Fact Sheet #16
October 1998

Relative Sensitivity of Colorado Groundwater to Pesticide Impact

Background

The Colorado Department of Agriculture is charged with protecting Colorado groundwater from contamination from pesticides. In order to guide prevention activities, a study was conducted to assess the relative sensitivity of the state's principal groundwater resources to pesticide contamination.

Aquifer Sensitivity is defined as the relative ease with which a pesticide applied on or near a land surface can migrate to the groundwater. Sensitivity is largely a function of the physical characteristics of the overlying area. Sensitivity is not dependent on management practices or pesticide characteristics. Aquifer **"vulnerability**" considers both the sensitivity of the aquifer, as well as the land use, management, and pesticide properties. This analysis of aquifer sensitivity must be used with other supporting information to determine where additional precautions must be taken to protect groundwater from pesticide contamination.

Aquifer Sensitivity Factors

A number of factors have been identified which may affect the susceptibility of groundwater to contamination from pesticides. Of the many possible factors, the following four primary factors were identified as critical in describing the sensitivity of groundwater to pesticide contamination in Colorado:

1) conductivity of exposed aquifers

2) depth to water table

3) permeability of materials overlying aquifers

4) availability of recharge for transport of contaminants

These selected factors incorporate the best data currently available for the entire state and incorporate important aspects of Colorado's unique climate and geology.

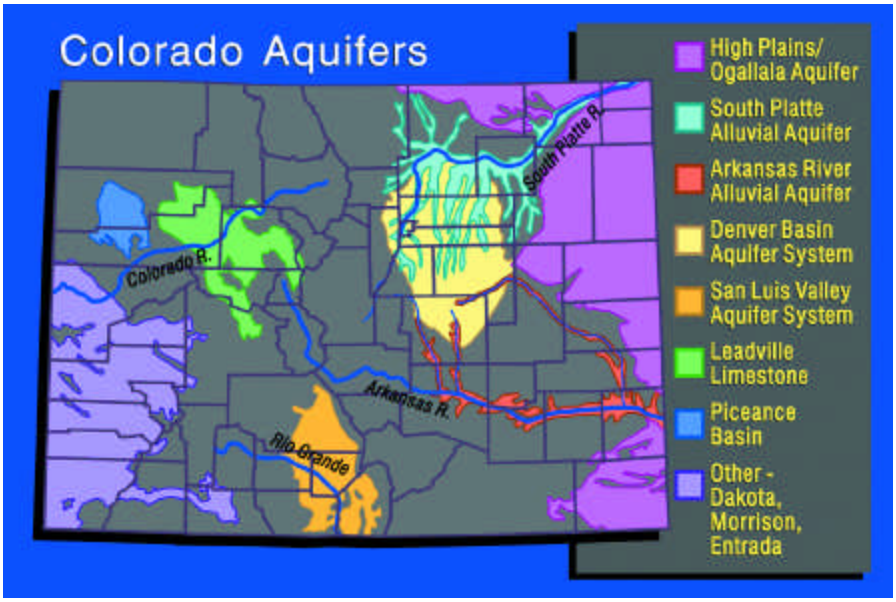

Figure 1. Principal aquifers of Colorado

Table 1. Sensitivity data layers and corresponding factors of consideration.

Data Layer (Index)	Value Range	Factor of Consideration
Location of aquifer (AQU)	0-1	Conductivity of exposed aquifers
Water table depth (WTD)	1-4	Depth to water table
Soil permeability (SOIL)	1-4	Permeability of overlying materials
Available recharge (RCH)	0-1	Availability of recharge for transport

Factor 1) - Extent of Primary Exposed Aquifers

In agricultural regions of Colorado, a number of aquifers supply water for domestic, irrigation, and commercial uses. Between these primary aquifers are regions where groundwater supplies are inconsistent and/or provide low water yields. Conductivity of these priority aquifers is highly variable, but overall is much higher than areas not underlain by one or more of these principal aquifers. Therefore **the presence or absence of one or more of these principal aquifers** was selected as the indicator of high conductivity aquifer areas.

