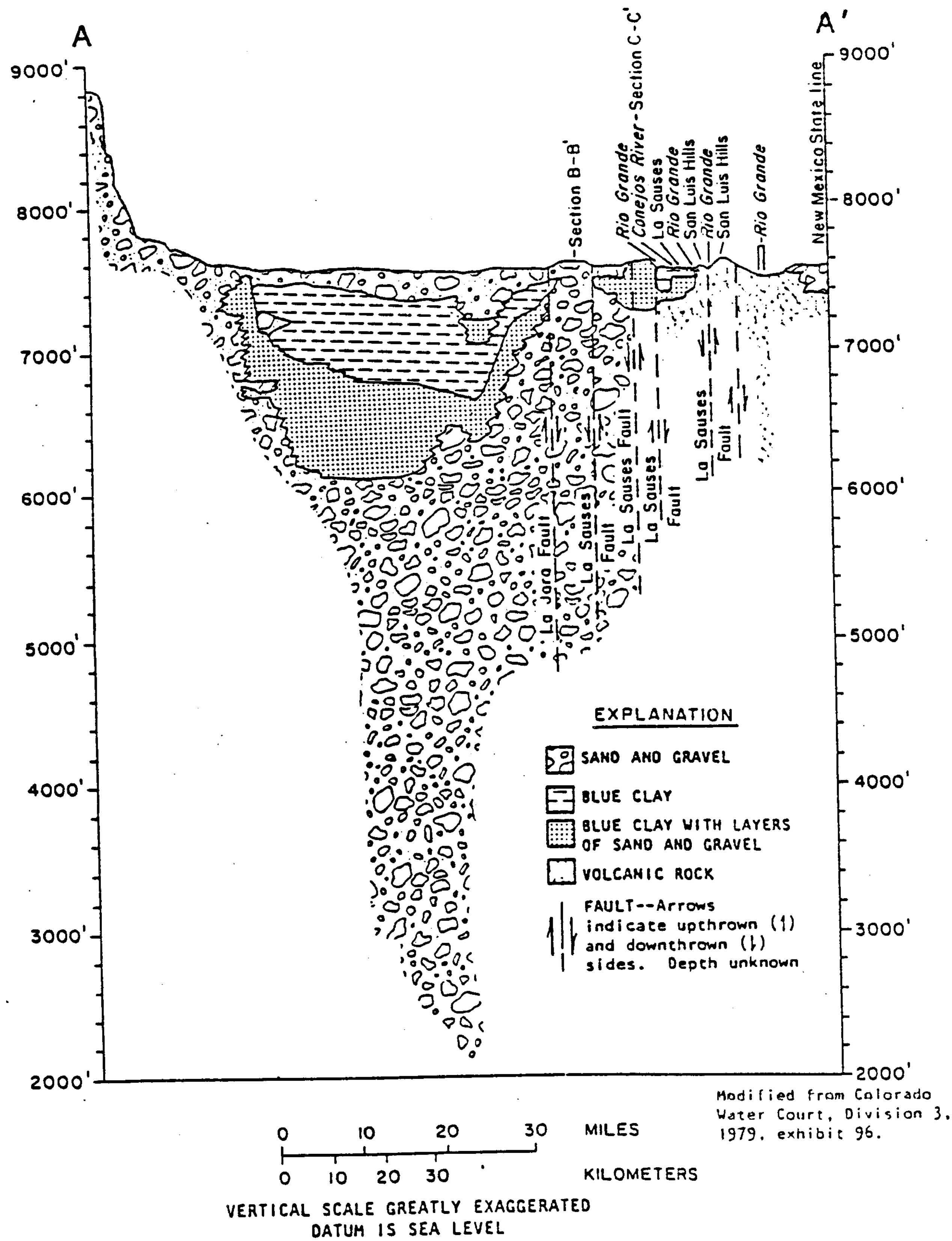


Figure 1. Geology of the San Luis Valley (Wilkins, 1986)

wetlands. Much of the water from the sump of the closed basin is lost to evaporation and transpiration. The Closed Basin Division Project was established as a multipurpose water-resource activity designed to remove water from the sump of the closed basin to augment downstream water users of the Rio Grande River (Elfrink, 1989).

Beneath the active confined unit lies an extremely thick sequence (from 1000 to 10,000 feet in depth) of relatively compact and indurated volcanic, volcanoclastic, and detrital sedimentary formations which comprise a passive aquifer system. The passive confined unit is characterized by low hydraulic conductivities, poor water quality, and an elevated geothermal gradient. Few wells within the valley have tapped even the upper portion of the passive confined aquifer system.

The unconfined aquifer of the San Luis Valley is crucially important because it supports most of the water needs of people within the valley. Because it is recharged from surface water, this aquifer unit is subjected to land use pollution.

1.2.3 Land and Water Use

Land use within the San Luis Valley is primarily agricultural. The economy within the valley is very dependent upon farming and ranching. The main crops produced are potatoes, barley, alfalfa, oats, lettuce, and meadow hay. Livestock production within the area involves cattle and sheep.

The primary use of groundwater in the valley is for irrigating. Farmers irrigate crops with center pivot sprinklers which are supplied by wells completed within the unconfined aquifer. Groundwater is also used to provide for municipal, domestic, and livestock needs. Not all of the water used in the valley is consumed; part returns to the streams or infiltrates to the unconfined groundwater system where it is available for reuse.

1.2.4 Groundwater Quality

The chemical quality of groundwater in the valley is the result of both natural and artificial (manmade) processes that change the chemical composition. As water enters the valley, the natural processes of evaporation, transpiration, leaching of minerals, and ion exchange begin to modify the chemical composition of the water. The use and reuse of water for irrigation, addition of fertilizers and pesticides, and water logging can also degrade the quality of the groundwater. The combined processes result in a general increase in the concentrations of nitrates and other dissolved ions.

Nitrates: The drinking standard for dissolved nitrate, expressed as nitrogen, is 10 milligrams per liter. The standard for dissolved nitrate, expressed as nitrate, is 45 milligrams per liter (US EPA, Drinking Water Standards, 1976). These standards are based upon possible health effects that may occur in infants. A large intake of nitrates constitutes a hazard primarily to infants less than three months old and to the young of certain warm blooded animals where conditions are favorable for nitrate reduction to nitrite in the gastrointestinal tract. When nitrite reaches the bloodstream, it reacts directly with hemoglobin to produce methemoglobin, which impairs oxygen transport. The differences in susceptibility to methemoglobinemia, also called "blue-baby syndrome", are not yet understood but seem to be related to a combination of factors including nitrate concentration, enteric bacteria, and the lower acidity characteristics of the digestive systems of baby mammals (Edelmann, 1984).

Nitrate concentrations in the unconfined aquifer of the San Luis Valley which exceed the drinking water standard have been noted by many sources in the past. Refer to (Emery, 1973), (Edelmann, 1984), (Williams, 1989), (Agro-Engineering, 1989), and (Glanzman, 1989) for a more detailed discussion.

Nitrite plus nitrate concentrations exceeding the drinking water standard have been noted near the town of Center in the San Luis Valley. The unconfined aquifer in this area could very well contain a plume of concentrated nitrates. The nitrate concentrations reported for this area could present a serious water quality problem. Wells should be tested before they are used as a source of drinking water for infants or young livestock.

Pesticides: Pesticides are commonly used as an integral part of standard farming practices within the San Luis Valley. These pesticides could contaminate the unconfined aquifer as a result of well contamination or solute transport through the unsaturated zone. Well contamination can also occur from a faulty back stop valve in the chemigation system, or through cracks and holes in the well casing. Some pesticides also have the potential to move through the ground with soil water and enter the aquifer.

1.3 RISK OF GROUNDWATER CONTAMINATION

The unconfined aquifer in the San Luis Valley is vulnerable to nitrate and pesticide contamination. The following circumstances create a situation in which the unconfined aquifer is highly vulnerable to pesticide contamination due to solute transport through the soil. The valley is primarily rural. A shallow unconfined aquifer underlies the valley. The aquifer serves as the major source of farm irrigation water, and crops of the valley are irrigated by center pivot sprinklers. Agricultural chemicals are used extensively and applied regularly to the primary cash crops. The soils are fairly sandy resulting in little retardation of the pesticides as they begin to move into the soil. The land slope of the valley is minimal causing the pesticide which dissolves in the excess irrigation water to infiltrate into the soil rather then running off of the land surface. The farming practices are homogeneous within selected areas of the valley creating a large region with similar contamination potential.

CHAPTER 2

SAMPLING AND MODELING PROCEDURES

2.1 SAMPLING PROCEDURES

The objective of sampling the groundwater in the San Luis Valley was to determine levels of pesticide contamination in the unconfined aquifer at the present time. Sampling was conducted in conjunction with the Colorado Department of Health's Water Quality Control Division Ground Water Unit. The San Luis Valley sampling program represents a continuation of the Colorado Department of Health's effort to assess the quality of Colorado's groundwater.

Thirty four irrigation wells were chosen across the San Luis Valley. The primary study area was the most intensely irrigated region in the valley bounded as follows: north of Highway 374 between Alamosa and Monte Vista, south of a point approximately six miles north of Center, east of the boundary between the basin and the San Juan Mountains and west of Highway 17 between Alamosa and Moffat. A total of 30 wells were sampled in this region. In addition, two wells were sampled near Blanca, and two near Antonito. Sites were chosen based upon their spatial distribution across the valley. Sampling sites were restricted to center pivot irrigation wells. In order to show any variations in water chemistry between early and late stages of the growing season, each well was sampled twice. The first inorganic sampling of each well was performed between May 22 and May 31, 1990. The first pesticides sampling was done between June 19 and July 7, 1990 and the second sampling for each analysis was performed between July 30 and August 17, 1990.

During the initial groundwater sampling, farmers were interviewed to determine which pesticides were being used. Information concerning land-use, such as tillage practices and irrigation schedules, was also gathered. This information was used as input into the screening models.

Standard Colorado Department of Health procedures were used to sample the groundwater across the valley. The sample collection bottles were precleaned by the laboratory prior to sampling. The pump on each center pivot sprinkler was activated and allowed to run for about five minutes to clear the residual water from the well casing before each sample was taken. The sprinkler was tapped upstream from any chemical injection points, whenever possible, to avoid contaminating the sample. Sample bottles were rinsed with the irrigation water before the sample was collected. Each sample was divided into four bottles and filtered or acidified to meet the analysis requirements. The bottles were sealed with teflon lids. The bottles were filled entirely with water to prevent residual air in the sampling bottle. Samples were then placed on ice and maintained at four degrees Celsius.

The Soil Testing Laboratory at Colorado State University performed a "Basic Water" and "Basic Metals" analysis on each inorganic sample collected. In addition to the basic inorganic analysis run at CSU, a sample was collected at each site and analyzed for Alkalinity, Total Dissolved Solids, and Hardness (A/T/H) at the Colorado Department of Health's Inorganics Laboratory. This additional data was justified because of the importance of the parameters and the value of data comparisons between the two labs.

In order to further compare the data generated by the two inorganics labs, "split" samples were collected at five of the 34 sites during the initial sampling period, and six of the 34 sites during the resampling. These samples were submitted to both the CSU Lab and the CDH Lab for complete inorganic analyses.

The pesticide analyses was performed by the CDH Organics Lab and included 16 pesticides. Table 1 lists the organic analytes checked at the CDH Lab.

2.2 CMLS SIMULATION PROCEDURE

The purpose of this part of the study was to evaluate the potential risk of groundwater contamination by pesticides in the San Luis Valley of Colorado using the computer program '<u>Chemical Movement in Layered Soils</u>' (CMLS). Through the use of this model the existing threat of pesticide contamination in the groundwater aquifer was estimated and an understanding of the solute transport processes occurring in the San Luis Valley was obtained. CMLS can also be used to determine which locations in the San Luis Valley have the greatest risk of being contaminated by agricultural chemicals. These results were then compared to those obtained by DRASTIC regarding the spatial distribution of contamination potential across the San Luis Valley.

'<u>Chemical Movement in Layered Soils</u>' (CMLS) is an interactive microcomputer model that describes the solute transport processes of a nonconservative chemical in soil. CMLS was written by the Department of Agronomy at Oklahoma State University and the Soil Science Department at the University of Florida (Nofziger and Hornsby, 1986). The model was written to serve as a management tool and a decision aid in the application of organic chemicals to soils.

Table 1. CDH Organic Laboratory - List of Analytes

Pesticide	Method Detection Limit ($\mu g/l$)	Practical Quantitation Limit ($\mu g/l$)
Lasso	0.380	3.80
Bravo	0.025	0.25
Lorsban	0.030	0.30
2,4-D	0.200	2.00
Dacthal (DCPA)	0.025	0.25
Di-Syston	0.300	3.00
Thiodan	0.015	0.15
Eptam	0.250	2.50
Pydrin	0.500	5.00
Methyl Parathion	0.500	5.00
Dual	0.750	7.50
Sencor	0.150	1.50
Prowl	0.800	8.00
Ambush	0.500	5.00
Kerb	0.760	7.60
Treflan	0.025	0.25

2.2.1 Model Theory

CMLS predicts the movement of the peak concentration of a polar organic chemical as a function of time after application. Simultaneously, CMLS calculates the relative concentration of the chemical at the center of mass as a function of time. The two processes of mobility and persistence are modeled separately.

Mobility: The mobility of the chemical is estimated from a mass balance of water and the retardation of the chemical. The purpose of modeling the mobility is to trace the movement of the peak concentration of the chemical downward through the soil. CMLS assumes that the chemical moves only in the liquid phase in response to soil water movement. The downward movement of the chemical depends upon the quantity of water passing the center of mass of the chemical and the retardation of the pesticide.

The depth of the peak concentration of the pesticide at any discrete time after the application date of the chemical is determined using a solute tracking approach. The change in depth of the chemical during the time interval of interest is added to the depth of the chemical on the previous date. If $\mathbf{d_j}$ indicates the depth of the peak concentration of the chemical at time **j** and **d**Δrepresents the change in the depth of the chemical during the time interval from **j-1** to **j** then:

$$d_j = d_{j-1} + \Delta d \qquad (2.1)$$

The change in the depth of the chemical within any time interval is a function of the amount of water passing the depth of the peak concentration of the chemical (**q**), the retardation factor of the chemical (**R**), and the volumetric water content of the soil at field capacity (θ_{FC}) such that:

$$\Delta d = \frac{q_j}{R\theta_{FC}} \qquad (2.2)$$

when $q_j>0$. If the amount of water passing the peak concentration of the chemical is not greater than zero, the change in the depth of the chemical during that time interval is assumed to be zero.

The retardation of the chemical is determined from:

$$R = 1 + \frac{(\rho_b) K_d}{\theta_{FC}} \qquad (2.3)$$

where ρ_b is the bulk density of the soil and $\mathbf{K_d}$ is the adsorption coefficient. The adsorption coefficient partitions the concentration of the chemical between an adsorbed phase ($\check{S}$) and a dissolved phase ($\check{C}$). The portion of the pesticide in the dissolved phase moves downward with the soil water while the portion of the chemical in the adsorbed phase is assumed to adhere to soil particles and become immobile. CMLS assumes that the adsorption coefficient follows a linear isotherm such that:

$$C=\frac{S}{K_d} \tag{2.4}$$

The adsorption coefficient depends on both chemical and soil properties and is assumed to be linearly related to the amount of organic carbon in the soil and the potential for adsorption of the chemical, i.e.

$$K_d=K_{oc}*f_{oc} \tag{2.5}$$

where $\mathbf{K_{oc}}$ is the organic carbon partitioning coefficient and $\mathbf{f_{oc}}$ is the fraction of organic carbon in the soil. The organic carbon partitioning coefficient is a property inherent to each specific chemical. The organic carbon fraction is a measure of the organic carbon within the soil. The organic carbon fraction can be approximated as forty percent of the organic matter content of the soil.

A mass balance is used to determine the amount of water passing the depth of the peak concentration of the chemical. The amount of water passing the chemical is equal to the amount of water entering the soil minus the amount of water stored above the depth of the chemical. The amount of water that can be stored above the depth of the chemical depends upon the moisture content of the soil before the water enters the soil and the available water holding capacity of the soil.

Once the mass balance is performed, the soil water content within the root zone is adjusted for evapotranspiration. The amount of water removed from each soil horizon is proportional to the available water holding capacity of that horizon. The soil moisture content in each horizon is not allowed to decrease below the permanent wilting point of that horizon. The model assumes that the solute will not move upward with water being lost to evapotranspiration.

Any water in excess of the available water holding capacity of the root zone once the entire rooting depth is recharged is allowed to infiltrate downward. If the chemical depth exceeds the root zone depth, the quantity of water passing the depth of the peak concentration of chemical is equal to the amount of water leaving the root zone, since the soil below the rooting depth is assumed to always be at field capacity.

Persistence: The relative amount of total chemical remaining in the soil profile is determined using an empirical first order exponential decay equation. The relative amount of chemical (M_j) remaining in the soil profile j days after the application date is determined by:

$$M_j = e^{\frac{-0.693 t_j}{t^{1/2}}} \qquad (2.6)$$

where **t** is the number of days since the pesticide was applied and $t^{1/2}$ is the degradation half life of the chemical. At the time of application **j** = 0 and M_0 = 1.

2.2.2 Model Assumptions

Major assumptions made in CMLS and their consequences include (Nofziger and Hornsby, 1987):

1) Chemicals move only in the liquid phase in response to soil water movement. This assumption ignores solute movement in the vapor phase. As such, volatilization is disregarded. If a chemical has a large Henry's Constant and readily volatilizes the model's estimate of the amount of chemical in the profile will likely exceed the actual amount present.

2) The chemical pulse is considered to be of infinitely small thickness and is computed as a point. As such, this model does not predict the dispersion of the solute. The model estimates the location of the peak of the chemical pulse. Some chemical will also be present at greater and lesser depths.

3) The adsorption process is assumed to obey a linear, reversible, equilibrium model. If the sorption is described by a nonlinear isotherm, the partition coefficient decreases with increasing solute concentration, and the depth to which the chemical moves will be dependant upon the concentration. This aspect is ignored by CMLS. If adsorption equilibrium is not obtained instantaneously, the chemical will move to depths greater than those predicted by CMLS. If adsorption is irreversible, the depth of the chemical will be less.

4) All water in the soil pore space participates in the solute transport process. Water present in the soil profile is completely displaced ahead of water entering the soil surface. If a portion of water is bypassed by the infiltrating water and preferential flow exists, this model will underestimate the depth of the peak concentration of the chemical.

5) Water entering the soil profile redistributes instantaneously to field capacity. This assumption is approached for coarse textured soils. If the water redistributes slowly, as in the case of fine textured soils, the depths predicted will be overestimated.

6) Evapotranspiration removes water from each soil horizon in the root zone in proportion to the amount of water available in that layer. No provision is made for nonuniform root densities or for root density changes with time. This assumption may tend to overestimate the depth of movement when the solute depth is within the root zone.

7) Water lost from the root zone by evapotranspiration is not replaced by water from below. This assumption implies that the chemical does not move upward in the soil. As a result, the chemical depth predicted may slightly exceed the actual depth.

8) The half life for biological degradation of the chemical is invariant over time. The chemical degradation rate is dependent upon a variety of environmental factors, so seasonal changes in degradation rates may be expected. These variations are ignored in this model.

2.2.3 CMLS Simulation Protocol

CMLS requires input data such as soil type, pesticide type, precipitation, and evapotranspiration. A flowchart with required input is shown in Figure 2. The items with an asterisk before them indicate the input parameters required specifically by CMLS. Major parameters are described briefly below.

CMLS was used to simulate sixteen different pesticides at three different locations within the San Luis Valley. The three locations were chosen based upon their spatial distribution across the valley. The three locations were called Site 9, Site 30, and Site 28. The site numbers correspond with locations that were actually sampled.

Flowchart of Information Required as Input for CMLS

Location:

1. Crop Type
2. Soil Type
3. Pesticide Type
4. Hydrogeology

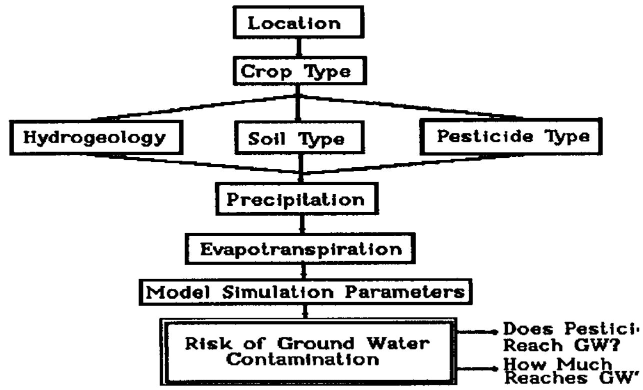


Figure 2

Crop Type:

*1. Maximum Rooting Depth
2. Precipitation Requirements
3. Evapotranspiration Needs
4. Chemicals Used
5. Planting & Harvesting Date

Soil Type (for each horizon):

*1. Depth to Bottom of Horizon
*2. Percent Organic Carbon
*3. Bulk Density
*4. Moisture Content at Field Capacity (Matric Potential of -0.1 bars)
*5. Moisture Content at the Permanent Wilting Point (Matric Potential of -15 bars)
*6. Moisture Content at Saturation (Matric Potential of 0 bars)
7. Porosity of Soil

Pesticide Type:

*1. Partitioning Coefficient Normalized for Organic Carbon Content
*2. Degradation Half-Life
*3. Application Date of Chemical
*4. Application Depth of Chemical
5. Amount of Chemical Applied to Soil Surface
6. Density of Pesticide

Hydrogeology:

1. Depth to Water Table
2. Depth of Unconfined Aquifer

Precipitation Record:

*1. Date
*2. Effective Precipitation

Evapotranspiration Record:

*1. Date
*2. Effective Evapotranspiration

Model Simulation Parameters:

*1. Date to End Simulation

Pesticide Type: The sixteen chemicals simulated include five potato insecticides, three potato herbicides, two potato fungicides, and one potato desiccant. Also included were four barley herbicides and one general herbicide. These sixteen chemicals are listed in Table 2. Notice that the chemicals listed in Table 2 are not the same as those listed in Table 1, the pesticides actually analyzed for. The list in Table 2 was compiled from a user survey of pesticides utilized in the valley. Asterisks indicate chemicals not included in the analysis list.

Table 2. Pesticides Used in CMLS Simulations

Trade Name	Chemical Common Name	K_{oc} ml/g	$T^{1/2}$ days	Pesticide Action	Utilization
Temik*	Aldicarb	30	30	Potato Insecticide	Light
Monitor*	Methamidophos	780	6	Potato Insecticide	Medium
Dy-Syston	Disulfoton	2000	4	Potato Insecticide	Medium
Asana*	Esfenvalerate	100000	50	Potato Insecticide	Medium
Pydrin	Fenvalerate	100000	50	Potato Insecticide	Heavy
Sencor	Metribuzin	41	30	Potato Herbicide	Heavy
Dual	Metolachlor	200	20	Potato Herbicide	Medium
Eptam	EPTC	280	30	Potato Herbicide	Heavy
Manzate*	Macozeb	1000	35	Potato Fungicide	Heavy
Bravo	Chlorothalonil	1380	20	Potato Fungicide	Heavy
Diquat*	Diquat	100000	3600	Potato Desiccant	Heavy
2,4-D	2,4-D	20	10	Grain Herbicide	Heavy
Rhomene*	MCPA	20	14	Grain Herbicide	Medium
Buctril*	Bromoxynil	1000	14	Grain Herbicide	Heavy
Hoelan*	Diclofop	48500	10	Grain Herbicide	Medium
Round-Up*	Glyphosate	10000	30	General Herbicide	Medium

The simulation was run for a five year period using actual cropping patterns and rainfall records. Average irrigation rates were added to precipitation records. Soil data was used from three representative sites within the valley. Average hydrogeologic data were used to represent worst case scenarios for water depth. Each of these parameters is discussed further below.

