Research Technical Completion Report

GROUND WATER VULNERABILITY MAPPING

by

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Table of Contents

List of Figures iv

List of Tables vii

Introduction 1
History of Ground Water Vulnerability Mapping 1
Introduction to the Present Study 1

PART 1

Application and Analysis of Rupert et al. Rating System 5
Summary of Rating System 5
Depth to Water 5
Soils 6
Recharge 6
Vulnerability Map 6
Verification Methodology 7
Independent Variables 7
Dependent Variable 7
Statistical Analysis 8
Eastern Snake River Plain Aquifer 10
Eastern and Middle Snake River Plain 10
Analysis Results and Interpretation 10
Burley Area of the Snake River Plain 11
Analysis Results and Interpretation 12
Summary 16
Rathdrum Prairie Aquifer 16
Depth to Water 17
Soils 17
Recharge 17
Vulnerability Map 23
Nitrate Observations 23
Analysis Results and Interpretation 23

Big Wood River-Silver Creek Aquifer 27
Depth to Water 27
Soils 29
Recharge 29
Vulnerability Map 29
Nitrates 30
Jerome Area 37
Depth to Water 37
Soils 37
Recharge 37
Vulnerability Map 43
Nitrates 43
Analysis Results and Interpretation 43
Discussion 47
Conclusions 48

PART 2

Jerome Pilot Project 49
Pilot Project Objectives 49
Location of the Project Area 49
Study Methodology 50
Depth to Water 50
Soils 52
Recharge 52
Septic Systems 55
Agricultural Chemicals 56
Potential Point Sources of Contamination 60
Public Water Supply Wells 65
Wellhead Protection 65
Surficial Geology 69
Summary of GIS Coverages 71
Analysis 77
Jerome Area 77
Rathdrum Prairie 80
Summary 81

PART 3

Conclusions and Recommendations 83
Conclusions from Task Completion 83
Application of the Rating System to Other Aquifers . . . 83
Verification of the Rating System 84
Mapping at a Detailed Scale - Jerome Area 85
General Conclusions 86
Recommendations for Future Research and Applications 87

Appendix A Polygon Values for Soils and Ground Water Vulnerability Ratings 91

Appendix B Explanation of Geologic Map Units 114

Appendix C ARC/INFO Coverages 118

Sources Cited 119

List of Figures

Figure 1	Project Locations	3
Figure 2	Rathdrum Prairie Aquifer Urban Areas Location Map	18
Figure 3	Rathdrum Prairie Aquifer - Depth to Water	19
Figure 4	Rathdrum Prairie Aquifer - Soils	20
Figure 5	Rathdrum Prairie Aquifer - Recharge	21
Figure 7	Rathdrum Prairie - Regression of Nitrate Observations on Vulnerability Score	24
Figure 6	Rathdrum Prairie Aquifer Vulnerability Map	25
Figure 8	Big Wood River - Depth to Water	28
Figure 9	Big Wood River - Regression of Nitrates on Vulnerability Score	30
Figure 10	Big Wood River - Soils	31
Figure 11	Big Wood River - Recharge	33
Figure 12	Big Wood River - Vulnerability Map	35
Figure 13	Jerome - Depth to Water	38
Figure 14	Jerome - Soils	39
Figure 15	Jerome - Recharge	41
Figure 16	Jerome - Relative Ground Water Vulnerability Map	45
Figure 17	Jerome - Water Table Contours	51
Figure 18	Jerome - Irrigation Types	53
Figure 19	Jerome - Surface Hydrology: Canals, Ditches, Ponds	54
Figure 20	Jerome - Point Coverage of Septic Systems	57
Figure 21	Jerome - House Counts in Census Blocks	58
Figure 22	Jerome - Field Boundaries in 1992	59
Figure 23	Jerome - Risk Assessment for Atrazine	61
Figure 24	Jerome - Risk Assessment for 2,4-D Amine	62
Figure 25	Jerome - Risk Assessment for Trifluralin	63
Figure 26	Jerome - Potential Point Sources of Contamination	64
Figure 27	Jerome - Confined Animal Feeding Operations	66
Figure 28	Jerome - Public Water Systems	67
Figure 29	Jerome - Wellhead Protection Zones	68
Figure 30	Jerome - Surficial Geology Map	73
Figure 31	Aerial Photo Composite of Jerome Study Area	75
Figure 32	Influence of Nitrate Observation (5.66 mg/l) on Nitrate vs Distance	78

Figure 33
Influence of Nitrate Observation (5.66 mg/l) on Nitrate vs Septic System Regression 78
Figure 34
Regressions of Nitrates vs Distance vs Septic Tanks Without the 5.66 mg/l Observation 80
Figure 35
Scatterplot of Data Points and the Fitted Regression Line for Nitrate vs Distance 81

List of Tables

Table 1	4 x 3 Contingency Table	8
Table 2	Contingency Table for Nitrate Observations on the Eastern Snake River Plain	10
Table 3	Contingency Table for Data Set 1	13
Table 4	Contingency Table for Data Set 2	14
Table 5	Contingency Table for Data Set 3	15
Table 6	Contingency Table for Data Set 4	16
Table 7	Summary of Independent Variable and Vulnerability Scores for Rathdrum Prairie	23
Table 8	Summary of Independent Variable and Vulnerability Scores - Big Wood River	29
Table 9	Summary of Independent Variable and Vulnerability Scores-Jerome	43
Table 10	Contingency Table for Jerome Data	47
Table 11	Radii for Wellhead Protection Zones in Feet	69
Table 12	Summary of Regression Results for the Jerome Area	79
Table 13	Summary of Regression Results for Rathdrum Prairie	81
Table 14	Matrix for Assessing Risk to Ground Water From Potential Contaminant Sources	90

Introduction

History of Ground Water Vulnerability Mapping

Protecting Idaho's ground water by predicting the vulnerability of ground water to contamination is the primary goal of the mapping system described in this report. This project was completed by the Idaho Water Resources Research Institute at the University of Idaho with funding from the Idaho Department of Health and Welfare, Division of Environmental Quality (DEQ). It continued work begun in the late 1980s to assess the vulnerability of ground water of the Snake River Plain aquifer in southern Idaho (Rupert et al. 1991).

Ground water vulnerability mapping was based on two concepts related to ground water pollution potential: hydrogeologic susceptibility and contaminant loading potential. A modified version of the U.S. Environmental Protection Agency's DRASTIC model (Aller et al. 1985) was used to map predicted levels of vulnerability across the eastern Snake Plain aquifer. The three variables from the seven-variable DRASTIC model used in the vulnerability study were depth to water, soils and recharge. Recharge is the movement of water downward from the surface or upper levels of an aquifer to deeper parts. The vulnerability rating resulted in four categories from low to very high. Urban areas and bodies of surface water were not included in the rating system. The mapping and analysis was done using a geographic information system (GIS), specifically ARC/INFO (ESRI 1993). Digital maps were developed for all or parts of 20 1:100,000 quadrangles covering the Snake Plain. The GIS coverages were constructed from original data of varying scales.

Introduction to the Present Study

There were three main tasks in this study. The first task was to apply the rating system developed by Rupert et al. (1991) to other types of aquifers in Idaho. The second task was to perform a verification of the rating system for its validity and reliability. The third task was to map components of ground water vulnerability at a scale of 1:24,000, modifying the vulnerability assessment method as necessary. An area in western Jerome County was chosen for examination and mapping at that scale.

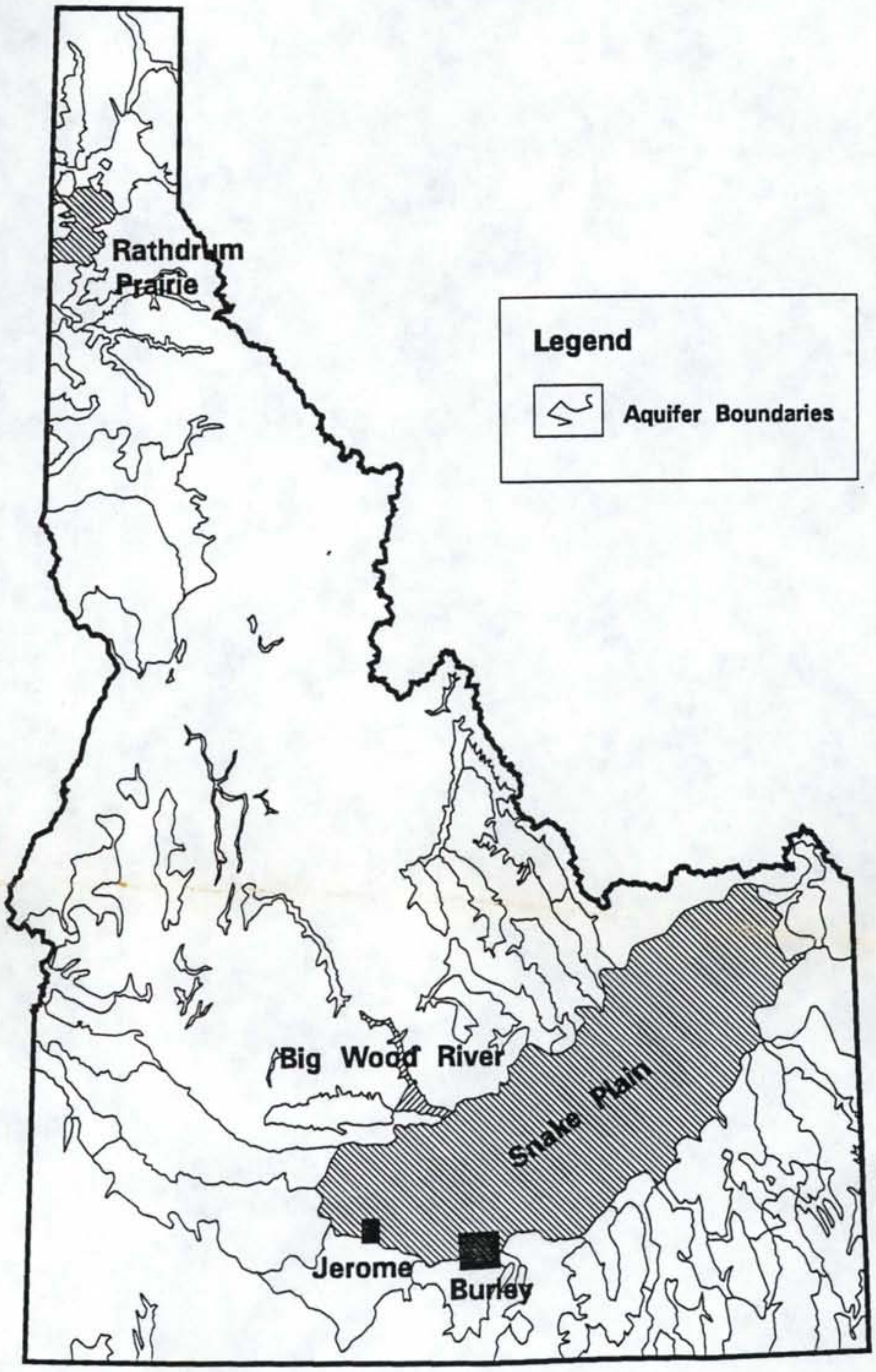
In task one, the Rupert rating system was applied to the Rathdrum Prairie aquifer in northern Idaho, to the Big Wood River-Silver Creek aquifer in south central Idaho, to a portion of the Snake River Plain aquifer near Burley, and to the Jerome County study area. In task two, a statistical analysis was performed on the application of the rating system to each of the aquifers as well. The results of tasks one and two are reported in the section, "Application and Analysis of Rupert et al. Rating System." The aquifers and portions of aquifers included in this study are shown in Figure 1.

The results of task three, mapping at a scale of 1:24,000, are presented in the "Jerome Pilot Project" section. The pilot project covers most of one United States Geological Survey (USGS) 7.5 minute quadrangle, approximately 45 square miles. Nine GIS coverages developed to assess ground water vulnerability in the Jerome area are shown and discussed.

The last section of the report, "Conclusions and Recommendations," summarizes what has been learned in the two studies and makes recommendations for future approaches to ground water vulnerability mapping.

Figure 1

Project Locations



Aquifer boundaries are adapted from Graham and Campbell, 1981.

PART 1

Application and Analysis of Rupert et al. Rating System

The rating system developed by Rupert et al. for ground water vulnerability is based on assigning points to criteria within the three variables of depth to first significant ground water, soils and recharge. This rating system will be summarized. Persons interested in an in-depth description of development of the rating system should refer to the report by Rupert et al. (1991).

Summary of Rating System

The Rupert et al. rating system utilized a modified form of DRASTIC (Aller et al. 1985) which was developed by the National Water Well Association under contract to the U.S. Environmental Protection Agency. The DRASTIC model evaluates the ground water pollution potential of a given hydrogeologic setting based on a set of defined characteristics along with ratings or "weights" assigned to those characteristics. The eastern Snake Plain vulnerability mapping project used three GIS layers. These layers differ from DRASTIC in that they are based on different sources of information, a finer scale, and a different point rating scheme. The project used a GIS, which enables enhanced data analysis and integration capabilities over the standard cartographic techniques used by DRASTIC. The three layers used in the modified approach include depth to water, soils and recharge.

Depth to Water

The depth to water layer for the Snake Plain aquifer was developed by the USGS. Depth to water is important for susceptibility assessment because areas where the ground water is close to the surface typically have a higher probability of ground water pollution than areas where ground water is deep. Water table contours were broken into categories with each category rated on a scale of 1 to 50 points to reflect its relative significance to ground water vulnerability. The following ratings were used:

Depth to water range	Rating (points)
1 to 25 feet	50
26 to 50 feet	35
51 to 100 feet	20
101 to 250 feet	10
> 250 feet	1

Soils

The soils layer information was derived from the State Soil Geographic Database (STATSGO) and SOILS-5 database developed by the Soil Conservation Service (SCS). Four soil-landscape characteristics were chosen to be included in the soils layer. They are: 1) permeability of the most restrictive layer; 2) depth to water table within the soils layer; 3) depth to bedrock, and 4) flooding frequency. The following ratings were used:

Soil characteristics		Rating (points)
permeability		2 to 20
depth to bedrock		1 to 10
depth to water table		0 to 8
flooding frequency		0 to 5
	Range	3 to 43

The score for each soil unit was then multiplied by three to determine the final soils susceptibility rating. This was done because the soils layer incorporates more than one criterion relevant to ground water susceptibility assessment.

Recharge

The recharge layer was developed from information about types of land cover. The type of land cover affects how water penetrates the ground surface and percolates to the water table. Over much of the eastern Snake Plain Aquifer, agricultural irrigation recharges ground water. This is reflected in the recharge classes.

Recharge Classes	Rating (points)
gravity-fed irrigated land	50
riparian areas	50
sprinkler-fed irrigated land	40
forests	30
dryland and agriculture	20
range land	20
bare rock (lava flows)	10
urban areas	no rating
surface water	no rating

Vulnerability Map

The depth to water, soils and recharge data layers were combined to derive the composite vulnerability map, with areas designated as low, moderate, high or very high vulnerability based on cumulative points. The vulnerability categories were distributed with 30 percent in the low, moderate and high categories and 10 percent in the very high category.

The Rupert et al. project resulted in development of the rating system and its application to the Snake River Plain aquifer. The final vulnerability map correlated visually with 13 instances of high levels of contaminants detected during ground water monitoring. The contaminants included pesticides, volatile organic chemicals and nitrates. These 13 wells were located in areas mapped as being high or very high vulnerability. Initial comparisons of just nitrate observations from portions of the aquifer also appeared to correlate with higher vulnerability categories. The report recommended a statistical analysis of the rating system as a next step.

Verification Methodology

A directive for the current project was to test the relationship between incidents of contamination and the vulnerability rating system for sites on at least three of the major aquifer types in Idaho. Nitrates and pesticides were designated as the contaminants to be used in the statistical analysis of the rating system. In this section of the report, the verification methodology is described. The statistical analysis procedures are explained and the contaminant data sets described for each of the geographical areas analyzed.

For two of the major aquifer types, the current rating system had to be constructed before the verification could be completed. The sources of information used in constructing the rating system will be explained. This section concludes with a discussion of the problems encountered in the verification process and conclusions about the results.

Independent Variables

The three variables which comprise the rating system -- depth to water, soils and recharge -- are the independent variables in the analysis.

Dependent Variable

Contamination level is the dependent variable. Data sets from DEQ and USGS were used to derive information on contaminant levels. Nitrate levels were selected as the only measure of contamination for two major reasons. More data points exist for nitrates than for pesticides or other contaminants. And, elevated nitrate levels generally are assumed to be linked to human related land uses and sources of contamination.

Statistical Analysis

The primary strategy of the statistical analysis was to determine if there was a relationship between the vulnerability rating and observed levels of contamination. Several different tests were used, depending largely on the availability of data for the dependent variable.

Contingency tables and logit modeling (Agresti 1994) were used for the data sets where there was a sufficient distribution of nitrate values. This approach examined whether the distribution of nitrate levels was independent of the vulnerability rankings. There were four rating system categories and three categories of nitrate levels. This array fit into a two-way, 4 x 3 contingency table, which has 12 cells (Table 1).

Table 1
4 x 3 Contingency Table

	Nitrate Levels (mg/l)		
Vulnerability Ranking	$N > 10$	$5 \leq N \leq 10$	$N < 5$
Very High			
High			
Medium			
Low			

Chi-square (χ^2) is a statistic used to test whether two characteristics, such as vulnerability ranking and nitrate level, are related or independent. The chi-square statistic tested the relationship between the vulnerability rankings (rows in the table), and nitrate observations (columns in the table). An assumption of this test is that there are at least five observations in each cell. Large values of χ^2 contradict the null hypothesis of independence.

The goodness of fit of a logit model can be quantified by comparing the observed counts to the estimated expected frequencies in the contingency table cells using the likelihood ratio statistic (G^2). Like the Pearson statistic in the χ^2 test, the G^2 statistic of positive and larger values indicates a relationship between the vulnerability ranking and nitrate observations. The value $p \leq 0.05$ was used as the level of significance for accepting the alternative hypothesis.

Two logit models were used in the analysis: the independence model and the dependence model. The first model took into account only the independent effects associated with the vulnerability ranking and nitrate observations. The second model took into account the joint effect of being classified in one of the vulnerability categories and in one of the nitrate levels, over and above the individual effect of each variable. The purpose of the analysis was to test the association between the empirically observed nitrate level and the vulnerability rating. Two hypotheses were formulated. The first is the null hypothesis and the second is the alternative hypothesis:

H_0: The observed nitrate level is independent of the vulnerability rating.
H_1: There is an association between the observed nitrate level and the vulnerability ranking.

The value $p \leq 0.05$ was used as the level of statistical significance for accepting the alternative hypothesis in this study. The p value is an acceptable probability limit, expressed as a percentage, within which the null hypothesis will be rejected, or the alternative hypothesis accepted. The 0.05 level is arbitrary, but a customarily conservative probability limit. Using this limit, means we will reject the null hypothesis only if in 5 percent or fewer of all the samples that could be taken from the population, the expected difference does not occur.

The statistical procedure followed the following steps:

1. Run the independence model and calculate the G^2 statistics.
2. Run the dependence model and calculate the G^2 statistics.
3. Calculate the difference between the G^2 statistics for the independence and dependence models.
4. Calculate the association statistic, Gamma. The Gamma statistic, similar to the Pearson correlation coefficient, ranges from -1 to 1, where 1 indicates a perfect, positive association.

If the likelihood ratio statistic (G^2) is a large value for the independence model and the difference between the G^2 for independence and dependence models is significant, then one can reject the null hypothesis and accept the alternative hypothesis that there is an association between the observed nitrate level and the vulnerability rating.

In areas with a narrow range of nitrate levels and consequently empty cells in the contingency table, linear regression was used to examine whether the nitrate observations were independent of the vulnerability ranking.

Eastern Snake River Plain Aquifer

The eastern portion of the Snake Plain aquifer, east of King Hill to Wyoming consists of the basalts of the Snake River Group, the associated sedimentary and pyroclastic interbeds, and the river and lake deposited sediments that were laid down around the southern, eastern, and northern margins of the basalt flows. The aquifer is recharged by percolation of precipitation and snowmelt, underflow from tributary basins, leakage from streams and infiltration of irrigation water (Graham and Campbell, 1981). The general aquifer boundaries are shown in Figure 1.

Eastern and Middle Snake River Plain

The original data developed by Rupert et al., included 1,978 nitrate sampling points distributed across the eastern Snake River Plain. Of those, 120 observations were from urban areas and were excluded from mapping and rating. The remaining 1,858 observations were analyzed using a logit model to test the relationship between the rating system and nitrate observations. The distribution of nitrate observations is depicted in Table 2.

Table 2
Contingency Table for Nitrate Observations on the Eastern Snake River Plain

	Nitrate Observations N = 1858			
Vulnerability Ranking	$N > 10$	$5 \leq N \leq 10$	$N < 5$	Row Totals
Very High	34	55	393	482
High	72	78	498	648
Medium	1	7	253	261
Low	10	32	425	467
Column Totals	117	172	1569	1858

Analysis Results and Interpretation

The statistics for the data indicate there is a statistically significant, but weak, relationship between the rating system and nitrate observations. The analysis is based on the distribution of the vulnerability ranks (very high, high, medium and low), and not the numerical ranking scores, which were not available. In the results, df means degrees of freedom, which derive from probability theory and which may reflect the sample size or number of linear assumptions for a contingency table.

The statistics for the data are:

Likelihood Ratio - Independence Model: $G^2 = 101.6$
$df = 6 \quad p = 0.0$

Likelihood Ratio - Dependence Model: $G^2 = 59.6$
$df = 5 \quad p = 0.0$

Gamma = 0.29 Standard Error = 0.04

$G^{2\,(Independent)} - G^{2\,(Dependent)} = 42.0 \qquad df = 1 \quad p = 0.0$

Burley Area of the Snake River Plain

The shallow, unconfined, alluvial aquifer system overlying the Eastern Snake River Plain aquifer in southern Minidoka County extends north from the Snake River near Burley to approximately 10 miles north of Paul, and from the Snake River near Rupert, west approximately 25 miles. This perched system is thought to be separated from the regional Eastern Snake River Plain aquifer by less permeable silt and clay beds and lenses within the alluvium. Well logs indicate the thickness of the silt and clay beds and lenses are highly variable, as is the 50 to several hundred foot vertical distance between the alluvial system and the regional aquifer (Brockway et al. 1992).

The dominant land cover type in the Burley study area was mapped (Rupert et al. 1991) as bare rock (lava flows), with small widely scattered areas of range land and irrigated land. The soils in the study area range from low to medium permeability with the soil permeability rating scores ranging from 23 to 77. The scale range for soils is from 6 to 126. The depth to water varies from 5 to 250 feet over the study area. In the northwestern area, depth to water is greatest, within the 100 to 250 feet rating category. In the southeastern area, water is shallow, within the 1 to 25 feet rating category. The shallow depth to water in the southeastern part of the study area coincides almost perfectly with the area mapped as very high vulnerability. The well data was not in a data base and it was not possible to relate the depths to the nitrate observations for particular wells in most cases.

Table 3 shows the study area with the rating system and categories of nitrates. For the Burley area, the sampling data includes nitrate observations from 1971 through 1991. The temporal distribution of the data within this time interval covers two periods; 1971 - 1973 and 1987 - 1991. The range of all nitrate observations was from 0 mg/l to 65 mg/l. From this 20 year period, four data subsets were developed for the statistical analysis of the relationship between the rating system and nitrate values.

1) Both data sets covering the time interval 1971 through 1991. The data set has one observation for each sampling well. For the wells with multiple observations, the August or September observation was retained. The data set includes 119 observations. Eight of the observations were excluded because they were made in urban areas. The analysis was made using 111 observations.

2) The same data set as in 1). The difference was that the arithmetic mean was calculated for wells with multiple observations. The mean was used, rather than the August or September observation.

3) A reduced data set covering the interval from 1987 through 1991. For the wells with multiple observations, the August or September observation was retained. The data set includes 89 observations.

4) The same data set as in 3). The difference was that the arithmetic mean was calculated for wells with multiple observations. The average was used, rather than the August or September observation.

Each nitrate data set was overlaid with the ground water vulnerability ranking map using the INTERSECT command in ARC/INFO. The output data from this operation was entered into contingency tables, one for each data set, and analyzed with a logit model for the association between the vulnerability rating and observed nitrate levels.

Analysis Results and Interpretation

Each of the four data sets was run using the CATMOD procedure in the statistical package SAS (SAS User's Guide 1990). CATMOD is a procedure for categorical data modeling. It analyzes data that can be represented by a contingency table. The CATMOD procedure fits linear models to functions of response frequencies and can be used for linear modeling, log-linear modeling and logistic regression. Two models representing independence and dependence assumptions were included in each run.

The following convention is used for reporting statistics for the logit model. If the G^2 statistic is significant for the independent model, then the dependent model is investigated and the statistics for both models are listed. Otherwise, only the statistics for the independent model are given. The model input data, results and their interpretation are presented for each data set.

1) Data set 1971 - 1991 with multiple observations from one sampling well represented by an August or September observation.

Table 3
Contingency Table for Data Set 1

	Nitrate Observations (mg/l)			
Vulnerability Ranking	N > 10	$5 \leq N \leq 10$	N < 5	Row Totals
Very High	5	6	11	22
High	6	41	29	76
Medium	1	3	1	5
Low	2	2	4	8
Column Totals	14	52	45	111

Likelihood Ratio for independence model $G^2 = 9.31$ df = 5 p = 0.15
Gamma = -0.07

The likelihood ratio statistic is not significant, thus supporting the null hypothesis that the observed nitrate levels are independent of the vulnerability ranking. The value of the Gamma statistic indicates the lack of association between the independent and dependent variables.

2) Data set 1971 - 1991, multiple observations represented by a mean nitrate value.

Table 4
Contingency Table for Data Set 2

	Nitrate Levels (mg/l)			
Vulnerability Ranking	$N > 10$	$5 \leq N \leq 10$	$N < 5$	Row Totals
Very High	5	6	11	22
High	7	40	29	76
Medium	1	3	1	5
Low	2	2	4	8
Column Totals	15	51	45	111

Likelihood Ratio for independence model $G^2 = 8.22$ df $= 6$ $p = 0.22$
Gamma = -0.07 Standard Error = 0.18

The likelihood ratio statistic is not significant. The conclusion for this data set is that observed nitrate levels are independent of the vulnerability ranking. The value of the Gamma statistic indicates the lack of association between the independent and dependent variables.

3) Data set for 1987 - 1991 with multiple nitrate values for one sampling well represented by an August or September observation. There were 89 observations, however seven were made in urban areas and therefore excluded from the analysis.

Table 5
Contingency Table for Data Set 3

	Nitrate Levels (mg/l)			
Vulnerability Ranking	N > 10	$5 \leq N \leq 10$	N < 5	Row Totals
Very High	5	6	11	22
High	9	28	10	47
Medium	0	5	0	5
Low	0	5	3	8
Column Totals	14	44	24	82

Likelihood Ratio - Independence Model: $G^2 = 17.30$ df = 6 p = 0.01
Likelihood Ratio - Dependence Model: $G^2 = 17.30$ df = 5 p = 0.01
$G^{2\,(Independent)} - G^{2\,(Dependent)} = 0.0$ df = 1 p = 0.0
Gamma = -0.1 Standard Error = 0.18

The likelihood ratio statistic is significant. However, the difference between G^2 for the independence and dependence models is insignificant and the alternative hypothesis of an association between the variables cannot be supported. The value of Gamma indicates a lack of association between the variables.

4) Data set for 1987 - 1991 with multiple nitrate observations represented by a mean value.

Table 6
Contingency Table for Data Set 4

	Nitrate Levels (mg/l)			
Vulnerability Ranking	N > 10	$5 \leq N \leq 10$	N < 5	Row Totals
Very High	5	6	11	22
High	9	28	10	47
Medium	0	5	0	5
Low	0	5	3	8
Column Totals	14	44	24	82

Likelihood Ratio - Independence Model: $G^2 = 17.30$ df = 6 p = 0.01
Same statistics for the Dependence Model
Gamma = -0.1 Standard Error = 0.18

The results and conclusions are the same as for data set 3.

Summary

There is a statistically significant relationship between the rating system and nitrate observations at the scale of the entire Eastern Snake River Plain aquifer. However, the rating system is independent of nitrate observations in the Burley area, a shallow, unconfined alluvial aquifer system overlying the regional Eastern Snake River Plain aquifer. The ratings of the three independent variables for the Burley area show that depth to water generally contributes the most points to the rating system.

Rathdrum Prairie Aquifer

The Spokane River-Rathdrum Prairie aquifer, underlying an area of about 350 square miles in northern Idaho and eastern Washington, was not included in the initial vulnerability study by Rupert et al. Consequently, the GIS coverages for the independent variables had to be built before the rating system could be analyzed. Only the Idaho portion of the aquifer was included in this study. It is shown in Figure 2 with the urbanized areas over the aquifer. The Spokane River-Rathdrum Prairie ground water system is primarily within glaciofluvial deposits consisting of fine to coarse sands and gravels. They are relatively free of fine-grained materials except near land surface. Thickness of the deposits is reported to be approximately 400 feet at the Idaho-Washington state line, of which 280 feet are saturated (Graham and Campbell 1981).

Depth to Water

Depth to water table data was provided by the North Idaho Regional Office of DEQ. The data was compiled from USGS measurements made in the late 1970s. The well locations had a resolution of 2.5 acres. The universal kriging method with linear drift was used to calculate the ground water contours. The depth to water map, corresponding to the rating system categories, was developed by subtracting the ground water surface elevation from the land surface elevation. The depth to water map is presented in Figure 3.

Soils

The soils coverage, shown in Figure 4, was digitized from the 1:24,000 base maps for an earlier Kootenai County and DEQ project and was used in the current project. The coverage has approximately 600 polygons representing soil map units. Attribute data such as permeability, depth to bedrock and depth to water table was compiled for the soil map units. Flooding frequency, the other attribute needed for the ranking system, was taken from the published soil surveys for the Kootenai County and Bonner County areas. Due to the large number and small size of many of the mapped soil units, the units are not labeled. Appendix A-1 lists the soil units by mapping frequency and criteria used in the rating system.

Recharge

The land use coverage was prepared by the state office of the Soil Conservation Service at a scale of 1:100,000 in 1991 (Figure 5). The two predominant land uses, by area, are irrigated cropland and forested land.

