QUANTIFYING LAND COVER IN A SEMI-ARID REGION OF TEXAS

A Thesis

by

JOSHUA MICHAEL PESCHEL

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2004

Major Subject: Biological & Agricultural Engineering

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Approved as to style and content by:

Ronald E. Lacey (Chair of Committee)	Patricia K. Haan (Member)
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ABSTRACT

Quantifying Land Cover in a Semi-Arid Region of Texas. (December 2004)

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Chair of Advisory Committee: Dr. Ronald E. Lacey

Changes with land cover and land use are closely integrated with water and other ecological processes at the land surface. Nowhere is that more apparent than in the Edwards Aquifer region of southcentral Texas. The Edwards Aquifer contributing and recharge zones cover approximately 18,000 square kilometers in parts of 15 counties in Texas and includes San Antonio and Austin, the nation's eighth and nineteenth largest cities, respectively. Population growth within the counties that intersect the Edwards Aquifer contributing and recharge zones has taken place over the last two decades, with the logical translation being an expanded infrastructure. This implies that a greater amount of impervious surface coverage and other land cover changes have occurred. This work quantified the changes in land cover within the Edwards Aquifer contributing and recharge zones between the years 1986 and 2000. Increasing trends in impervious surface area and woodland growth were identified. Additionally, a new ArcView software tool was developed to process SSURGO soil data for use within the ArcView SWAT model. Hydrologic modeling for the Upper Sabinal River watershed, located within the Edwards Aquifer region, revealed that the high resolution SSURGO data produces different results when used in place of the existing STATSGO soils data.

Finally, an index of urbanization was developed and evaluated to assist investigators in identifying potential areas of urbanization.

ACKNOWLEDGMENTS

I would like to thank my committee members, Dr. Ron Lacey, Dr. Patti Haan, and Dr. Urs Kreuter, for supporting me in this work, both academically and financially. I am honored to call you colleagues and friends. I would also like to thank the graduate students in the Biological & Agricultural Engineering Department. I cherish the many friendships that I have made over the last few years. Finally, I would like to thank Cassie for all that she has helped me with.

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CHAPTER I

INTRODUCTION

Land cover is intrinsically connected to the structural and functional balances of local ecosystems. Ecological parameters such as wildlife habitat, carbon sequestration, and water availability may exhibit dynamic shifts when land cover changes are introduced (Forman and Godron, 1986). Modifications to ecological parameters can be readily observed at the local ecosystem level (Dugas et al., 1998). When moving to the landscape level, however, the effects of land cover change on the parameters affecting local ecosystems become less discernable (Hall and Hay, 2003). To illustrate, consider the partial removal of a woody plant species within an ecosystem. The consequences of this management practice can be observed and measured locally, but quantifying the influences of associated land cover change within adjacent ecosystems at the landscape level is not as straightforward (Wilcox, 2002). Water availability may be increased locally, yet the quantity and quality of wildlife habitat may decline both locally and in adjacent ecosystems due to habitat fragmentation (Arrington et al., 2002). Quantifying local ecosystem land cover change to evaluate its influence at the landscape level is essential for predictive modeling within at-risk regions.

Background

At-risk regions signify those with fragile ecosystems where relatively minor imbalances in local ecological parameters can directly or indirectly result in negative

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The thesis follows the style and format of *Transactions of the ASAE.*

impacts on human society. The Edwards Aquifer contributing and recharge zones of Texas (Figure 1) can be classified as an at-risk region, because semi-arid climatic characteristics with highly variable rainfall result in a large degree of uncertainty for water resources planning. In addition, unique karstic geological features in the recharge region and highly permeable soils in withdrawal areas compound planning difficulties by adding water balance sensitivity (Loaiciga et al., 2000; Khorzad, 2003).

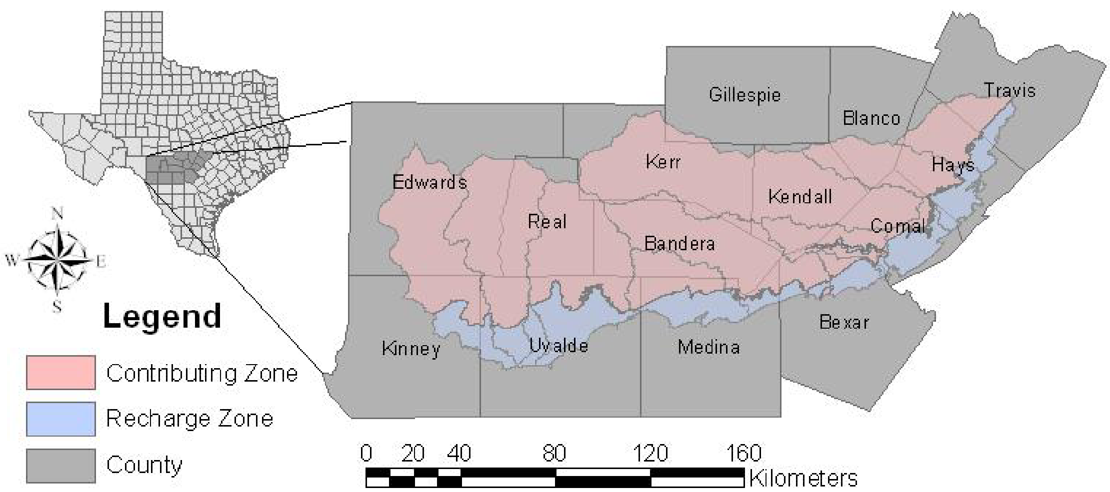

Figure 1. Contributing and recharge zones of the Edwards aquifer.

The conterminous area of the Edwards Aquifer contributing and recharge regions is approximately 17,750-km^2 stretching across 15 counties. Located within these boundaries are the cities of San Antonio and Austin, the eighth and nineteenth largest cities in the United States, respectively. United States census data from 1980 through 2000 (Table 1) indicate 20-year population growth ranging from 6.35% in Edwards County to 149% in Bandera County (U.S. Census Bureau, 1980; 1990; 2000).

Table 1. United States census data for Edwards aquifer counties (1980 through 2000).

County	Population in 1980	Population in 1990	Population in 2000	% Change 1980 to 1990	% Change 1980 to 2000
Bandera	7084	10562	17645	49.10	149.08
Bexar	988800	1185394	1392931	19.88	40.87
Blanco	4681	5972	8418	27.58	79.83
Comal	36446	51832	78021	42.22	114.07
Edwards	2033	2266	2162	11.46	6.35
Gillespie	13532	17204	20814	27.14	53.81
Guadalupe	46708	64873	89023	38.89	90.59
Hays	40594	65614	97589	61.63	140.40
Kendall	10635	14589	23743	37.18	123.25
Kerr	28780	36304	43653	26.14	51.68
Kinney	2279	3119	3379	36.86	48.27
Medina	23164	27312	39304	17.91	69.68
Real	2469	2412	3047	-2.31	23.41
Travis	419573	576407	812280	37.38	93.60
Uvalde	22441	23340	25926	4.01	15.53

Interpretations of these types of population changes have often implied concomitant land cover change towards urbanization (Otterstrom, 2001). Furthermore, rates of urbanization and related land cover changes may have varied within these regions; the extent of which is currently unknown.

Problem Statement

Population growth rates within the counties that overlay the Edwards Aquifer contributing and recharge zones have increased, sometimes significantly, over the last two decades, which has led to an expanded infrastructure. This implies that a greater amount of impervious surface coverage and other related land cover changes have occurred within the two zones over time. Increases in impervious surface coverage and related changes in land cover have influenced water, sediment, and chemical yields within ecosystems (Sleavin et al., 2000; Tong and Chen, 2002; Holland et al., 2004). As a result, ecological parameters such as wildlife habitat, carbon sequestration, and water availability and quality are often negatively affected.

Quantifying land cover changes to examine the yield responses within and among ecosystems is necessary for evaluating the extent of human influence at the landscape level within the Edwards Aquifer region. To better understand the effects of land cover change on different ecological parameters, modeling software packages have been developed to simulate hydrologic and other environmental conditions. The ArcView Soil and Water Assessment Tool (ArcView SWAT) is an established, geographical information system (GIS) modeling tool for predicting the impacts of land management practices on water, sediment, and chemical yields (Neitsch et al., 2002; Di Luzio et al., 2002). ArcView SWAT was originally designed to study large interconnected basins, such as the Edwards Aquifer contributing and recharge regions, at the landscape level (Neitsch et al., 2002). As a consequence, large areal input data sets are required for generating model predictions. A historical suite of classified land cover data does not currently exist for the Edwards Aquifer contributing and recharge zones, but soil and climate data for the two zones are available. Unfortunately, data format incompatibilities create a barrier to direct use within ArcView SWAT. A method is needed to convert the soil and climate data into a format that can be easily input into the ArcView SWAT model.

The extent of urbanization within the Edwards Aquifer contributing and recharge zones over time is of primary interest. The term “urbanization” is frequently used but not easily defined. A straightforward definition based on readily observed parameters, such as impervious surface coverage and population density, is needed to identify watersheds that may be more at-risk than others. An indexed level of urbanization will help guide and prioritize future modeling initiatives to investigate the effects of urbanization within the Edwards Aquifer contributing and recharge regions.

Objectives

The focus of this research is to classify, quantify, and reliably assess historical land cover changes and the extent of urbanization within the Edwards Aquifer contributing and recharge zones between 1986 and 2001. The specific objectives of this research include:

1) Classify remotely-sensed Landsat Thematic Mapper (TM) satellite imagery to determine land cover changes within the Edwards Aquifer contributing and recharge zones between 1986 and 2001. Changes in land cover have been documented within the Edwards Aquifer region, but a suite of classified historical land cover data to evaluate actual change does not currently exist for the region.

2) Assemble a comprehensive online GIS data library for the Edwards Aquifer contributing and recharge zones for the period 1986 through 2001. Historical data sets contained within the online GIS data library will include all necessary physical and climatic parameters in a format suitable for modeling applications within the ArcView SWAT model.

3) Design and implement an algorithm that allows Soil Survey Geographic (SSURGO) 2.0 data sets to be used within the ArcView SWAT model. State Soil Geographic (STATSGO) data is the standard soils data set available for use within the ArcView

SWAT model; however, the new and much higher resolution SSURGO 2.0 data sets have never been available for use because of format incompatibility.

4) Develop and implement a methodology to identify urbanizing watersheds within the Edwards Aquifer contributing and recharge zones between 1986 and 2001, using land cover and census data as indicators. An increase in parameters such as the amount of impervious surface coverage and population density implies the occurrence of urbanization.

CHAPTER II

LITERATURE REVIEW

Though a historically comprehensive and consistent record of land cover change does not exist for the Edwards Aquifer contributing and recharge regions, the area is currently one of the most studied sections of the United States (Khorzad, 2003). The majority of related research studies have focused on surface and groundwater modeling (Puente, 1976; Barrett and Charbeneau, 1997; Loaiciga et al., 2000; Scanlon et al., 2003), karst geologic and geochemical features unique to the region (Oetting et al., 1996; Ferrill and Morris, 2003; Musgrove and Banner, 2004), and vegetation management (Wu et al., 2001; Rosenthal et al., 2002; Afinowicz et al., 2003).

The driving force behind these types of research studies has been the need to understand and protect different ecological parameters within the region (Veni, 1999). For example, San Antonio, one of the 25 most populated and fastest growing metropolitan areas in the United States, relies exclusively on the Edwards Aquifer as the sole source of water (Esquilin, 2002). Agriculture-related operations in the rural portion of the Aquifer also rely on the Edwards as the sole water source (Thurow et al., 2001). Both of these demand issues have integral ties to regional ecological parameters, specifically, carbon sequestration and wildlife habitat (Kreuter et al., 2001).

Previous research studies within the Edwards Aquifer region have not adequately addressed comprehensive land cover change. More specifically, prior studies have not examined the actual impacts of changes in spatially distributed landscape elements and the corresponding effects on local and landscape level ecological parameters within the

Edwards Aquifer contributing and recharge zones. Precluding this research question is the lack of a quantitative assessment and prioritization of land cover change studies for the region. A reliable and consistent historical land surface and climatic record is necessary to facilitate modeling efforts. The following sections of this chapter outline prior land cover data set development and urbanization studies that have been conducted for the Edwards Aquifer contributing and recharge zones.

Available Land Cover Data Sets

With the mainstream introduction and implementation of GIS software packages, demand for land cover data sets in a digital format has increased. As a result, such data sets have been sporadically developed over the years by different governmental and regulatory agencies. Available in the public domain are four certified digital land cover data sets that characterize all or at least portions of, the Edwards Aquifer contributing and recharge zones. These available data sets are: the Texas Parks and Wildlife Department (TPWD) vegetation map, the 1:250,000-scale land use and land cover data set created by the United States Geological Survey (USGS), the National Land Cover Data set (NLCD) also produced by the USGS, and the Edwards Aquifer land use and land cover data set authorized by the Texas Commission on Environmental Quality (TCEQ) through the USGS. Each data set represents different periods of time, spatial scales, levels of classification, and accuracy. Development and recommended usage summaries for the four publicly available digital land cover data sets are outlined in Table 2 and discussed further in the following sections.

Table 2. Summary characteristics for publicly available digital land cover data sets for the Edwards Aquifer contributing and recharge zones.

Land Cover Data Set	Period of Study	Spatial Scale	Classification Level	Data Source	Accuracy Assessment	Extent of Coverage
Texas Parks & Wildlife Department	1972 through 1975	1:24,000	Anderson Level III or higher	Landsat I and II MSS imagery	Not performed	Entire region
USGS 1:250,000 Land Use/Land Cover	1977 through early 1980s	1:250,000	Anderson Level II	Aerial photography	Not performed	Entire region
USGS National Land Cover Data	Early 1990s	1:250,000	Anderson Level II	Landsat 5 TM imagery	74% overall accuracy	Entire region
TCEQ Land Use/Land Cover	1995 through 1996	1:24,000	Anderson Level III	Landsat 5 TM imagery	Not performed	Recharge zone only

Texas Parks and Wildlife Department Vegetation Map

In 1984, investigators at the TPWD created a hardcopy vegetation map, including cropland, to characterize the different vegetation cover types across Texas (McMahan et al., 1984). The sources of the map were Landsat 1 and 2 Multi-Spectral Scanner (MSS) satellite imagery, coupled with ground surveys, both taken over a period of 4 years (1972 through 1976). The hardcopy vegetation map was later digitized and converted into its current GIS format. Figures 2 presents the Edwards Aquifer contributing and recharge zones characterized by the TPWD vegetation map. The spatial scale of the vegetation map is not explicitly stated, however, metadata do indicate that the vegetation data should not be used for large scale, site-specific analyses (TPWD, 1998). Given the level of vegetation species detail contained in the data set, the land cover classification would likely be considered Anderson Level III or higher (Anderson et al., 1976). Table 3 presents a summary of the Anderson classification descriptions. From the information

Table 3. Summary descriptions of the Anderson classification system.

Classification Level	Spatial Scale	Recommended Usage	Data Sources
I	1:250,000	National, interstate, or statewide level	Landsat imagery
II	1:80,000	National, interstate, or statewide level	High altitude data at approximately 12,400-m
III	1:24,000	Intrastate, regional, county, or municipal level	Medium altitude data between 3,100-m and 12,400-m
IV	1:12,000	Intrastate, regional, county, or municipal level	Low altitude data below 3,100-m

given in Table 3, it can be inferred that the corresponding spatial scale of the TPWD vegetation map is approximately 1:24,000. However, a primary data source used to

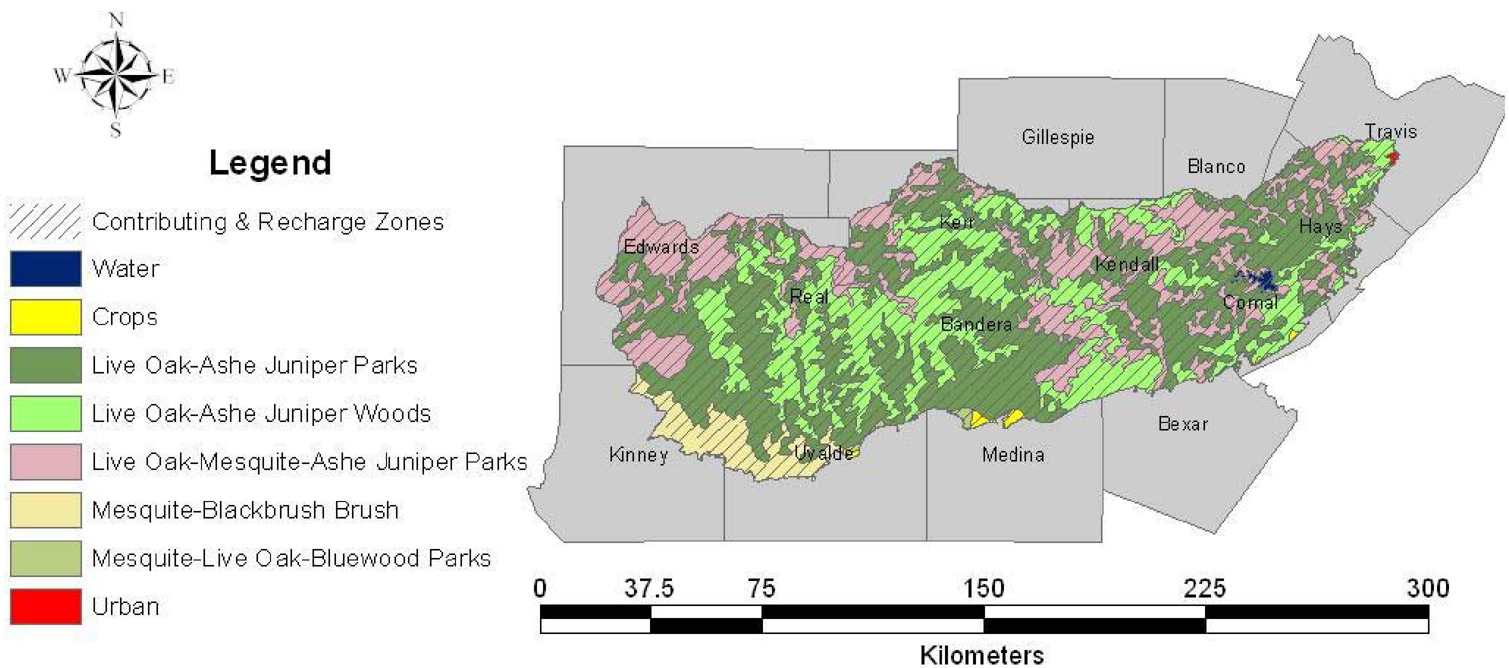

Figure 2. Texas Parks and Wildlife Department vegetation map for the Edwards Aquifer contributing and recharge zones.

develop the map was Landsat imagery, which indicates that the actual spatial scale is coarser (between 1:24,000 and 1:250,000). The TPWD vegetation map illustrates an example of conflict between the level of classification and the spatial scale of the source data. An accuracy assessment was not performed for the TPWD vegetation map.

Although there are obvious advantages of classification level associated within this data set, three significant problems related to objective one of this research are present. First, though the vegetation map was produced in 1984, the source images and survey periods predate the specified period of study by 10 years. The TPWD vegetation map would be acceptable for small-scale applications where little or no land cover change has been verifiably observed since the original study. The second problem lies within the classification methodology. The TPWD vegetation map represents a year-round land cover composite. In other words, though a species may be dormant for a certain period of the year, it will be included in the data set. It is unclear how vegetation would have actually been distributed at different times of the year, therefore, seasonal adjustments would be necessary for further modeling use, depending on the period of study desired. Finally, the TPWD vegetation map was created using Landsat MSS imagery, which was obtained from the Landsat 1 satellite (launched July 23, 1972) and possibly, the Landsat 2 satellite (launched January 22, 1975). Later Landsat satellites launched, through Landsat 5, contained the MSS sensor. Landsat 4 (launched July 16, 1982) and Landsat 5 (launched March 1, 1984) also carried the higher spatial and spectral resolution Thematic Mapper (TM) sensor. With the launch of Landsat 7 in April of 1999, the MSS and TM sensors were replaced with the improved spectral resolution Enhanced Thematic

Mapper Plus (ETM+) sensor. Only Landsat 5 remains accurately recording MSS data, yet the expected lifetime of the satellite has been exceeded and thus, the continuity of the imagery is uncertain. Future Landsat satellites will not likely include the MSS and TM sensors since image band overlap exists with the ETM+ sensor (NASA, 2004). Therefore, current and future attempts to reproduce similar vegetation maps for the Edwards Aquifer contributing and recharge zones using the TPWD vegetation map methodology are extremely limited due to the lack of available source data.

United States Geological Survey 1:250,000 Land Use and Land Cover Data

Through the availability of Landsat satellite and other remotely-sensed imagery, additional land cover initiatives were developed. The USGS used aerial photography composites from 1977 through the early 1980s as a data source to produce the first comprehensive, large-scale land use and land cover (LULC) map of the conterminous United States. The spatial scale of the LULC data set is 1:250,000, which would be adequate for large river basin scale modeling (USDA-NRCS, 1995). With this level of spatial scale, the LULC data set would most aptly be described as Anderson Level II (Anderson et al., 1976). Land cover accuracy assessments for the LULC data set were not made available. Figures 3 presents the Edwards Aquifer contributing and recharge zones as defined by the USGS LULC data set.

The USGS LULC data set contains the same fundamental problems as the TPWD vegetation map, while possessing additional undesirable characteristics. First, the source data period again predates the required period of study. The timeline of the source data acquisition also remains unclear. Within the given dates (1977 through the early 1980s),

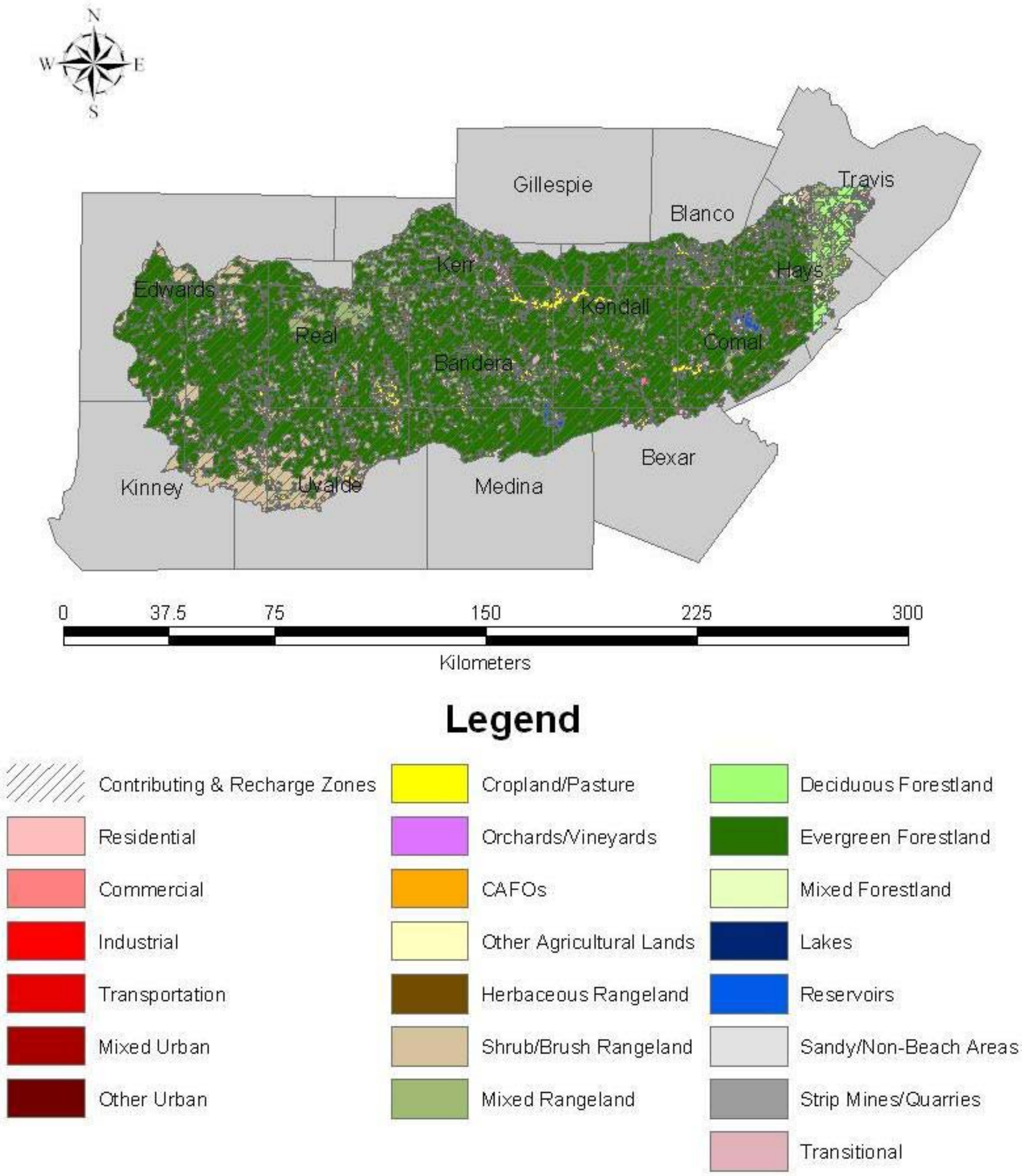

Figure 3. United States Geological Survey 1:250,000 land use and land cover data for the Edwards Aquifer contributing and recharge zones.

several land cover changes could have taken place, which may not be captured in the final LULC product. Like the TPWD vegetation map, the LULC data set is a land cover composite, containing vegetation that would not necessarily appear year-round. The source data also presents a problem since aerial photography was used. There is no consistent temporal record associated with aerial photography data sources. If a reasonable frequency of aerial photography data had been kept, it is still unlikely that sensor instrumentation would remain similar. The LULC data set would provide the best use of resources when incorporated within time-specific studies, used in conjunction with ancillary data sets (USGS, 1990).

United States Geological Survey National Land Cover Data

The integration of Landsat 5 imagery, modern classification techniques and ancillary data sources was realized in the 1992 USGS National Land Cover Data (NLCD) product. A 21-class land cover scheme was derived from Landsat 5 TM satellite imagery. The NLCD classification system utilizes a modified form of the Anderson Level II classification system, with some land cover categories being combined (USGS, 2003). Landsat 5 TM source data were used from the early 1990s. Additional image scenes were added for regions where cloud cover prohibited land cover classification. It is not known if non-1992 imagery were substituted for the land cover classification within the Edwards Aquifer region. A standard unsupervised clustering algorithm was used to develop a seasonal composite from the imagery and aerial photography with ground surveys were used to identify the land cover clusters. An accuracy assessment was published with the NLCD data indicates an association with U.S. Environmental

Protection Agency (U.S. EPA) region number 6. In the case of U.S. EPA region 6, which encompasses Texas, the overall accuracy was 74% (Wickham et al., 2004). Figures 4 presents the USGS NLCD Edwards Aquifer contributing and recharge zones.

The USGS NLCD provides the same level of spatial scale as the USGS 1:250,000 LULC data set. The source data period is also well defined for the NLCD product. However, the seasonal composite and overall accuracy of the data set bring its use for modeling purposes into question. According to the accuracy assessment published with the data, urban lands within EPA Region 6 were only accurately classified at the 46% level. Furthermore, barren lands were classified at a 26% level of accuracy (Wickham et al., 2004). Though these figures do not indicate specifically where the low level of accuracy exists, they are an indicator to the possible error associated with the data set. Both urban and barren lands (low ground cover) are important within the scope of this research. Therefore it is essential that a certain level of accuracy be present.

Texas Commission on Environmental Quality Edwards Aquifer Land Cover Data

The final land cover data set available in the public domain is distributed by the TCEQ. The development of the product was originally conduced by the USGS. The period of acquisition for the Landsat 5 imagery was during the years 1995 through 1996. A modified Anderson Level III classification was performed on the image data, which utilized aerial photography and ground surveys for validation (TCEQ, 2001). As a result, the spatial scale is 1:24,000. An accuracy assessment was not provided for the TCEQ land cover data set. Figure 5 presents the TCEQ land cover data for the Edwards Aquifer contributing and recharge zones.

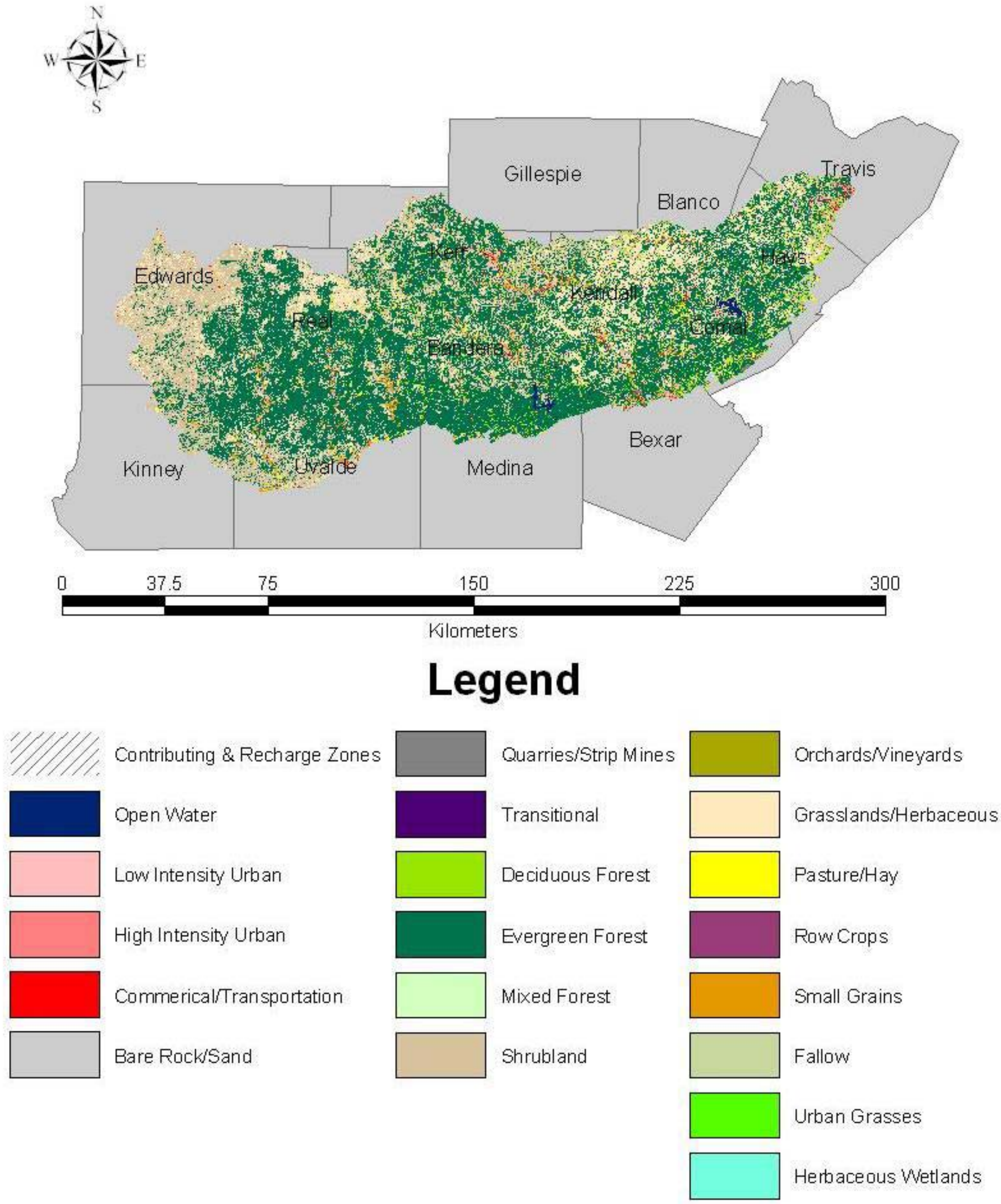

Figure 4. United States Geological Survey National Land Cover Data for the Edwards Aquifer contributing and recharge zones.

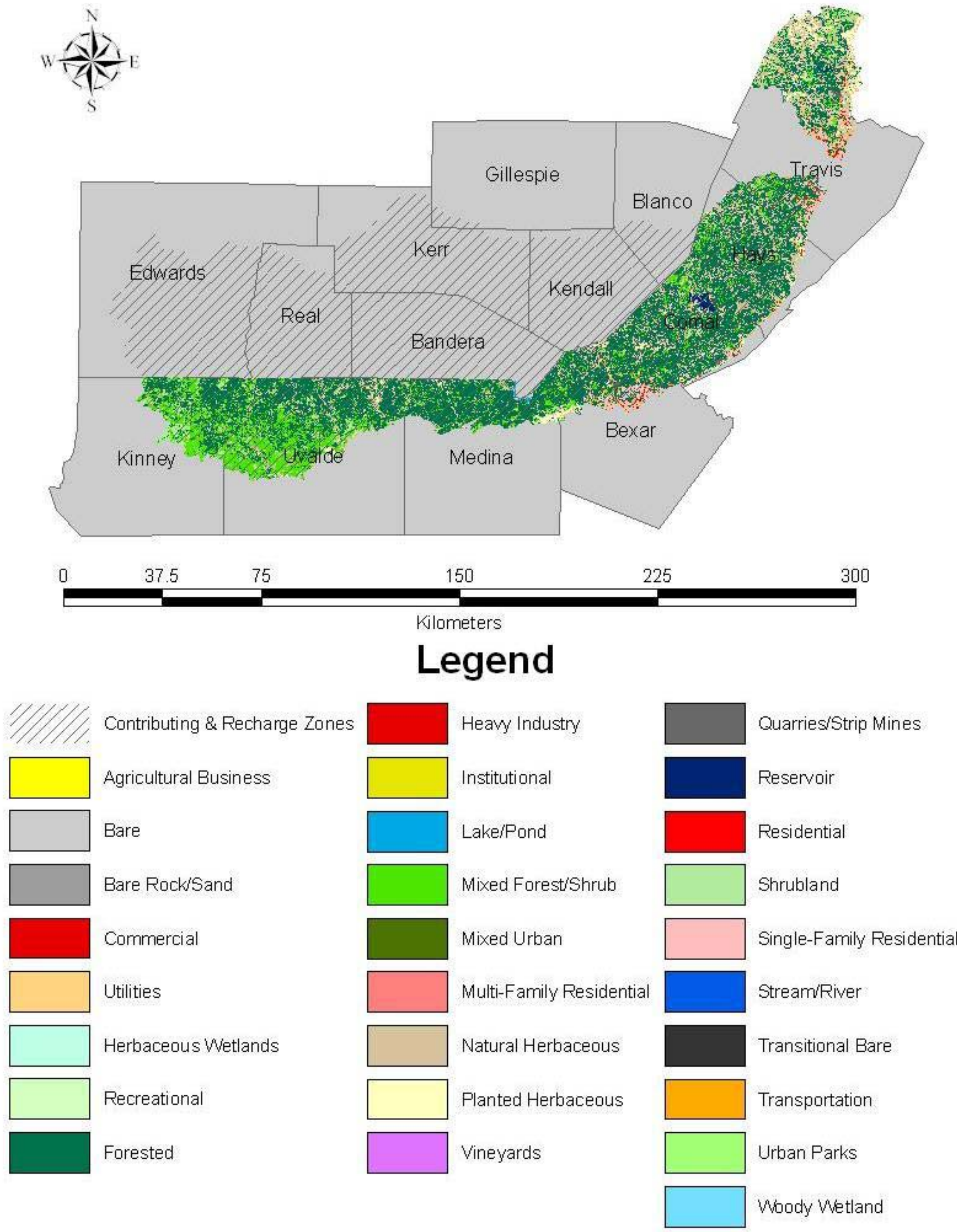

Figure 5. Texas Commission on Environmental Quality land cover data for the Edwards Aquifer contributing and recharge zones.

It is expected, yet unknown, that the TCEQ data set represents a seasonal composite of land cover for the region. As can be seen from Figure 5, the TCEQ land cover data set does not adequately depict the area of interest for this study. Only the recharge zone is fully characterized, while the contributing zone is not included. The TCEQ data set is useful from a resolution perspective for studies in the recharge zone, but the data set is not entirely sufficient because of its incompleteness for the contributing zone.