Factor 2) - Depth to Water Table

Depth to the water table affects the length of time required for a pesticide to reach the groundwater. Since reasonably extensive data on depth to water table is available, **depth to water table is incorporated directly** into the sensitivity analysis.

Factor 3) - Permeability of Materials Overlying Aquifers

The permeability of the materials overlying the aquifer affects the time required for water to reach the groundwater, an important consideration when dealing with chemicals such as pesticides that break down over time. Soil characteristics related to permeability include soil texture, particle size distribution, soil structure, and hydrologic group. The hydrologic group designation describes runoff potential of a soil. Soils with high runoff potential will accordingly have low infiltration potential. Because the hydrologic group designation includes consideration of several factors important in controlling the infiltration rate of a soil, it is felt that it carries more information for an analysis at this scale than other single soil parameters. Therefore, the **hydrologic group designation was chosen as the best available representation of the permeability of materials overlying the aquifers**.

Factor 4) - Recharge Availability

The amount of water available for transport of pesticide to the groundwater is an important consideration in Colorado's semi-arid climate. Average annual precipitation in Colorado's agricultural areas ranges from approximately 7 to 17 inches. Low precipitation, coupled with high evapotranspiration rates, leaves little moisture available for infiltration and subsequent aquifer recharge. Estimates of natural recharge rates in agricultural areas of Colorado are around 10 percent of precipitation or approximately 1 inch/year. Estimates of recharge rates from irrigated agriculture range from 5 to 30 inches/year depending on irrigation type, soil properties, and management. Due to the relative abundance of recharge under irrigated agriculture compared with the limited natural recharge supply in Colorado's climate, **the presence or absence of irrigated agriculture was chosen as an indicator of recharge availability**.

Map Description

A geographic information system (GIS) analysis was conducted to incorporate the data layers into a sensitivity map. A GIS is a computer system that allows comparison and analysis of spatial data layers or "digital maps." Each layer and its respective range of values are shown in Table 1 and were used to develop the sensitivity map.