Figure 2
Rathdrum Prairie Aquifer Urban Areas Location Map

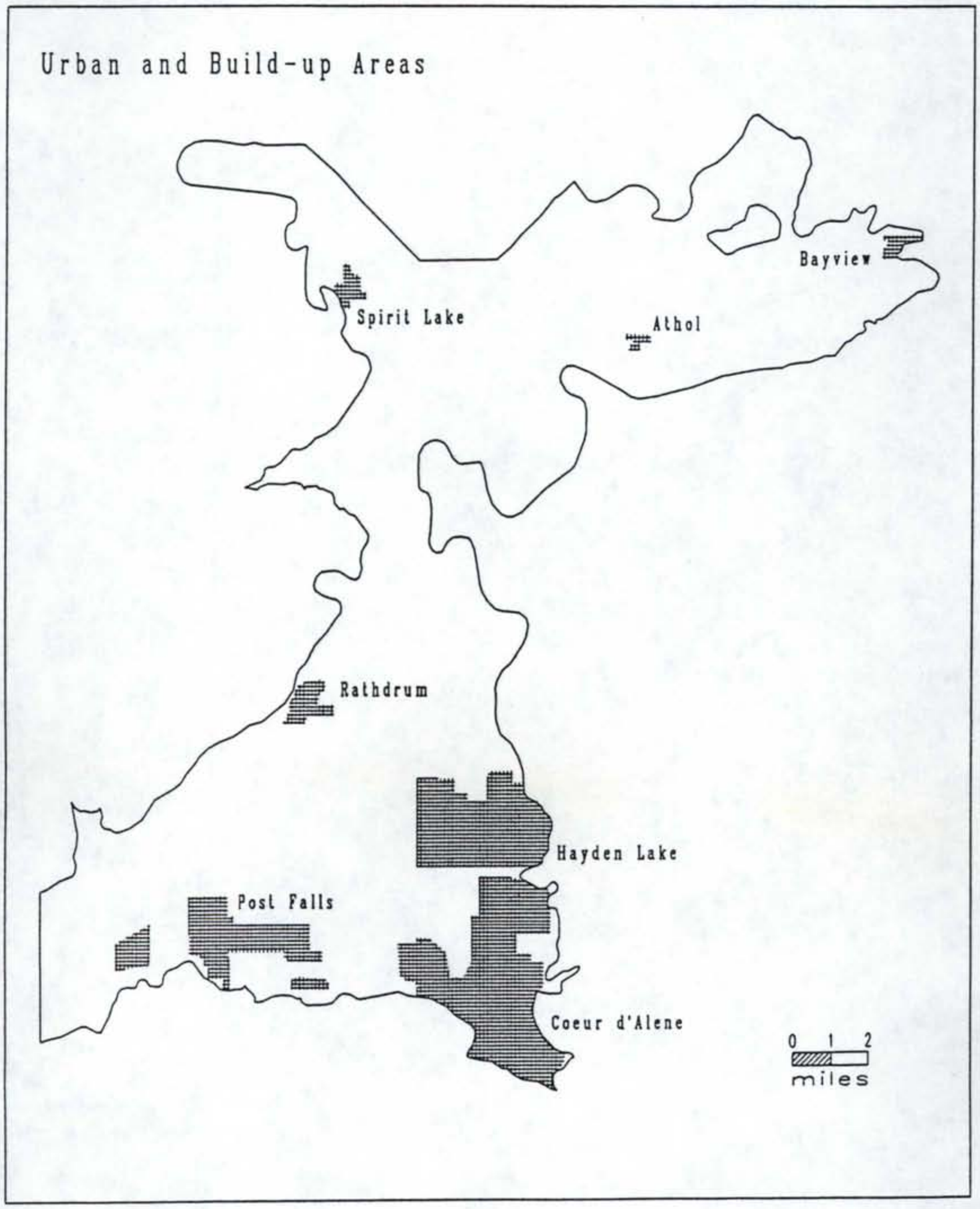


Figure 3
Rathdrum Prairie Aquifer - Depth to Water

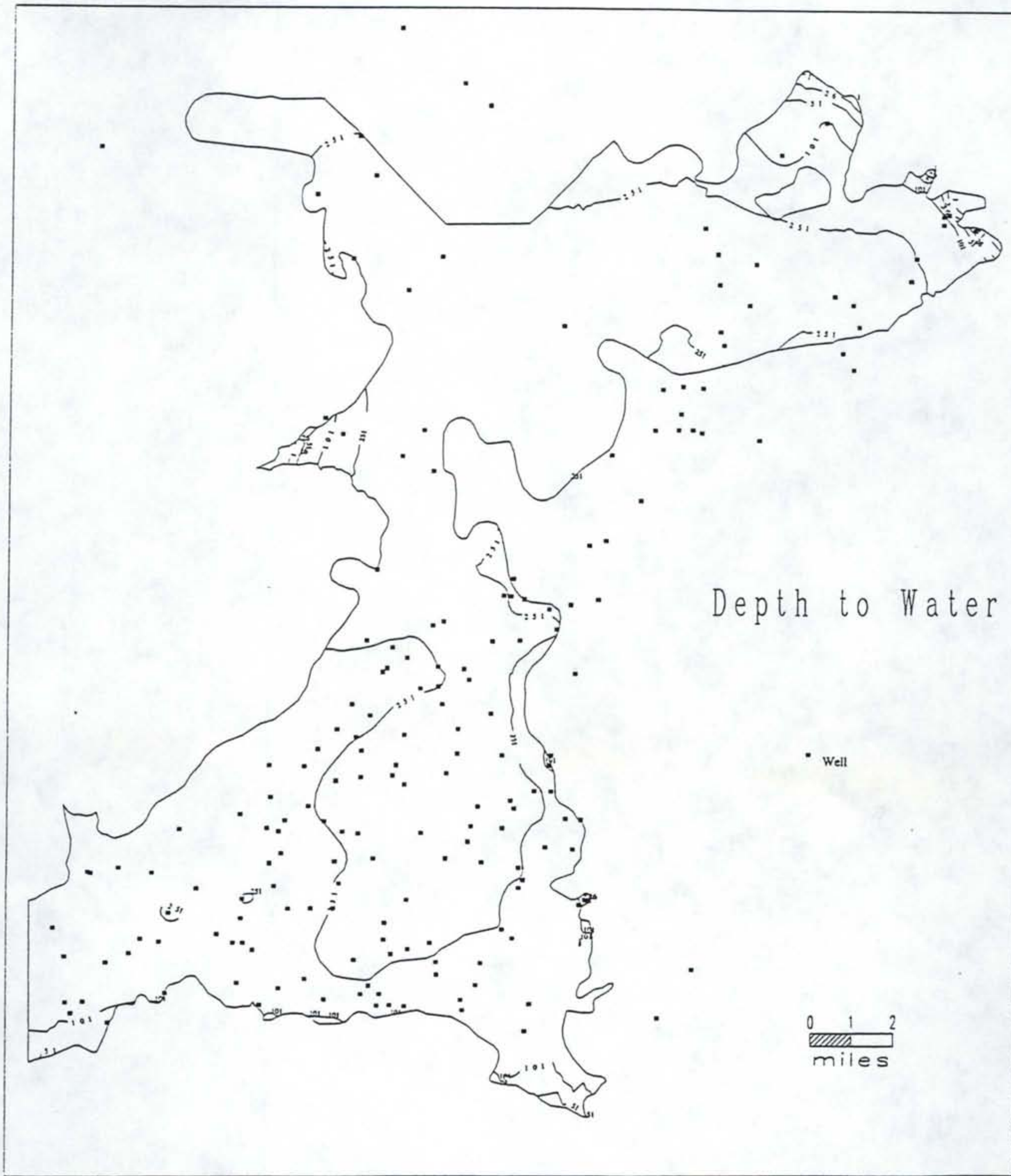


Figure 4
Rathdrum Prairie Aquifer - Soils

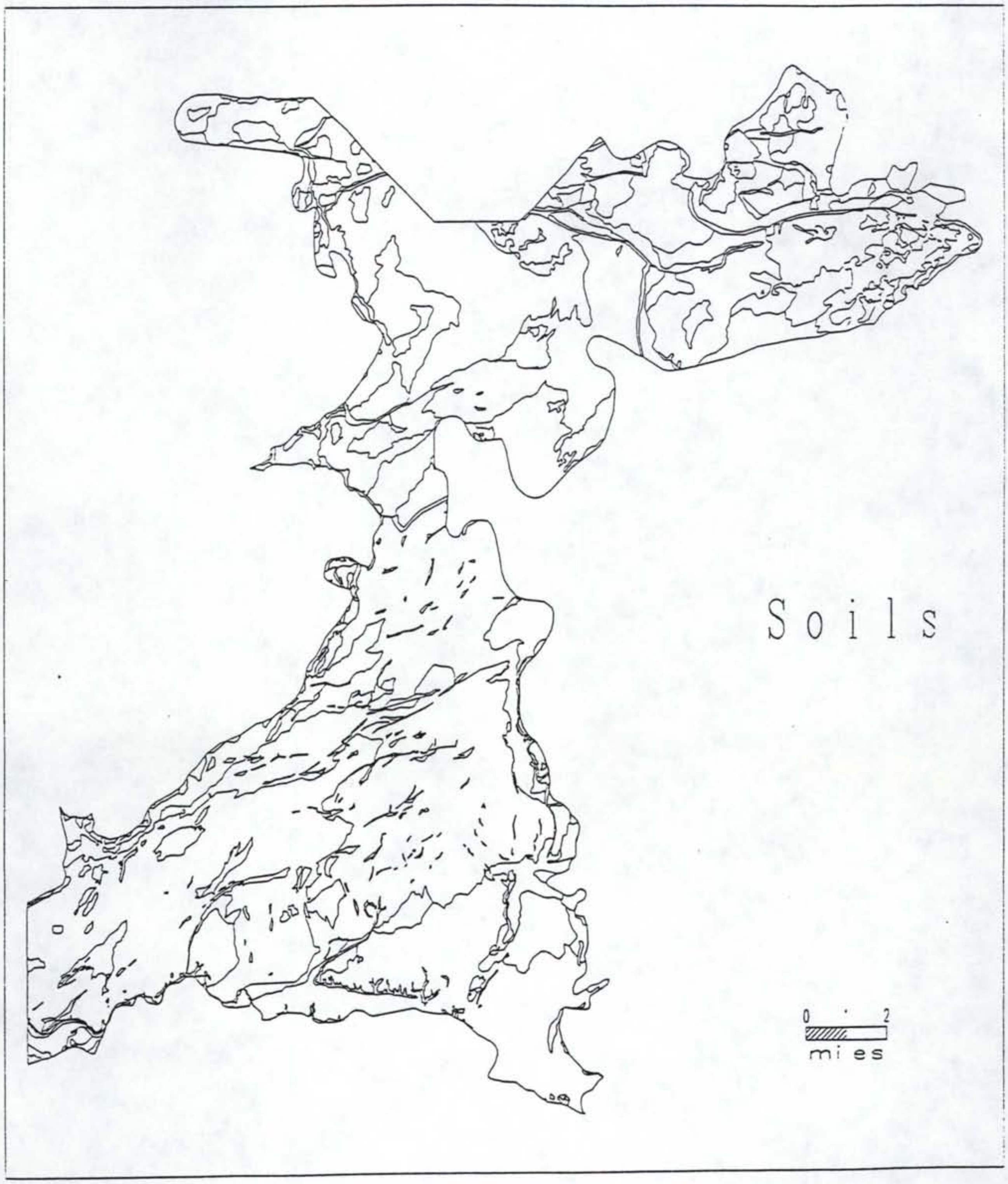
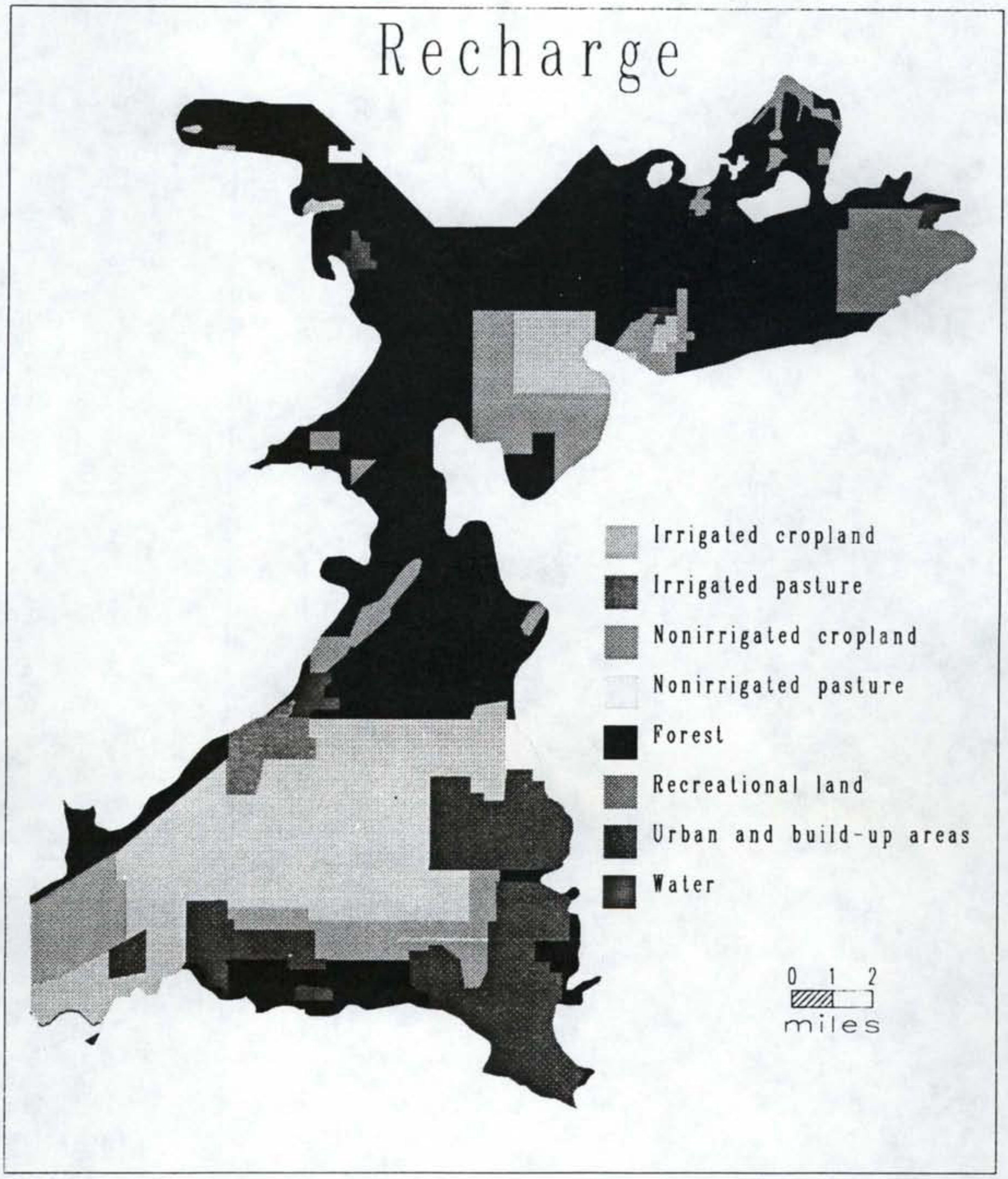


Figure 5
Rathdrum Prairie Aquifer - Recharge



Vulnerability Map

The composite vulnerability map is shown in Figure 6. A relatively large portion of the land over the aquifer is classified as urban or built-up. Urban areas were excluded from the vulnerability ranking system. The ratings for the three independent variables are shown in Table 7. The means for soils and land use are similar, however, soils were weighted by a factor of three in the Rupert et al. system. The ratings for each of the 1,264 polygons used to determine the vulnerability scores are included in Appendix A.

Table 7
Summary of Independent Variable and Vulnerability Scores for Rathdrum Prairie

	Independent Variable Scores			
Independent Variables	Minimum	Maximum	Median	Mean
Depth to Water	1	50	10.0	10.5
Soils	18	87	21.0	31.0
Land Use	20	40	30.0	29.9
Vulnerability	42	167	62.0	71.4

Nitrate Observations

The nitrate observations, made as part of the aquifer sampling program, were provided by the Panhandle Health District and North Regional Office of DEQ. The observations are from 44 wells over the period from July 1982 to the present. A number of nitrate observations were not included in the analysis because they were made in urbanized areas. Urbanized areas were excluded from consideration in the Rupert et al. rating system.

Analysis Results and Interpretation

The rating system was tested using 44 nitrate observations from wells on the Idaho portion of the aquifer. The nitrate values ranged from a minimum of 0.07 mg/l to a maximum of 3.32 mg/l. The mean equals 0.61 with a standard deviation of 0.61.

The data distribution was unsuitable for a contingency table/logit model analysis as all the nitrate observations were below 5 mg/l. Consequently, the explanatory power of the ranking scheme was tested using a General Linear Model regression analysis. The vulnerability score was the independent variable and nitrate was the dependent variable. Figure 7 shows the regression line of nitrates and vulnerability scores.

The coefficient of determination (R^2) is a number between 0 and 1.0. The larger the number, the stronger the relationship between the variables in the regression equation. The coefficient of determination is a measure of the variance explained by a model. For the Rathdrum Prairie aquifer, nitrate observations regressed on the vulnerability scores resulted in $R^2 = 0.05$. The relationship was not statistically significant with $p = 0.16$ (the adopted significance level is $p \leq 0.05$). A possible nonlinear relationship between nitrates and vulnerability was investigated by plotting the regression residuals against nitrate estimates. The residuals formed a cloud of points which did not indicate a nonlinear transformation would show a relationship.

Figure 7
Rathdrum Prairie - Regression of Nitrate Observations on Vulnerability Score

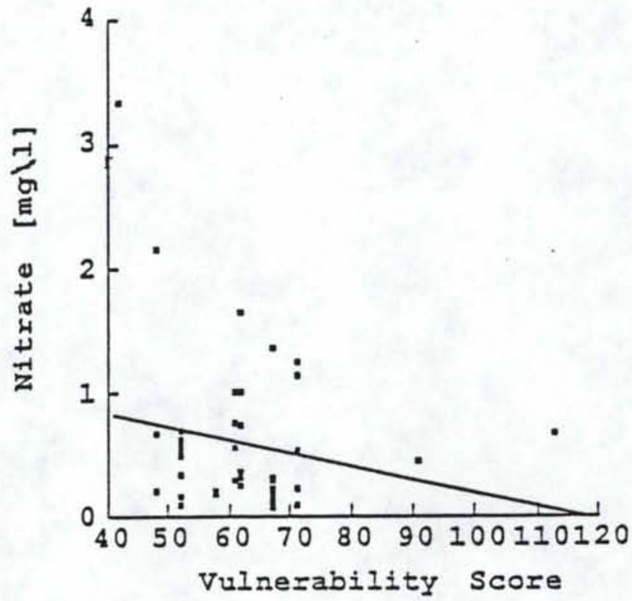
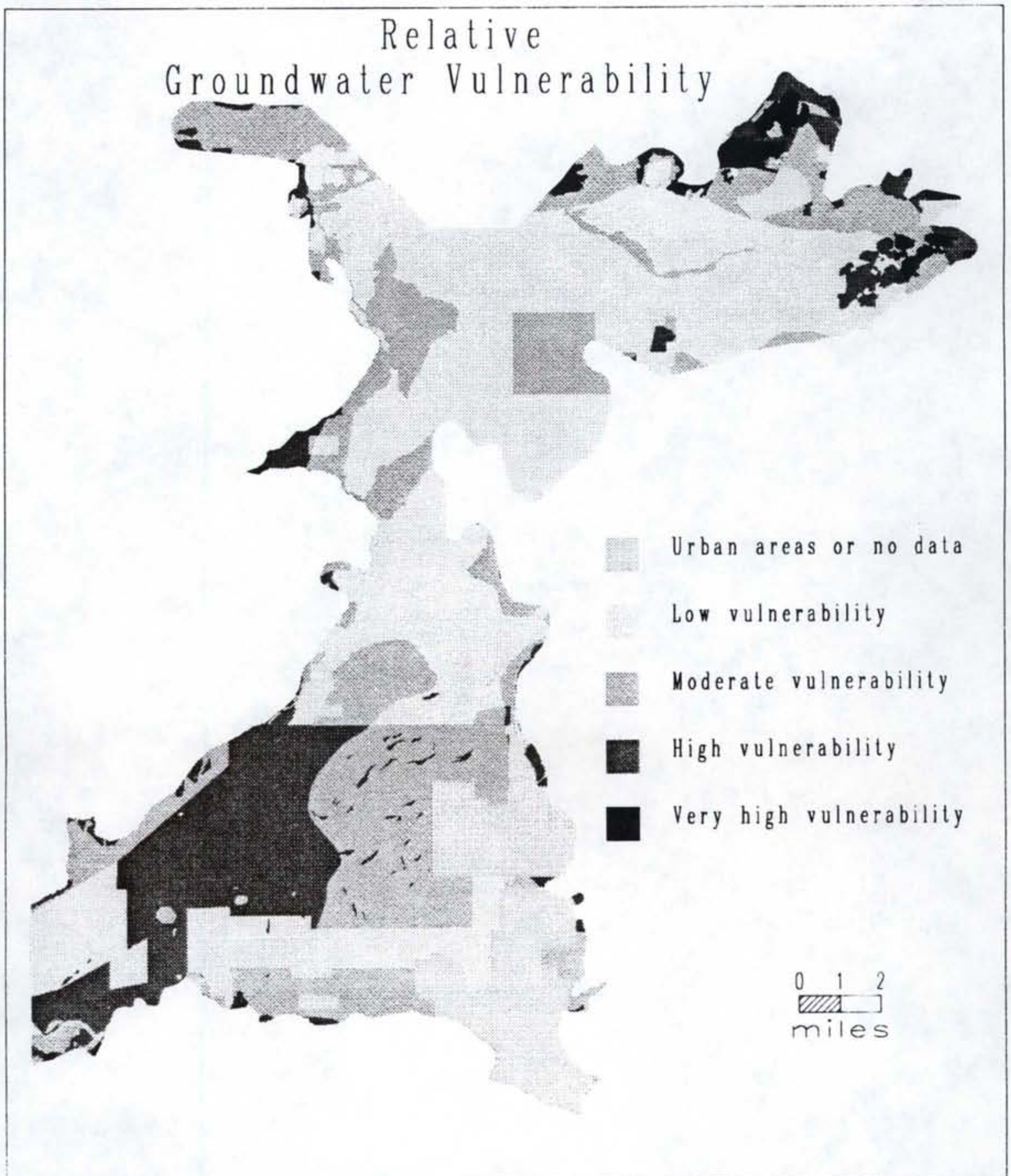


Figure 6
Rathdrum Prairie Aquifer Vulnerability Map



Big Wood River-Silver Creek Aquifer

The Big Wood-Silver Creek area is north of the Snake Plain and was not included in the first vulnerability mapping project area. The entire aquifer is shown in Figure 1. However, only the southern portion was used in the verification process. This aquifer represents one of the major intermontane valley aquifers of southeastern Idaho. Data about this area are scarce.

The intermontane valleys typically are filled with unconsolidated to poorly consolidated sedimentary rocks and alluvium as much as several thousand feet thick. The valleys are commonly fault bounded and separated by mountains composed primarily of consolidated marine sedimentary rocks with lesser amounts of volcanic and granitic rocks (Clark and Kendy 1992). Large quantities of water move through and are stored in coarse grained valley fill and alluvial aquifers that, in most places, are hydraulically connected with streams. Alluvium along streams is the most productive aquifer and, in places, can yield several thousand gallons per minute to a single well.

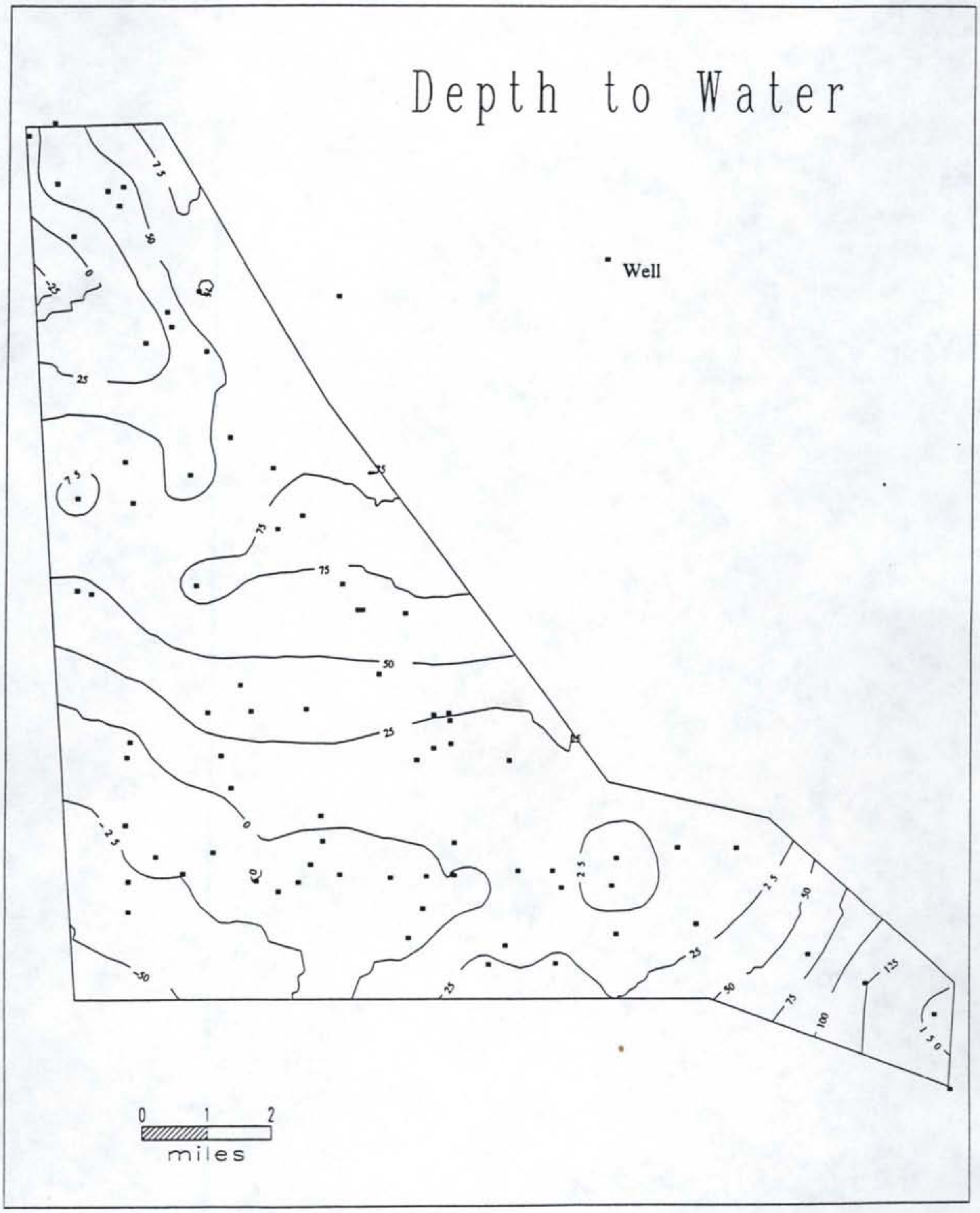
The Big Wood-Silver Creek system is primarily within sedimentary valley fill materials. The thickness of the sediments is estimated to range from 30 to more than 580 feet. Basalts of the Snake River Group also contain ground water in the southeastern part of the Silver Creek basin (Graham and Campbell 1981).

Depth to Water

Depth to water values were provided by staff from the University of Idaho Experiment Station in Kimberly who are conducting a hydrologic study of the Big Wood River-Silver Creek triangle aquifer (Brockway 1993). These 1993 data, from 80 wells in the southern part of the Big Wood River valley, were used to define the study area. The study area does not correspond with an aquifer or drainage basin.

Sixteen wells in the southwestern part of the study area had negative values, meaning the water table was above ground. The values from these wells were interpolated with the other positive values, using kriging with linear drift, to develop the water table contours. The depth to water map is shown in Figure 8.

Figure 8
Big Wood River - Depth to Water



Soils

The soils coverage was developed from the 1:250,000 STATSGO data because the 1:24,000 soils map was not available in digital format for the Big Wood River area. Only eight soil mapping units and 14 soil polygons exist within the study area. The component table in the STATSGO data base was used to derive the attributes used in the rating system. The soils coverage is shown in Figure 10.

Recharge

The 1:100,000 land use coverage was provided by the State Office of the Soil Conservation Service. The land use information is from the early 1980s. The land use information is being updated, but was not available for the current study. This coverage, used to indicate recharge potential, is shown in Figure 11. The predominant land uses in the early 1980s were irrigated cropland and pasture.

Vulnerability Map

The three input coverages were unioned and the vulnerability score for each polygon on the vulnerability map was computed and categorized. Union is a type of map overlay operation used in GIS where two or more maps are superimposed, creating new spatial and topological relationships. The independent variables and the vulnerability ratings are summarized in Table 8. Depth to water plays a more important role in the final rating in the Big Wood area than in the Rathdrum (Table 7) and Jerome (Table 9) areas. Land use, the indicator of recharge, is also important relative to soils. The ratings for all the polygons included in the overall vulnerability rating are listed in Appendix A-4.

Table 8
Summary of Independent Variable and Vulnerability Scores - Big Wood River

	Independent Variable Scores			
Independent Variables	Minimum	Maximum	Median	Mean
Depth to Water	10	50	35.0	34.0
Soils	57	75	72.0	68.7
Land Use	20	50	40.0	34.9
Vulnerability	87	175	137.0	137.6

There are three factors which may influence the vulnerability rating. First, the soils data came from the 1:250,000 STATSGO data, which is general information. Consequently there were only 14 soils polygons and the soils coverage did not contribute substantially to the variation in vulnerability scores. The vulnerability map for the Big Wood-Silver Creek area reflects more about the depth to water and land use coverages.

Second, the southwestern part of the study area had negative depth to water values. This situation did not occur in the original vulnerability study and surface water was not included in the rating system. In the current study, these areas were allocated 50 points, corresponding to the 1 to 25 foot depth to water range in the scale. Third, the land use coverage could be significantly outdated in some parts of the study area, especially south of Hailey. This could influence the recharge rating.

The composite vulnerability ratings are mapped in Figure 12.

Nitrates

A search of the USGS and Idaho Department of Water Resource's Environmental Data Management System (EDMS) data bases resulted in only eight nitrate observations for the Big Wood-Silver Creek area. The observations were made between 1981 and 1992. The nitrate values ranged from 0.1 to 1.08 mg/l.

Analysis Results and Interpretation

The small sample size makes the statistical analysis of the rating system in this area unreliable. The regression analysis resulted in an $R^2 = 0.08$. The relationship was statistically insignificant at $p = 0.59$. Figure 9 is a scatterplot of the data points and the regression line.