The following input parameters were used for each of the CMLS simulations:

Crop Type: Russet Potato/Steptoe Barley Rotation
- **Rooting Depth:** 36 inches for both crops
- **Planting & Harvesting Date:** 5/15 - 9/20 for Potatoes; 4/10 - 8/15 for Barley

Soil Type: As Indicated by Location
- **Depth to Bottom of Horizon:** Infinite
- **Percent Organic Carbon:** As Indicated by Soil Type
- **Bulk Density:** As Indicated by Soil Type
- **Moisture Content @ FC:** As Indicated by Soil Type
- **Moisture Content @ PWP:** As Indicated by Soil Type
- **Moisture Content @ Sat'n:** As Indicated by Soil Type
- **Porosity of Soil:** 0.437 for loamy sand; 0.453 for sandy loam

Pesticide Type: Each of the Sixteen Pesticides Listed in Table 2
- **Partitioning Coef:** As Indicated by Pesticide Type
- **Degradation Half Life:** As Indicated by Pesticide Type
- **Application Date:**
  - 06/01/1984 for Preemergence Herbicides
  - 06/15/1984 for Postemergence Herbicides
  - 07/14/1984 for Fungicides
  - 08/01/1984 for Insecticides
  - 08/30/1984 for Desiccants
- **Application Depth:** 0 inches
- **Amount Applied to Soil:** As Indicated by Pesticide Type
- **Density:** As Indicated by Pesticide Type

Hydrogeology:
- **Depth to Water Table:** 5 feet
- **Depth of Unconfined Aquifer:** 90 feet

Model Simulation Parameters:
- **Date to Begin Simulation:** 01/01/1984
- **Date to End Simulation:** 12/30/1988

Crop Type: The cropping pattern of rotating between potatoes and barley is common in the San Luis Valley. CMLS is not capable of simulating crop rotations therefore each crop was simulated separately. A root depth of thirty-six inches was used for both crops (Agro-Engineering, 1983).

Soil Type: The soil data used for the CMLS simulations came from soil samples which were obtained during an initial sampling survey between June 22 and June 30, 1990. The soil was sampled between three and twelve inches below the soil surface. Soil analysis was performed by the CSU Soil Testing Laboratory. The soil information is summarized in Table 3.

Table 3. Soil Information Used in CMLS Simulations

Soil Name	Organic Carbon (%)	Bulk Density (g/cm^3)	Water Content @ FC (%)	Water Content @ PWP (%)	Water Content @ Sat'n (%)	Porosity
Site30	0.60	1.86	13.4	8.6	47.0	0.453
Site 9	0.36	1.53	13.0	7.6	41.3	0.453
Site28	0.28	1.30	8.3	5.9	35.6	0.437

Hydrogeology: The depth from the soil surface to the water table was assumed to be five feet across the entire valley. This is a rough estimate. The water table depth actually varies spatially across the valley. The water table depth averages twelve feet or greater west of Colorado Highway 285 and averages a depth of five to twelve feet in the central part of the valley. The water table is shallower than five feet in the Closed Basin located in the eastern part of the valley (Edelmann and Buckles, 1983). The water table also varies temporally with the season. The water level usually reaches a high in early spring after the snow runoff has recharged the aquifer and this level decreases through the summer and fall. For modeling purposes, these spatial and temporal variations in water table depth were ignored and a uniform water table depth of five feet was assumed to exist. The value of five feet was chosen because it represents a worse case scenario for the central portion of the valley where pesticide use is most intense.

Precipitation: Precipitation, for modeling purposes, includes all water that infiltrates into the soil. The precipitation files used for all CMLS simulations were taken from actual rainfall records for the San Luis Valley and average irrigation application data for each specific crop. Different precipitation files for the two different crops were produced because each crop has specific irrigation requirements.

The potato precipitation file is composed of actual rainfall data, recorded at the Alamosa weather station during the years from 1984 through 1988, and the average irrigation requirements for Russet variety potatoes under center pivot irrigation. The irrigation application information was obtained from Agro-Engineering. Twenty-six and nine-tenths inches of water were applied annually in this simulation. This precipitation record is shown in Figure 3.

Figure 4 shows the water applied to barley. It contains the same rainfall precipitation data for 1984 through 1988 with the average irrigation requirements for Steptoe Barley superimposed upon it. This amount of water averaged to be twenty-eight and three-fifths inches annually.

Evapotranspiration: The evapotranspiration files contain the average evapotranspiration requirements for each crop during the growing season. Evapotranspiration is assumed to be zero outside of the growing season. This information was obtained from Agro-Engineering. The potato file contains average evapotranspiration needs for Russet potatoes. An average of sixteen and one-tenth inches of water was required by the crop within each growing season. Figure 5 shows this data.

Figure 6 shows the amount of water required by barley. An average of eighteen and one-half inches of evapotranspiration water per growing season was required by Steptoe Barley. Once again, evapotranspiration was assumed to be insignificant outside of the crop growing season.

Precipitation Records

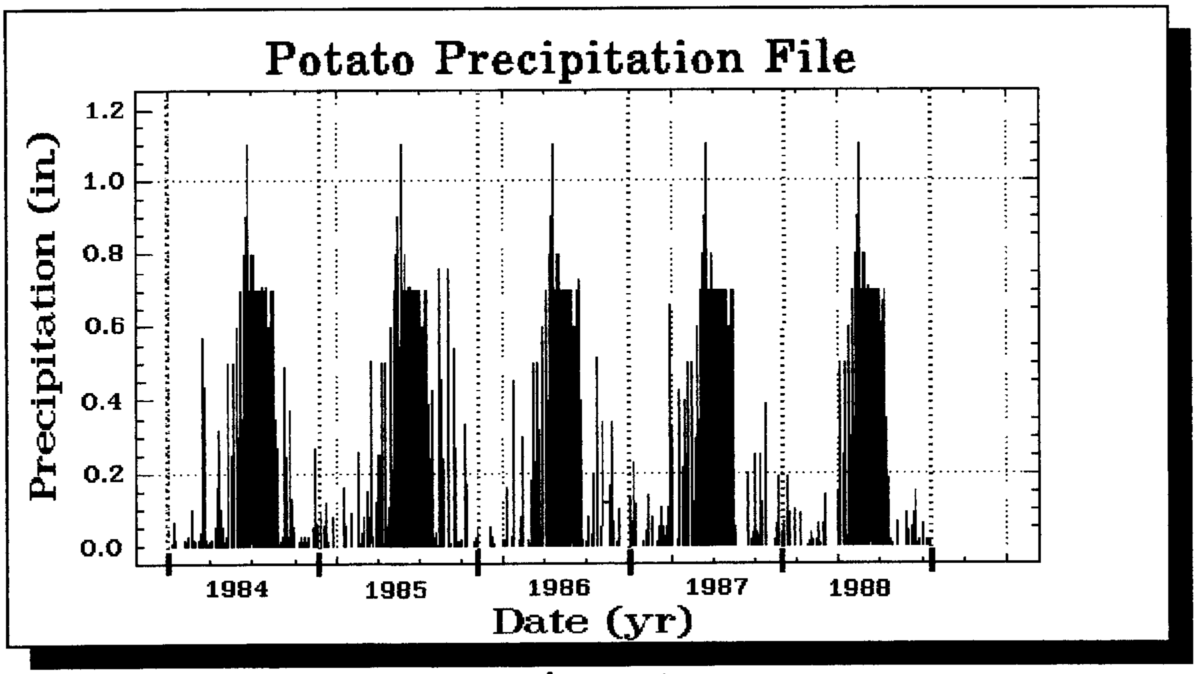


Figure 3

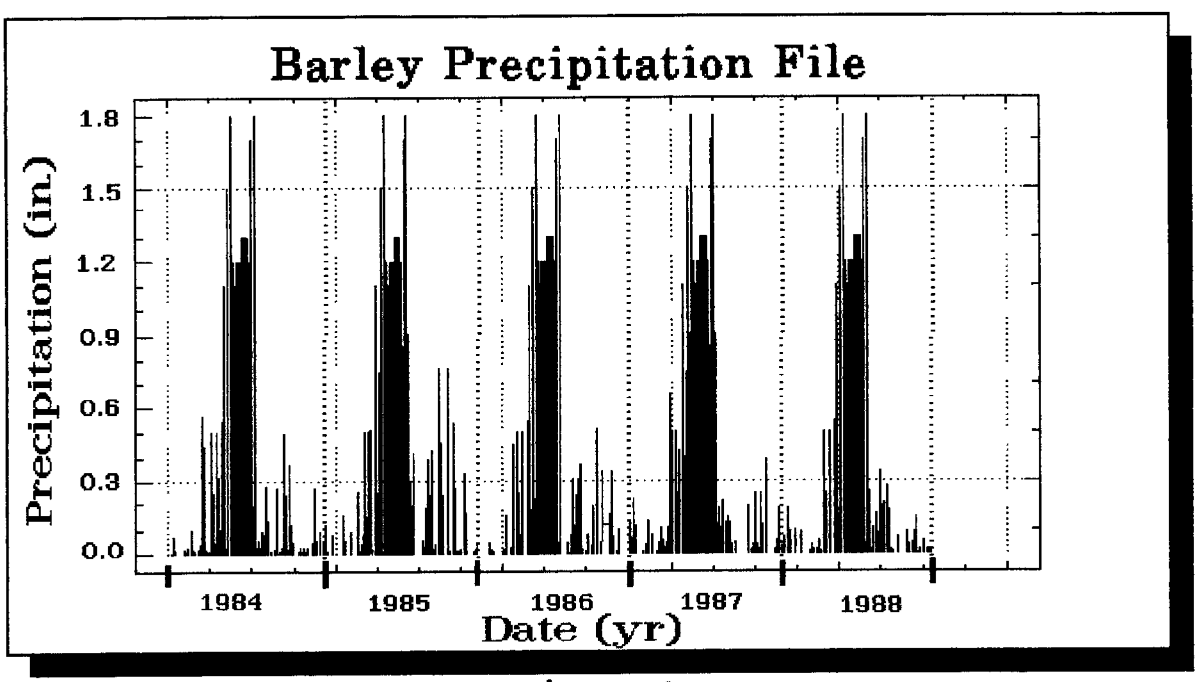


Figure 4

Evapotranspiration Records

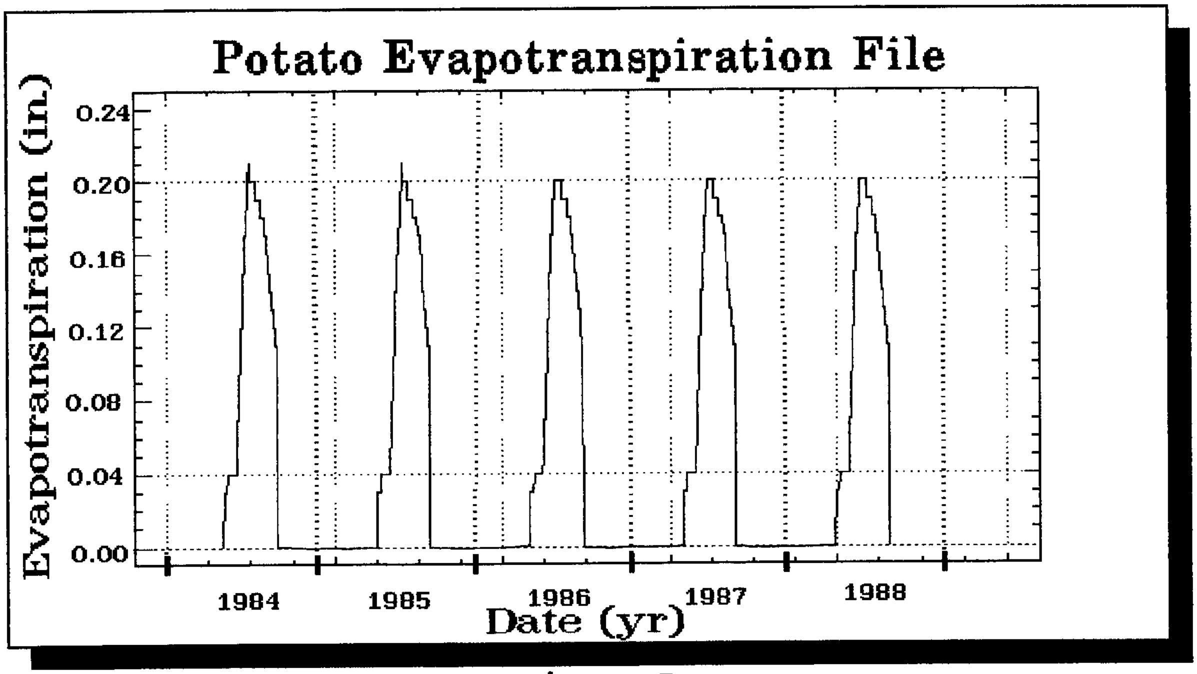


Figure 5

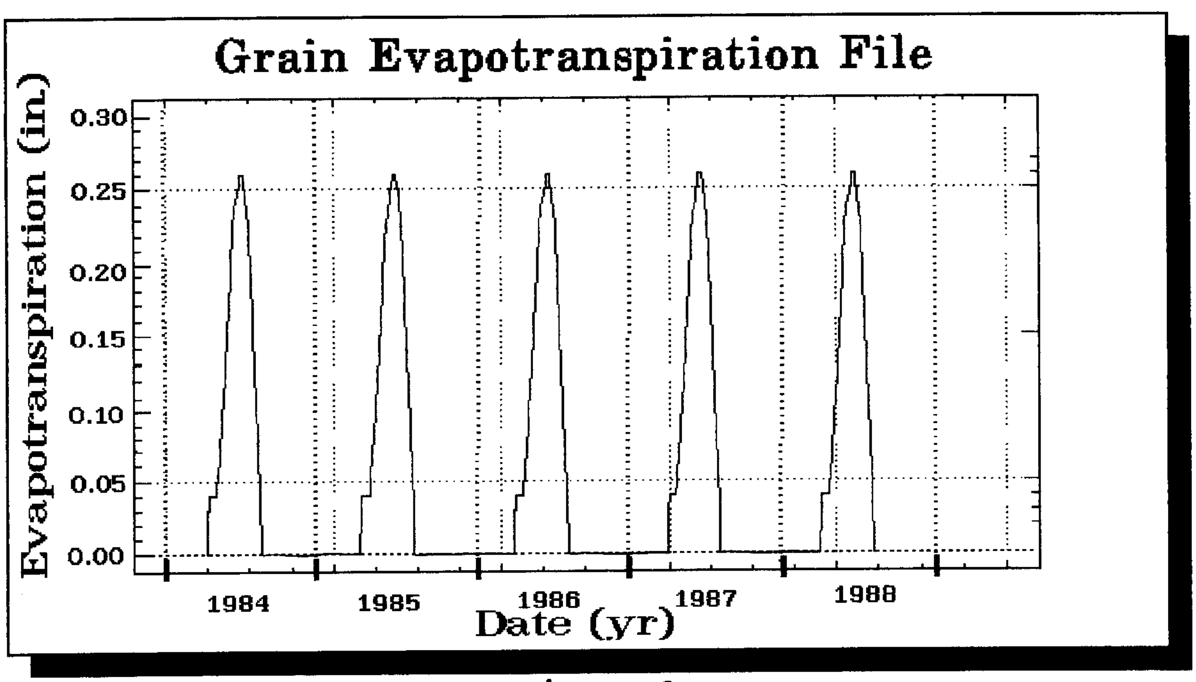


Figure 6

2.3 DRASTIC MAP PREPARATION

Pesticide DRASTIC is a pollution potential index designed to evaluate the relative vulnerability of land areas to groundwater contamination from pesticides. The use of DRASTIC involved characterizing the San Luis Valley with seven hydrogeological parameters. All seven parameters were superimposed to create a pollution potential index for each mapping unit. A DRASTIC map for the San Luis Valley was then developed that can be used to determine the locations within the valley that are most vulnerable to groundwater pollution. The system has two major facets: the designation of mappable units, termed hydrogeologic settings, and the superposition of the DRASTIC relative rating system.

Hydrogeological settings form the basis of the system and incorporate the major hydrogeological factors that control groundwater movement. These factors include: the depth to groundwater, the net recharge into the aquifer, the aquifer media, the soil media, the topography of the land surface, the impact of the vadose zone media upon groundwater movement, and the hydraulic conductivity of the aquifer. The word DRASTIC is an acronym which represents these seven factors. DRASTIC incorporates each of these parameters into a relative ranking scheme that uses a combination of weights and ratings to produce a numerical representation of the pollution potential of that hydrogeological setting. DRASTIC is a weighted-linear-additive index (Aller et al., 1987).

It should be clearly recognized that DRASTIC is an index. As such, the numeric value of a DRASTIC rating is meaningless on its own. It is only when this rating is compared to ratings from different hydrogeological settings that the relative pollution potential can be delineated. Further, pollution potential is a combination of hydrogeologic factors, anthropogenic influences, and contaminant properties in any given location. The DRASTIC system has been designed to include only the hydrogeological factors that influence pollution potential. DRASTIC does not predict the movement of a solute. For this reason, DRASTIC cannot be used to differentiate between the pollution potential of different pesticides or evaluate anthropogenic influences.

DRASTIC was designed to assist planners, managers and administrators in the task of evaluating the relative vulnerability of different hydrogeological settings to groundwater contamination. DRASTIC was designed by the National Water Well Association under the sponsorship of the Robert S. Kerr Environmental Research Laboratory and in conjunction with the United States Environmental Protection Agency. Model development occurred over a period of five years between 1983 and 1987.

The DRASTIC model was developed using a Delphi approach. A technical advisory committee with thirty seven members was surveyed. The committee members represent prominent individuals with groundwater expertise from federal and state agencies, the Canadian government and private consultants. The committee provided the guidance and direction needed to create the DRASTIC system as a synthesis of many different approaches and opinions.

Pesticide DRASTIC is a modified version of the DRASTIC model designed specifically to rate the pollution potential of a land area in response to pesticide usage. Pesticide DRASTIC differs from DRASTIC in the assignment of relative weights on the seven DRASTIC factors. The form of DRASTIC used in this paper is the Pesticide DRASTIC version.

2.3.1 The DRASTIC Rating

Pesticide DRASTIC produces a numeric index representing the pollution potential for each specific hydrogeologic setting. This rating is obtained using the following equation:

$$D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W \qquad \text{(Eq. 2.8)}$$

where each variable represents the following parameters:

D = **D**epth to Water Table
R = Net **R**echarge
A = **A**quifer Media
S = **S**oil Media
T = **T**opography (Slope)
I = **I**mpact of the Vadose Zone Material
C = Hydraulic **C**onductivity

and the subscripts represent the parameter rating and weight:

R = Rating (1 to 10)
W = Weight (2 to 5)

Each Pesticide DRASTIC factor has been evaluated by the developers of the method with respect to each other to determine the relative importance of each parameter. Each factor has been assigned a weight from two to five. The most significant parameters have a weight of five while the least significant factors have a weight of two. These weights are constant and may not be changed by the user. Each DRASTIC factor is also divided into either ranges or significant media types. The different ranges for each parameter and the assigned weights are given in Appendix A.

2.3.2 Model Assumptions

DRASTIC has four major assumptions (Aller et al., 1987):

1) The contaminant is introduced at the ground surface.

2) The contaminant is flushed into the groundwater by recharge.

3) The contaminant has the mobility of water.

4) Each hydrogeological setting evaluated with DRASTIC is 100 acres or larger.

Assumption three has been relaxed with the development of Pesticide DRASTIC. Caution should be exercised when large deviations from these assumptions occur.

2.3.3 Simulation Protocol

The following protocol was used to implement DRASTIC and create a pollution potential map for the San Luis Valley.

1) Data concerning the seven DRASTIC hydrogeological parameters was gathered to represent the San Luis Valley.

2) The spatial variation of each parameter was mapped onto a separate overlay. A piece of Matte Acetate (overhead transparency) taped to a map of the San Luis Valley composed each overlay.

3) Boundary lines were drawn on the overlay to represent changes in the DRASTIC parameter. The DRASTIC range and weight for that parameter were then placed in each appropriate mapping unit.

4) Once an overlay for each parameter had been constructed, they were all superimposed upon each other and the DRASTIC Pollution Potential Index was calculated for each mapping unit.

2.3.4 Description of the Factors in DRASTIC

This section provides a brief description of each of the seven hydrogeologic parameters required by DRASTIC.

Depth to Water Table: The distribution of the depth to the water table in the San Luis Valley was obtained from the work of Repplier et al. (1981). The overlay of depth to water used for the DRASTIC analysis is shown in Figure 7.

Net Recharge: Net recharge is the annual amount of water per unit area of land that infiltrates the ground surface and will eventually reach the water table. The amount of recharge can be estimated for a given mapping unit as the annual evapotranspiration of the soil cover subtracted from the sum of the annual precipitation amount and the annual irrigation water. It was assumed that potatoes were the common crop grown across the valley. An average of about twenty inches of irrigation water is applied to potatoes annually, and an average of about sixteen inches is required by Russet potatoes to fulfill the evapotranspiration needs of the crop. The San Luis Valley receives an average of seven inches of precipitation annually. For the DRASTIC simulation an annual net recharge amount of eleven inches was used. This parameter was assumed homogeneous across the entire San Luis Valley study area.

Aquifer Media: The unconfined aquifer in the San Luis Valley is quite thin, ranging from about 40 to 100 feet in thickness, and consists of sand and gravel.

Soil Media: The soil media refers to the uppermost layer of the vadose zone characterized by biological activity. The soil types for the study area within the San Luis Valley were obtained from the SCS soil surveys of Alamosa Area, Colorado, Rio Grande County Area, Colorado, and Saguache County Area, Colorado. From the SCS soil surveys a generalized map of the spatial distribution of soil types was produced. This overlay was then used for the DRASTIC simulation. This map is shown in Figure 8.

Topography: Topography refers primarily to surface slope. The average slope of the valley floor is six feet per mile (Hanna and Harmon, 1989), a 0.114 percent slope. Because the valley is relatively flat, this slope was assumed uniform across the entire study area.

Impact of the Vadose Zone Material: The vadose zone material was assumed to be the same as the media within the unconfined aquifer because of the shallow characteristics of the aquifer. A vadose zone material comprised of sand and gravel was used for the DRASTIC simulation.

Hydraulic Conductivity: A map of the hydraulic conductivities of the San Luis Valley could not be found from the literature. The hydraulic conductivities for the unconfined aquifer were estimated as the quotient of reported transmissivities and estimated average saturated thickness of the aquifer. An estimation of the spatial variation of the transmissivity within the San Luis Valley was presented in a feasibility study of the Closed Basin Project by the USGS (Leonard and Watts, 1988). The saturated thickness of the aquifer was obtained from the depth to water and the depth to the top of the first confining clay layer as reported in an atlas of groundwater quality (Repplier et al., 1981). The overlay of hydraulic conductivity used for the DRASTIC simulation is shown in Figure 9. The values obtained for the hydraulic conductivity agree with estimates made by Hanna and Harmon (1989) which state that the hydraulic conductivity ranges from 35 ft/day (262 gal/day/ft^2) on the east side of the valley to 235 ft/day (1757 gal/day/ft^2) on the west side of the valley (Hanna and Harmon, 1989).