Urbanization Studies

Urbanization is often defined as the conversion of rural lands to urban and other built-up uses (Alig et al., 2004). For the purposes of this study, urbanization will be defined as the presence of human activity as represented by two parameters: impervious surfaces and population. The conversion and use of land for agricultural purposes can also be considered a form of urbanization, though the transient nature of crop growth, rotation, and conversion to rangeland make exact quantitative assessments less reliable. In other words, while agricultural uses may fluctuate over time, the presence of impervious surfaces typically remains constant or increases. The impact of impervious surfaces is also more pronounced than that of agricultural uses since ecological parameters such as wildlife habitat and carbon sequestration are effectively eliminated unless those parameters are integrated into the urban landscape. The presence of trees and similar vegetation along city streets in San Antonio and Austin are one example of ecological parameter integration that may allow ecosystem services, such as carbon sequestration, within an urbanized environment. Another ecological parameter, water availability, may also be affected by impervious surfaces that limit infiltration and increase surface runoff within the hydrologic cycle. In the Edwards Aquifer region where infiltration mechanisms and rates have been shown to be geologically unique, quantifying the presence and evolution of impervious surfaces is of great interest.

Limited land cover classification studies within the Edwards Aquifer contributing and recharge zones have indicated that urbanization is increasing. Buffer zone studies for the Leon Creek watershed in Bexar County were conducted to assess vegetation change from 1987 through 1999. Within a 100-ft creek buffer throughout the entire watershed, vegetation was shown to decrease by 3.5%, indicating an increase in the percentage of urbanized areas (Cummins, 2000). A temporal ecological services study that included three watersheds in the San Antonio area (Salado Creek, Upper San Antonio River, and Leon Creek) found a collective net increase in impervious surface coverage of 125.1-km^2 between 1976 and 1991. As a percentage of the total study area, an 8.2% increase in impervious surface coverage was identified. Simultaneously, or during the same period, agricultural lands were found to decrease by 526-km^2, or 34% of the study area, while forest and woodland areas experienced a net increase of 358-km^2, or 23% of the three watersheds. A separate classification was not made for grassland, but it was indicated that rangelands were included in the agricultural lands category. These trends show that impervious surfaces and forestland have increased in this segment of the Edwards Aquifer region over time (Harris, 2000). While these two analyses provide a relatively acceptable quantitative measure of urbanization within the region, the areas of study overlay only about 5% of the Edwards Aquifer contributing and recharge zones.

CHAPTER III

BASE MAP DEVELOPMENT

Remotely-sensed satellite imagery provides a source of reliable data for land cover change characterization and analysis. The increased availability and low-cost of satellite imaging technology has made its use practical for studying large areas such as the Edwards Aquifer contributing and recharge zones. Among the many historical satellite image data sets available for public use, the Landsat program is currently the longest running, worldwide, land cover data acquisition program (USGS, 2004a). The historical Landsat record ranges from July 1972 through the present, spanning seven satellites. Prior to Landsat 4, the Multi-Spectral Sensor (MSS) was the single recording instrument aboard the satellite. The MSS was capable of recording four wavelength bands of the electromagnetic spectrum at a spatial resolution of 79-m (Table 4). Landsat 4 was the first satellite to carry the Thematic Mapper (TM) sensor and began acquiring image data in July 1982. The Landsat 4 and 5 TM sensors recorded six spectral bands at spatial resolutions of 28.5-m. In April 1999, 30-m standard band spatial resolution and a 15-m panchromatic band feature were implemented within the Enhanced Thematic Mapper Plus (ETM+) sensor and launched onboard the Landsat 7 satellite (Table 5) (Lillesand

Table 4. Landsat Multi-Spectral Sensor (MSS) bands and common usages.

Band	Bandwidth (mm)	Example Application
1	0.50 – 0.60	Green reflectance from healthy vegetation
2	0.60 – 0.70	Chlorophyll absorption for plant differentiation
3	0.70 – 0.80	Biomass surveys
4	0.80 – 0.90	Biomass surveys and water body delineation

Table 5. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) bands and common usages.

Band	Bandwidth (mm)	Example Application
1	0.45 – 0.52	Deciduous/coniferous differentiation
2	0.52 – 0.60	Green reflectance from healthy vegetation
3	0.63 – 0.69	Chlorophyll absorption for plant differentiation
4	0.76 – 0.90	Biomass surveys and water body delineation
5	1.55 – 1.75	Plant moisture content and cloud/snow differentiation
7	2.08 – 2.35	Thermal mapping and soil moisture

and Kiefer, 1994). The higher spatial and spectral resolutions of the TM and ETM+ sensors significantly improved the ability to classify ground objects within the image data versus the MSS sensor capabilities (Badhwar et al., 1984).

Image Classification Methods

Digital satellite images are composed of pixels with associated brightness values over a specified range that depends on the method of data recording (i.e. the sensor). For example, an 8-bit Landsat TM image pixel is capable of having a discrete brightness value over the range of 0 to 255. Mathematically, an image can be represented as a k-dimensional $m \times n$ matrix with each element possessing a discrete value from the set of all possible values that the sensor is capable of producing. To generalize, the collection of brightness values (BV) over the spatial domain i, j of spectral image band k is defined by the following expression

$$BV_{ijk} = \begin{pmatrix} x_{11k} & x_{12k} & x_{13k} & \cdots & x_{1nk} \\ x_{21k} & x_{22k} & x_{23k} & \cdots & x_{2nk} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1k} & x_{m2k} & x_{m3k} & \cdots & x_{mnk} \end{pmatrix} \tag{1}$$

where $i = 1, 2, \ldots, m$, $j = 1, 2, \ldots, n$ and $k = 1, 2, \ldots, r$. The parameters m and n represent the vertical and horizontal spatial dimensions of the image, respectively. The parameter r is the number of spectral bands that the given sensor is capable of recording. This representation can be used for further mathematical transformation, analysis, and classification of image data.

Three primary methods exist to classify images: unsupervised, supervised, and artificial (Jensen, 1996). Unsupervised classification is the application of a computer algorithm to locate and group similar image band pixel values. These clusters of spectral features can then be categorized into specific land cover types. Two unsupervised classification methods most often employed are the Iterative Self-Organizing Data Analysis Technique (ISODATA) and a related clustering algorithm, often referred to as c-means or k-means. For example, Clapham (2003) used the ISODATA technique to classify land cover from Landsat TM imagery within a series of urbanizing watersheds. Although land cover classes were well discerned, particularly between impervious surfaces and different canopy covers, a complete accuracy assessment was not provided for this study. In a separate study, impervious surface coverage in urbanizing watersheds was explicitly derived from Landsat TM imagery using the ISODATA technique. An accuracy analysis revealed a root mean square error of 10.6%, which was shown to be consistent with digitizing errors for aerial photographs that were used for the validation (Wu and Murray, 2003). Clustering-related algorithms have also shown promise, particularly in large areas where agricultural or forested land cover types are dominant elements within the landscape. Classification accuracies of 75% and greater have been achieved in certain cases (Oetter et al., 2001; Gutierrez et al., 2004). Unsupervised methods are advantageous due to the minimal computation time required for classification. However, actual accuracy can be sacrificed since the only real basis of classification is the relative spectral values of the image, which may vary within and between seasons; no external data or contexts are considered (Schowengerdt, 1997).

Supervised classification methods rely upon *a priori* knowledge of a particular land cover present in an image data set. Homogeneous training areas and land cover classes are initially specified. A computer algorithm is then applied to associate an image pixel value with a particular land cover class, based on some specification of the pixel value belonging to a previously defined category. Maximum likelihood and minimum distance are two common supervised classification techniques used to produce classified land cover data sets. The maximum likelihood technique has recently been applied to monitor urban land cover change using Landsat TM imagery in semi-arid regions (Stefanov et al., 2001; Helmschrot and Flugel, 2002). Classification accuracies of 85% and greater were achieved using this technique. Tapiador and Casanova (2003) used the minimum distance technique to classify Landsat TM imagery for regional urban planning directives. A classification correlation coefficient was determined to be 0.68, which implied a relatively high degree of accuracy. In another application, burned forest canopy tracking was successfully undertaken using a multi-temporal series of Landsat TM images. Using kappa analysis, an accuracy level of 76% or greater was determined for the land cover classifications (Miller and Yool, 2002). Unlike unsupervised classification, supervised methods require significantly greater computational times.

The accuracy of supervised classification methods is, however, often much greater than that produced by unsupervised classification (Schowengerdt, 1997).

The third category of image classification, artificial methods, typically includes some form of fuzzy logic or neural network classifier. Like the supervised classification method techniques described, a training data set is first specified. Input image data are coupled with a corresponding classified data set to train and produce a numerical classifier. The classifier is then applied to the remaining image data set to categorize the different land cover types based on spectral and sometimes, contextual, information. Forest mapping has been a primary application area for land cover classification research using artificial methods. Large conifer forests have been classified using Landsat TM imagery (Pax-Lenney et al., 2001). Accuracies for these forest classifications using artificial methods have been at the 86% level (Carpenter et al., 1999). Abulgasim et al. (1999) developed a fuzzy neural network technique to classify and detect various land cover changes in an arid environment, in which land cover classification accuracies were approximately 86% and greater. Jang and Foody (1998; 2001) have also illustrated the accuracy advantages of artificial classification over conventional unsupervised and supervised classification techniques within a sub-urban context using Landsat TM imagery. When using artificial classification techniques, computation time is typically minimal and a high degree of accuracy can be attained, depending on the accuracy of the training data set. Inconsistencies in training data sets may logically translate into errors when the land cover classifications are produced (Schowengerdt, 1997). Among the different classification methods, there appears to be no general or ideal technique for classifying land cover data. The area of study and desired level of classification will dictate the method that is used.

Image Data Acquisition and Classification Procedure

The Landsat satellites have a sun-synchronous, 16-day polar orbit with each 185-km × 185-km image footprint identifiable by numerical path and row values of the World Reference System (WRS). Four Landsat images are required to overlay the Edwards Aquifer contributing and recharge zones, including: Path 27 Row 39, Path 27 Row 40, Path 28 Row 39, and Path 28 Row 40 (Figure 6).

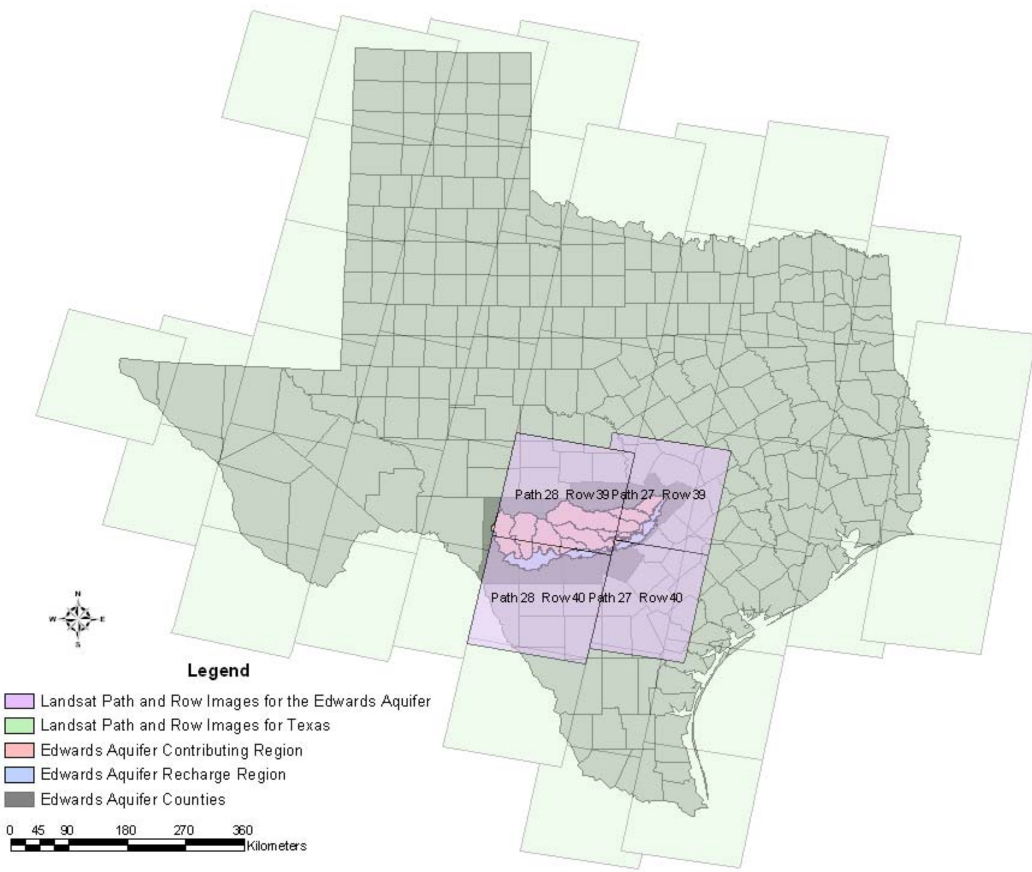

Figure 6. Landsat path and row image footprints for Texas and the Edwards Aquifer contributing and recharge zones.

A comprehensive list of cloud-free historic Landsat TM and ETM+ imagery was compiled using the USGS Global Visualization (GloVis) website (USGS, 2004b). Cloud-free images were necessary since clouds typically exhibit high pixel brightness values and can easily be misclassified. Landscape elements, such as roads, parking lots, and bare soil, are often characterized by high pixel brightness values and can therefore be grossly overestimated because of the presence of clouds. Relatively cloud-free images with matching dates for 1986 through 2001 were selected from the comprehensive Landsat image list. An additional constraint for image scene selection was that the image acquisition period be from March through August, to maximize the level of discernment between different vegetation classes, especially agricultural areas and grasslands (Peterson et al., 2002; Price et al., 2002). Table 6 presents a brief description of the Landsat images selected for this study. Three sets of image data that did not meet the exact selection constraints were included in the final list because of the

Table 6. Landsat image scenes used in the study.

Path/Row Coordinates	Acquisition Date	Satellite
27/39	July 20, 1986	Landsat 5
27/39	November 28, 1993	Landsat 5
27/39	March 15, 2001	Landsat 7
27/39	July 21, 2001	Landsat 7
27/40	July 20, 1986	Landsat 5
27/40	November 28, 1993	Landsat 5
27/40	March 15, 2001	Landsat 7
28/39	July 27, 1986	Landsat 5
28/39	May 11, 1993	Landsat 5
28/39	April 4, 2000	Landsat 7
28/39	July 12, 2001	Landsat 5
28/40	July 27, 1986	Landsat 5
28/40	May 11, 1993	Landsat 5
28/40	April 4, 2000	Landsat 7
28/40	July 12, 2001	Landsat 5

lack of cloud-free images. The Path 27 Row 39 and Path 27 Row 40 image set from November 28, 1993 was included as the closest cloud-free match to the May 11, 1993 data. Image data from 2001 that met the seasonal requirement were used to substitute for cloud-filled 2000 image data of the region. Both constraint deviations were expected to produce negligible effects. As can be inferred from Table 6, a 7-year time interval (to be denoted further as 1986, 1993, and 2000) was adopted for this study. Landsat 5 TM images were obtained directly from the USGS (USGS, 2004b). Landsat 7 ETM+ image data were acquired from the Texas Natural Resources Information System (TNRIS) (TNRIS, 2004a). For ease of integration with other data sets, all Landsat TM images were requested in the Universal Transverse Mercator (UTM) Zone 14 North coordinate system with the World Geographic System of 1984 (WGS84) datum. The image data were delivered in the hierarchical data format (HDF). They were unable to be classified directly, therefore a series of image processing steps were first necessary to prepare the image data for classification.

Image Processing

Though the image scenes were requested in the specified UTM coordinate system, the image data were -8.89 degrees out of rotation from the actual vertical for georeferencing purposes. The out-of-rotation extent was determined through trial and error image rotation and ground point validation. The Environment for Visualizing Images (ENVI), a software package produced by Research Systems, Inc., was used to rotate the image data to the correct geo-referenced position. The nearest neighbor algorithm was selected for the rotation process since it introduced the least amount of re sampling error within the final product (Jensen, 1996). After an image was rotated, each of its six individual image bands were converted to the geo-referenced tagged image file format (geo-tiff). The geo-tiff format was a necessary intermediate processing step to transfer the image data from the HDF format to the GIS software.

Once in the geo-tiff format, each image band was converted to the native Arc grid format using the ArcGIS 8.1 ArcToolbox program. ArcView and ArcGIS are GIS software programs produced by the Environmental Systems Research Institute (ESRI). The Arc grid format was required for further image processing within the ArcGIS software environment. A coordinate system misalignment phenomenon was observed when the image band grids were loaded into the ArcGIS program; therefore, a spatial adjustment was necessary for each set of image grids. Geo-referenced 2003 Texas Department of Transportation (TxDOT) shapefiles obtained from TNRIS were used to manually align each of the image grids (TNRIS, 2004b). Appendix A presents the alignment point coordinates and the spatial adjustments made for each image grid.

Many of the constituent geologic boundaries of the Edwards Aquifer contributing and recharge zones intersected more than one image scene. To resolve this problem, image scenes of identical or similar acquisition dates were merged together using the ArcGIS program to produce continuous scenes. Table 7 presents the image scenes that were merged. To reduce the amount of data in order to speed image classification, 8-digit hydrologic unit code (HUC) boundaries defined by the USGS were used to reduce the image scenes to the watershed areas. Geo-referenced 8-digit HUC shapefiles were obtained from the USGS website and the ArcGIS program was used to clip the image grid data based on the watershed boundaries (USGS, 2004c). Table 8 presents the 12 8-digit HUC watersheds used to compartmentalize the image grid data.

Table 7. Landsat image scenes merged for use in the study.

Path/Row Coordinates	Acquisition Date
27/39, 27/40	July 20, 1986
27/39, 27/40	November 28, 1993
27/39, 27/40	March 15, 2001
28/39, 28/40	July 27, 1986
28/39, 28/40	May 11, 1993
28/39, 28/40	April 4, 2000
27/39, 28/39	July 27, 1986 and July 27, 1986
27/39, 28/39	November 28, 1993 and May 11, 1993
27/39, 28/39	July 21, 2001 and July 12, 2001
28/39, 27/40	July 27, 1986 and July 20, 1986
28/39, 27/40	May 11, 1993 and November 28, 1993
28/39, 27/40	July 12, 2001 and March 15, 2001

Table 8. USGS 8-digit HUC watersheds used to reduce image data.

Watershed Name	Contributing Zone Area (km^2)	Recharge Zone Area (km^2)	Total Watershed Area (km^2)
Austin-Travis Lakes	750.75	229.96	3,204.00
San Marcos	989.44	332.28	3,535.95
Upper San Antonio	100.61	189.50	1,328.66
Middle Guadalupe	118.65	367.34	5,557.47
Cibolo	587.63	87.89	2,211.33
Upper Guadalupe	3,734.87	0.00	3,734.87
Medina	1,931.12	204.65	3,492.07
Hondo	650.28	462.37	2,800.59
Upper Frio	1,754.29	658.20	6,129.79
Nueces Headwaters	1,957.94	192.57	2,150.52
Upper Nueces	0.00	168.50	4,886.29
West Nueces	1,869.26	381.85	2,297.18

After each image grid band was clipped, the data were converted to the geo-tiff format and imported into the ENVI program. Associated image bands for each watershed per acquisition period were digitally stacked and saved in the native ENVI image format for faster image classification. The final products of the image processing were three temporally different Landsat image scenes for each 8-digit HUC watershed listed in Table 8.

Image Classification Technique

A principal component transform (PCT) was initially performed on each stacked watershed image using the ENVI program. Landsat image bands are often highly correlated and the PCT reduces the correlation while redistributing the total image variance of the transformed data. The de-correlation and variance optimization can increase the level of discernment between landscape elements (Schowengerdt, 1997). The first three PCT bands for each stacked watershed image were produced and saved in the ENVI integer format for classification.

Given the large area of the Edwards Aquifer contributing and recharge zones, a rapid and effective method of image classification was necessary. A modified ISODATA unsupervised and supervised technique was chosen for its speed and reasonably acceptable historical level of classification accuracy. Through a trial and error process, a sound and reliable hybrid image classification methodology was developed (Figure 7). The ISODATA technique was applied to each stacked watershed image with 255 classes being specified. The number of ISODATA iterations was set to 20 with a change threshold of 5%. Either 20 iterations or a 5% or less change in the number of pixels per

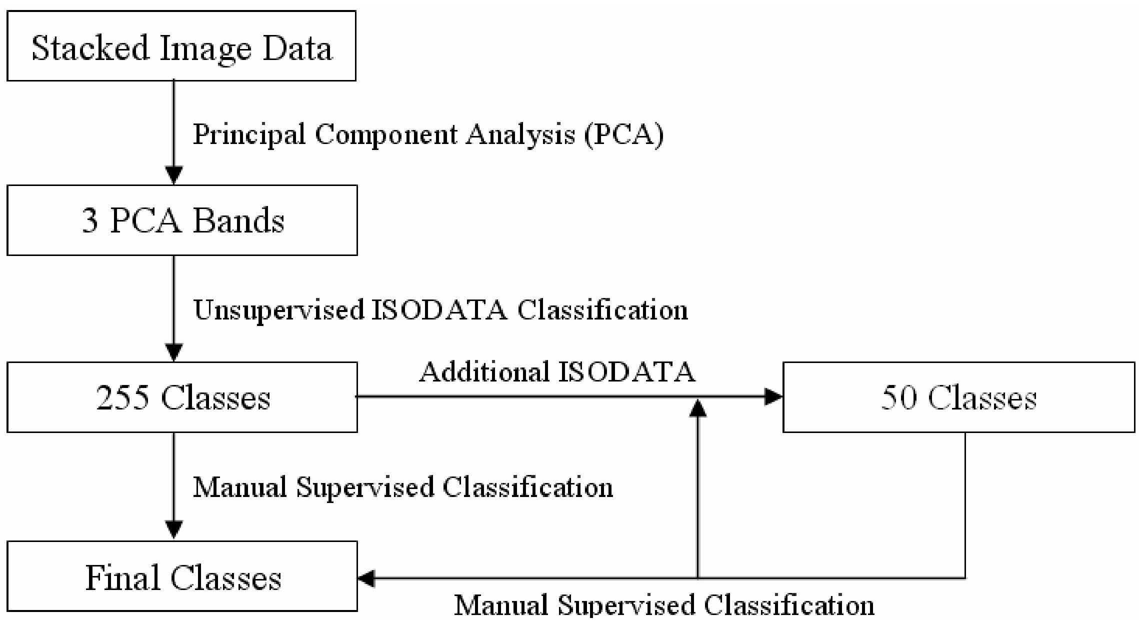

Figure 7. Schematic of the hybrid image classification methodology.

class ended the algorithm. The minimum number of pixels per class was defined as 10,000 with a minimum class distance of 5.0 and a maximum class standard deviation of 1.0; a maximum of two classes were allowed to be merged. An additional maximum standard deviation from the class mean requirement was set to 4.45. All of these specified values fall within the standard ranges of the ISODATA parameters outlined by Jensen (1996). After the initial classification process was completed for each stacked watershed image, the resulting single-band classified products were first converted to the geo-tiff format, followed by a conversion to the Arc grid format as outlined in the previous section.

Once the initial unsupervised classification was completed, each of the 255 classes per classified product was manually assigned to one of five primary land cover categories: water, impervious surface, irrigated land, grassland, or woodland. These land cover categories were adapted from the Anderson classification system (Anderson et al., 1976). Three sources of land cover data were used to assign one of the 255 classes to a primary category. The original Landsat image data and the 1992 USGS NLCD were used to assign classes that were relatively large in magnitude and easily discernable. Geo-referenced digital orthophotoquads (DOQQ) were obtained from TNRIS and used to further identify less discernable classes (TNRIS, 2004c). The DOQQ files are digitized aerial photography with a 1-meter spatial resolution that are available for dates from 1994 through 1997. Classes that could not be readily assigned, or heavily mixed classes, were merged using the ArcGIS program to create a mask overlay for reclassification of the stacked watershed image. Only those unassigned pixels were included in the re-classification process. The previously defined ISODATA technique with a reduced number of 50 classes was used to re-classify the stacked watershed image. The resulting classes were again assigned to one of the five primary categories. Generally, the re-classification procedure had to be undertaken no more than two times per stacked watershed image.

Two ancillary data sets were incorporated to increase the level of classification accuracy. The first was the USGS National Hydrography Dataset (NHD). The 1:100,000-scale NHD is a continuously updated digital collection of all water bodies in the United States. The data set is derived from U.S. EPA reach files and USGS digital line graph (DLG) information. The NHD is available from the USGS in a georeferenced shapefile format (USGS, 2004d). NHD files for each of the 12 8-digit HUC watersheds were obtained and converted to the Arc grid format at the appropriate spatial resolutions (28.5-m or 30-m). The 2003 TxDOT shapefiles were obtained for each of the 15 Edwards Aquifer contributing and recharge zone counties. The shapefiles were merged into one large data set and clipped for each 8-digit HUC watershed using the ArcGIS program. Identical copies of the clipped TxDOT shapefiles were associated with each stacked watershed image and then manually edited to remove any transportation elements not present within the corresponding image. Each modified TxDOT shapefile was then converted to the Arc grid format at the appropriate spatial resolution (28-m or 30-m). After the classification data layers were completed for each stacked watershed image, the NHD, TxDOT, and classification layers were merged together using the ArcMap program to form a final classification product.

An error matrix accuracy assessment was performed for each final classification product (Congalton and Green, 1999). Mathematically, the error matrix can be represented as given in Equation 2.

$$Error_{ij} = \begin{pmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1m} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mm} \end{pmatrix} \tag{2}$$

The collection of error values (Error) is over the domain i, j where $i = j = 1, 2, \ldots, m$. The parameter m represents the individual elements of the land cover classification set, which includes water, impervious surface, irrigated land, grassland, and woodland. Each column and row vector is summed to provide a column and row total. The producer accuracy of the classification product is defined by the following expression

$$PA_i = \frac{x_{ii}}{x_{+j}} \tag{3}$$

where the producer accuracy (PA) for each land cover class i is the class value divided by its column total. The user accuracy of the classification product is defined by the following expression

$$UA_i = \frac{x_{ii}}{x_{i+}} \tag{4}$$

where the user accuracy (UA) for each land cover class i is the class value divided by its row total. The overall accuracy is determined by dividing the sum of the individual class values x_{ii} by the row total, x. This expression is given in Equation 5

$$Overall = \frac{\sum x_{ii}}{x} \tag{5}$$

where Overall is the overall accuracy value. A 70% overall accuracy for the entire region of study was defined for an acceptable level of classification. 100 random samples for each land cover classification category per time period were obtained and verified against the DOQQ files. Therefore, a total of 500 points per time period were used to evaluate the accuracy for each classified Edwards Aquifer contributing and recharge zone product. Appendix B provides the detailed results of the accuracy assessment.

Image Classification Results

The final results of the image classifications for the Edwards Aquifer contributing and recharge zones are shown in Figures 8 though 10. Tables 9 and 10 present the areas of the Edwards Aquifer contributing and recharge zones occupied by the five land cover classes. Within the Edwards Aquifer contributing zones, the area covered by water, impervious surface, and woodland increased from 1986 through 2000, while irrigated land and grassland were found to decrease (Table 9). The largest increase was the percent of impervious surface area (19.24%), with the largest decrease being grassland (18.81%). In the recharge zone, results indicate that the amount of area covered by water decreased, while area of irrigated land increased (Table 10). Like in the contributing zone, the impervious surface area experienced the largest increase (50.71%) while the change in woodland represented the second largest increase (9.55%) and grassland reflected the largest decrease (20.16%). These change trends are further examined by evaluating the land cover characteristics of individual watershed results found throughout the Edwards Aquifer contributing and recharge zones.

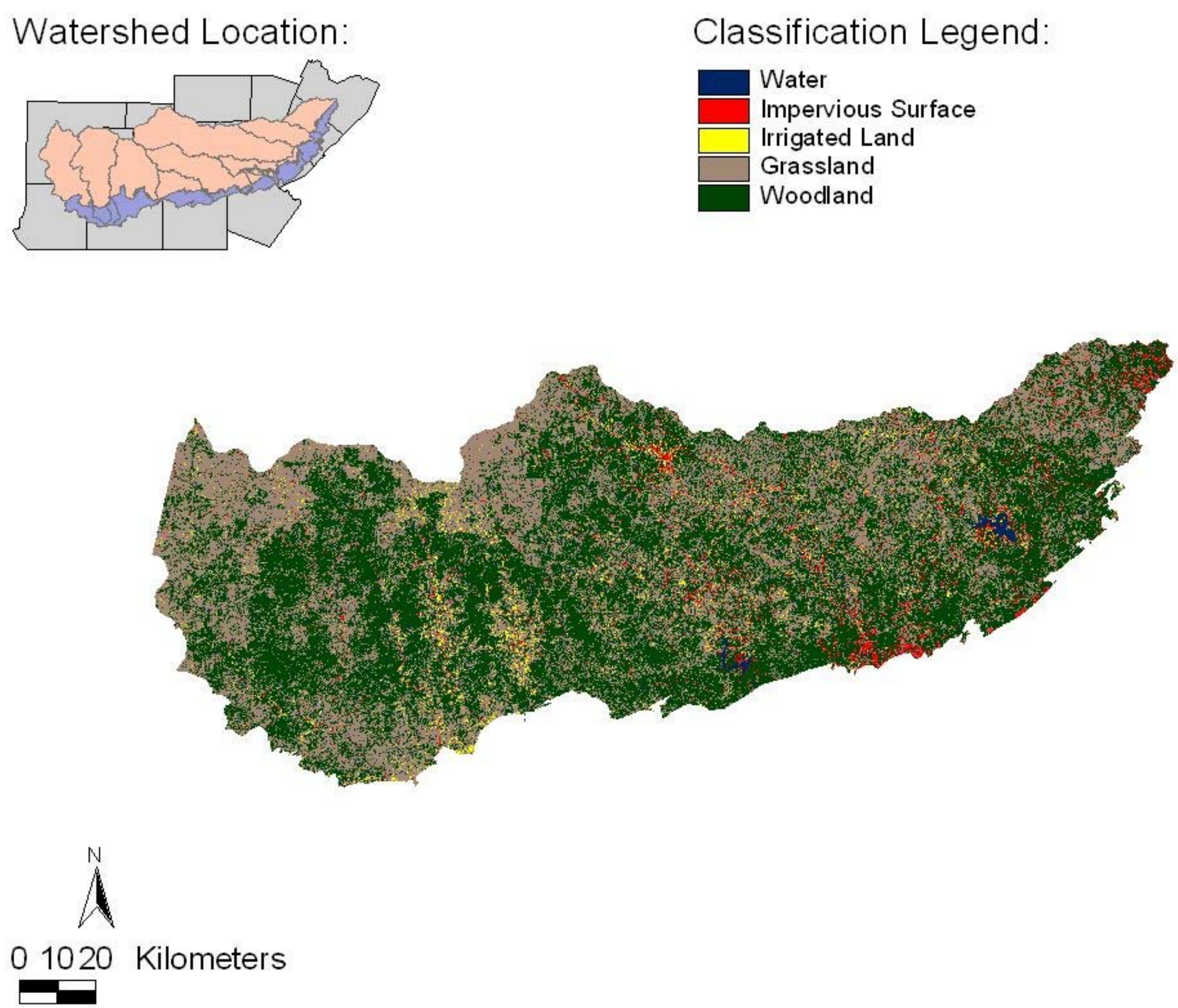

Figure 8. Land cover classification of the Edwards Aquifer contributing and recharge zones for 1986.

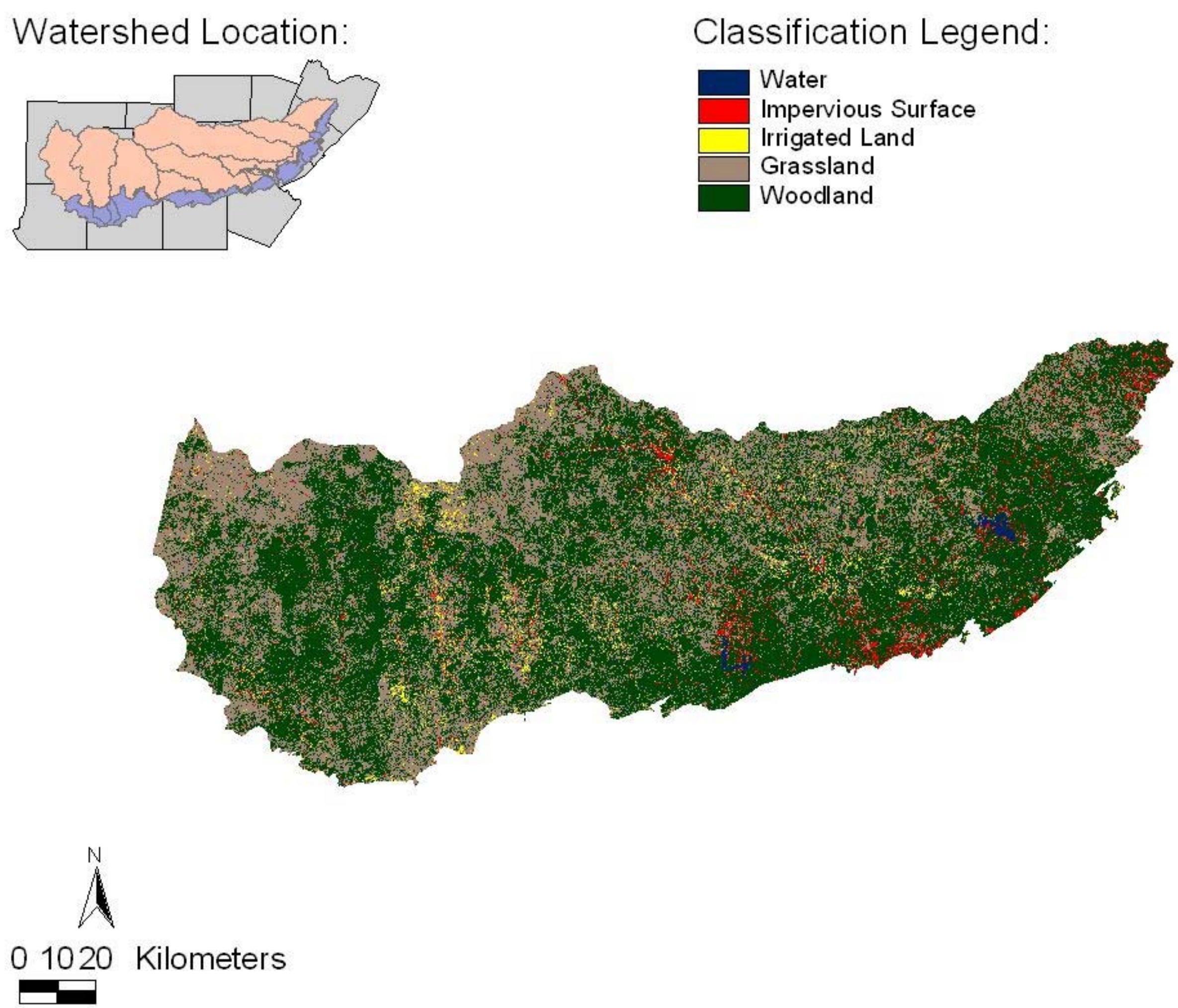

Figure 9. Land cover classification of the Edwards Aquifer contributing and recharge zones for 1993.