Figure 9
Big Wood River - Regression of Nitrates on Vulnerability Score

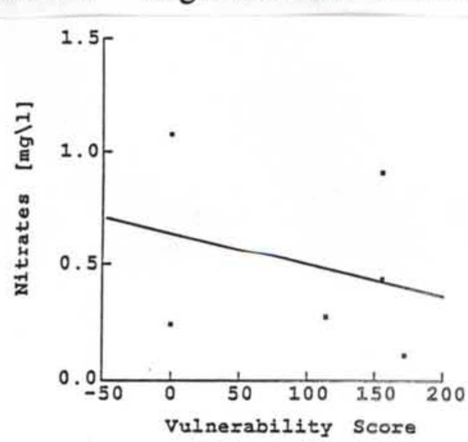


Figure 10
Big Wood River - Soils

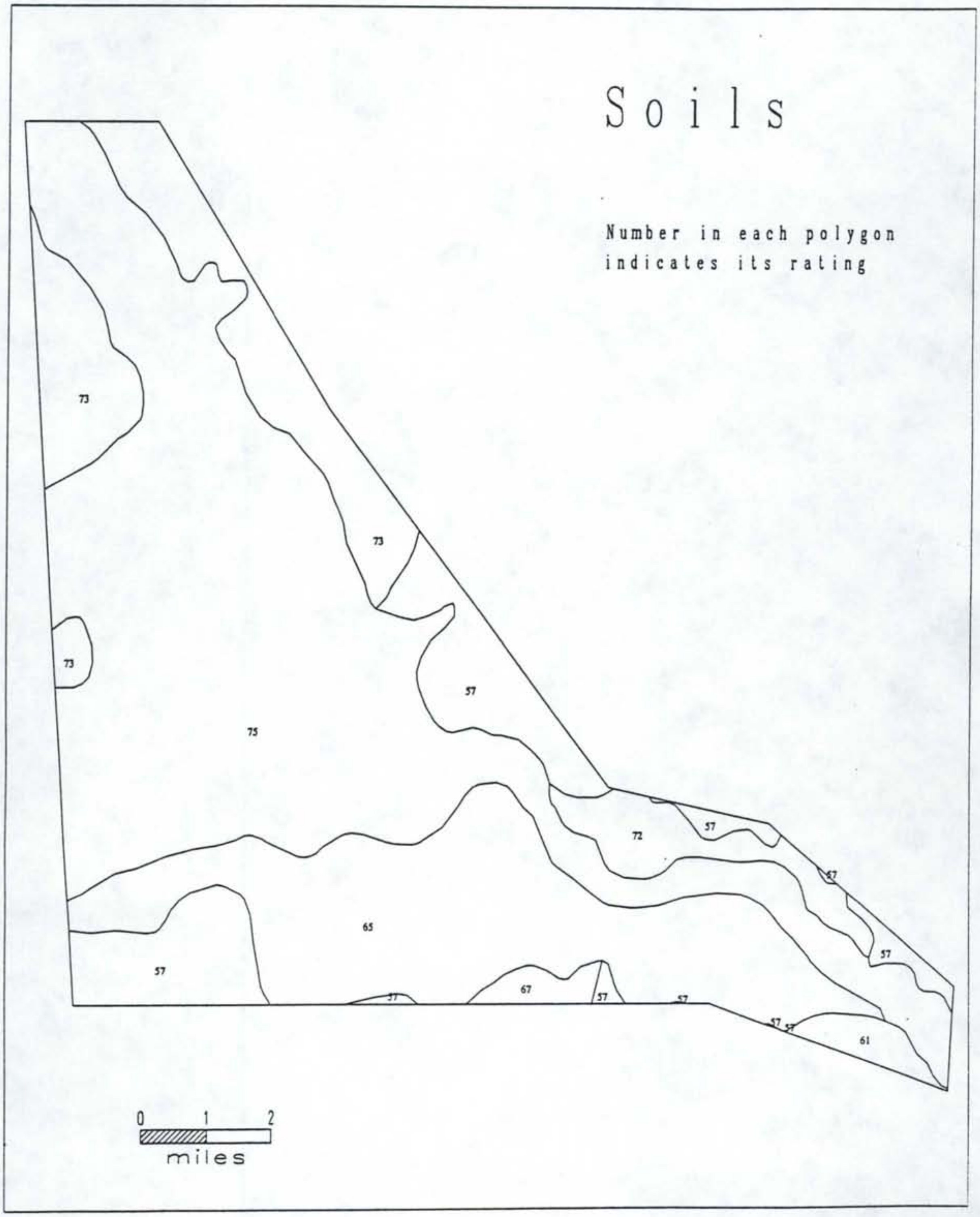


Figure 11
Big Wood River - Recharge

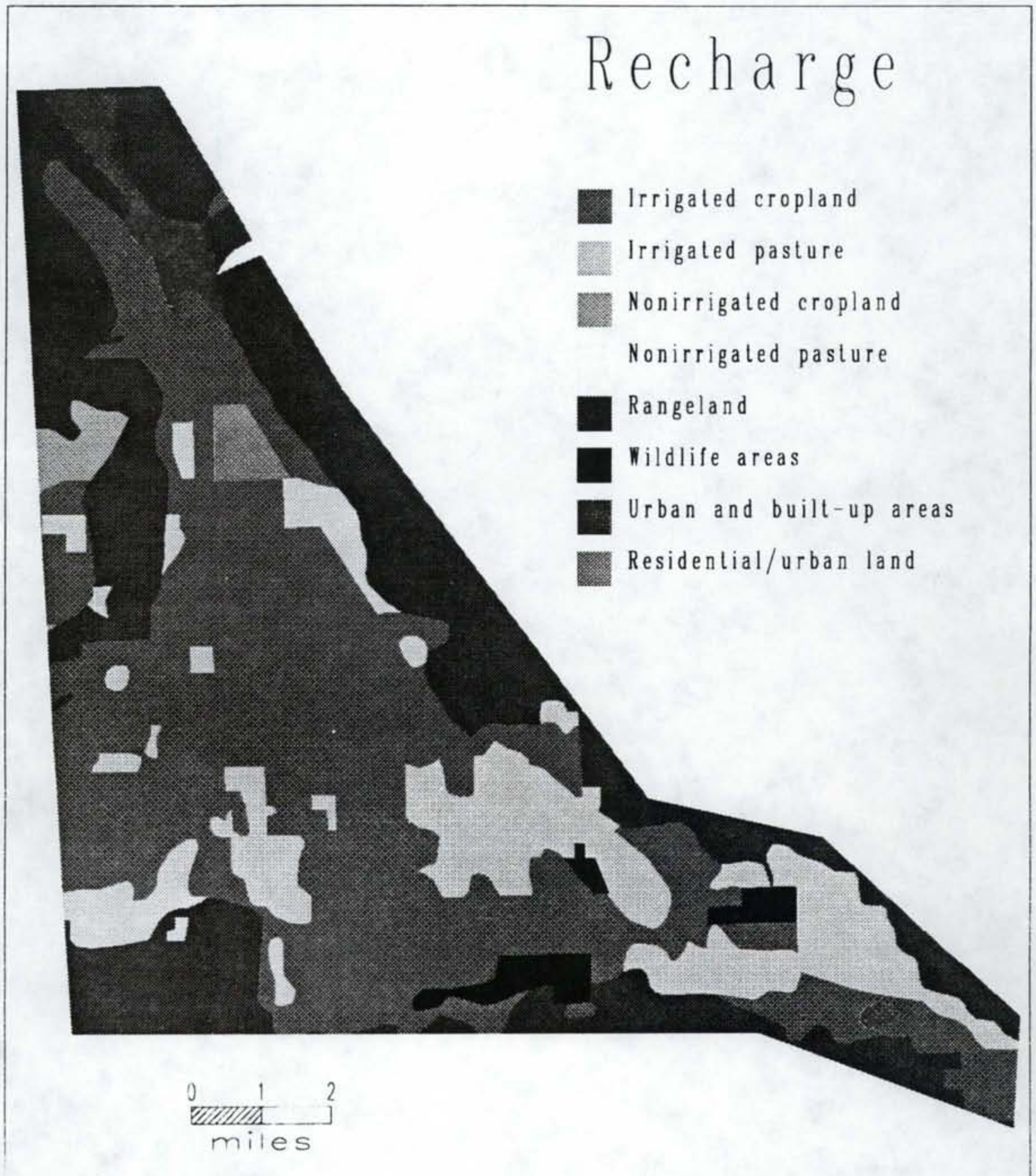
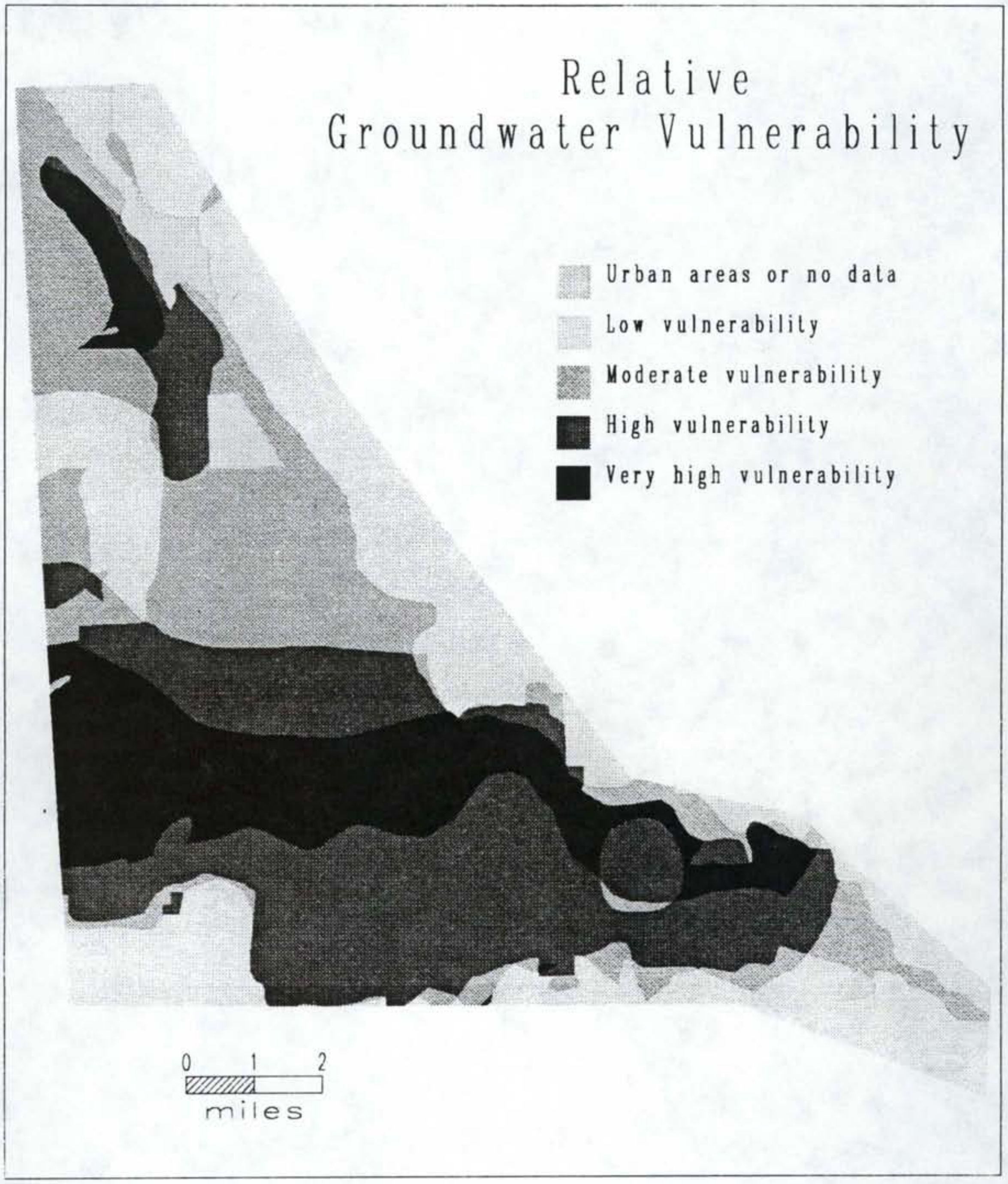


Figure 12
Big Wood River - Vulnerability Map



Jerome Area

The southwestern portion of Jerome County was mapped at the 1:24,000 scale. The study area covers approximately 45 square miles. The verification process was applied to this area, although it is part of the regional Eastern Snake Plain aquifer, to determine if scale would affect the rating system results.

Depth to Water

The depth to water coverage was built from measurements of 75 domestic wells made in fall 1992 (Norris-Willing 1993). Kriging, with linear drift, was used to interpolate the point data and to develop the coverage (Figure 13) of water table contours with 10 foot intervals and from that, the depth to water map, matching the rating system, was constructed.

Soils

The state office of the Soil Conservation Service provided 1:24,000 soils data for the Scott's Pond State Agricultural Water Quality Project. The coverage has attribute items that can be related to two data base files. The soils coverage is shown in Figure 13.

Recharge

There were two sources for the recharge layer. The first was the 1:100,000 land use coverage from the state office of the Soil Conservation Service. That coverage was compiled for the Scott's Pond SAWQP in 1991 on 1:24,000 base maps, which were field checked (Hoover 1993). The SCS coverage typically mapped land use by quarter sections (160 acres). For example, a quarter section may have been mapped as sprinkler irrigated, even though a central pivot system might covered a 130 acre circular area within the quarter section.

The second source was an irrigation coverage from the Idaho Department of Water Resources. IDWR compiled the irrigation coverage from 1:40,000 air photos taken in 1992 and interpreted by the Bureau of Reclamation.

The IDWR coverage had a large number of non-irrigated acres in the western half of the Jerome study area that the SCS coverage did not have. These lands were assigned a rating of 20 points, equal to rating scale categories of range land or dry land agriculture. The discrepancy may have been due to the different methods of map compilation and the different years. The 1992 season was unusually dry in the Jerome area. Since there was no objective way of determining which coverage was more accurate, two composite vulnerability maps were generated, one with each of the recharge coverages. The SCS coverage is shown in Figure 14.

Figure 13
Jerome - Depth to Water

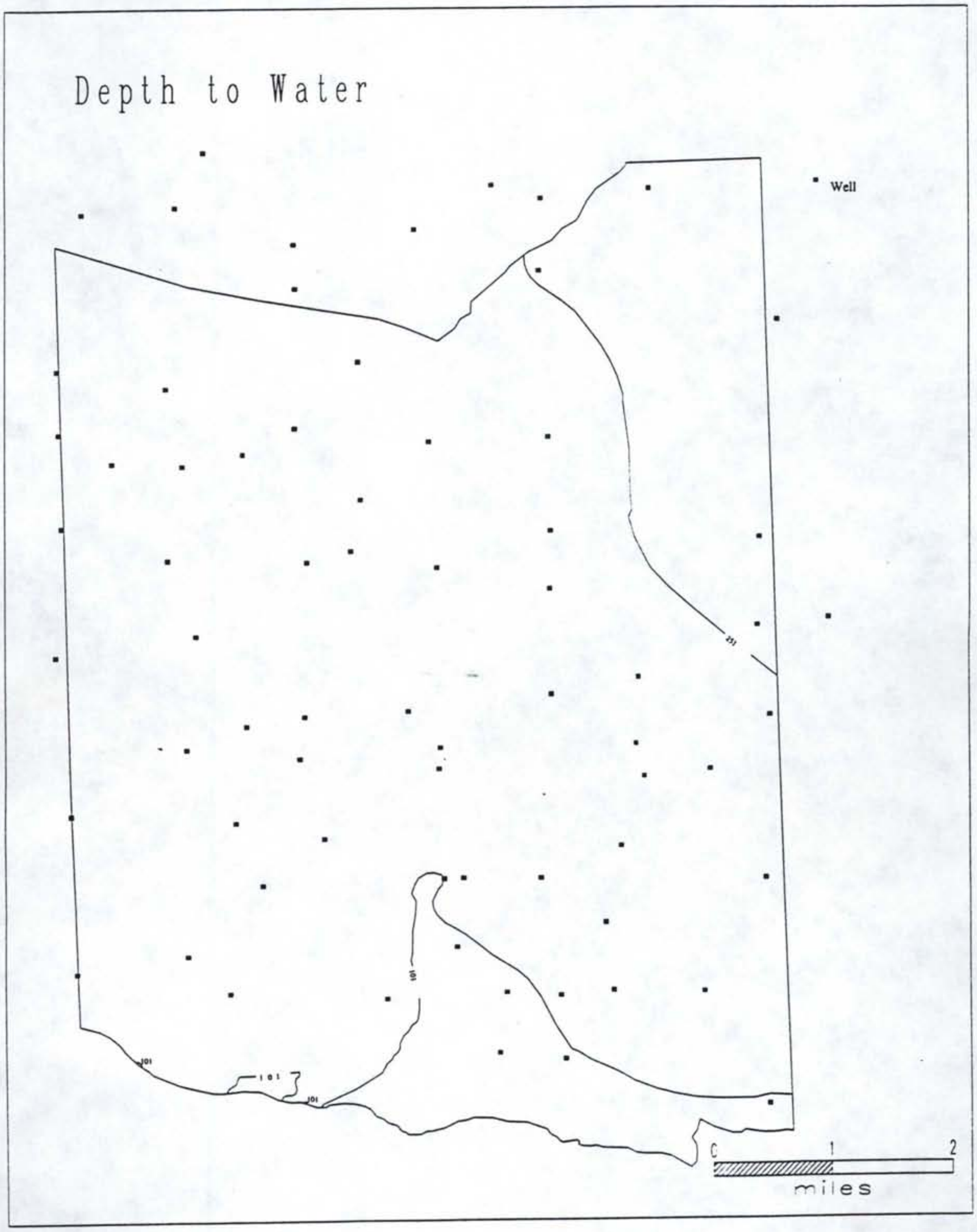


Figure 14
Jerome - Soils

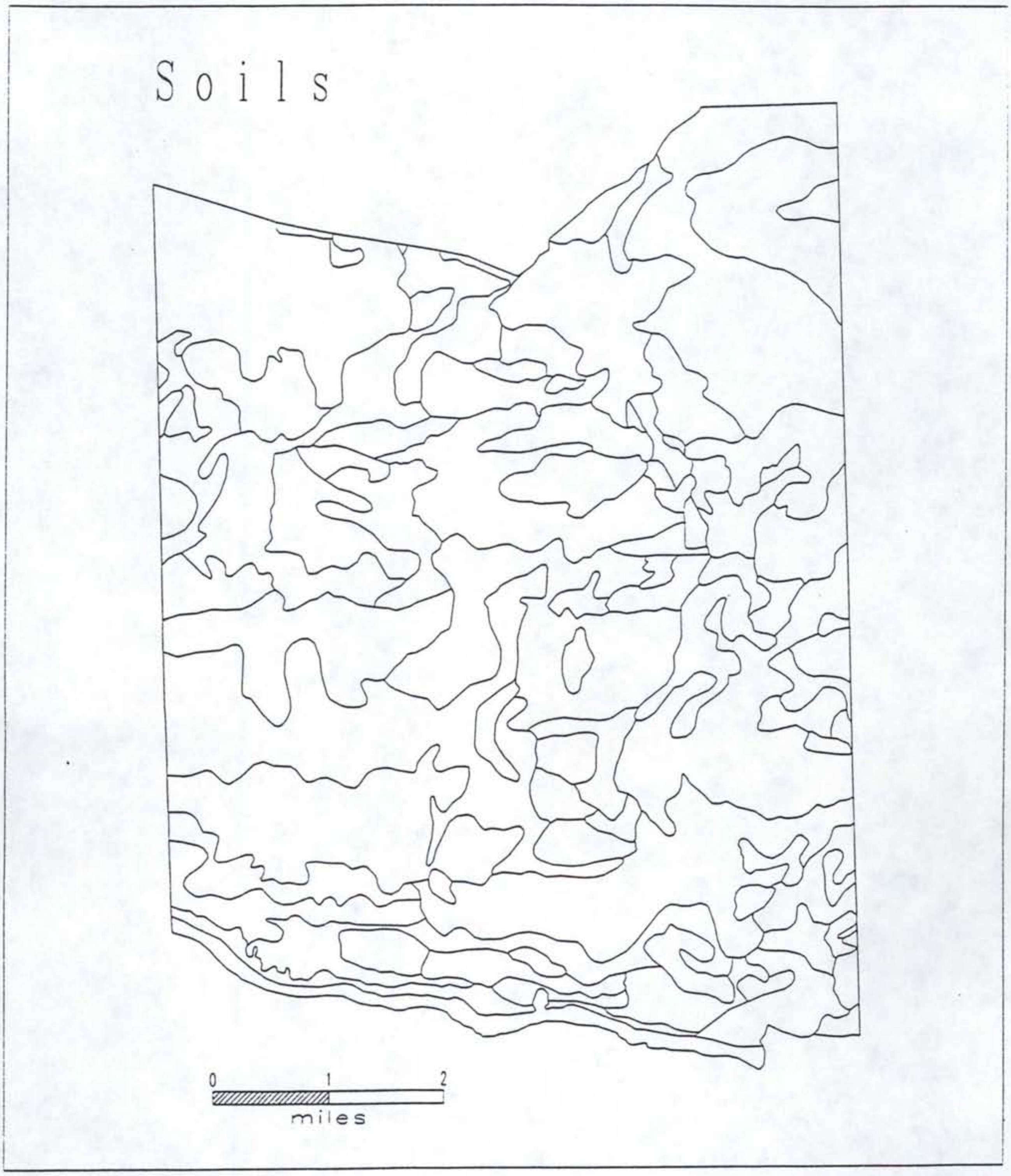
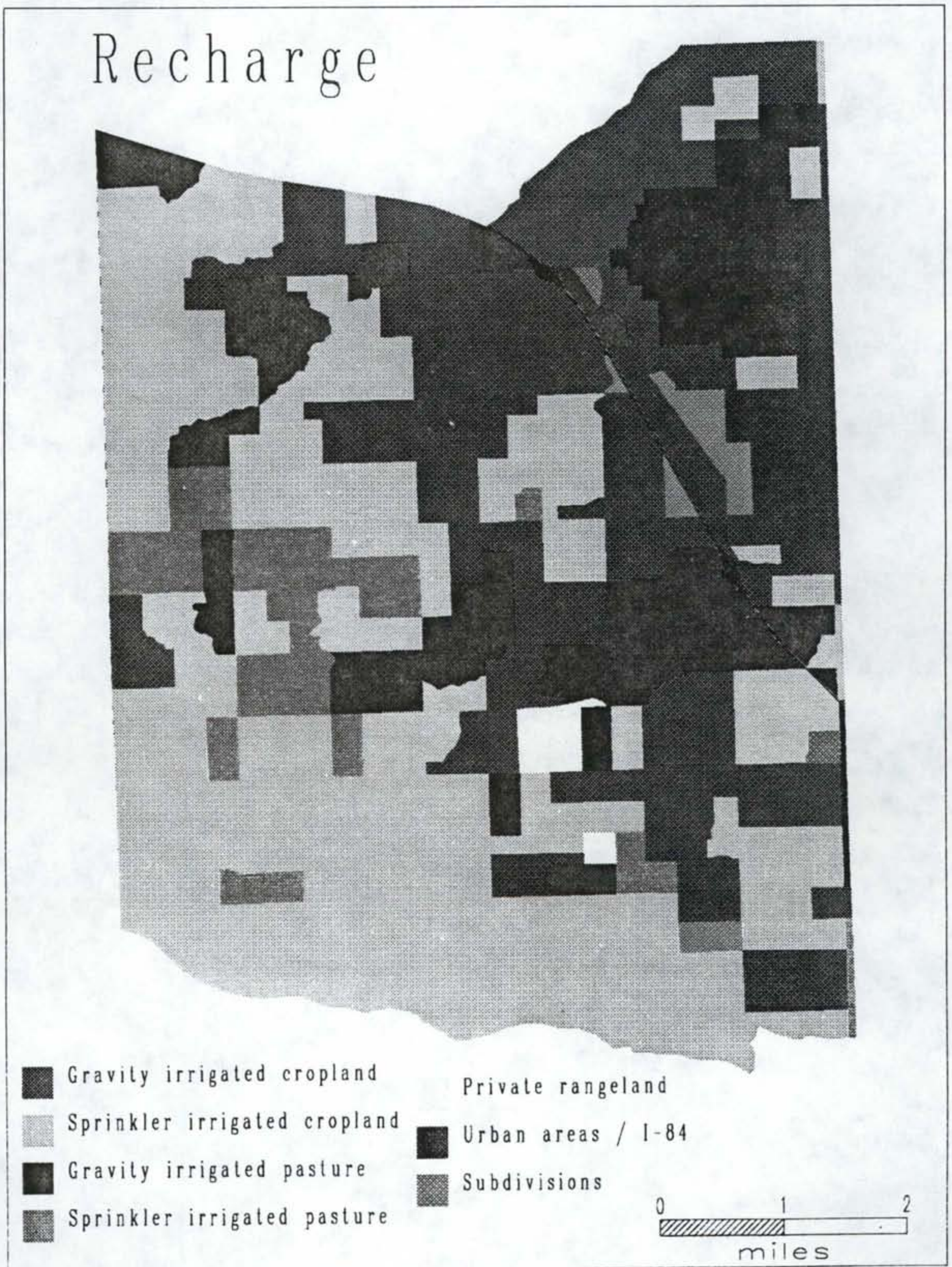


Figure 15
Jerome - Recharge



A residential subdivision land classification used in the SCS coverage was not included in the original Snake Plain vulnerability study. After consulting with SCS staff, the residential subdivision lands were assigned a rating of 20 points, equal to the range land classification.

Vulnerability Map

The three coverages were unioned and calculations completed for the vulnerability categories. The vulnerability ranks are mapped in Figure 16. According to the Rupert rating system, the vulnerability classifications were apportioned so that the top 10 percent were very high, and the remaining 90 percent equally apportioned to the high, moderate and low categories. A comparison was made of this proportional classification to an areal apportionment. They were very similar coverages.

Table 9 summarizes the ratings for the independent variables and the overall vulnerability.

Table 9
Summary of Independent Variable and Vulnerability Scores- Jerome

	Independent Variable Scores			
Independent Variables	Minimum	Maximum	Median	Mean
Depth to Water	1	20	10.0	10.0
Soils	27	57	36.0	37.9
Land Use	20	50	40.0	43.2
Vulnerability	48	127	92.0	91.4

Nitrates

Nitrate data were obtained from two sources. The Scott's Pond project included monthly monitoring of 27 wells, 13 of which are in the Jerome study area. In addition, 22 other nitrate observations from non urban locations were used. These observations were from U.S.G.S. measurements. The nitrate data were from 1987 to 1991 and ranged from 1.02 mg/l to 5.66 mg/l.

Analysis Results and Interpretation

The distribution of data points was unsuitable for analysis with a logit model, based on the contingency table (Table 10), as can be seen by the number of cells with no data.

Figure 16
Jerome - Relative Ground Water Vulnerability Map

Table 10
Contingency Table for Jerome Data

	Nitrate Levels		
Vulnerability Ranking	N > 10	$5 \leq N \leq 10$	N < 5
Very High	0	0	3
High	0	1	15
Medium	0	0	13
Low	0	0	3

The ranking system was tested with a General Linear Model regression, with nitrate as the dependent variable and vulnerability score as the independent variable. The results indicate the ranking system is independent of the observed nitrate levels in the Jerome study area. The $R^2 = 0$ and the F tests are not significant.

As an additional step, the regression analysis was run for each component of the ranking system. None of the models was statistically significant or had an R^2 greater than 0.10. A possible nonlinear relationship between vulnerability rankings and nitrates was analyzed by plotting the regression residuals against nitrate estimates. The residuals do not form a pattern indicating a transformation of the data is appropriate.

Discussion

The greatest problem with performing the statistical verification of the vulnerability rating system is the lack of data. The lack of nitrate observations made logit modeling impossible for several of the ground water systems. The distribution of nitrate sample points -- in space, in time, and in range of values -- may explain the inability to conclusively verify or reject the rating system.

Data for the independent variables was a limited in some areas. For example, depth to water maps did not exist for the Rathdrum Prairie or the Big Wood-Silver Creek areas. For this analysis, a depth to water map for the Rathdrum Prairie was generated using 1970s data, the most current data available. It was subsequently compared to a ground water contour map being generated by the U.S.G.S. from early 1990s data and found to be very similar. If the newly collected data for the Big Wood River-Silver Creek triangle had not been available, a depth to water map could not have been constructed for that area.

The land use map for the Big Wood River area is based on 1981 information. Substantial changes in land use have occurred since that time. The Soil Conservation Service is preparing an updated land use map, but it was not available at the time of this study.

To complete a statistical analysis with a high level of confidence, more systematic sampling of a study area would be required. The sampling density could be determined based on an assessment of hydrogeological conditions of the ground water resource. The spatial distribution of samples from the Rathdrum area is highly clustered, leaving many parts of the study area unsampled. The number of samples available for the Big Wood area is insufficient for a statistical analysis. The precise number of samples required for a statistical analysis is a function of the size of the area and the density necessary to capture spatial variability of both the inherent susceptibility factors and the potential contaminant sources.

Another factor which is important in a statistical verification of a vulnerability model is time. Adequate sampling of an area over time would permit trend analysis and make it possible to establish travel times for observed contaminants. It then may be possible to describe relationships between land use at other time periods with observed nitrate levels or other contaminants in the present.

There is also the question of whether land use is a valid indicator of recharge. On the Snake River Plain where recharge is largely from irrigated agriculture, land use may be an indicator of recharge potential. On the Rathdrum Prairie, however, where some portion of recharge is due to precipitation, and where extensive surface water in lakes, streams and rivers create recharge zones (Painter 1991), land use may not be indicative of recharge potential. Land use may be an indicator of relative contaminant loading potential more than recharge.

Conclusions

The only statistical relationship between the rating system and nitrate observations was found for the regional Eastern Snake River Plain aquifer and it was a weak relationship. There are two conclusions that can be made from these results. One, the rating system appears to work only for the coarse mapping scale on the Eastern Snake River Plain where there is a large data set.

The second is that any conclusions are weakened by data limitations such as not being able to replicate the numerical ratings used by Rupert et al. in developing the vulnerability ratings, and by the small number of nitrate observations in some areas and the uneven distribution of sample points over space and time for the independent and dependent variables. Given the data limitations, a statistical verification analysis of a general model may be premature.

PART 2

Jerome Pilot Project

Pilot Project Objectives

A designated task of the project was to investigate ground water vulnerability for a portion of Jerome County within a statewide agricultural water quality project at a scale of 1:24,000. The objectives were to develop at least eight GIS coverages and to determine if a modified rating scale or some other approach could be developed to map vulnerability in the area. The GIS coverages were to include: water table contours, soils, recharge, septic systems, potential point sources of contamination, pesticide use, existing and proposed public water supply wells, and wellhead protection areas.

Location of the Project Area

Part of the pilot project area was predetermined. The pilot project was designated for Jerome County, within the Scott's Pond State Agricultural Water Quality Program (SAWQP), north of the Snake River, which formed the southern project boundary, to a line just north of the City of Jerome. The eastern and western boundaries were set as part of the current project. The location is shown in Figure 1.

The Scott's Pond project is an on-going cooperative project of the DEQ and the North Side Soil Conservation District, Soil Conservation Service and Soil Conservation Commission. The project includes slightly more than 100 square miles north of the Snake River in western Jerome County and includes the City of Jerome. The Scott's Pond project is designed to determine if implementing agricultural best management practices (BMPs) on cropland in this subwatershed, can reduce transport of agricultural pollutants to the Snake River. The project includes monitoring of surface and ground water to develop baseline conditions and to evaluate and prioritize land uses contributing to surface water pollutants.

The eastern and western boundaries of the pilot project were chosen to coincide with the area covered by one U.S.G.S. 7.5 minute quadrangle -- the Jerome Quadrangle. The western boundary extends approximately one half mile into Gooding County. The eastern boundary is approximately 0.9 miles east of the north-south Jerome Road. Some of the maps developed in the current project extend beyond the Scott's Pond project boundary on the north and west. The current project included information to the northern and western edges of the quadrangle map, whereas the Scott's Pond hydrologic boundary dips slightly to the south on the northern boundary and follows the Gooding-Jerome County line on the west.

Study Methodology

The pilot project provided opportunities to examine relationships between variables other than the ones included in the Rupert et al. rating scheme. The mapping scale of the GIS coverages provides more detail about susceptibility and vulnerability factors of the local area than was available in the initial study. Most of the additional coverages relate to potential contaminant sources rather than the geophysical features of the aquifer and land surface.

The basic approach was to gather data for the designated GIS coverages from secondary sources where possible. Some data were generated specifically for this project, such as depth to water. Where secondary data were used, the sources are documented. Where data were generated, the procedures are described.

The construction of each GIS coverage will be discussed in detail. This is followed by a discussion of opportunities and problems in developing the coverages. Conclusions about relationships between independent variables and nitrate observations and future applications of these procedures concludes this part of the report.

Depth to Water

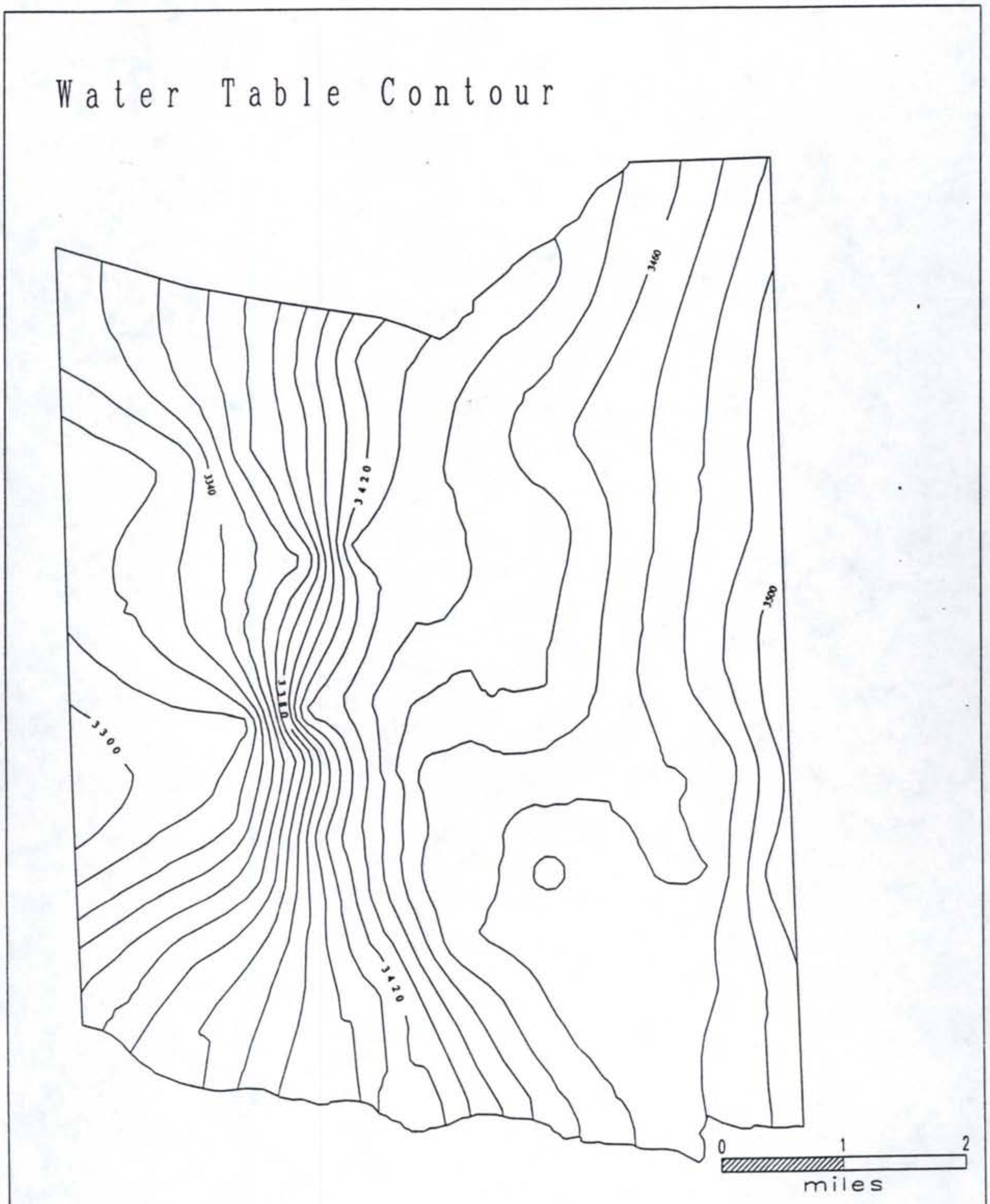
The depth to water coverage (Figure 13), was developed from water table contours generated from 75 well measurements made Oct. 9 through 11, 1992. Water level measurements were taken from domestic wells distributed across the project area with at least one well per section. The criteria for selecting wells included input from DEQ personnel, permission from the current well owner, and the need to have an even distribution of sample points across the study area (Norris-Willing 1993).

Measurements were made using a standard surveyor's steel tape, or electrical probe when ground water was too deep for a steel tape. Measurements were made over a slightly larger area than that covered by the Jerome Quadrangle.

The raw data were used to generate ground water contours with 10 foot intervals using Surfer ver 4.13 computer software. The ground water is at its greatest depth, more than 300 feet, in the northeast corner of the study area. The depth decreases from east to west and north to south. Ground water was measured at about 100 feet deep near the southern and western boundaries of the study area.

The final map was generated in ARC/INFO and is shown in Figure 17. The universal method of kriging with linear drift calculated the spatial interpolation from point data. The depth to water map was constructed by subtracting ground water elevation from surface elevation.

Figure 17
Jerome - Water Table Contours



Soils

The soils coverage, including a relational attribute file, was provided at 1:24,000 map scale by the Soil Conservation Service state office. The soils coverage is shown in Figure 14.

Recharge

Land use, along with surface hydrology created by the agricultural irrigation system of canals, ditches and ponds, were included as indicators of recharge in the project area. Land use data came from several sources. The Soil Conservation Service state office provided digital data for land use at the scale of 1:100,000. That coverage, from 1991 was field checked (Hoover 1993) and included seven categories of land use including sprinkler irrigated cropland, gravity irrigated cropland and irrigated pasture. Some areas of land use were generalized to 160 acres. For example, a center pivot sprinkler which may have irrigated 130 acres, was mapped as a 160 acre block.