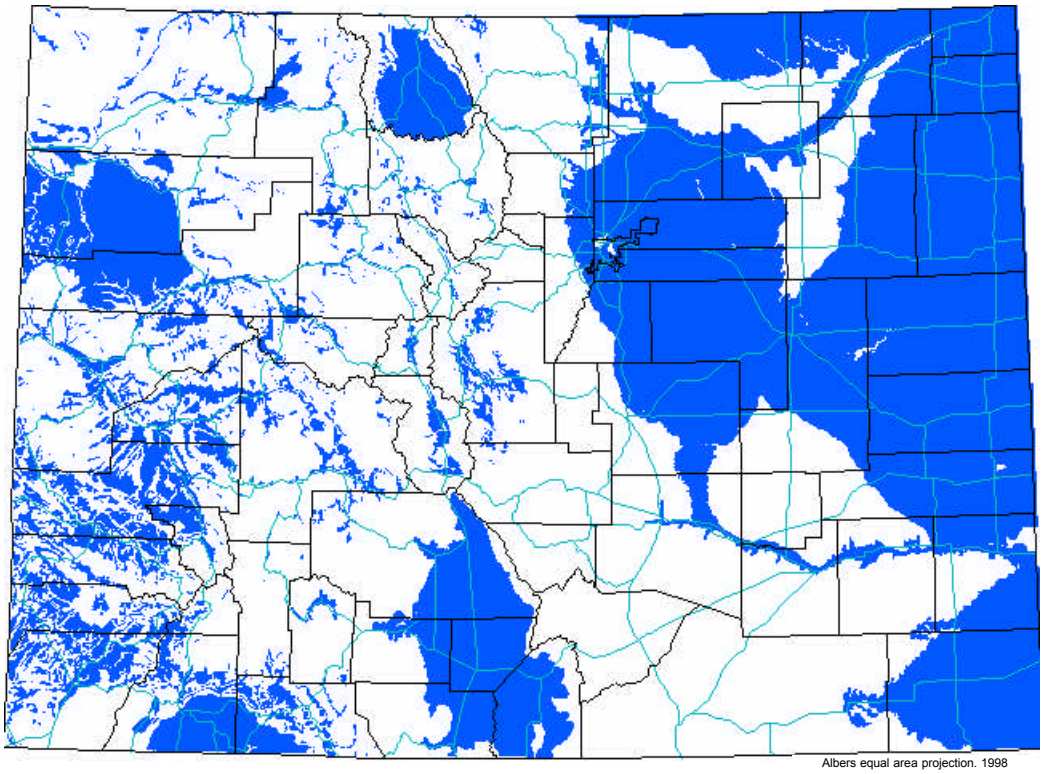

Figure 2. Extent of principal water table aquifers in Colorado (AQU Index)

Aquifer Index

The aquifer map was developed from digitized published reports of aquifer extent or from digitized general geologic maps (figure 2). All areas overlying exposed principal aquifers were assigned a value of 1. Other areas are assigned a value of 0.

Water Table Depth Index

Information on depth to water table was obtained from published reports summarizing water table elevation surveys or from reports of well measurements and well logs. Water table depths were divided into 3 categories for use in sensitivity index calculation (Table 2). The map of the water table depth index is shown in Figure 3.