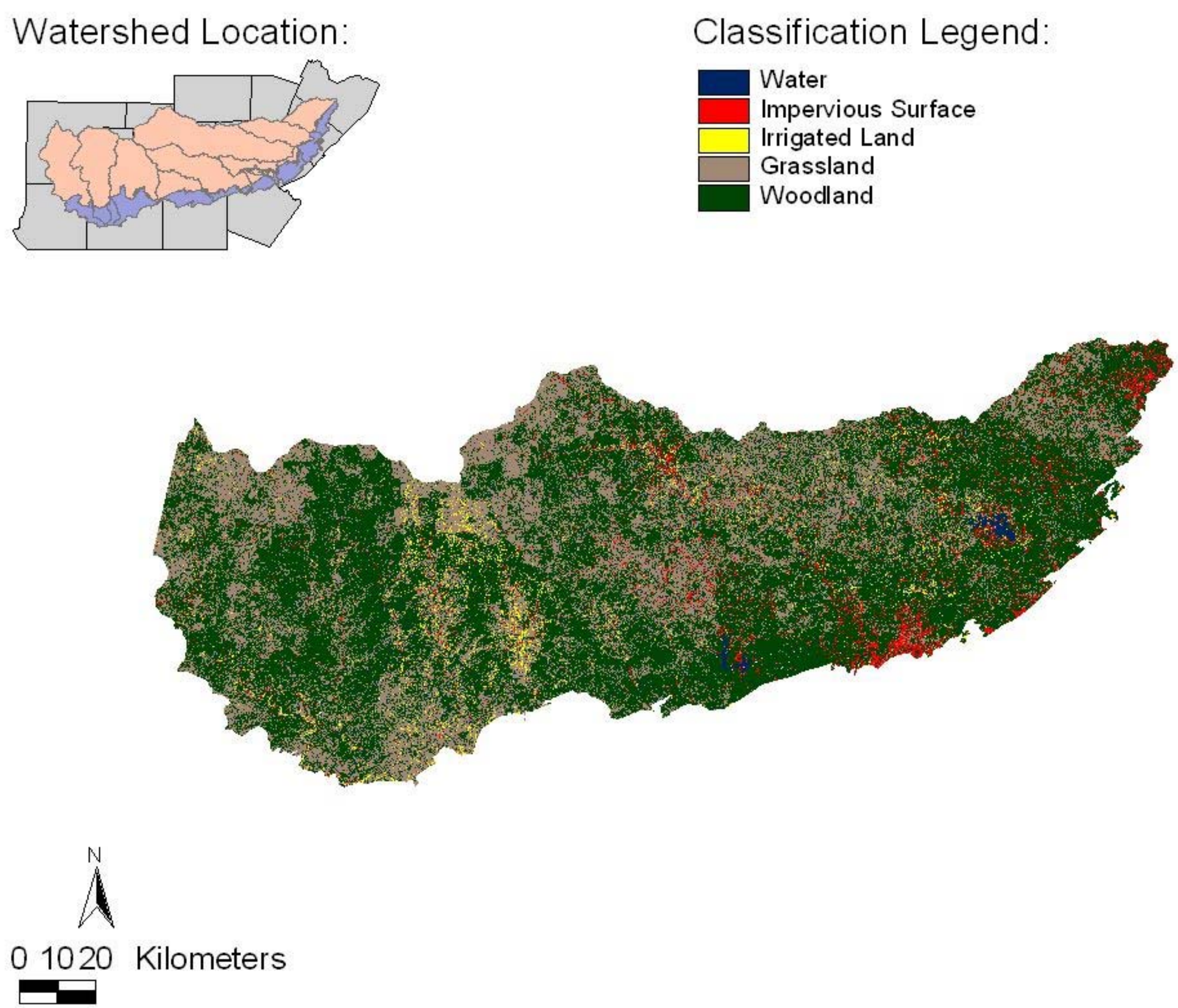

Figure 10. Land cover classification of the Edwards Aquifer contributing and recharge zones for 2000.

Table 9. Land cover classification results for the Edwards Aquifer contributing zone from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	335.74	363.87	370.80	4.74
Impervious Surface	408.12	446.34	496.24	19.24
Irrigated Land	311.66	296.77	296.16	-8.04
Grassland	5,366.14	5,464.49	5,066.59	-18.81
Woodland	6,540.05	7,873.39	8,215.06	15.50

Table 10. Land cover classification results for the Edwards Aquifer recharge zone from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	75.78	73.50	75.71	-0.10
Impervious Surface	116.29	130.97	175.26	50.71
Irrigated Land	65.28	69.68	67.70	3.72
Grassland	1,176.47	946.00	939.24	-20.16
Woodland	1,841.30	2,054.97	2,017.21	9.55

The Austin-Travis Lakes watershed area that overlays the Edwards Aquifer contributing zone equals 750.75-km^2 (Figures 11 through 13). The watershed contributing zone includes the city of Austin and adjacent metropolitan areas; thus a higher than average level of urban growth was expected. Table 11 presents the land

Table 11. Land cover classification results for the Austin-Travis Lakes contributing zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	15.96	14.50	15.36	-3.75
Impervious Surface	53.52	50.67	63.64	18.91
Irrigated Land	0.00	1.19	0.00	0.00
Grassland	364.45	271.36	266.11	-26.98
Woodland	316.82	413.03	405.64	28.03

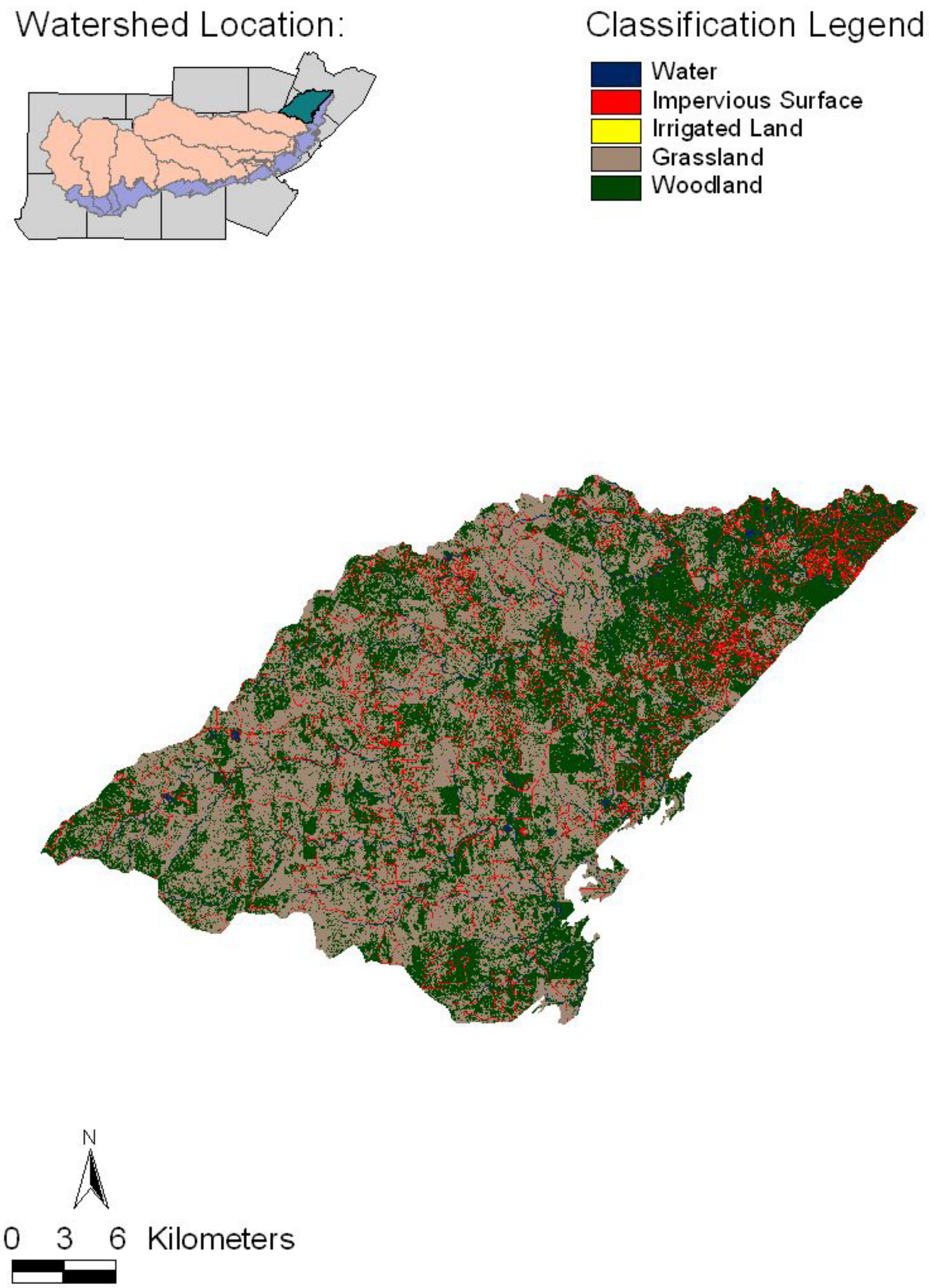

Figure 11. Land cover classification of the Austin-Travis Lakes watershed overlay of the Edwards Aquifer contributing zone for 1986.

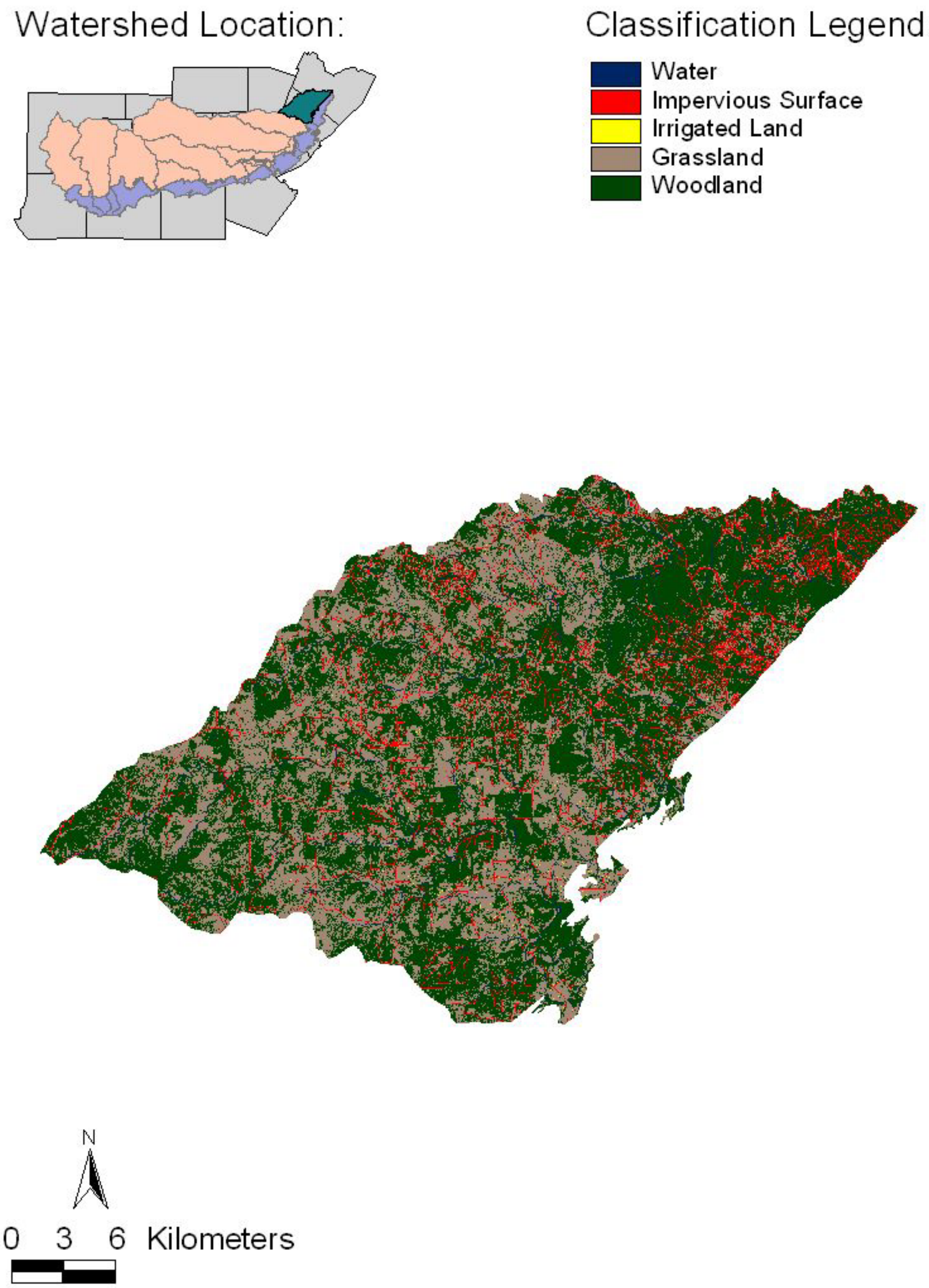

Figure 12. Land cover classification of the Austin-Travis Lakes watershed overlay of the Edwards Aquifer contributing zone for 1993.

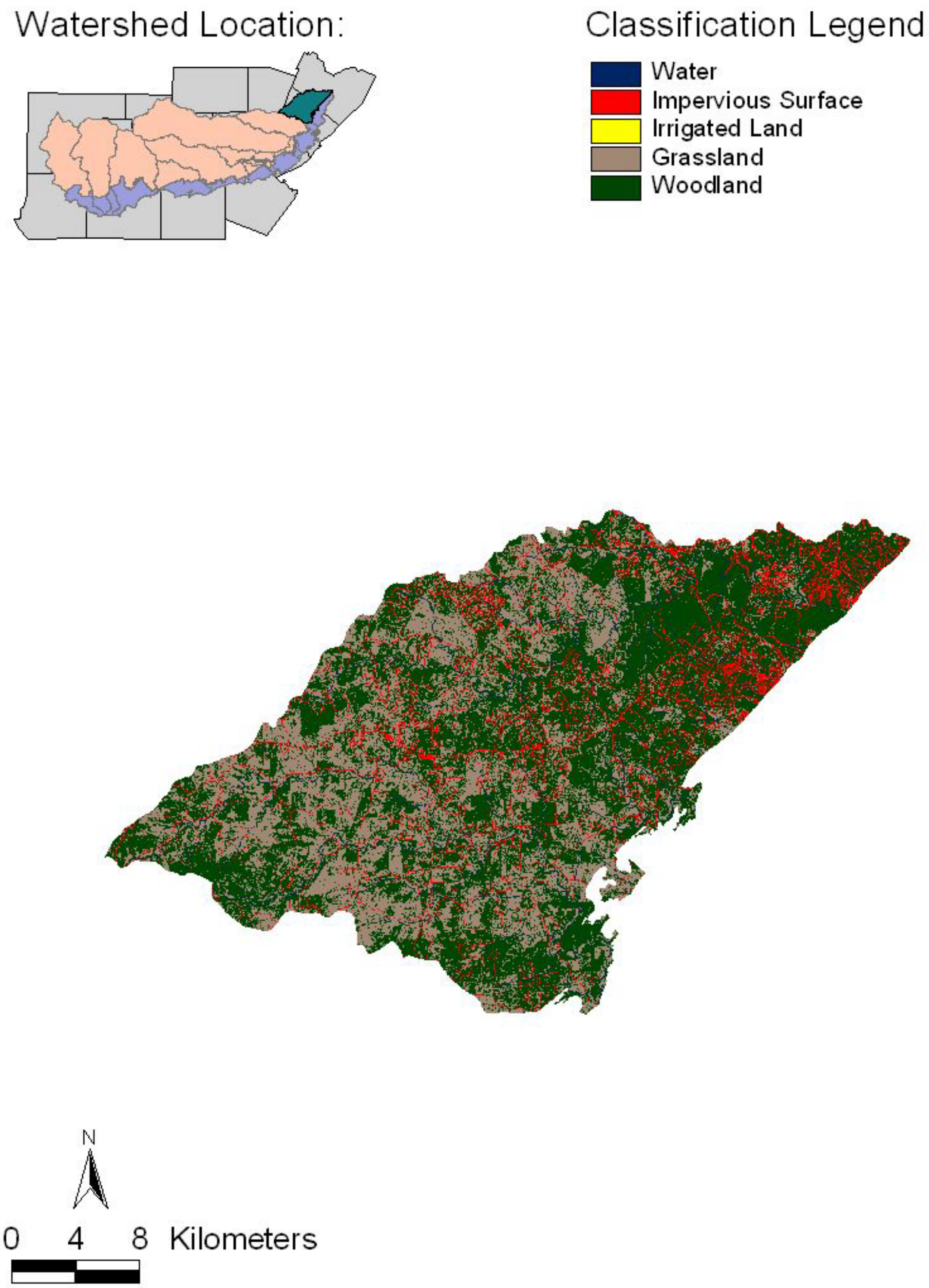

Figure 13. Land cover classification of the Austin-Travis Lakes watershed overlay of the Edwards Aquifer contributing zone for 2000.

cover classification results for the Austin-Travis Lakes contributing zone. The area covered by water decreased by 3.75% and may have been caused by channelization in the urban areas, whereby drainage moves across the land surface faster, resulting in less freestanding water. Because of the large number of urban streams, hydrologic non-activity at the time of image acquisition could also have been a cause. The coverage of impervious surface area increased by 18.91%, which is not surprising for an urban area. The low level of irrigated land did not change over time. Since irrigated areas, such as golf courses, could have been classified as irrigated land, this is given as the reason for detection in the 1993 classification. The area covered by grassland had the largest decrease (26.98%) while the area covered by woodland had the largest increase (28.03%). With the exception of water, the results found for the Austin-Travis Lakes contributing zone reflected the general land cover change trends of the Edwards Aquifer contributing zone.

The Austin-Travis Lakes watershed area that overlays the Edwards Aquifer recharge zone equals 229.96-km^2 (Figures 14 through 16). Table 12 presents the results for the Austin-Travis Lakes recharge zone. As with the watershed contributing zone, the

Table 12. Land cover classification results for the Austin-Travis Lakes recharge zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	6.20	5.39	5.77	-6.95
Impervious Surface	25.56	28.01	36.02	40.90
Irrigated Land	0.00	0.00	0.00	0.00
Grassland	104.14	85.54	69.06	-33.68
Woodland	94.06	110.29	119.11	26.64

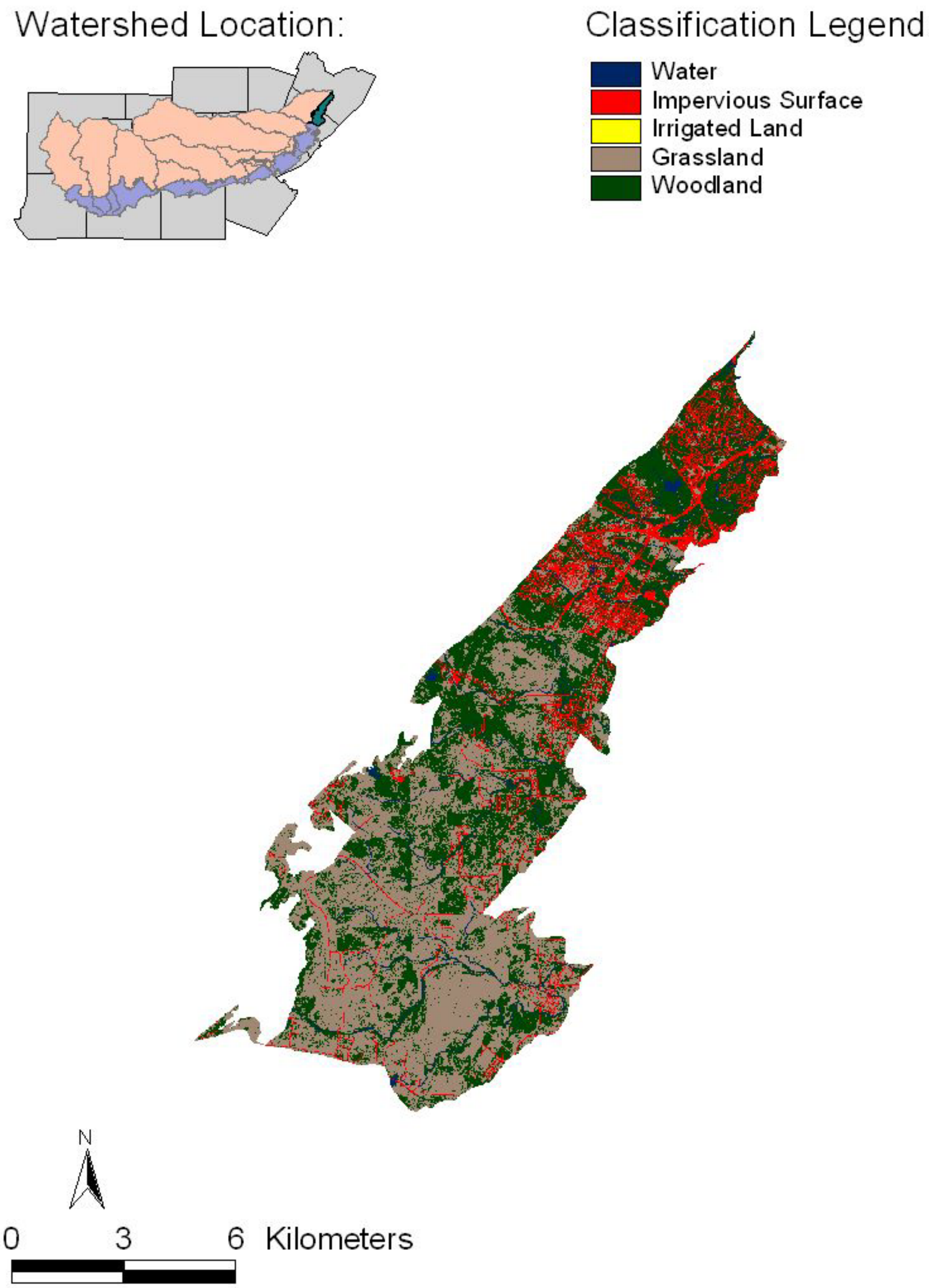

Figure 14. Land cover classification of the Austin-Travis Lakes watershed overlay of the Edwards Aquifer recharge zone for 1986.

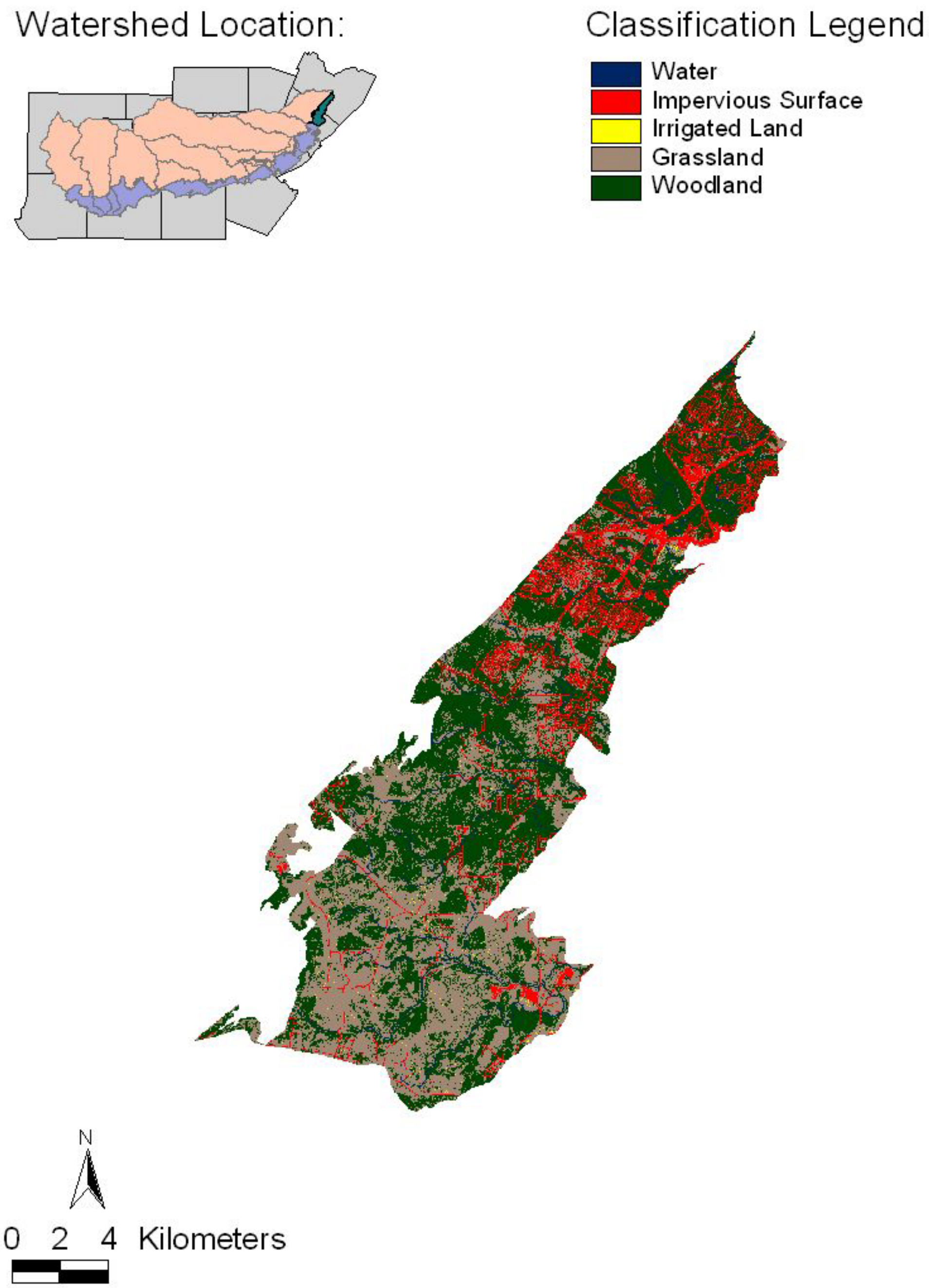

Figure 15. Land cover classification of the Austin-Travis Lakes watershed overlay of the Edwards Aquifer recharge zone for 1993.

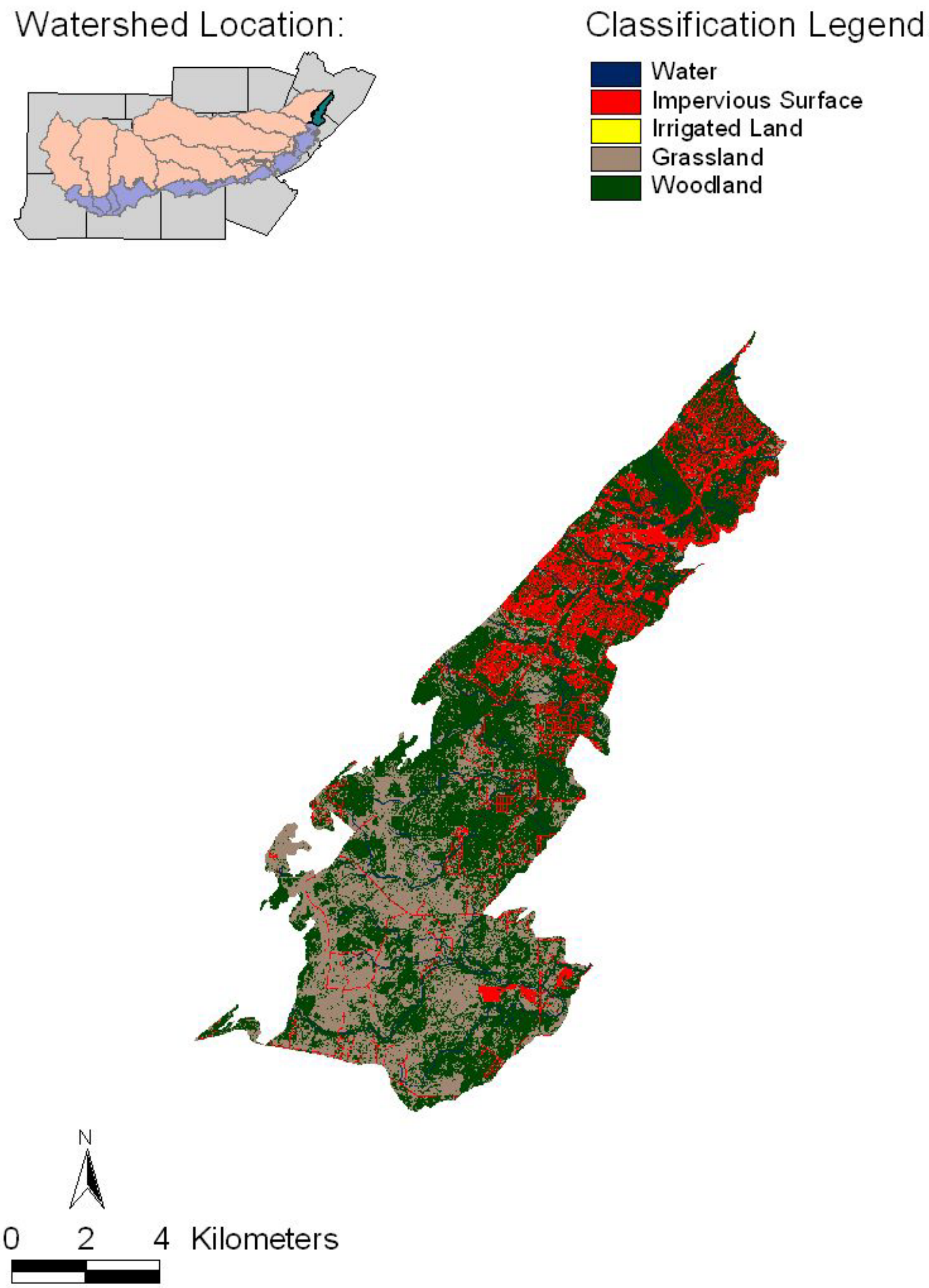

Figure 16. Land cover classification of the Austin-Travis Lakes watershed overlay of the Edwards Aquifer recharge zone for 2000.

watershed recharge zone includes the city of Austin with the same metropolitan growth, and therefore a higher level of urban-related growth was expected. The area covered by water decreased by 6.95%. The decrease in water coverage may have been caused by channelization, resulting in less freestanding water. The large number of urban streams with hydrologic non-activity at the time of image acquisition could also have been a cause. The area covered by impervious surfaces increased by 40.90%, which was the largest increase throughout the watershed recharge zone. There were no irrigated lands classified for the Austin-Travis Lakes recharge zone. The area of the watershed recharge zone covered by grassland experienced the largest decrease (33.68%) and the area covered by woodland had the second largest growth (26.64%). With the exception of irrigated lands, the results found for the Austin-Travis Lakes recharge zone reflect the same trends of the Edwards Aquifer recharge zone.

The San Marcos watershed area that overlays the Edwards Aquifer contributing zone equals 989.44-km^2 (Figures 17 through 19). Table 13 presents the land cover classification results for the San Marcos watershed contributing zone. The watershed

Table 13. Land cover classification results for the San Marcos contributing zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	17.73	18.77	18.86	6.34
Impervious Surface	41.34	37.72	57.87	39.98
Irrigated Land	22.96	11.72	15.21	-33.74
Grassland	398.91	264.47	182.55	-54.24
Woodland	508.50	656.77	714.96	40.60

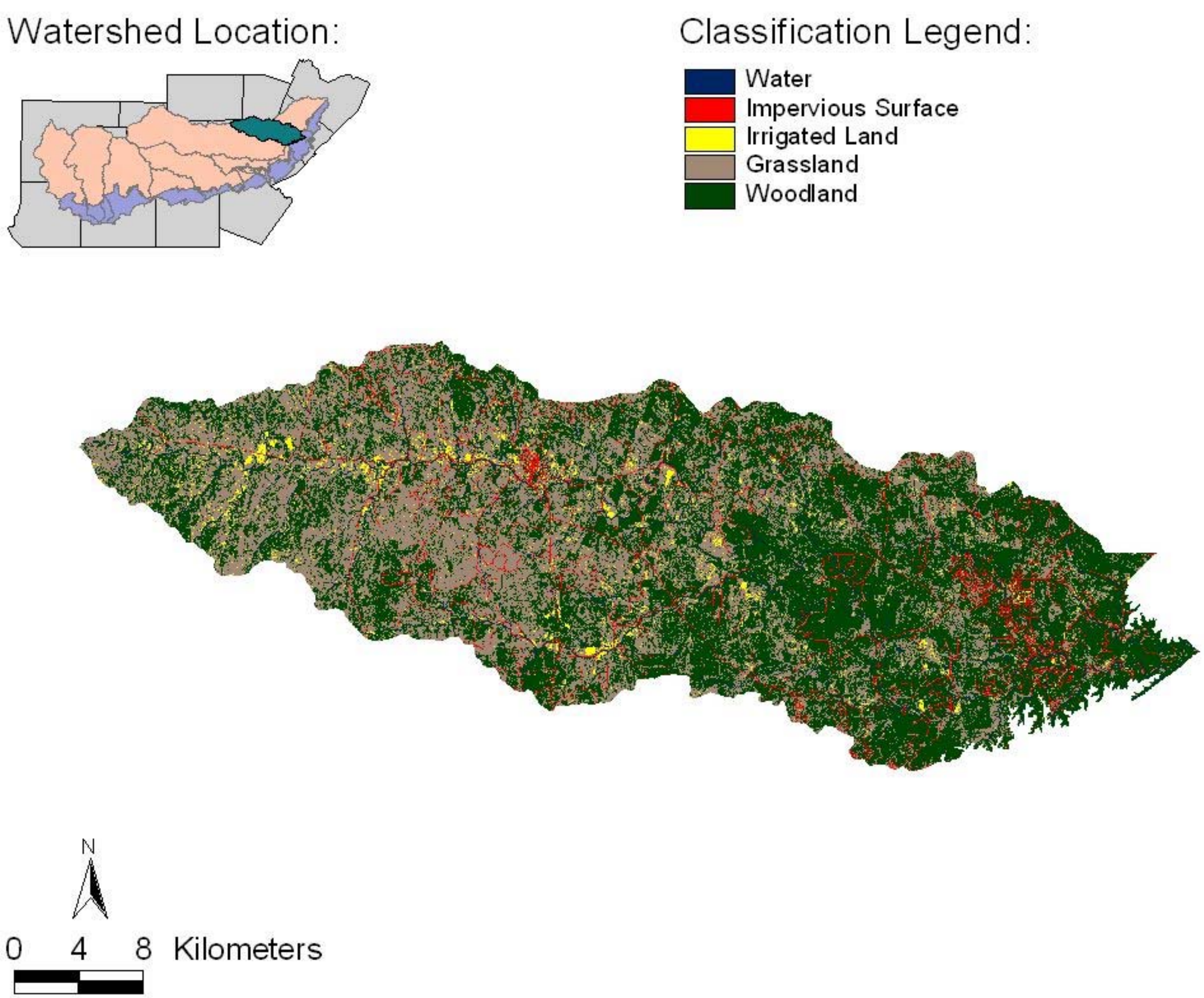

Figure 17. Land cover classification of the San Marcos watershed overlay of the Edwards Aquifer contributing zone for 1986.