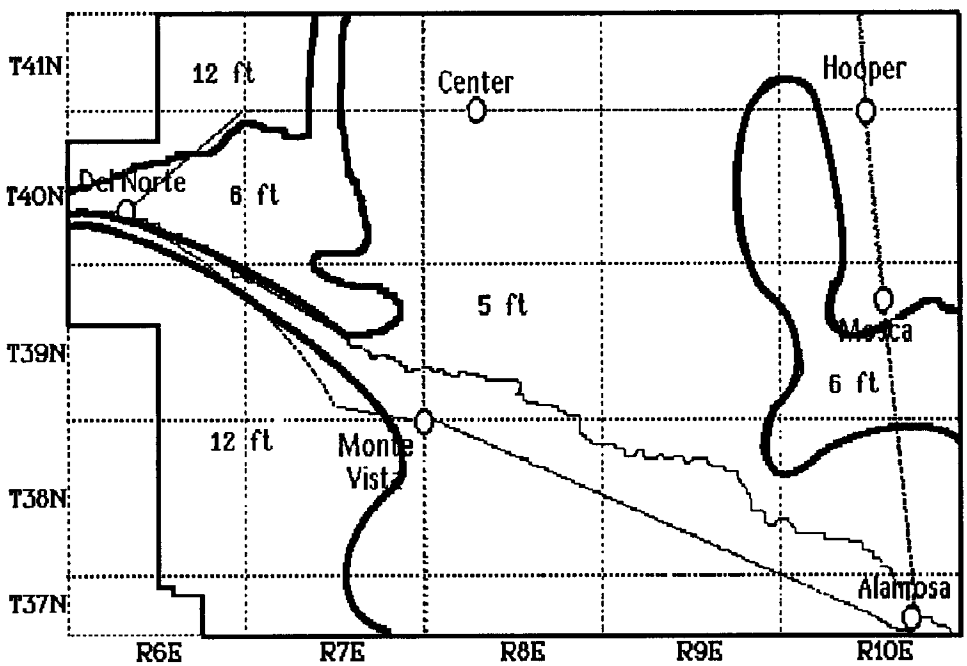


Figure 7. DRASTIC Overlay of Depth to Water

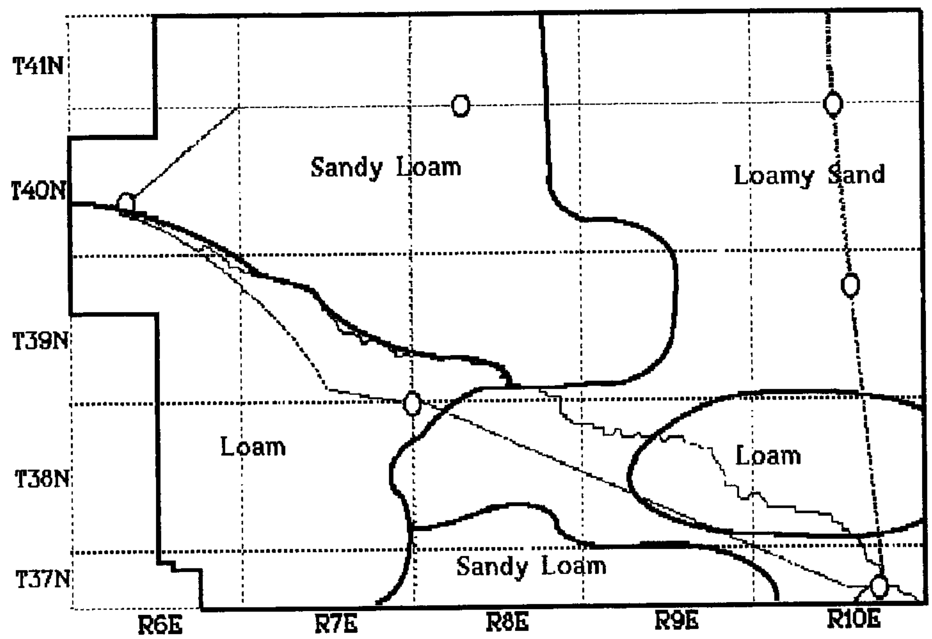


Figure 8. DRASTIC Overlay of Soil Media

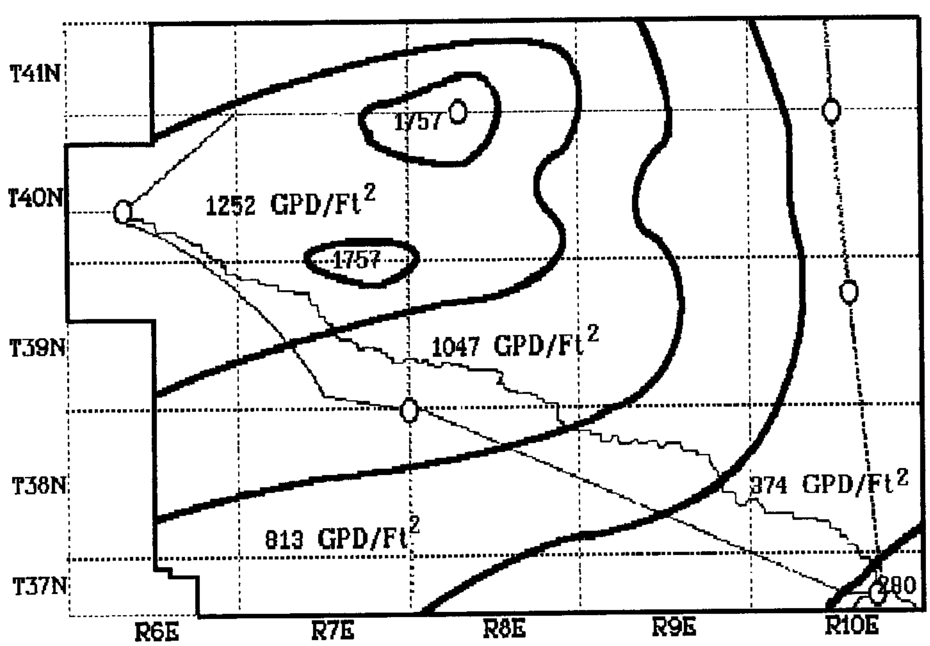


Figure 9. DRASTIC Overlay of Hydraulic Conductivity

CHAPTER 3

RESULTS

3.1 SAMPLING RESULTS

Pesticides were found in the water samples at five of the thirty-four sites during the first sampling and ten of the thirty-four sites during the second sampling. High nitrate levels were evident in many of the samples from both the early and late sampling times. Table 3 summarizes the results for the first sampling. Table 4 summarizes the results for the second sampling. Bold print indicates sample locations where a pesticide was found or nitrate levels were in exceedence of drinking water standards.

In the first set of data, there were four wells located in the Sargent district between the towns of Monte Vista and Center in which **Sencor** was found. **Sencor** is used heavier within this region than in the rest of the study area. The concentration of **Sencor** in all four of these samples was at or below the practical quantitation limit of 1.5 micrograms per liter (1.5 ppb). Three of these samples contained only trace amounts of **Sencor**, while the fourth sample had a concentration of 1.5 micrograms per liter. **Eptam** was found in one sample. The concentration of **Eptam** found in this sample was 7 micrograms per liter.

The same wells were sampled again at the end of the growing season. The second set of samples had six detectable levels of **Bravo**, one **2,4-D**, two **Sencor**, and two **Eptam**. Concentrations were all at trace levels except for one sample containing **Sencor**. Nine of the samples with detectable levels of pesticides were again in the Sargent District. Of the four wells in this area with detectable levels of **Sencor** in the first sampling, three had detectable levels of pesticides in the second sampling although only one contained **Sencor**. The site at which **Sencor** was detected in both samplings had a trace level in the first data set and a level of 2.8 micrograms/liter in the second set. **Eptam** and **Bravo** were detected in one well and **Bravo** was detected in the second well sample. The fifth well in the first sampling that contained **Eptam** was found to have detectable levels of **Bravo** in the second sampling.

The existence of five detections in the first sampling and eleven detections of pesticides in the second sampling raises concern for contamination of the groundwater in the San Luis Valley. However, the results from the direct sampling program are inconclusive. When samples had detectable levels of pesticides, the source of the pesticide could have been caused by a local well problem or sample contamination and may not reflect any general aquifer contamination. As indicated on Table 3 and

Table 3. First Sampling Results					
#	Analyte Found	Amount (µg/l)	NO_3 as N (µg/l)	NO_3 (µg/l)	Flag
1	None	BDL	1.2	5.3	Well
2	None	BDL	**18.1**	**80.2**	
3	None	BDL	**13.4**	**59.3**	
4	**Sencor**	**Trace**	**15.8**	**70.0**	
5	None	BDL	0.1	0.4	
6	None	BDL	0.1	0.4	
7	None	BDL	**12.3**	**54.5**	
8	None	BDL	**10.4**	**46.1**	
9	None	BDL	8.5	37.6	
10	None	BDL	**18.3**	**81.0**	
11	None	BDL	6.7	29.7	
12	**Sencor**	**Trace**	**13.1**	**58.0**	Sample
13	None	BDL	**21.8**	**96.5**	
14	None	BDL	1.8	8.0	
15	None	BDL	**15.6**	**69.1**	
16	None	BDL	1.5	6.6	
17	None	BDL	8.0	35.4	
18	None	BDL	4.0	17.7	
19	None	BDL	7.5	33.2	
20	None	BDL	3.2	14.2	
21	None	BDL	**22.3**	**98.8**	
22	**Eptam**	**7.0**	8.0	35.4	Sample
23	None	BDL	0.6	2.7	
24	None	BDL	0.7	3.1	
25	None	BDL	**10.5**	**46.5**	
26	**Sencor**	**1.5**	**16.0**	**70.9**	Well
27	**Sencor**	**Trace**	**15.2**	**67.3**	Sample
28	None	BDL	0.4	1.8	
29	None	BDL	7.8	34.5	
30	None	BDL	2.3	10.2	
31	None	BDL	5.1	22.6	Well
32	None	BDL	2.8	12.4	
33	None	BDL	0.4	1.8	
34	None	BDL	7.4	32.8	

Well = Well Head Problem
Sample = Sampling Problem

Table 4. Second Sampling Results

#	Analyte Found	Amount (μg/l)	NO_3 as N (mg/l)	NO_3 (mg/l)	Flag
1	None	BDL	1.8	8.0	Well
2	None	BDL	**11.6** **12.0**	**51.4** **53.1**	
3	None	BDL	**13.3**	**58.9**	
4	None	BDL	**16.0**	**70.9**	
5	None	BDL	1.9	8.4	
6	None	BDL	0.9 1.0	4.0 4.4	
7	**Bravo**	**Trace**	**12.6**	**55.8**	
8	None	BDL	**13.7**	**60.7**	
9	None	BDL	9.5 9.6	42.1 42.5	
10	None	BDL	**22.6**	**100.1**	
11	None	BDL	9.5	42.1	
12	**Eptam &** **Bravo**	**Trace** **Trace**	**13.1** **12.6**	**58.0** **55.8**	
13	None	BDL	**23.9**	**105.9**	
14	None	BDL	7.0	31.0	
15	**Bravo**	**Trace**	**15.6**	**69.1**	
16	None	BDL	1.5	6.6	
17	**Eptam**	**Trace**	7.8	34.5	
18	**Sencor**	**Trace**	4.0	17.7	
19	None	BDL	7.5	33.2	
20	None	BDL	6.9	30.6	
21	None	BDL	**22.3**	**98.8**	
22	**Bravo**	**Trace**	7.5 7.6	33.2 33.7	
23	**2,4-D**	**Trace**	0.6	2.7	
24	None	BDL	0.7 1.4	3.1 6.2	
25	None	BDL	11.4	50.3	
26	**Sencor**	**2.8**	23.0	101.9	Well
27	**Eptam**	**Trace**	14.2	62.9	
28	None	BDL	0.3	1.3	
29	None	BDL	2.8	34.5	
30	None	BDL	1.9	8.4	
31	None	BDL	5.5	24.4	Well
32	None	BDL	3.9	17.3	
33	None	BDL	0.7	3.1	
34	**Bravo**	**Trace**	6.2	27.5	

Well = Well Head Problem
Sample = Sampling Problem

Table 4, the sample quality in three of the five contaminated samples in the first sampling may have been compromised during the sampling process. In the second sampling, at least two of the sites had been flagged as having well bore problems.

Negative laboratory results do not necessarily preclude pesticide contamination, however. Samples were taken from small ports resulting in high velocity flow and the possibility of pesticide volatilization. Additionally, pump intakes for the irrigation wells in the valley are typically 60 feet deep with screened intervals of up to 80 feet. The dilution factor in this situation is very significant and could result in nondetectable levels when, in fact, portions of the aquifer could be contaminated.

3.2 CMLS SIMULATION RESULTS

CMLS models the solute depth and the relative amount of pesticide remaining as a function of elapsed time. Three types of graphs summarize the information obtained for a specific pesticide.

Figure 10 is an example of the degradation curve obtained. At point B, one-hundred percent of the chemical is present when the chemical is initially applied to the field. The relative amount of chemical then degrades from point B to point A. The degradation rate is assumed to be a first order exponential decay. At point A virtually all of the chemical is gone. The small amount of chemical remaining at A continues to decrease as the period of time between point A and point C elapses. The relative amount of chemical present at any given time is a function of the half-life of the chemical.

Figure 11 shows the solute movement of the chemical. In the region between point A and point C, the depth of the solute at a given time is primarily a function of the net amount of water infiltrating and the adsorption partitioning coefficient. The shape of the curve from region A to C shows the seasonal variations in the amount of water added to the soil. Notice how the slope of the curve changes significantly at point A. At point A virtually all of the chemical has degraded. For this reason, the region from point A to B is of primary interest.

Figure 12 is perhaps the most informative graph from a groundwater contamination perspective. It shows the relative amount of pesticide remaining at different solute depths. The relative amount of chemical remaining decreases as the depth of the chemical increases in the region from point B to point A. The relative amount of chemical remaining is virtually zero past the solute depth corresponding to point A. From this graph you can read off the concentration of a chemical at the water table depth directly.

Figure 13 shows a three-dimensional plot of these three variables. The points marked on the previous graphs correspond to the points on this graph. The three-dimensional plot contains all of the information shown in Figures 10, 11, and 12.

Figure 14 through Figure 18 show the relative amount of chemical which remains at different depths for the five pesticides which have the highest pollution potential. **Eptam** was included in Figure 19 because this pesticide was found in the field sampling program.

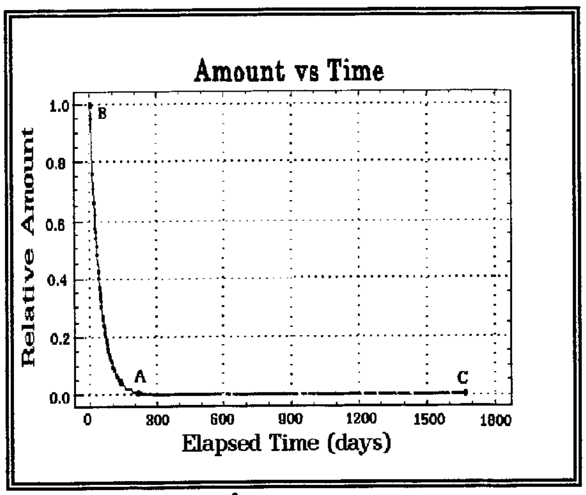


Figure 10

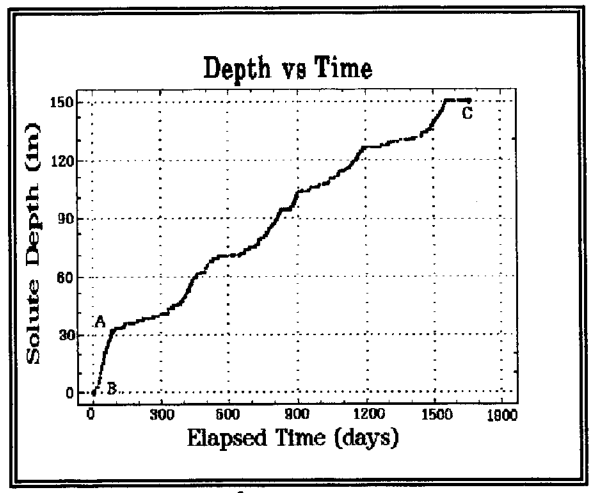


Figure 11

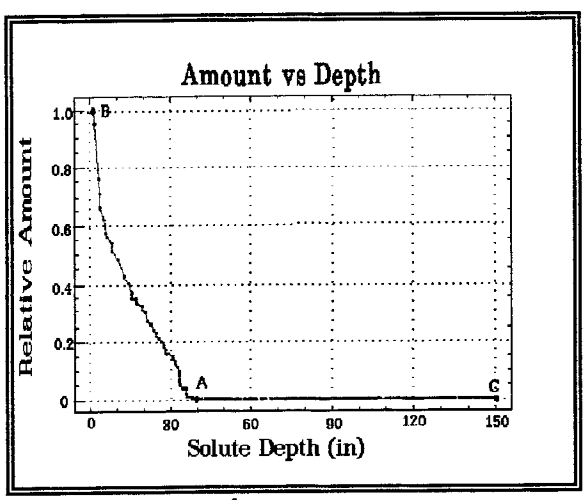


Figure 12

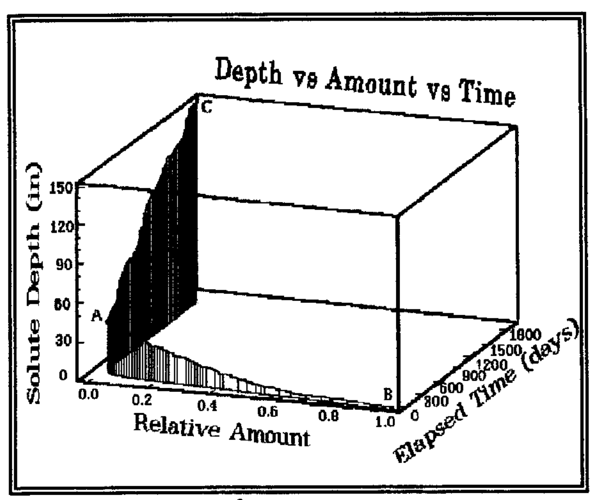


Figure 13

Figure 14

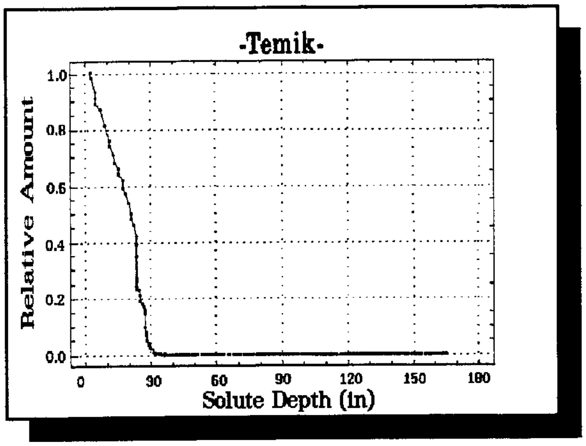


Figure 15

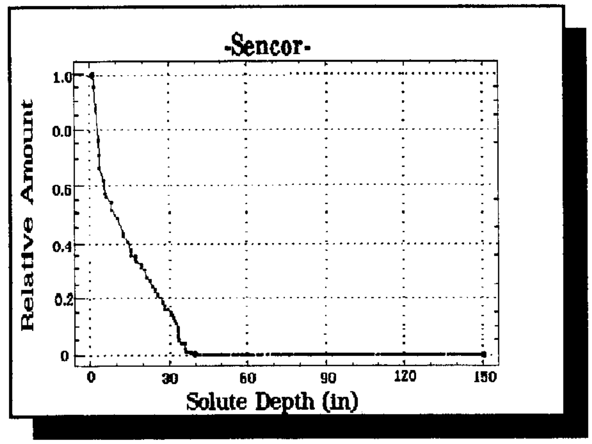


Figure 16

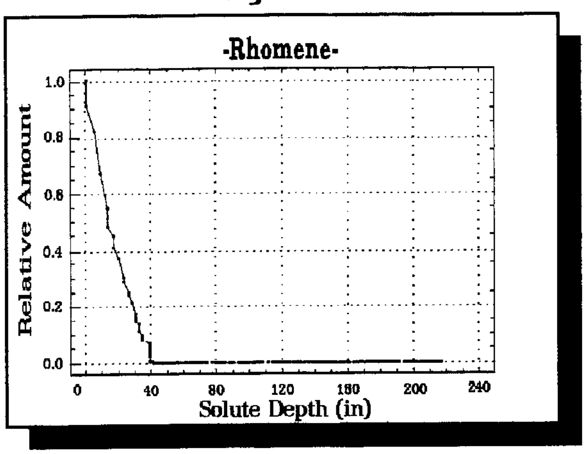


Figure 17

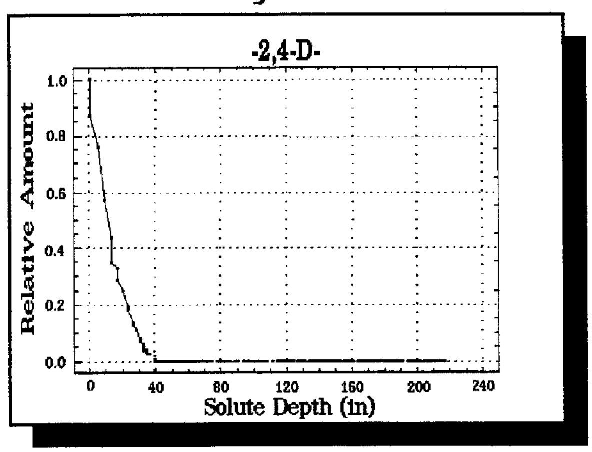


Figure 18

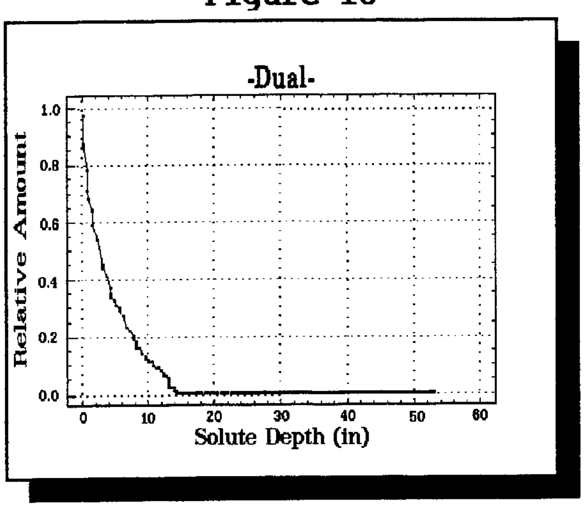
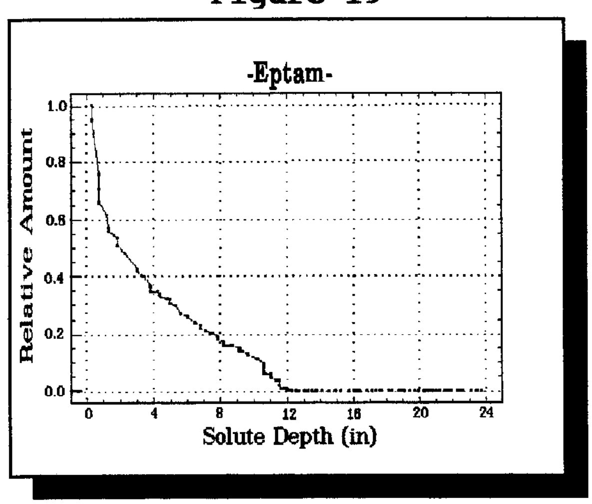


Figure 19



3.2.1 Risk of Groundwater Contamination

On sandy loam soils, four of the chemicals considered pose a threat to an unconfined aquifer with a water table at a five foot depth (Table 5). Two of these chemicals, **Temik** and **Sencor**, are used on potatoes and the other two chemicals, **Rhomene** and **2,4-D**, are used on barley.

Temik poses the greatest risk to groundwater contamination. It is not quite as mobile as the two grain pesticides but it is more persistent. **Temik** is a potato insecticide used for aphid and Colorado potato beetle control. It is extremely toxic with a toxicity category rating of I. Although **Temik** poses the greatest danger to an aquifer at a five foot depth, it's use in the valley is almost nonexistent.

Sencor is a selective herbicide used on potatoes. **Sencor** has the same degradation rate as **Temik**, however, it is slightly less mobile. **Sencor** is moderately toxic with a toxicity rating of III. Although it is not quite as hazardous as **Temik**, **Sencor** is used very heavily in the San Luis Valley. For this reason, it is the most likely candidate to contaminate the aquifer.

Rhomene is a selective herbicide used on barley. It is moderately toxic with a toxicity category rating of III. **Rhomene** is much more mobile than the two potato pesticides but it also degrades quicker. **Rhomene** is used lightly in the valley.

2,4-D is also a selective herbicide for use on barley. It has the same mobility as **Rhomene** but it degrades more rapidly. **2,4-D** is a more dangerous chemical than **Rhomene.** With a toxicity class of II, it is considered very toxic. **2,4-D** is used heavily in the San Luis Valley.

Table 5. CMLS Simulation Summary for Sandy Loam Soil

Risk of Reaching a Five Foot Water Table in Site 9 Soil

Chemical	Relative Amount (%)	Time Elapsed to Reach GW (days)
Temik	$4.3*10^{-3}$	435
Sencor	$2.7*10^{-3}$	456
Rhomene	$2.3*10^{-6}$	355
2,4-D	$2.1*10^{-9}$	355

In general, the risk of groundwater contamination on loamy sand soils is higher than the risk of similar contamination in sandy loam soils (Table 6). The loamy sand soil texture, noted by a smaller percentage of clay particles and a larger percentage of sand particles, is accompanied by a smaller amount of organic matter. With a lower fraction of organic carbon in the soil, the mobility of each chemical increases.

The CMLS simulations on the loamy sand soil revealed the same four pesticides which were identified as potential leachers on the sandy loam soil. Each of these chemicals had a higher mobility and a higher relative concentration in the groundwater, however. **Rhomene** moved up in rank to become the most persistent pesticide and subsequently poses the greatest risk of groundwater contamination in this type of soil. **2,4-D**'s persistence also moved it up in rank to have only a slightly less pollution potential than **Temik**.

Dual became adequately mobile to reach the groundwater table in a loamy sand soil. **Dual** is a selective herbicide used upon potatoes. It receives medium usage in the San Luis Valley. **Dual** is moderately toxic with a toxicity rating of III. **Dual** is fairly nonpersistent, which made it the least likely of the five chemicals to contaminate the groundwater.