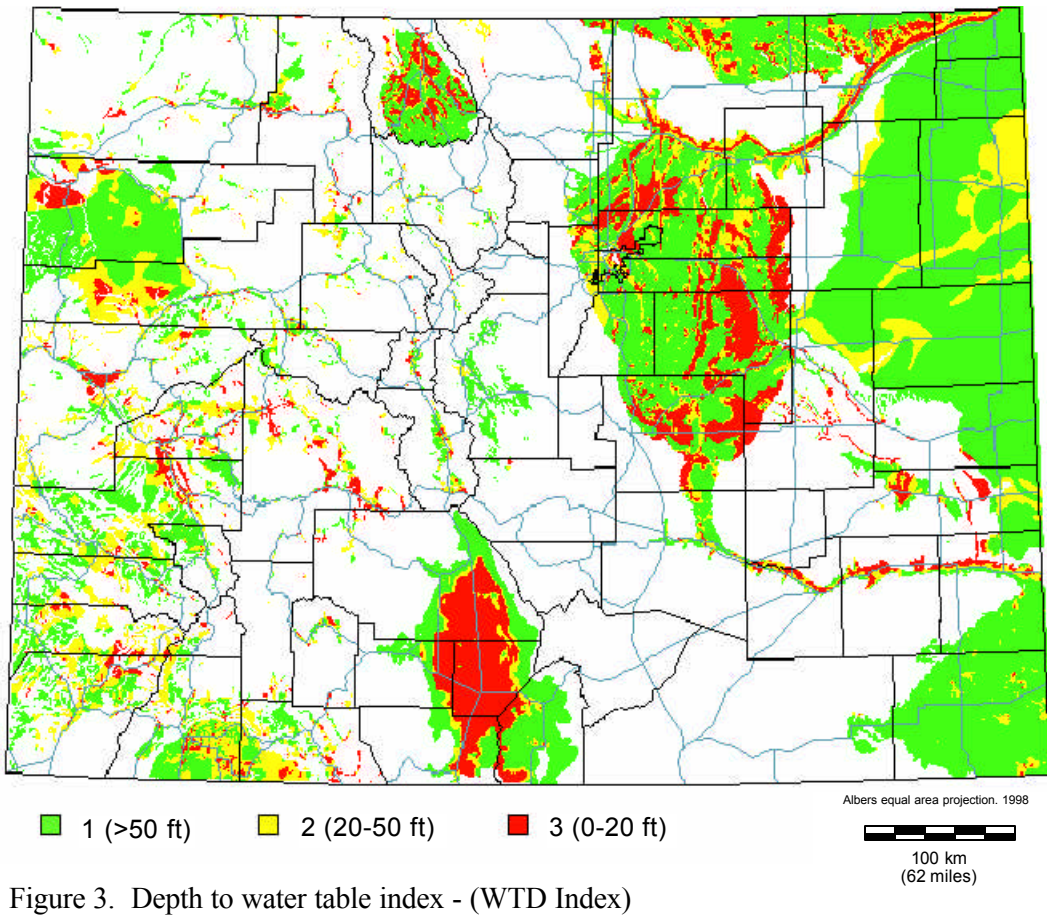

Figure 3. Depth to water table index - (WTD Index)

Table 2. Water table depth index interpretation. (WTD Index)

WTD Index	Depth to Water Table	Interpretation
1	Greater than 50 feet	Low sensitivity
2	20-50 feet	↓
3	0-20 feet	Higher sensitivity

Soil index

Soil map units were reclassified based on their hydrologic group classification. In cases where a single map unit includes soils with different hydrologic group designations, the hydrologic group representative of the majority of land area was selected as most representative of the map unit. The hydrologic groups were assigned numerical indices based on their likelihood to transmit water to underlying groundwater (Table 3). The map of the soil index is shown in figure 4.

Table 3. Relationship of SOIL index to hydrologic groups.

SOIL Index	Hydrologic Group	Infiltration Rates
1	D	Very slow
2	C	Slow
3	B	Moderate
4	A	High