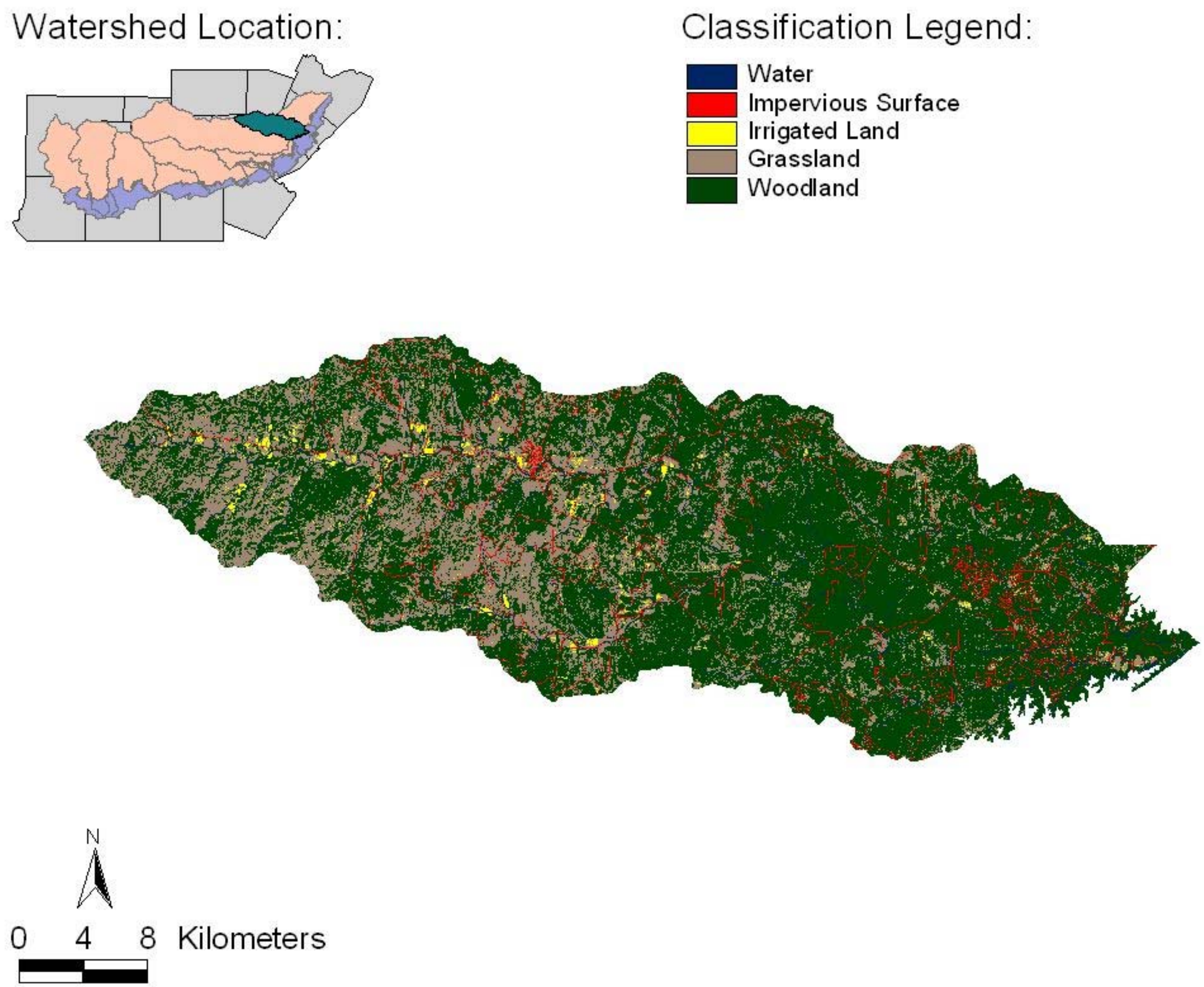

Figure 18. Land cover classification of the San Marcos watershed overlay of the Edwards Aquifer contributing zone for 1993.

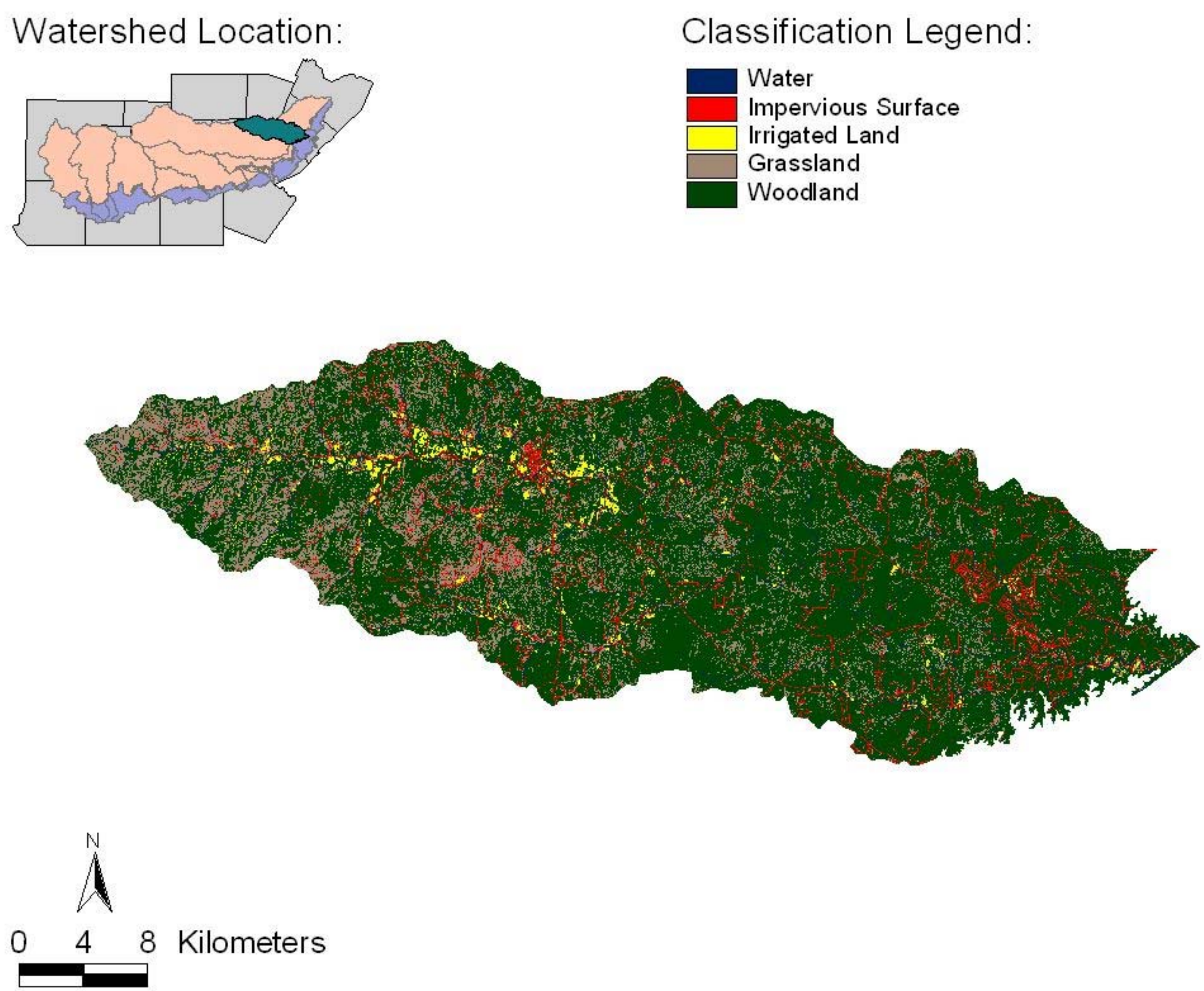

Figure 19. Land cover classification of the San Marcos watershed overlay of the Edwards Aquifer contributing zone for 2000.

contributing zone does not intersect with any major cities but is northwest of the Interstate 35 corridor; some increased urban growth was expected. The increase in water coverage may have been caused by higher water levels present in some of the reservoirs that are distributed within the watershed contributing zone. The area of impervious surfaces increased by 39.98%, which was a much higher level than expected. Given the greater amount of agricultural areas, misclassification of uncropped bare soil as impervious surface could have led to this increase. Irrigated lands decreased by 33.74%. Agriculture within the San Marcos watershed is extremely heavy east of Interstate 35; therefore transient agricultural uses west of this transportation structure are a possibility and could have contributed to this decline. The area covered by grassland had the largest decrease (54.24%) while the area covered by woodland had the largest increase (40.60%). The results found for the San Marcos contributing zone reflect the identical land cover change trends of the Edwards Aquifer contributing zone.

The San Marcos watershed area that overlays the Edwards Aquifer recharge zone equals 332.28-km^2 (Figures 20 through 22). Table 14 presents the land cover classification results for the San Marcos watershed recharge zone. The watershed

Table 14. Land cover classification results for the San Marcos recharge zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	7.56	5.93	6.08	-19.57
Impervious Surface	9.58	9.01	13.91	45.21
Irrigated Land	1.94	4.57	3.05	57.05
Grassland	83.89	53.46	34.43	-58.96
Woodland	229.31	259.31	274.81	19.84

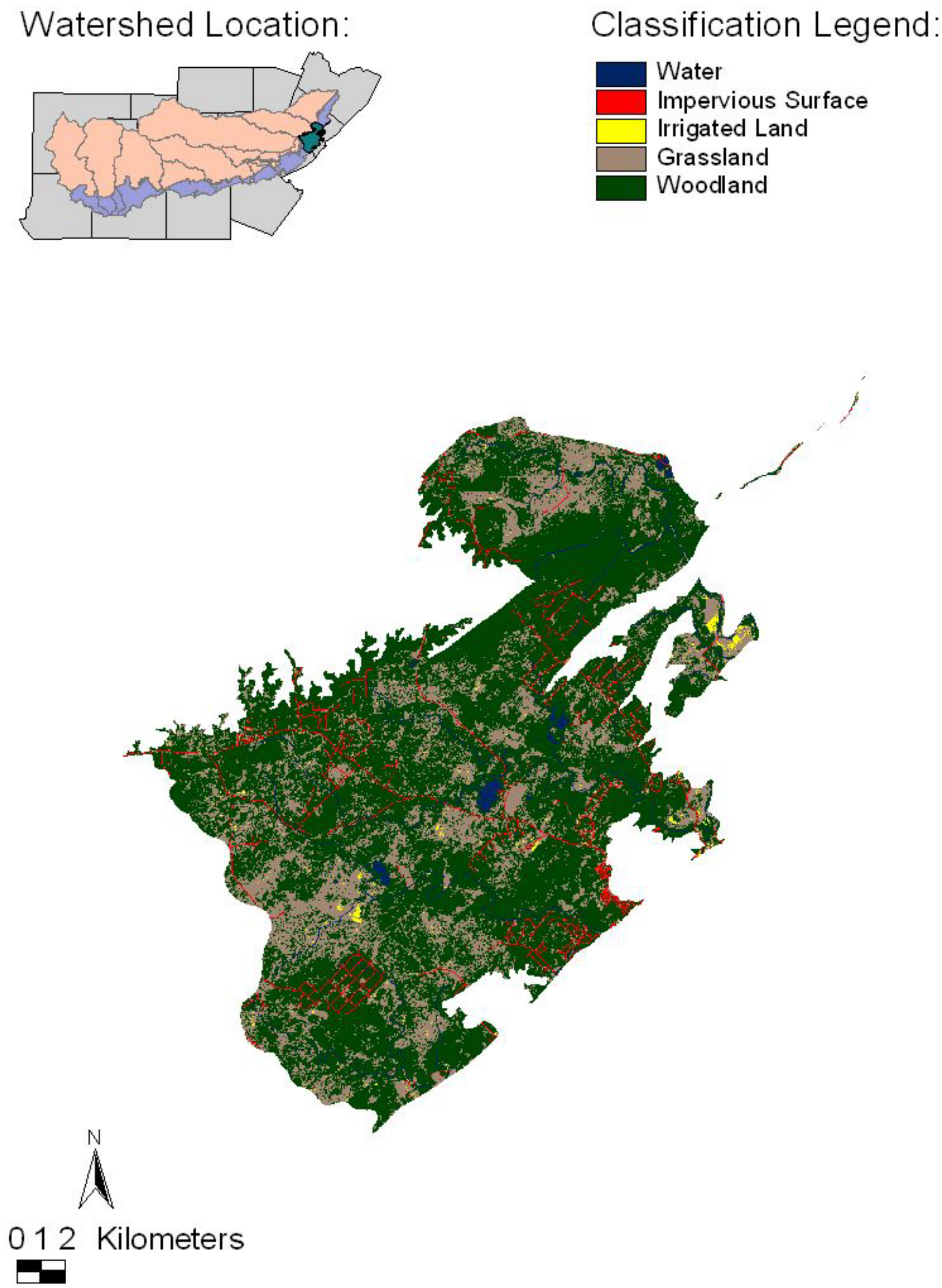

Figure 20. Land cover classification of the San Marcos watershed overlay of the Edwards Aquifer recharge zone for 1986.

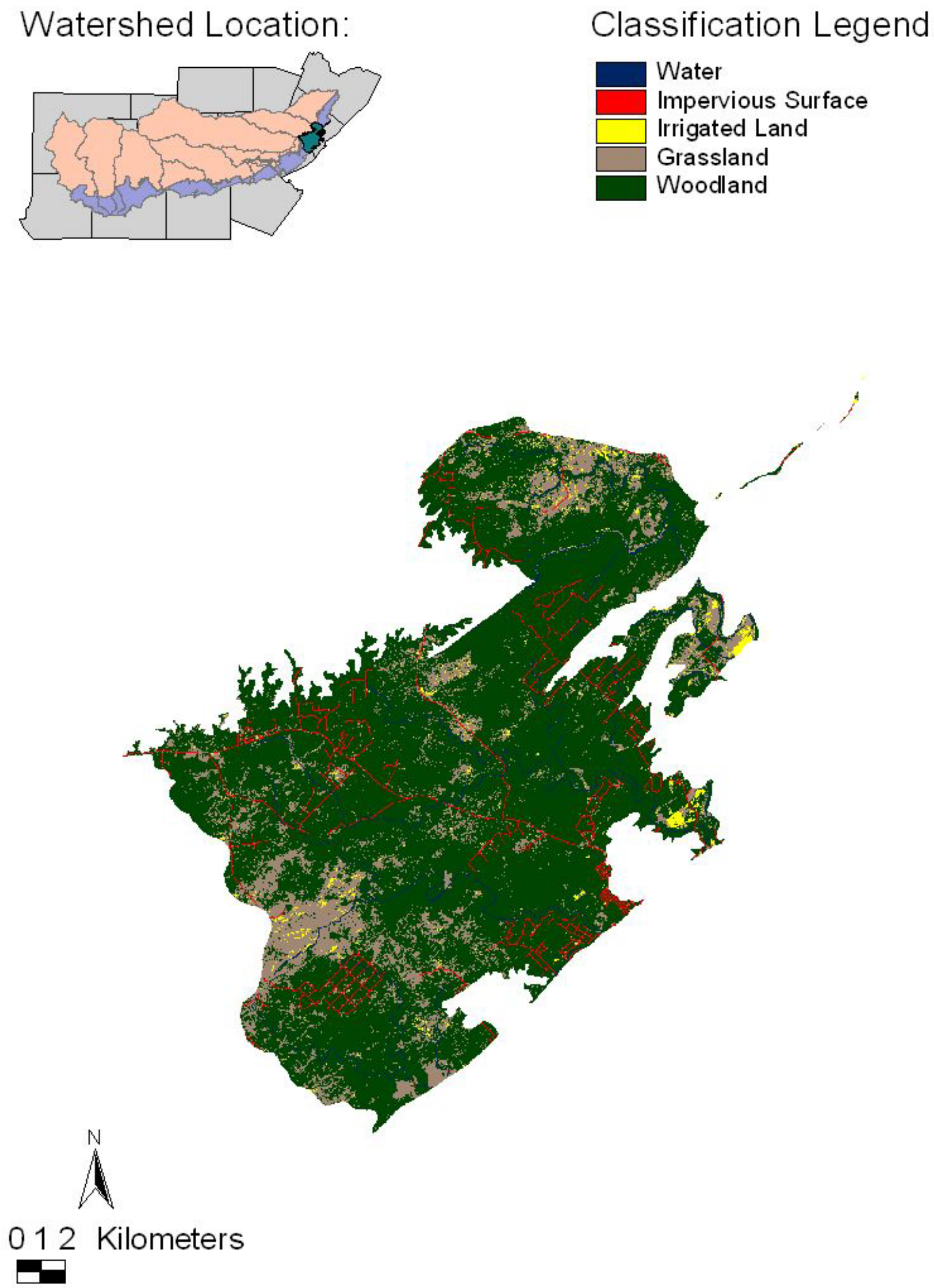

Figure 21. Land cover classification of the San Marcos watershed overlay of the Edwards Aquifer recharge zone for 1993.

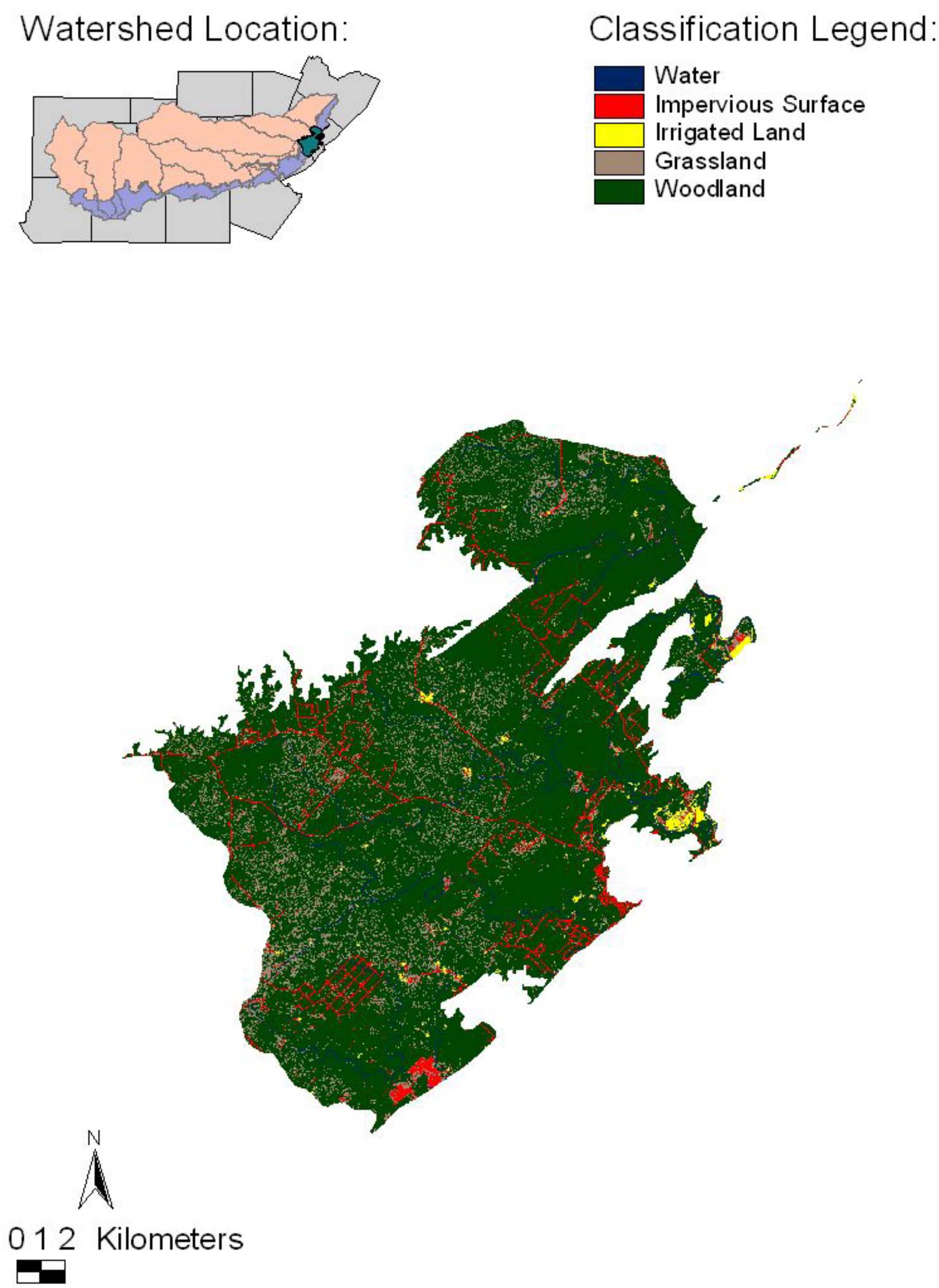

Figure 22. Land cover classification of the San Marcos watershed overlay of the Edwards Aquifer recharge zone for 2000.

recharge zone is immediately adjacent to Interstate 35; therefore a higher level of urban related growth was expected than in the contributing zone. The results for the San Marcos recharge zone showed that the area covered by water had a decrease of 19.57%. The decrease in water coverage may have been caused by stream channelization, resulting in less freestanding water. There were no reservoirs identified within the watershed recharge zone. The area covered by impervious surfaces increased by 45.21%, which was the second largest increase. Irrigated lands classified for the San Marcos recharge zone increased by 57.05%. This location is much closer to the heavy agricultural areas east of Interstate 35. The area of the watershed recharge zone covered by grassland experienced the largest decrease (58.96%) and the area covered by woodland had the third largest increase (19.84%). With the exception of water, the results found for the San Marcos recharge zone reflect the same general trends of the Edwards Aquifer recharge zone.

The Upper San Antonio watershed area that overlays the Edwards Aquifer contributing zone equals 100.61-km^2 (Figures 23 through 25). Table 15 presents the land cover classification results for the Upper San Antonio contributing zone. The

Table 15. Land cover classification results for the Upper San Antonio contributing zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	1.43	1.35	1.43	-0.29
Impervious Surface	8.85	10.65	13.89	56.87
Irrigated Land	0.28	0.20	0.21	-26.78
Grassland	27.12	17.11	15.64	-42.34
Woodland	62.93	71.29	69.45	10.37

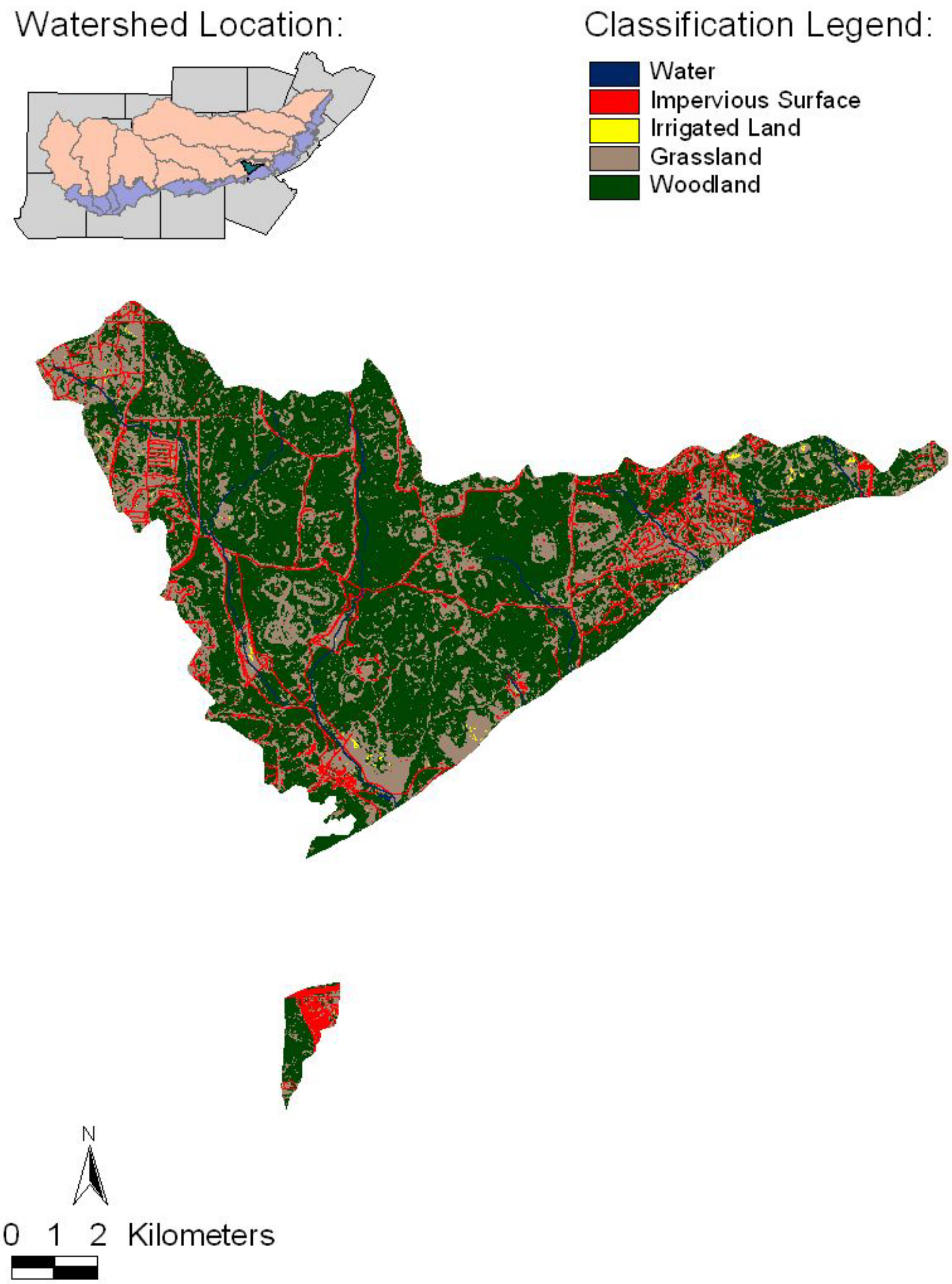

Figure 23. Land cover classification of the Upper San Antonio watershed overlay of the Edwards Aquifer contributing zone for 1986.

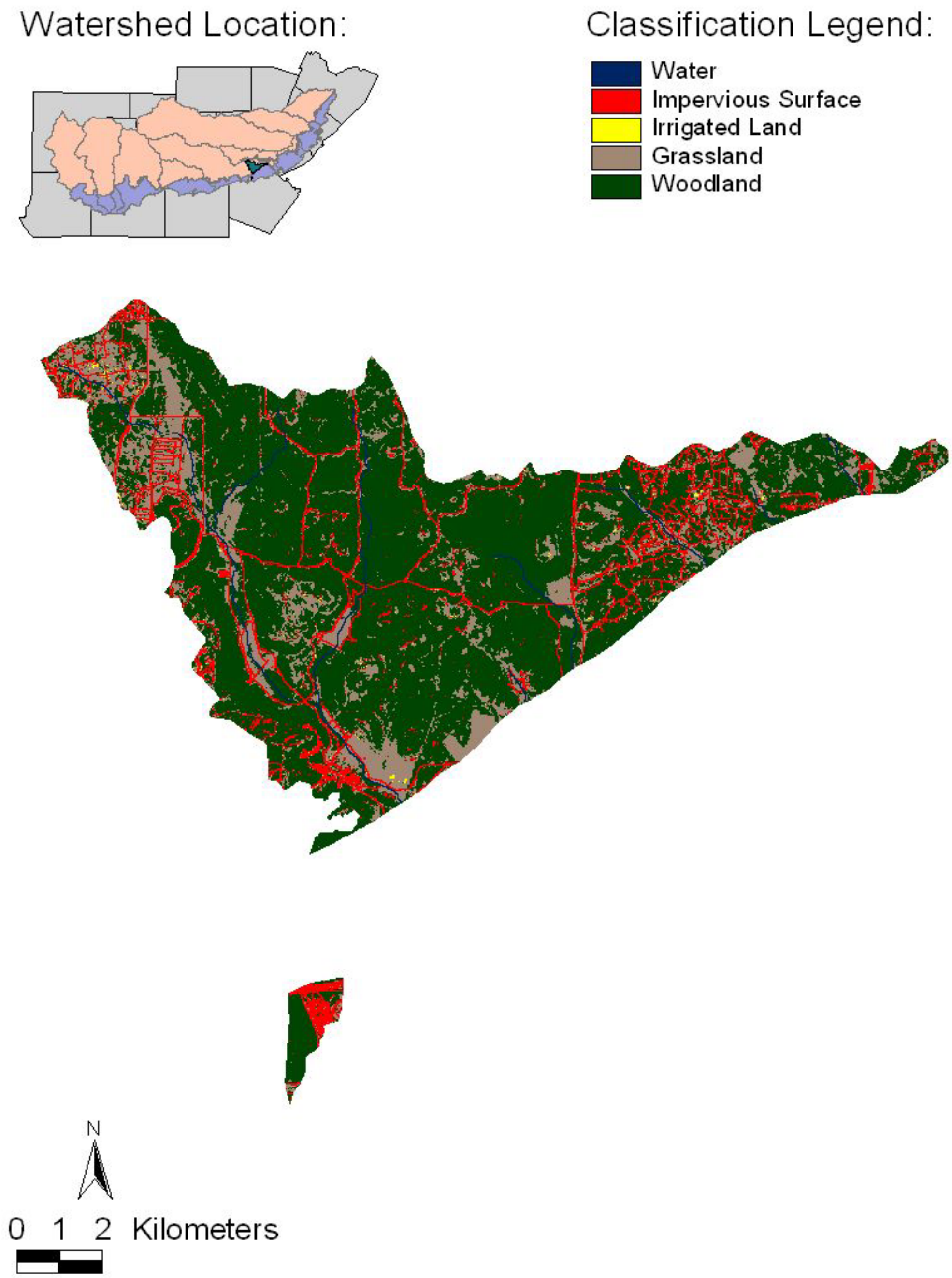

Figure 24. Land cover classification of the Upper San Antonio watershed overlay of the Edwards Aquifer contributing zone for 1993.

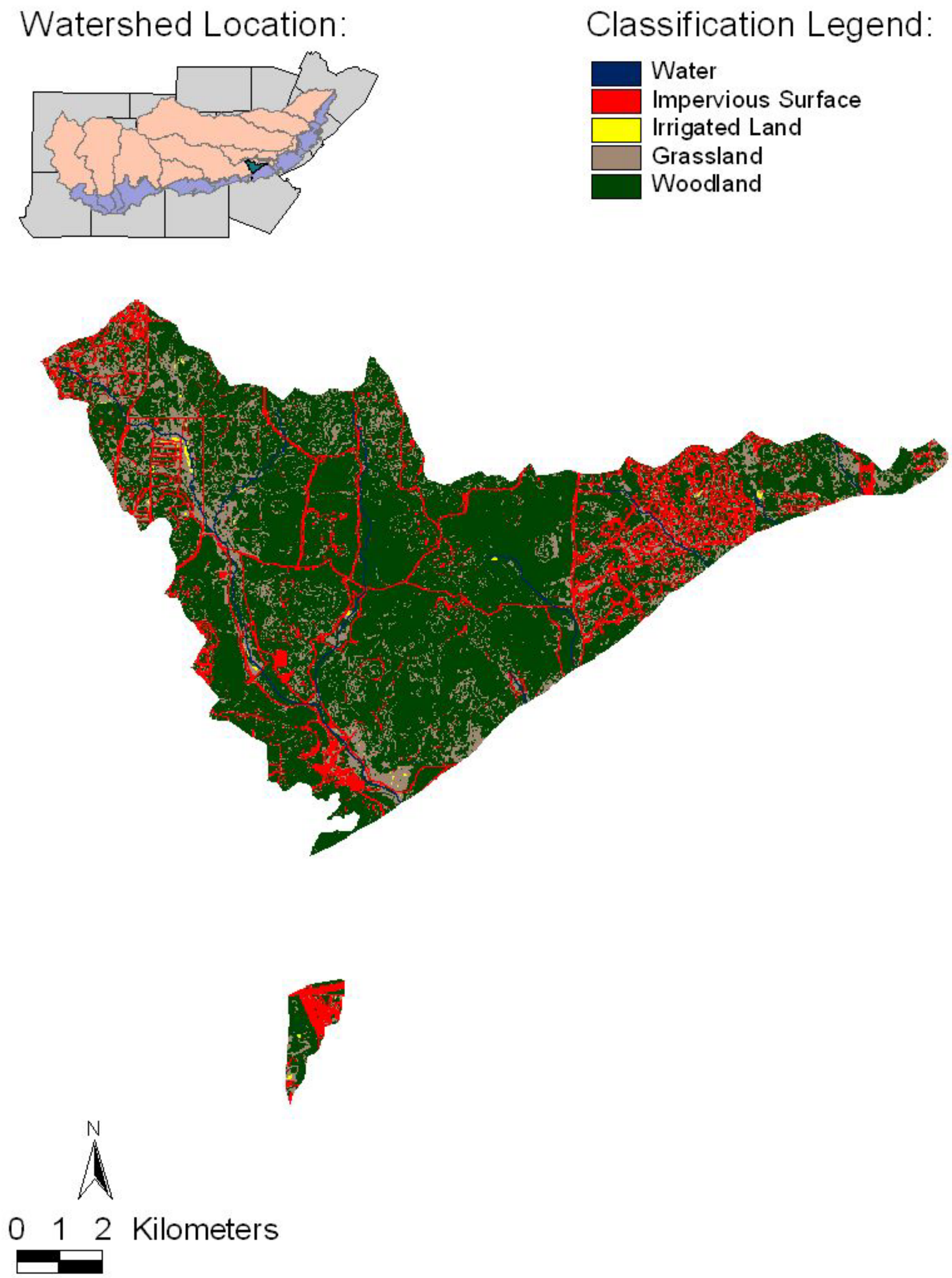

Figure 25. Land cover classification of the Upper San Antonio watershed overlay of the Edwards Aquifer contributing zone for 2000.

watershed contributing zone partially intersects with the northern section of the city of San Antonio; therefore increased urban growth was expected. Within the results for the Upper San Antonio contributing zone, the area covered by water decreased by 0.29%. This reduction was very small given the area of the watershed contributing zone and could therefore be considered negligible. The area of impervious surfaces was the largest increase at 56.87%, which was consistent with the results expected. Irrigated lands decreased by 26.78%. A low level of cropland exists in this northern area of Bexar County so the reduction was likely attributed to other irrigated lands. Impervious surface misclassification of bare soil that was once used for an agricultural purpose could have occurred. The area covered by grassland had the largest decrease (42.34%) while the area covered by woodland had the second largest increase (10.37%). With the exception of water, the results found for the Upper San Antonio contributing zone reflect the general land cover change trends of the Edwards Aquifer contributing zone.

The Upper San Antonio watershed area that overlays the Edwards Aquifer recharge zone equals 189.50-km^2 (Figures 26 through 28). Table 16 presents the land cover classification results for the Upper San Antonio recharge zone. As with the watershed

Table 16. Land cover classification results for the Upper San Antonio recharge zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	4.46	4.33	4.56	2.30
Impervious Surface	32.33	38.04	61.89	91.41
Irrigated Land	0.77	0.57	1.35	74.30
Grassland	41.91	24.51	26.22	-37.43
Woodland	110.03	122.05	95.48	-13.22

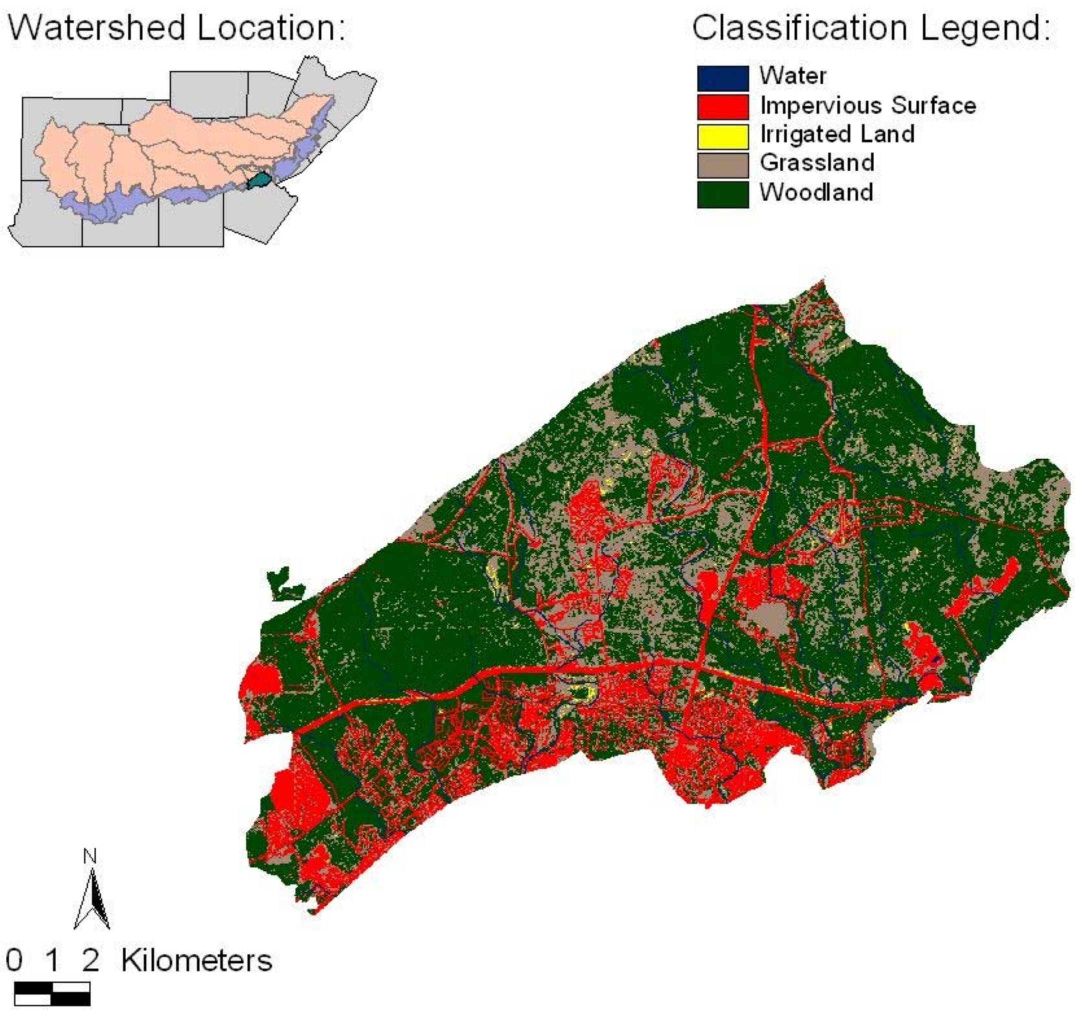

Figure 26. Land cover classification of the Upper San Antonio watershed overlay of the Edwards Aquifer recharge zone for 1986.