From the CMLS results, it can be concluded that **Rhomene**, **Temik**, **2,4-D**, **Sencor**, and **Dual** all have the potential to reach a five foot water table. The management practices used in the San Luis Valley dictate that **Sencor** and **2,4-D** are the most heavily used pesticides of these five potential contaminants. As a result, **Sencor** and **2,4-D** will be the pesticides most likely found in the ground water.

Table 6. CMLS Simulation Summary for Loamy Sand Soil

Risk of Reaching a Five Foot Water Table in Site 28 Soil

Chemical	Relative Amount (%)	Time Elapsed to Reach GW (days)
Rhomene	$2.2*10^{-1}$	124
Temik	$3.5*10^{-2}$	377
2,4-D	$1.9*10^{-2}$	124
Sencor	$1.6*10^{-2}$	344
Dual	$5.8*10^{-16}$	1145

It should be noted that the above analysis only considers groundwater contamination by solute transport through the vadose zone and much of this input is difficult to determine accurately. Other potential pathways of contamination, such as direct introduction into the well bore, have not been considered. The existence of preferential soil pathways, such as soil cracks, root holes, or animal holes, which allow the solute to reach the water table in a much shorter time have also been ignored.

Pesticide Ranking:

Pesticides can be directly ranked by two separate processes: mobility and persistence. Chemicals that have both a high mobility and a high persistence pose the greatest risk of contaminating the ground water. If a chemical is very mobile it is capable of reaching a groundwater aquifer, but if it also degrades rapidly then the concentration of that chemical in the groundwater will be negligible. Similarly, if a chemical is very persistent but is immobile, it will remain at the surface of the soil and pose very little threat to an aquifer.

Mobility is the ability of the pesticide to move downward through the soil. A high mobility is characterized by a small partitioning coefficient, indicating that most of the chemical dissolves and moves with the soil water rather than adsorbing onto soil particles. Table 7 classifies the pesticides by their relative mobility. The chemicals are ranked from 1 to 14. A mobility ranking of one represents the most mobile chemical which will reach the greatest depth within any given amount of time. Pesticides with the same mobility are given the same rank.

Persistence is a measure of how quickly a chemical degrades. Persistent chemicals are characterized by a long half-life. The chemicals are ranked by persistence in Table 8. A ranking of one indicates the chemical that is most persistent and will be found in the greatest relative concentration at any given time.

Figure 20 illustrates the relative ranking of the pesticide mobility and persistence. Notice as a general observation that the chemicals which are highly mobile are not very persistence. Likewise, the chemicals which are very persistent are not very mobile. This indicates that the pesticides being used in the San Luis Valley have been chosen properly.

Figure 21 shows the relative ranking of the pesticide mobility and persistence depicted in a stacked bar graph. From this graph it can be seen that the chemicals which are most dangerous in relative terms, are the pesticides with the lowest combined ranking. Figure 21 reveals that **2,4-D**, **Rhomene**, **Temik**, **Sencor**, **Dual**, and **Eptam** have a higher contamination potential than the other pesticides.

Table 7. CMLS Pesticide Mobility Ranking				
Ranked by Solute Depth after One Year in a Sandy Loam Soil (Site 9 Soil)				
Mobility Rank	**Chemical**	**Action**	**Solute Depth in 1 yr (in)**	**Partition Coef [K_{oc}]**
1	2,4-D	Grain Herbicide	61.9	20
1	Rhomene	Grain Herbicide	61.9	20
2	Temik	Potato Insecticide	49.6	30
3	Sencor	Potato Herbicide	45.3	41
4	Dual	Potato Herbicide	17.8	200
5	Buctril	Grain Herbicide	19.2	1000
6	Eptam	Potato Herbicide	13.7	280
7	Monitor	Potato Insecticide	5.7	780
8	Manzate	Potato Fungicide	4.4	1000
9	Bravo	Potato Fungicide	3.3	1380
10	Dy-Syston	Potato Insecticide	2.3	2000
11	Round Up	General Herbicide	0.5	10000
12	Hoelan	Grain Herbicide	0.1	48500
13	Asana	Potato Insecticide	0	100000
13	Pydrin	Potato Insecticide	0	100000
14	Diquat	Potato Desiccant	0	100000

* 1 is the most mobile

* 14 is the least mobile

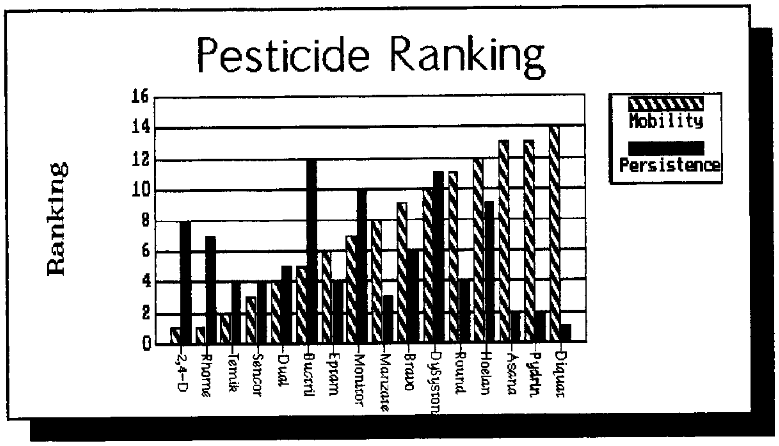
Table 8. CMLS Pesticide Persistence Ranking				
Ranked by Relative Amount Remaining after One Year in a Sandy Loam Soil (Site 9 Soil)				
Persistence Rank	**Chemical**	**Action**	**Relative Amount @ 1 yr (%)**	**Half Life (days)**
1	Diquat	Potato Desiccant	93	3600
2	Pydrin	Potato Insecticide	0.63	50
2	Asana	Potato Insecticide	0.63	50
3	Manzate	Potato Fungicide	0.073	35
4	Temik	Potato Insecticide	0.022	30
4	Sencor	Potato Herbicide	0.022	30
4	Eptam	Potato Herbicide	0.022	30
4	Round Up	General Herbicide	0.022	30
5	Dual	Potato Herbicide	$2.9*10^{-4}$	20
6	Bravo	Potato Fungicide	$3.2*10^{-5}$	20
7	Rhomene	Grain Herbicide	$1.5*10^{-6}$	14
8	2,4-D	Grain Herbicide	$1.1*10^{-9}$	10
9	Hoelan	Grain Herbicide	$1*10^{-9}$	10
10	Monitor	Potato Insecticide	$4.9*10^{-17}$	6
11	Dy-Syston	Potato Insecticide	$3.4*10^{-26}$	4
12	Buctril	Grain Herbicide	$2.2*10^{-33}$	14

* 1 is the most persistent

* 12 is the least persistent

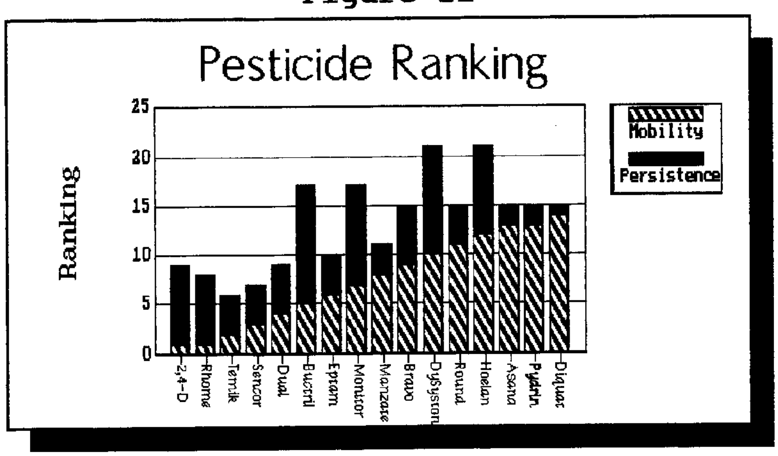
Summary of CMLS Results

Figure 20



1 = Most Mobile/Persistent
14 = Least Mobile/Persistent

Figure 21



1 = Most Mobile and Persistent
21 = Least Mobile and Persistent

Location Ranking:

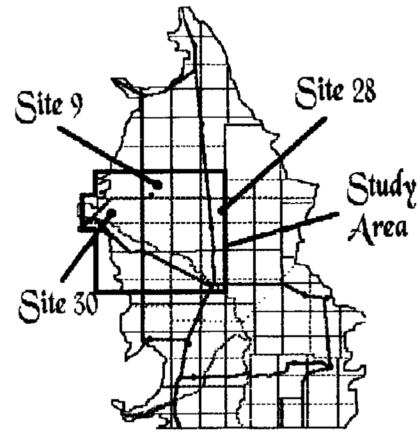


Fig 22. Map of San Luis Valley

The geography of the soils in the valley effects the mobility of the chemicals. The soils of the western side of the San Luis Valley are primarily sandy loam with gravel or cobbles. In the center of the valley the soils are sandy loam. The soils on the east side of the valley tend to be a loamy sand. The soils directly on the eastern edge of the valley are entirely sand. The variation in soil type across the valley is caused by an aeolian process whereby strong north-eastern winds move the sand particles eastward and drop them before passing over the Sangre de Cristo Mountains.

As a general rule, the risk of groundwater contamination is smallest on the western side of the valley. The risk increases as you move east across the valley. This phenomena occurs because the soil texture becomes sandier toward the eastern side of the valley. The increase in sand separates is accompanied by a decrease in clay and organic matter. The mobility of each pesticide is a strong function of the fraction of organic carbon in the soil. As this fraction of organic carbon decreases, the mobility of the chemical increases. As a result, the chemical reaches a given depth in a shorter amount of time and at a higher relative concentration. This implies that pesticides applied to sandier soils pose a greater risk of contaminating the groundwater.

Three different locations were chosen for analysis with CMLS. These sites include Site 30 on the west side of the valley, Site 9 in the center of the valley, and Site 28 on the east side of the valley. The locations are shown in Figure 22. The change in mobility with soil type can be seen in Table 9 for a selection of pesticides. As is evident, the mobility of each chemical increased when applied to the eastern soil. This conclusion agreed with the soil influence described by DRASTIC. In actuality, however, this process probably is not as pronounced as the table would suggest because the clear soil texture variation only occurs in the surface horizon and the underlying secondary and tertiary horizons probably do not vary as significantly across the valley.

The actual variation in pollution potential across the valley is small. While the surface soil type indicates that the eastern portion of the valley is at the highest risk, the intensive pesticide use in the central portion of the valley shifts the risk back westward.

Table 9. CMLS Location Ranking

Difference in Mobility with Soil Type after One Year

Chemical	Site 30 Soil	Site 9 Soil	Site 28 Soil
	Solute Depth After 1 yr (in)	Solute Depth After 1 yr (in)	Solute Depth After 1 yr (in)
2,4-D	47.1	61.9	99.2
Rhomene	47.1	61.9	99.2
Temik	35.8	49.6	69.9
Sencor	32.1	45.3	59.3
Buctril	2.4	19.2	7.1
Dual	9.9	17.8	24.8
Eptam	7.4	13.7	19.5
Manzate	2.3	4.4	6.6

3.2.2 SENSITIVITY

A study was performed to determine how sensitive CMLS is to the input parameters required by the model. The twelve variables used by CMLS are listed in Table 10. The model is more dependent upon some of these variables than others. In addition, some parameters have a larger natural range of variability than others, and affect CMLS disproportionately. This range of uncertainty can be caused by low accuracy in variable measurements, by a lack of confidence in reported values, or by natural fluctuations associated with the variable.

The ranges of values associated with each variable were determined by observing the natural fluctuations of that variable in the San Luis Valley or by noting the differences in the value of that parameter recorded in the literature by different sources. The ranges of uncertainty assumed for each variable are given in Table 10.

Simulations were performed by varying the parameter of interest while all other parameters were set constant. The effect of each parameter's range of variability on the CMLS results was quantified by noting the depth of the solute when one percent of the initial amount of chemical remained.

From the model theory, it is clearly evident that CMLS is strongly dependent upon the pesticide half life, partitioning coefficient and soil organic carbon content. However, some of the other parameters have a large range of natural variability. The effect that each variable had upon CMLS within its expected range of variability is shown in Table 10.

Table 10 shows the importance of obtaining accurate information. The values of the pesticide degradation half-life and partitioning coefficient must be reasonable. It is often hard to obtain these values with confidence because the values reported in the literature vary.

Table 10. CMLS Sensitivity to Input Parameters						
Rank	Parameter	Natural Variability	Constant Value	Simulated Range	Difference in Solute Depth @ Amount=1%	Difference in Relative Amount @ Depth=60 in.
1	Pesticide Half-Life	± 30 days	30 days	1 to 60	42.2	$5.2*10^{-3}$
2	Pesticide Partitioning Coefficient	± 50 ml/g	41 ml/g	1 to 100	40.6	$4.0*10^{-2}$
3	Soil Moisture @ Field Capacity	± 5 %	13 %	8 to 18	25.7	$1.0*10^{-2}$
4	Evapotranspiration	± 5 in	16.1 in	11.0 to 21.6	23.1	$7.9*10^{-5}$
5	Organic Carbon Fraction	± 0.2 %	0.36 %	0.16 to 0.56	15.4	$1.6*10^{-4}$
6	Precipitation	± 7 in	25.9 in	19.7 to 32.8	12.1	$4.8*10^{-4}$
7	Crop Rooting Depth	± 12 in	36 in	24 to 48	11	$4.5*10^{-5}$
8	Soil Bulk Density	± 0.25 g/cm^3	1.53 g/cm^3	1.28 to 1.78	4.1	$3.6*10^{-5}$
9	Pesticide Application Depth	+ 4 in	0 in	0 to 4	1.1	$6.0*10^{-6}$
10	Pesticide Application Date	± 15 days	6/1/84	5/15/84 to 6/15/84	0.2	$1.2*10^{-5}$
11	Soil Moisture @ Wilting Point	± 2.5 %	7.6 %	5 to 10	0.1	0.0
12	Soil Moisture @ Saturation	± 10 %	51.3 %	41.3 to 61.3	0.0	0.0

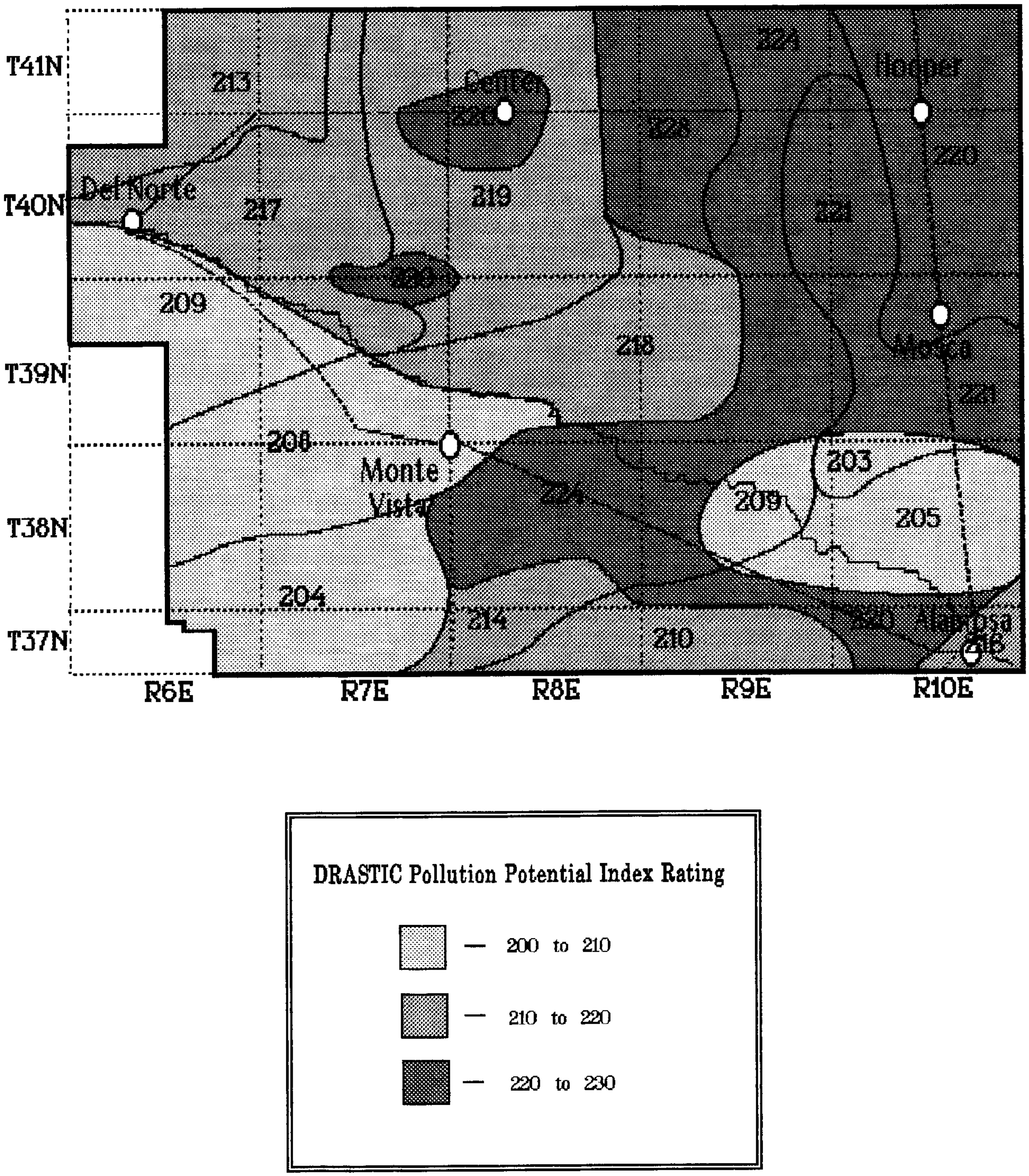
3.3 DRASTIC RESULTS

Two basic conclusions can be drawn from this part of the study. First, the unconfined aquifer within the entire San Luis Valley is highly vulnerable to groundwater contamination in comparison to other regions of the state. Secondly, the variation in the pollution potential across the valley is very small because the hydrogeology of the valley is homogeneous.

Figure 23 shows the DRASTIC Map of the San Luis Valley. The fine delineation between locations on the DRASTIC map is meaningless because the data used to create this map was coarse. As a result, DRASTIC does not reveal the locations within the San Luis Valley which are most vulnerable to ground water contamination. The intensity of pesticide use in the San Luis Valley is more important than the hydrogeology for determining the areas of high contamination vulnerability.

The spatial distribution of the DRASTIC results obtained from this simulation are sensitive to three of the DRASTIC parameters used to calculate the pollution potential index. The soil media plays the largest factor in determining the pollution potential of a mapping unit. The depth to the water table moderately effects the DRASTIC results. DRASTIC is minimally dependent upon the hydraulic conductivity.

Figure 23. DRASTIC Map for the San Luis Valley



CHAPTER 4

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

4.1 SUMMARY

The goals of this project were accomplished by:

1) evaluating groundwater contamination in the San Luis Valley through direct sampling in conjunction with the Colorado Department of Health,

2) evaluating two screening models for their ability to predict leaching potential,

3) determining the relative importance of hydrogeologic factors, agricultural management factors, and pesticide characteristics with respect to groundwater pollution in the San Luis Valley.

Thirty-four irrigation wells were sampled twice during the summer of 1990, once early in the growing season and again in late summer. In the first sampling, four samples had detectable levels of **Sencor**. One sample had detectable levels of **Eptam**. In the second set of samples, there were six samples with detectable levels of **Bravo**, one sample with detectable levels of **2,4-D**, two samples containing **Sencor**, and two samples containing **Eptam**. Interestingly, **Sencor** and **Eptam** are applied early in the growing season, corresponding with the date of the first sampling; while **Bravo** and **2,4-D** are applied later in the growing season, corresponding to the date of the second sampling.

Two screening tools were evaluated in this project. The solute transport model called CMLS, an acronym for Chemical Movement in Layered Soils (Nofziger and Hornsby, 1986), was used to determine which pesticides would most likely contaminate groundwater. A hydrogeologic index called DRASTIC (Aller et al., 1987) was utilized to predict which areas had the greatest risk of contamination.

Input for the solute transport model was obtained from interviews with 34 farmers in the valley, direct soil sampling, various literature sources, and information from Agro-Engineering. The interview provided information on the pesticides used, irrigation schedules, application dates and amounts, tillage practices and crop rotations. The soils were collected at three sites, one on the west side of the valley, one in the center and one on the east side of the valley. These were analyzed for particle size distribution and organic carbon content. The hydrogeology and climate of the valley were obtained from the literature and weather records at Alamosa, Colorado. Information on irrigation scheduling and evapotranspiration were obtained from Agro-Engineering.

The vadose zone transport of sixteen different pesticides was simulated for three locations in the San Luis Valley over a five year period. The sixteen chemicals included five potato insecticides, three potato herbicides, two potato fungicides, one potato dessicant, four barley herbicides, and one general herbicide. The mobility and persistence of each pesticide were ranked individually and collectively, irrespective of the other variables that affect transport.

The CMLS simulations revealed that **2,4-D**, **Rhomene**, **Temik**, and **Sencor** have the highest leaching potential. **Dual**, **Buctril**, and **Eptam** have a slightly smaller pollution potential. The remaining nine pesticides evaluated were considered nonleachers. Ranking of the pesticides simply by the sum of their mobility and persistence resulted in six of the same seven chemicals identified as potential leachers. This list included **Manzate** instead of **Buctril** and the order was slightly different, i.e. **Temik**, **Sencor**, **Rhomene**, **2,4-D**, **Dual**, **Eptam**, and **Manzate**.

A sensitivity study using CMLS showed that the pesticide half-life, organic carbon partitioning coefficient, soil moisture, evapotranspiration, organic carbon content, and total water input are the most significant variables with respect to leaching. Of these, the half-life and partitioning coefficient are the most important, but also the most subject to error.

Pesticide DRASTIC was the second screening tool evaluated in this study. Pesticide DRASTIC is a pollution potential index designed to evaluate the relative vulnerability of land areas to groundwater contamination as a function of hydrogeologic variations. DRASTIC was used in this study to determine if locations within the valley could be identified that are more susceptible to groundwater contamination because of hydrogeologic factors.

Results from the DRASTIC study indicated that the Pollution Potential Index for the San Luis Valley varied from about 200 to 240. This indicates that the unconfined aquifer in the valley is highly vulnerable to groundwater contamination. However, the variation across the valley was very small.

4.2 CONCLUSIONS

The direct sampling program completed in the San Luis Valley during the summer of 1990 indicates that the groundwater has nitrate levels above drinking water standards in some areas and may contain low levels of pesticides. Some water samples from irrigation wells in the valley contained detectable levels of **Sencor**, **Eptam**, **Bravo**, and **2,4-D**. The results from the sampling program are, however, inconclusive. Some of the detectable levels of pesticide found by the sampling program can be explained by sample contamination. Sample contamination partially accounts for the reason why **Sencor** and **Eptam**, which are applied early in the growing season, were found in the first sampling, while **Bravo** and **2,4-D**, which are applied later in the growing season, were found in the second sampling. In some cases, well bore problems indicate that the contamination sampled is local and not indicative of a generally contaminated aquifer.

On the other hand, the samples were taken from small ports at high velocities, causing possible volatilization of the pesticides. A more serious consideration arises from the fact that the samples were taken from wells that have intake sections typically 60 feet or deeper and screened intervals of up to 80 feet. The dilution factor in this situation can become significant and could result in nondetectable levels of pesticides and low levels of nitrates when, in fact, the aquifer is significantly contaminated.

The DRASTIC map developed in this study indicates that the San Luis Valley aquifer is highly vulnerable to contamination when compared to other areas of Colorado. However, the variability in the Pollution Potential Index is small because of the homogeneity of the valley and, as a result, the model cannot adequately differentiate between discrete locations in the valley.

CMLS was found to be more useful that DRASTIC for determining pollution potential. **Sencor**, **Eptam**, **Dual**, **Bravo**, and **2,4-D** were found in the sampling program. CMLS determined that **Sencor**, **Eptam**, **Dual**, and **2,4-D** were potential leachers. The other four pesticides that CMLS indicated have potential for groundwater contamination were **Temik**, **Rhomene**, **Buctril**, and **Manzate**. These four chemicals were not tested for by the analytical laboratory. The chemicals which were involved in each phase of the project are summarized in Table 11. The only pesticide found in the sampling program that CMLS did not predict was **Bravo**. One possible reason why **Bravo** was found in the sampling program is its heavy use in the valley during the time period corresponding with the second sampling period. CMLS also showed **Dual** as a potential leacher but **Dual** was not found in the sampling program. **Dual** receives only medium usage in the valley.