Another coverage from the Idaho Department of Water Resources mapped irrigated areas by field and by type of irrigation method based on 1992 data. There was some discrepancy between the SCS and IDWR maps for irrigated agriculture because the SCS map was based on land use categories rather than specific field mapping. Another reason for discrepancy is that the SCS and IDWR coverages were based on information from two different years. In the southeast portion of the study area, more farmers used sprinkler irrigation in 1992, which was a very dry year. When irrigation water is abundant, flood irrigation is most often used due to the lower cost of irrigating. A map of irrigation types based on IDWR field-level information is shown in Figure 18.

Some social changes may explain a portion of the discrepancy. The difference in irrigation methods mapped in different years may be due to aging of farmers, government regulations, and/or labor requirements. For these reasons, a number of farmers have invested in sprinkler irrigation in recent years despite its higher cost (Barton 1994). A shift from the less efficient flood irrigation to sprinkler irrigation may have occurred in the Jerome study area during the period when the two data sets were collected.

A third source of information was the 1992 compliance slides from the Agricultural Stabilization and Conservation Service (ASCS). The study area was aerial photographed in June 1992 for compliance with crop subsidy programs. The slides were scanned into the computerized coverage of the study area and edge matched to create an aerial view of the study area. Given the scanning resolution and the UTM coordinate system used in the registered images, one pixel is approximately three meters square on the ground. This provided a detailed view of land uses and irrigation patterns.

In many landscapes, surface water, such as riparian areas, lakes and ponds, are aquifer recharge zones. There is little natural surface hydrology in the study area, but the system of

Figure 18
Jerome - Irrigation Types

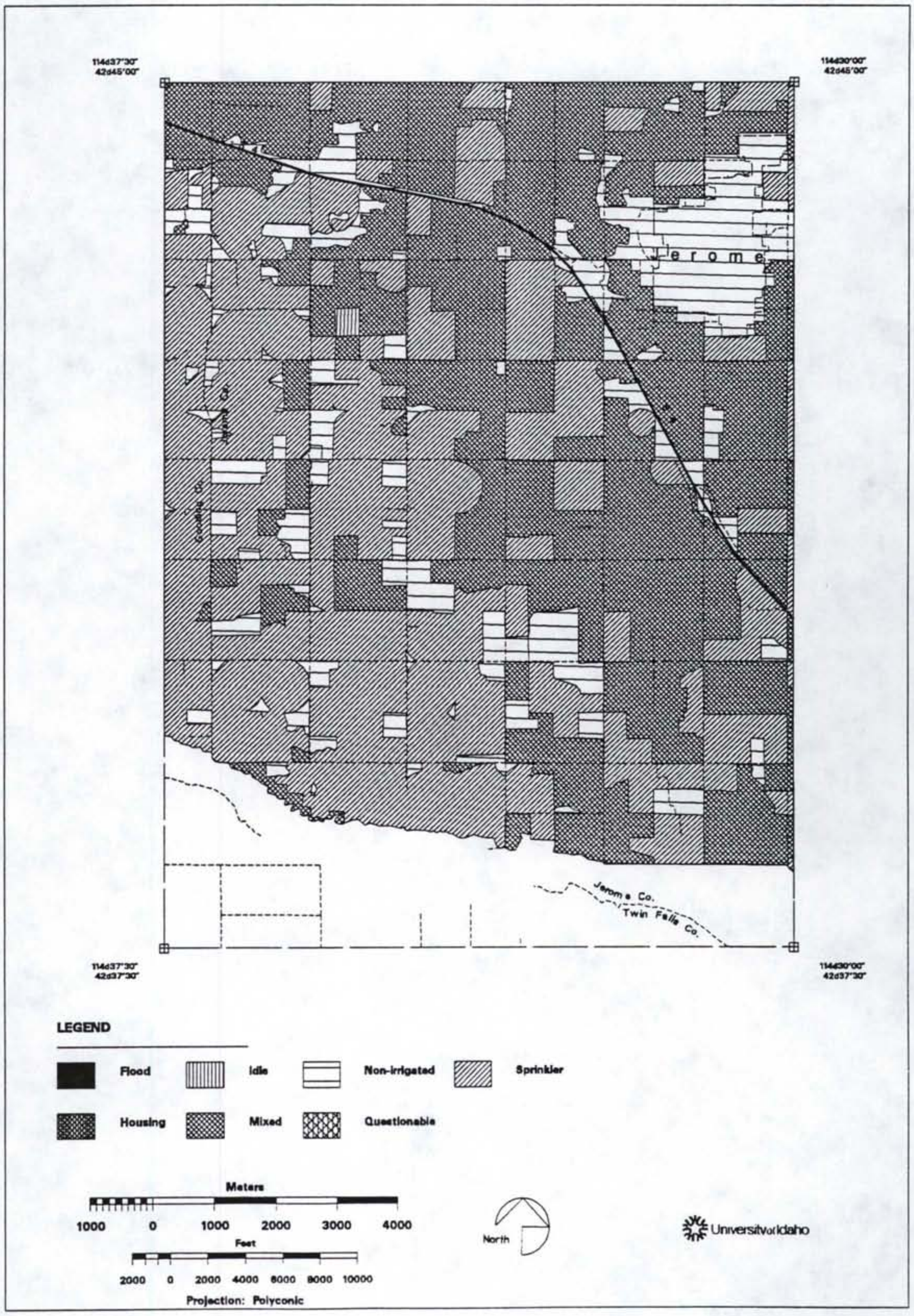
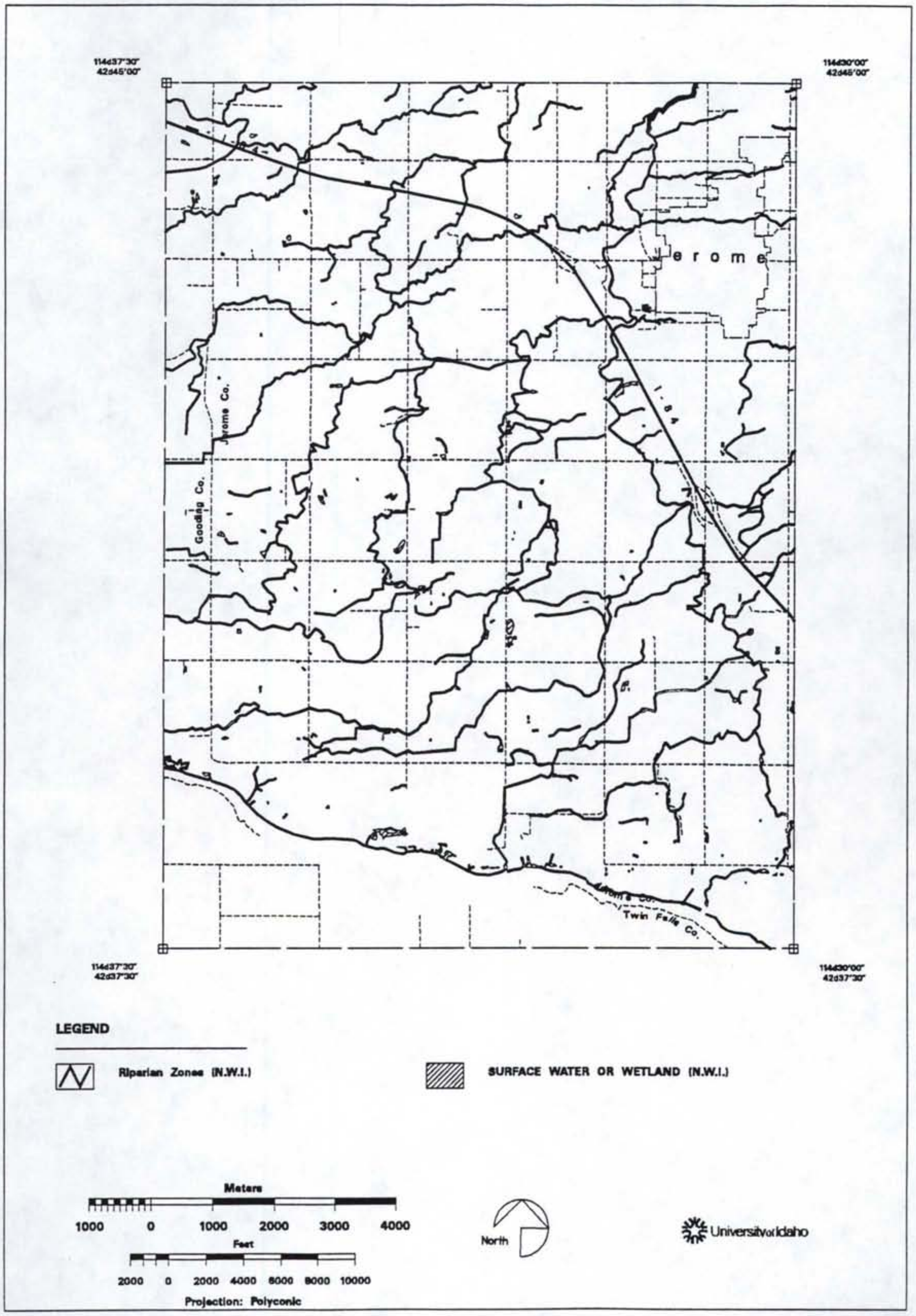


Figure 19
Jerome - Surface Hydrology: Canals, Ditches, Ponds



irrigation canals, ditches and ponds creates a surface hydrology with potential recharge zones. The National Wetland Inventory Maps (1991) from the U.S. Fish and Wildlife Service were digitized and a coverage of "Surface Hydrology: Canals, Ditches and Ponds," created in order to include another potential element of recharge. Figure 19 shows the man made surface hydrology of irrigation canals, ditches, return flow ponds and lagoons.

Infiltration from these man made features also carries contaminants in the water into the soil and possibly the ground water.

Septic Systems

Using the scanned digital files as background images, the locations of houses were digitized into an ARC/INFO point coverage. The boundaries of the City of Jerome sewer system were mapped. No community sewage systems, which require permits, existed in the study area. The assumption was made that all houses outside the Jerome municipal sewer system boundaries were on septic systems.

U.S. Census data was used to verify this coverage. The house count data within all census blocks in the study area were extracted from Topologically Integrated Geographic Encoding and Referencing (TIGER) System files from the 1990 census. The house data, as identified on the point coverage, was then used to match the number of households within each census block. Based on this procedure and the assumption of a one-to-one correlation between houses and septic systems, 1,161 sites were identified in the study area. They were evenly distributed throughout the Jerome Quadrangle, but were clustered along county roads. Figure 20 displays the point coverage of septic systems. Figure 21 shows the house counts in census blocks in the study area.

Tiger files were used to estimate the number of bedrooms per housing unit for four census block groups representing more than 95 percent of the study area. The overall average was 2.93 bedrooms per residence. This made it possible to estimate the amount of effluent, containing nutrients and contaminants, discharged daily in the study area. Idaho regulations (IDAPA 16.01.03007.08, Title 1 Ch. 3) use a standard of 250 gallons per day of effluent for a single family dwelling or mobile home with three bedrooms. At this rate, an estimated 290,000 gallons of effluent were discharged per day within the study area. The amount of total nitrogen released from these septic systems is estimated at 38 kilograms per day, using the average release of 40 mg/l total nitrogen per septic system (Canter and Knox 1985).

The estimate does not take into account septic design adequacy, septic system age or adequate maintenance of septic systems. Septic system permits are issued by the health district. Information about septic system design is available for 1989 and later, but on paper files, not in digital format.

Agricultural Chemicals

Currently, there is very little public information on the application of agricultural chemicals. Some regulations apply to applicators and distributors of certain chemicals, but their use in a geographical area is not known. Consequently, the approach was to prepare a crop type map for the study area and to assume the use of common chemicals for those crops at recommended application rates.

The digital images created from the ASCS compliance slides contained a great deal of information about agricultural land uses within the study area. Field boundaries and sub-fields, demarcating various crop types and rotation patterns, were digitized from the digital images directly on screen. Each sub-field with a particular crop was saved as a polygon. A general plat map of Jerome County, depicting land ownership patterns, helped verify the boundaries of agricultural fields. Figure 22 depicts field boundaries in 1992.

Additionally, the SCS in a Scott's Pond report, has identified three primary crop rotation patterns in the study area (U.S.D.A. 1993). The number after each crop indicates the consecutive years that crop is grown.

1) Bean focus: alfalfa hay (3) to beans (3) to grain (1)
2) Feed focus: alfalfa hay (3) to silage corn (4) to barley (1)
3) Potato/Beet focus: alfalfa hay (3) to potato/beet (1) to wheat (1) to corn (1) to wheat (1) to potato/beet (1)

The SCS also has identified a number of agricultural chemicals used in the Scott's Pond project area which have a risk of leaching. They are: Atrazine, Temik, Sencor, Mocap, Thimet, 2,4-D, Eptam, Roundup, Baleton, 2,4-D Amine, Bactril and Treflan.

Use of agricultural chemicals is not limited to farm fields. Many of the same chemicals are used on canal, highway, road and railroad rights-of-way and on lawns and gardens. Information from the Idaho Department of Transportation (Galvin 1993) and the Jerome County Weed Supervisor (Hahn 1993) made it possible to document, in general, which chemicals are used along highway and county road rights-of-way. The two most widely used pesticides along rights-of-way are 2,4-D amine and Roundup. Along the railroad right-of-way and some other areas where crops are not grown, Crovar is used. Most pesticides are spot applied along the rights-of-way.

However, no procedure was developed to map crop types within the digitized field boundaries. ASCS records were checked and crops designated for some fields, but not all farmers participate in the programs administered by ASCS. Consequently, information was

Figure 20
Jerome - Point Coverage of Septic Systems

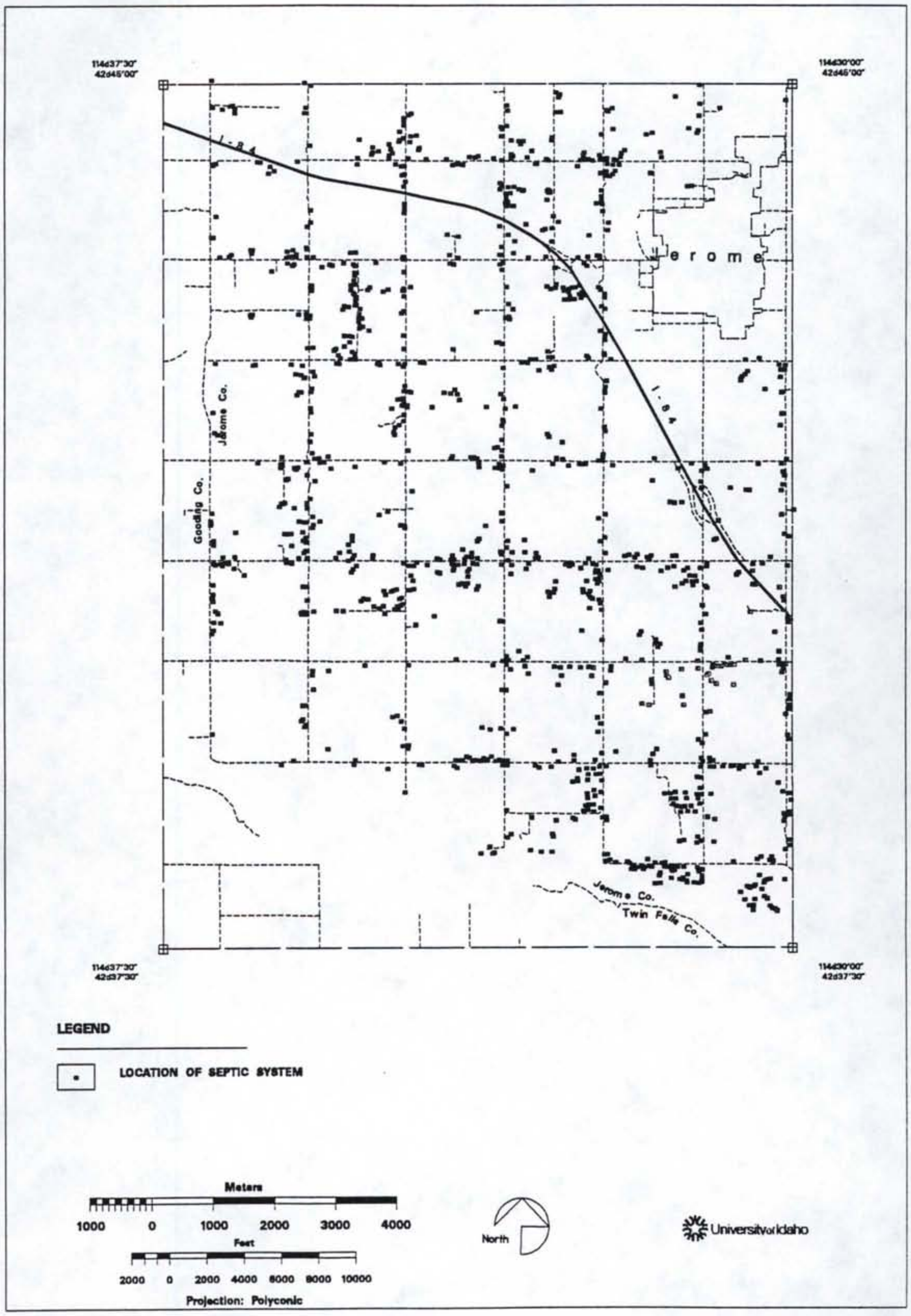


Figure 21
Jerome - House Counts in Census Blocks

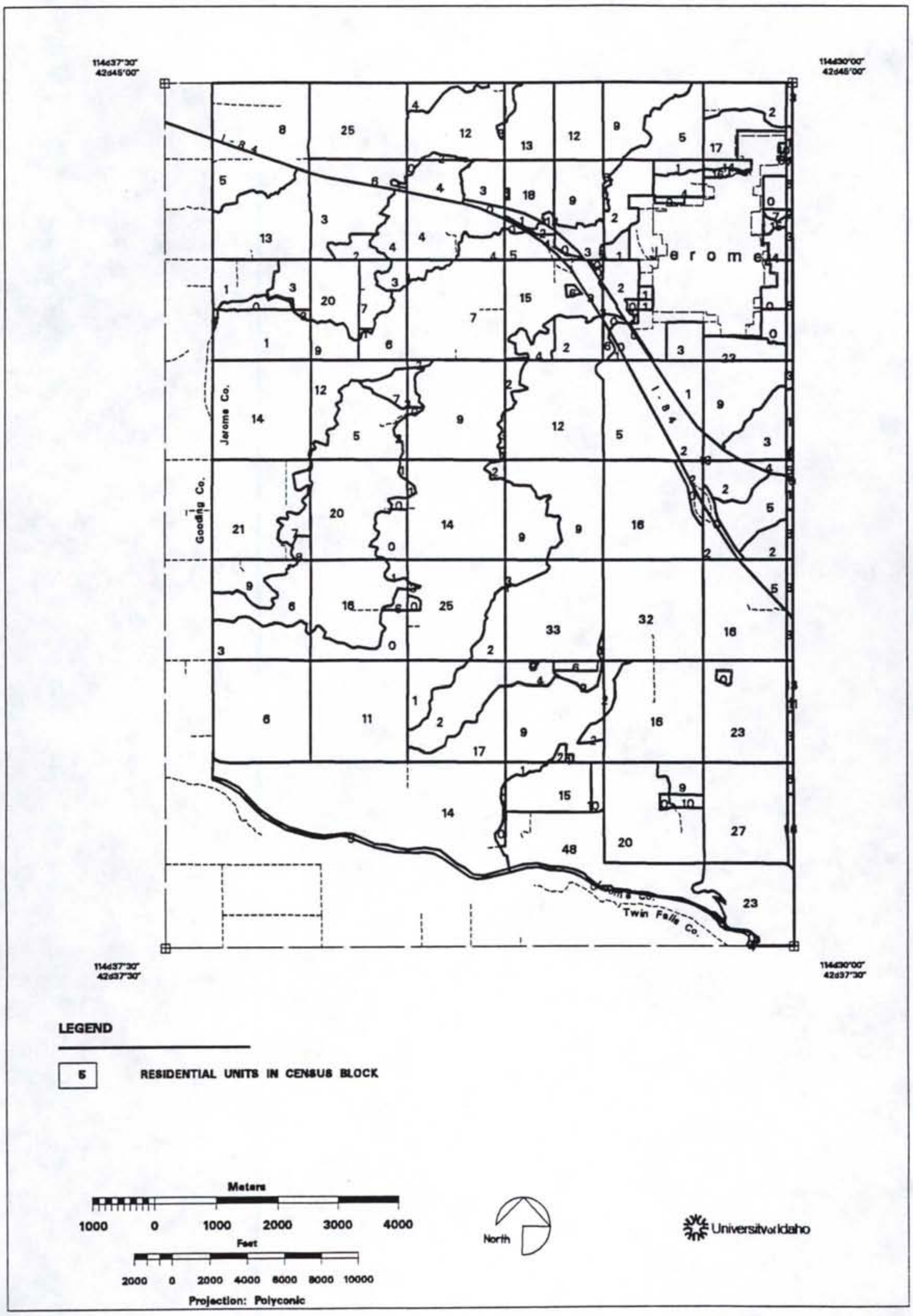
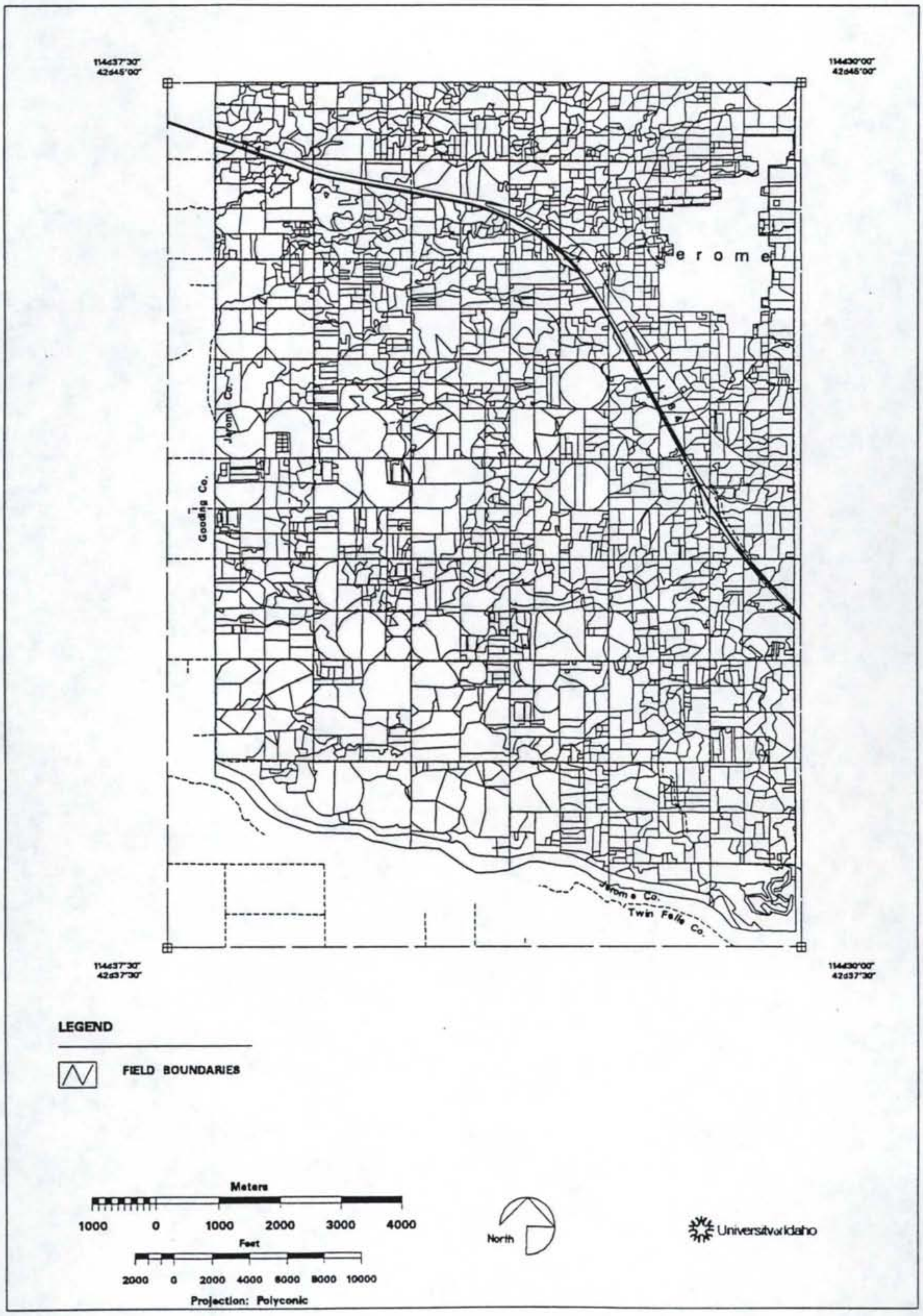


Figure 22
Jerome - Field Boundaries in 1992



not available for many fields. The aerial photos were not sufficient for remote sensing applications to identify crop types. The county assessor's office taxes farm land based on its productivity as evidenced by the types of crops grown, but it was not feasible to create a map using that information. It was not possible to develop a relatively complete crop type map with the information available.

In the absence of a crop type map, the next approach was to assess the relative risk levels for leaching of several agricultural chemicals which may be used in the study area. The software PESTCON, being developed by the College of Agricultural at the University of Idaho, uses soil leaching and runoff potentials of specific chemicals to derive a relative level of risk of contamination. The leaching and runoff potentials are from SCS soils data (Bechinski 1993). The ratings are high, medium and low. The leaching potential was assessed for three pesticides, all of which are herbicides. The pesticides Atrazine and 2,4-D Amine are commonly used in the study area. The relative risk maps are shown in Figures 23 and 24. The pesticide Trifulralin may be used in the area less often. The relative leaching potential is shown in Figure 25.

Comparison of the PESTCON generated risk levels for the three chemicals indicates leaching potential varies. For the three compared here, Atrazine was ranked the highest, followed by 2,4-D Amine and Trifluralin. It is difficult to isolate a reason for the common high and low risk areas because the risk index is based on the interplay of factors. The factors include, but are not limited to, the half-life of the chemical, water solubility, soil organic carbon absorption coefficients, hydrologic soils groups and soil horizon depth (Goss 1992, Gustafson 1989).

Potential Point Sources of Contamination

This coverage, shown in Figure 26, is a composite of a number of types of potential point sources of contamination, including petroleum, injection of contaminated surface water, animal waste and sewage effluent. Each of the potential point sources is described, along with the source of information.

Underground Storage Tanks/Leaking Underground Storage Tanks (UST/LUST)

DEQ maintains a data base with registered UST/LUST sites in Idaho. The data base locates the sites by street address. Some, but not all sites in Jerome County and the City of Jerome were located and mapped as points. In cases where the location was not verifiable, the site was not mapped. Consequently, this is an incomplete coverage of UST/LUST sites. DEQ is beginning a statewide project to locate accurately UST/LUSTsites using global positioning system (GPS) technology. When that is completed the sites will be accurately mapped by latitude and longitude.