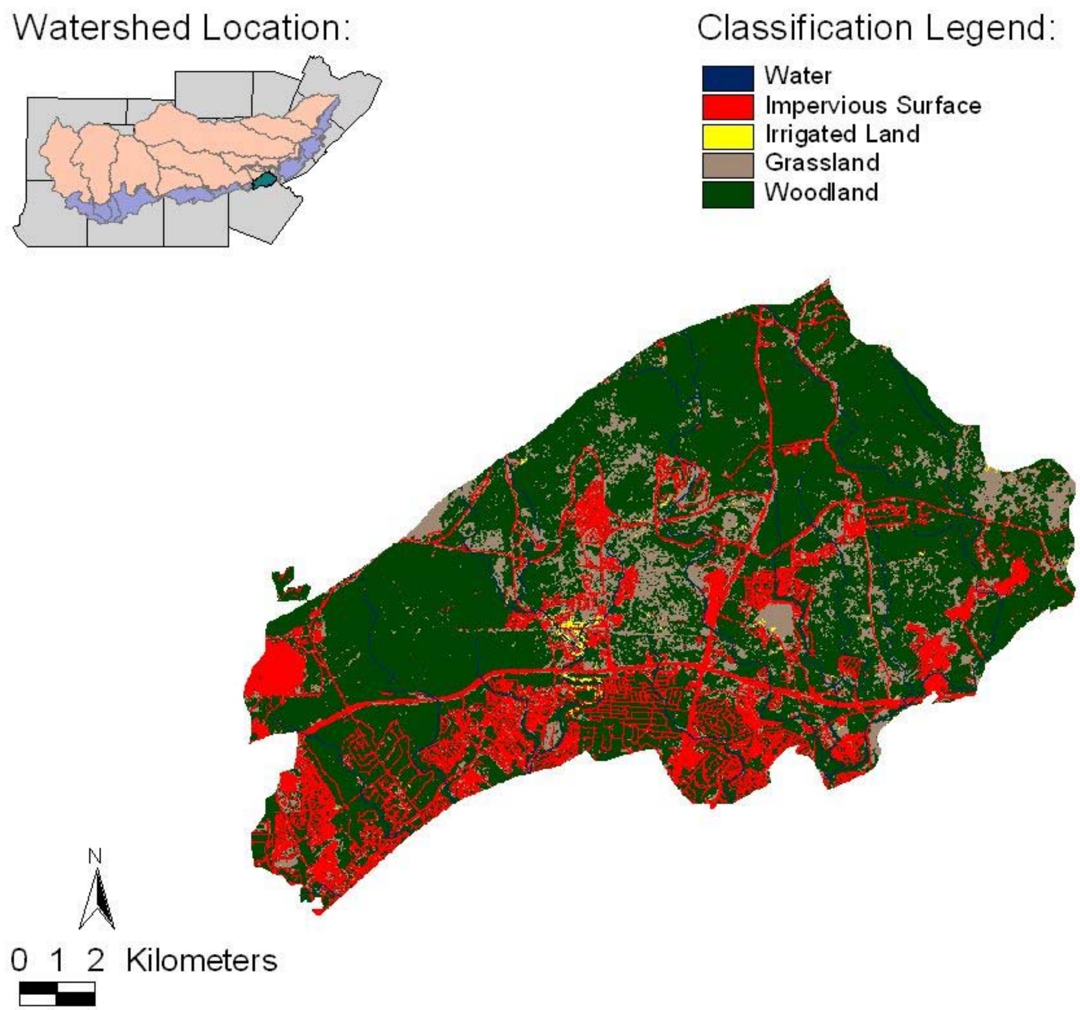

Figure 27. Land cover classification of the Upper San Antonio watershed overlay of the Edwards Aquifer recharge zone for 1993.

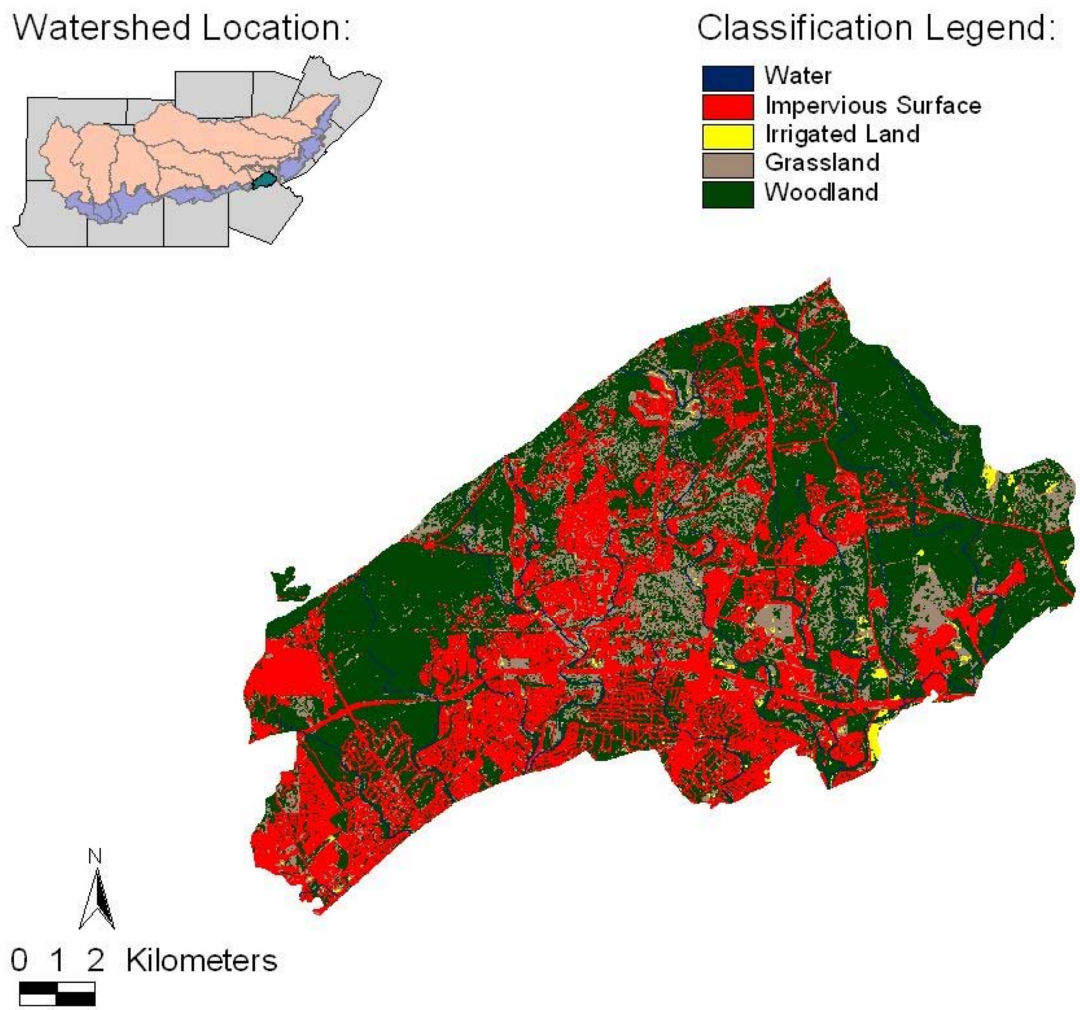

Figure 28. Land cover classification of the Upper San Antonio watershed overlay of the Edwards Aquifer recharge zone for 2000.

contributing zone, the watershed recharge zone largely intersects with the northern part of the city of San Antonio, and therefore a very high level of urban-related growth was expected. The results for the Upper San Antonio recharge zone showed that the area covered by water increased by 2.30%. The increase in water coverage may have been caused by increased water levels in a few of the reservoirs located in the watershed recharge zone. The area covered by impervious surfaces increased by 91.41%, which was the largest increase for the watershed recharge zone. Irrigated lands increased by 74.30% and could have been attributed to expanding urban green spaces that are irrigated. The area of the watershed recharge zone covered by grassland experienced the largest decrease (37.43%) and the area covered by woodland had the second largest decrease (13.22%). Woodland was likely replaced by impervious surfaces. With the exceptions of water and woodland, the results found for the Upper San Antonio recharge zone generally reflect the same trends of the Edwards Aquifer recharge zone.

The Middle Guadalupe watershed area that overlays the Edwards Aquifer contributing zone equals 118.65-km^2 (Figures 29 through 31). Table 17 presents the land cover classification results for the Middle Guadalupe contributing zone. The

Table 17. Land cover classification results for the Middle Guadalupe contributing zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	4.27	4.43	3.73	-12.62
Impervious Surface	6.82	6.62	9.23	35.34
Irrigated Land	2.20	1.30	4.54	106.85
Grassland	28.66	13.02	10.04	-64.96
Woodland	76.71	93.28	91.10	18.77

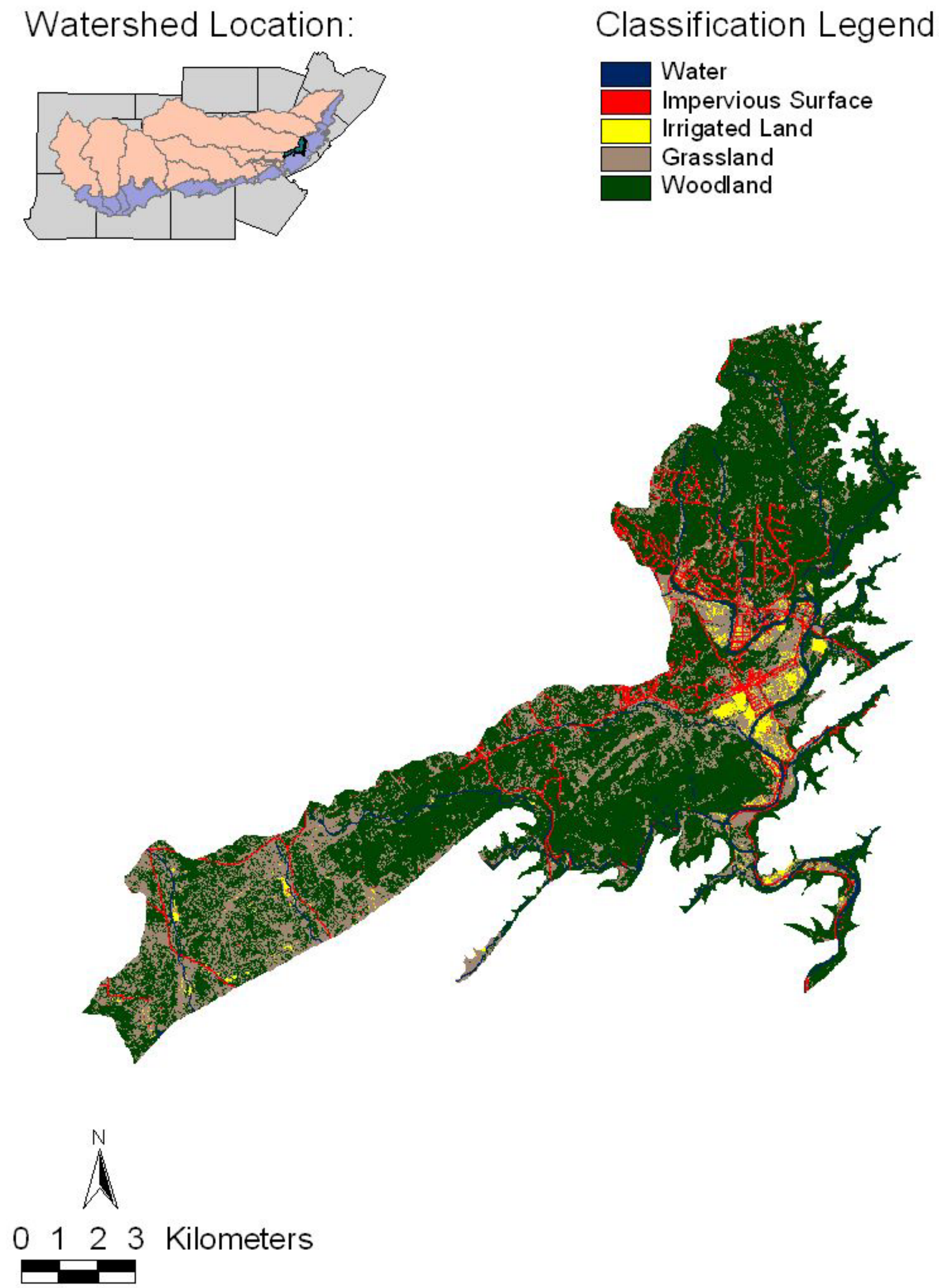

Figure 29. Land cover classification of the Middle Guadalupe watershed overlay of the Edwards Aquifer contributing zone for 1986.

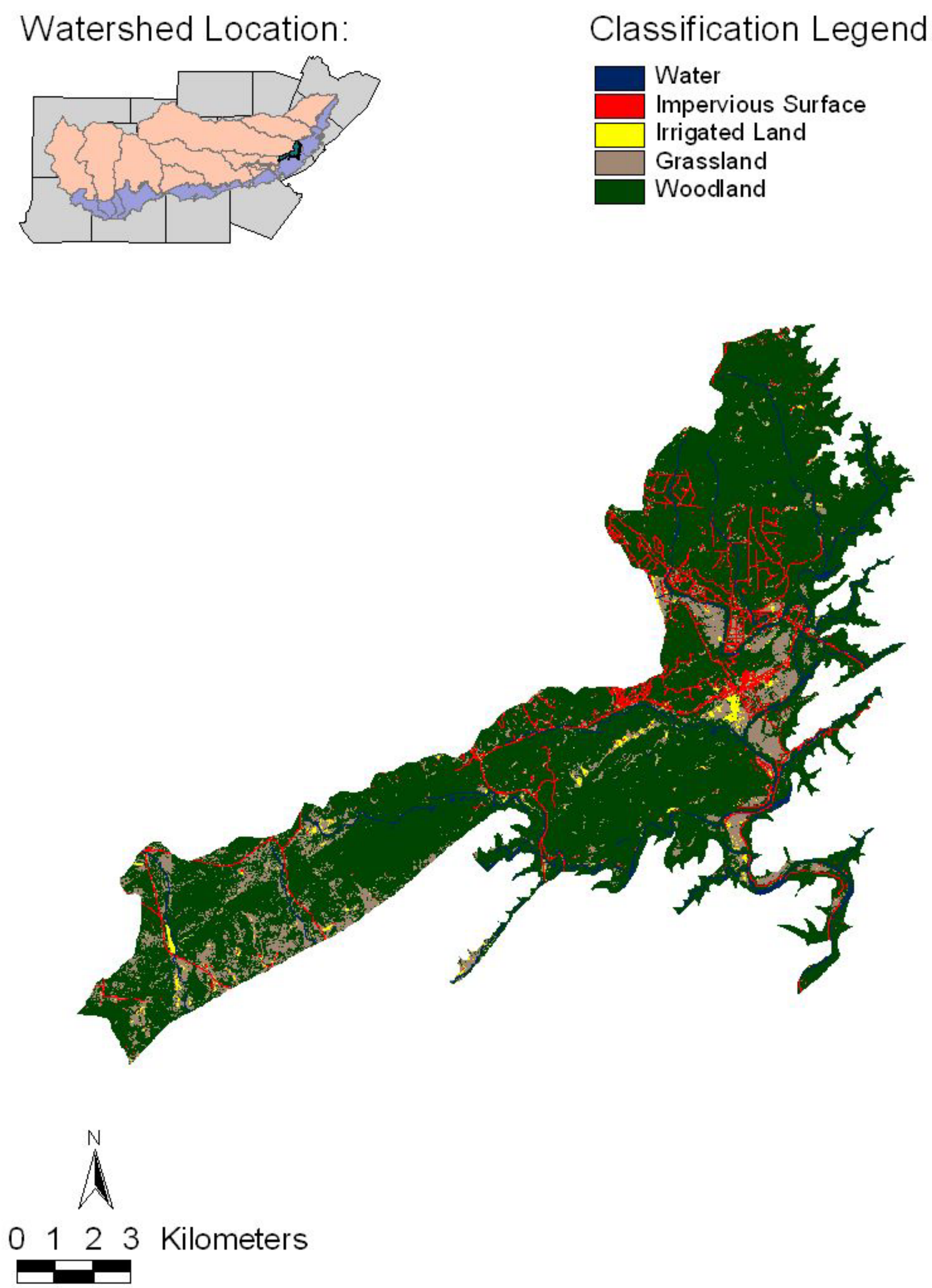

Figure 30. Land cover classification of the Middle Guadalupe watershed overlay of the Edwards Aquifer contributing zone for 1993.

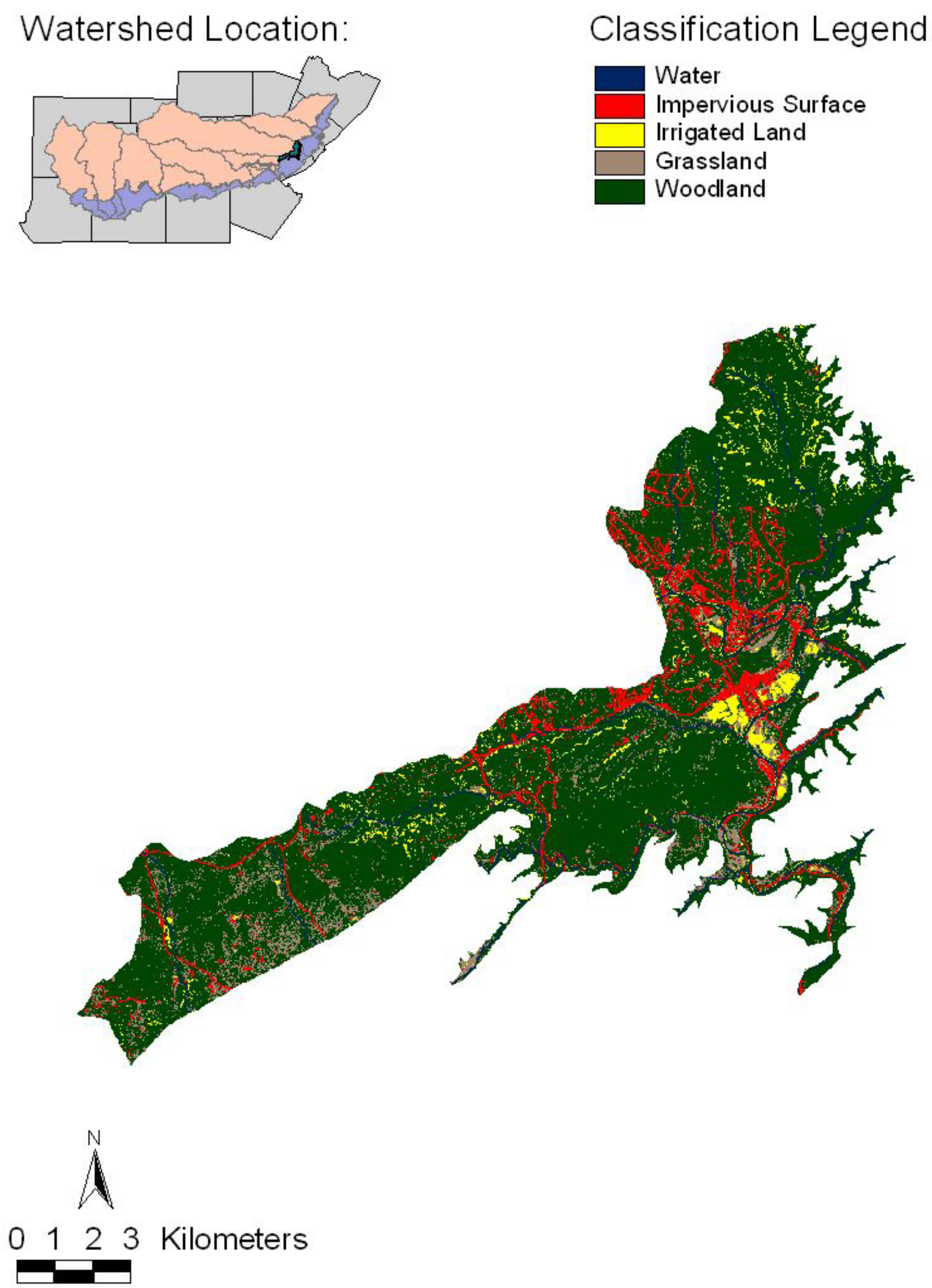

Figure 31. Land cover classification of the Middle Guadalupe watershed overlay of the Edwards Aquifer contributing zone for 2000.

watershed contributing zone does not intersect with any major cities but is northwest of the Interstate 35 corridor and a small degree of urban growth was expected. Within the results for the Middle Guadalupe contributing zone, the area covered by water decreased by 12.62%. The decrease in water coverage may have been caused by the misclassification of interior reservoirs in 1986 and 1993, but not in 2000. At each time period, there did not appear to be any interior reservoirs present within the watershed contributing zone. The area of impervious surfaces increased by 35.34%. Irrigated lands increased by 106.85%, which was the largest increase. The initial area classified as irrigated land was low and this seemingly large increase was not that significant. The area covered by grassland had the largest decrease (64.96%) while the area covered by woodland had the third largest increase (18.77%). With the exception of water, the results found for the Middle Guadalupe contributing zone reflect the general land cover change trends of the Edwards Aquifer contributing zone.

The Middle Guadalupe watershed area that overlays the Edwards Aquifer recharge zone equals 367.34-km^2 (Figures 32 through 34). Table 18 presents the land cover classification results for the Middle Guadalupe recharge zone. The watershed recharge

Table 18. Land cover classification results for the Middle Guadalupe recharge zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	6.53	6.31	6.38	-2.31
Impervious Surface	18.21	20.03	27.74	52.34
Irrigated Land	2.22	3.09	3.20	44.54
Grassland	105.61	43.94	48.84	-53.75
Woodland	234.77	293.98	281.17	19.76

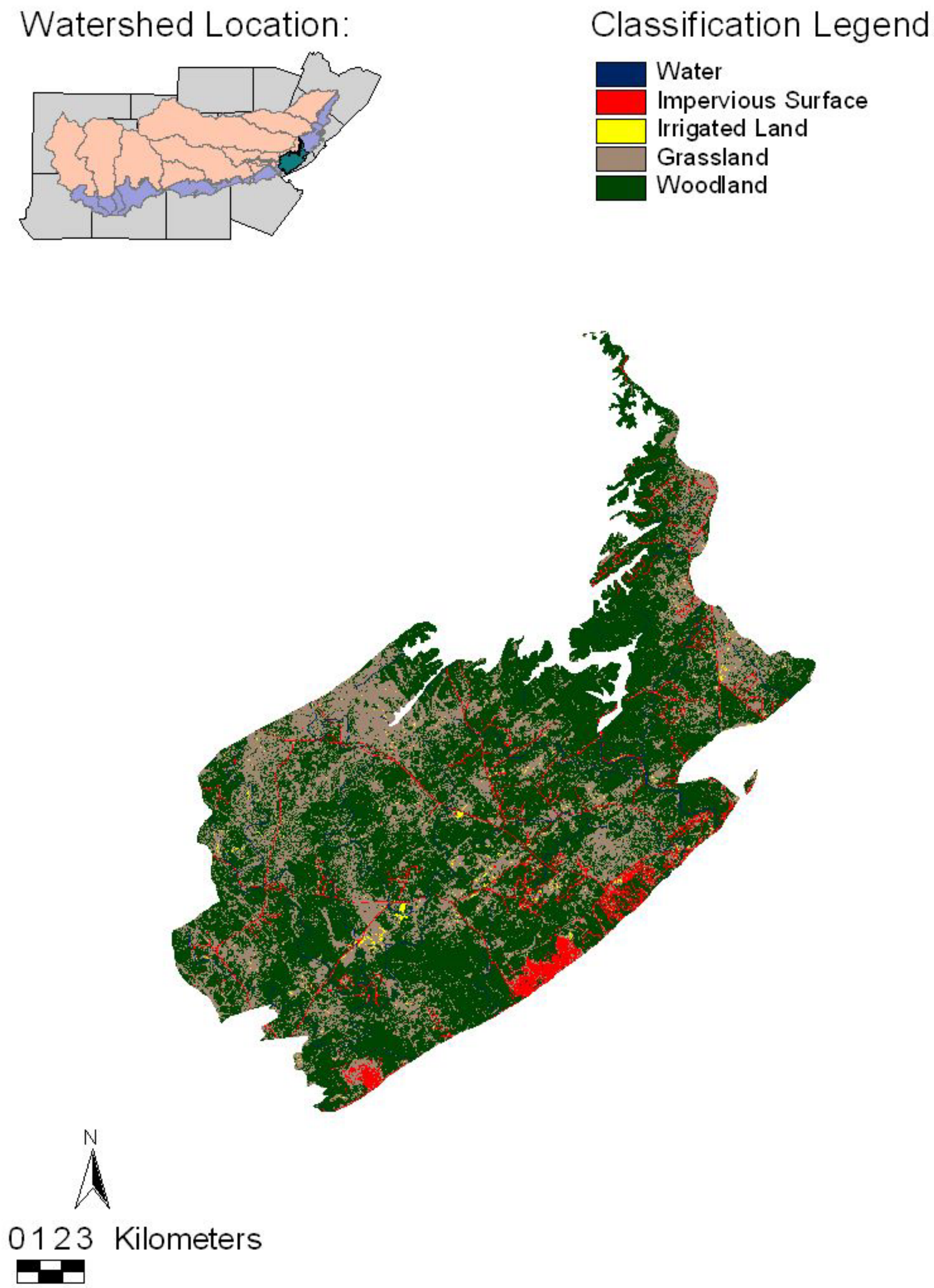

Figure 32. Land cover classification of the Middle Guadalupe watershed overlay of the Edwards Aquifer recharge zone for 1986.

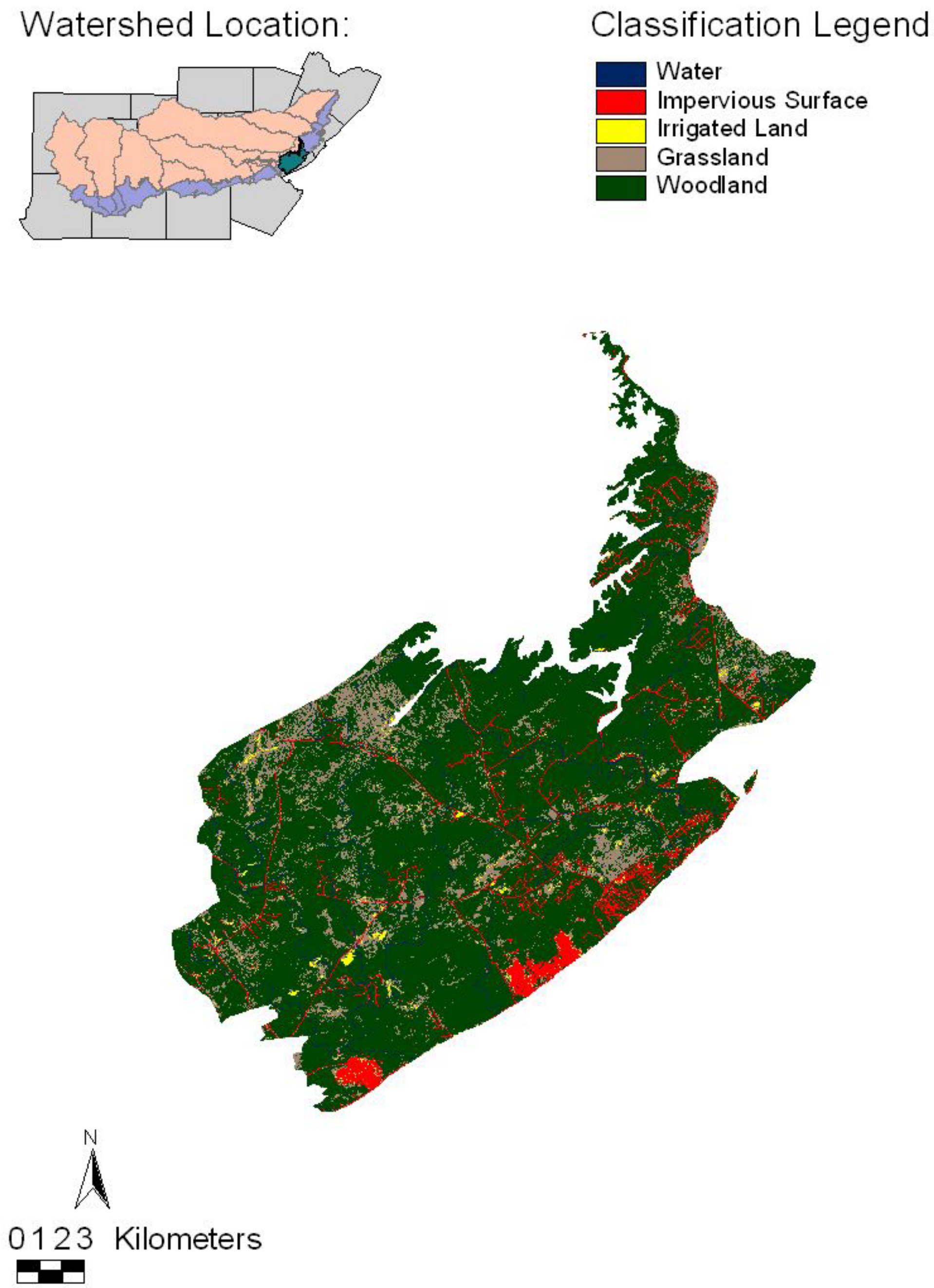

Figure 33. Land cover classification of the Middle Guadalupe watershed overlay of the Edwards Aquifer recharge zone for 1993.

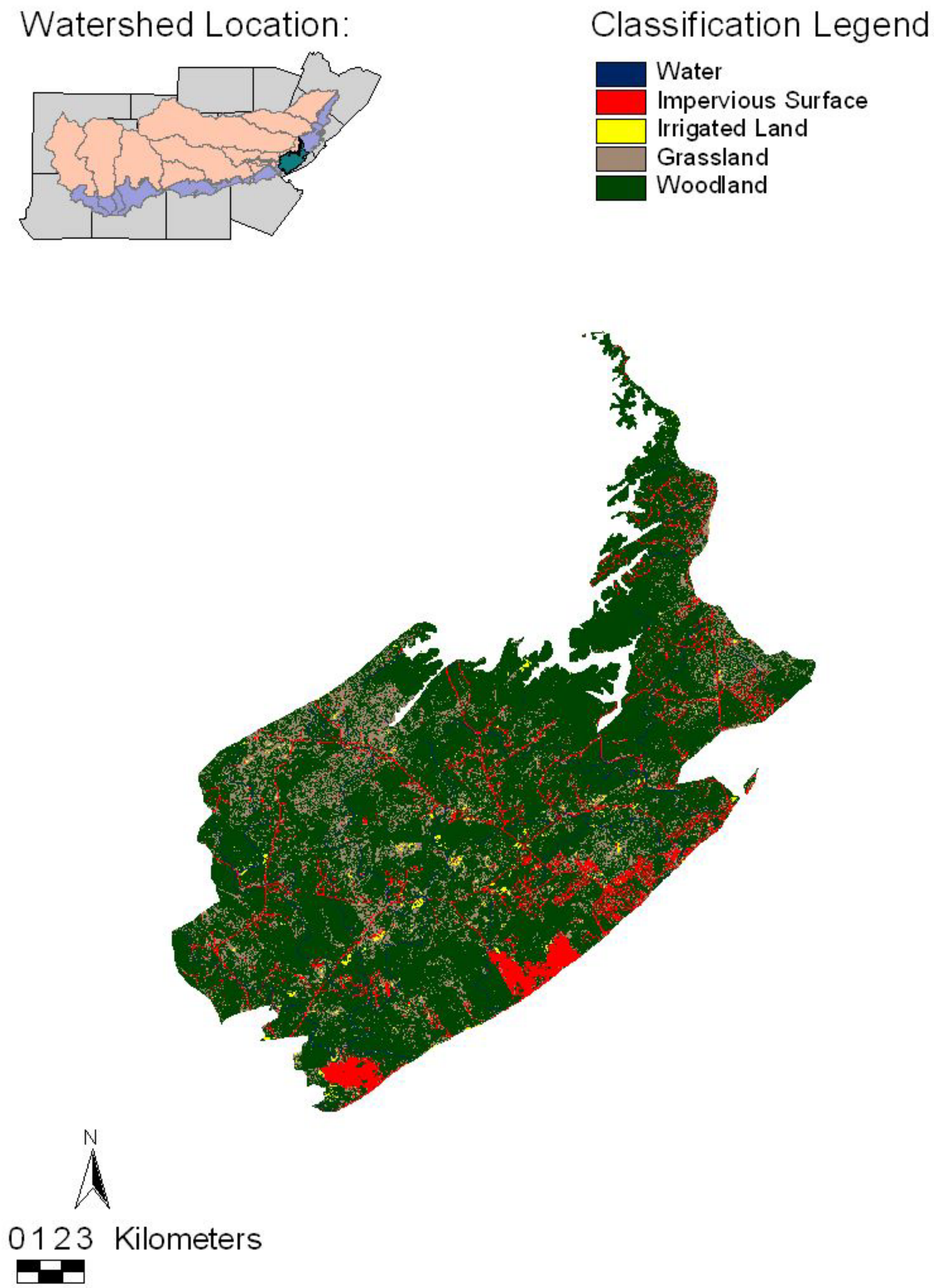

Figure 34. Land cover classification of the Middle Guadalupe watershed overlay of the Edwards Aquifer recharge zone for 2000.

zone is immediately adjacent to Interstate 35 and a higher level of urban-related growth was more likely to be found than was identified within the contributing zone. The results for the Middle Guadalupe recharge zone showed that the area covered by water had a decrease of 2.31%. The decrease in water coverage was relatively small and could be considered a negligible change. The area covered by impervious surfaces increased by 52.34%, which was the largest increase throughout the watershed recharge zone. Irrigated lands increased by 44.54%. This location is immediately adjacent to the heavy agricultural areas east of Interstate 35; therefore it was expected that irrigated agriculture in the watershed recharge zone could have fluctuated more. The area of the watershed recharge zone covered by grassland experienced the largest decrease (53.75%) and the area covered by woodland had the third largest increase (19.76%). The results found for the Middle Guadalupe recharge zone reflect the identical trends experienced across the entire Edwards Aquifer recharge zone.