Table 11. Indentification of Analytes				
Chemical Trade Name	Lab Analyte	Identified in Field Survey	Leachers Indentified by CMLS	Found in Sampling Program
Ambush	X	X		
Asana		X		
Bravo	X	X		X
Buctril		X	X	
Dacthal (DCPA)	X			
Diquat		X		
Dy-Syston	X	X		
Dual	X	X	X	
Eptam	X	X	X	X
Hoelan		X		
Kerb	X			
Lasso	X			
Lorsban	X			
Manzate		X	X	
Methyl Parathion	X	X		
Monitor		X		
Prowl	X	X		
Pydrin	X	X		
Rhomene		X	X	
Round-Up		X		
Sencor	X	X	X	X
Temik		X	X	
Thiodan	X	X		
Treflan	X			
2,4-D	X	X	X	X

One of the goals of this project was to determine the relative importance of hydrogeology, agricultural management practices, and the pesticide properties with respect to leaching potential in the San Luis Valley. Because of the uniformity of the valley's hydrogeology, management practices and pesticide properties are considered to be more important in determining pollution potential. Pesticide properties can be used to rank each agricultural chemical by its potential ability to contaminate the groundwater. Regardless of rank, however, the pesticides most heavily used in the area should be evaluated as potential candidates which will likely be found in the groundwater.

The Sargent district in the central part of the valley is the area in which pesticides are used most intensely and this is the area where the most samples had detectable levels of contaminants. Table 12 summarizes relative pesticide use in the valley. There are eight pesticides that are heavily used according to a farmer survey. They are: **Pydrin**, **Sencor**, **Eptam**, **Manzate**, **Bravo**, **Diquat**, **2,4-D**, and **Buctril**. Of these, **Manzate**, **Buctril**, and **Diquat** were not analyzed for in the laboratory. If we eliminate **Pydrin** and **Diquat** as potential leachers because of their exceptionally high adsorption coefficients, the pesticides remaining are **Sencor**, **Eptam**, **Bravo**, and **2,4-D**. These were the four pesticides detected in the sampling program. This raises the possibility that a chemical with even a moderate mobility can leach, and be detected, if it is used heavily enough.

Table 12. Pesticide Use in the San Luis Valley				
Trade Name	**Chemical Common Name**	**Found in Sampling Program**	**Pesticide Action**	**Utilization in SLV**
Temik*	Aldicarb	N.A.	Potato Insecticide	Light
Monitor*	Methamidophos	N.A.	Potato Insecticide	Medium
Dy-Syston	Disulfoton	N.D.	Potato Insecticide	Medium
Asana*	Esfenvalerate	N.A.	Potato Insecticide	Medium
Pydrin	Fenvalerate	N.D.	Potato Insecticide	Heavy
Sencor	Metribuzin	X	Potato Herbicide	Heavy
Dual	Metolachlor	N.D.	Potato Herbicide	Medium
Eptam	EPTC	X	Potato Herbicide	Heavy
Manzate*	Macozeb	N.A.	Potato Fungicide	Heavy
Bravo	Chlorothalonil	X	Potato Fungicide	Heavy
Diquat*	Diquat	N.A.	Potato Desiccant	Heavy
2,4-D	2,4-D	X	Grain Herbicide	Heavy
Rhomene*	MCPA	N.A.	Grain Herbicide	Medium
Buctril*	Bromoxynil	N.A.	Grain Herbicide	Heavy
Hoelan*	Diclofop	N.A.	Grain Herbicide	Medium
Round-Up*	Glyphosate	N.A.	General Herbicide	Medium

X = Pesticide Found in Sampling Program
N.A. = Pesticide not Analyzed by Laboratory
N.D. = Pesticide Analyzed for but not Detected

4.3 RECOMMENDATIONS

The results of this study showed that the San Luis Valley has a high potential for groundwater contamination from both nitrates and pesticides. However, the direct sampling program was inconclusive. Recommendations for further work are given in the following sections.

Additional Groundwater Sampling: A long-term monitoring program for the valley should be instigated with clearly defined monitoring goals and the location of the wells chosen rigorously. Sampling should be done using shallow monitoring wells and drinking water wells. The drinking water wells would be used for determining health risks. Monitoring wells rather than irrigation wells will reduce sample contamination and allow differentiation between well bore problems and general aquifer contamination. More importantly, chemicals that may have been present but not detected in irrigation well samples because of the large dilution factor can be found. If shallow monitoring wells are used for sampling, pesticides just entering the aquifer will be detectable and changes in agricultural practices can be initiated to reduce leaching of that chemical before significant contamination of the entire aquifer occurs.

Vadose Zone Sampling: A research program designed to monitor and evaluate movement of chemicals in the unsaturated zone should be instigated. The purpose of this program would be to calibrate solute transport models for conditions in the San Luis Valley. The valley is unique in many ways that affect chemical transport. For example, CMLS determined that the pesticide half-life and adsorption coefficient were the two most important parameters in predicting chemical movement. It is highly unlikely that literature values of these parameters are adequate for predicting solute transport in the San Luis Valley. Correctly calibrated and verified computer models would be useful in evaluating new pesticides and alternative management practices in terms of groundwater pollution potential.

Educational Program: In order to effectively prevent groundwater problems in the San Luis Valley, the farmers themselves must have the knowledge and tools to evaluate their own management decisions. The farmers in the valley are well organized so that a series of workshops could be easily arranged. Personnel from Agro-Engineering, the SLV Research Station, the Potato Administrative Committee and others in the valley could be approached to work with CSU Cooperative Extension (Fort Collins) and the Colorado Department of Health on these programs.

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APPENDIX A

Table A1. DRASTIC Ranges and Weight for Depth to Water

Depth to Water (Feet)	
Range	Rating
0-5	10
5-15	9
15-30	7
30-50	5
50-75	3
75-100	2
100+	1
Pesticide Weight: 5	

(Aller, 1987)

Table A2. DRASTIC Ranges and Weight for Net Recharge

Net Recharge (Inches)	
Range	Rating
0-2	1
2-4	3
4-7	6
7-10	8
10+	9
Pesticide Weight: 4	

(Aller, 1987)

Table A3. DRASTIC Ranges and Weight for Aquifer Media

Aquifer Media

Range	Rating
Massive Shale	2
Metamorphic/Igneous	3
Weathered Metamorphic	4
Glacial Till	5
Sandstone/Limestone	6
Massive Sandstone	6
Massive Limestone	6
Sand and Gravel	8
Basalt	9
Karst Limestone	10

Pesticide Weight: 3

(Aller, 1987)

Table A4. DRASTIC Ranges and Weight for Soil Media

Soil Media	
Range	Rating
Thin or Absent	10
Gravel	10
Sand	9
Loamy Sand	8
Peat	8
Shrinking Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Muck	2
Nonshrinking Clay	1
Pesticide Weight: 5	

(Aller, 1987)

Table A5. DRASTIC Ranges and Weight for Topography

Topography (Percent Slope)	
Range	Rating
0-2	10
2-6	9
6-12	5
12-18	3
18+	1
Pesticide Weight: 3	

(Aller, 1987)

Table A6. DRASTIC Ranges and Weight for Vadose Material

Impact of Vadose Zone Media

Range	Rating
Confining Layer	1
Silt/Clay	3
Shale	3
Limestone	6
Sandstone	6
Bedded Limestone/Sandstone	6
Sand and Gravel with Silt/Clay	6
Metamorphic/Igneous	4
Sand and Gravel	8
Basalt	9
Karst Limestone	10

Pesticide Weight: 4

(Aller, 1987)

Table A7. DRASTIC Ranges and Weight for Conductivity

Hydraulic Conductivity (U.S. Gal/day/ft^2)

Range	Rating
1-100	1
100-300	2
300-700	4
700-1000	6
1000-2000	8
2000+	10

Pesticide Weight: 2

(Aller, 1987)

APPENDIX B

San Luis Valley Study

Pesticide Index

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1990

Table of Contents

Objective

The purpose of this pesticide index is to provide a compilation of literature on pesticides used in the San Luis Valley. The emphasis of this study has been to collect the solute transport properties and the toxicological properties for each pesticide. The nomenclature, physical, and chemical properties of each pesticide are also included in this index for reference.

This information has been compiled for a study of the potential threat of ground water contamination posed by each pesticide. The San Luis Valley is an intensely irrigated, relatively flat basin, containing a shallow, unconfined aquifer. As a result, the valley is a high risk suspect for ground water contamination.

This index contains information specific to each chemical. Information concerning pesticide usage for the San Luis Valley has also been included. The pesticide utilization and usage information is a result of an initial sampling survey of farmers in the valley. Between June 22 and June 30, 1990, thirty four sites across the valley were surveyed. An even spatial distribution of sites was chosen to represent the San Luis Valley north of the Rio Grande River. Each site represents a 160 acre field. Farmers were questioned concerning the pesticide usage on each site during the past five years. Information concerning soil type, crop type, tillage, and irrigation practice was also obtained. Because some of the farmers owned two or more of the sites surveyed, the thirty-four survey sites surveyed represent twenty-three independent farmers.

The San Luis Valley Study information included in this index consists of the pesticide utilization in the valley, the general application date, the application method, and the application rate of pesticides used by farmers in the San Luis Valley. The pesticide utilization is a representation of the relative number of farmers who use the pesticide. The sample size of this study was statistically small, therefore, the results contained in this index do not represent the entire population with a high degree of confidence. For that reason, the San Luis Valley results contained in this index should not be taken as fact. Hopefully, however, these results infer the general pesticide practices of the farmers in the San Luis Valley and as such provide valuable insight concerning pesticide use.

The most common cropping practice in the valley is a potato/barley rotation. Ninety-seven percent of all the sites surveyed had grown grain within the last five years. Eight-eight percent of the sites had grown potatoes within the last five years. A secondary crop appears to be alfalfa. Eight percent of the sites sampled had grown alfalfa, primarily for soil reclamation purposes.

Twenty-nine different pesticides were encountered in the San Luis Valley during the initial survey. A list of these pesticides is shown in Appendix A. Information could not be found for four of these twenty-nine pesticides. The commonly used trade names for these four pesticides are *Champ, Dinoseb, Ridamil,* and *Super Tin*. Because of the lack of information, these four pesticides were not included in this index. The properties of the other twenty five pesticides encountered in the San Luis Valley are contained on the following pages.

Because this report represents a compilation of the available literature on each pesticide, it does not hold any claim to the validity of the information reported. Notwithstanding, there was a great deal of agreement in content between the many sources sited. When a discrepancy of an inference between sources transpired, the result occurring most often in the literature was adopted for this compilation. This information presents the most accurate representation of the pesticide knowledge known by the author at this time.

How to Use this Index

The following description indicates the information found in this pesticide index for each chemical listed. This index contains twenty five different pesticides which have been used in the San Luis Valley. The chemicals are listed alphabetically by the trade name commonly used in the valley.

Nomenclature:

This category includes information used for product identification.

Common Name:

This is the universally common chemical name for each compound in contrast to the name of a specific product. The common name appears in italics.

Trade Names:

The trade names are the popular names with which each pesticide is marketed. The trade names are listed with the primary name used in the San Luis Valley first, followed by the secondary names.

CAS #:

The C.A. Reference is a number assigned by the Chemical Abstract Service of the American Chemical Society (ACS) to each specific chemical compound. This number is included to reference each chemical to the abstract with which the chemical is registered with the ACS.

Manufacturer:

The primary manufacturer listed is the company which developed the compound including the patent date, and nation. The following names list manufacturers who market the product in the United States.

Use:

This category lists the specific actions of each pesticide.

Pesticide Action:

The pesticide action indicates the general category of pesticide of each compound: either insecticide, herbicide, or fungicide. It also indicates specific actions of the compound in a given category.

Crops Used Upon:

This heading lists the crops upon which the pesticide can be safely applied. The crops listed include only those commonly grown in the San Luis Valley.

Pests Controlled:

This category lists the common pests, either insects, weeds, or fungi, which a compound is designed to eradicate.

Application Date:

The application date refers to the date or plant stage at which the chemical should be applied.

Application Method:

The application method refers to the mode with which the pesticide is applied. The listing of each method is important for indicating the target location where each chemical is applied. The application location will directly effect the runoff potential, volatility, and persistence, of each pesticide which ultimately divides the deposition location of the chemical between the soil, the foliage, and the air.

Application Rate:

The application rate lists the manufacturer's recommended mass (pounds) of active ingredient (ai) which should be applied per acre (A). The amount of solution in which the chemical should be dissolved per acre is also indicated when that information is available and applicable.

Pesticide Type:

The pesticide type refers to the chemical grouping in which each pesticide is arranged. Common chemical categories within which insecticides are grouped include: organophosphates, carbamates, and synthetic pyrethroids. Herbicides are commonly categorized as: organophosphates, phenoxys, pyridine salts, carbamates and thiocarbamates, dinitroanilines, and phenols. Fungicides are commonly categorized as carboxylic acid derivatives or carbamates.

Organophosphates are generally highly soluble, have short half lives and are readily hydrolyzed. They are used as stomach and contact poisons, and as systemic insecticides for nearly every type of insect controlled.

Carbamates are not commonly used against pests in soil. There mode of action is the inhibition of the cholinesterase enzyme. They are fairly soluble in water and, therefore, are commonly mobile, although they typically have a short half life. Carbamate insecticides can be highly toxic. Carbamate herbicides generally possess a lower mammalian toxicity.

Synthetic pyrethroids degrade readily in soil. They maintain high insecticidal activity and low mammalian toxicity. They are commonly stable in air and sunlight and, as such, exert a prolonged residual action.

Phenoxys are a key herbicide because they are selective to broad leaf weeds in cereals and grasses and are translocated through the plant. They have a complex mechanism of action, effecting cellular division, phosphate metabolism and nucleic acid metabolism. They are usually moderately toxic, and relatively nonpersistent.

The pyridine compounds are systemic herbicides used to control broad leaf weeds.

The dinitroanilines are generally used for selective weed control as a preplanting soil incorporation treatment prior to weed germination. The nitroanilines inhibit both root and shoot growth when absorbed by roots. They also have an involved biochemical effect which inhibits the development of several enzymes and the uncoupling of oxidative phosphorylation. They usually have a very low water solubility which minimizes leaching and mobility.

Phenol derivatives are highly toxic to humans by every route of entry into the body. They are nonselective foliar herbicides that are most effective in hot weather.

Formulation Type:

The formulation is the physical form in which the product is distributed. These formulations are specific for a given product and are constantly changing with the market.

The initial behavior of a pesticide is often a function of it's formulation. For example, about thirty times more wettable powders than emulsified concentrates will be lost if both are applied to the soil surface and immediately subjected to irrigation or rain.

Most formulations are designed to be mixed with water and sprayed through nozzles. Different formulation types are listed below.

1) Aqueous concentrations are water based mixtures which are diluted for spraying.
2) Emulsifiable concentrates form emulsions in the spray tank and are kept mixed by agitation.
3) Wettable powders are added to spray water and are kept in suspension by agitation.
4) Dispersible granules are powders formed into pellets which break down on contact with the carrier and form suspensions similar to wettable powders.
5) Dispersible liquids are suspensions of very fine pesticide particles in a thick liquid which is immiscible with the carrier.
6) Microcapsules are tiny polymer spheres which are suspended in the spray water.
7) Soluble powders dissolve in the carrier.
8) Soluble solutions are solutions of the pesticide in a solvent that is immiscible with the carrier.
9) Granules and pellets are formulations which are not designed to be mixed with a liquid but instead are applied by spreaders.

Initial San Luis Valley Study:

This section represents a compilation of the information gathered during an initial survey of farmers in the San Luis Valley. Look to the Objectives section for further details. This category is intended to represent the pesticide usage practices in the valley.

Pesticide Action:

The action refers to the general pesticide category as well as the crop that the pesticide is commonly used upon in SLV.

SLV Pesticide Utilization:

The SLV pesticide utilization indicates the relative amount of San Luis Valley farmers who use a particular pesticide upon their crop. The amount of use is indicated by the key words "light", "medium", or "heavy", followed by the percent utilization by farmers surveyed in the Initial San Luis Valley Study.

National Utilization:

The national pesticide utilization indicates the relative amount of farmers nationwide who use the particular pesticide. The amount of use is indicated by the key words "light", "medium", or "heavy", followed by the mass (pounds) of active ingredient (ai) which is used in the United States yearly (Yr). This information was taken from (Gianessi, 1986) who estimated the total amount of pesticide used nationally.

Application Date:

The application date refers to the time of the year in which the pesticide is applied to crops in the San Luis Valley.

Application Method:

The application method refers to the mode with which the pesticide is applied. The information listed represents only those methods of application for a particular pesticide which were explicitly stated by the farmers surveyed during the Initial San Luis Valley Study. As such, they do not represent all available application methods, nor do they appear to represent all methods utilized in the San Luis Valley. Specifically, aerial application seems to be severely under represented by this study, perhaps showing a local trend away from aerial implementation.

Application Rate:

The application rate represents the range of concentrations of active ingredient (ai) which farmers currently apply to their fields per acre.

<u>Chemical Properties</u>:

This category contains information concerning the chemical properties of each pesticide.

Structural Formula:

The figure represents the chemical formula for each pesticide.

Chemical Abstract Name:

The chemical abstract name is the chemical name used to refer to a specific compound by the Collective Index Chemical Abstracts.

Molecular Formula:

The molecular formula delineates the chemical composition of a molecule of the compound.

Molecular Weight:

The molecular weight indicates the relative molecular mass for each compounds in the units of grams per mole of the pesticide.

Analysis Method:

The analysis method refers to the technique of evaluation used to analyze the product and residuals of the compound in the environment. Included with the residual analysis is the EPA Method used to examine water samples for the presence of the compound, if such a method exists.

Common analysis methods are gas-liquid chromatography (glc), high pressure or performance liquid chromatography (hplc), infrared analysis (ir), mass spectrometry (ms), and combined gas chromatography-mass spectrometry (gc-ms).

<u>Physico-Chemical Properties</u>:

This category contains information concerning the physical properties of each pesticide.

State/Color/Odor:

This heading lists information concerning the physical appearance and odor of the pesticide in a pure condition.

Vapor Pressure:

The vapor pressure of the compound is expressed in the units of Pascals or millimeters of mercury at a given temperature.

Specific Gravity:

The specific gravity of the compound is the ratio of the density of the pesticide to the density of a reference substance (water) at a specific condition. The temperature of the compound and of the water at which the test was performed is indicated as a ratio after the specific gravity.

Density:

The density of the compound is the mass per unit volume of the pesticide. This quantity is represented with the units of gram per cubic centimeter. The temperature at which the density was determined follows the value.

Shelf Life:

The shelf life is included when available. The shelf life indicates how long the pesticide can be stored in ambient conditions before it will degrade.

Stability:

This heading indicates the pesticides stability to the environment. Tendencies toward photodegradation or microbial degradation are mentioned when applicable.

Boiling Point:

The normal boiling point indicates the temperature in degrees Celsius at which the liquid pesticide will vaporize at atmospheric pressure.

Melting Point:

The melting point indicates the temperature in degrees Celsius at which the solid pesticide will liquify at atmospheric pressure.

Mol Surface Area:

This heading indicates the average surface area of one molecule of the pesticide in square Angstroms.

Toxicological Properties:

This category indicates the general toxicity of each pesticide.

Acute Toxicity:

The acute toxicity indicates the fatal, oral toxicity of the compound toward adult, male, white rats. The values are recorded as the milligrams of chemical required to kill a rat per kilogram of body weight. The dose reported is that amount which kills fifty percent of the test animals to which it is administered under the experimental conditions of the LD_{50} test.

Toxicity Category:

The toxicity category is an estimation of the oral toxicity of the compound to humans which has been adopted by the EPA. The toxicity rating is based solely upon the acute, oral LD_{50} dose for rats. The categories range from I to IV, with I indicating supertoxicity and IV indicating a slight toxicity.

Probable Lethal Dose:

The probable lethal dose indicates the quantity of the pesticide which will presumably result in death to humans if ingested orally. The probable, oral, lethal dose for man is based upon the acute toxicity for rats. The quantities reported are suggested by (Ware, 1978).

Dermal Effects:

The dermal effects are the probable side effects of the pesticide when contacted with skin on a human.

Critical Concentration:

The critical concentration indicates the enforceable maximum contaminant level (MCL) set by the United States EPA as concentration guideline limits in drinking water. Concentrations are set as parts per billion (ppb) equal to micrograms per liter.

Phytotoxicity:

Phytotoxicity indicates that the compound is poisonous to plants. Included in this category are the plants which display phytotoxic tendencies towards a given pesticide and the conditions under which these tendencies occur.

Precautions:

Included under this heading are general precautions which should be followed to avoid toxicity problems. Additionally, the toxicity to bees and fish is indicated here.

Soil Transport Properties:

This category contains information concerning the solute transport properties of the pesticides in soil. This information is helpful in assessing each compounds potential for contaminating ground water.

Mobility:

The general mobility of a pesticide indicates the tendency of the compound to move down into the soil with ground water. The mobility classification is indicated using the following key words suggested by (Loftis, 1990): "very mobile", "moderately mobile", "slightly mobile", "nearly immobile", and "immobile". "Very mobile" means that the pesticide will move readily with water, while the classification "immobile" indicates that the pesticide should not move with water.

The pesticide mobility is dependent upon the organic carbon partition coefficient and the pesticide solubility. The concentration of the pesticide in the soil is divided between the concentration of pesticide dissolved in the soil water and the concentration of pesticide adsorbed on the soil solids. The greater the organic carbon partition coefficient (K_{oc}), the greater the distribution partition coefficient (K_d). This indicates that a greater percentage of the chemical is adsorbed onto soil particles in contrast to being dissolved into the ground water. Likewise, the less soluble the compound is in water, the less likely will be it's tendency to move downward with the ground water. This also results in a lower mobility.

Leaching Potential:

Similar to the General Mobility, the leaching potential indicates the tendency of the pesticide to move in solution with water and leach downward below the root zone into deep percolation. The ratings of "large", "medium", "small", and "total use" describes the potential for leaching. A rating of "large" means the chemical has a high potential for leaching. The "total use" rating means the pesticide should not leach with percolating water.

Partition Coef:

The organic carbon partition coefficient (K_{oc}) is a measure of the tendency of the pesticide to attach itself, by chemical or physical bonds, to soil particle surfaces. The organic carbon partition coefficient is the partition coefficient (K_d) normalized with respect to the organic carbon content of the soil. The units are milliliters of pesticide per gram of organic carbon in the soil. Pesticides with a higher K_{oc} value have a stronger attachment to soil and a small tendency to move along with water into the soil. Conversely, pesticides with a lower K_{oc} value will tend to move with water and have a potential for deep percolation below the root zone or a potential of being carried off by surface water.

Solubility:

The solubility of the pesticide at room temperature is the total amount of pesticide which will dissolve in a given volume of water. The value reported is the solubility of the pure active ingredient and not necessarily that of the formulated product. The solubility is given in parts per million or milligrams of pesticide per liter of water.

Solubility is a fundamental physical property of a chemical and will strongly effect the ease at which the compound can be dissolved into the soil water, or washed off of the soil particles upon which it might absorb. In general, if the solubility is 1 mg/l or less, the compound will tend to avoid dissolving into the soil water and will stay near the soil surface. This concentration of pesticide can be lost off the field by erosion or in the sediment phase of runoff.

Persistence:

The general persistence of a chemical is the tendency to avoid being broken down or lost. The persistence of a chemical is a function of it's volatilization and decomposition. Volatilization indicates a compounds tendency to evaporate into the air and be lost from the solid/liquid phase environment of the soil/ground water system. Decomposition refers to the breakdown of the organic pesticide molecules by sunlight (photodecomposition) or by microbial activity.

The ratings of "persistent", "moderate", and "nonpersistent" represent the tendency of the pesticide to break down. "Persistent" indicates that the pesticide will not degrade, while "nonpersistent" indicates that the pesticide will readily decompose or volatilize.

Surface Loss Potential:

The surface loss potential indicates the tendency of the pesticide to move with sediment in runoff. Ratings for runoff potential are "small", "medium", and "large". A "large" rating means that the pesticide has a high tendency to move with sediment upon which it has adsorbed, while a "small" rating indicates that the pesticide has a low potential to move with sediment.

Half Life:

Half life, given in days, is the time required for pesticides in soils to be degraded so that their concentration decreases by one-half. Degredation can be caused by a number of sources including sunlight and microbes.