Figure 23
Jerome - Risk Assessment for Atrazine

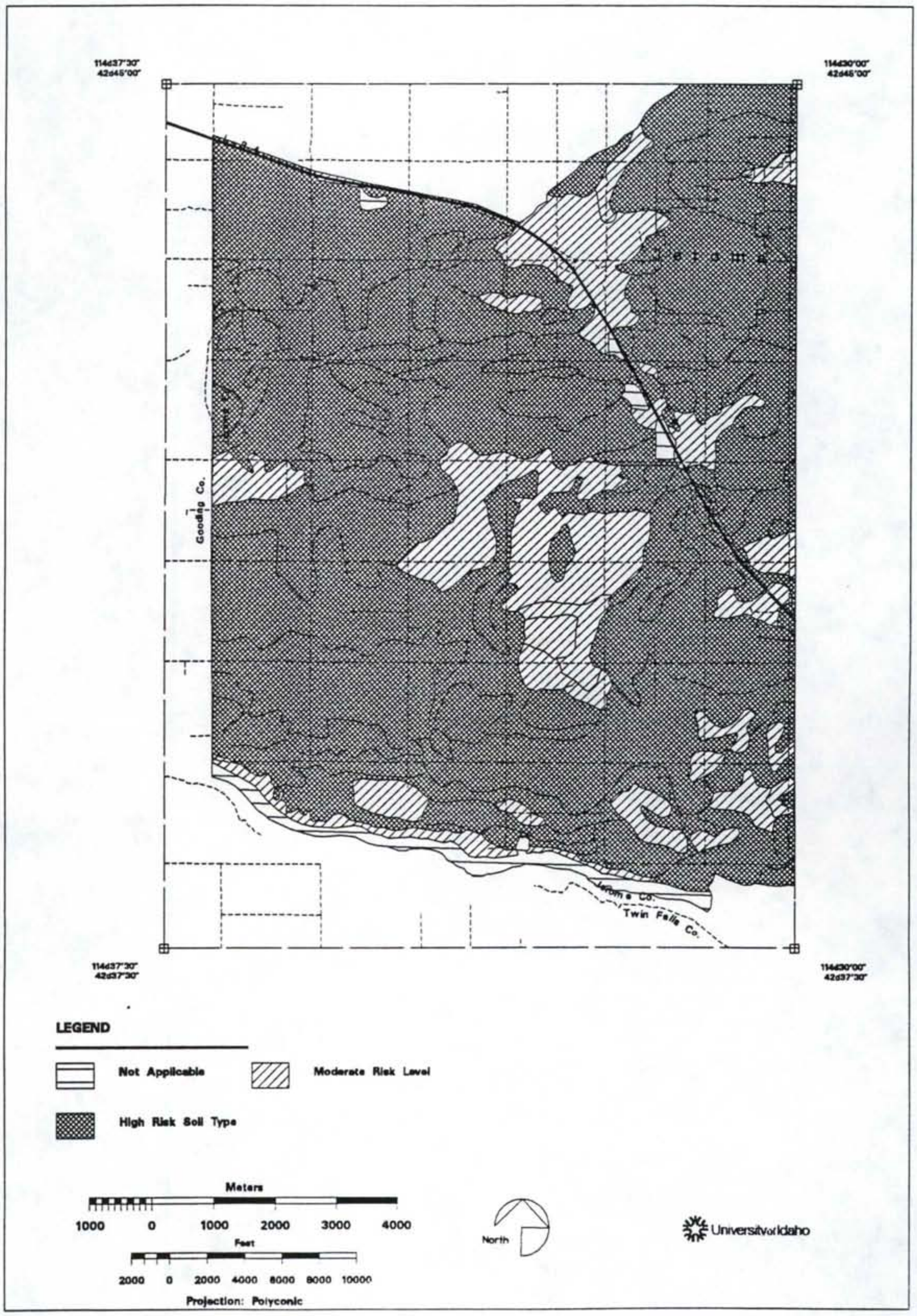


Figure 24
Jerome - Risk Assessment for 2,4-D Amine

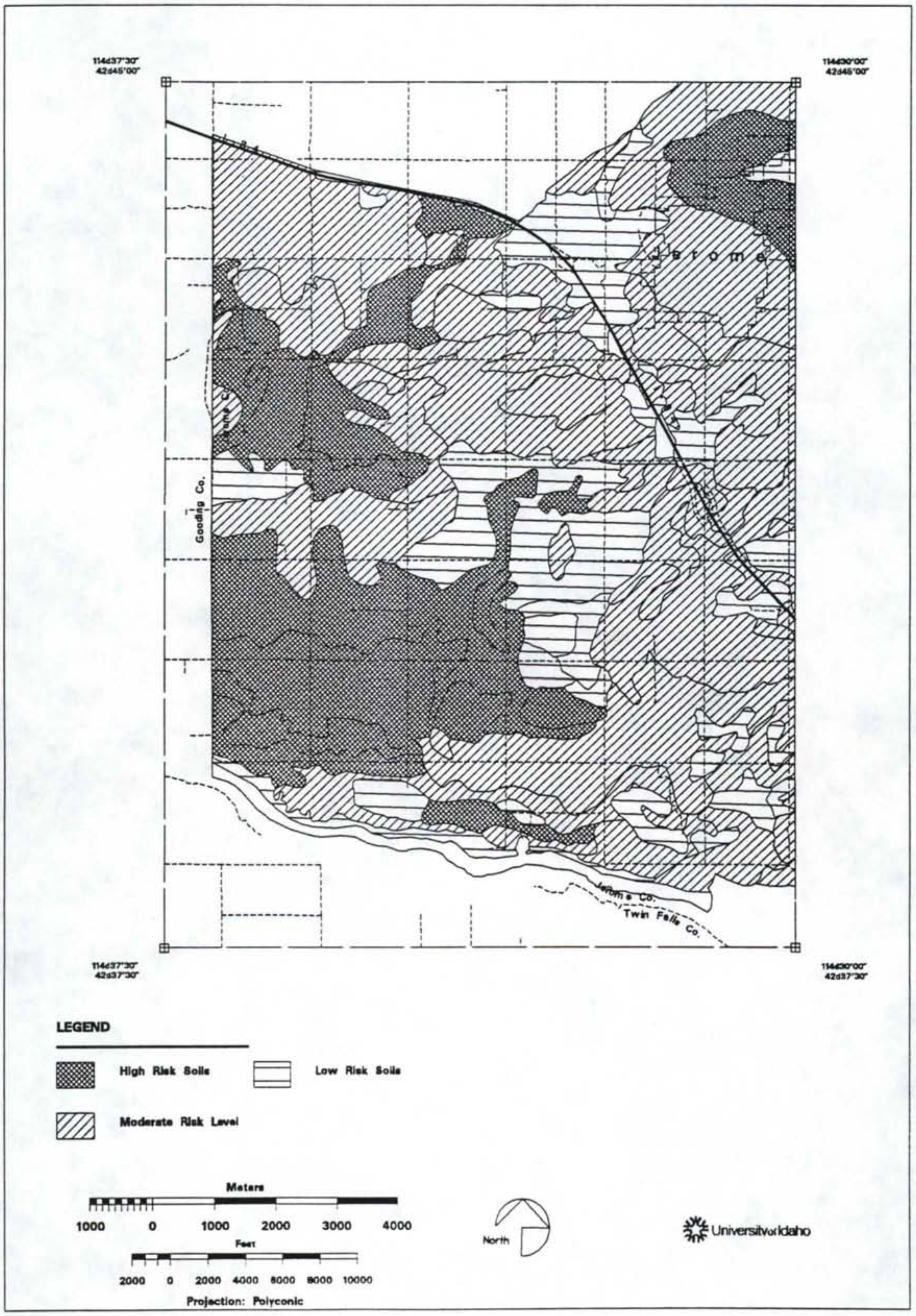


Figure 25
Jerome - Risk Assessment for Trifluralin

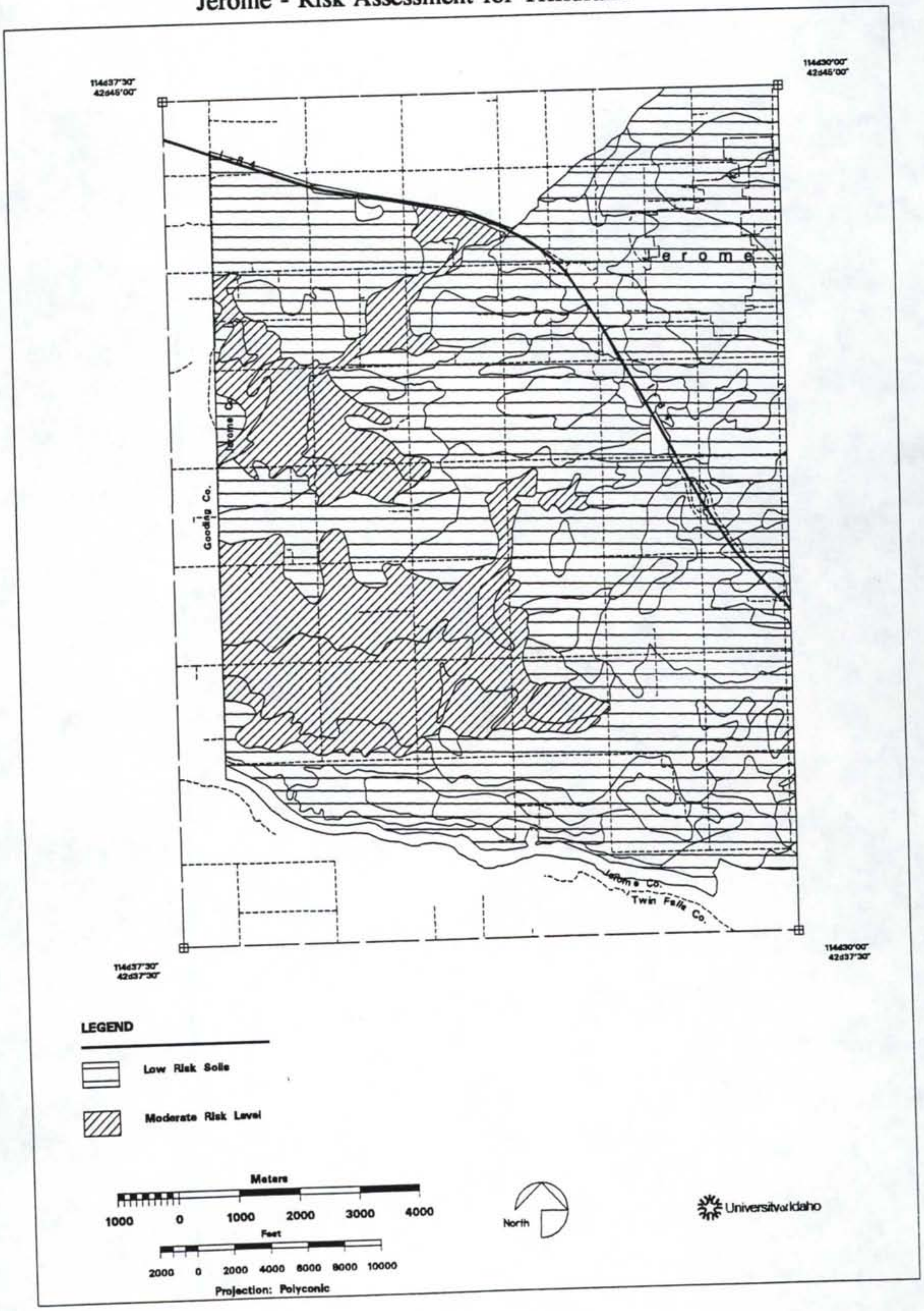
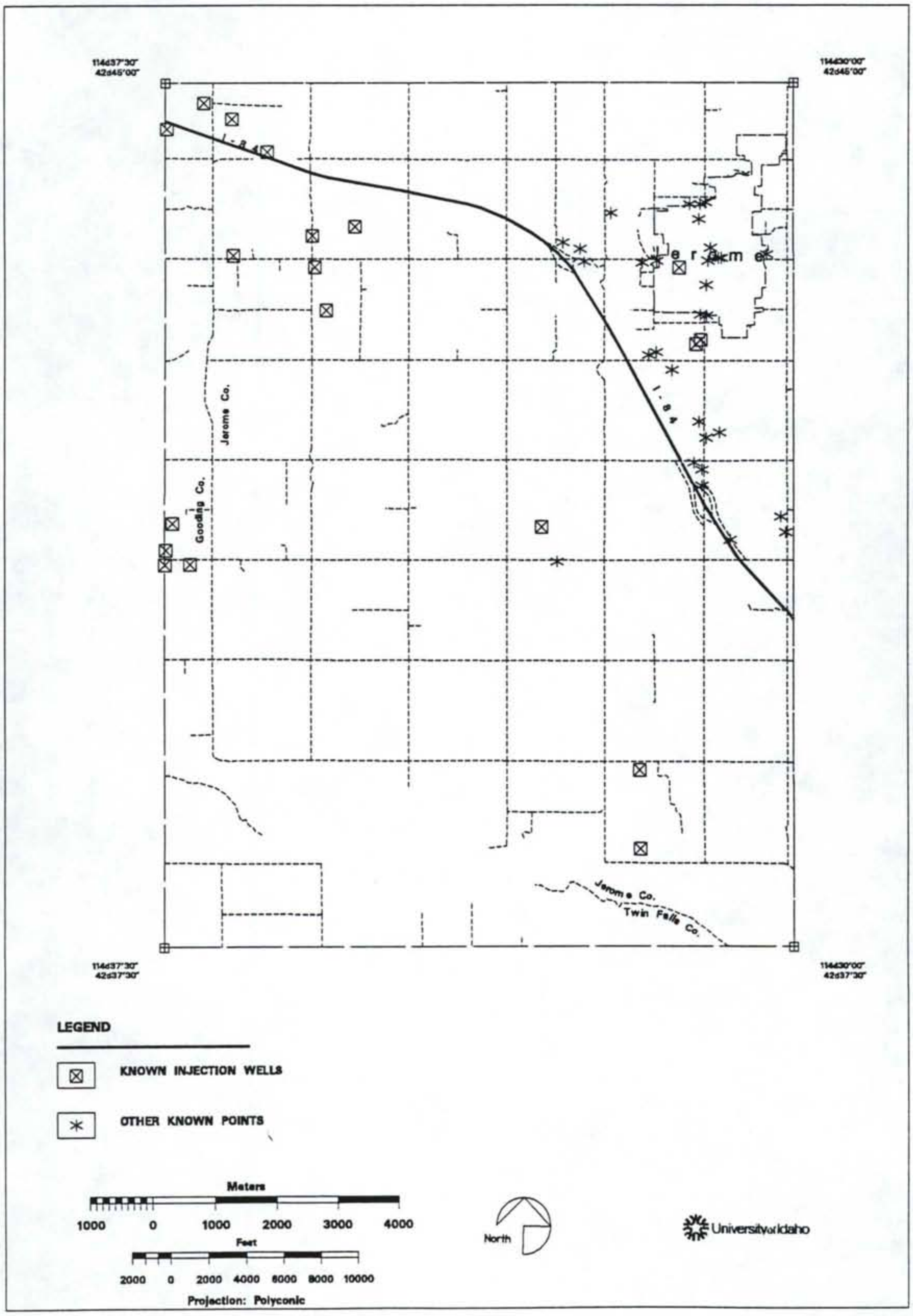


Figure 26
Jerome - Potential Point Sources of Contamination



Injection Wells

The Idaho Department of Water Resources maintains a list of known injection wells and storm drains in Idaho. A field map from 1993 provided locations for Class V, deep (greater than 18 feet) injection wells which had been verified in the study area (Mitchell 1993). The mapped wells are predominantly for agricultural runoff waste water.

Confined Animal Feeding Operations (CAFOs)

The CAFOs were mapped from visual analysis of the ASCS slides and are shown in Figure 27. The visual mapping method resulted in a conservative number of CAFOs identified when compared to a field checked map prepared by the SCS. The visual method was not based on regulatory definitions of CAFOs, but rather those that were evident from the aerial photographs.

Sewage Treatment Plant

The sewage treatment plant for the City of Jerome discharges treated effluent into an irrigation canal.

Public Water Supply Wells

DEQ maintains a data base of public drinking water systems in Idaho. A public water system is defined in the Idaho Rules for Public Drinking Water Systems (IDAPA 16.01.08000) as serving at least 15 service connections or regularly serving at least 25 individuals daily at least 60 days of the year. Public water supply wells permitted in the Jerome study area are shown in Figure 28.

A total of 13 public systems with 15 wells were identified. Examples of public water systems include wells serving municipalities, subdivisions, campgrounds, highway rest areas, businesses, churches and schools and other public buildings which are not served by the municipal water system. Regulations apply to testing of public water systems which do not apply to other types of wells, such as individual domestic wells.

Wellhead Protection

Wellhead protection zones were mapped for the City of Jerome wells only. The city's wells are at three locations, one of which is not on the Jerome Quadrangle, but on the adjoining Falls City Quadrangle. For the wellhead protection coverage, both 7.5 minute U.S.G.S. quadrangles were included and are shown in Figure 29.

The Idaho Wellhead Protection Plan Draft (Idaho Department of Health and Welfare 1992) details three goals for wellhead protection in Idaho. The primary goal is to prevent contamination of drinking water from land use impacts. Prevention actions include

Figure 27
Jerome - Confined Animal Feeding Operations

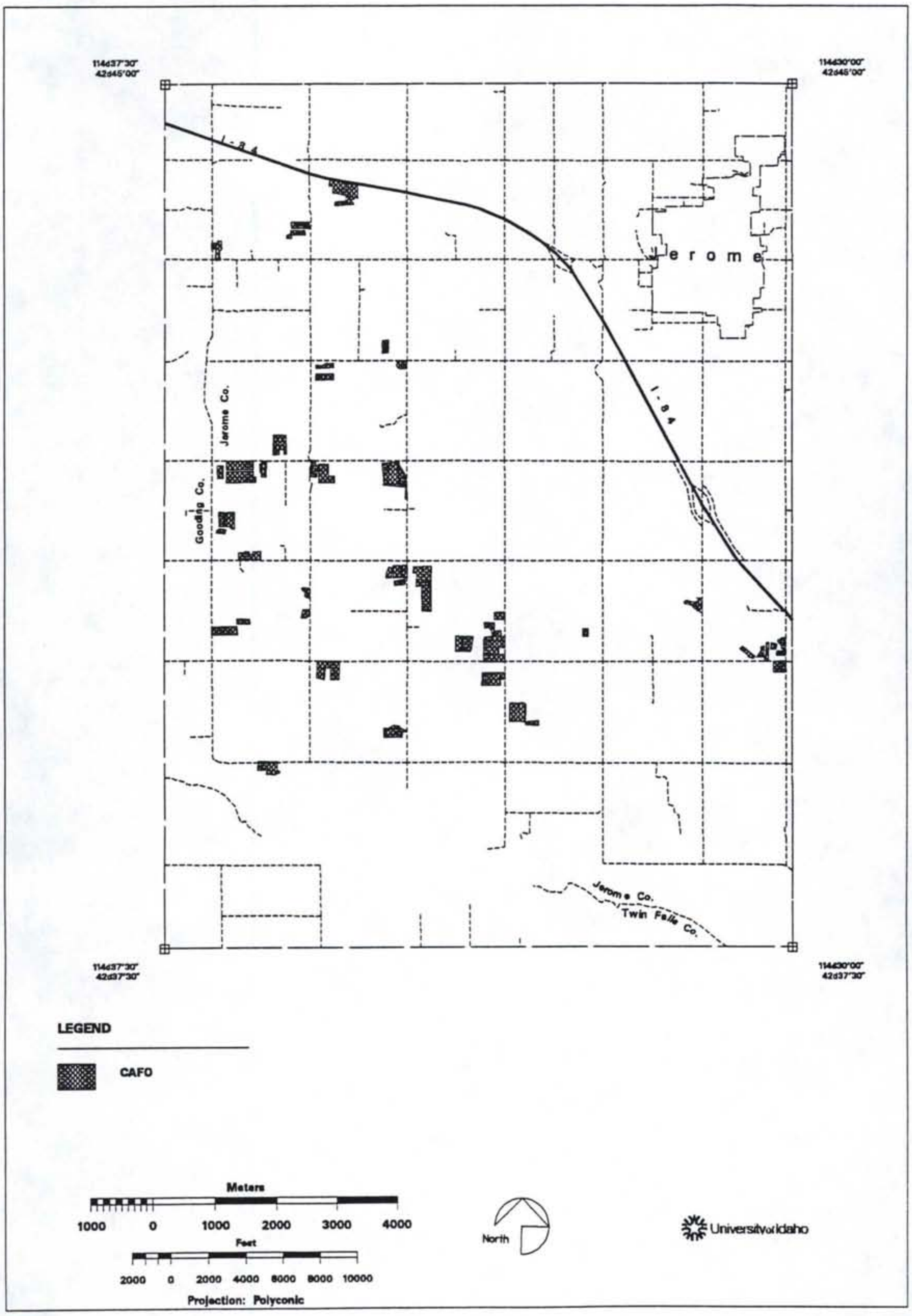


Figure 28
Jerome - Public Water Systems

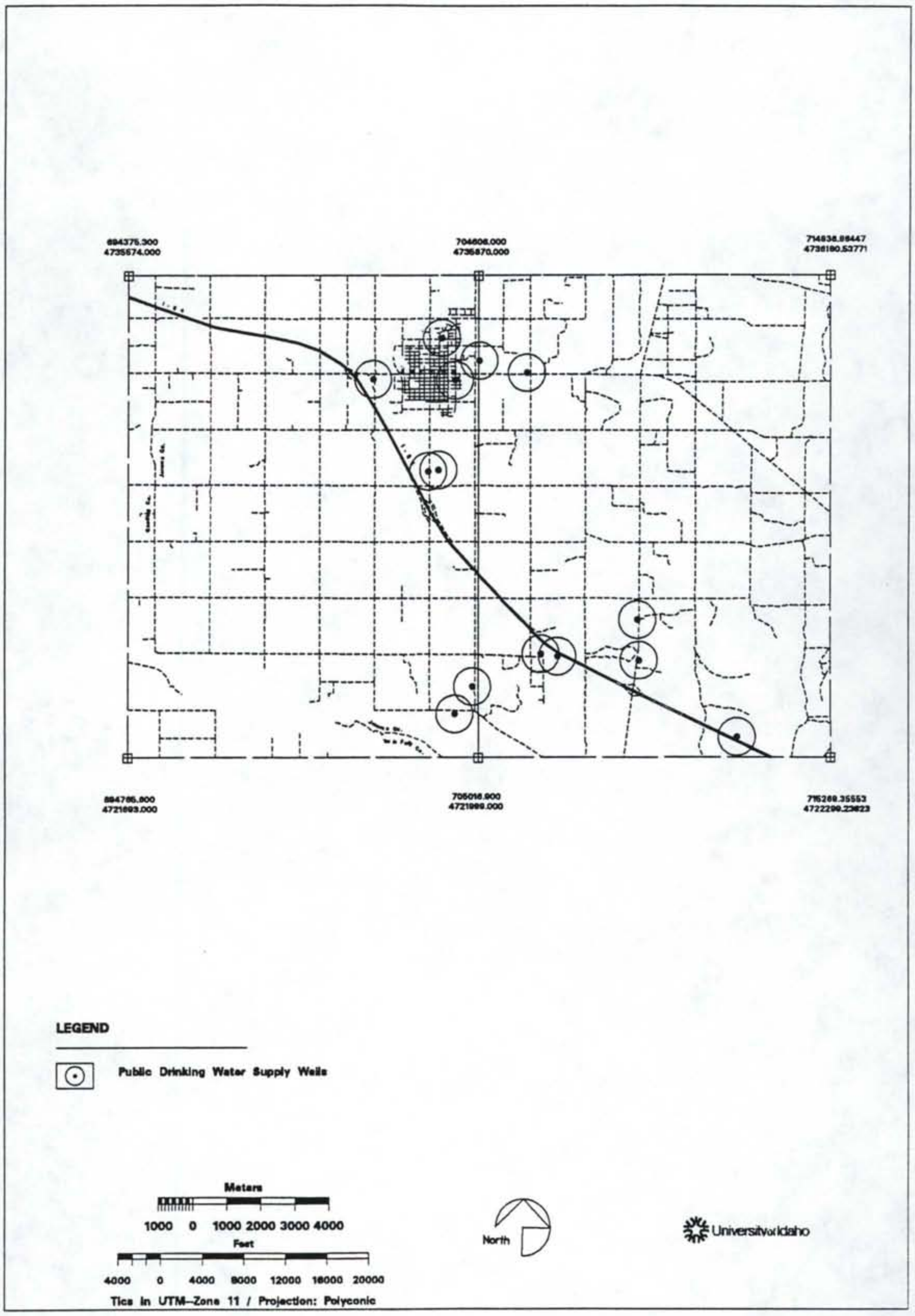
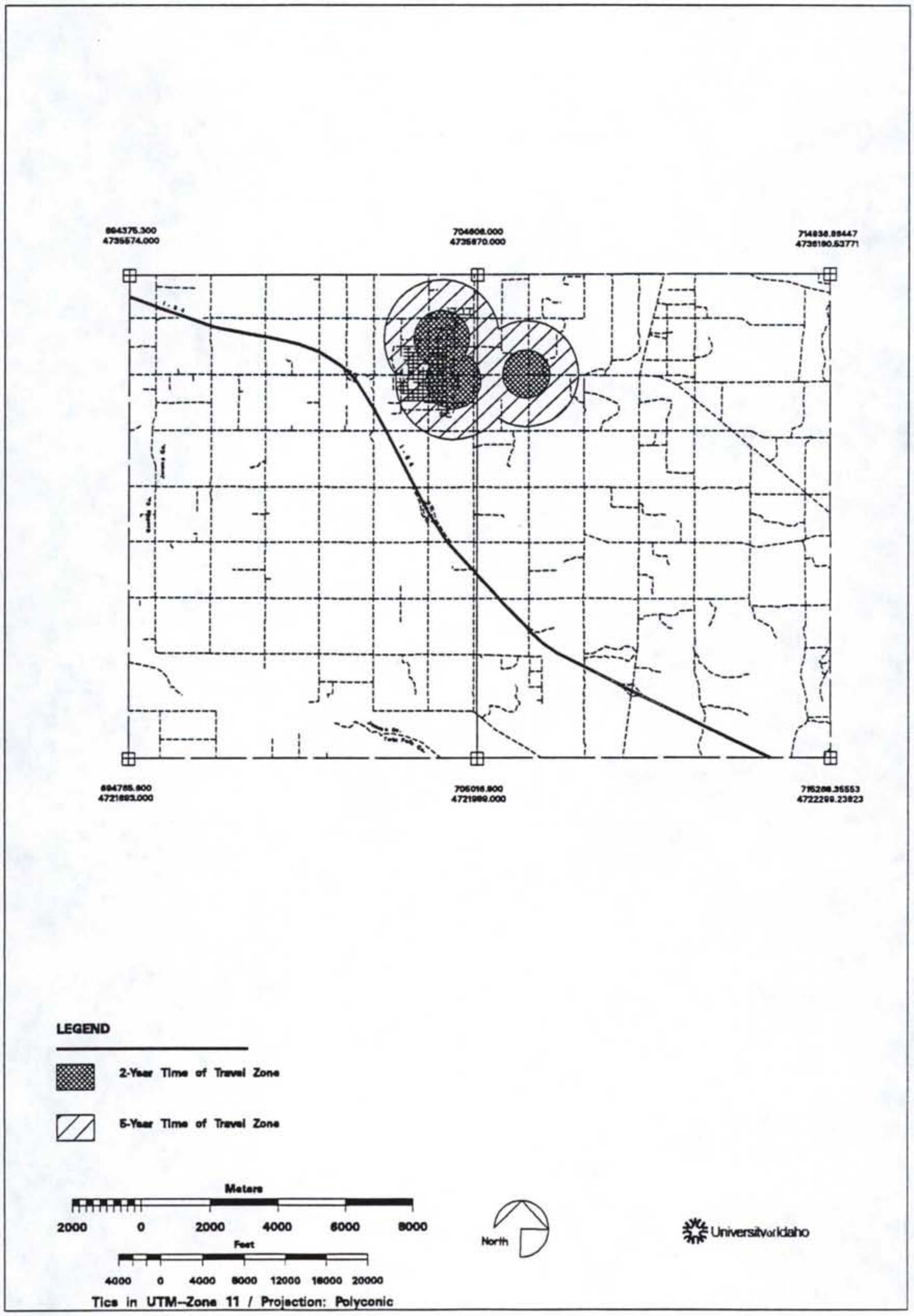


Figure 29
Jerome - Wellhead Protection Zones



implementing best management practices, using local ordinances and providing public education. A secondary goal is to provide a response action area. Response actions would be used when prevention is not feasible or to address existing contamination problems. The last goal is to protect all or a portion of the area of contribution to a well.

There are two main approaches to delineating wellhead protection areas in Idaho -- basic and refined. The basic approach was adopted for this project. The protection zones were delineated using calculated fixed radii based on available, existing hydrogeologic data. The refined approach used site specific data and more sophisticated methods to delineate the protection zones.

Under the basic approach, three protection zones may be defined. Zone IA is an area no smaller than a 50 foot radius around a well and 100 feet around a spring. Zone IB is an area outside the minimum boundaries defined in Zone IA and extending to the two year time of travel boundary. Zone II is an area outside the two year time of travel, extending to the five year time of travel boundary. The time of travel is the time required for a contaminant to move in the saturated zone from a specific point to a well.

Zone 1A is not depicted for the City of Jerome wells because mapping of this small radius requires site specific delineation of the boundary at a map scale of 1:3,600 or larger. That detailed scale of information was not available for this study. The other two zones are mapped based on the information about well yields displayed in Table 11.

Table 11
Radii for Wellhead Protection Zones in Feet

	Rate of Yield (Gallons Per Minute)									
Zone	50	100	500	1000	2000	3000	4000	5000	6000	7000
IB	1800	1800	2000	2300	2700	3100	3500	3900	4200	4600
II	4400	4400	4700	5000	5600	6000	6500	6900	7300	7700

Surficial Geology

Knowledge of the geology and hydrogeology of the unsaturated zone -- the material between the land surface and the water table surface -- is essential to understanding some of the physical factors which influence possible ground water contamination. DEQ contracted with the Idaho Geological Survey to map and describe the surficial geology of western Jerome County and to determine a general methodology for mapping and categorizing the unsaturated zone in terrains similar to the study area.

Although the literature on the Snake River Plain is voluminous, the geology of Jerome County has been studied only on a regional scale prior to the study completed in 1993 (Gillerman and Schiappa 1993). The study, which included a literature review, examination of well drillers' logs, and field mapping at 1:24,000 scale, resulted in identification of nine mapping units (Figure 30), most of which are different basalt flows. The flows were identified through field observation and paleomagnetic differentiation.

Basalt flows in Jerome County show the characteristic hummocky relief on top of the flow due to pressure ridges that form when the basalt cools. There is approximately 25 feet of vertical relief between the bottom and top of fresh pressure ridges. Over time, the low spots on the flow surfaces are filled with windblown material, either sand or silt-sized loess. Consequently, the older flows show less relief and decreasing height of the pressure ridges over the surrounding land surface. On the Snake River Plain, and elsewhere, this geomorphological variation provides a relative time scale to date the basalt lavas. It also controls land use, as the youngest flows have too much rock outcrop to farm.

In western Jerome County, grazing is the predominant land use over the two youngest flows (Qlc and Qss). Older flows have been sufficiently covered with soil and loess or sand to support irrigated farming. However, even the oldest flow has some outcrops, suggesting a maximum depth of soil and sediment cover of 25 to 30 feet.

The Jerome area unsaturated aquifer consists of a thick (100 to 400 feet) stack of olivine tholeiite basalt lavas. Six individual flows can be distinguished on the surface. They probably are a few million years old and erupted from typical shield volcanoes of the Snake River Plain. Local deposits of cinders, palagonite and pillow basalt indicate that some flows entered or erupted through lakes, wet sediments and old river canyons. Cinders, rubble and fracture zones, both vertical and horizontal, may have resulted, controlling the regional ground water flow and spring locations. Well logs, regional geologic patterns and exposures in the canyon walls all suggest that sedimentary interbeds are thin and constitute only local lenses for the upper 400 feet of aquifer in the area.

Most of the cover material consists of windblown silt-sized soil called loess. On the western edge of the mapped area, fine windblown sand is present. Sand is slightly coarser than silt grains. Hydrologically, loess has a property that distinguishes it from most other sedimentary units. Loess commonly has its highest hydraulic conductivity in the vertical direction. This is due to the massive, unstratified or nonlayered nature of the deposit and to the common occurrence of caliche-armored root casts that provide pipe-like conduits for water moving downward in the subsurface.

The study conclusion is that although the ground water is 100 to 400 feet below the surface in the mapping area, it is at high risk of contamination. The lack of thick soil cover, the high vertical permeability of the loess and the basalt, apparent lack of clay in the soil and the lack of sedimentary aquitards within the basalt result in few impediments to transport of contaminants.

Summary of GIS Coverages

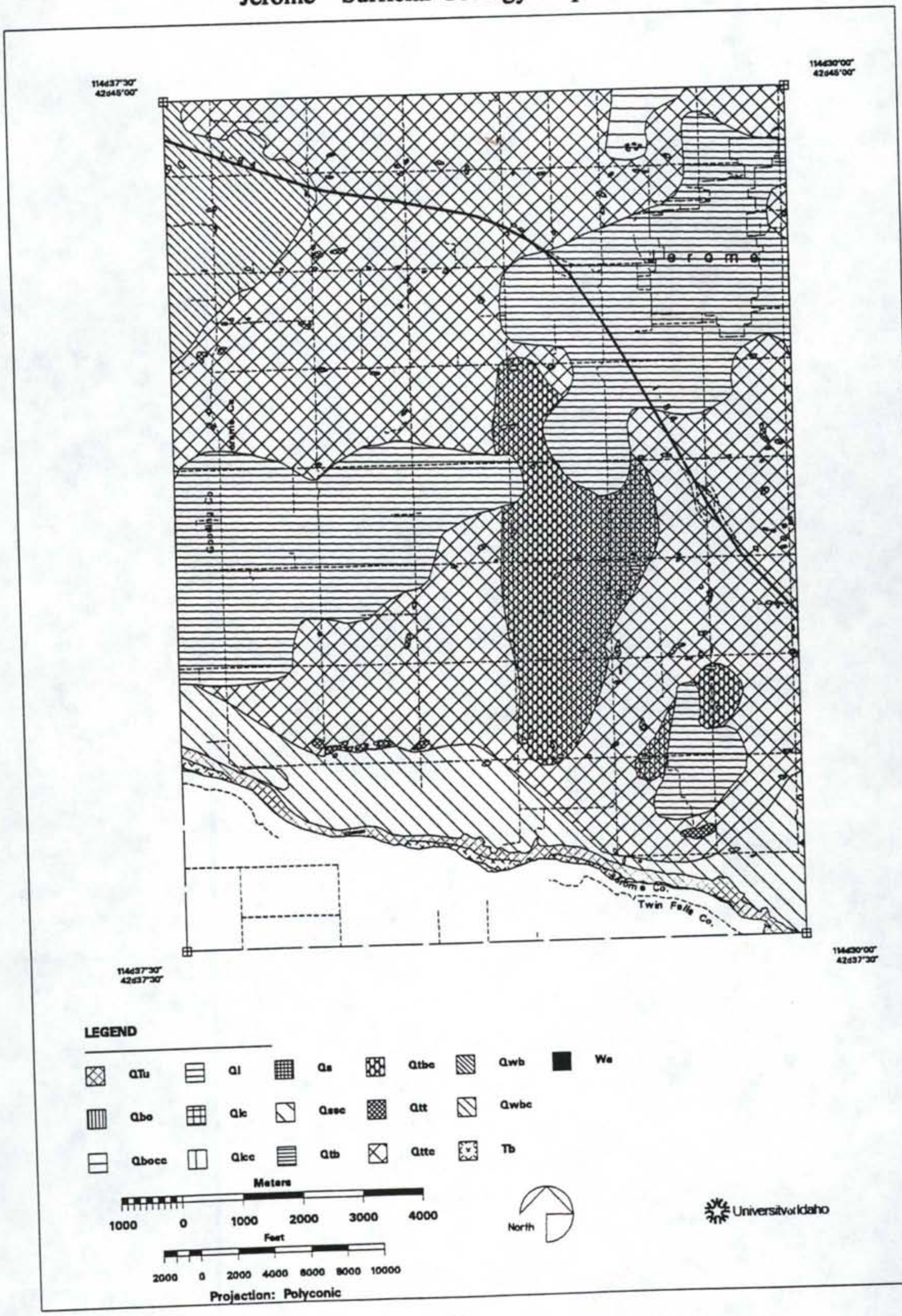
A number of GIS coverages were developed which give a multidimensional view of the study area. By combining the different coverages, analyses of spatial and statistical relationships can be examined. The use of aerial photography provided an up-to-date view of the land uses and activities. Using the GIS, information from the aerial photos was extracted to develop a coverage of septic systems. This information and other data can be superimposed on all or a portion of the study area to show relationships that otherwise may be difficult or impossible to see. Figure 31 is a composite aerial view of the study area with an overlay of roads and streams, and quadrangle boundaries. The data compiled for this portion of the study also provide a baseline of conditions in 1992 - 1993.

Key to Surficial Geology Map - Figure 30

An explanation of geologic mapping units is included in Appendix B.