The Cibolo watershed area that overlays the Edwards Aquifer contributing zone equals 587.63-km^2 (Figures 35 through 37). Table 19 presents the land cover classification results for the Cibolo contributing zone. The watershed contributing zone

Table 19. Land cover classification results for the Cibolo contributing zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	15.43	9.96	10.85	-29.67
Impervious Surface	27.68	27.71	27.33	-1.28
Irrigated Land	11.69	26.76	9.76	-16.55
Grassland	196.79	123.39	107.99	-45.13
Woodland	336.04	399.82	431.71	28.47

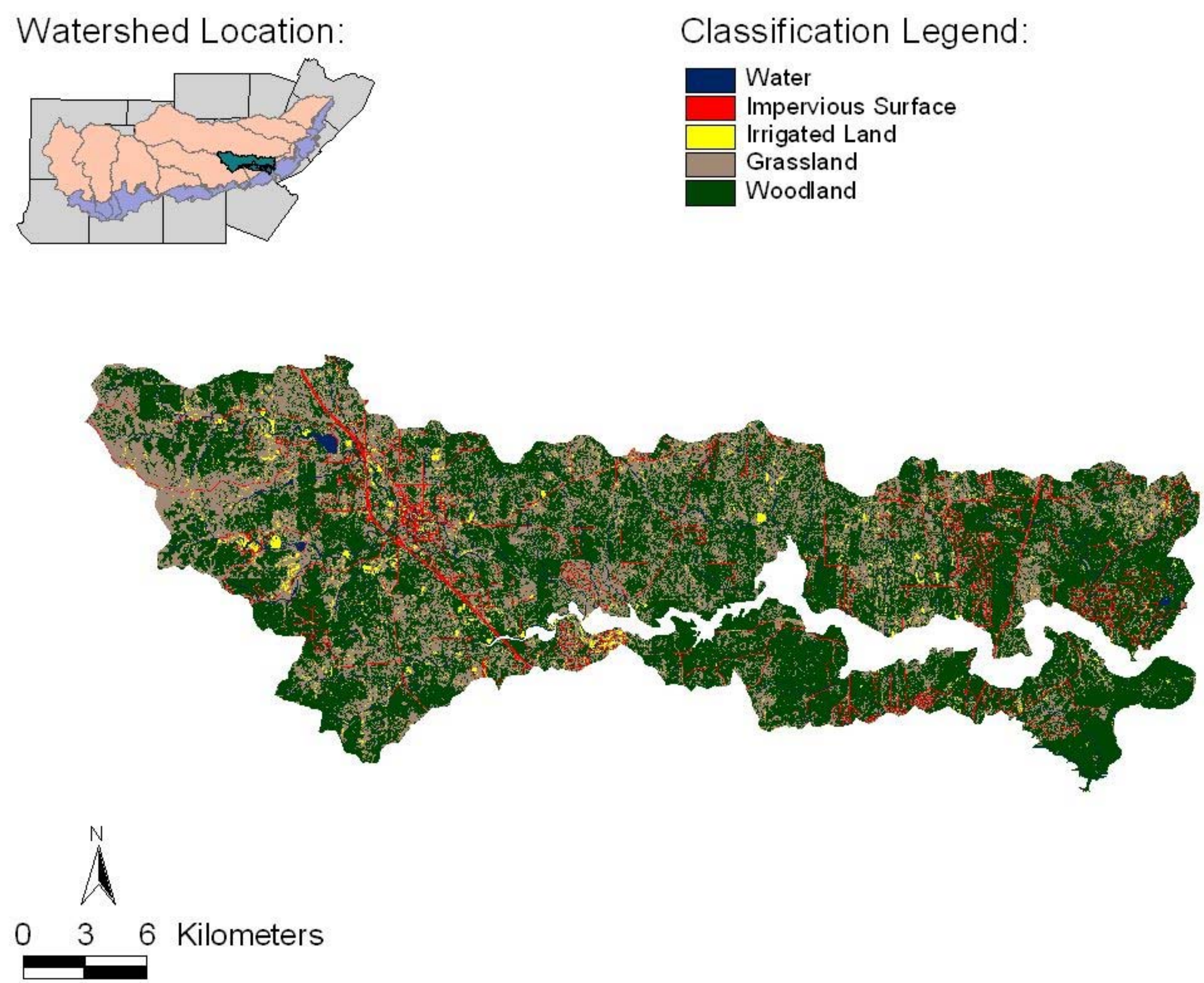

Figure 35. Land cover classification of the Cibolo watershed overlay of the Edwards Aquifer contributing zone for 1986.

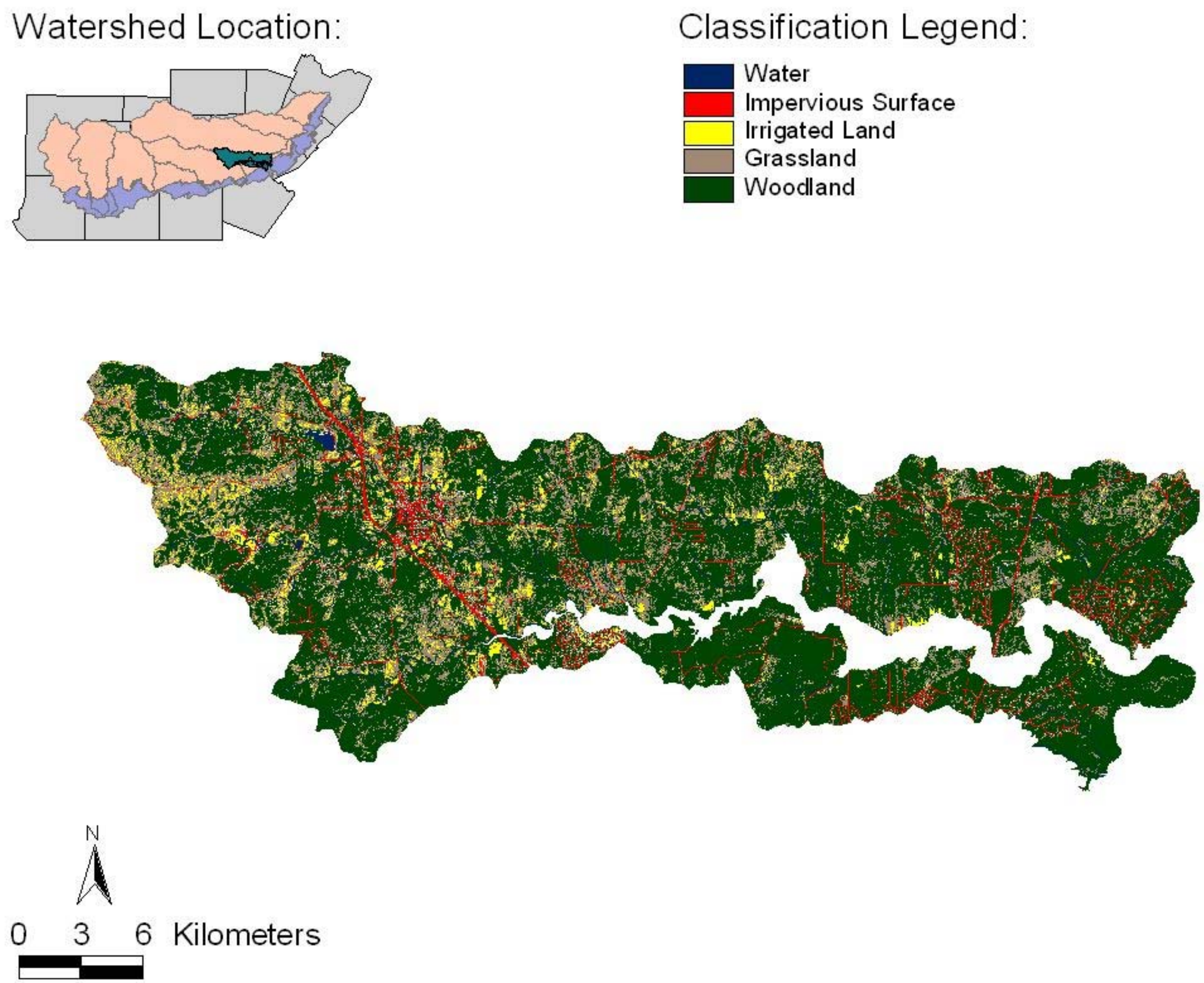

Figure 36. Land cover classification of the Cibolo watershed overlay of the Edwards Aquifer contributing zone for 1993.

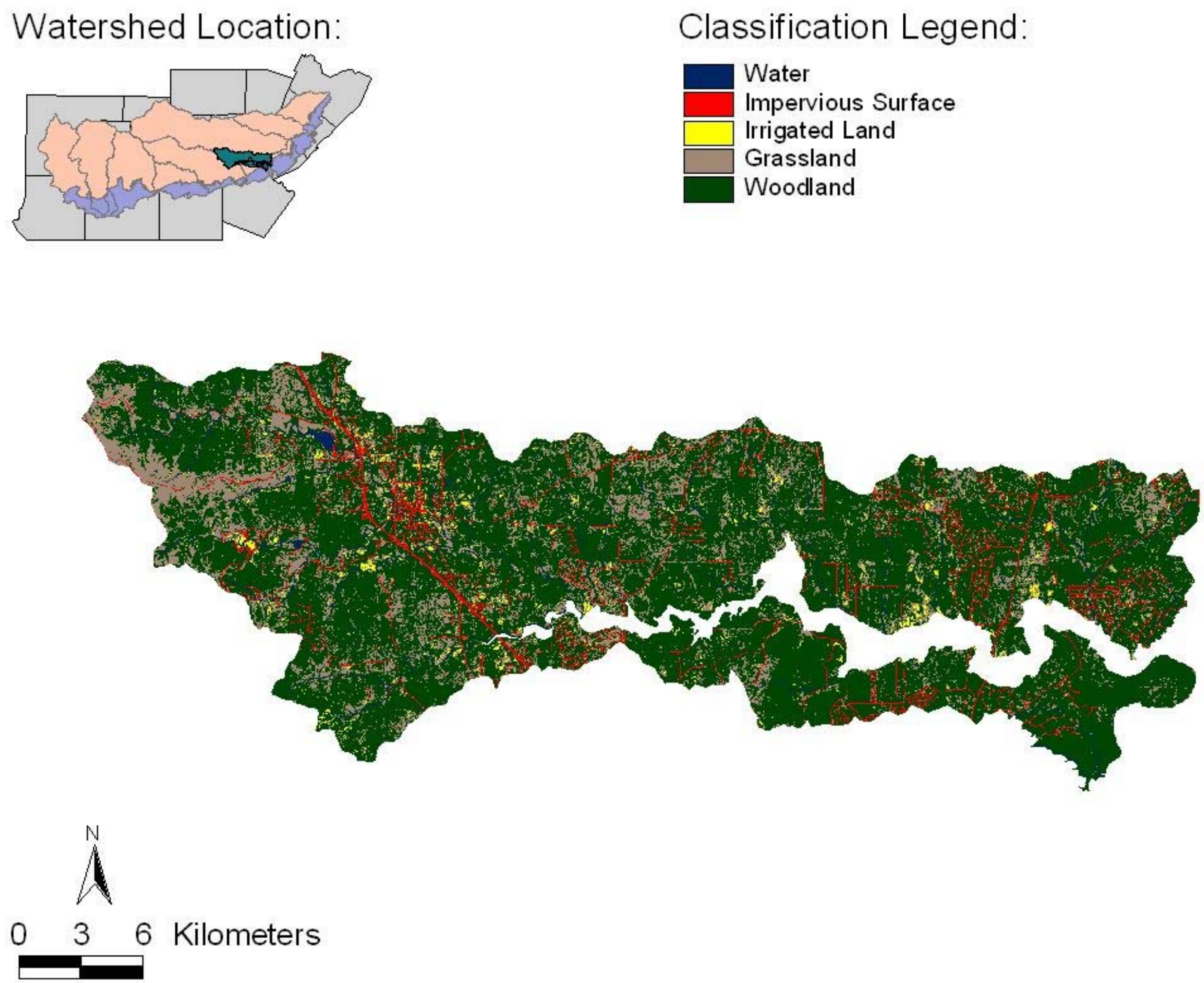

Figure 37. Land cover classification of the Cibolo watershed overlay of the Edwards Aquifer contributing zone for 2000.

includes the northern portion of Bexar County. Within the results for the Cibolo contributing zone, the area covered by water decreased by 29.67%. The decrease in water coverage may have been caused by decreased water levels in a few of the reservoirs located in the western portion of the watershed recharge zone. The area of impervious surfaces decreased by 1.28%. The actual likelihood of this result is very low but misclassification of bare soil or low vegetation cover could have resulted in higher levels of impervious surfaces classified for the 1986 and 1993 images. The low level of decrease (0.35-km^2) could really be considered negligible given the size of the watershed contributing zone. Irrigated lands were found to have decreased by 16.55%. Agriculture has more of a presence within the watershed recharge zone. The area covered by grassland had the largest decrease (45.13%) while the area covered by woodland had the largest increase (28.47%). With the exception of water and impervious surface area, the results found for the Cibolo contributing zone reflect the same general land cover change trends of the Edwards Aquifer contributing zone.

The Cibolo watershed area that overlays the Edwards Aquifer recharge zone equals 87.89-km^2 (Figures 38 through 40). Table 20 presents the land cover classification

Table 20. Land cover classification results for the Cibolo recharge zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	4.07	3.82	4.20	3.23
Impervious Surface	1.83	1.88	2.61	42.65
Irrigated Land	3.78	7.82	5.81	53.88
Grassland	21.01	15.11	12.12	-42.29
Woodland	57.20	59.25	63.13	10.38

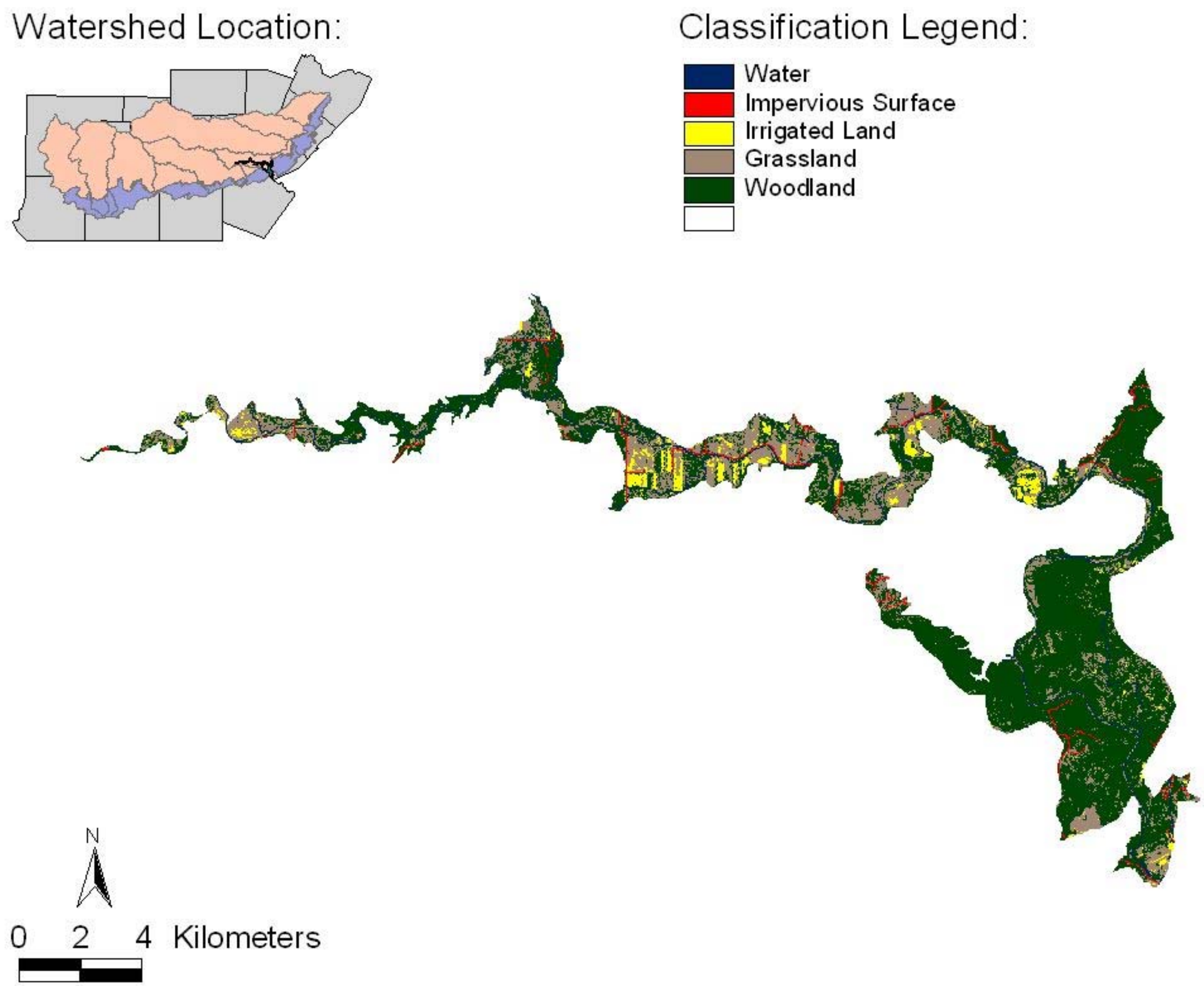

Figure 38. Land cover classification of the Cibolo watershed overlay of the Edwards Aquifer recharge zone for 1986.

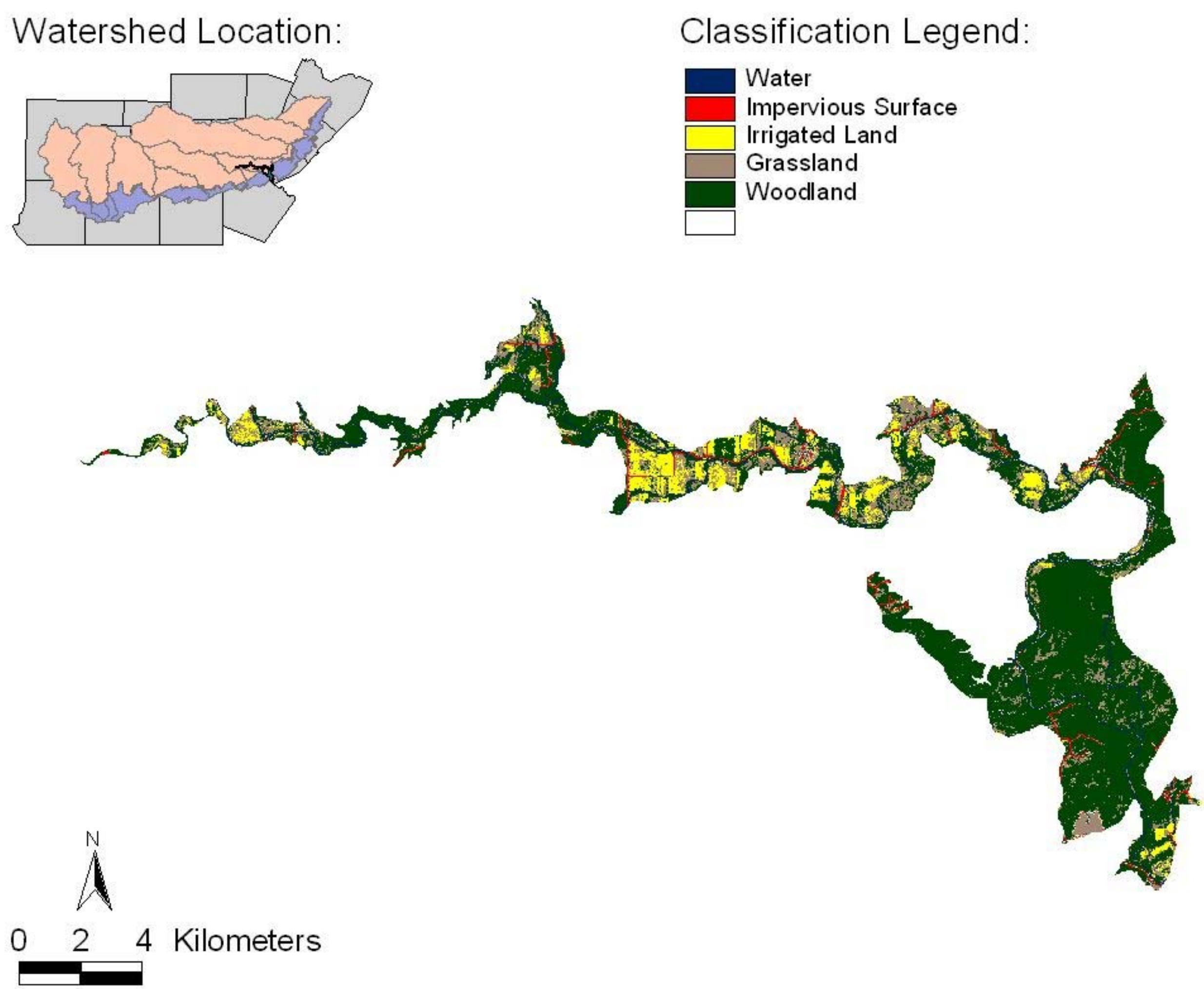

Figure 39. Land cover classification of the Cibolo watershed overlay of the Edwards Aquifer recharge zone for 1993.

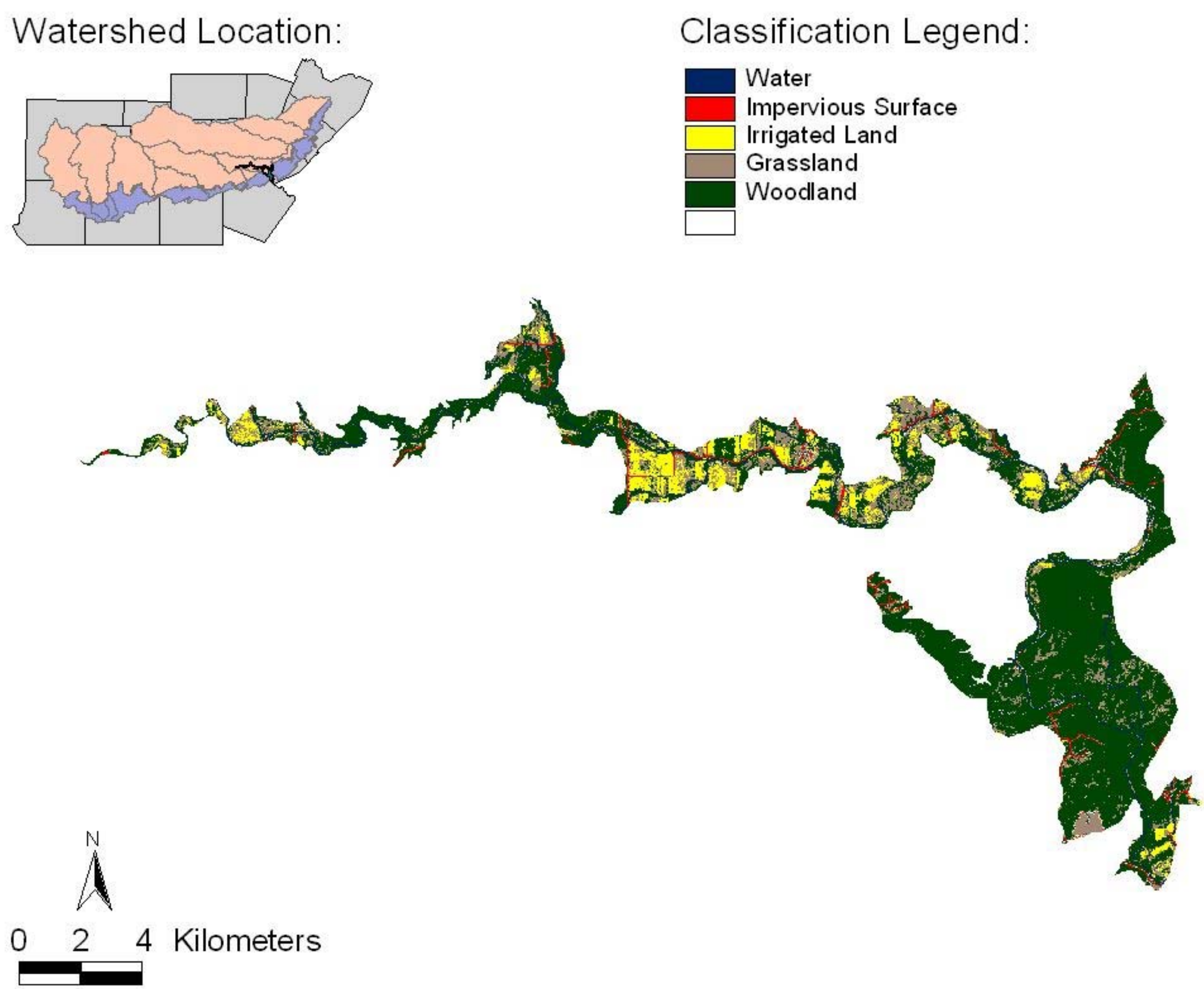

Figure 40. Land cover classification of the Cibolo watershed overlay of the Edwards Aquifer recharge zone for 2000.

results for the Cibolo recharge zone. As with the watershed contributing zone, the watershed recharge zone is located in northern Bexar County, but is not integrated into any urban areas. The results for the Cibolo recharge zone showed that the area covered by water increased by 3.23%. Increased levels of water within the stream networks may have caused the increase in water coverage, but the actual increase in area was negligible. The area covered by impervious surfaces increased by 42.65%, which was the second largest increase throughout the watershed recharge zone. Irrigated lands were found to have the largest increase at 53.88%, but the actual area represents a relatively small component of the watershed recharge zone. Given the presence of agriculture seen in the imagery, this increase was expected within the classification results. The area of the watershed recharge zone covered by grassland experienced the largest decrease (42.29%) and the area covered by woodland had the third largest growth (10.38%). With the exception of a slight decrease in water, the results found for the Cibolo recharge zone reflect the same trends of the Edwards Aquifer recharge zone.

The Upper Guadalupe watershed area that overlays the Edwards Aquifer contributing zone equals 3,734.87-km^2 (Figures 41 through 43). Table 21 presents the

Table 21. Land cover classification results for the Upper Guadalupe contributing zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	107.02	119.78	118.44	10.67
Impervious Surface	134.33	131.37	136.45	1.58
Irrigated Land	84.25	67.33	73.48	-12.79
Grassland	1,803.96	1,659.39	1,644.24	-8.85
Woodland	1,605.30	1,757.00	1,762.26	9.78

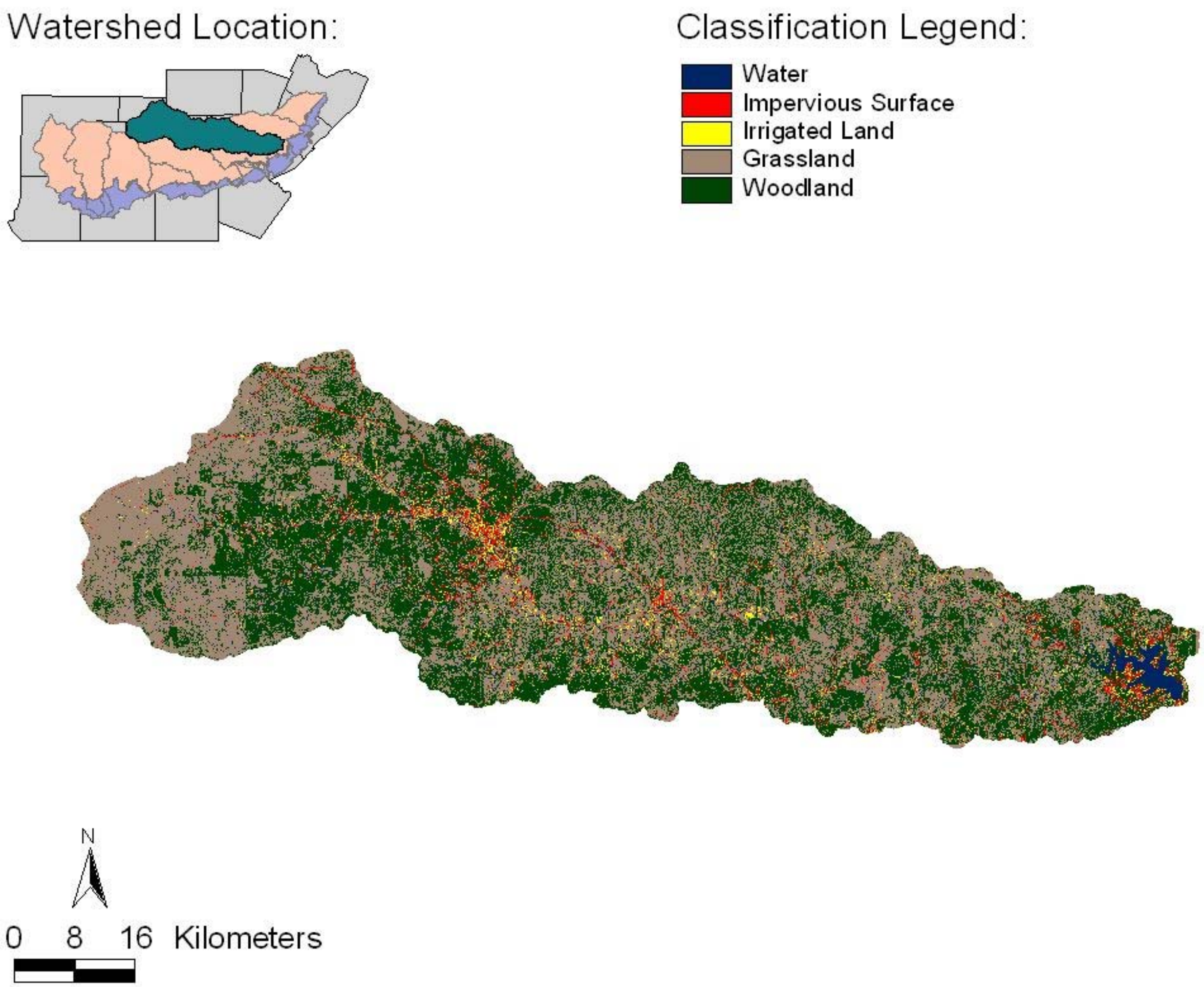

Figure 41. Land cover classification of the Upper Guadalupe watershed overlay of the Edwards Aquifer contributing zone for 1986.

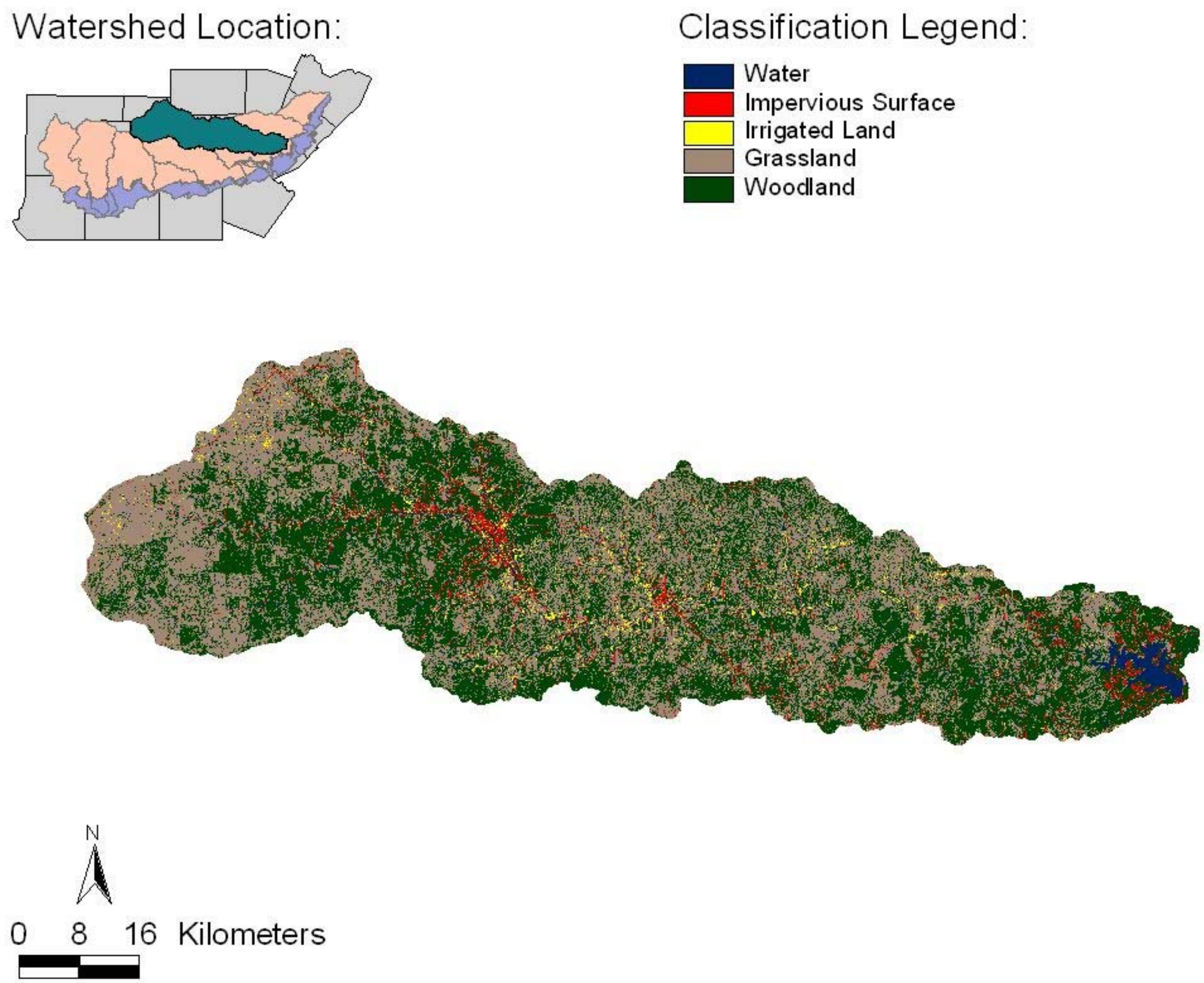

Figure 42. Land cover classification of the Upper Guadalupe watershed overlay of the Edwards Aquifer contributing zone for 1993.