Pesticide degradation can be fairly accurately described by assuming that each successive elapsed half-life will decrease the pesticide concentration by one half. Half lives vary depending on soil moisture, sunlight, temperature, oxygen status, soil microbial populations and other factors.

Henry's Constant:

Henry's constant provides an indication of the volatilization of a chemical. Volatilization is a measure of how easily a chemical is evaporated from the soil/water environment into the air. Henry's constant is a ratio of the concentration of solute in the vapor phase (in the air) to the concentration of solute dissolved in the liquid phase (in the water). Henry's constant is expressed in the units of atmospheres times cubic meters per mole (atm m^3/mole).

Ambush

Common Name: *Permethrin*

CAS #: 52645-53-1

Trade Names: Ambush
Atroban, Biothrin, Brunol, Coopex, Corsair, Detmol, Dragnet, Ectiban, Eksmin, Evercide, Gard-Star, Hard-Hitter, Imperator, Insectaban, Kafil, Outflank, Over-time, Perigen, Permandine, Permectrin, Permit, Perthrine, Pounce, Pramex, Qamlin, Residroid, Rondo, Stockade, Stomoxin, Talcord,Tornade, Torpedo

Manufacturer: National Research Development Corp., 1974-England
FMC Corp, ICI Americas, Shell Chem.

Use:

Pesticide Action: Contact & Stomach Poison Insecticide

Crops Used Upon: Potatoes, Alfalfa

Pests Controlled: Alfalfa Weevil,Army worm,boll weevil,boll worm,bud worm,cabbage worm,codling moth,Colorado potato beetle,cotton leaf perforator, diamondback moth,European corn borer,flea beetle,flies,leaf miners,lice,loopers,lygus,Mexican bean beetle,mosquitos,naval orange worm,peach twig borer,pear psylla,termites,ticks,white flies

Application Date: Apply when insects appear

Application Method: Foliar Spray, Chemigation

Application Rate: 0.05 - 0.2 lb ai/A

Chemical Classification: Synthetic-Pyrethroid Compound

Formulation Type: Emulsifiable Concentrate, Wettable Powder

Initial San Luis Valley Study:

Pesticide Action: Potato Insecticide

SLV Pesticide Utilization: Light: 3% of potato growers sampled

National Utilization: Medium: 1475000 lb ai/Yr

Application Date: Mid June to Early July

Application Method: Chemigation

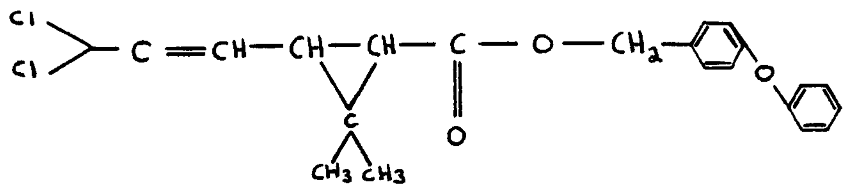
Application Rate:

Ambush

Common Name: *Permethrin*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: (3-Phenoxyphenyl)-methyl(±)cis-trans-3-(2,2-dichloroethenyl)-2,2) dimethylcyclopropane-carboxylate

Molecular Formula: $C_{21}H_{20}Cl_2O_3$

Molecular Weight (g/mole): 391.3

Analysis Method - **Product**: glc
Residue: glc - EPA Method # 508

Physico-Chemical Properties

State/Color/Odor: Yellow-Brown Liquid

Vapor Pressure: 261 mPa @ 30°C

Boiling Point (°C): 34 to 39

Specific Gravity: 1.214 25/25

Melting Point (°C):

Density (g/cm³): 1.21

Mol Surface Area (Å²):

Shelf Life:

Stability: Does not break down from sunlight

Ambush

Common Name: *Permethrin*

Toxicological Properties

Acute Toxicity **(LD_{50} [mg/kg])**: Rat: 450 mg/kg

Toxicity Category: II: Very Toxic

Probable Lethal Dose: 1 teaspoon to 2 tablespoons

Dermal Effects: eye & skin irritation

Critical Concentration **(MCL)**:

Phytotoxicity: Nonphytotoxic when used as directed

Precautions: Toxic to fish & bees

Soil Transport Properties:

Mobility: Immobile

Persistence: Nonpersistent

Leaching Potential: Small

Surface Loss Potential: Large

Partition Coef (ml/g): 10600

Half Life (days): 30

Solubility: 0.2 mg/l @ 30°C

Henry's Constant:

Asana

Common Name: *Esfenvalerate*

Trade Names: Asana
Sumi-alpha
Halmark

CAS #:

Manufacturer: Sumitomo Chem, 1982-Japan
Shell Co, DuPont Co.

Use:

Pesticide Action: Stomach poison Insecticide

Crops Used Upon: Potatoes

Pests Controlled: European corn borer, Colorado potato beetle, boll worms, aphids, white fly, loopers, codling moth, pear moth, psylla, leafminer

Application Date: Apply when insects appear

Application Method: Crop plant spray in water or oil

Application Rate: 7.5 to 50 g ai/ha

Chemical Classification: Synthetic pyrethroid compound
Alpha isomer of Fenvalerate

Formulation Type: Emulsifiable Concentrates

Initial San Luis Valley Study:

Pesticide Action: Potato Insecticide

SLV Pesticide Utilization:Medium: 23% of potato growers sampled

National Utilization:

Application Date: Mid July to Early August

Application Method: Chemigation/Ground Rig

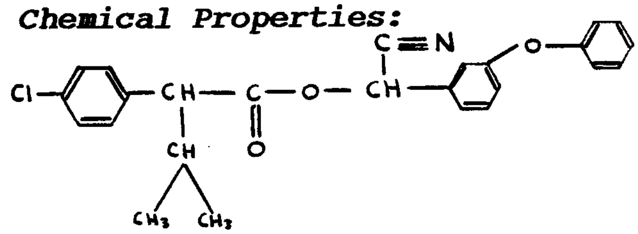
Application Rate: 0.025 to 0.05 lb ai/A

Asana

Common Name: *Esfenvalerate*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: s-alpha-Cyano-3-phenoxybenzyl-(s)-2-(4-chlorophenyl)-s-methylbutyrate

Molecular Formula:

Molecular Weight (g/mole):

Analysis Method - **Product**:
Residue: glc - EPA Method # 508

Physico-Chemical Properties

State/Color/Odor:

Vapor Pressure:

Boiling Point (°C):

Specific Gravity:

Melting Point (°C):

Density (g/cm³):

Mol Surface Area (Å²):

Shelf Life:

Stability:

Asana

Common Name: *Esfenvalerate*

Toxicological Properties

Acute Toxicity (**LD_{50} [mg/kg]**): Rate: 325 mg/kg

Toxicity Category: II: Very Toxic

Probable Lethal Dose: 1 teaspoon to 2 tablespoons

Dermal Effects:

Critical Concentration (**MCL**):

Phytotoxicity: Injury noted on cucumbers, eggplant, tomatoes, pears, and mandrin oranges

Precautions: Toxic to fish

Soil Transport Properties:

Mobility: Immobile

Persistence: Moderate

Leaching Potential: Small

Surface Loss Potential: Large

Partition Coef (ml/g): 100000

Half Life (days): 50

Solubility: 0.1 mg/l

Henry's Constant:

Assert

Common Name: *Imazamethabenz-Methyl*

Trade Names: Assert
AC222,293
Dagger

CAS #:

Manufacturer: American Cyanamid Co, 1982-USA

Use:

Pesticide Action: Selective Herbicide

Crops Used Upon: Barley, Wheat

Pests Controlled: wild oats, black grass, silky bentgrass, wild mustard, wild buckwheat, field pennycrest, wild radish

Application Date: Postemergence - Grains past 2 leaf stage

Application Method: Aerial Application

Application Rate: 0.18 to 0.46 lb ai/A

Chemical Classification: Imidazole Compound

Formulation Type: Emulsifiable Concentrates

Initial San Luis Valley Study:

Pesticide Action: Grain Herbicide

SLV Pesticide Utilization: Light: 6% of grain growers sampled

National Utilization:

Application Date: Mid May to Late May

Application Method: Ground Rig

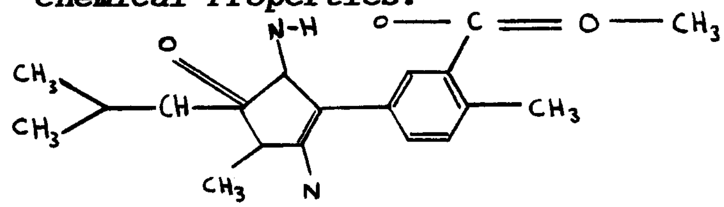
Application Rate:

Assert

Common Name: *Imazamethabenz-Methyl*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: methyl 6-(4-isopropyl-4-methyl-5-oxo-2-imidazolin-2-yl)-m-toluate

Molecular Formula:

Molecular Weight (g/mole):

Analysis Method - **Product:**
Residue: No EPA Method

Physico-Chemical Properties

State/Color/Odor:

Vapor Pressure:

Specific Gravity:

Density (g/cm³):

Shelf Life:

Stability:

Boiling Point (°C):

Melting Point (°C):

Mol Surface Area (Å²):

Assert

Common Name: *Imazamethabenz-methyl*

Toxicological Properties

Acute Toxicity **(LD_{50} [mg/kg])**: Rate: 2333 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects: May cause skin & eye irritation

Critical Concentration **(MCL)**:

Phytotoxicity:

Precautions:

Soil Transport Properties:

Mobility: Slightly Mobile

Persistence: Moderate

Leaching Potential:

Surface Loss Potential:

Partition Coef (ml/g):

Half Life (days):

Solubility:

Henry's Constant:

Bravo

Common Name: *Chlorothalonil*

Trade Names: Bravo Blazon, Clort Osip, Daconil 2787, Nopocide

CAS #: 1897-45-6

Manufacturer: Fermenta Plant Protection
Diamond Shamrock

Use:

Pesticide Action: Preventative Fungicide

Crops Used Upon: Potatoes

Pests Controlled: Early & late blight, leaf spot, dollar spot, brown patch, gray leaf spot, Helminthosporium ssp, brown rot, leaf curl, shot hole, Curvularia ssp, powdery mildew, downy mildew, apple scab, fly speck, sooty blotch, grey mold, anthracnose, alternaria, brown spot, botrytis gray

Application Date: When plants are 6 inches high

Application Method: Crop Foliar Spray, Chemigation

Application Rate: 1 to 2 lb/A of 75% material

Chemical Classification: Carboxylic acid derivative

Formulation Type: Wettable powder, tablets, exothermic powder

Initial San Luis Valley Study:

Pesticide Action: Potato Fungicide

SLV Pesticide Utilization: Heavy: 40% of potato growers sampled

National Utilization: Medium: 5620000 lb ai/Yr

Application Date: Late June to Early August

Application Method: Chemigation/Ground Rig

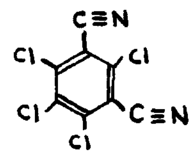
Application Rate: 0.75 to 1 pint/A

Bravo

Common Name: *Chlorothalonil*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: tetrachloroisophthalonitrile

Molecular Formula: $C_8Cl_4N_2$

Molecular Weight (g/mole): 265.9

Analysis Method - Product: glc
Residue: glc - EPA Method # 508

Physico-Chemical Properties

State/Color/Odor: White crystalline solid, odorless

Vapor Pressure: 1.3 Pa @ 40°C

Boiling Point (°C): 350

Specific Gravity:

Melting Point (°C): 250

Density (g/cm^3):

Mol Surface Area (Å^2):

Shelf Life:

Stability: Not broken down by UV light

Bravo

Common Name: *Chlorothalonil*

Toxicological Properties

Acute Toxicity (LD_{50} [mg/kg]): Rat: 10000 mg/kg

Toxicity Category: IV: Slightly Toxic

Probable Lethal Dose: 1 pint to 1 quart

Dermal Effects: Can cause allergic reactions

Critical Concentration (MCL):

Phytotoxicity: Golden apples & grapes show fruit russet
Roses can be injured

Precautions: Toxic to fish

Soil Transport Properties:

Mobility: Immobile
Moderately mobile in sand

Persistence: Moderate

Leaching Potential: Small

Surface Loss Potential: Large

Partition Coef (ml/g): 1380

Half Life (days): 20

Solubility: 0.6 mg/kg @ 25°C

Henry's Constant:

Buctril/Bronate

Common Name: *Bromoxynil*

Trade Names: Buctril/Bronate
Brominal, Nu-Lawn,
Weeder, Pardner, Torch

CAS #: 1689-84-5

Manufacturer: May-Baker, 1963-England
Amchem Products, Chipman Chem., Rhone-Poulenc

Use:

Pesticide Action: Selective, contact Herbicide (photosynthetic & respiratory inhibitor)

Crops Used Upon: Barley, wheat, alfalfa

Pests Controlled: seedling broad leaf weeds
Lambsquarter, smartweed, black nightshade, hairy nightshade, wild buckwheat, sunflower, shepardspurse, tansy mustard, Russian thistle, pigweed, kochia, wild mustard, tumble mustard

Application Date: Postemergence - before 2-4 leaf stage

Application Method: Foliar Spray in water

Application Rate: 0.25 to 0.5 lb ai/A in 5-25 gal water

Chemical Classification: Octanoic acid ester

Formulation Type: Emulsifiable concentrates

Initial San Luis Valley Study:

Pesticide Action: Grain Herbicide

SLV Pesticide Utilization: Heavy: 67% of grain growers sampled

National Utilization: Medium: 1472560 lb ai/Yr

Application Date: Late May to Early June

Application Method: Chemigation/Ground Rig

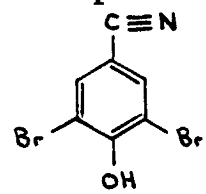
Application Rate: 1 to 2 pints/A

Buctril/Bronate

Common Name: *Bromoxynil*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: 3,5-dibromo-4-hydroxybenzonitrile-(4-cyano-2,6-dibromophenol)

Molecular Formula: $C_7H_3Br_2NO$

Molecular Weight (g/mole): 276.9

Analysis Method - Product:
Residue: No EPA Method Available

Physico-Chemical Properties

State/Color/Odor: Light buff to creamy powder, white, odorless

Vapor Pressure:

Specific Gravity:

Density (g/cm³):

Boiling Point (°C):

Melting Point (°C): 190

Mol Surface Area (Å²):

Shelf Life: > 2 yrs

Stability: Non Volatile, stable in sunlight

Buctril/Bronate

Common Name: *Bromoxynil*

Toxicological Properties

Acute Toxicity (LD_{50} [mg/kg]): Rats: 190 mg/kg

Toxicity Category: II: Very Toxic

Probable Lethal Dose: 1 teaspoon to 2 tablespoons

Dermal Effects:

Critical Concentration (MCL):

Phytotoxicity:

Precautions: Toxic to fish, Avoid drift

Soil Transport Properties:

Mobility: Slightly Mobile	**Persistence**: Nonpersistent
Leaching Potential: Small	**Surface Loss Potential**: Medium
Partition Coef (ml/g): 1000	**Half Life (days)**: 14
Solubility: 130 mg/l @ 25°C	**Henry's Constant**:

2,4-D

Common Name: *2,4-D*

CAS #: 94-75-7

Trade Names: 2,4-D
Emulsamine, Esteron, Fernoxone, Formula 40, Hedonal, HiDep, Lithane, Phenox, Verton, Weed-B-Gone, Weedar-64, Weedone 638, AquaKleen, Crotilin, Dicamine, DMA-4, Demise, Dikamin, Dikonirt, Dymec

Manufacturer: Amchem Products, 1942-USA
Agrolinz Chem, Rhone-Poulenc, Dow Chem

Use:

Pesticide Action: Selective, Translocated Herbicide

Crops Used Upon: Barley, Wheat, Oats

Pests Controlled: Broad leaf weeds
Bindwood, Canada thistle, chickweed, cocklebur, golden rod, ivy, heary cress, jimsonweed, lambsquarters, locoweed, mustard, pigweed, plantain, Russian thistle, purslane, sunflowers, willows

Application Date: Preemergence or Postemergence-when grain is fully tillered before boot stage

Application Method: Preemergence-band or broadcast
Postemergence-foliar spray

Application Rate: 0.25 to 4 lb ai/A in 2-100 gal water

Chemical Classification: Translocated phenoxy herbicide

Formulation Type: Aqueous solution

Initial San Luis Valley Study:

Pesticide Action: Grain Herbicide

SLV Pesticide Utilization: Heavy: 33% of grain growers sampled

National Utilization: Heavy: 39390000 lb ai/Yr

Application Date: Late May to Mid June

Application Method: Chemigation/Ground Rig

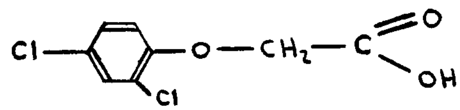
Application Rate: 1 to 1.5 Pt/A

2,4-D

Common Name: *2,4-D*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: 2,4-Dichlorophenoxyacetic acid

Molecular Formula: $C_8H_6Cl_2O_3$

Molecular Weight (g/mole): 221.04

Analysis Method - **Product**: glc
Residue: glc - EPA Method # 515

Physico-Chemical Properties

State/Color/Odor: White crystals, odorless

Vapor Pressure: $6*10^{-7}$ mm Hg **Boiling Point (°C)**: 160

Specific Gravity: 1.565 20/04 **Melting Point (°C)**: 135-138

Density (g/cm³): 1.565 @ 20°C **Mol Surface Area (Å²)**: 386

Shelf Life:

Stability:

2,4-D

Common Name: *2,4-D*

Toxicological Properties

Acute Toxicity (LD_{50} [mg/kg]): Rats: 375 mg/kg

Toxicity Category: II: Very Toxic

Probable Lethal Dose: 1 teaspoon to 2 tablespoons

Dermal Effects: May cause eye & skin irritation

Critical Concentration (MCL): 70 ppb

Phytotoxicity: cotton, tomatoes, grapes, fruit trees, ornamental, & grasses are sensitive

Precautions: Avoid drift

Soil Transport Properties:

Mobility: Moderate

Persistence: Nonpersistent

Leaching Potential: Medium

Surface Loss Potential: Small

Partition Coef (ml/g): 20

Half Life (days): 10

Solubility: 890 mg/l @ 20°C

Henry's Constant: $4.8*10^{-11}$

Diquat

Common Name: *Diquat*

CAS #: 85-00-7

Trade Names: Diquat
Actor, Aquacide, Dextrone, Diquatdibromide, Midstream, Preeglone, Priglone, Reglone, Reglox, Weed Killer, Concentrated D, Reglone, Pathclear, Weedol, Weedtrine II, Clean Sweep

Manufacturer: ICI Ltd, 1958-England
Valent Chem, Chevron Chem

Use:

Pesticide Action: Nonselective Contact Desiccant

Crops Used Upon: Potatoes

Pests Controlled: All annual plants

Application Date: Postemergence-Apply 7 days prior to harvest

Application Method: Ground Rig, Aerial Spray

Application Rate: 1 to 2 lb ai/A in 20-100 gal water

Chemical Classification: Pyridinium salt

Formulation Type: Aqueous Solution

Initial San Luis Valley Study:

Pesticide Action: Potato Desiccant

SLV Pesticide Utilization: Heavy: 13% of potato growers sampled

National Utilization: Small: 107,700 lb ai/Yr

Application Date: Late August to Early September

Application Method: Chemigation/Ground Rig/Aerial

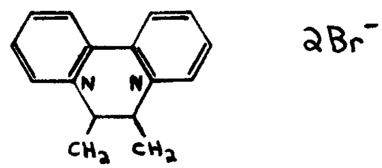
Application Rate:

Diquat

Common Name: *Diquat*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: 6,7 Dihydrodipyridol-(1,2-a:2',1'-c)-pyrazidinium dibromide ion bromide salt

Molecular Formula: $C_{12}H_{12}N_2$

Molecular Weight (g/mole): 184.2

Analysis Method - **Product:** UV Spectroscopy
Residue: glc - EPA Method # 548 & colorimetry

Physico-Chemical Properties

State/Color/Odor: Yellow solid, Aqueous solution is dark reddish-brown

Vapor Pressure: NonVolatile

Boiling Point (°C): Salts Char

Specific Gravity: 1.24 20/20

Melting Point (°C): Salts Char

Density (g/cm³): 1.243 @ 20°C

Mol Surface Area (Å²):

Shelf Life: Indefinite

Stability: Inactivated immediately on contact with soil
Highly susceptible to UV light degradation & microbial breakdown

Diquat

Common Name: *Diquat*

Toxicological Properties

Acute Toxicity (LD_{50} [mg/kg]): Rats: 231 mg/kg

Toxicity Category: II: Very Toxic

Probable Lethal Dose: 1 teaspoon to 2 tablespoons

Dermal Effects: skin irritation, delay of healing, eye irritant, damage to nails, nose bleeding

Critical Concentration (MCL):

Phytotoxicity:

Precautions: Avoid drift, do not apply to wet crops

Soil Transport Properties:

Mobility: Immobile

Persistence: Persistent

Leaching Potential: Small

Surface Loss Potential: Large

Partition Coef (ml/g): 100000

Half Life (days): 3600

Solubility: 700000 mg/l

Henry's Constant:

Dual

Common Name: *Metolachlor*

Trade Names: Dual Bricep, CGA-24705, Duelor, Medal, Ontract, Pennant

CAS #: 51218-45-2

Manufacturer: CIBA-Geigy Chem., 1974-USA

Use:

Pesticide Action: Selective Herbicide (germination inhibitor)

Crops Used Upon: Potatoes

Pests Controlled: Barnyard grass, chickweed, crabgrass, foxtails, galinsoga, goosegrass, millets, nightshade, nutgrass, panicum, pigweed, purslane, signal grass, smartweed, red rice, yellow nutsedge

Application Date: Preemergence or Preplant

Application Method: Preemergence: soil surface spray
Preplant: incorporated 2 inches into soil

Application Rate: 1 to 4 lb ai/A

Chemical Classification: Acetamide compound

Formulation Type: Emulsifiable concentrates

Initial San Luis Valley Study:

Pesticide Action: Potato Herbicide

SLV Pesticide Utilization:Medium: 17% of potato growers sampled

National Utilization: Large: 38082000 lb ai/Yr

Application Date: Mid June to Late June

Application Method: Chemigation/Ground Rig

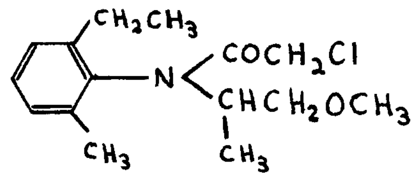
Application Rate: 1.5 to 3 Pt/A

Dual

Common Name: *Metolachlor*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: 2-chloro-n-(2-ethyl-6-methyl phenyl)-n-(2-methoxyl-1-methylethyl) acetamide

Molecular Formula: $C_{15}H_{22}ClNO_2$

Molecular Weight (g/mole): 283.8

Analysis Method - **Product:** glc
Residue: glc - EPA Method # 507

Physico-Chemical Properties

State/Color/Odor: Colorless liquid

Vapor Pressure: 1.7 mPa @ 20°C

Specific Gravity: 1.12 20/04

Density (g/cm³): 1.12 @ 20°C

Boiling Point (°C): 100

Melting Point (°C):

Mol Surface Area (Å²):

Shelf Life:

Stability:

Dual

Common Name: *Metolachlor*

Toxicological Properties

Acute Toxicity (LD_{50} [mg/kg]): Rats: 2780 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects: May cause eye and skin irritation

Critical Concentration (MCL): 100 ppb

Phytotoxicity:

Precautions: Toxic to fish

Soil Transport Properties:

Mobility: Nearly Immobile

Persistence: Moderate

Leaching Potential: Medium

Surface Loss Potential: Medium

Partition Coef (ml/g): 200

Half Life (days): 20

Solubility: 530 mg/l @ 20°C

Henry's Constant:

Dy-Syston

Common Name: *Disulfoton*

CAS #: 298-04-4

Trade Names: Dy-Syston
Dimaz, Dithiodemeton, Dithiosystox
Frumin-Al, Knave, Solvirex,
Thiodemetan

Manufacturer: Bayer AG, 1956-Germany
Mobay Chem, Sandoz LTD.