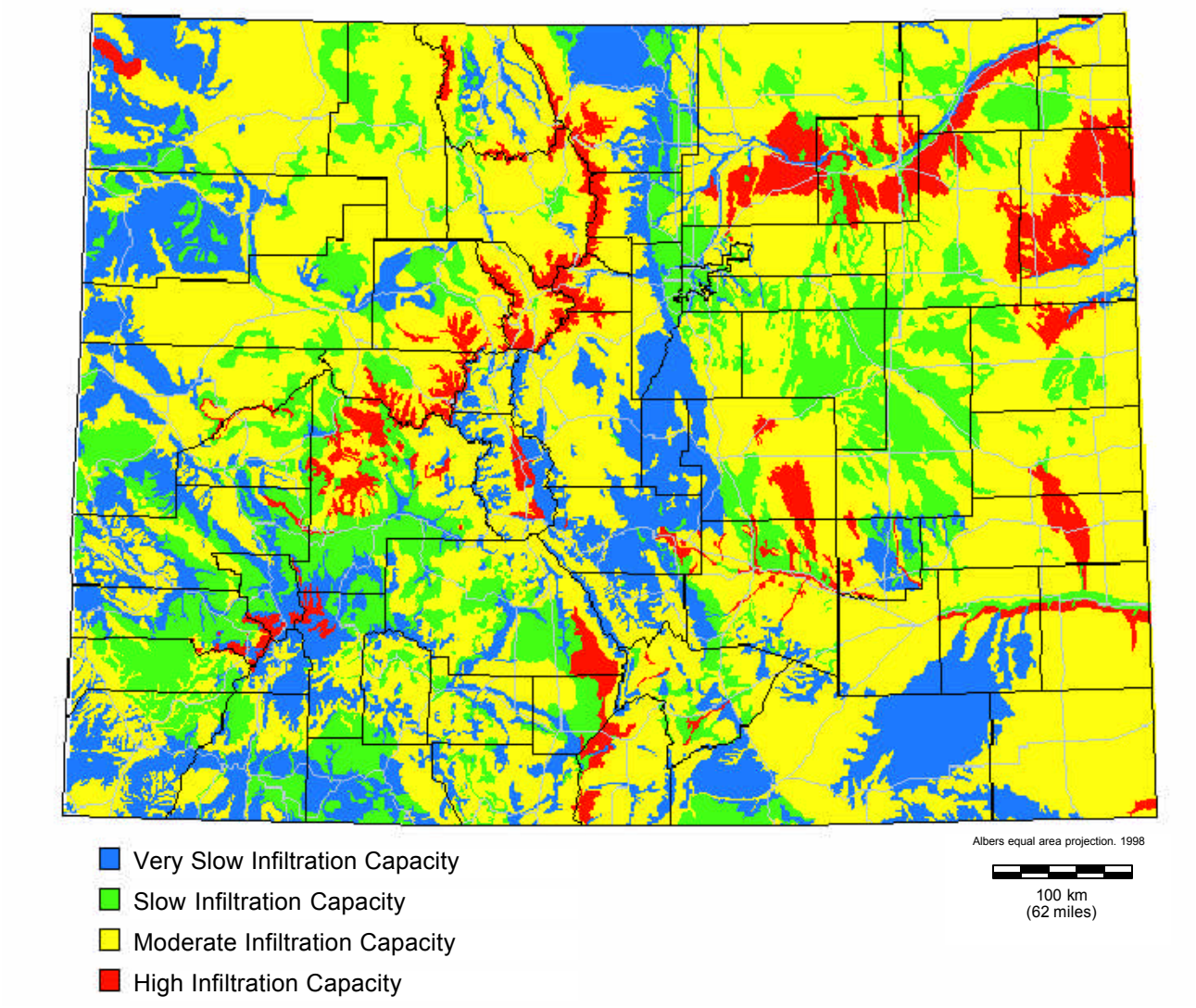

Figure 4. Index of soil infiltration capacity in Colorado - (SOIL Index)