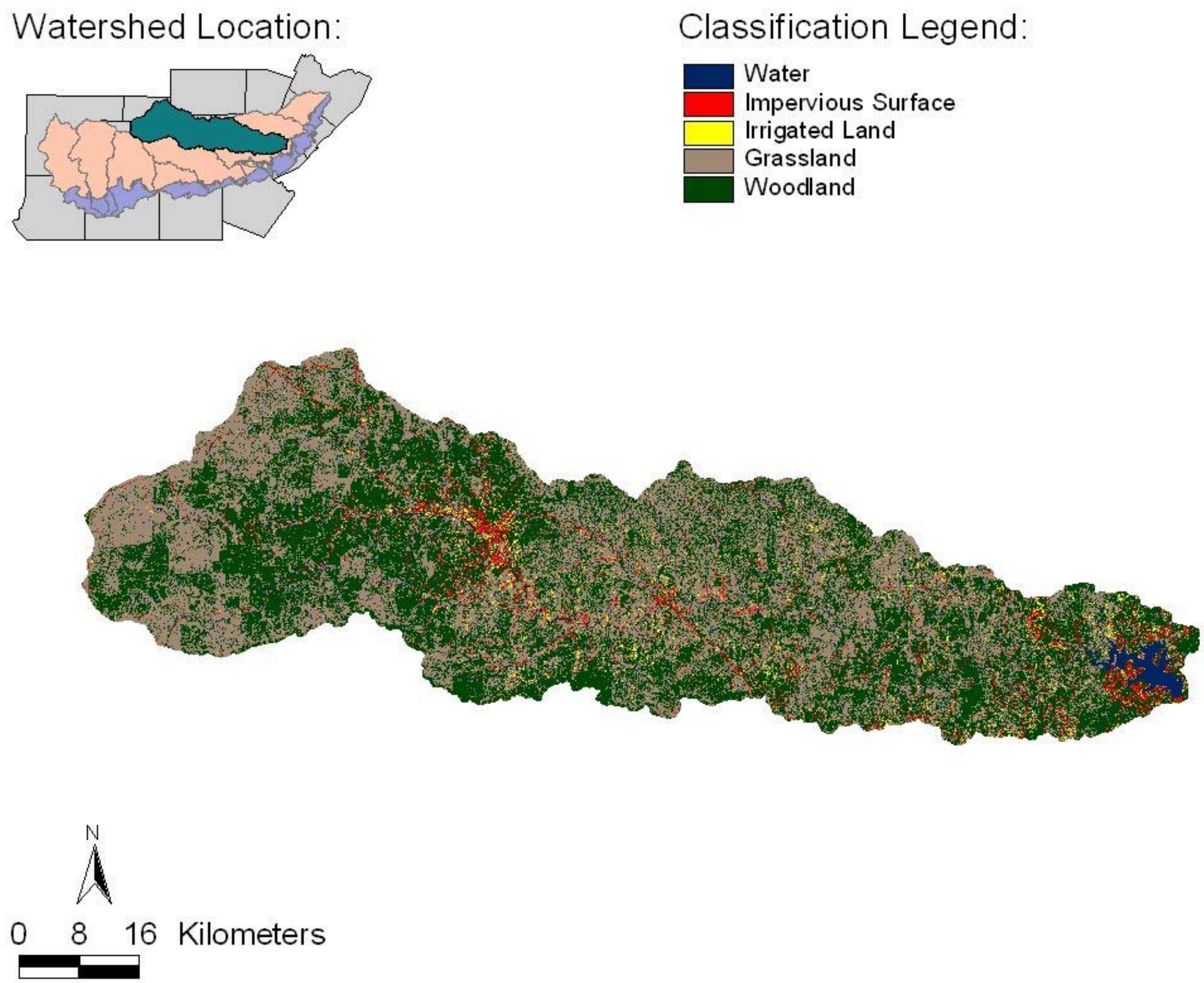

Figure 43. Land cover classification of the Upper Guadalupe watershed overlay of the Edwards Aquifer contributing zone for 2000.

land cover classification results for the Upper Guadalupe contributing zone. There is no portion of the Upper Guadalupe watershed that overlays the Edwards Aquifer recharge zone. The watershed contributing zone is the largest of the watershed areas and spans eight counties. Within the results for the Upper Guadalupe contributing zone, the area covered by water increased by 10.67%. This increase could have been caused by increased water levels in the spatially extensive Canyon Lake reservoir system. The area of impervious surfaces had a very small increase at 1.58%. Irrigated land decreased by 12.79%, which was the largest decrease. A relatively low level of cropland exists throughout the Upper Guadalupe contributing zone. Irrigated agriculture misclassification as woodland could have occurred but an actual decrease over time was certainly realistic. The area covered by grassland had the second largest decrease (8.85%) while the area covered by woodland had the second largest increase (9.78%). The results found for the Upper Guadalupe contributing zone reflect the identical land cover change trends of the Edwards Aquifer contributing zone.

The Medina watershed area that overlays the Edwards Aquifer contributing zone equals 1,931.12-km^2 (Figures 44 through 46). Table 22 presents the land cover

Table 22. Land cover classification results for the Medina contributing zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	61.64	64.49	65.57	6.37
Impervious Surface	79.85	86.07	97.15	21.66
Irrigated Land	50.74	20.31	11.45	-77.44
Grassland	718.26	648.29	662.17	-7.81
Woodland	1,020.63	1,111.97	1,094.79	7.27

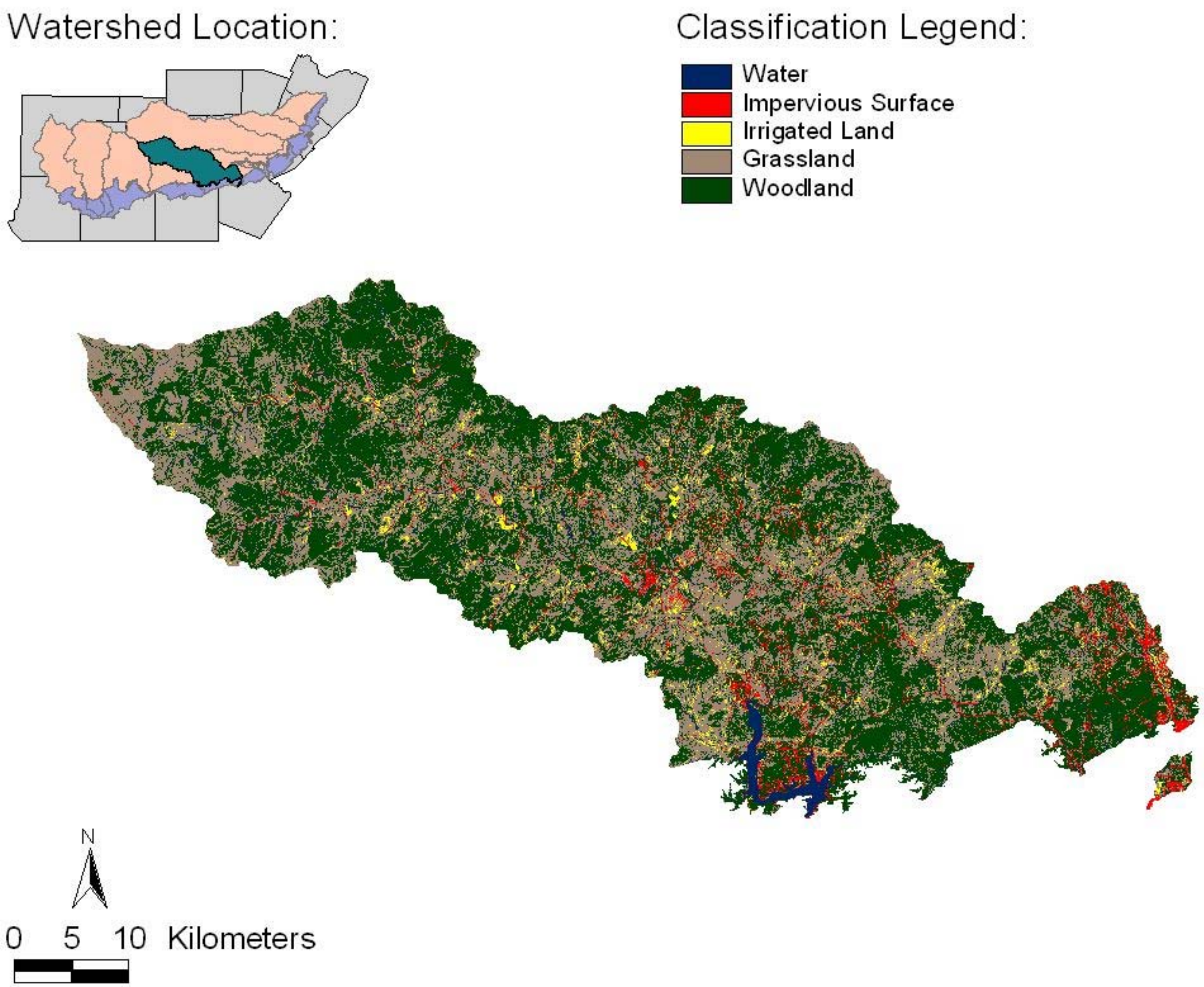

Figure 44. Land cover classification of the Medina watershed overlay of the Edwards Aquifer contributing zone for 1986.

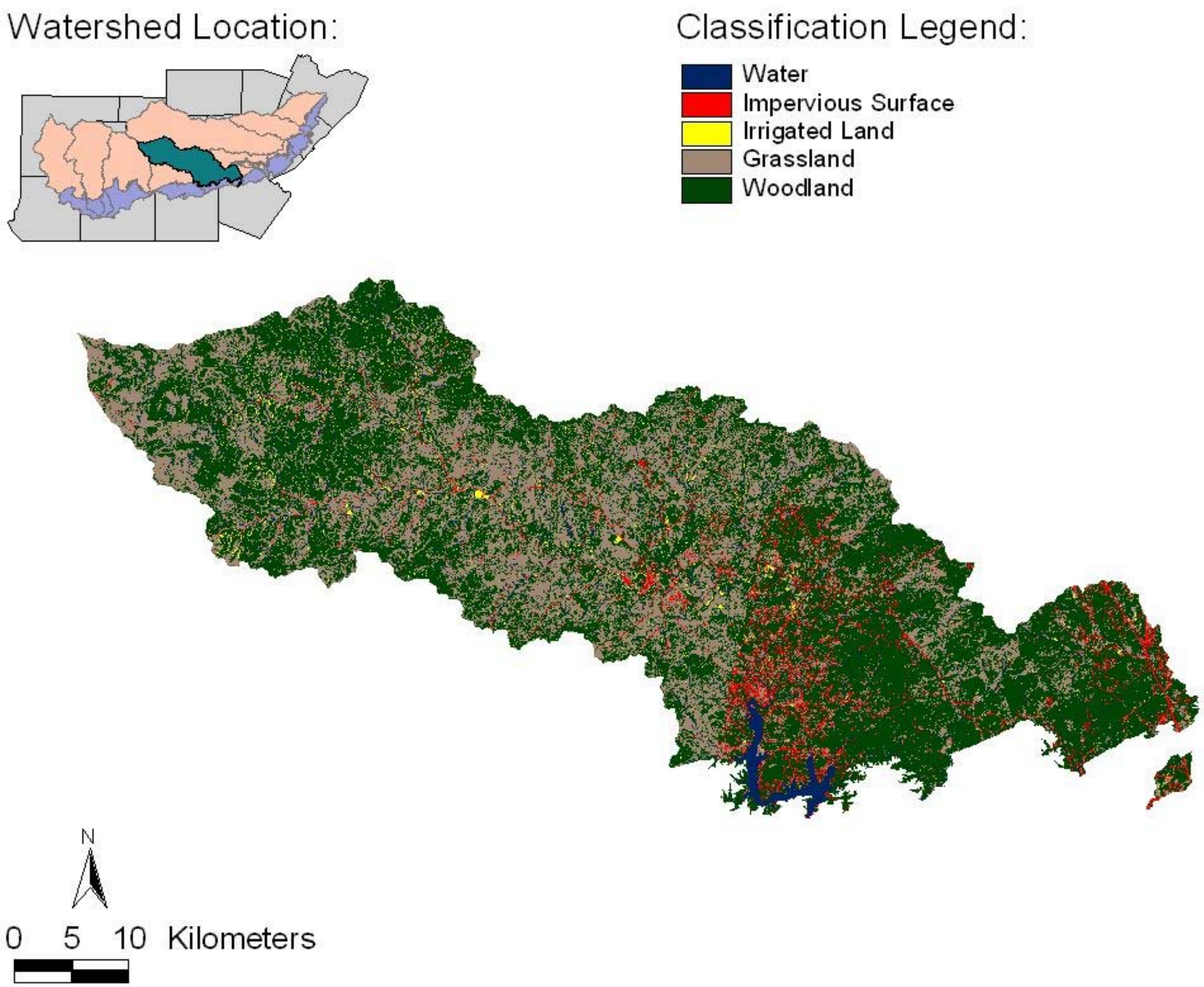

Figure 45. Land cover classification of the Medina watershed overlay of the Edwards Aquifer contributing zone for 1993.

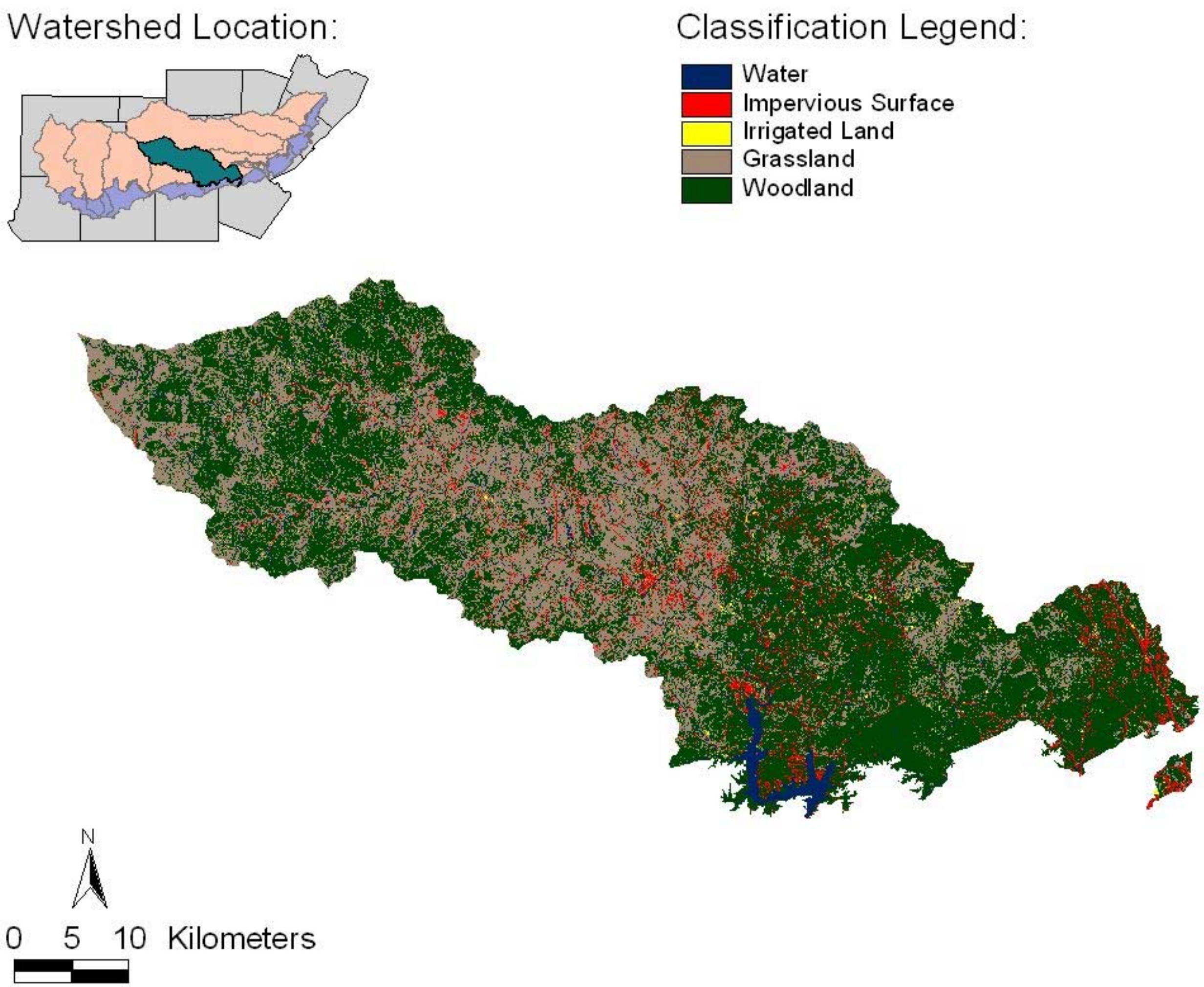

Figure 46. Land cover classification of the Medina watershed overlay of the Edwards Aquifer contributing zone for 2000.

classification results for the Medina contributing zone. The watershed contributing zone partially intersects with the northwestern section of the city of San Antonio; therefore increased urban growth was expected. Within the results for the Medina contributing zone, the area covered by water increased by 6.37%. This increase was likely the result of higher or fluctuating water levels in the Media Lake reservoir system. The area of impervious surfaces was the largest increase at 21.66%, which was consistent with the results expected. Irrigated lands decreased by 77.44%. A low level of cropland exists in this northwestern portion of the Medina watershed and fluctuations could have occurred. Impervious surface misclassification of bare soil that was once used for an agricultural or irrigated lands purpose could have also occurred. The area covered by grassland had the second largest decrease (7.81%) while the area covered by woodland had the second largest increase (7.27%). The results found for the Medina contributing zone reflect the identical land cover change trends of the Edwards Aquifer contributing zone.

The Medina watershed area that overlays the Edwards Aquifer recharge zone equals 204.65-km^2 (Figures 47 through 49). Table 23 presents the land cover classification

Table 23. Land cover classification results for the Medina recharge zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	4.33	5.07	4.55	4.90
Impervious Surface	13.03	12.14	12.65	-2.92
Irrigated Land	1.10	0.45	0.42	-61.69
Grassland	32.58	12.36	5.58	-82.89
Woodland	153.60	174.63	181.45	18.13

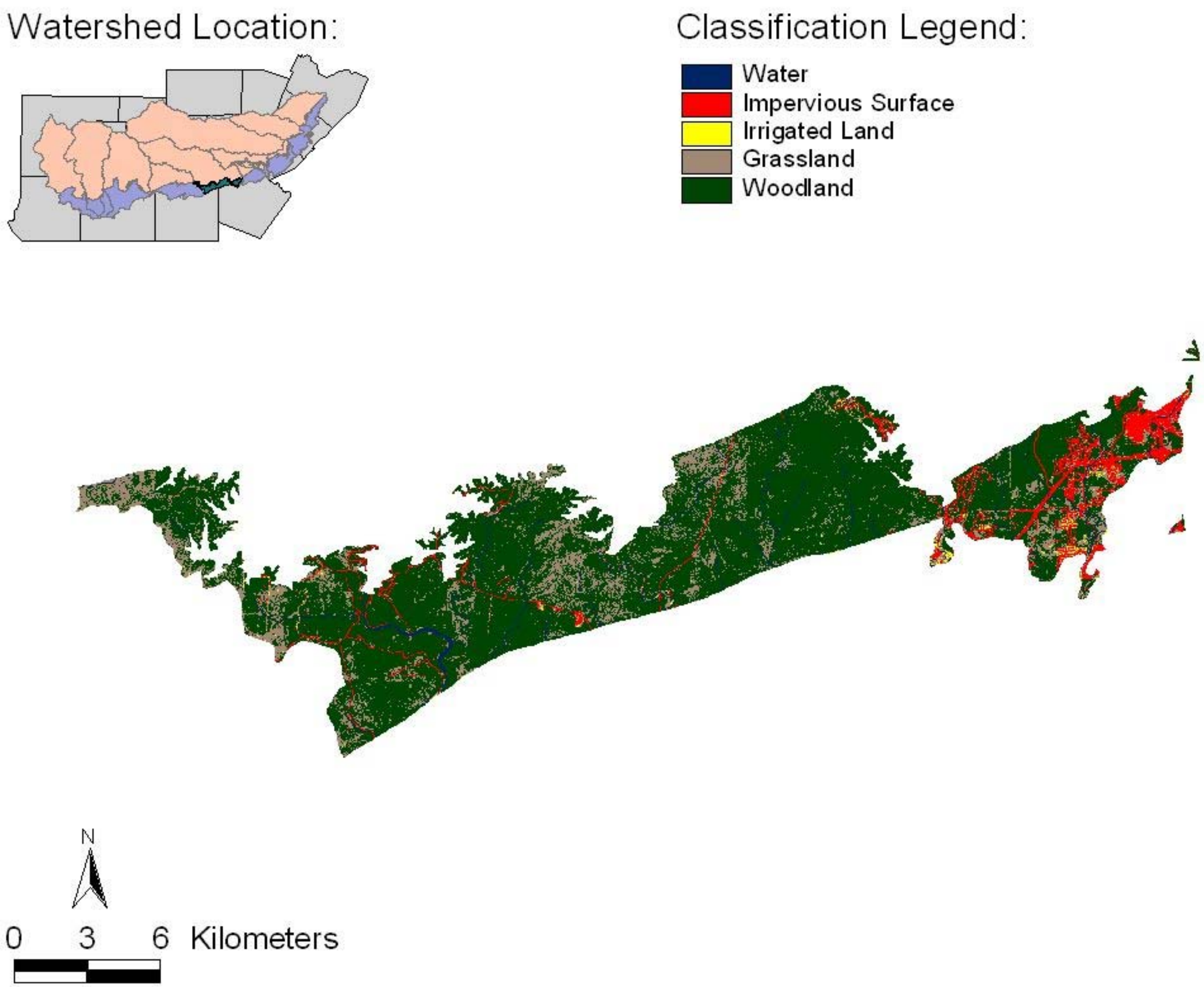

Figure 47. Land cover classification of the Medina watershed overlay of the Edwards Aquifer recharge zone for 1986.

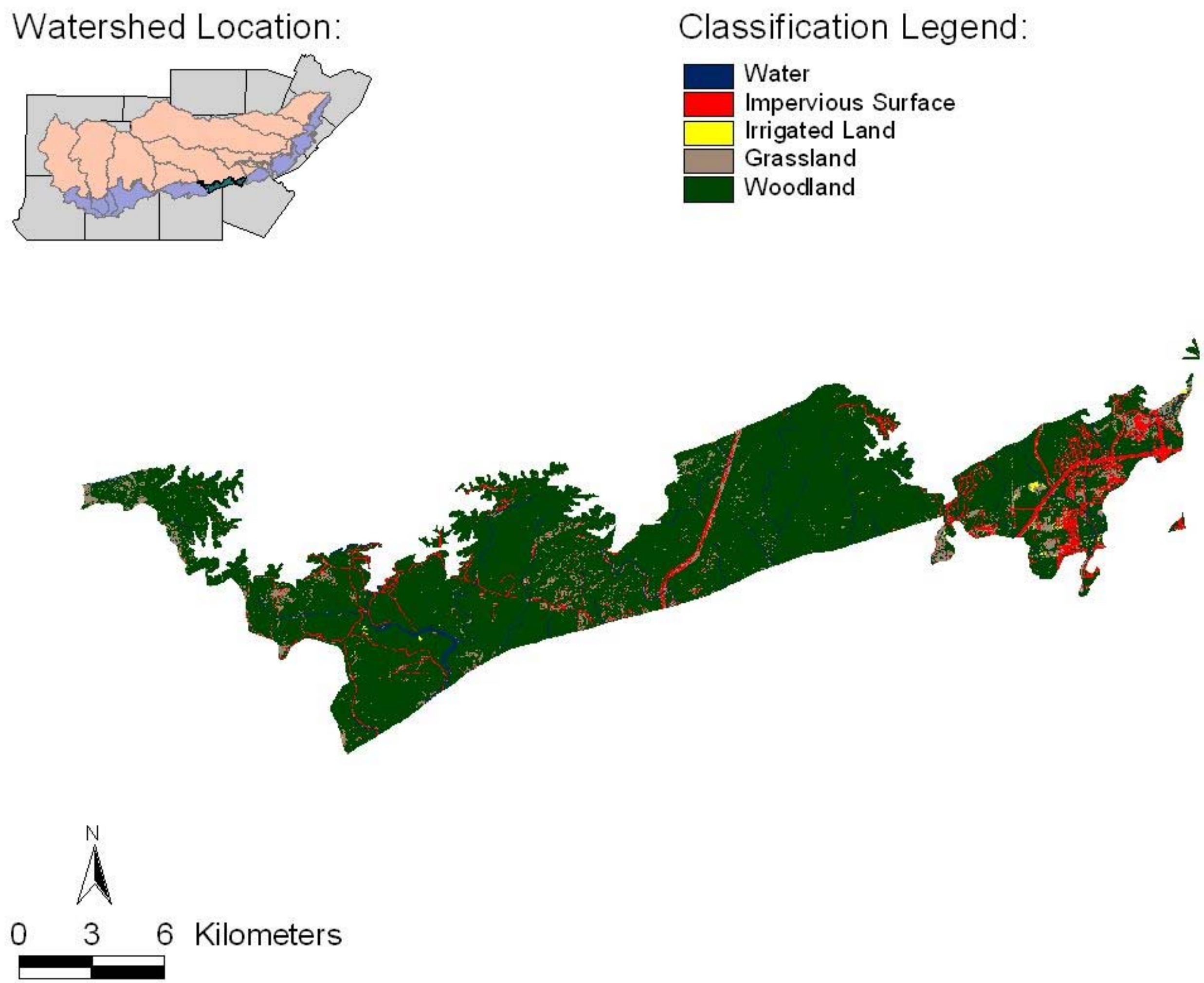

Figure 48. Land cover classification of the Medina watershed overlay of the Edwards Aquifer recharge zone for 1993.

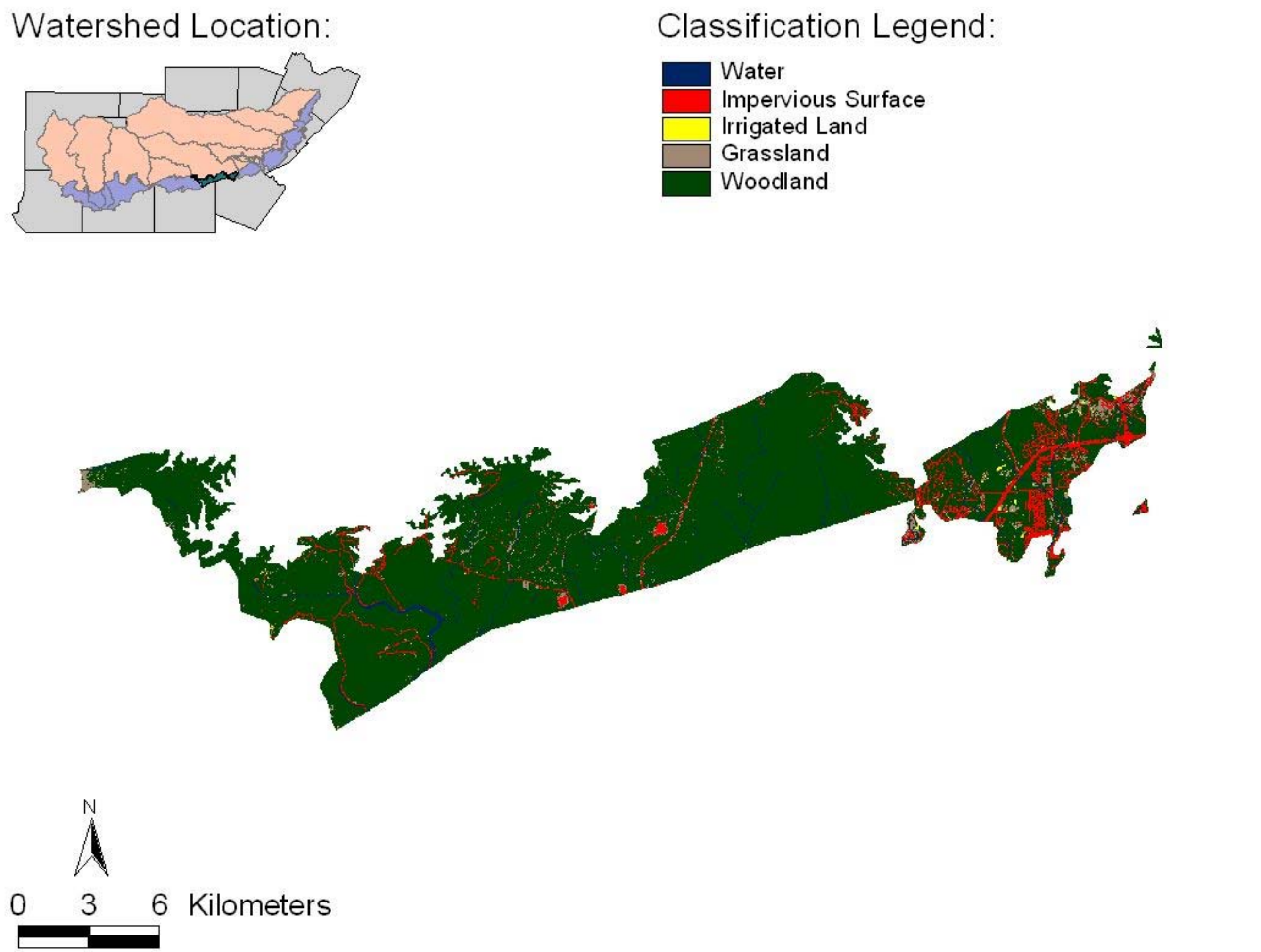

Figure 49. Land cover classification of the Medina watershed overlay of the Edwards Aquifer recharge zone for 2000.

results for the Medina recharge zone. As with the watershed contributing zone, the watershed recharge zone largely intersects with the northwestern part of the city of San Antonio and a very high level of urban-related growth was expected. The results for the Medina recharge zone showed that the area covered by water increased by 4.90%. The increase in water coverage may have been caused by increased or fluctuating water levels in the Media Lake reservoir system. The area covered by impervious surfaces decreased by 2.92%, which was not an expected result. Misclassification of bare soil as impervious surfaces in the 1986 image was the likely cause. Irrigated lands decreased by 61.69%, however the area involved is very small so the change was likely negligible. The area of the watershed recharge zone covered by grassland experienced the largest decrease (82.89%) and the area covered by woodland had the largest increase (18.13%). Woodland likely replaced irrigated agriculture observed at earlier time periods. With the exception of grassland and woodland, the results found for the Medina recharge zone generally did not reflect the same trends of the Edwards Aquifer recharge zone.

The Hondo watershed area that overlays the Edwards Aquifer contributing zone equals 650.28-km^2 (Figures 50 through 52). Table 24 presents the land cover

Table 24. Land cover classification results for the Hondo contributing zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	14.61	16.13	15.41	5.46
Impervious Surface	6.53	6.53	6.86	5.03
Irrigated Land	11.79	26.28	13.72	16.31
Grassland	204.82	184.18	171.19	-16.42
Woodland	412.52	417.16	443.11	7.41

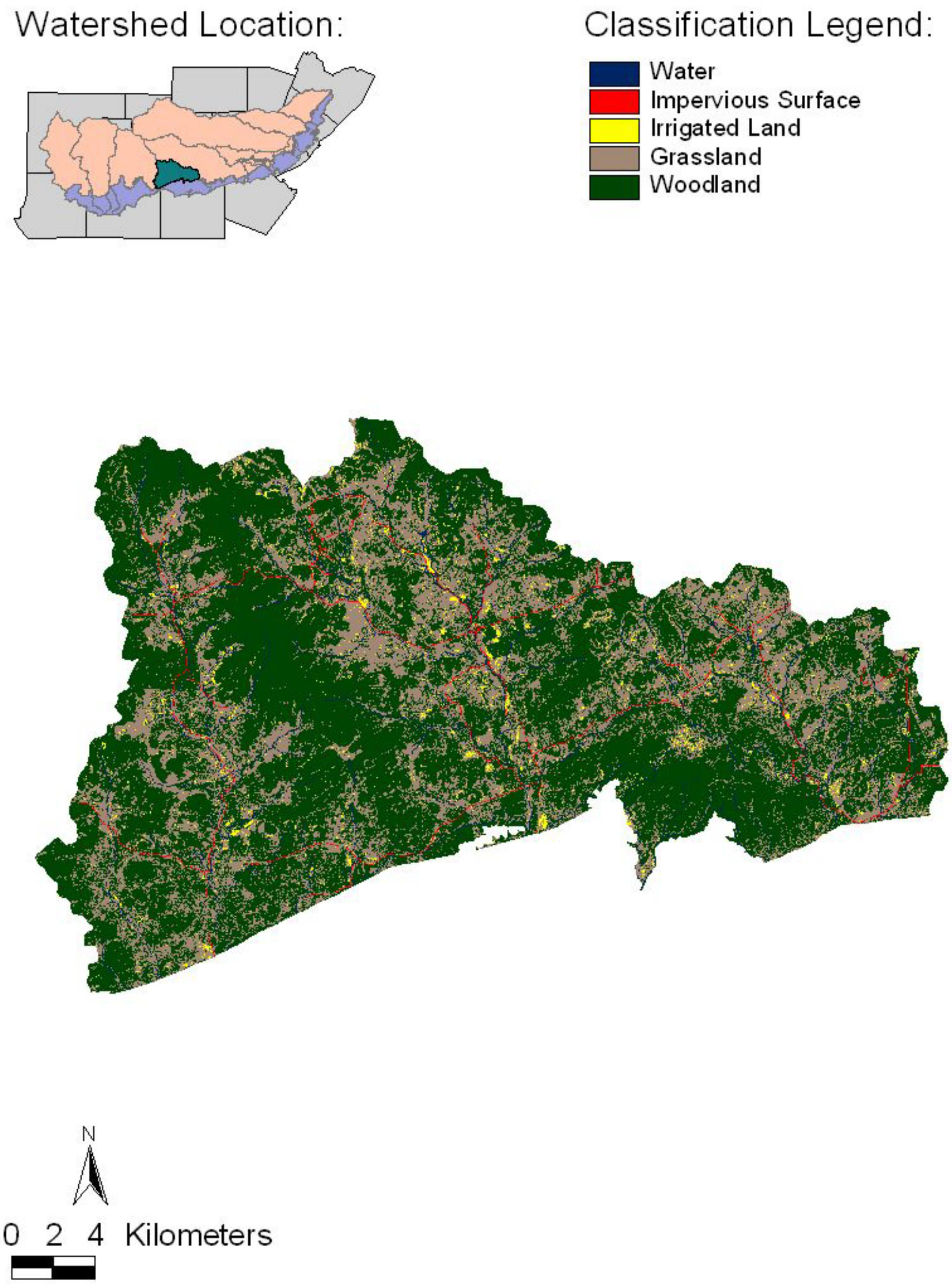

Figure 50. Land cover classification of the Hondo watershed overlay of the Edwards Aquifer contributing zone for 1986.

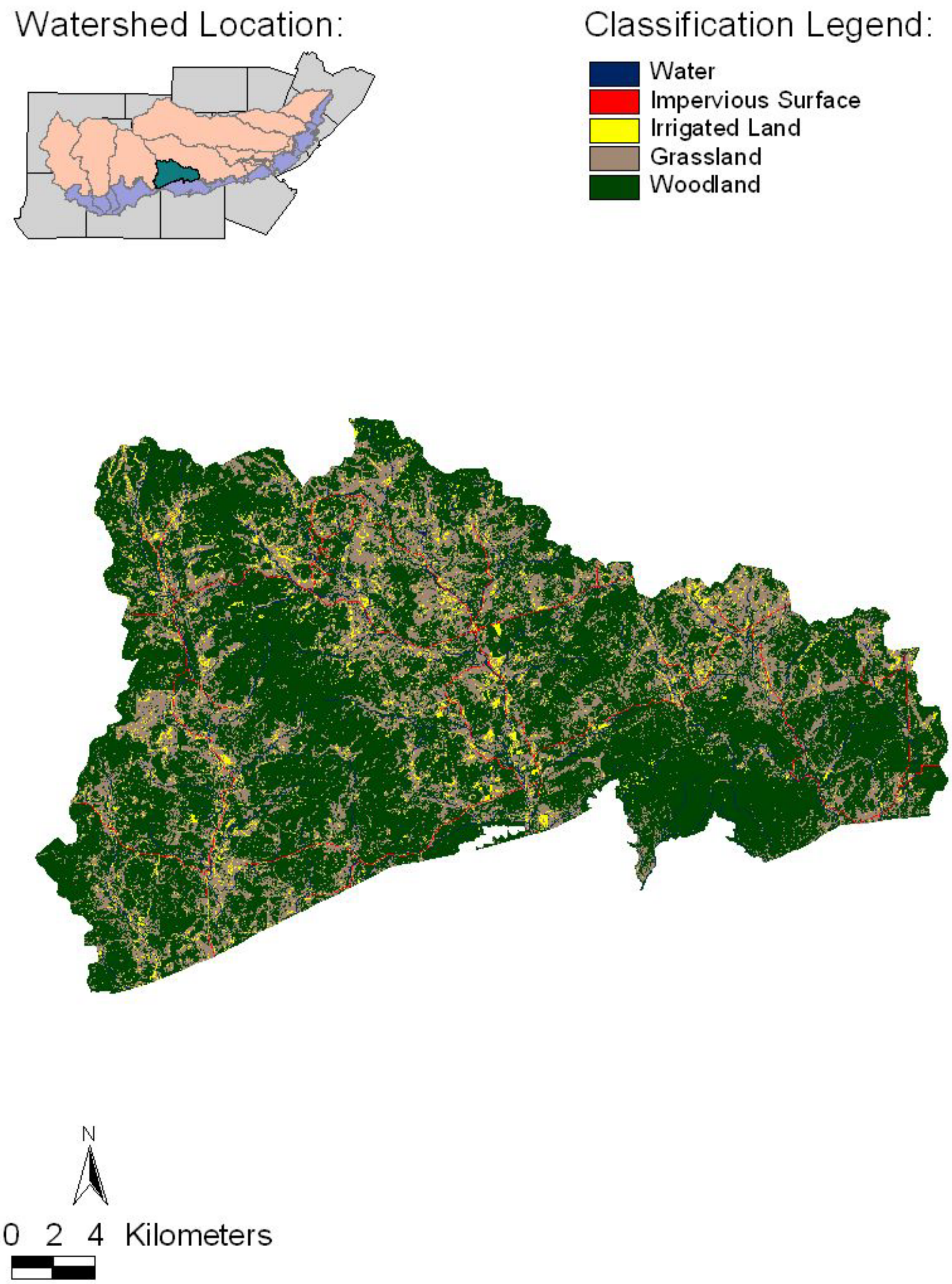

Figure 51. Land cover classification of the Hondo watershed overlay of the Edwards Aquifer contributing zone for 1993.