Use:

Pesticide Action: Selective, Systemic Insecticide-Acaricide

Crops Used Upon: Potato, Alfalfa, Barley

Pests Controlled: Aphids, mites, thrips, leafhoppers, fleabeetles, lace bugs, leaf rollers, whiteflies, mealy bugs, leaf miners, Mexican bean beetles

Application Date: Preplant, preemergence or postemergence

Application Method: Drilling or broadcast, foliar spray

Application Rate: 0.5 to 3 lb ai/A

Chemical Classification: Organophosphorus compound

Formulation Type: Emulsifiable concentrate, granules, wettable powder, dry seed dressing

Initial San Luis Valley Study:

Pesticide Action: Potato Insecticide

SLV Pesticide Utilization: Medium: 10% of potato growers sampled

National Utilization: Medium: 2111200 lb ai/Yr

Application Date: Late July to Early August

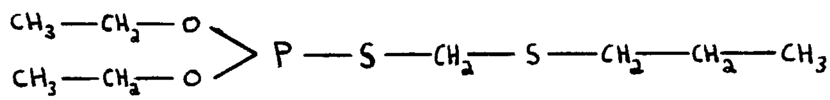
Application Method:

Application Rate: 13.5 to 20 lb ai/A

Dy-Syston

Common Name: *Disulfoton*

Chemical Properties:

Structural Formula: 

Chemical Abstract Name: o,o-Diethyl-s-2-ethyl thioethyl phosphorodithioate

Molecular Formula: $C_8H_{19}O_2PS_3$

Molecular Weight (g/mole): 274.41

Analysis Method - **Product**: glc or paper chromatography
Residue: glc - EPA Method # 507

Physico-Chemical Properties

State/Color/Odor: Pale Yellow oil

Vapor Pressure: 1.8 mm Hg **Boiling Point (°C)**: 62

Specific Gravity: 1.144 20/04 **Melting Point (°C)**:

Density (g/cm³): 1.144 @ 20°C **Mol Surface Area (Å²)**:

Shelf Life:

Stability:

Dy-Syston

Common Name: *Disulfoton*

Toxicological Properties

Acute Toxicity (**LD_{50} [mg/kg]**): Rat: 8.6 mg/kg

Toxicity Category: I: Extremely Toxic

Probable Lethal Dose: A pinch to 1 teaspoon

Dermal Effects: Absorbed through the skin

Critical Concentration (**MCL**):

Phytotoxicity: High dosage results in seed injury, leaf burn to alfalfa, bulb injury to garden lily

Precautions: Phytotoxic injury more pronounced in light, sandy soils. Toxic to fish & bees

Soil Transport Properties:

Mobility: Nearly Immobile

Persistence: Nonpersistent

Leaching Potential: Small

Surface Loss Potential: Medium

Partition Coef (ml/g): 2000

Half Life (days): 4

Solubility: 25 mg/l

Henry's Constant: $2.6*10^{-2}$

Eptam

Common Name: *EPTC*

Trade Names: Eptam
Genep, Knoxweed, Witox

CAS #: 759-94-4

Manufacturer: Stauffer Chem, 1954-USA
ICI, Valent

Use:

Pesticide Action: Selective Herbicide

Crops Used Upon: Potatoes, Alfalfa

Pests Controlled: Annual grasses and some broad leaf weeds
Nutgrass, johnsongrass, quackgrass, foxtails, sandburs, wild oats, barnyard grass, chickweed, nightshade, lambsquarter, pigweed, henbit, purslane

Application Date: Preplant & Postemergence

Application Method: Preplant: incorporated into soil 2-4 inches
Postemergence: through sprinkler

Application Rate: 2 to 7.5 lb ai/A in 40-100 gal of water

Chemical Classification: Thiocarbamate Compound

Formulation Type: Emulsified Concentrates, Granules

Initial San Luis Valley Study:

Pesticide Action: Potato Herbicide

SLV Pesticide Utilization: Heavy: 33% of potato users sampled

National Utilization: Medium: 9550000 lb ai/Yr

Application Date: Late May to Mid June

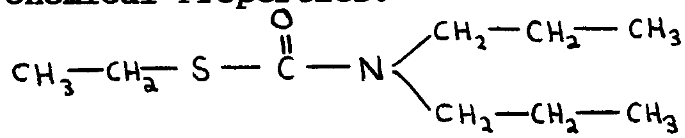
Application Method: Chemigation/Ground Rig

Application Rate: 1.5 to 3.5 pints/A

Eptam

Common Name: *EPTC*

Chemical Properties:

Structural Formula: 

Chemical Abstract Name: s-ethyl dipropyl thiocarbamate

Molecular Formula: $C_9H_{19}NOS$

Molecular Weight (g/mole): 189.3

Analysis Method - Product: glc
Residue: glc - EPA Method # 507

Physico-Chemical Properties

State/Color/Odor: Light yellow liquid with an amine odor

Vapor Pressure: $1.97*10^{-2}$

Boiling Point (°C): 127

Specific Gravity: 0.9658 20/20

Melting Point (°C):

Density (g/cm³): 0.964 @ 20°C

Mol Surface Area (Å²):

Shelf Life: Indefinite life under ambient conditions

Stability: Readily volatilizes, microbial breakdown is insignificant, Decomposes in 4-6 weeks in warm, moist soil.

Eptam

Common Name: *EPTC*

Toxicological Properties

Acute Toxicity **(LD_{50} [mg/kg]):** Rats: 1630-2550 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects:

Critical Concentration **(MCL):**

Phytotoxicity:

Precautions:

Soil Transport Properties:

Mobility: Nearly Immobile

Persistence: Nonpersistent

Leaching Potential: Medium

Surface Loss Potential: Medium

Partition Coef (ml/g): 280

Half Life (days): 30

Solubility: 375 mg/l @ 25°C

Henry's Constant:

Far-Go

Common Name: *Triallate*

Trade Names: Far-Go Avadex-BW, Showdown

CAS #: 2303-17-5

Manufacturer: Monsanto Co., 1959-USA

Use:

Pesticide Action: Selective Herbicide

Crops Used Upon: Barley, Wheat

Pests Controlled: Wild Oats

Application Date: Preemergence

Application Method: Soil Incorporation at 2 inches depth

Application Rate: 1 to 1.5 lb ai/A in 5 gal/A water

Chemical Classification: Carbamate compound

Formulation Type: Emulsifiable concentrate, granules

Initial San Luis Valley Study:

Pesticide Action: Grain Herbicide

SLV Pesticide Utilization: Light: 3% of grain growers sampled

National Utilization: Medium: 3911000 lb ai/Yr

Application Date: Early June

Application Method: Chemigation

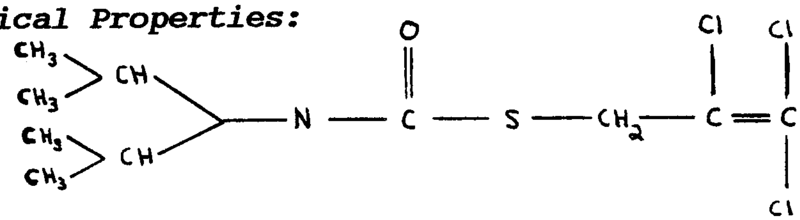
Application Rate: 12.5-15 lb ai/A

Far-Go

Common Name: *Triallate*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: S-2,3,3-Trichloroallyl diisopropylthiolcarbamate

Molecular Formula: $C_{10}H_{16}Cl_3NOS$

Molecular Weight (g/mole): 304.7

Analysis Method - Product: glc
Residue: glc - No EPA Method

Physico-Chemical Properties

State/Color/Odor: Oily liquid

Vapor Pressure: 16 mPa @ 25°C **Boiling Point (°C)**: 148

Specific Gravity: 1.273 25/04 **Melting Point (°C)**: 30

Density (g/cm³): 1.273 @ 25°C **Mol Surface Area (Å²)**:

Shelf Life:

Stability: Stable to Light

Far-Go

Common Name: *Triallate*

Toxicological Properties

Acute Toxicity (LD_{50} [mg/kg]): Rat: 1675 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects: Possible eye & skin irritation

Critical Concentration (MCL):

Phytotoxicity:

Precautions:

Soil Transport Properties:

Mobility: Nearly Immobile

Persistence: Moderate

Leaching Potential: Small

Surface Loss Potential: Large

Partition Coef (ml/g): 3600

Half Life (days): 60

Solubility: 4 mg/l @ 25°C

Henry's Constant:

Harmony

Common Name: *Thiameturon-methyl*

Trade Names: Harmony
DPX-M6316
Pinnacle

CAS #:

Manufacturer: Dupont de Nemours, 1982-USA

Use:

Pesticide Action: Selective Herbicide

Crops Used Upon: Barley, Wheat

Pests Controlled: cleavers, cowcockle, pennycress, koehia, lambsquarters, tarweed, pigweed, purslane, Russian thistle, wildbuck wheat, wild garlic, wild mustard

Application Date: Postemergence-weeds less than 4 inches tall

Application Method: foliar spray

Application Rate: 0.33-0.67 oz ai/A

Chemical Classification: Sulfonylurea compound

Formulation Type: Granules

Initial San Luis Valley Study:

Pesticide Action: Grain Herbicide

SLV Pesticide Utilization: Light: 3% of grain growers sampled

National Utilization:

Application Date:

Application Method:

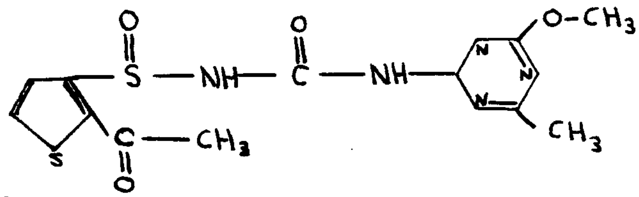
Application Rate:

Harmony

Common Name: *Thiameturon-methyl*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: methyl 3-[[94-methoxy-6-methyl-1,3,5-triazin-2-yl) amino-carbonyl] aminosulfonyl]-2-thiophencarboxylate

Molecular Formula:

Molecular Weight (g/mole):

Analysis Method - Product:
Residue:

Physico-Chemical Properties

State/Color/Odor:

Vapor Pressure:

Boiling Point (°C):

Specific Gravity:

Melting Point (°C):

Density (g/cm^3):

Mol Surface Area ($Å^2$):

Shelf Life:

Stability:

Harmony

Common Name: *Thiameturon-methyl*

Toxicological Properties

Acute Toxicity (LD_{50} [mg/kg]): Rat: 5000 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects: May cause slight eye and skin irritation

Critical Concentration (MCL):

Phytotoxicity:

Precautions:

Soil Transport Properties:

Mobility:

Leaching Potential:

Partition Coef (ml/g):

Solubility:

Persistence:

Surface Loss Potential:

Half Life (days):

Henry's Constant:

Hoelan

Common Name: *Diclofop-methyl*

Trade Names: Hoelan
Hoegrass
Illoxan

CAS #: 51338-27-3

Manufacturer: Hoechst AG, 1974-Germany

Use:

Pesticide Action: Selective, Contact and Translocated Herbicide

Crops Used Upon: Potatoes, Barley, Wheat, Alfalfa

Pests Controlled: Annual Grasses
Barnyard grass, foxtails, goosegrass, volunteer corn, crabgrass, panicum, ryegrass, wild oats

Application Date: Postemergence when grass is in 1-4 leaf stage

Application Method: Aerial, foliar spray, surface incorporation

Application Rate: 0.75 to 1.25 lb ai/A

Chemical Classification: Diphenyl ether compound

Formulation Type: Emulsifiable concentrates

Initial San Luis Valley Study:

Pesticide Action: Grain Herbicide

SLV Pesticide Utilization: Medium: 13% of grain growers sampled

National Utilization: Medium: 1102000 lb ai/Yr

Application Date: Mid May to Early June

Application Method: Chemigation

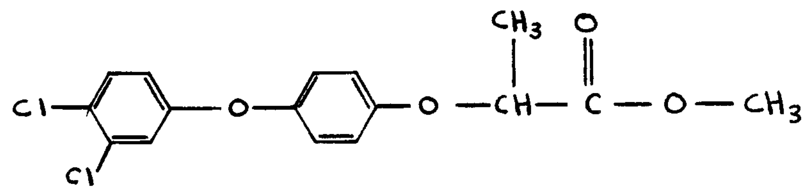
Application Rate: 1.3 to 2.6 Pt/A

Hoelan

Common Name: *Diclofop-methyl*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: 2-(4-(2,4-dichlorophenoxy)phenoxy)-methyl propanoate

Molecular Formula: $C_{15}H_{12}Cl_2O_4$

Molecular Weight (g/mole): 327.2

Analysis Method - **Product:** glc
Residue: glc- No EPA Method

Physico-Chemical Properties

State/Color/Odor: Colorless crystalline solid

Vapor Pressure: 34.4×10^{-6} Pa @ 20°C

Boiling Point (°C):

Specific Gravity:

Melting Point (°C): 40

Density (g/cm³):

Mol Surface Area (Å²):

Shelf Life:

Stability:

Hoelan

Common Name: *Diclofop-methyl*

Toxicological Properties

Acute Toxicity **(LD_{50} [mg/kg])**: Rat: 2140 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects: May cause eye & skin irritation

Critical Concentration **(MCL)**:

Phytotoxicity:

Precautions: Toxic to fish

Soil Transport Properties:

Mobility: Nearly Immobile

Persistence: Nonpersistent

Leaching Potential: Small

Surface Loss Potential: Large

Partition Coef (ml/g): 48500

Half Life (days): 10

Solubility: 3 mg/kg @ 22°C

Henry's Constant:

Lasso

Common Name: *Alachlor*

CAS #: 15972-60-8

Trade Names: Lasso
Alanex, Alanox, Alazine,
Lazo, Pillarzo, Satochlor,
Stake

Manufacturer: Monsanto Co., 1967-USA

Use:

Pesticide Action: Selective Herbicide

Crops Used Upon: Potatoes

Pests Controlled: Annual Grasses & Broad leaf weeds
Purslane, goosegrass, carpet weed, Florida pursley, pigweed, barnyard grass, crabgrass, foxtails, fall panicum, witch grass, lambsquarter, yellownut grass

Application Date: Preemergence

Application Method: Soil surface spray, soil incorporation (0.5-2 inches deep), broadcast or band

Application Rate: 1.5 to 4 lb ai/A

Chemical Classification: Acetanilide compound

Formulation Type: Emulsifiable concentrates, granules, micro-encapsulated liquids

Initial San Luis Valley Study:

Pesticide Action: Potato Herbicide

SLV Pesticide Utilization: Light: 3% of potato growers sampled

National Utilization: Heavy: 85155000 lb ai/Yr

Application Date:

Application Method: Ground Rig

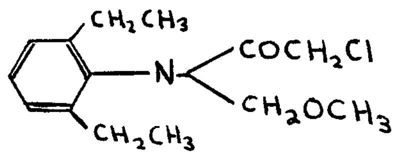
Application Rate:

Lasso

Common Name: *Alachlor*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: 2-chloro-2',-6'-diethyl-n-(methoxymethyl) acetanilide

Molecular Formula: $C_{14}H_{20}ClNO_2$

Molecular Weight (g/mole): 269.8

Analysis Method - **Product:** glc
Residue: glc - EPA Method # 507

Physico-Chemical Properties

State/Color/Odor: Cream Colored Solid

Vapor Pressure: 2.2*10-5 mm Hg

Boiling Point (°C): 100

Specific Gravity: 1.125 25/15.6

Melting Point (°C): 40.5

Density (g/cm³): 1.124 @ 25°C

Mol Surface Area (Å²): 472

Shelf Life:

Stability: Stable to UV light, microbial degradation prominent

Lasso

Common Name: *Alachlor*

Toxicological Properties

Acute Toxicity **(LD_{50} [mg/kg]):** Rats: 930 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects: can cause eye & skin irritation

Critical Concentration **(MCL):** 2 ppb

Phytotoxicity:

Precautions:

Soil Transport Properties:

Mobility: Slightly Mobile

Persistence: Nonpersistent

Leaching Potential: Medium

Surface Loss Potential: Medium

Partition Coef (ml/g): 190

Half Life (days): 14

Solubility: 242 mg/l @ 25°C

Henry's Constant: $2.4*10^{-8}$

Manzate/Dithane

Common Name: *Mancozeb*

Trade Names:Manzate, Dithane M45 Fore,Mancofol,Manzeb,Manzin-80, Nemispor,Penncozeb,Policar-MZ

CAS #: 8018-01-7

Manufacturer: Rohm & Hass, Pennwalt & DePont Chem., 1961-USA

Use:

Pesticide Action: Protectant Fungicide

Crops Used Upon: Potato, Barley, Wheat

Pests Controlled: Fusarium seed piece decay, seedborne common scab, phytophthora infestants, alternaria leaf spot, anthracnose, bitter rot, black rot, botrytis leaf blight, brown rot, cedar apple rust, cercospora leaf spot, dollar spot, downy mildew, blight, fly speck, gray leaf spot, Helminthosporium ssp., phythophythoria, pythium blight, rhizoctonia brown patch, rust, scab dead arm, septoria leaf spot, snow mold, sooty blotch

Application Date: postemergence

Application Method: foliar spray, chemigation

Application Rate: 0.8 to 8 lb ai/A

Chemical Classification: Carbamate compound

Formulation Type: Wettable powder, dusts, dispersible liquids, dispersible granules

Initial San Luis Valley Study:

Pesticide Action: Potato Fungicide

SLV Pesticide Utilization: Heavy: 67% of potato growers sampled

National Utilization: Medium: 1690000 lb ai/Yr

Application Date: Early July to Mid August

Application Method: Chemigation/Ground Rig

Application Rate: 0.5 to 1.5 qt/A

Manzate/Dithane

Common Name: *Mancozeb*

Chemical Properties:

Structural Formula: $[-SCS.NHCH_2CH_2NHCS.S.Mn^-]_x (Zn)_y$

Chemical Abstract Name: ethylenebisdithiocarbamate ion/manganese ethylenebisdithiocaramate plus zinc ion

Molecular Formula: Not Disclosed

Molecular Weight (g/mole): Not Disclosed

Analysis Method - **Product**: glc
Residue: glc - EPA Method # NPS4

Physico-Chemical Properties

State/Color/Odor: grayish-yellow powder

Vapor Pressure:

Boiling Point (°C):

Specific Gravity:

Melting Point (°C):

Density (g/cm³):

Mol Surface Area (Å²):

Shelf Life:

Stability: Decomposes at high temperatures if moist

Manzate/Dithane

Common Name: *Mancozeb*

Toxicological Properties

Acute Toxicity (LD_{50} [mg/kg]): Rats: 4500 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects: May cause skin irritation

Critical Concentration (MCL):

Phytotoxicity: Nonphytotoxic when used as directed

Precautions: Toxic to fish

Soil Transport Properties:

Mobility: Nearly Immobile

Persistence: Nonpersistent

Leaching Potential: Small

Surface Loss Potential: Large

Partition Coef (ml/g): 1000

Half Life (days): 35

Solubility: 0.5 mg/l

Henry's Constant:

Monitor

Common Name: *Methamidophos*

Trade Names: Monitor
Tamaron
Bay 71628
Hamidop

CAS #: 10265-92-6

Manufacturer: Chevron Chem., 1967-USA
Bayer AG, Mobay, Valent Chem.

Use:

Pesticide Action: Systemic, residual Insecticide-Acaricide (Stomach Poison)

Crops Used Upon: Potatoes, Alfalfa

Pests Controlled: Locusts, aphids, flea beetles, worms, whiteflies, cabbage loopers, thrips, cutworms, Colorado potato beetle, potato tuber worms, army worms, mites leafhoppers

Application Date: Apply when insects appear

Application Method: foliar spray, chemigation

Application Rate:

Chemical Classification: organic phosphate compound

Formulation Type: Emulsifiable concentrates, wettable powder, granules, non aqueous liquid concentrates

Initial San Luis Valley Study:

Pesticide Action: Potato Insecticide

SLV Pesticide Utilization:Medium: 10% of potato growers sampled

National Utilization: Light: 941000 lb ai/Yr

Application Date: Early July to Late July

Application Method: Chemigation

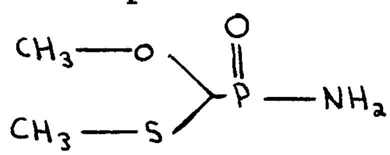
Application Rate: 1 to 2 Pt/A

Monitor

Common Name: *Methamidophos*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: O,S-dimethyl phosporamidothioate

Molecular Formula: $C_2H_8NO_2PS$

Molecular Weight (g/mole): 141.1

Analysis Method - **Product**: ir spectrometry or glc
Residue: glc - EPA Method # 507

Physico-Chemical Properties

State/Color/Odor: White crystalline solid

Vapor Pressure: $3*10^{-4}$ mm Hg

Specific Gravity:

Density (g/cm³):

Shelf Life:

Stability:

Boiling Point (°C):

Melting Point (°C): 44.5

Mol Surface Area (Å²):

Monitor

Common Name: *Methamidophos*

Toxicological Properties

Acute Toxicity (**LD_{50} [mg/kg]**): Rat: 29.9 mg/kg

Toxicity Category: I: Extremely Toxic

Probable Lethal Dose: A pinch to 1 teaspoon

Dermal Effects:

Critical Concentration (**MCL**):

Phytotoxicity: Nonphytotoxic when used as directed

Precautions: High mammalian toxicity (birds & wildlife)
Toxic to bees

Soil Transport Properties:

Mobility: Very Mobile

Persistence: Nonpersistent

Leaching Potential: Small

Surface Loss Potential: Medium

Partition Coef (ml/g): 780

Half Life (days): 6

Solubility: 100000

Henry's Constant:

Penncap-m

Common Name: Methyl Parathion

Trade Names: Penncap-m
Partron-m, Bladan-m, Folidol-m, Metacide, Metafor, Methyl Niran, Metron, Nitrox, Tekwaisa, Wofactox

CAS #: 298-00-0

Manufacturer: Bayer AG, 1949-Germany
Cheminova

Use:

Pesticide Action: Contact & Stomach Poison Insecticide-Acaricide

Crops Used Upon: Barley, Wheat, Potato, Alfalfa

Pests Controlled: Aphids, army worms, flea beetles, leaf hoppers, leaf miners, scale, mealy bugs, mites, boll weevils, thrips, mosquitos

Application Date: Apply when insects appear

Application Method: Foliar Spray, Chemigation

Application Rate: 0.25 to 2 lb ai/A

Chemical Classification: Organic Phosphate

Formulation Type: Emulsifiable Concentrate, Wettable Powder

Initial San Luis Valley Study:

Pesticide Action: Grain Insecticide

SLV Pesticide Utilization: Light: 3% of grain growers sampled

National Utilization: Large: 11336000 lb ai/Yr

Application Date: Mid July to Early August

Application Method: Ground Rig

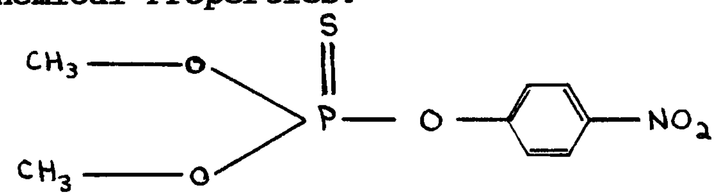
Application Rate: 0.25 to 0.5 lb ai/A

Penncap-m

Common Name: *Methyl Parathion*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: o,o-dimethyl-o-p-nitrophenyl phosphorothioate

Molecular Formula: $C_8H_{10}NO_5PS$

Molecular Weight (g/mole): 263.2

Analysis Method - **Product**: glc or hplc
Residue: glc - EPA Method # 507

Physico-Chemical Properties

State/Color/Odor: Colorless crystalline

Vapor Pressure: $1*10^{-4}$ mm Hg **Boiling Point (°C)**:

Specific Gravity: 1.358 20/04 **Melting Point (°C)**: 35

Density (g/cm³): 1.358 @ 20°C **Mol Surface Area (Å₂)**:

Shelf Life:

Stability:

Penncap-m

Common Name: *Methyl Parathion*

Toxicological Properties

Acute Toxicity (**LD_{50} [mg/kg]**): Rats: 9 mg/kg

Toxicity Category: I: Extremely Toxic

Probable Lethal Dose: A pinch or 1 teaspoon

Dermal Effects: Absorbed readily through skin

Critical Concentration (**MCL**):

Phytotoxicity: Nonphytotoxic

Precautions: Avoid drift, Toxic to fish

Soil Transport Properties:

Mobility: Immobile

Persistence: Nonpersistent

Leaching Potential: Total Use

Surface Loss Potential: Medium

Partition Coef (ml/g): 5100

Half Life (days): 5

Solubility: 60 mg/l @ 25°C

Henry's Constant: $1.2*10^{-3}$

Poast

Common Name: *Sethoxydim*

Trade Names: Poast
Basf 9052, Checkmate, Expand,
Fervinal, Grasidim, Nabu,
Nabugram, NP55, Sertin3