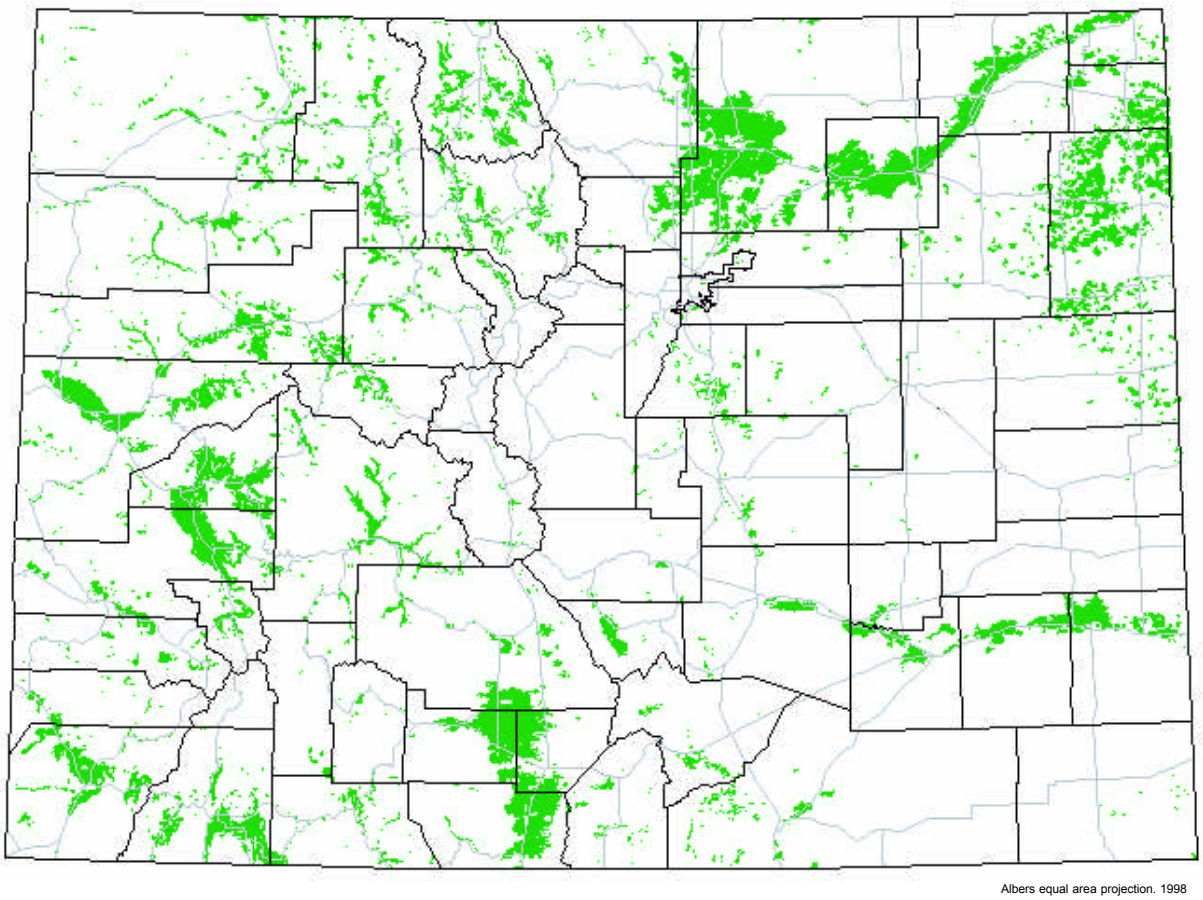

Figure 5. Extent of irrigated areas in Colorado - (RCH Index)

Recharge Index

For the western part of the state within the drainage basin of the Colorado River, location of irrigated lands was obtained from a detailed analysis by the U.S. Bureau of Reclamation. For the remainder of the state, data on location of irrigated lands were obtained from satellite imagery. For calculation of the aquifer sensitivity index, irrigated lands were assigned the value of 1, and non-irrigated lands were assigned to 0. (Figure 5)

Calculation of Aquifer Sensitivity Index (SENSITIVITY)

A sensitivity range was then calculated and scaled to 1 to 4 to obtain the index of SENSITIVITY (Table 4). The map of the SENSITIVITY index is shown in figure 6.

Table 4. Sensitivity index and interpretation.

SENSITIVITY Index	Interpretation
1	Area of low recharge and/or aquifer conductivity
2	Low sensitivity
3	Moderate sensitivity
4	High sensitivity