Ql	**Loess and other surficial material**
Qlcc	**Quaternary cover over basalt**
Qssc	**Quaternary cover over basalt**
Qbocc	**Quaternary cover over basalt**
Qwbc	**Quaternary cover over basalt**
Qttc	**Quaternary cover over basalt**
Qtbc	**Quaternary cover over basalt**
Qlc	**Quaternary Lincoln County basalt**
Qs	**Quaternary Sand Springs basalt**
WA	**Water affected**
Qbo	**Quaternary big olivine basalt**
Qwb	**Quaternary west basalt**
Qtt	**Quaternary Thousand Springs basalt**
Qtb	**Quaternary Thousand Springs black basalt**
QTu	**Quaternary and tertiary undifferentiated**
Tb	**Tertiary Banbury basalt**

Figure 30
Jerome - Surficial Geology Map



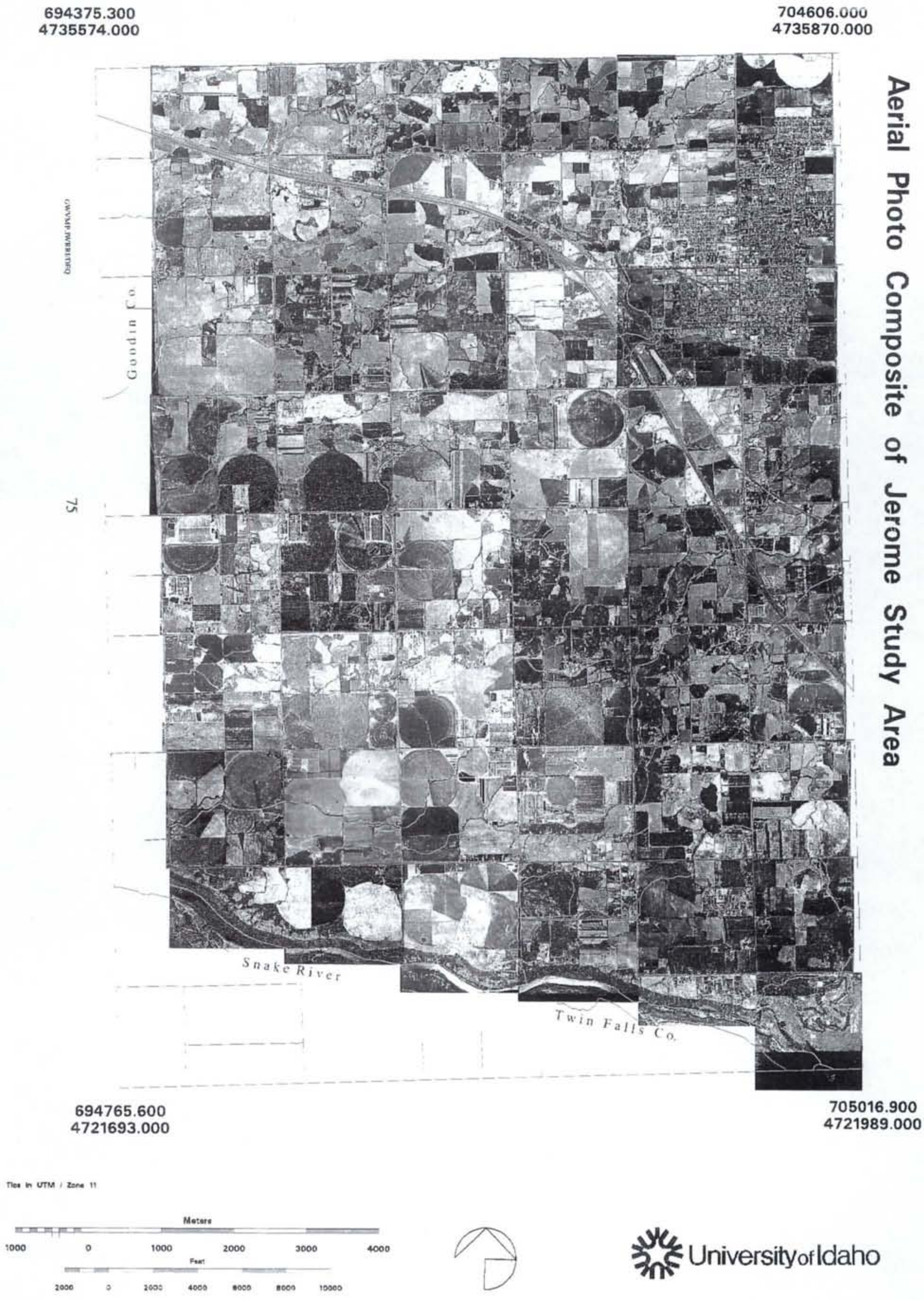


Figure 31
Aerial Photo Composite of Jerome Study Area

Analysis

Jerome Area

Construction of the various GIS coverages for the Jerome Quadrangle created the opportunity to examine relationships between variables associated with the inherent susceptibility of the aquifer and potential contaminant sources and potential contaminant sources and nitrate observations.. The GIS makes possible the intersection of different types of information such as nitrate levels and septic systems, or confined animal feeding operations; soils and septic systems, etc. A spatial comparison can be made visually as well as creating cross referenced categories of variables. For example, a query can be made to show all sampling wells within a certain distance of a LUST site.

A number of relationships were examined for a statistical association between nitrate observations and potential sources of nitrate contamination. The current model, with nitrate as the dependent variable and vulnerability score as the dependent variable, was expanded by incorporating two additional independent variables: distance in meters from a sampling well to the nearest surface water (DISTANCE), and number of septic tanks within a 200 meter buffer around each sampling well (TANK200). Surface water is the artificial surface hydrology created by irrigation canals, ditches, ponds and CAFO lagoons (Figure 19).

The points with zero distance values in Figures 31 and 32 represent sampled wells that are within a five meter buffer of surface water. Values greater than zero represent the distance, in meters, from the five meter buffer. The surface water features were buffered by five meters to distribute spatially a potential error in the geographic location of these features.

First, each new variable was regressed on nitrates. Then the new variables were incorporated into the model statement along with the vulnerability score. Finally, the interaction effect between DISTANCE and TANK200 was tested by incorporating into the equation an additional term: DISTANCE*TANK200. On its own, DISTANCE was not significant.

A scatterplot showed one nitrate observation of 5.66 mg/l appearing as an outlier. The effects of that observation on the regression lines were plotted and are shown in Figures 31 and 32. The nitrate observation had a positive pulling effect on the DISTANCE regression line and an insignificant negative pulling effect on the TANKS200 regression line.

The large circle in the upper right of Figure 32 denotes the pulling effect of one sample point (5.6 mg/l) on the correlation coefficient ($R = 0.32$). A correlation coefficient may be a number between -1.0 and 1.0 which indicates the relative strength of a relationship. Figures 31 and 32 are influence plots. These plots display the influence of each point on the slope of the fitted regression line. The larger the size of the circle, the larger the influence of a given point.

Figure 32
Influence of Nitrate Observation (5.66 mg/l) on Nitrate vs Distance

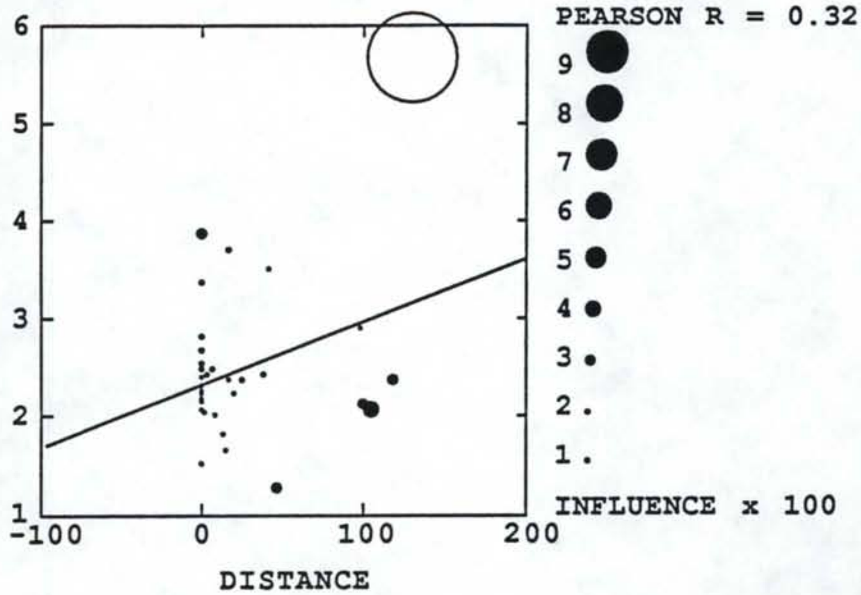
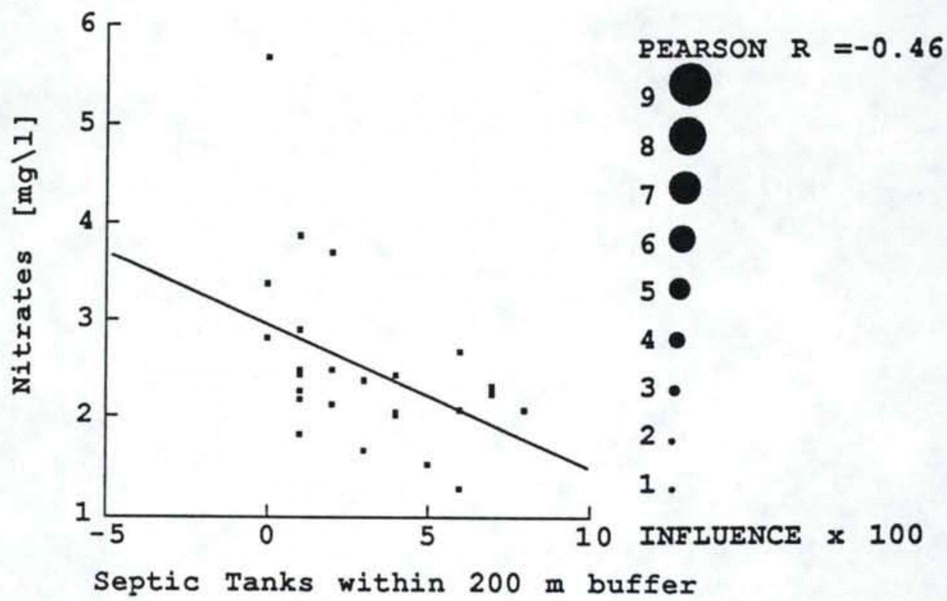


Figure 33
Influence of Nitrate Observation (5.66 mg/l) on Nitrate vs Septic Tanks



The fact that the well with the nitrate level of 5.6 mg/l has a zero value on the ordinate axis in Figure 33 means that there is not a septic tank within the 200 meter buffer of this well. The negative correlation coefficient indicates there is an inverse relationship between observed nitrates and number of septic systems within the buffer.

The regression analysis was repeated for the data set without the 5.66 mg/l nitrate observation. The results of both analyses are summarized in Table 12.

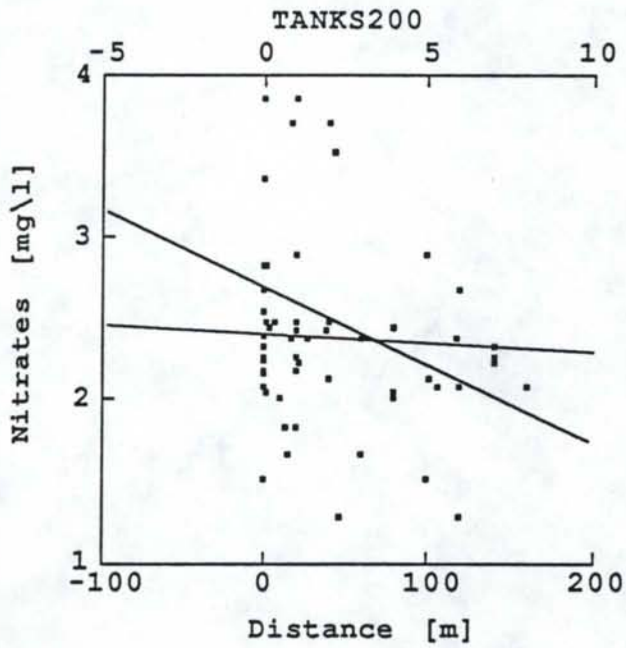
Table 12
Summary of Regression Results for the Jerome Area
N = 35

	Entire Data Set		Data Set Without 5.66 mg/l	
Independent Variables	R^2	P	R^2	P
Distance	0.10	0.06	0.01	0.84
Tanks200	0.21	0.02	0.21	0.02
Vulnerability Distance Tanks200	0.29	0.04	0.19	0.17
Vulnerability Distance Tanks200 Distance*Tanks	0.46	0.01	0.20	0.27

The regression results show that the exclusion of the highest nitrate observation does have a strong effect on the regression of distance on nitrates. The result is not the same for septic tanks regressed on nitrates, which remains significant. The weakened interaction between distance and septic tanks is shown in Figure 34.

Other relationships between nitrates and distance to CAFOs and point sources were examined and found to be statistically not significant. However, the conclusion of no relationships between those variables and nitrates is not certain, due to the sparse nitrate data and their uneven distribution across the study area. In order to be able to perform more specific investigations, more work needs to be done on determining contaminant loading from potential sources. For example, estimated nitrogen use by county is not specific enough. Nitrogen application rates in identified areas such as fields or farms can be mapped and related to a data base containing information such as depth to water, nitrate levels, etc.

Figure 34
Regressions of Nitrates vs Distance vs Septic Tanks Without the 5.66 mg/l Observation



Rathdrum Prairie

Due to the availability of data, only distance from a wetland as defined in the National Wetlands Inventory (USFWS 1991), was incorporated into the regression equation as an independent variable with vulnerability score. Whereas the NWI map of the Jerome study area primarily depicted surface hydrology associated with the irrigation system, the wetlands in the Rathdrum area tend to be naturally occurring. Figure 35, a scatterplot of the observations and regression line, shows a negative relationship between nitrate levels and proximity to the nearest wetland or other surface hydrological feature. The regression results show a positive interaction effect between the vulnerability score and the proximity to a wetland or other surface hydrology. Regression results are summarized in Table 13.

Figure 35
Scatterplot of Data Points and the Fitted Regression Line for Nitrate vs Distance

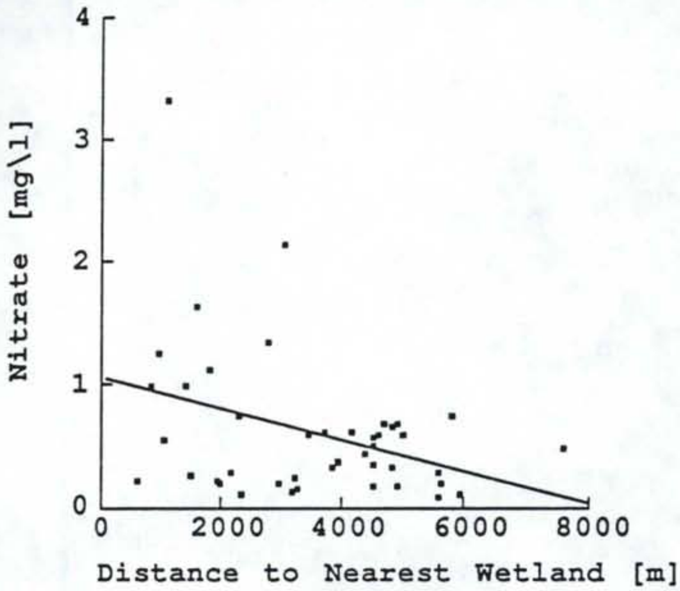


Table 13
Summary of Regression Results for Rathdrum Prairie
N = 44

Independent Variables	R^2	P
Distance	0.13	0.02
Vulnerability Distance	0.20	0.01
Vulnerability Distance Distance* Vulnerability	0.40	0.001

Summary

The analysis shows for both a portion of the Snake River Plain and the Rathdrum Prairie aquifers there are statistical relationships between nitrates and septic systems and nitrates and distance to wetlands or surface water. The results of the analysis, although promising in terms of identifying additional explanatory variables, cannot be treated as conclusive due to the small number of data points and their uneven spatial distribution. The results indicate the association between nitrates and proximity to wetlands and the number of septic tanks without demonstrating causal relationships.

PART 3

Conclusions and Recommendations

The three main tasks of the study were to: apply the rating system to other types of aquifers; perform a verification of the rating system for its validity and reliability, and to map components of ground water vulnerability at a detailed scale, modifying the assessment method as necessary. In completing these tasks, a number of conclusions and recommendations were developed. The task related conclusions and recommendations will be discussed first. Other conclusions, related to data sources and technical aspects of constructing the GIS coverages will be discussed second. Suggestions for future research conclude this part of the report.

Conclusions from Task Completion

Application of the Rating System to Other Aquifers

The lack of existing data for depth to water, soils and recharge, presented some challenges in applying the rating system to the Rathdrum Prairie and Big Wood River aquifers. It is likely that similar lack of data would be a problem over much of the state. For example, it was possible to construct the depth to water coverage for a portion of the Big Wood River Valley aquifer only because of data from a new research project. The soils were, however, available only at a scale of 1:250,000, from the STATSGO data base for the Big Wood River area. This resulted in incongruence of scales of data and over generalization of the soils coverage. Land use information was from the early 1980s. Many land use changes have occurred in the Big Wood River valley since that time.

Another difficulty in applying the rating system to other aquifers occurred when situations not included in the system developed by Rupert et al. were encountered. For example, surface water was explicitly excluded from the Rupert system. In the Big Wood River area there were negative depth to water values where ground water was at the land surface. Also, urban areas were excluded from the Rupert system, but on the Rathdrum Prairie, the highest nitrate observations were found in urban areas. Decision criteria for situations found in other parts of the state would need to be developed for a rating system to be applied statewide.

It appears that land use is not a suitable indicator of recharge in all areas of the state. In the southern part of the state, irrigated agriculture and the surface hydrology created by the irrigation systems are a significant contributor in recharge. Mapping those land uses may indicate recharge potential. In northern Idaho and some of the intermontane valleys, recharge occurs from precipitation and surface water. Although land use modifies recharge, it does not appear to indicate actual recharge areas or rates.

Verification of the Rating System

The lack of data was a problem for the verification analyses as well. The data about the independent and dependent variables that do exist often are difficult to find and to access. In the next few years this may be less of a problem as the Environmental Data Management System (EDMS) being developed by the Idaho Department of Water Resources acquires more existing data and cooperators who will enter their data into the system.

The dependent variable in the analysis was nitrate observations. The generally small number of nitrate samples, and their uneven temporal and spatial distributions preclude making definitive conclusions about statistical relationships between the rating system and ground water contamination by nitrates.

A question to be addressed is whether total nitrate level is the most appropriate dependent variable. Nitrate observations were chosen because of the relative availability of data compared to data on chlorides, bacteria, pesticides or other water quality parameters. There may be relationships between independent variables and other water quality parameters which were not tested due to lack of data.

The verification process showed a statistically significant, weakly linear association with nitrate levels for the eastern Snake River Plain. The same relationship was not found in two other parts of the state where the system was tested at the regional level. The statistical relationship may be due to the large number of observations, which could result in a statistically significant relationship, but one where the explained variance is very low.

A General Accounting Office (GAO) report which analyzed 40 ground water vulnerability assessment methods, concluded that the models examined have not been shown to predict ground water contamination accurately (U.S.G.A.O. 1992). The methods focused on susceptibility factors and did not include contaminant loading. The results of the analysis suggest that the models suffer from a lack of sound scientific basis. "In most cases they appear to be oversimplifications and therefore cannot be used to make consistently accurate predictions" (p. 63).

The GAO report also concluded that the models generally have not been tested at the subcounty level, which is the appropriate level for a differential protection strategy for ground water. The three variables used in the Rupert et al. system may be necessary, but not sufficient to capture the variability within and between aquifer systems. Consequently, a rating system based on depth to water, recharge and soils may be just a starting point in identifying factors with varying levels of importance in ground water systems across the variable hydrogeologic conditions of Idaho.

Mapping at a Detailed Scale - Jerome Area

The Rupert et al. system was applied to variables mapped at a scale of 1:100,000. The Jerome area pilot project was mapped at the subcounty scale of 1:24,000. The Jerome area was chosen for this mapping effort largely because several GIS coverages and water quality data existed for this western portion of the Scott's Pond project area.

Constructing the new GIS coverages presented some challenges due to lack of data and the costs of data generation. The aerial photos from the ASCS, digitally pieced together to create a composite aerial photograph of the study area, provided recent information about the area which was used to create or to verify other coverages. Without the aerial photos, it would have been impossible to develop the septic system point coverage, for example. They also were useful in verifying some land use information and in seeing spatial relationships and distributions of land uses.

Although the soils and land use (recharge) coverages were available in digital format for the Jerome study area, depth to water was not. This was the costliest data to generate as it entailed making a mass measurement of depth to water in a network of wells across the study area. The effort was led by a graduate student in hydrogeology from Boise State University who assembled a team of students to log most of the raw data over a two day period (Norris-Willing 1993). Accurate depth to water mapping is important information as it establishes generalized flow patterns and the gradient of ground water at contour intervals of 10 feet..

The surficial geology map created by the Idaho Geological Survey depicts a somewhat homogeneous subsurface, but one that includes fairly random fractures of the basalt. This leads to the conclusion that it is not possible to map susceptible zones, such as areas of interbedded gravels or sediments, which may be recharge zones to ground water. Conversely, the areas of contact of the different flows may provide pathways to ground water. More specific investigation of the unsaturated zone would lead to greater understanding of recharge mechanisms and contaminant transport in this area of the eastern Snake Plain aquifer where several land uses were found to relate to nitrate observations.

The statistical analysis showed relationships between nitrates and natural wetlands and surface water and irrigation canals, ditches, ponds and septic systems. Other relationships, between CAFOS and point sources and nitrates were not statistically significant. The strength of the conclusions are tempered by the small number of nitrate observations, and their uneven distribution in time and space. For future statistical analyses, a greater number of dependent variable observations spread more evenly across a study area and with sufficient observations at different time periods, may result in more conclusive evidence regarding relationships between the independent and dependent variables.

General Conclusions

The use of aerial photography to document types of land use activities and spatial relationships enhanced this project. The photographs used in this study were ones that had been made for another purpose. Even more information relevant to ground water vulnerability mapping could have been obtained from aerial photographs taken according to project specifications for time of year, scale, type of film, etc. The use of aerial photography and remote sensing should be included as an element in further applications of vulnerability mapping for surface and/or ground water.

There continue to be problems in using TIGER-II for mapping septic locations as house addresses still require digital conversions if they are to be matched with the TIGER-II data. If pertinent information from the septic permits, including location address, was entered into a digital database at the time of application for a septic permit, accurate descriptions and locations of systems could be input to a GIS.

Another problem with accurate locations occurred because the existing well databases are too general to use with modern geo-referencing in the GIS. For example, primarily due to the legal requirement imposed by the Public Land Survey System, wells in the U.S. Geological Survey National Water Information System, are geographically referenced by township-range notation to the quarter quarter section. This limits the spatial accuracy and resolution of the well data. With appropriate use of global positioning satellite (GPS) technology, the spatial accuracy of the data will be greatly improved. Several projects, to locate LUST/UST sites and public water supply wells using GPS are being undertaken by DEQ, but results were not available for this study.

The statistically significant relationships identified for the Jerome area indicate this scale and these specific types of variables are appropriate for investigating ground water vulnerability at the subcounty level. A methodology that addresses variables at the map scale of 1:24,000 may be possible to develop. It was easier and less costly to develop the data and GIS coverages for some contaminant loading sources, or vulnerability factors, than for the inherent hydrogeological factors associated with susceptibility.

The analysis, though promising, is incomplete in several areas. Information about the vadose zone and specific characteristics of the aquifer, such as conductivity, limited the ability to undertake a technical assessment of what may be key susceptibility factors in the Jerome area.

Also, some key vulnerability factors were not measured. The data does not currently exist to measure the loading contributions of some agricultural activities, especially nutrients and pesticides used on crops, and on nutrient contributions from CAFOS. In addition, urban and suburban contributions of nutrients and agricultural chemicals may be substantial, but they are unknown. While some data are available on a county level, without developing and testing methods of estimation, verified through field observation or surveys of residents, it is impossible to allocate use levels to geographic locations. Due to the inherent variability in physical conditions across the study area, an assessment of ground water vulnerability with a high level of certainty and predictability will not be possible without location specific data.

Recommendations for Future Research and Applications

A report by the National Research Council (1993), "Ground Water Vulnerability Assessment," lists recommendations for a research agenda (p. 10 and 11) aimed at reducing uncertainty in vulnerability assessments and improving opportunities to use them effectively. They correspond to and extend the research and informational needs identified during the work to map ground water vulnerability in Idaho. Some of the recommendations are broad, such as:

- Develop a better understanding of all processes that affect the transport and fate of contaminants.
- Improve the chemical databases, currently the source of much uncertainty in vulnerability assessments.

Others relate to site specific considerations, such as:

- Determine the circumstances in which the properties of the intermediate vadose zone are critical to vulnerability assessments and develop methods for characterizing the zone for assessments.
- Develop methods for accounting for soil macropores and other preferential flow pathways that can affect vulnerability. These investigations should include evaluations of the uncertainty in methods and measurements as they affect the assessment.

Still others identify needs for processes which are applicable in all vulnerability assessments. These include:

- Establish more meaningful categories of vulnerability for assessment methods.
- Determine which processes are most important to incorporate into vulnerability assessments at different spatial scales.

This study is a step in developing approaches and variables in ground water vulnerability prediction. Regardless of the method, much data on attributes and geography are required to conduct a ground water vulnerability assessment. In addition, suitable analytical tools are required to prepare, combine, study and display the various components of the assessment.

This project demonstrated the value of using GIS as a way to store and create information about an area and to analyze it. Using digital data and a GIS allows the analysis process to be dynamic and updated as more data become available. In the future, other statistical analyses should be employed to investigate different types of relationships between variables.

Because data generation and collection is expensive, additional planning is recommended before undertaking further vulnerability assessments. Several questions may be raised about the reasons for undertaking vulnerability assessment and who will use the information.

- What type of vulnerability assessment is desirable?

There are two general types of vulnerability assessments. One seeks to identify specific vulnerability referenced to a specific contaminant, contaminant class or human activity. The other addresses intrinsic susceptibility and is for assessments that do not consider the attributes and behavior of specific contaminants.

- What is the intended use of the vulnerability assessment?

The National Research Council (1993) identified four broad categories. First, assessments can be used in the policy analysis and development processes to identify potential for ground water contamination and the need for protection and to aid in examining the relative impacts of alternative ways to control contamination.

Second, vulnerability assessments can be used in program management to guide allocation of scarce resources and target areas where the greatest levels of effort are warranted.

Third, vulnerability assessments may be used to inform land use decisions such as alteration of land use activities to reflect the potential for ground water contamination. Or, they may be used to develop best management practices that land owners and users may adopt as they become more aware of the ground water impacts of their activities.

Finally, is the use of vulnerability assessments to improve general education and awareness of a region's hydrologic resources.

- What technical and institutional considerations need to be taken into account in developing a vulnerability assessment?

Technical considerations include an evaluation of the type and form of the results or output. Is a vulnerability map the most appropriate, or a table of activities and probabilities of contamination? The adequacy of the data available or to be collected and the analysis of uncertainty in the assessment and how it may affect the consequent decisions should be considered.

Institutional issues include the time frame in which the assessment is meant to apply, how the vulnerability assessment will be coordinated with other programs and needs, and the cost of the assessment and the value of the information to be gained. The availability of personnel and physical or equipment resources to perform an assessment should be considered along with the plans and activities of other agencies that may have an interest in the assessment.

The questions are appropriate in light of the findings of this study. The verification analysis did identify relationships between some wetlands (including canals, ponds and lakes), and septic systems and nitrates. This shows that a refined mapping approach, considering site specific variables, has potential for identifying vulnerability for types of land uses and potential contaminant sources in an area.

Enough site specific information has been accumulated for this portion of the eastern Snake River Plain aquifer, that a complete hydrogeological picture of the area, overlain by general land uses and human activities is nearly complete. The benefits of continuing research in this area could result in identifying critical variables to ground water vulnerability for the fractured basalts of the eastern Snake River Plain. A vulnerability model which would be valid and reliable just for this aquifer would result in substantial protection of drinking water and beneficial uses due to the large number of people and activities dependent on the water from the Snake River Plain aquifer. However, it is not likely that variables developed for the Snake River Plain are directly transferrable to other ground water resources in Idaho.

Recharge amounts and mechanisms should be addressed in future research in Idaho. Surficial mapping should occur on a watershed or subwatershed basis so interconnections between surface and ground water can be identified and quantified. At the map scale of 1:24,000, it may be possible to identify naturally and artificially occurring recharge areas. In addition, the precipitation patterns and influence on recharge should be investigated. Whereas in southern Idaho the assumption is that most recharge is from irrigated agriculture, water quality monitoring in the Scott's Pond SAWQP indicates that contaminants are flushed into the ground water with late winter and spring snowmelt. The Idaho Ground Water Model is being applied by the Idaho Department of Water Resources across the Snake River Plain. When this model is verified, it may provide a useful tool in describing and quantifying localized recharge to this large aquifer.

At the same time, a different approach to protecting ground water might be more cost effective and easier to implement at a detailed scale for those areas where extensive data on inherent susceptibility factors are not available. Some method of risk based assessment, considering the activities that are occurring on the land surface, and the number of people or economic uses at risk, may produce reliable results in the absence of extensive hydrogeologic data.

This risk approach could have the dual benefit of protecting surface and ground water as most recharge to ground water is from surface water. For any ground water resource, the contributing surface watersheds would be important in mapping risk variables. The risk variables could be categorized in a number of different ways. A simple matrix (see Table 14) along the dimensions of probability of contamination and level of contamination illustrates one possible way to begin categorizing risks to ground water from human activities.

Methods to rank the risks of an area along the dimensions of probability and level of contamination could be applied to any ground water resources. The methodology could be the same across the state, but the contents of the cells would reflect the conditions of an identified geographic area.

Table 14
Matrix for Assessing Risk to Ground Water
From Potential Contaminant Sources

	Low Probability of Contamination	**High Probability of Contamination**
Low Level of Contamination		
High Level of Contamination		

The development of any type of rating system needs to incorporate information from local experts. For example, when Dr. Chang presented preliminary results of the vulnerability rating for the Rathdrum Prairie to the North Idaho Regional Office of DEQ, the staff had several suggestions for variables which may be important to their area. They believed industrialization should be included in the model and the depth to water layer should be given less weight. Developing regional or smaller scale models would preclude creating a standard model for the entire state. However, the regional models could capture the variability in the known susceptibility and contaminant loading potential of an area.

The matrix could be a useful tool for managers to rank the relative risks to ground water associated with the predominant land uses and activities of their area. For example, septic systems may be identified as having a high probability of a low level of contamination. Or, in areas with industries which use or transfer potential contaminants, an industrial park may be identified as having a low probability of contamination (based on probability of an accident), coupled with a high level of contamination. Best management practices may be introduced, or ordinances developed, which would further reduce the risk of an accident or the potential level of contamination. The management goal would be to move activities from the high probability or contamination cells to the low cells.

Future research efforts involving social data about the population of an area and its characteristics should include use of the new TIGER-II files which will include greater address ranges and improved accuracy. This database includes potentially valuable information which is readily available. As the accuracy is improved, it may be a dependable, useful source of information and a way to identify how the identified risks may affect the population, in total or in part.

There are several directions which future ground water vulnerability studies could take. Addressing the questions raised in the future research section may help target scarce resources to achieve the greatest possible protection of Idaho's ground water resources.

Appendix A

Polygon Values for Soils and Ground Water Vulnerability Ratings

Appendix A-1
Soils Ratings for Rathdrum Prairie

SCSSOIL	FREQ	ANFLOOD	PERM	WTDEPL	ROCKDEPL	SOILRATE
0	15					
2	16	NONE	0.60	6.00	60	21
3	7	NONE	0.60	6.00	60	21
10	2	NONE	6.00	0.00	65	75
11	1	NONE	6.00	0.00	65	75
15	2	FREQ	2.00	0.00	65	66
20	5	NONE	2.00	6.00	60	27
23	11	NONE	0.60	6.00	60	21
24	6	NONE	0.60	6.00	60	21
25	5	NONE	20.00	0.00	65	87
28	6	NONE	2.00	6.00	20	39
29	1	NONE	0.60	0.00	60	48
35	1	NONE	6.00	0.00	65	75
42	1	FREQ	2.00	0.00	65	66
43	1	NONE	0.60	6.00	60	21
45	5	NONE	0.60	6.00	60	21
52	1	NONE	20.00	0.00	65	87
55	10	NONE	20.00	0.00	65	87
59	1	NONE	6.00	0.00	60	78
63	1	NONE	6.00	0.00	60	78
100	1	NONE	0.00	0.00	0	0
101	2	NONE	0.20	0.00	60	39
102	3	NONE	2.00	6.00	60	27
103	7	NONE	0.60	6.00	20	21
104	48	NONE	0.60	6.00	60	21
105	2	NONE	0.60	6.00	20	33
106	1	NONE	0.60	6.00	20	33
107	30	NONE	0.60	6.00	60	21
108	12	NONE	0.60	6.00	60	21
110	1	OCCAS	0.20	3.00	60	54
118	2	NONE	6.00	0.00	0	72
119	3	NONE	0.60	6.00	60	21
120	31	NONE	0.60	6.00	60	21
121	25	NONE	0.00	0.00	0	0
126	19	NONE	0.60	6.00	60	21
127	28	NONE	0.60	6.00	60	21
128	2	NONE	0.60	6.00	60	21
129	6	NONE	0.60	6.00	60	21
130	2	NONE	2.00	6.00	60	27
134	1	NONE	0.20	6.00	40	18
136	6	NONE	0.60	6.00	10	42
142	5	NONE	0.60	6.12	20	33
143	2	NONE	0.60	6.00	20	33
144	6	NONE	0.60	6.00	20	33
145	18	NONE	0.60	6.00	20	33

Appendix A-1

146	1	NONE	0.60	6.00	40	24
148	2	NONE	0.60	6.00	20	33
149	15	NONE	2.00	6.00	60	27
150	19	NONE	2.00	6.00	60	27
151	1	NONE	0.06	1.00	60	33
156	72	FREQ	0.60	3.00	60	60
158	1	FREQ	0.20	1.50	60	54
159	2	FREQ	0.60	0.10	60	60
160	2	FREQ	0.60	1.00	60	60
161	42	NONE	0.60	6.00	60	21
162	3	NONE	2.00	6.00	60	27
163	11	NONE	0.00	0.00	0	0
164	1	NONE	0.06	1.00	60	33
166	1	NONE	0.06	0.00	0	33
171	1	NONE	0.20	6.00	20	27
174	3	NONE	2.00	6.00	60	27
177	3	NONE	2.00	0.00	40	63
178	7	NONE	0.60	6.00	20	33
179	1	NONE	0.00	0.00	0	0
183	5	NONE	0.60	6.00	20	33
184	1	NONE	0.60	6.00	20	33
185	1	NONE	0.60	6.00	20	33
194	5	NONE	2.00	6.00	40	30
195	1	NONE	0.60	6.00	40	24
198	4	NONE	0.60	6.00	40	24
199	3	NONE	0.60	6.00	40	24
201	1	NONE	0.60	6.00	20	24

FREQ: frequency of SCSSOIL; ANFLOOD: flooding; PERM: permiability; WTDEPL: depth to water table; ROCKDEPL: depth to bedrock; SOILRATE: soil rating multiplied by a weight of 3.