CAS #: 74051-80-2

Manufacturer: Nippon Suda, 1978-Japan
BASF

Use:

Pesticide Action: Selective Herbicide

Crops Used Upon: Potatoes, Alfalfa

Pests Controlled: All annual grasses & most perennial grasses

Application Date: Postemergence up to 6-8 leaf stage

Application Method: Target weed foliar spray

Application Rate: 0.1 to 1 lb ai/A

Chemical Classification: Cyclohexane compound

Formulation Type: Emulsifiable Concentrates

Initial San Luis Valley Study:

Pesticide Action: Potato Herbicide

SLV Pesticide Utilization: Light: 3% of grain growers sampled

National Utilization: Light: 92000 lb ai/Yr

Application Date:

Application Method:

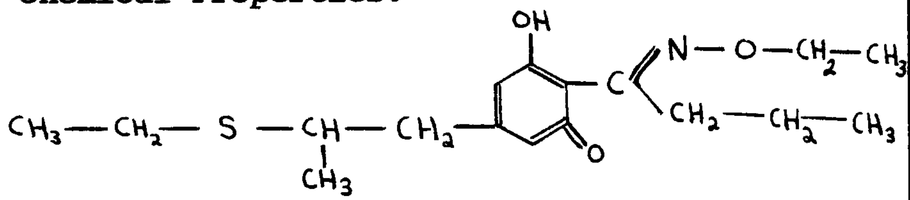
Application Rate:

Poast

Common Name: *Sethoxydim*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: 2-[1-(ethoxyimino) butyl]-5-[2-ethylthio propyl]-3-hydroxy-2-cyclohexen-1-one

Molecular Formula: $C_{17}H_{29}NO_3S$

Molecular Weight (g/mole): 327.5

Analysis Method - Product: hplc
Residue: hplc - No EPA Method

Physico-Chemical Properties

State/Color/Odor: liquid

Vapor Pressure:

Boiling Point (°C): > 90

Specific Gravity: 1.043 25/04

Melting Point (°C):

Density (g/cm³): 1.043 @ 25°C

Mol Surface Area (Å²):

Shelf Life:

Stability:

Poast

Common Name: *Sethoxydim*

Toxicological Properties

Acute Toxicity **(LD_{50} [mg/kg]):** Rats: 2676 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects: Can cause eye & skin irritation

Critical Concentration **(MCL):**

Phytotoxicity:

Precautions:

Soil Transport Properties:

Mobility: Nearly Immobile

Persistence: Nonpersistent

Leaching Potential: Small

Surface Loss Potential: Small

Partition Coef (ml/g): 50

Half Life (days): 5

Solubility: 1000 mg/l @ 20°C

Henry's Constant:

Prowl

Common Name: *Pendimethalin*

Trade Names: Prowl
Accotab, Gogasan, Herbadox,
Pre-M, Stomp, Way-Up

CAS #: 40487-42-1

Manufacturer: American Cyanamid Co., 1972-USA

Use:

Pesticide Action: Herbicide

Crops Used Upon: Barley, Wheat, Potatoes

Pests Controlled: Annual grasses, small annual broad leaf weeds
Foxtails, barnyard grass, panicum, crabgrass, pigweed, velvet leaf, lambsquarter, purslane, johnsongrass

Application Date: Preemergence & preplant

Application Method: Soil incorporation or soil surface spray

Application Rate: 1 to 2 lb ai/A

Chemical Classification: Dinitroaniline compound

Formulation Type: Emulsifiable concentrate

Initial San Luis Valley Study:

Pesticide Action: Grain Herbicide

SLV Pesticide Utilization: Light: 3% of Grain

National Utilization: Medium: 2864800 lb ai/Yr

Application Date:

Application Method:

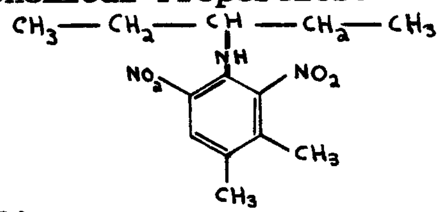
Application Rate: 1.5 to 2 Pt/A

Prowl

Common Name: *Pendimethalin*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: n-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitro benzenamine

Molecular Formula: $C_{13}H_{19}N_3O_4$

Molecular Weight (g/mole): 281.3

Analysis Method - Product: glc
Residue: glc - EPA Method # 507

Physico-Chemical Properties

State/Color/Odor: Orange-yellow crystals

Vapor Pressure: 4 mPa @ 25°C

Boiling Point (°C):

Specific Gravity:

Melting Point (°C): 56 C

Density (g/cm³):

Mol Surface Area (Å²):

Shelf Life:

Stability:

Prowl

Common Name: *Pendimethalin*

Toxicological Properties

Acute Toxicity (LD$_{50}$ [mg/kg]): Rats: 1250 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects:

Critical Concentration (MCL):

Phytotoxicity:

Precautions: Toxic to fish

Soil Transport Properties:

Mobility: Nearly Immobile

Persistence: Moderate

Leaching Potential: Small

Surface Loss Potential: Large

Partition Coef (ml/g): 24300

Half Life (days): 60

Solubility: 0.5 mg/l @ 20°C

Henry's Constant:

Pydrin

Common Name: *Fenvalerate*

CAS #: 51630-58-1

Trade Names: Pydrin
Pyrid, Ectrin, Extrin, Tirade, Tribute, Aqmatrine, Belmark, Moscade, San Marton, Sumibac, Sumicidin, Sumifleece, Sumifly, Sumitick

Manufacturer: Sumitomo Chem., 1974-Japan
DuPont, Shell Chem. Co.

Use:

Pesticide Action: Selective, Contact, Stomach Poison, Insecticide

Crops Used Upon: Potatoes

Pests Controlled: cotton armyworm, cutworm, corn borer, flies, cockroaches, crickets, locusts, fleas, spiders, boll worm, leafhoppers, lepidoptera species, aphids

Application Date: Apply when insects appear

Application Method: ground spray or aerial application

Application Rate: 0.05 to 0.2 lb ai/A

Chemical Classification: Synthetic pyrethroid compound

Formulation Type: Emulsifiable Concentrates

Initial San Luis Valley Study:

Pesticide Action: Potato Insecticide

SLV Pesticide Utilization: Heavy: 33% of potato growers sampled

National Utilization: Medium: 1270000 lb ai/Yr

Application Date: Late July to Mid August

Application Method: Chemigation/Ground Rig

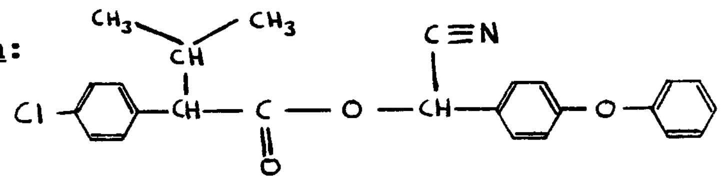
Application Rate: 0.1 to 0.2 lb ai/A

Pydrin

Common Name: *Fenvalerate*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: s-cyano-(3-phenoxyphenyl)-methyl 4-chloro alpha (1-methylethyl) benzenacetate

Molecular Formula: $C_{25}H_{22}ClNO_3$

Molecular Weight (g/mole): 419.9

Analysis Method - **Product:** glc or hplc
Residue: glc - EPA Method # 508

Physico-Chemical Properties

State/Color/Odor: Viscous yellow or brown oily liquid

Vapor Pressure: $2.8*10^{-7}$ mm Hg

Boiling Point (°C): 300

Specific Gravity: 1.2 23/04

Melting Point (°C):

Density (g/cm³): 1.2 @ 23°C

Mol Surface Area (Å²):

Shelf Life: 2 yrs under ambient conditions

Stability: Breaks down slowly in sunlight, stable to heat

Pydrin

Common Name: *Fenvalerate*

Toxicological Properties

Acute Toxicity (LD_{50} [mg/kg]): Rats: 82-451 mg/kg

Toxicity Category: II: Very Toxic

Probable Lethal Dose: 1 teaspoon to 2 tablespoons

Dermal Effects: Irritating to skin & eyes

Critical Concentration (MCL):

Phytotoxicity: spotting on young tomatoes using high doses

Precautions: Highly toxic to fish and bees

Soil Transport Properties:

Mobility: Immobile

Persistence: Moderate

Leaching Potential: Small

Surface Loss Potential: Large

Partition Coef (ml/g): 100000

Half Life (days): 50

Solubility: 0.1 mg/l @ 20°C

Henry's Constant:

Rhomene

Common Name: *MCPA*

CAS #: 94-74-6

Trade Names: Rhomene
Agritox, Agroxone, Chiptox, Cornox-M, Dikotex, Hedonal-M, Kilsem, Krezone, Linormone, MCP, Mephanac, Metaxon, Raphonone, Rohenc, Rhonox, Shammox, Shamrox, Trasan, Vacate, Weedor MCPA, Weedone MCPA, Zelan

Manufacturer: Plant Protection LTD., 1945-England
Monsanto, Dow Chem., Cheminova

Use:

Pesticide Action: Hormone Selective, Translocated Herbicide

Crops Used Upon: Barley, Wheat, Alfalfa

Pests Controlled: Broad leaf annual & perennial weeds
Mustard, plantain, arrowhead lily, sedges, bindweed, bowhead, lambsquarters, puncture vine, ragweed, cocklebur, purslane, peppergrass

Application Date: Postemergence-when grain is 8-10 inches tall

Application Method: Aerial or ground application

Application Rate: 0.2 to 2 lb ai/A in 5-100 gal water

Chemical Classification: Translocated phenoxy herbicide

Formulation Type: Emulsifiable Concentrates

Initial San Luis Valley Study:

Pesticide Action: Grain Herbicide

SLV Pesticide Utilization: Medium: 9% of grain growers sampled

National Utilization: Medium: 9875000 lb ai/Yr

Application Date: Mid May to Early June

Application Method: Chemigation/Ground Rig

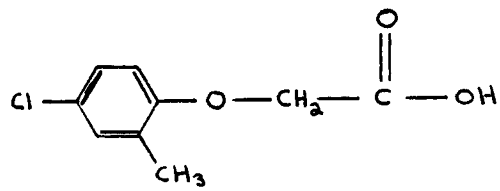
Application Rate: 0.5 to 3 Pt/A

Rhomene

Common Name: *MCPA*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: 2-methyl-4-chlorophenoxyacetic acid

Molecular Formula: $C_9H_9ClO_3$

Molecular Weight (g/mole): 200.6

Analysis Method - **Product**: ir spectrometry or glc
Residue: glc - EPA Method # 515

Physico-Chemical Properties

State/Color/Odor: light brown solid

Vapor Pressure: $200*10^{-6}$ Pa

Boiling Point (°C):

Specific Gravity: 1.56 25/15

Melting Point (°C): 119

Density (g/cm³): 1.558

Mol Surface Area (Å²):

Shelf Life:

Stability: NonVolatile

Rhomene

Common Name: *MCPA*

Toxicological Properties

Acute Toxicity (LD_{50} [mg/kg]): Rats: 700 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects: May be irritating to eyes and skin

Critical Concentration (MCL):

Phytotoxicity: will injure grasses

Precautions: Avoid drift. Do not apply on light, sandy soils.

Soil Transport Properties:

Mobility: Moderate

Persistence: Moderate

Leaching Potential: Large

Surface Loss Potential: Small

Partition Coef (ml/g): 20

Half Life (days): 14

Solubility: 270000 mg/l

Henry's Constant:

Round-Up

Common Name: *Glyphosate*

Trade Names: Round-Up
Accord, Arcade, Azural, Glycel, Hockey, Kleenup, Muster, Ranger, Rodeo, Shackle, Solado, Spasor, Sting

CAS #: 1071-83-6

Manufacturer: Monsanto Chem., 1972-USA

Use:

Pesticide Action: Broad Spectrum, Translocated Herbicide

Crops Used Upon: Barley, Wheat, Alfalfa, Potatoes

Pests Controlled: Perennial Weeds
Quakgrass, johnsongrass, bermuda grass, bentgrass, thistles, milkweek, cattails, kudzu, bindweed, sedges, horsetails, bahia grass, kikuyu grass, poison ivy

Application Date: Postemergence: when weeds have 4 leaves

Application Method: Foliar Spray

Application Rate: 0.5 to 4 lb ai/A in 20-100 gal water

Chemical Classification: Organophosphorus compound

Formulation Type: Soluble Solution

Initial San Luis Valley Study:

Pesticide Action: General Herbicide

SLV Pesticide Utilization: Medium: 9% of all growers sampled

National Utilization: Medium: 6308000 lb ai/Yr

Application Date: When needed

Application Method: Ground Rig

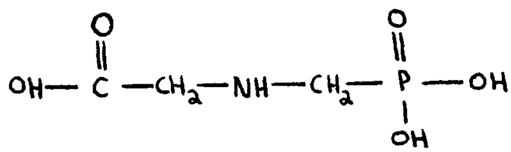
Application Rate:

Round-Up

Common Name: *Glyphosate*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: n-(phosphonomethyl) glycine (isopropylamine salt)

Molecular Formula: $C_3H_8NO_5P$

Molecular Weight (g/mole): 169.1

Analysis Method - Product:
Residue: hplc - No EPA Method

Physico-Chemical Properties

State/Color/Odor: Zwitterion structure, colorless crystals

Vapor Pressure:

Boiling Point (°C):

Specific Gravity: 0.5 25/04

Melting Point (°C): 200

Density (g/cm³): 0.5 @ 25°C

Mol Surface Area (Å²):

Shelf Life:

Stability:

Round-Up

Common Name: *Glyphosate*

Toxicological Properties

Acute Toxicity **(LD_{50} [mg/kg]):** Rats: 4900 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects: May cause eye & skin irritation

Critical Concentration **(MCL):**

Phytotoxicity: Low crop selectivity

Precautions: Avoid drift

Soil Transport Properties:

Mobility: Immobile

Leaching Potential: Small

Partition Coef (ml/g): 10000

Solubility: 1000000 mg/l

Persistence: Moderate

Surface Loss Potential: Large

Half Life (days): 30

Henry's Constant:

Sencor

Common Name: *Metribuzin*

Trade Names: Sencor
Sencoral
Sencorex
Lexone

CAS #: 21087-64-9

Manufacturer: Bayer AG, 1969-Germany
Mobay Chem. Co., DuPont

Use:

Pesticide Action: Selective Herbicide

Crops Used Upon: Potatoes, Alfalfa, Barley

Pests Controlled: Ragweed, pigweed, cocklebur, mustard, crabgrass, goosegrass, panicum, foxtail

Application Date: Preplant or Postemergence with weeds less than 1.5 inches tall

Application Method: Soil Incorporation, Soil Surface

Application Rate: 0.33 to 1 lb ai/A

Chemical Classification: Triazine compound

Formulation Type: Wettable Powder, Aqueous Suspension

Initial San Luis Valley Study:

Pesticide Action: Potato Herbicide

SLV Pesticide Utilization: Heavy: 30% of potato growers sampled

National Utilization: Heavy: 10600000 lb ai/Yr

Application Date: Late May to Mid June

Application Method: Chemigation/Ground Rig

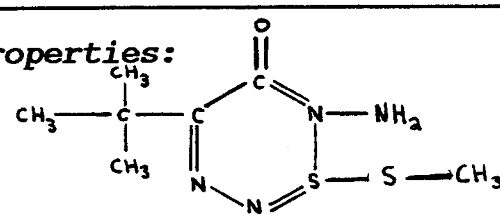
Application Rate: Preplant: 0.5 to 1 lb ai/A
Postemergence: 0.25 to 0.5 lb ai/A

Sencor

Common Name: *Metribuzin*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: 4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5-(4H)-one

Molecular Formula: $C_8H_{14}N_4OS$

Molecular Weight (g/mole): 214.3

Analysis Method - **Product:** ir spectrometry
Residue: glc - EPA Method # 507

Physico-Chemical Properties

State/Color/Odor: Colorless crystals, slight sulphurous odor

Vapor Pressure: $1*10^{-6}$ mm Hg

Boiling Point (°C):

Specific Gravity:

Melting Point (°C): 125.7

Density (g/cm³):

Mol Surface Area (Å²): 402

Shelf Life:

Stability: Microbial decomposition in moist soil

Sencor

Common Name: *Metribuzin*

Toxicological Properties

Acute Toxicity (**LD_{50} [mg/kg]**): Rats: 2200-2345 mg/kg

Toxicity Category: III: Moderately Toxic

Probable Lethal Dose: 1 ounce to 1 pint

Dermal Effects:

Critical Concentration (**MCL**):

Phytotoxicity:

Precautions: do not use on sandy or sandy loam soils with less than 2% organic matter.

Soil Transport Properties:

Mobility: Moderate

Persistence: Moderate

Leaching Potential: Large

Surface Loss Potential: Medium

Partition Coef (ml/g): 41

Half Life (days): 30

Solubility: 1220 mg/l

Henry's Constant: 88

Temik

Common Name: *Aldicarb*

Trade Names: Temik
Sentry

CAS #: 116-06-3

Manufacturer: Union Carbide, 1965-USA
Rhone-Poulenc

Use:

Pesticide Action: Systemic Insecticide-Acaricide-Nematocide (Cholinesterase Inhibitor)

Crops Used Upon: Potatoes, Alfalfa

Pests Controlled: Aphids, mites, Colorado potato beetle, thrips, lygus, fleahoppers, boll weavils, flea beetles, wireworms, leafminers, webworms, mealy bugs, leafhoppers, nematodes

Application Date: Apply when insects appear

Application Method: ground spray

Application Rate: 0.5 to 10 lb ai/A

Chemical Classification: Carbamate compound

Formulation Type: Granules

Initial San Luis Valley Study:

Pesticide Action: Potato Insecticide

SLV Pesticide Utilization: Light: 3% of potato growers sampled

National Utilization: Medium: 2270000 lb ai/Yr

Application Date: Late July to Early August

Application Method:

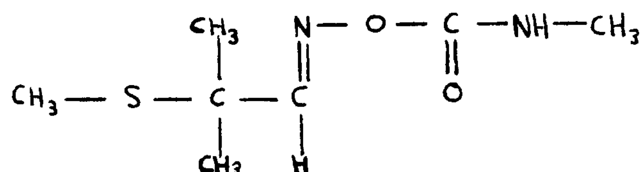
Application Rate: 14 to 20 lb ai/A

Temik

Common Name: *Aldicarb*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: 2-methyl-2-(methylthio) propionaldehyde-O-(methylcarbamoyl) oxime

Molecular Formula: $C_7H_{14}N_2O_2S$

Molecular Weight (g/mole): 190.3

Analysis Method - **Product:** ir spectrometry
Residue: glc - EPA Method # NPS4

Physico-Chemical Properties

State/Color/Odor: Colorless crystals

Vapor Pressure: $1*10^{-4}$ mm Hg

Boiling Point (°C):

Specific Gravity:

Melting Point (°C): 99

Density (g/cm³):

Mol Surface Area (Å²):

Shelf Life:

Stability:

Temik

Common Name: *Aldicarb*

Toxicological Properties

Acute Toxicity (LD_{50} [mg/kg]): Rats: 0.9 mg/kg

Toxicity Category: I: Supertoxic

Probable Lethal Dose: A taste or 1 grain

Dermal Effects: Unknown

Critical Concentration (MCL):

Phytotoxicity: Slight phytotoxicity

Precautions: Highly Toxic! Rapidly absorbed through skin

Soil Transport Properties:

Mobility: Moderate

Persistence: Moderate

Leaching Potential: Large

Surface Loss Potential: Small

Partition Coef (ml/g): 30

Half Life (days): 30

Solubility: 6000 mg/l @ 25°C

Henry's Constant: $4.8*10^{-11}$

Thiodan

Common Name: *Endosulfan*

CAS #: 115-29-7

Trade Names: Thiodan
Benzoepin, Beosit, Chlortiepin, Cyclodain, Malix, Melophen, Thifor, Thimul, Thionex, Thiosulfan, Tionel, Tiovel

Manufacturer: Hoechst AG, 1956-Germany
FMC Corp.

Use:

Pesticide Action: Nonsystemic, Contact Insecticide (Stomach Poison)

Crops Used Upon: Potatoes, Alfalfa, Barley, Wheat

Pests Controlled: Aphids, beetles, bollworms, psyllids, tsetse fly, leafhoppers, fleabeetles, stem borers, stinkbugs, bollweevils, loopers, corn ear worms, peach twig borers, armyworms, cyclamen mites

Application Date: Apply when insects appear

Application Method: Crop Foliar Spray

Application Rate: 0.2 to 4 lb ai/A

Chemical Classification: Cyclodien chlorohydrocarbon

Formulation Type: Emulsifiable Concentrate, Wettable Powder

Initial San Luis Valley Study:

Pesticide Action: Potato Insecticide

SLV Pesticide Utilization: Light: 3% of potato growers sampled

National Utilization: Light: 977800 lb ai/Yr

Application Date:

Application Method: Aerial Application

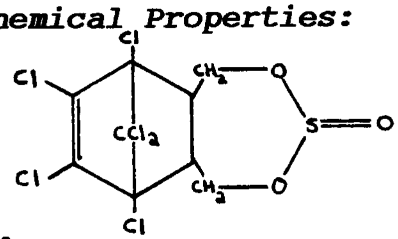
Application Rate:

Thiodan

Common Name: *Endosulfan*

Chemical Properties:

Structural Formula:



Chemical Abstract Name: 6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-venzodioxathiepin-3-oxide

Molecular Formula: $C_9H_6Cl_6O_3S$

Molecular Weight (g/mole): 406.9

Analysis Method - Product: ir spectrometry
Residue: glc - EPA Method # 508

Physico-Chemical Properties

State/Color/Odor: brown crystalline solid, sulfur dioxide odor

Vapor Pressure: 1.2 Pa @ 80°C

Boiling Point (°C):

Specific Gravity:

Melting Point (°C):70-100

Density (g/cm³):

Mol Surface Area (Å²):

Shelf Life:

Stability: Stabile to Sunlight

Thiodan

Common Name: *Endosulfan*

Toxicological Properties

Acute Toxicity **(LD_{50} [mg/kg]):** Rats: 80-110 mg/kg

Toxicity Category: II: Very Toxic

Probable Lethal Dose: 1 teaspoon to 2 tablespoons

Dermal Effects:

Critical Concentration **(MCL):**

Phytotoxicity: Concord grapes, lima beans, alfalfa, birch trees, geraniums, chrysanthemums

Precautions: Toxic to fish

Soil Transport Properties:

Mobility: Nearly Immobile	**Persistence**: Nonpersistent
Leaching Potential: Small	**Surface Loss Potential**: Large
Partition Coef (ml/g): 200000	**Half Life (days)**: 43
Solubility: 0.33 mg/l @ 22°C	**Henry's Constant**:

Appendix A

Pesticides Commonly Used in the San Luis Valley

Trade Name	Common Name	Action	
Ambush	Permethrin	Potato	Insecticide
Asana	Esfenvalerate	Potato	Insecticide
Assert	Imazamethabenz	Grain	Herbicide
Bravo	Chlorothalonil	Potato	Fungicide
Buctril/Bronate	Bromoxynil	Grain	Herbicide
Champ	Champ	Potato	Fungicide
2,4-D	2,4-D	Grain	Herbicide
Dinoseb	DNBP	Grain	Herbicide
Diquat	Diquat	Potato	Desiccant
Dual	Metolachlor	Potato	Herbicide
Dy-Syston	Disulfoton	Potato	Insecticide
Eptam	EPTC	Potato	Herbicide
Far-Go	Triallate	Grain	Herbicide
Harmony	Thiameturon	Grain	Herbicide
Hoelan	Diclofop	Grain	Herbicide
Lasso	Alachlor	Potato	Herbicide
Manzate/Dithane	Mancozeb	Potato	Fungicide
Monitor	Methamidophos	Potato	Insecticide
Penncap-M	Methyl Parathion	Grain	Insecticide
Poast	Sethoxydim	Potato	Herbicide
Prowl	Pendimethalin	Grain	Herbicide
Pydrin	Fenvalerate	Potato	Insecticide
Rhomene	MCPA	Grain	Herbicide
Ridamil	Ridamil	Grain	Herbicide
Round-Up	Glyphosate	General	Herbicide
Sencor	Metribuzin	Potato	Herbicide
Super-Tin	Triphenyltin	Potato	Fungicide
Temik	Aldicarb	Potato	Insecticide
Thiodan	Endosulfan	Potato	Insecticide

Appendix B

Trade Name & Common Name Cross Reference

Appendix C

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