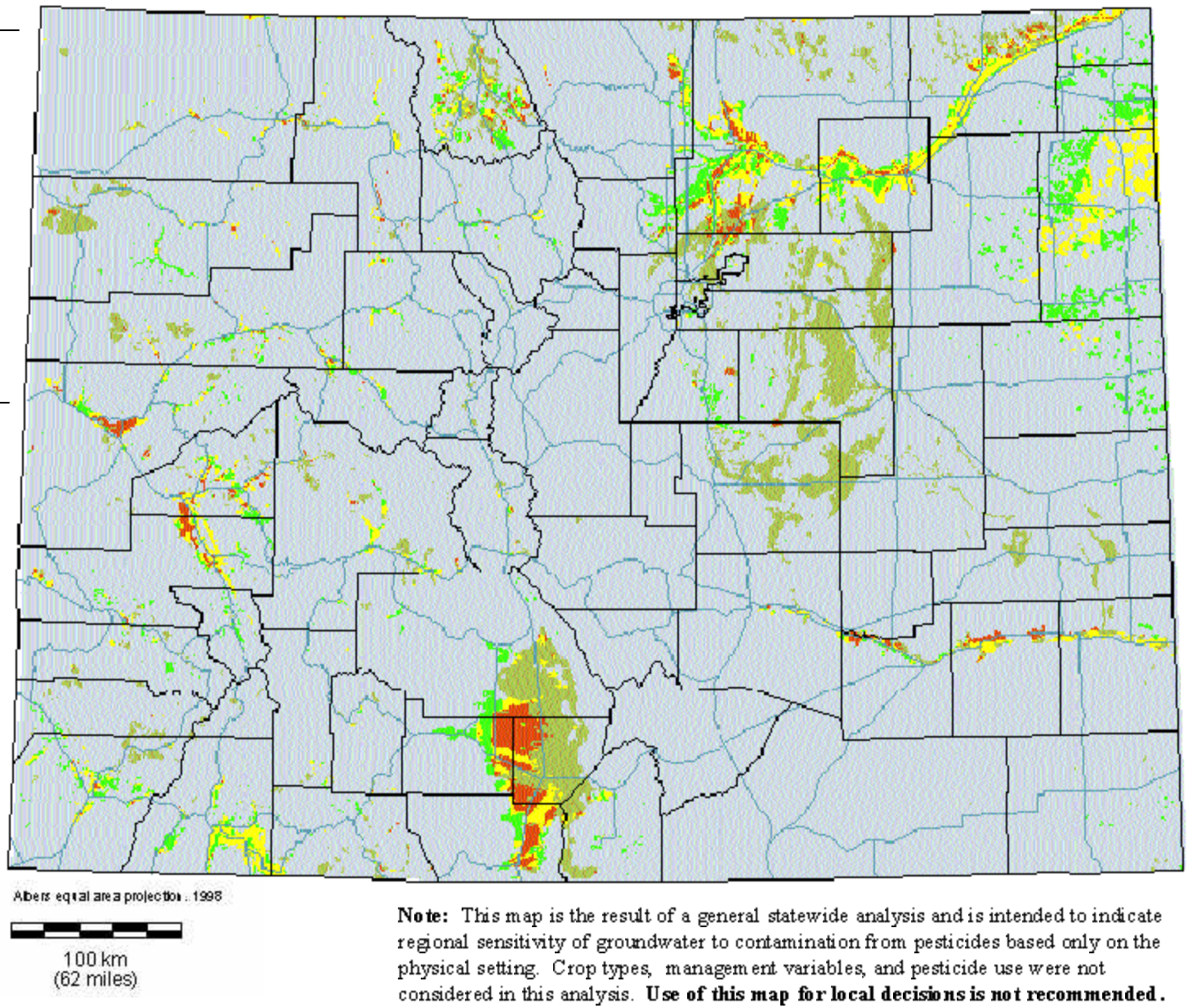

Figure 6. Relative sensitivity of Colorado groundwater to pesticide contamination based upon aquifer location, depth to groundwater, soil permeability, and available recharge.

Interpretation of the Sensitivity Map

This map was developed with the objective of a regional-scale assessment of groundwater sensitivity to pesticide contamination. The information presented in the maps should be used to support conclusions concerning areas on a minimum scale of tens of miles. Areas that are denoted on the map as having a low sensitivity may contain individual fields overlying small areas of very sensitive groundwater. Additionally, groundwater delineated as having a low sensitivity may be susceptible to contamination if irrigation or pesticide management practices promote leaching.

Sensitivity index values of 1 (green) represent areas that are not irrigated and/or do not overlie highly conductive aquifers. Conversely, sensitivity index values of 4 (red) represent areas where a very shallow water table in a highly conductive aquifer coincide with at least moderately permeable soils that receive irrigation. Additionally, areas with shallow water tables but which are not currently irrigated are also shown on the final analysis map since these areas might merit particular attention if brought under irrigation in the future.

The map is intended as a general guide in identifying areas of the state in which groundwater, due to its hydrologic and geologic setting, is more or less susceptible to contamination from pesticide use. The analysis considers only the hydrogeologic setting. No consideration of actual pesticide use, crop patterns, management practices, etc. was attempted. Therefore, **this analysis should be combined with knowledge of other factors which might contribute to the overall vulnerability of the groundwater resource in development of protection strategies and management plans**.

This report was prepared by Dr. Maurice Hall, Radford University, in cooperation with the Colorado Department of Public Health and Environment, Colorado State University Cooperative Extension, and the Colorado Department of Agriculture.

For more information or copies of the full report on this sensitivity analysis, contact Reagan Waskom of CSU at 970/491-6103, Brad Austin of the Colorado Department of Public Health and Environment at 303/692-3572, or Robert P. Wawrzynski of the Colorado Department of Agriculture at 303/239-4151.