Appendix A-2
Ground Water Vulnerability Rating
By Polygon for Rathdrum Prairie

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
0	0	0	0	0
1	91	20	50	21
2	91	20	50	21
3	91	20	50	21
4	91	20	50	21
5	91	20	50	21
6	145	20	50	75
7	76	20	35	21
8	157	20	50	87
9	76	20	35	21
10	101	30	50	21
11	86	30	35	21
12	130	20	35	75
13	167	30	50	87
14	0	30	50	0
15	140	30	35	75
16	101	30	50	21
17	86	30	35	21
18	167	30	50	87
19	101	30	50	21
20	152	30	35	87
21	142	20	35	87
22	152	30	35	87
23	167	30	50	87
24	67	30	10	27
25	127	30	10	87
26	142	20	35	87
27	61	20	20	21
28	127	20	20	87
29	127	20	20	87
30	61	20	20	21
31	88	30	10	48
32	79	30	10	39
33	61	30	10	21
34	142	20	35	87
35	125	30	20	75
36	127	20	20	87
37	61	20	20	21
38	137	30	20	87
39	127	20	20	87
40	137	30	20	87
41	71	30	20	21
42	61	20	20	21
43	71	30	20	21
44	115	20	20	75
45	79	30	10	39
46	0	30	10	0
47	152	30	35	87
48	61	30	10	21
49	137	30	20	87
50	71	30	20	21
51	142	20	35	87
52	71	30	20	21
53	127	20	20	87
54	71	30	20	21
55	61	30	10	21
56	127	20	20	87
57	0	0	0	87

VULNER_ID	VULRATE	LURATE	DWRATE	SOILRATE
58	0	0	0	21
59	86	30	35	21
60	142	20	35	87
61	86	30	35	21
62	71	30	20	21
63	86	30	35	21
64	121	20	35	66
65	71	30	20	21
66	61	20	20	21
67	67	30	10	27
68	127	30	10	87
69	61	20	20	21
70	61	30	10	21
71	61	30	10	21
72	71	30	20	21
73	77	40	10	27
74	67	30	10	27
75	71	30	20	21
76	127	20	20	87
77	127	20	20	87
78	61	20	20	21
79	127	20	20	87
80	125	30	20	75
81	61	30	10	21
82	51	20	10	21
83	71	30	20	21
84	61	30	10	21
85	71	30	20	21
86	106	30	10	66
87	61	20	20	21
88	137	30	20	87
89	71	30	20	21
90	51	20	10	21
91	127	20	20	87
92	71	30	20	21
93	61	30	10	21
94	58	30	1	27
95	117	20	10	87
96	137	30	20	87
97	127	30	10	87
98	61	30	10	21
99	52	30	1	21
100	61	30	10	21
101	61	30	10	21
102	137	30	20	87
103	52	30	1	21
104	48	20	1	27
105	42	20	1	21
106	48	20	1	27
107	51	20	10	21
108	58	30	1	27
109	61	20	20	21
110	127	20	20	87
111	71	40	10	21
112	71	40	10	21
113	61	30	10	21
114	118	30	10	78
115	79	30	10	39

Appendix A-2

VUNLER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
116	0	0	0	39
117	0	0	0	78
118	42	20	1	21
119	127	30	10	87
120	89	40	10	39
121	79	30	10	39
122	52	30	1	21
123	61	30	10	21
124	117	20	10	87
125	127	30	10	87
126	61	30	10	21
127	127	30	10	87
128	61	20	20	21
129	61	30	10	21
130	61	30	10	21
131	52	30	1	21
132	58	30	1	27
133	117	20	10	87
134	51	20	10	21
135	127	20	20	87
136	52	30	1	21
137	0	30	10	0
138	127	30	10	87
139	127	30	10	87
140	61	30	10	21
141	52	30	1	21
142	71	30	20	21
143	0	0	0	87
144	118	30	10	78
145	71	30	20	21
146	0	0	0	87
147	127	20	20	87
148	51	20	10	21
149	127	30	10	87
150	61	30	10	21
151	51	20	10	21
152	70	30	1	39
153	79	30	10	39
154	127	30	10	87
155	0	0	0	21
156	52	30	1	21
157	61	30	10	21
158	52	30	1	21
159	127	30	10	87
160	127	30	10	87
161	52	30	1	21
162	71	30	20	21
163	51	20	10	21
164	61	30	10	21
165	117	20	10	87
166	61	30	10	21
167	51	20	10	21
168	61	30	10	21
169	0	0	10	21
170	117	20	10	87
171	127	30	10	87
172	52	30	1	21
173	127	30	10	87
174	113	30	50	33
175	113	30	50	33
176	61	30	10	21
177	0	0	10	30
178	127	30	10	87
179	52	30	1	21
180	61	30	10	21
181	83	30	20	33
182	98	30	35	33
183	0	0	10	21
184	117	20	10	87

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
185	61	30	10	21
186	52	30	1	21
187	52	30	1	21
188	127	30	10	87
189	61	30	10	21
190	52	30	1	21
191	52	30	1	21
192	118	30	1	87
193	117	20	10	87
194	73	30	10	33
195	97	30	1	66
196	58	30	1	27
197	61	30	10	21
198	70	30	10	30
199	51	20	10	21
200	117	20	10	87
201	61	30	10	21
202	0	0	10	75
203	0	20	10	0
204	0	0	10	21
205	61	30	10	21
206	61	30	10	21
207	61	30	10	21
208	52	30	1	21
209	127	30	10	87
210	113	30	50	33
211	98	30	35	33
212	52	30	1	21
213	52	30	1	21
214	52	30	1	21
215	52	30	1	21
216	51	20	10	21
217	113	30	50	33
218	61	30	10	21
219	0	0	10	21
220	51	20	10	21
221	83	30	20	33
222	70	30	10	30
223	61	30	10	21
224	52	30	1	21
225	51	20	10	21
226	0	0	10	21
227	52	30	1	21
228	52	30	1	21
229	58	30	1	27
230	71	30	20	21
231	61	30	10	21
232	42	20	1	21
233	61	30	10	21
234	61	30	10	21
235	42	20	1	21
236	67	30	10	27
237	51	20	10	21
238	52	30	1	21
239	51	20	10	21
240	107	40	1	66
241	68	40	1	27
242	70	30	10	30
243	52	30	1	21
244	62	40	1	21
245	86	30	35	21
246	42	20	1	21
247	62	40	1	21
248	62	40	1	21
249	61	30	10	21
250	61	30	10	21
251	68	40	1	27
252	0	0	50	33
253	61	30	10	21

Appendix A-2

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
254	0	0	50	33
255	0	0	35	33
256	0	0	35	21
257	0	0	20	21
258	52	30	1	21
259	70	30	10	30
260	0	0	50	21
261	52	30	1	21
262	0	0	10	21
263	58	30	1	27
264	71	30	20	21
265	61	30	10	21
266	0	0	50	21
267	67	30	10	27
268	61	30	10	21
269	52	30	1	21
270	52	30	1	21
271	67	30	10	27
272	62	40	1	21
273	52	30	1	21
274	86	30	35	21
275	42	20	1	21
276	52	30	1	21
277	68	40	1	27
278	52	30	1	21
279	58	30	1	27
280	62	40	1	21
281	67	30	10	27
282	58	30	1	27
283	0	0	20	21
284	80	40	1	39
285	52	30	1	21
286	97	30	1	66
287	52	30	1	21
288	61	30	10	21
289	70	30	1	39
290	0	0	10	21
291	61	30	10	21
292	61	30	10	21
293	52	30	1	21
294	52	30	1	21
295	61	30	10	21
296	52	30	1	21
297	0	0	1	75
298	0	0	0	0
299	52	30	1	21
300	0	0	20	21
301	0	0	20	21
302	71	30	20	21
303	0	30	1	0
304	71	30	20	21
305	52	30	1	21
306	71	30	20	21
307	0	0	0	21
308	61	30	10	21
309	52	30	1	21
310	101	30	50	21
311	61	30	10	21
312	86	30	35	21
313	101	30	50	21
314	55	30	1	24
315	101	30	50	21
316	86	30	35	21
317	0	0	1	21
318	52	30	1	21
319	52	30	1	21
320	61	30	10	21
321	52	30	1	21
322	71	30	20	21

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
323	101	30	50	21
324	61	30	10	21
325	112	30	10	72
326	101	30	50	21
327	55	30	1	24
328	52	30	1	21
329	101	30	50	21
330	122	30	20	72
331	52	30	1	21
332	55	30	1	24
333	52	30	1	21
334	137	30	35	72
335	86	30	35	21
336	52	30	1	21
337	112	30	10	72
338	152	30	50	72
339	52	30	1	21
340	103	30	1	72
341	58	30	1	27
342	86	30	35	21
343	101	30	50	21
344	71	30	20	21
345	64	30	10	24
346	137	30	35	72
347	71	30	20	21
348	61	30	10	21
349	61	30	10	21
350	52	30	1	21
351	101	30	50	21
352	52	30	1	21
353	152	30	50	72
354	52	30	1	21
355	52	30	1	21
356	0	0	1	27
357	122	30	20	72
358	61	30	10	21
359	67	30	10	27
360	137	30	35	72
361	52	30	1	21
362	71	30	20	21
363	86	30	35	21
364	112	30	10	72
365	71	30	20	21
366	61	30	10	21
367	61	30	10	21
368	52	30	1	21
369	0	30	35	0
370	0	0	1	27
371	61	30	10	21
372	61	30	10	21
373	52	30	1	21
374	52	30	1	21
375	73	30	10	33
376	61	30	10	21
377	64	30	1	33
378	52	30	1	21
379	52	30	1	21
380	52	30	1	21
381	52	30	1	21
382	52	30	1	21
383	58	30	1	27
384	52	30	1	21
385	52	30	1	21
386	52	30	1	21
387	42	20	1	21
388	42	20	1	21
389	52	30	1	21
390	52	30	1	21
391	52	30	1	21

Appendix A-2

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
392	103	30	1	72
393	52	30	1	21
394	0	30	1	0
395	52	30	1	21
396	52	30	1	21
397	42	20	1	21
398	52	30	1	21
399	52	30	1	21
400	55	30	1	24
401	52	30	1	21
402	52	30	1	21
403	52	30	1	21
404	0	0	1	21
405	0	0	1	21
406	52	30	1	21
407	58	30	1	27
408	52	30	1	21
409	42	20	1	21
410	52	30	1	21
411	52	30	1	21
412	52	30	1	21
413	62	40	1	21
414	62	40	1	21
415	62	40	1	21
416	62	40	1	21
417	42	20	1	21
418	52	30	1	21
419	42	20	1	21
420	42	20	1	21
421	52	30	1	21
422	62	40	1	21
423	42	20	1	21
424	42	20	1	21
425	42	20	1	21
426	52	30	1	21
427	71	40	10	21
428	64	30	1	33
429	51	20	10	21
430	62	40	1	21
431	61	30	10	21
432	61	30	10	21
433	42	20	1	21
434	52	30	1	21
435	62	40	1	21
436	61	30	10	21
437	61	30	10	21
438	51	20	10	21
439	64	30	1	33
440	52	30	1	21
441	42	20	1	21
442	0	30	10	0
443	42	20	1	21
444	51	20	10	21
445	64	30	1	33
446	61	30	10	21
447	62	40	1	21
448	61	30	10	21
449	52	30	1	21
450	62	40	1	21
451	51	20	10	21
452	71	40	10	21
453	71	40	10	21
454	51	20	10	21
455	51	20	10	21
456	61	30	10	21
457	42	20	1	21
458	42	20	1	21
459	52	30	1	21
460	0	20	10	0

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
461	51	20	10	21
462	52	30	1	21
463	64	30	1	33
464	0	30	1	0
465	62	40	1	21
466	52	30	1	21
467	67	30	10	27
468	62	40	1	21
469	52	30	1	21
470	42	20	1	21
471	42	20	1	21
472	42	20	1	21
473	42	20	1	21
474	42	20	1	21
475	61	30	10	21
476	73	30	10	33
477	52	30	1	21
478	73	30	10	33
479	61	30	10	21
480	42	20	1	21
481	73	30	10	33
482	67	30	10	27
483	83	30	20	33
484	52	30	1	21
485	77	30	20	27
486	61	30	10	21
487	52	30	1	21
488	83	30	20	33
489	52	30	1	21
490	61	30	10	21
491	71	30	20	21
492	83	30	20	33
493	52	30	1	21
494	52	30	1	21
495	42	20	1	21
496	86	30	35	21
497	0	0	0	33
498	98	30	35	33
499	58	30	1	27
500	92	30	35	27
501	98	30	35	33
502	77	30	20	27
503	61	20	20	21
504	67	20	20	27
505	57	20	10	27
506	51	20	10	21
507	51	20	10	21
508	51	20	10	21
509	52	30	1	21
510	51	20	10	21
511	42	20	1	21
512	52	30	1	21
513	67	20	20	27
514	86	30	35	21
515	71	30	20	21
516	92	30	35	27
517	42	20	1	21
518	61	30	10	21
519	101	30	50	21
520	42	20	1	21
521	42	20	1	21
522	107	30	50	27
523	107	30	50	27
524	101	30	50	21
525	52	30	1	21
526	61	30	10	21
527	104	30	50	24
528	113	30	50	33
529	67	30	10	27

Appendix A-2

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
530	42	20	1	21
531	113	30	50	33
532	0	30	1	0
533	67	30	10	27
534	52	30	1	21
535	77	30	20	27
536	0	0	0	24
537	42	20	1	21
538	42	20	1	21
539	113	30	50	33
540	52	30	1	21
541	104	30	50	24
542	52	30	1	21
543	0	30	50	0
544	58	30	1	27
545	0	30	0	0
546	0	30	1	0
547	51	20	10	21
548	55	30	1	24
549	52	30	1	21
550	52	30	1	21
551	52	30	1	21
552	52	30	1	21
553	0	30	1	0
554	52	30	1	21
555	52	30	1	21
556	52	30	1	21
557	61	30	10	21
558	52	30	1	21
559	0	30	1	0
560	52	30	1	21
561	0	30	1	0
562	52	30	1	21
563	52	30	1	21
564	52	30	1	21
565	58	30	1	27
566	58	30	1	27
567	0	30	1	0
568	52	30	1	21
569	52	30	1	21
570	42	20	1	21
571	52	30	1	21
572	61	30	10	21
573	52	30	1	21
574	52	30	1	21
575	52	30	1	21
576	0	30	1	0
577	85	30	1	54
578	0	30	1	0
579	52	30	1	21
580	0	30	1	0
581	0	30	1	0
582	52	30	1	21
583	52	30	1	21
584	52	30	1	21
585	0	30	1	0
586	52	30	1	21
587	52	30	1	21
588	58	30	1	27
589	52	30	1	21
590	52	30	1	21
591	61	30	10	21
592	61	30	10	21
593	64	30	1	33
594	52	30	1	21
595	61	30	10	21
596	64	30	1	33
597	52	30	1	21
598	51	20	10	21

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
599	64	30	1	33
600	52	30	1	21
601	52	30	1	21
602	61	30	10	21
603	42	20	1	21
604	52	30	1	21
605	52	30	1	21
606	42	20	1	21
607	52	30	1	21
608	64	30	1	33
609	42	20	1	21
610	52	30	1	21
611	52	30	1	21
612	52	30	1	21
613	52	30	1	21
614	52	30	1	21
615	52	30	1	21
616	61	30	10	21
617	61	30	10	21
618	61	30	10	21
619	52	30	1	21
620	42	20	1	21
621	42	20	1	21
622	42	20	1	21
623	82	30	10	42
624	61	30	10	21
625	54	20	1	33
626	54	20	1	33
627	45	20	1	24
628	51	20	10	21
629	51	20	10	21
630	63	20	10	33
631	54	20	10	24
632	63	20	10	33
633	51	20	10	21
634	51	20	10	21
635	51	20	10	21
636	61	30	10	21
637	61	30	10	21
638	0	30	10	0
639	61	30	10	21
640	64	30	10	24
641	52	30	1	21
642	0	30	1	0
643	61	30	10	21
644	0	30	10	0
645	64	30	10	24
646	52	30	1	21
647	52	30	1	21
648	52	30	1	21
649	73	30	10	33
650	52	30	1	21
651	52	30	1	21
652	0	0	10	21
653	61	30	10	21
654	51	20	10	21
655	0	30	1	0
656	0	0	10	21
657	61	30	10	21
658	61	30	10	21
659	0	0	10	21
660	0	0	10	21
661	0	0	10	33
662	61	30	10	21
663	61	30	10	21
664	91	30	1	60
665	61	30	10	21
666	0	0	10	33
667	52	30	1	21

Appendix A-2

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
668	61	30	10	21
669	52	30	1	21
670	73	30	10	33
671	52	30	1	21
672	67	30	10	27
673	52	30	1	21
674	61	30	10	21
675	0	0	10	60
676	61	30	10	21
677	100	30	10	60
678	52	30	1	21
679	71	40	10	21
680	110	40	10	60
681	62	40	1	21
682	62	40	1	21
683	73	30	10	33
684	0	0	10	21
685	71	40	10	21
686	0	0	10	21
687	61	30	10	21
688	52	30	1	21
689	100	30	10	60
690	61	30	10	21
691	61	30	10	21
692	71	40	10	21
693	61	30	10	21
694	52	30	1	21
695	100	30	10	60
696	0	0	10	21
697	0	0	10	21
698	52	30	1	21
699	61	30	10	21
700	71	40	10	21
701	0	0	10	60
702	52	30	1	21
703	83	40	10	33
704	71	40	10	21
705	52	30	1	21
706	61	30	10	21
707	71	40	10	21
708	57	20	10	27
709	0	20	10	0
710	51	20	10	21
711	71	40	10	21
712	52	30	1	21
713	52	30	1	21
714	71	40	10	21
715	71	40	10	21
716	62	40	1	21
717	62	40	1	21
718	62	40	1	21
719	62	40	1	21
720	62	40	1	21
721	0	40	10	0
722	51	20	10	21
723	71	40	10	21
724	0	40	1	0
725	101	40	1	60
726	62	40	1	21
727	62	40	1	21
728	101	40	1	60
729	71	40	10	21
730	62	40	1	21
731	101	40	1	60
732	71	40	10	21
733	62	40	1	21
734	0	20	10	0
735	62	40	1	21
736	57	20	10	27

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
737	61	30	10	21
738	101	40	1	60
739	62	40	1	21
740	101	40	1	60
741	61	30	10	21
742	0	20	10	0
743	62	40	1	21
744	72	20	10	42
745	84	20	10	54
746	62	40	1	21
747	62	40	1	21
748	62	40	1	21
749	62	40	1	21
750	71	40	10	21
751	101	40	1	60
752	94	20	20	54
753	42	20	1	21
754	62	40	1	21
755	101	40	1	60
756	62	40	1	21
757	71	40	10	21
758	42	20	1	21
759	62	40	1	21
760	101	40	1	60
761	71	40	10	21
762	73	30	10	33
763	71	40	10	21
764	73	30	10	33
765	101	40	1	60
766	110	40	10	60
767	110	40	10	60
768	62	40	1	21
769	71	40	10	21
770	61	30	10	21
771	61	20	20	21
772	101	40	1	60
773	71	40	10	21
774	71	40	10	21
775	71	40	10	21
776	110	40	10	60
777	71	40	10	21
778	51	20	10	21
779	71	40	10	21
780	82	20	20	42
781	72	20	10	42
782	62	40	1	21
783	101	40	1	60
784	110	40	10	60
785	62	40	1	21
786	110	40	10	60
787	61	20	20	21
788	51	20	10	21
789	62	40	1	21
790	0	0	0	33
791	0	0	0	21
792	0	0	10	21
793	0	0	10	0
794	0	0	10	21
795	110	40	10	60
796	0	0	1	21
797	0	0	1	21
798	0	0	1	60
799	90	20	10	60
800	71	40	10	21
801	73	30	10	33
802	71	40	10	21
803	101	40	1	60
804	110	40	10	60
805	0	0	1	60

Appendix A-2

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
806	51	20	10	21
807	0	0	10	60
808	0	0	10	0
809	71	40	10	21
810	62	40	1	21
811	61	30	10	21
812	0	0	1	21
813	0	0	10	21
814	0	0	10	21
815	0	0	10	21
816	101	40	1	60
817	101	40	1	60
818	101	40	1	60
819	61	30	10	21
820	0	0	10	21
821	101	40	1	60
822	61	30	10	21
823	110	40	10	60
824	0	0	10	27
825	0	0	1	60
826	0	0	10	42
827	62	40	1	21
828	0	0	10	60
829	62	40	1	21
830	110	40	10	60
831	101	40	1	60
832	0	0	10	21
833	0	40	10	0
834	101	40	1	60
835	0	40	1	0
836	0	0	10	21
837	61	30	10	21
838	101	40	1	60
839	110	40	10	60
840	73	30	10	33
841	0	0	10	0
842	100	30	10	60
843	101	40	1	60
844	67	30	10	27
845	101	40	1	60
846	62	40	1	21
847	100	30	10	60
848	61	30	10	21
849	73	30	10	33
850	0	0	1	21
851	0	0	10	33
852	61	30	10	21
853	67	30	10	27
854	0	0	1	60
855	0	0	10	21
856	0	0	10	0
857	71	40	10	21
858	71	40	10	21
859	67	30	10	27
860	0	0	10	27
861	67	30	10	27
862	73	30	10	33
863	0	0	1	60
864	0	0	1	60
865	62	40	1	21
866	73	30	10	33
867	62	40	1	21
868	0	0	10	21
869	71	40	10	21
870	101	40	1	60
871	110	40	10	60
872	61	30	10	21
873	0	0	10	21
874	0	0	1	60

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
875	110	40	10	60
876	0	0	10	60
877	101	40	1	60
878	0	0	1	60
879	101	40	1	60
880	62	40	1	21
881	71	40	10	21
882	110	40	10	60
883	0	0	1	60
884	62	40	1	21
885	0	0	1	21
886	110	40	10	60
887	101	40	1	60
888	0	0	1	60
889	101	40	1	60
890	62	40	1	21
891	0	0	10	0
892	0	0	1	21
893	110	40	10	60
894	0	0	10	21
895	0	0	10	0
896	51	20	10	21
897	110	40	10	60
898	61	30	10	21
899	61	30	10	21
900	0	0	10	0
901	0	0	1	21
902	101	40	1	60
903	0	0	1	21
904	51	20	10	21
905	101	40	1	60
906	71	40	10	21
907	62	40	1	21
908	71	40	10	21
909	71	40	10	21
910	62	40	1	21
911	101	40	1	60
912	0	0	1	21
913	0	0	1	21
914	0	0	1	0
915	0	0	10	33
916	42	20	1	21
917	52	30	1	21
918	0	30	1	0
919	52	30	1	21
920	61	30	10	21
921	42	20	1	21
922	42	20	1	21
923	73	30	10	33
924	42	20	1	21
925	48	20	1	27
926	73	30	10	33
927	110	40	10	60
928	61	30	10	21
929	58	30	1	27
930	58	30	1	27
931	67	30	10	27
932	101	40	1	60
933	0	30	10	0
934	62	40	1	21
935	110	40	10	60
936	101	40	1	60
937	61	30	10	21
938	42	20	1	21
939	67	30	10	27
940	0	40	10	0
941	110	40	10	60
942	57	20	10	27
943	51	20	10	21

Appendix A-2

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
944	101	40	1	60
945	51	20	10	21
946	71	40	10	21
947	57	20	10	27
948	0	0	1	27
949	0	0	10	27
950	0	0	10	21
951	0	0	10	21
952	73	30	10	33
953	61	30	10	21
954	68	40	1	27
955	0	40	10	0
956	57	20	10	27
957	68	40	1	27
958	51	20	10	21
959	110	40	10	60
960	92	30	35	27
961	77	30	20	27
962	77	40	10	27
963	0	0	10	21
964	62	40	1	21
965	107	30	50	27
966	0	0	10	27
967	62	40	1	21
968	67	30	10	27
969	0	0	20	27
970	62	40	1	21
971	101	40	1	60
972	62	40	1	21
973	110	40	10	60
974	71	40	10	21
975	62	40	1	21
976	71	40	10	21
977	0	0	10	21
978	0	0	20	27
979	71	40	10	21
980	0	0	10	21
981	0	0	10	27
982	71	40	10	21
983	0	0	10	21
984	0	0	10	21
985	0	0	10	27
986	77	40	10	27
987	0	0	10	21
988	74	40	1	33
989	71	40	10	21
990	71	40	10	21
991	57	20	10	27
992	51	20	10	21
993	51	20	10	21
994	51	20	10	21
995	51	20	10	21
996	51	20	10	21
997	90	20	10	60
998	51	20	10	21
999	71	40	10	21
1000	0	0	10	21
1001	62	40	1	21
1002	90	20	10	60
1003	0	0	10	24
1004	0	0	20	24
1005	51	20	10	21
1006	71	40	10	21
1007	74	30	20	24
1008	51	20	10	21
1009	68	40	1	27
1010	0	0	20	21
1011	71	30	20	21
1012	51	20	10	21

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
1013	57	20	10	27
1014	0	0	10	27
1015	0	0	10	21
1016	42	20	1	21
1017	42	20	1	21
1018	48	20	1	27
1019	42	20	1	21
1020	48	20	1	27
1021	51	20	10	21
1022	61	30	10	21
1023	42	20	1	21
1024	0	0	10	21
1025	0	0	10	21
1026	0	0	1	21
1027	0	0	20	21
1028	42	20	1	21
1029	77	40	10	27
1030	0	0	10	60
1031	0	0	20	21
1032	0	0	1	21
1033	77	40	10	27
1034	61	30	10	21
1035	48	20	1	27
1036	0	0	10	27
1037	0	0	10	21
1038	61	30	10	21
1039	42	20	1	21
1040	67	30	10	27
1041	61	30	10	21
1042	51	20	10	21
1043	0	0	10	0
1044	0	0	10	27
1045	0	0	1	27
1046	0	0	10	60
1047	0	20	10	0
1048	0	0	10	0
1049	57	20	10	27
1050	51	20	10	21
1051	0	0	10	21
1052	0	0	10	21
1053	0	0	10	21
1054	90	20	10	60
1055	48	20	1	27
1056	48	20	1	27
1057	71	40	10	21
1058	0	0	1	27
1059	0	0	10	60
1060	57	20	10	27
1061	0	0	10	27
1062	51	20	10	21
1063	51	20	10	21
1064	0	0	10	27
1065	0	0	1	27
1066	0	0	1	27
1067	0	0	1	27
1068	0	0	10	27
1069	90	20	10	60
1070	61	30	10	21
1071	0	0	10	21
1072	67	30	10	27
1073	58	30	1	27
1074	58	30	1	27
1075	67	30	10	27
1076	0	0	10	27
1077	0	0	10	27
1078	67	30	10	27
1079	0	0	10	21
1080	67	30	10	27
1081	67	30	10	27

Appendix A-2

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
1082	0	0	1	27
1083	0	0	10	33
1084	0	0	10	27
1085	0	40	10	0
1086	73	30	10	33
1087	0	0	10	27
1088	0	0	10	21
1089	100	30	10	60
1090	71	40	10	21
1091	90	20	10	60
1092	71	40	10	21
1093	0	30	10	0
1094	0	0	10	27
1095	57	20	10	27
1096	61	30	10	21
1097	67	30	10	27
1098	67	30	10	27
1099	71	40	10	21
1100	67	30	10	27
1101	67	30	10	27
1102	0	0	10	27
1103	51	20	10	21
1104	57	20	10	27
1105	51	20	10	21
1106	71	40	10	21
1107	67	30	10	27
1108	71	40	10	21
1109	64	30	10	24
1110	67	30	10	27
1111	67	30	10	27
1112	61	30	10	21
1113	71	40	10	21
1114	71	40	10	21
1115	73	30	10	33
1116	67	30	10	27
1117	0	20	10	0
1118	77	40	10	27
1119	0	0	10	27
1120	0	20	10	0
1121	0	0	0	27
1122	0	0	10	27
1123	0	0	10	27
1124	0	40	10	0
1125	0	0	10	21
1126	0	0	10	0
1127	0	0	10	27
1128	83	40	10	33
1129	0	0	10	0
1130	0	0	10	0
1131	71	40	10	21
1132	83	40	10	33
1133	67	30	10	27
1134	0	0	10	27
1135	110	40	10	60
1136	67	30	10	27
1137	0	0	10	27
1138	0	0	10	27
1139	110	40	10	60
1140	77	40	10	27
1141	67	30	10	27
1142	93	40	20	33
1143	93	40	20	33
1144	0	40	20	0
1145	0	0	10	33
1146	0	40	10	0
1147	81	40	20	21
1148	87	40	20	27
1149	0	40	20	0
1150	0	0	10	27
1151	93	40	20	33
1152	93	40	20	33
1153	67	30	10	27
1154	0	40	10	0
1155	87	40	20	27
1156	0	0	10	27
1157	81	40	20	21
1158	0	0	10	0
1159	100	30	10	60
1160	67	30	10	27
1161	0	40	20	0
1162	0	0	10	0
1163	67	30	10	27
1164	67	30	10	27
1165	67	30	10	27
1166	0	0	10	27
1167	0	0	10	21
1168	0	0	10	0
1169	0	0	10	0
1170	77	30	20	27
1171	77	40	10	27
1172	0	0	10	27
1173	77	30	20	27
1174	77	30	20	27
1175	0	0	10	27
1176	77	30	20	27
1177	67	30	10	27
1178	77	30	20	27
1179	89	40	10	39
1180	77	40	10	27
1181	0	0	10	27
1182	0	40	10	0
1183	0	0	10	0
1184	87	40	20	27
1185	0	40	10	0
1186	0	0	10	21
1187	0	0	10	0
1188	0	20	10	0
1189	0	40	20	0
1190	0	0	20	0
1191	51	20	10	21
1192	71	40	10	21
1193	61	20	20	21
1194	0	0	20	21
1195	0	0	10	21
1196	51	20	10	21
1197	81	40	20	21
1198	0	0	20	21
1199	0	0	20	0
1200	67	30	10	27
1201	0	40	20	0
1202	0	20	20	0
1203	0	0	20	27
1204	69	20	10	39
1205	0	0	20	0
1206	81	40	20	21
1207	0	0	10	21
1208	0	0	10	39
1209	73	20	20	33
1210	0	20	20	0
1211	0	0	10	21
1212	0	40	20	0
1213	51	20	10	21
1214	0	20	20	0
1215	81	40	20	21
1216	87	40	20	27
1217	71	40	10	21
1218	0	0	20	21
1219	0	0	20	21

Appendix A-2

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
1220	0	0	10	21
1221	0	0	10	21
1222	67	20	20	27
1223	61	20	20	21
1224	73	20	20	33
1225	0	0	20	21
1226	99	40	20	39
1227	0	0	20	39
1228	67	20	20	27
1229	103	20	20	63
1230	113	30	20	63
1231	100	20	20	60
1232	0	0	10	42
1233	103	20	20	63
1234	77	30	20	27
1235	103	20	20	63
1236	0	20	20	0
1237	76	20	35	21
1238	76	20	35	21
1239	100	20	20	60
1240	115	20	35	60
1241	67	20	20	27
1242	88	20	35	33
1243	82	20	35	27
1244	0	0	20	27
1245	0	0	10	42
1246	0	0	10	33
1247	0	0	10	24
1248	0	0	10	33
1249	73	30	10	33
1250	64	30	10	24
1251	67	30	10	27
1252	0	0	35	27
1253	77	30	20	27
1254	0	0	35	33
1255	0	0	20	18
1256	0	0	20	33
1257	0	0	35	33
1258	0	0	35	33
1259	0	0	35	27
1260	0	0	35	18
1261	0	0	35	33
1262	0	0	20	27
1263	0	0	35	27

Appendix A-3
Soils Ratings for Big Wood River

	SEQNUM	COMPCT	ANFLOOD	WTDEPL	ROCKDEPL	PERM
ID157						
	3	17	NONE	6.0	60	14.0
	4	8	NONE	6.0	60	0.2
	9	7	NONE	6.0	60	7.2
	10	36	NONE	6.0	60	7.2
	11	7	NONE	6.0	40	0.6
	12	7	FREQ	0.0	60	6.0

Rate = 25 x 3 = 75

ID364	2	5	NONE	6.0	60	0.6
	4	20	NONE	6.0	20	8.0
	6	30	NONE	6.0	40	0.6
	9	25	NONE	6.0	20	0.9

Rate = 24.5 x 3 = 73.5

ID147						
	2	10	NONE	6.0	40	0.1
	3	15	NONE	6.0	40	0.6
	4	8	NONE	6.0	60	0.2
	6	12	NONE	6.0	60	1.4
	8	9	NONE	6.0	60	0.2
	9	16	NONE	6.0	20	0.1
	10	9	NONE	6.0	20	0.9
	11	8	NONE	6.0	20	0.2

Rate = 19.2 x 3 = 57.6

ID250						
	3	20	NONE	6.0	60	14.0
	4	29	NONE	6.0	20	0.6
	5	4	NONE	6.0	20	0.6
	7	7	NONE	6.0	10	0.2
	8	5	NONE	6.0	0	0.2
	9	6	NONE	6.0	40	2.9
	10	4	NONE	6.0	20	0.6
	12	4	NONE	6.0	60	6.0
	13	4	NONE	6.0	40	0.9

Rate = 24.4 x 3 = 73.2

Appendix A-3

ID253

1	8	RARE	6.0	10	0.6
3	8	FREQ	0.5	60	0.2
4	79	OCCAS	2.0	60	0.6

Rate = 21.7 x 3 = 65.1

ID159

1	24	NONE	6.0	10	0.6
3	9	NONE	6.0	10	2.0
7	20	NONE	6.0	40	0.6
8	31	NONE	6.0	20	0.9

Rate = 24.1 x 3 = 72.3

ID248

4	5	NONE	6.0	40	0.1
5	4	NONE	6.0	40	0.3
12	7	NONE	6.0	20	2.0
13	28	NONE	6.0	40	0.6
14	36	NONE	6.0	20	0.9

Rate = 22.6 x 3 = 67.8

ID148

1	30	NONE	6.0	20	0.4
2	40	NONE	6.0	60	0.6
3	30	NONE	6.0	20	0.4

Rate = 20.4 x 3 = 61.2

SEQNUM: sequence number; COMPCT: component percentage; ANFLOOD: flooding; WTDEPL: depth to water; ROCKDEPL: depth to bedrock; PERM: permiability

Appendix A-4
Ground Water Vulnerability Rating
By Polygon for Big Wood River

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
0	0	0	0	0
1	113	20	20	73
2	113	20	20	73
3	0	0	20	73
4	0	0	20	75
5	0	0	35	75
6	130	20	35	75
7	145	20	50	75
8	0	0	35	73
9	128	20	35	73
10	130	20	35	75
11	155	45	35	75
12	170	45	50	75
13	143	20	50	73
14	115	20	20	75
15	145	20	50	75
16	143	50	20	73
17	0	0	20	75
18	155	45	35	75
19	0	0	20	73
20	115	20	20	75
21	113	20	20	73
22	115	20	20	75
23	113	20	20	73
24	0	0	20	75
25	115	20	20	75
26	115	20	20	75
27	140	45	20	75
28	0	0	20	73
29	115	20	20	75
30	168	45	50	73
31	128	20	35	73
32	138	45	20	73
33	145	20	50	75
34	130	20	35	75
35	138	45	20	73
36	128	20	35	73
37	113	20	20	73
38	113	20	20	73
39	113	20	20	73
40	0	0	20	75
41	115	20	20	75
42	0	0	35	75
43	115	20	20	75
44	115	20	20	75
45	160	50	35	75
46	140	45	20	75
47	115	20	20	75
48	130	20	35	75
49	140	45	20	75
50	115	20	20	75
51	113	20	20	73
52	115	20	20	75
53	140	45	20	75
54	135	40	20	75
55	135	40	20	75
56	135	40	20	75
57	135	40	20	75
58	140	45	20	75
59	145	50	20	75
60	135	40	20	75
61	97	20	20	57
62	115	20	20	75
63	113	20	20	73
64	135	40	20	75
65	150	40	35	75
66	97	20	20	57
67	130	20	35	75
68	145	50	20	75
69	160	50	35	75
70	130	20	35	75
71	115	20	20	75
72	148	40	35	73
73	128	20	35	73
74	122	45	20	57
75	130	20	35	75
76	128	20	35	73
77	135	40	20	75
78	155	45	35	75
79	153	45	35	73
80	145	50	20	75
81	143	20	50	73
82	160	50	35	75
83	168	45	50	73
84	112	20	35	57
85	160	50	35	75
86	170	45	50	75
87	130	20	35	75
88	175	50	50	75
89	145	20	50	75
90	132	40	35	57
91	170	45	50	75
92	127	20	50	57
93	147	40	50	57
94	137	45	35	57
95	152	45	50	57
96	147	40	50	57
97	137	45	35	57
98	137	45	35	57
99	175	50	50	75
100	137	45	35	57
101	127	20	50	57
102	175	50	50	75
103	127	20	50	57
104	175	50	50	75
105	175	50	50	75
106	145	20	50	75
107	157	50	50	57
108	165	50	50	65
109	175	50	50	75
110	172	50	50	72
111	142	20	50	72
112	127	20	50	57
113	175	50	50	75
114	175	50	50	75
115	170	45	50	75
116	170	45	50	75
117	167	45	50	72
118	165	40	50	75
119	152	45	35	72
120	175	50	50	75
121	142	20	50	72
122	157	50	50	57
123	172	50	50	72

Appendix A-4

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
124	160	45	50	65
125	170	45	50	75
126	160	45	50	65
127	160	45	50	65
128	165	50	50	65
129	157	50	35	72
130	165	50	50	65
131	165	50	50	65
132	160	50	35	75
133	175	50	50	75
134	127	20	35	72
135	162	40	50	72
136	165	50	50	65
137	155	40	50	65
138	157	50	35	72
139	160	45	50	65
140	165	40	50	75
141	145	20	50	75
142	175	50	50	75
143	160	45	50	65
144	165	40	50	75
145	165	40	50	75
146	112	20	20	72
147	97	20	20	57
148	160	50	35	75
149	170	45	50	75
150	155	40	50	65
151	175	50	50	75
152	155	40	50	65
153	165	50	50	65
154	165	50	50	65
155	160	45	50	65
156	155	45	35	75
157	170	45	50	75
158	165	50	50	65
159	135	20	50	65
160	150	50	35	65
161	127	20	50	57
162	145	45	35	65
163	142	50	20	72
164	135	20	50	65
165	127	20	50	57
166	97	20	20	57
167	165	50	50	65
168	97	20	20	57
169	112	20	20	72
170	165	50	50	65
171	157	50	50	57
172	165	50	50	65
173	145	20	50	75
174	145	50	20	75
175	165	50	50	65
176	150	50	35	65
177	165	50	50	65
178	165	50	50	65
179	150	50	35	65
180	152	45	50	57
181	142	50	20	72
182	87	20	10	57
183	150	50	35	65
184	152	45	50	57
185	160	45	50	65
186	135	20	50	65
187	127	20	50	57
188	165	50	50	65
189	165	50	50	65

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
190	145	50	20	75
191	102	20	10	72
192	135	50	20	65
193	135	20	50	65
194	140	40	35	65
195	132	50	10	72
196	87	20	10	57
197	135	50	10	75
198	105	20	10	75
199	135	20	50	65
200	125	40	20	65
201	120	20	35	65
202	150	50	35	65
203	135	20	50	65
204	150	50	35	65
205	137	20	50	67
206	127	20	50	57
207	165	50	50	65
208	160	45	50	65
209	145	45	35	65
210	160	45	50	65
211	105	20	10	75
212	105	20	10	75
213	167	50	50	67
214	120	20	35	65
215	117	50	10	57
216	152	50	35	67
217	137	20	50	67
218	155	40	50	65
219	135	40	20	75
220	135	40	20	75
221	125	40	20	65
222	122	20	35	67
223	135	50	10	75
224	120	20	35	65
225	0	0	20	75
226	125	40	10	75
227	0	0	20	65
228	142	40	35	67
229	0	0	10	75
230	135	20	50	65
231	125	40	10	75
232	0	0	10	65
233	112	20	35	57
234	135	20	50	65
235	152	45	50	57
236	115	40	10	65
237	87	20	10	57
238	147	45	35	67
239	152	45	50	57
240	105	20	20	65
241	135	20	50	65
242	127	20	50	57
243	127	20	50	57
244	120	20	35	65
245	105	20	10	75
246	135	20	50	65
247	112	20	35	57
248	135	50	10	75
249	115	40	10	65
250	135	20	50	65
251	112	20	35	57
252	127	20	50	57
253	105	20	20	65
254	95	20	10	65
255	117	50	10	57

Appendix A-4

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
256	91	20	10	61
257	101	20	20	61
258	111	40	10	61
259	111	40	10	61
260	125	40	10	75
261	105	20	10	75
262	95	20	10	65
263	91	20	10	61
264	97	20	20	57
265	97	20	20	57
266	111	40	10	61
267	97	20	20	57
268	105	20	10	75
269	91	20	10	61

VULNER_ID = Polygon identification number
VULNRATE = Vulnerability Rating
LURATE = Land Use (Recharge) Rating
DWRATE = Depth to Water Rating
SOILRATE = Soils Rating

Appendix A-5
Soils Ratings for Jerome Area

SCSSOIL	FREQ	SOILRATE
	1	0
10	3	30
17	1	48
18	4	48
33	5	36
47	9	36
56	5	46
58	18	42
60	1	57
70	7	48
71	2	48
83	9	27
84	4	54
97	5	51
99	1	30
108	1	47
122	4	30
123	2	30
132	10	27
133	1	27

FREQ: frequency of SCSSOIL; SOILRATE: soil rating multiplied by a weight of 3

Appendix A-6
Ground Water Vulnerability Rating
By Polygon for Jerome Area

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
0	0	0	0	0
1	71	40	1	30
2	81	50	1	30
3	71	40	1	30
4	81	50	1	30
5	71	40	1	30
6	71	40	1	30
7	99	50	1	48
8	31	0	1	30
9	81	50	1	30
10	93	50	1	42
11	81	50	1	30
12	81	50	1	30
13	81	50	1	30
14	31	0	1	30
15	87	50	10	27
16	102	50	10	42
17	71	40	1	30
18	77	40	10	27
19	71	40	1	30
20	108	50	10	48
21	81	50	1	30
22	98	40	10	48
23	90	50	10	30
24	108	50	10	48
25	87	50	10	27
26	108	50	10	48
27	114	50	10	54
28	87	50	10	27
29	31	0	1	30
30	77	40	10	27
31	104	40	10	54
32	92	40	10	42
33	96	40	10	46
34	106	50	10	46
35	102	50	10	42
36	49	0	1	48
37	99	50	1	48
38	58	0	10	48
39	102	50	10	42
40	102	50	10	42
41	52	0	10	42
42	58	0	10	48
43	108	50	10	48
44	106	50	10	46
45	81	50	1	30
46	40	0	10	30
47	102	50	10	42
48	102	50	10	42
49	31	0	1	30
50	102	50	10	42
51	106	50	10	46
52	106	50	10	46
53	87	50	10	27
54	81	50	1	30
55	108	50	10	48
56	106	50	10	46
57	78	20	10	48

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
58	108	50	10	48
59	90	50	10	30
60	77	40	10	27
61	87	50	10	27
62	87	50	10	27
63	106	50	10	46
64	102	50	10	42
65	101	40	10	51
66	96	40	10	46
67	87	50	10	27
68	37	0	10	27
69	86	40	10	36
70	92	40	10	42
71	90	50	10	30
72	96	50	10	36
73	96	50	10	36
74	90	50	10	30
75	77	40	10	27
76	106	50	10	46
77	37	0	10	27
78	108	50	10	48
79	86	40	10	36
80	28	0	1	27
81	102	50	10	42
82	80	40	10	30
83	96	40	10	46
84	81	50	1	30
85	78	50	1	27
86	86	40	10	36
87	90	50	10	30
88	78	20	10	48
89	40	0	10	30
90	71	40	1	30
91	60	20	10	30
92	90	50	10	30
93	114	50	10	54
94	84	20	10	54
95	87	50	10	27
96	96	50	10	36
97	77	40	1	36
98	87	50	1	36
99	57	20	10	27
100	92	40	10	42
101	102	50	10	42
102	57	20	10	27
103	48	20	1	27
104	96	40	10	46
105	86	40	10	36
106	90	50	10	30
107	114	50	10	54
108	87	50	10	27
109	77	40	10	27
110	87	50	10	27
111	102	50	10	42
112	57	20	1	36
113	66	20	10	36
114	106	50	10	46
115	86	40	10	36

Appendix A-6

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
116	96	50	10	36
117	77	40	10	27
118	93	50	1	42
119	87	50	10	27
120	111	50	10	51
121	87	50	10	27
122	92	40	10	42
123	102	50	10	42
124	63	20	1	42
125	102	50	10	42
126	102	50	10	42
127	72	20	10	42
128	114	50	10	54
129	78	50	1	27
130	101	40	10	51
131	92	40	10	42
132	78	50	1	27
133	102	50	10	42
134	93	50	1	42
135	111	50	10	51
136	86	40	10	36
137	87	50	10	27
138	96	50	10	36
139	63	20	1	42
140	37	0	10	27
141	48	20	1	27
142	87	50	10	27
143	57	20	10	27
144	48	20	1	27
145	87	50	10	27
146	86	40	10	36
147	78	50	1	27
148	96	40	10	46
149	86	40	10	36
150	114	50	10	54
151	64	0	10	54
152	101	40	10	51
153	96	40	10	46
154	84	20	10	54
155	87	50	1	36
156	48	20	1	27
157	66	20	10	36
158	57	20	10	27
159	86	40	10	36
160	60	20	10	30
161	90	50	10	30
162	57	20	10	27
163	37	0	10	27
164	87	50	10	27
165	57	20	10	27
166	87	50	10	27
167	77	40	10	27
168	77	40	10	27
169	87	50	1	36
170	77	40	10	27
171	60	20	10	30
172	87	50	10	27
173	87	50	10	27
174	114	50	10	54
175	77	40	10	27
176	80	40	10	30
177	77	40	10	27
178	96	40	10	46
179	96	50	10	36

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
180	77	40	10	27
181	96	50	10	36
182	96	40	10	46
183	87	50	10	27
184	96	50	10	36
185	77	40	10	27
186	87	50	10	27
187	102	50	10	42
188	96	40	10	46
189	101	40	10	51
190	37	0	10	27
191	87	50	10	27
192	106	50	10	46
193	77	40	10	27
194	96	40	10	46
195	101	40	10	51
196	87	50	10	27
197	106	50	10	46
198	96	40	10	46
199	77	40	10	27
200	102	50	10	42
201	52	0	10	42
202	102	50	10	42
203	87	50	10	27
204	90	50	10	30
205	80	40	10	30
206	77	40	10	27
207	77	40	10	27
208	102	50	10	42
209	87	50	10	27
210	96	50	10	36
211	106	50	10	46
212	90	50	10	30
213	96	50	10	36
214	106	50	10	46
215	77	40	10	27
216	92	40	10	42
217	37	0	10	27
218	86	40	10	36
219	86	40	10	36
220	96	50	10	36
221	86	40	10	36
222	106	50	10	46
223	87	50	10	27
224	96	50	10	36
225	86	40	10	36
226	86	40	10	36
227	80	40	10	30
228	87	50	10	27
229	77	40	10	27
230	96	50	10	36
231	106	50	10	46
232	77	40	10	27
233	40	0	10	30
234	87	50	10	27
235	86	40	10	36
236	87	50	10	27
237	77	40	10	27
238	90	50	10	30
239	86	40	10	36
240	86	40	10	36
241	96	50	10	36
242	87	50	10	27
243	102	50	10	42
244	96	50	10	36

Appendix A-6

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
245	87	50	10	27
246	77	40	10	27
247	77	40	10	27
248	87	50	10	27
249	52	0	10	42
250	102	50	10	42
251	87	50	10	27
252	96	50	10	36
253	90	50	10	30
254	102	50	10	42
255	96	40	10	46
256	96	40	10	46
257	77	40	10	27
258	96	40	10	46
259	46	0	10	36
260	86	40	10	36
261	102	50	10	42
262	106	50	10	46
263	106	50	10	46
264	52	0	10	42
265	86	40	10	36
266	102	50	10	42
267	102	50	10	42
268	96	50	10	36
269	96	50	10	36
270	96	40	10	46
271	86	40	10	36
272	92	40	10	42
273	111	50	10	51
274	111	50	10	51
275	77	40	10	27
276	102	50	10	42
277	87	50	10	27
278	92	40	10	42
279	102	50	10	42
280	37	0	10	27
281	86	40	10	36
282	96	50	10	36
283	102	50	10	42
284	77	40	10	27
285	77	40	10	27
286	101	40	10	51
287	106	50	10	46
288	96	40	10	46
289	96	40	10	46
290	108	50	10	48
291	86	40	10	36
292	96	50	10	36
293	46	0	10	36
294	86	40	10	36
295	108	50	10	48
296	77	40	10	27
297	78	20	10	48
298	57	20	10	27
299	108	50	10	48
300	102	50	10	42
301	96	50	10	36
302	96	50	10	36
303	86	40	10	36
304	108	50	10	48
305	98	40	10	48
306	106	50	10	46
307	111	50	10	51
308	96	50	10	36
309	96	40	10	46
310	92	40	10	42

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
311	78	20	10	48
312	96	40	10	46
313	96	40	10	46
314	108	50	10	48
315	102	50	10	42
316	101	40	10	51
317	72	20	10	42
318	66	20	10	36
319	101	40	10	51
320	101	40	10	51
321	87	50	10	27
322	57	20	10	27
323	87	50	10	27
324	111	50	10	51
325	108	50	10	48
326	116	50	20	46
327	87	50	10	27
328	77	40	10	27
329	87	50	10	27
330	106	50	10	46
331	96	40	10	46
332	106	40	20	46
333	96	40	10	46
334	116	50	20	46
335	87	50	10	27
336	87	50	10	27
337	96	40	10	46
338	87	50	10	27
339	96	40	10	46
340	87	50	10	27
341	77	40	10	27
342	86	40	10	36
343	77	40	10	27
344	77	40	10	27
345	98	40	10	48
346	101	40	10	51
347	96	40	10	46
348	96	50	10	36
349	96	50	10	36
350	111	50	10	51
351	101	40	10	51
352	111	40	20	51
353	111	50	10	51
354	121	50	20	51
355	108	50	10	48
356	116	50	20	46
357	98	40	10	48
358	80	40	10	30
359	86	40	10	36
360	77	40	10	27
361	77	40	10	27
362	101	40	10	51
363	81	20	10	51
364	121	50	20	51
365	106	40	20	46
366	111	40	20	51
367	98	40	10	48
368	57	20	10	27
369	76	20	10	46
370	96	40	10	46
371	96	40	10	46
372	106	50	10	46
373	111	50	10	51
374	121	50	20	51
375	116	50	20	46
376	77	40	10	27

Appendix A-6

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
377	108	50	10	48
378	92	40	10	42
379	108	50	10	48
380	97	50	20	27
381	87	40	20	27
382	87	50	10	27
383	106	50	10	46
384	116	50	20	46
385	101	40	10	51
386	96	40	10	46
387	97	50	20	27
388	77	40	10	27
389	96	50	10	36
390	98	40	10	48
391	108	50	10	48
392	86	40	10	36
393	80	40	10	30
394	96	50	10	36
395	108	50	10	48
396	77	40	10	27
397	77	40	10	27
398	96	50	10	36
399	98	40	10	48
400	86	40	10	36
401	108	50	10	48
402	77	40	10	27
403	86	40	10	36
404	97	40	10	47
405	96	50	10	36
406	77	40	10	27
407	87	50	10	27
408	96	50	10	36
409	98	40	10	48
410	86	40	10	36
411	98	40	10	48
412	87	50	10	27
413	98	40	10	48
414	86	40	10	36
415	57	20	10	27
416	66	20	10	36
417	80	40	10	30
418	86	40	10	36
419	92	40	10	42
420	96	40	20	36
421	78	20	10	48
422	92	40	10	42
423	98	40	10	48
424	87	40	20	27
425	86	40	10	36
426	90	40	20	30
427	80	40	10	30
428	86	40	10	36
429	66	20	10	36
430	108	50	10	48
431	87	50	10	27

VULNER_ID	VULNRATE	LURATE	DWRATE	SOILRATE
432	102	50	10	42
433	96	50	10	36
434	86	40	10	36
435	77	40	10	27
436	92	40	10	42
437	102	50	10	42
438	102	40	20	42
439	92	40	10	42
440	108	40	20	48
441	108	50	10	48
442	98	40	10	48
443	96	40	20	36
444	96	40	20	36
445	96	40	20	36
446	108	40	20	48
447	107	40	20	47
448	98	40	10	48
449	108	40	20	48
450	107	40	20	47
451	97	40	10	47
452	86	40	10	36
453	108	40	20	48
454	108	40	20	48
455	96	40	20	36
456	112	50	20	42
457	106	50	20	36
458	102	40	20	42
459	117	40	20	57
460	127	50	20	57
461	117	40	20	57
462	102	40	20	42

VULNER_ID = Polygon identification number
VULNRATE = Vulnerability Rating
LURATE = Land Use (Recharge) Rating
DWRATE = Depth to Water Rating
SOILRATE = Soils Rating

Appendix B

Explanation of Geologic Map Units

Appendix B -1

V.S. Gillerman and T. Schiappa
Idaho Geological Survey
Summer, 1993

EXPLANATION OF GEOLOGIC MAP UNITS

Ql--LOESS AND OTHER SURFICIAL MATERIAL--Soil-covered areas with none to less than 5% bedrock outcrop. Surficial parent material consists predominantly of light-brown silty loess, typically 5 to 10 feet thick, but locally to 20 feet. Soil developed to about 3 feet depth typcially includes a 3-6 inch-thick zone of moderately developed calcareous plates, but not a solid duripan. Thin vertical fractures and caliche-coated root casts are common in the few good exposures of the loess. The western portion of map area is underlain by fine-grained aeolian sand, locally forming vegetated dunes.

Qlcc--QUATERNARY COVER OVER BASALT--Soil and loess over Lincoln County Basalt. Approximately 1 to 20 feet of cover filling in the irregular surface of basalt, with scattered basalt outcrops.

Qssc--QUATERNARY COVER OVER BASALT--Soil and loess over Sand Springs Basalt. Approximately 1 to 20 feet of cover filling in the irregular surface of basalt, with scattered basalt outcrops.

Qbocc--QUATERNARY COVER OVER BASALT--Soil and loess over Big Olivine Basalt. Approximately 1 to 20 feet of cover filling in the irregular surface of basalt, with scattered basalt outcrops.

Qwbc--QUATERNARY COVER OVER BASALT--Soil and loess over West Basalt. Approximately 1 to 20 feet of cover filling in the irregular surface of basalt, with scattered basalt outcrops.

Qttc--QUATERNARY COVER OVER BASALT--Soil and loess over Thousand Springs Basalt. Approximately 1 to 20 feet of cover filling in the irregular surface of basalt, with scattered basalt outcrops.

Qtbc--QUATERNARY COVER OVER BASALT--Soil and loess over Thousand Springs Black Basalt. Approximately 1 to 20 feet of cover filling in the irregular surface of basalt, with scattered basalt outcrops.

Qlc--QUATERNARY LINCOLN COUNTY BASALT--Dark bluish-gray vesicular basalt from source north of study area. Massive matrix with 20%, 2-3 mm plagioclase laths, 2-3 % 2-4 mm olivine phenocrysts. Glomeroporphyritic with approx. 1-2 % glomeroporphroblasts of plagioclase/olivine 5-8 mm in diameter. Very fresh with low caliche. Geomorphic surface very young, sparsely vegetated and not farmed; pressure ridge outcrops up to approximately 20 feet high. Normal (+) polarity paleomagnetism; abundant outcrops.

Qs--QUATERNARY SAND SPRINGS BASALT--Very fresh, medium gray plagioclase-

Appendix B - 1

olivine basalt. Highly vesicular with 3-5% small, 1-2 mm olivine phenocrysts, 1/2 mm plagioclase phenocrysts, 20-30% microvesicles. Some olivine globules dictytaxitic texture with plagioclase laths. Fresh iridescent vesicle linings, only minor caliche, weakly to moderately magnetic. Young geomorphic surface, unfarmed; outcrops to 20 feet high. Reverse polarity by (-) paleomagnetic data.

WATER-AFFECTED: Quenched plagioclase-olivine pillow basalt with 35% fine plagioclase laths and 3-5% olivine phenocrysts. Outstanding pillow textures with fresh glassy exteriors and vesicular interiors in rubbly, permeable rock. Extremely fresh overall.

Qbo--QUATERNARY BIG OLIVINE BASALT--Dark gray, vesicular basalt from source at "Vent 4054" in sections 23 and 24, T7S, R17E. Vesicles vary from medium size to microvesicular, giving rock a somewhat vuggy appearance. Contains 10%, 3 - 6 mm olivine phenocrysts, 3-5% , 1-2 mm plagioclase phenocrysts. Locally dictytaxitic. Reverse polarity indicated by (-) paleomagnetic data; outcrops are 5-10 feet maximum height.

Qwb--QUATERNARY WEST BASALT--Correlative with Wendell Grade Basalt (Qwg) of Malde (1966). Similar to Qbo but can be distinguished by smaller amount and size of olivine phenocrysts. Dark gray , fairly massive and dense basalt with 3-5%, 1-3 mm olivine phenocryst, 1-2% tiny plagioclase laths. Bimodal vesicle sizes which vary locally. Normal polarity indicated by (+) paleomagnetic data; maximum outcrop height is 5-10 feet in any one area.

Qtt--QUATERNARY THOUSAND SPRINGS BASALT--Medium gray basalt, coarsely to finely vesicular and magnetic. Source vent was Flattop Butte and possibly hill "Lincoln 4071" at section 31, T6S, R17E, northeast of Jerome. Contains 20% fine-grained plagioclase with a few larger 2-4 mm euhedral phenocrysts. Sparse 2% 1 mm olivine in glomeroclusters. Moderately to strongly glomeroporphyritic with 50/50 plag/olivine, 4-7 mm diameter clusters. Distinctive sunburst textures of plagioclase laths. Matrix fine-grained, massive and grainy looking. Rare inclusions of vesicular and massive bands. Moderate caliche infilling. Reverse polarity indicated by (-) paleomagnetic data; outcrop heights up to 5-15 feet. Includes cinder cone vents with bedded cinders and palagonite tuff breccias, located at pits just north of Jerome Golf Course.

Qtb--QUATERNARY THOUSAND SPRINGS BLACK BASALT--Black matrix basalt with medium sized vesicles. 1-2%, 3-4 mm plagioclase phenocrysts and 1% 1 mm olivine phenocrysts. Very sparse, small olivine-plagioclase clusters. Magnetic with locally sealed columnar joints. Different from other Qtt by lack of abundant glomeroblasts. Qtb very fresh, very black, microporous. Reverse polarity indicated by (-) paleomagnetic data. Possible vent at Sonnickson Butte, south of Jerome; outcrops have maximum heights of 1-5 feet. Geomorphic evidence suggests this is oldest surficial basalt in map area.

Appendix B - 1

QTu--QUATERNARY AND TERTIARY UNDIFFERENTIATED--Undifferentiated Quaternary and Tertiary basalts, talus, and melon gravels exposed in the north wall of the Snake River Canyon. Includes units mapped by Covington and Weaver (USGS Map I-1947D) as basalts (Qi7, Qi9, Qi10, Tg), gravel (Qg), melon gravel (Qm) of the Bonneville Flood, talus (Qtl), and recent alluvium (Qal), all of which overlie Banbury Basalt in the bottom of the Canyon. Approximately 200 feet of basalts are exposed in the upper cliffs, above 250 feet of talus-covered wall. Melon Gravel and alluvium cover the floor of the canyon near the river.

Tb--TERTIARY BANBURY BASALT--Dark gray and brown flows of olivine basalts, altered to saprolite. Spheroidal weathering. Outcrops in bottom of Snake River Canyon (USGS Map I-1947-D) and appears to be fairly impermeable. Numerous springs emerge along top of the Banbury suggesting it may act as basal aquitard for unsaturated aquifer.

Appendix C

ARC/INFO Coverages

Name	Description	Geo-coverage	Source
AQUIFERS	Aquifer boundaries	Idaho	DEQ
BLOCKS	Census blocks	Jerome Quad	Census/TIGER
BURLEY	Boundary of Burley study area	Burley	P. Jankowski
CAFO	CAFO	Jerome Quad	Digital Images (ASCS Slides)
DPTH2H2O	Groundwater levels	Jerome Quad	K. Chang
FBND	Field boundaries	Jerome Quad	Digital Images (ASCS Slides)
FC_STR	Streams	Falls City Q.	USGS-DLG
FC_QUAD	Quad boundaries	Falls City Q.	IDWR-TIC Cover
IDAHO	State outline coverage	Idaho	K. Chang
INJECT	Injection wells and other point sources	Jerome Quad	DEQ-UST/LUST
JER_STR	Streams	Jerome Quad	USGS-DLG
JERIRG_0	Irrigation types	Jerome Quad	IDWR
JEROMEQD	Quad boundaries	Jerome Quad	IDWR-TIC Cover
JGEOL	Surfacial geology	Jerome Quad	IGS
JSLIDES	Slide library: collection of TIFF image files	Jerome Quad/ PLSS sections	USDA/ASCS (Slides)
JSOILS	Soil types	Jerome Quad	USDA/SCS
JWELLS	Wells surveyed	Jerome Quad	BSU
LANDUSE	Land uses	Jerome/Scotts Pond Area	USDA/SCS
PUBWELLS	Public drinking water supply wells	Jerome Quad	DEQ
R6	Roads/Highways	Jerome Quad	USGS-DLG
R7	Roads/Highways	Falls City Q.	USGS-DLG
RANGELND	Rangeland	Jerome Quad	Digital Images (ASCS Slides)
SEPTICS	Septic systems coverage	Jerome Quad	Digital Images (ASCS Slides)
TEMPLATE	PLSS section boundaries	Jerome Quad	USGS 7.5' Topo
USGSWELL	Wells	Jerome Quad	USGS-NWIS
VULNER	Relative groundwater vulnerability rankings	Jerome Quad	K. Chang
WELLHEAD	Wellhead protection wells	Jerome & F.C. Quadrants	DEQ
WETLANDL	Riparian zones & canals	Jerome Quad	USFWS-NWI
WETLANDP	Wetlands, ponds & lakes	Jerome Quad	USFWS-NWI
WHBUF	Wellhead protections zones	Jerome/Falls City Quads	DEQ

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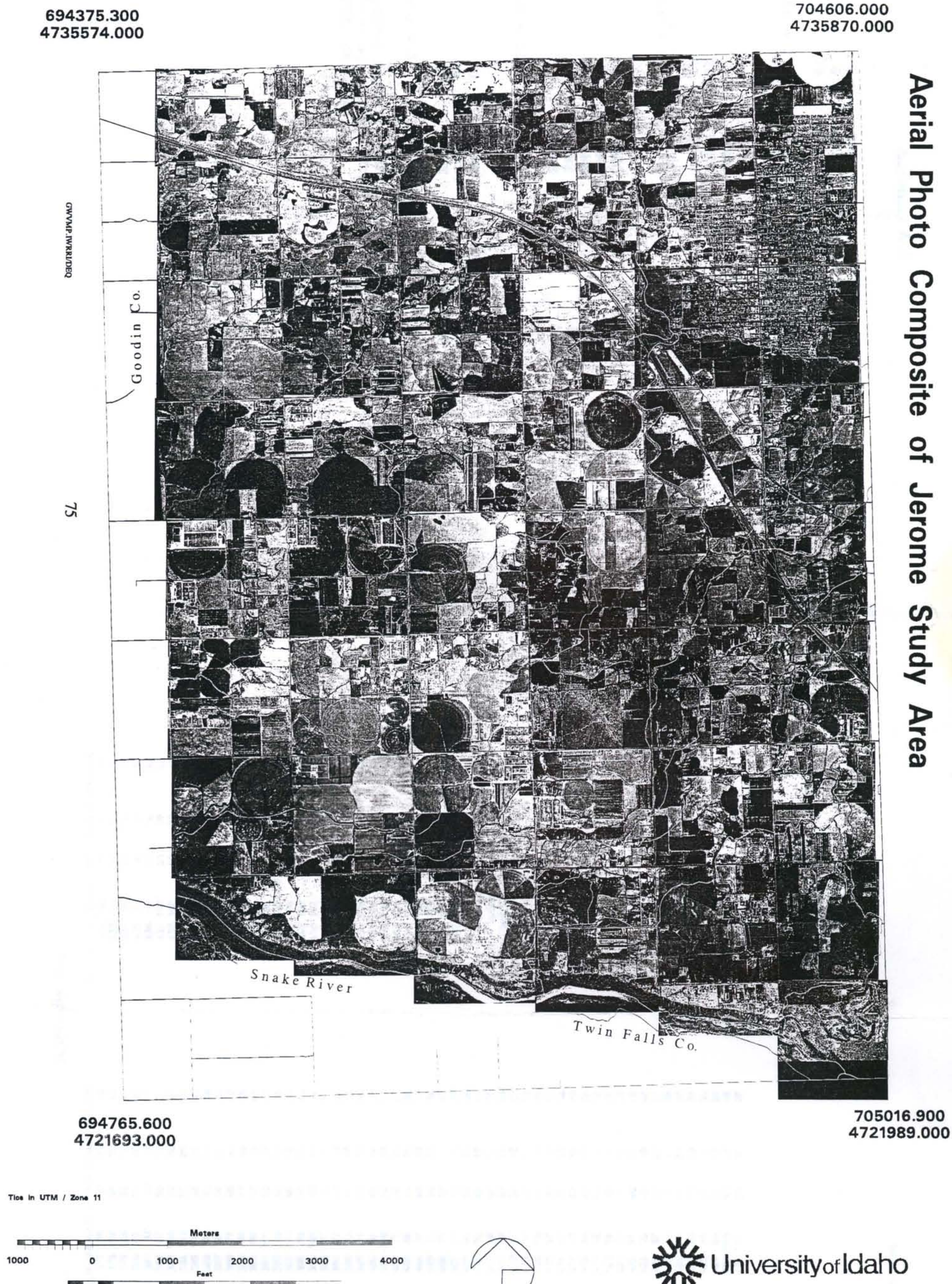

Figure 31
Aerial Photo Composite of Jerome Study Area