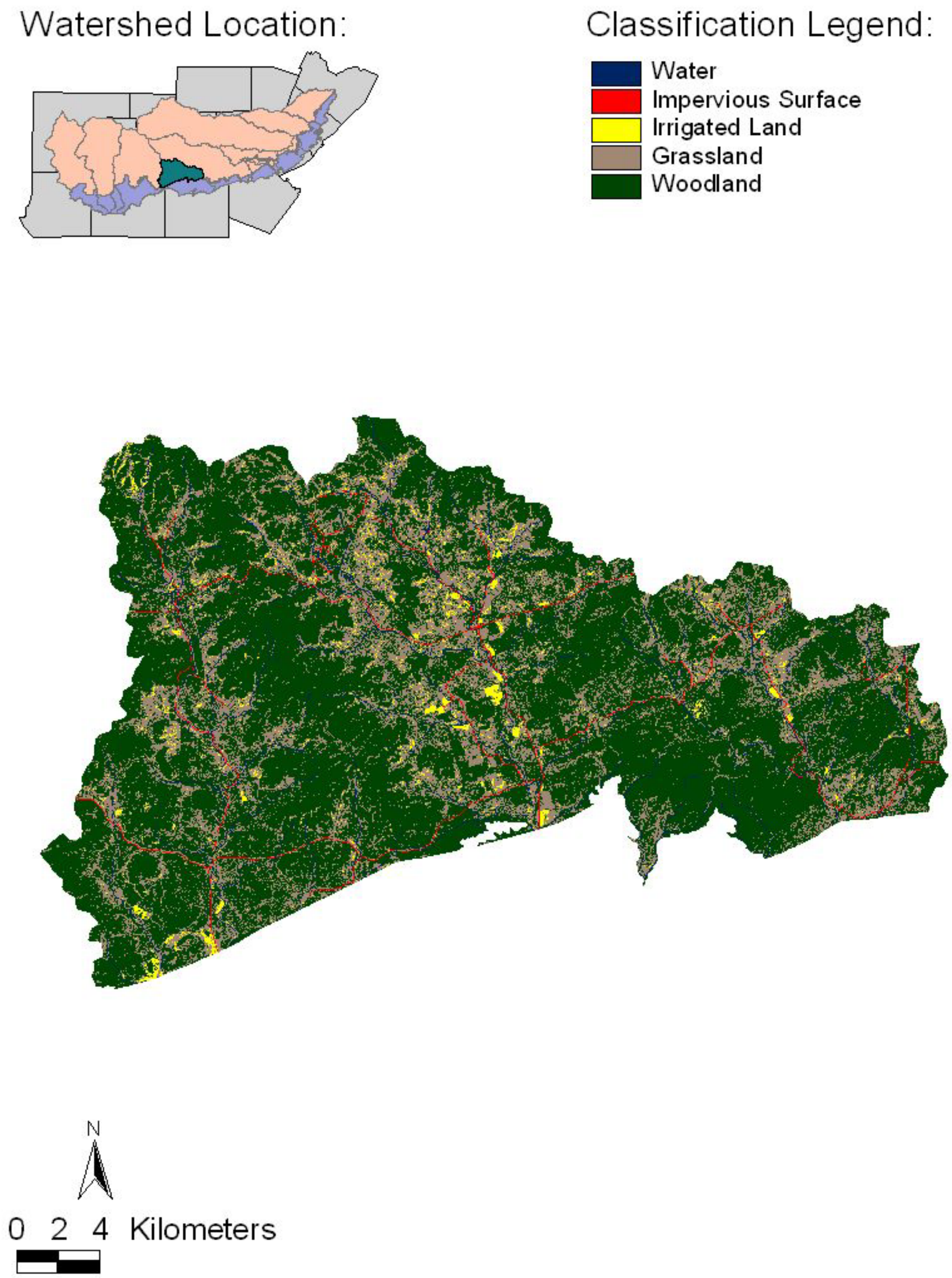

Figure 52. Land cover classification of the Hondo watershed overlay of the Edwards Aquifer contributing zone for 2000.

classification results for the Hondo contributing zone. The watershed contributing zone does not intersect with any urban areas, therefore only changes in vegetation were expected. Within the results for the Hondo contributing zone, the area covered by water increased by 5.46%. The slight increase in water coverage may have been caused by higher water levels present in some of the lakes and ponds that are distributed within the watershed contributing zone. The area of impervious surfaces increased by 5.03%, which was expected. Irrigated lands increased by 16.31%. Crop growth is heavy in the southern portion of the Hondo watershed; therefore transient agricultural areas within the contributing zone are a possibility and could have contributed to this increase. The area covered by grassland had the largest and only decrease (16.42%) while the area covered by woodland had the second largest increase (7.41%). With the exception of water, the results found for the Hondo contributing zone reflect the general land cover change trends of the Edwards Aquifer contributing zone.

The Hondo watershed area that overlays the Edwards Aquifer recharge zone equals 462.37-km^2 (Figures 53 through 55). Table 25 presents the land cover classification results for the Hondo recharge zone. Like the watershed contributing zone, the

Table 25. Land cover classification results for the Hondo recharge zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	10.15	10.47	10.61	4.50
Impervious Surface	3.73	3.73	4.08	9.42
Irrigated Land	8.58	6.32	2.35	-72.57
Grassland	114.73	83.37	87.99	-23.30
Woodland	325.18	358.49	357.33	9.89

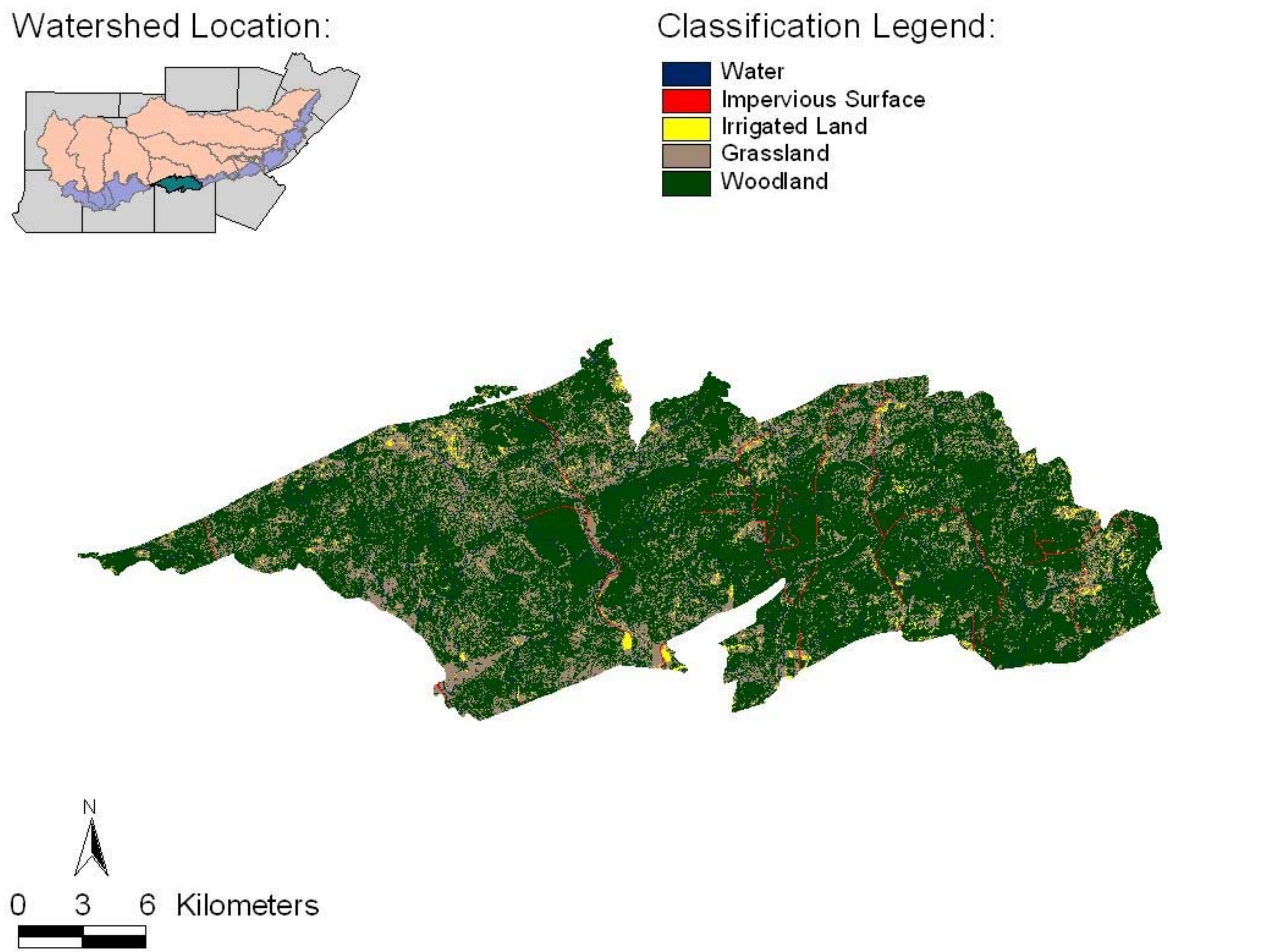

Figure 53. Land cover classification of the Hondo watershed overlay of the Edwards Aquifer recharge zone for 1986.

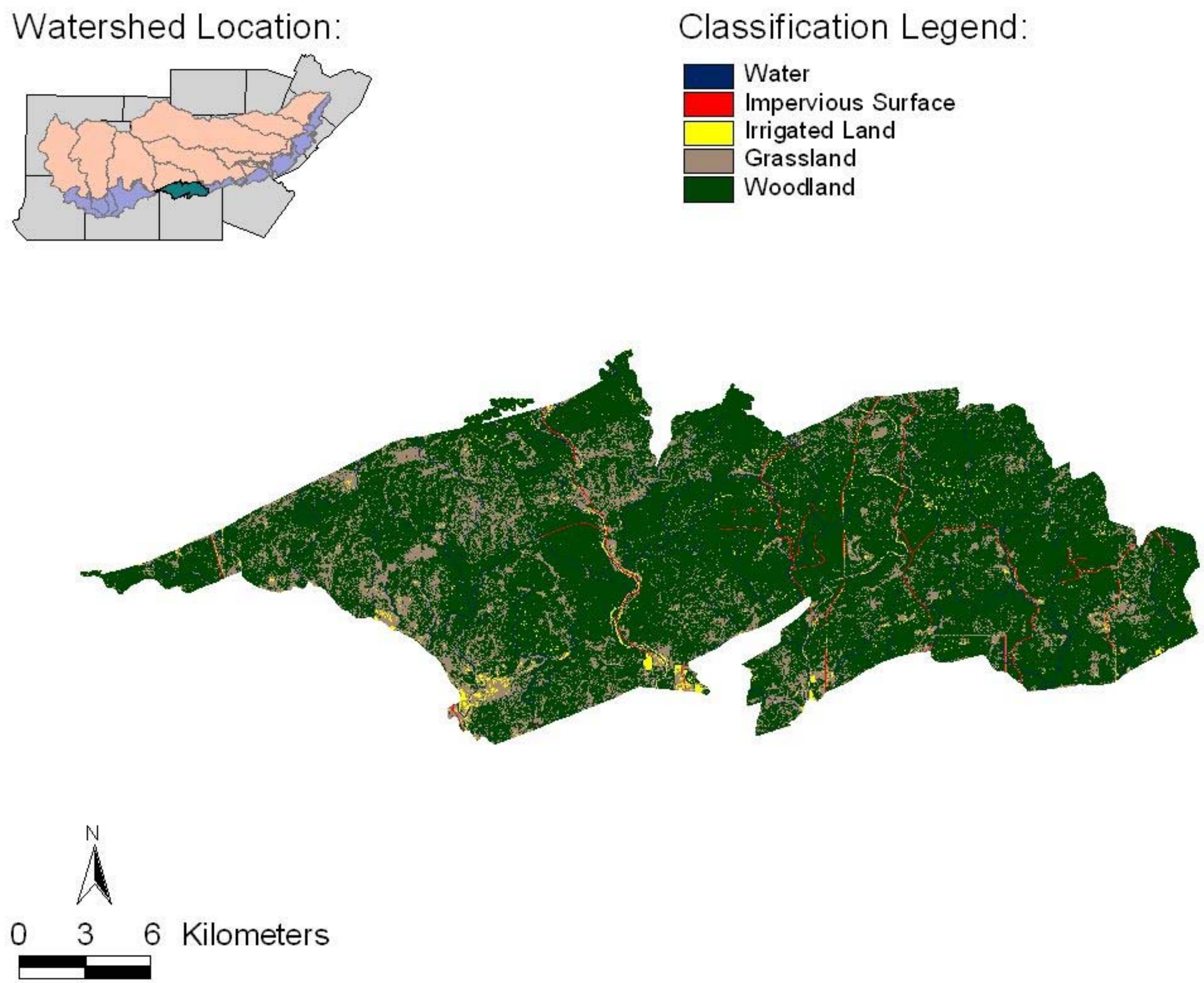

Figure 54. Land cover classification of the Hondo watershed overlay of the Edwards Aquifer recharge zone for 1993.

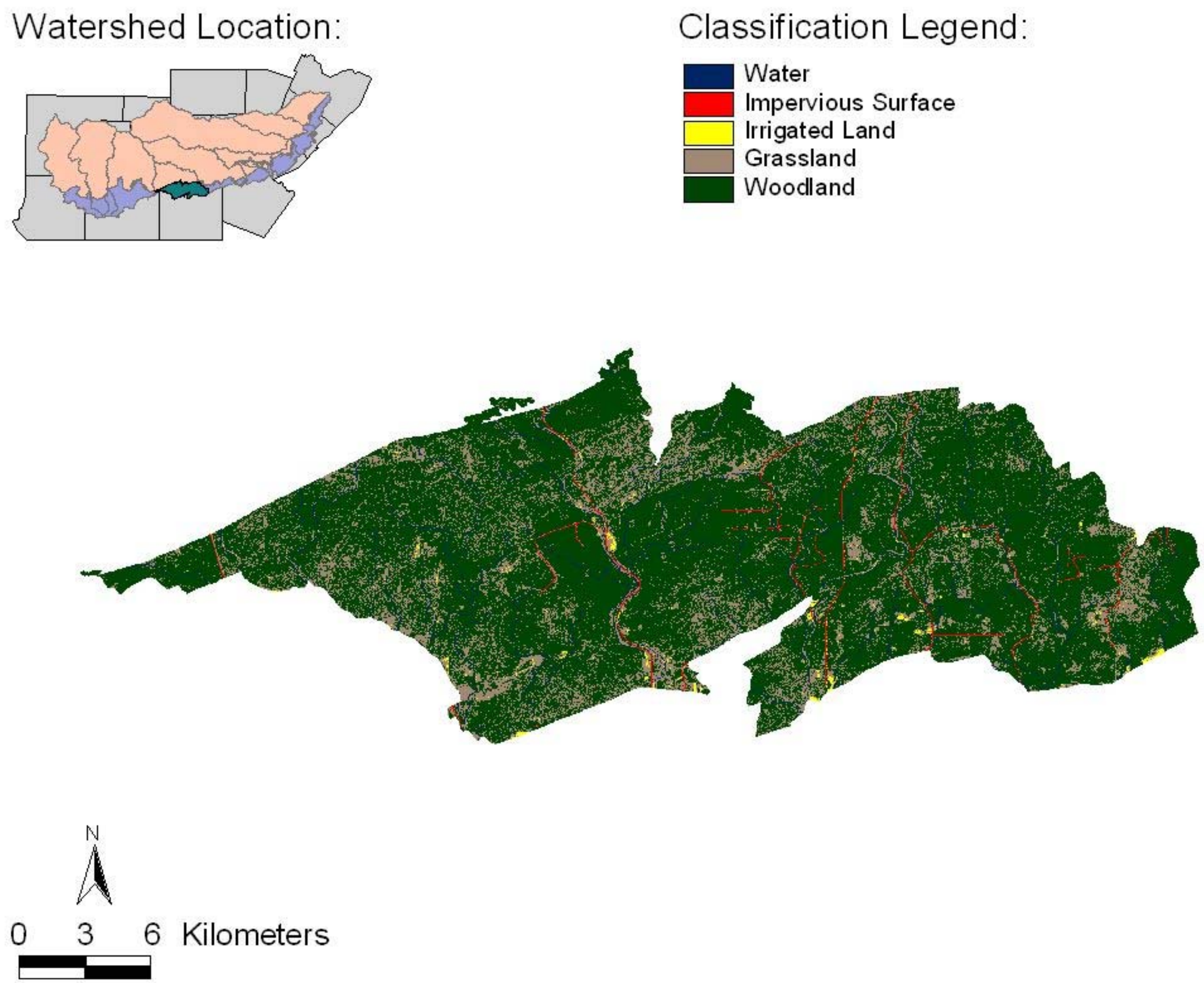

Figure 55. Land cover classification of the Hondo watershed overlay of the Edwards Aquifer recharge zone for 2000.

watershed recharge zone is not adjacent to any urban areas. Only vegetation changes were expected. The results for the Hondo recharge zone showed that the area covered by water had an increase of 4.50%. The increase in water coverage may have been caused by higher water levels within agriculture-related lakes or ponds. There were no reservoirs identified within the watershed recharge zone. The area covered by impervious surfaces increased by 9.42%, which was the second largest increase throughout the watershed recharge zone. Irrigated lands classified for the Hondo recharge zone decreased by 72.57%. This location is much closer to the heavy agricultural areas towards the south but transient crop growth likely contributed to this decrease. The area of the watershed recharge zone covered by grassland experienced the largest decrease (72.57%) and the area covered by woodland had the largest increase (9.89%). With the exception of water and irrigated land, the results found for the Hondo recharge zone reflect the same general trends of the Edwards Aquifer recharge zone.

The Upper Frio watershed area that overlays the Edwards Aquifer contributing zone equals 1,754.29-km^2 (Figures 56 through 58). Table 26 presents the land cover classification results for the Upper Frio contributing zone. Within the results for the

Table 26. Land cover classification results for the Upper Frio contributing zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	44.76	44.38	47.29	5.66
Impervious Surface	27.89	43.78	38.13	36.68
Irrigated Land	101.63	107.07	136.50	34.30
Grassland	633.20	659.71	646.77	2.14
Woodland	946.81	899.36	885.61	-6.46

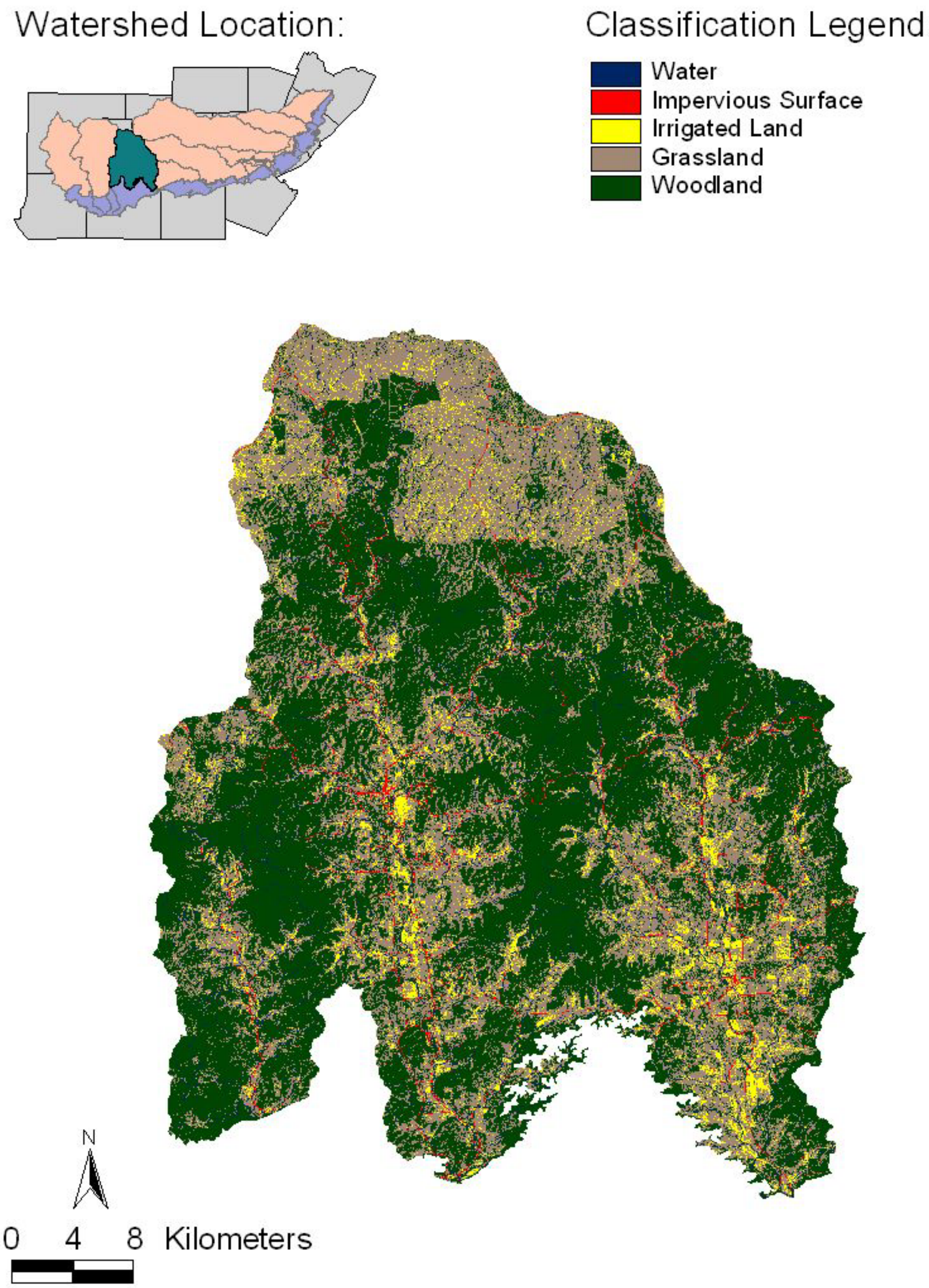

Figure 56. Land cover classification of the Upper Frio watershed overlay of the Edwards Aquifer contributing zone for 1986.

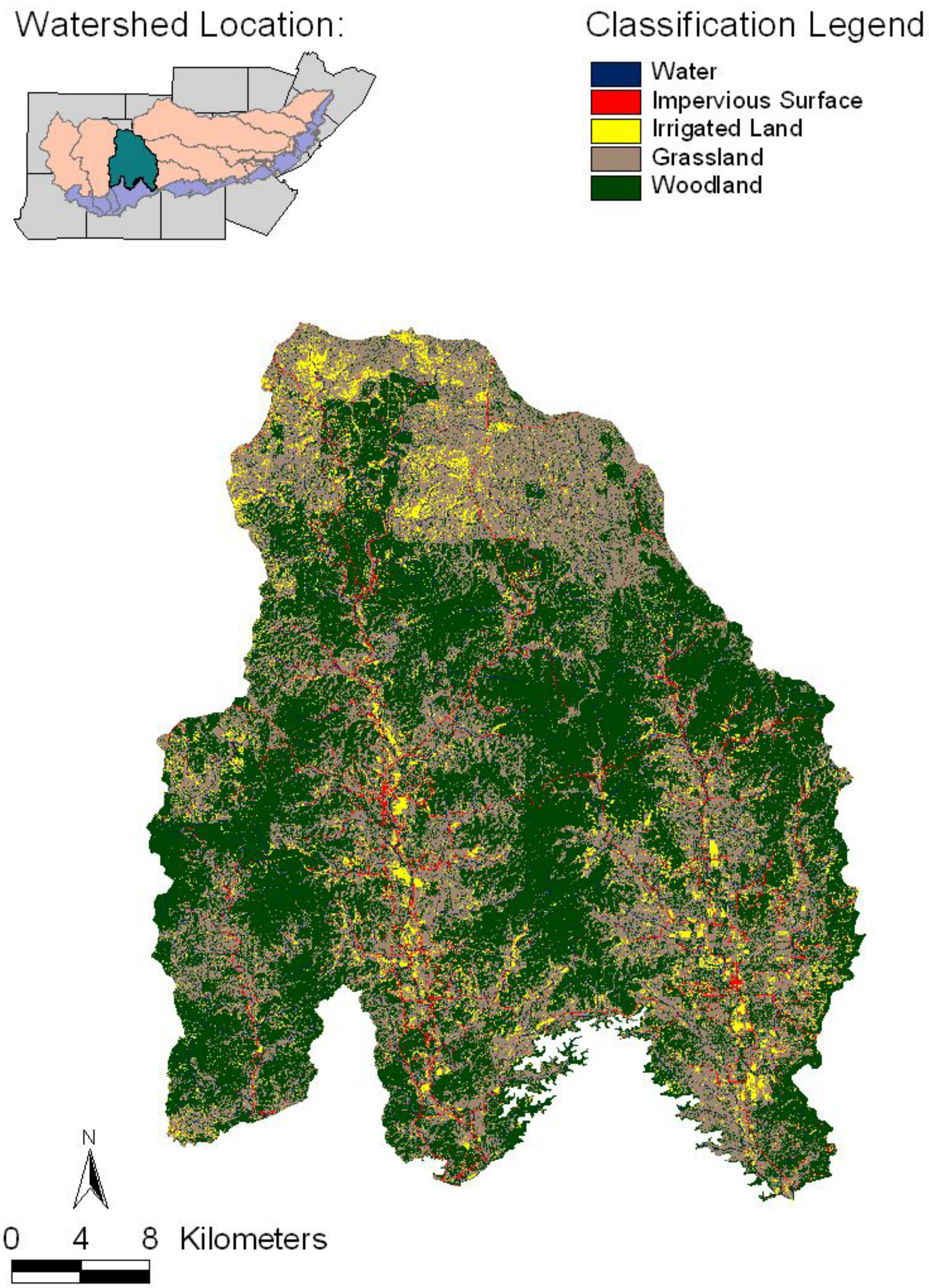

Figure 57. Land cover classification of the Upper Frio watershed overlay of the Edwards Aquifer contributing zone for 1993.

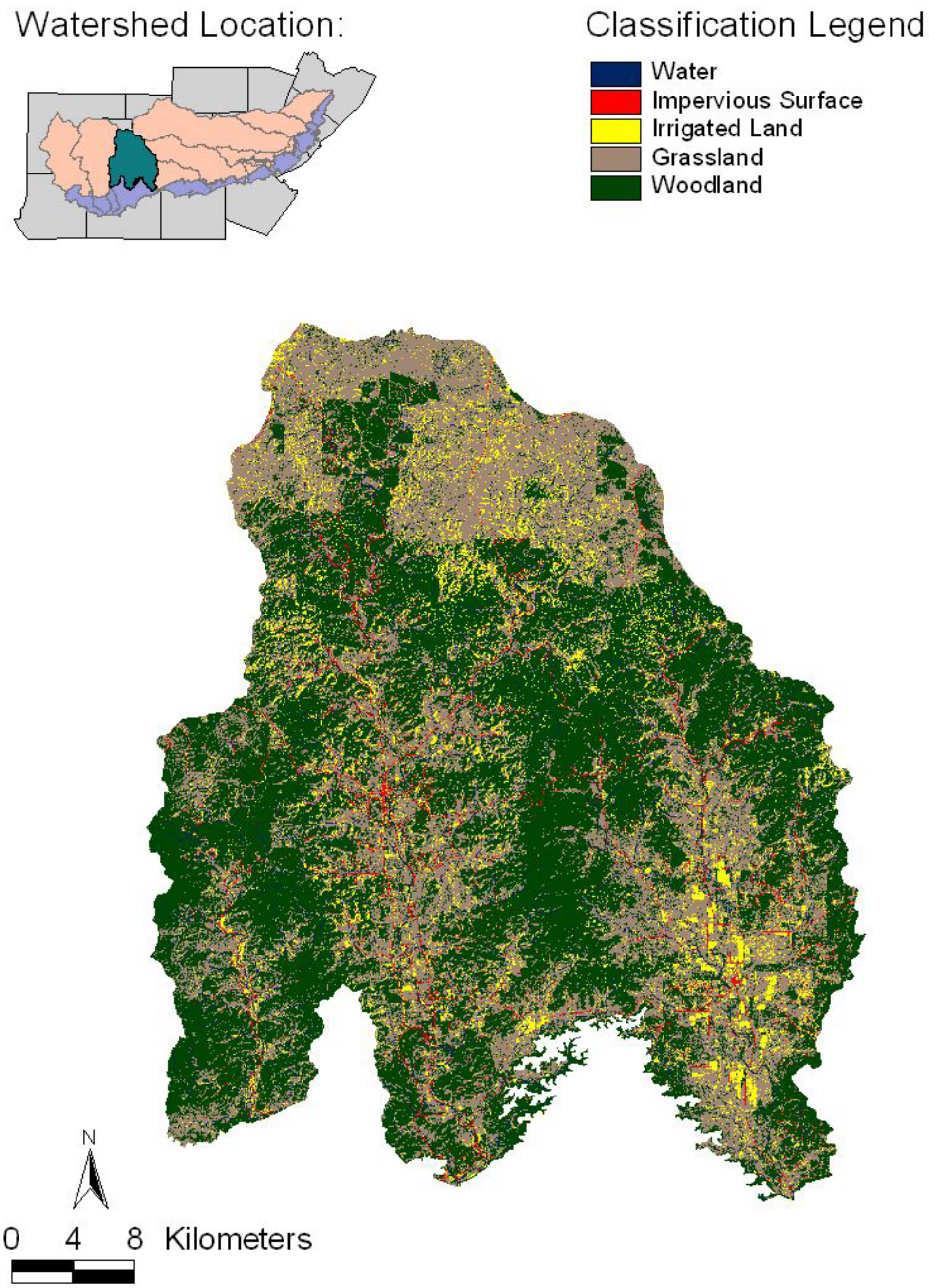

Figure 58. Land cover classification of the Upper Frio watershed overlay of the Edwards Aquifer contributing zone for 2000.

Upper Frio contributing zone, the area covered by water increased by 5.66%. The increase in water coverage may have been caused by increased water levels in the larger rivers of the watershed contributing zone. The area of impervious surfaces increased by 36.68%, though the actual likelihood of this is low because of low levels of urbanization within the watershed contributing zone. Misclassification of bare soil or low vegetation cover could have resulted in higher levels of impervious surfaces for the later images. Irrigated land was found to have an increase of 34.30%. Agriculture has a strong presence throughout the Upper Frio watershed. The area covered by grassland had the lowest increase (2.14%) while the area covered by woodland had the only decrease (6.46%). The reduction of woodland was not consistent with other watershed trends, but could be the result of increased mixed land cover that was misclassified. With the exception of water and impervious surfaces, the results found for the Upper Frio contributing zone did not reflect the same general land cover change trends of the Edwards Aquifer contributing zone.

The Upper Frio watershed area that overlays the Edwards Aquifer recharge zone equals 658.20-km^2 (Figures 59 through 61). Table 27 presents the land cover

Table 27. Land cover classification results for the Upper Frio recharge zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	15.55	15.47	16.12	3.66
Impervious Surface	6.16	8.08	6.50	5.56
Irrigated Land	35.31	31.86	31.25	-11.52
Grassland	283.91	300.74	316.03	11.31
Woodland	317.27	302.05	288.31	-9.13

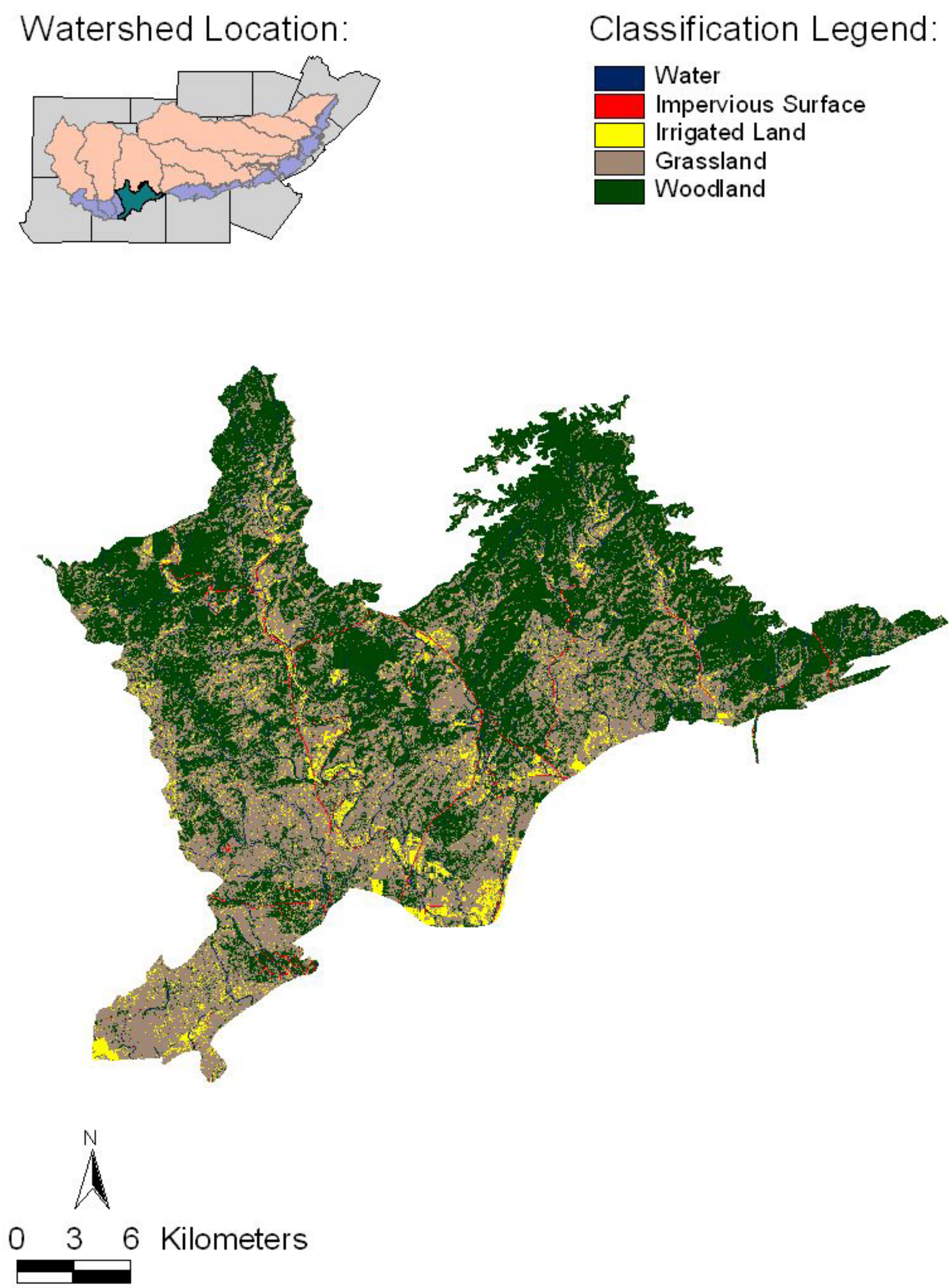

Figure 59. Land cover classification of the Upper Frio watershed overlay of the Edwards Aquifer recharge zone for 1986.

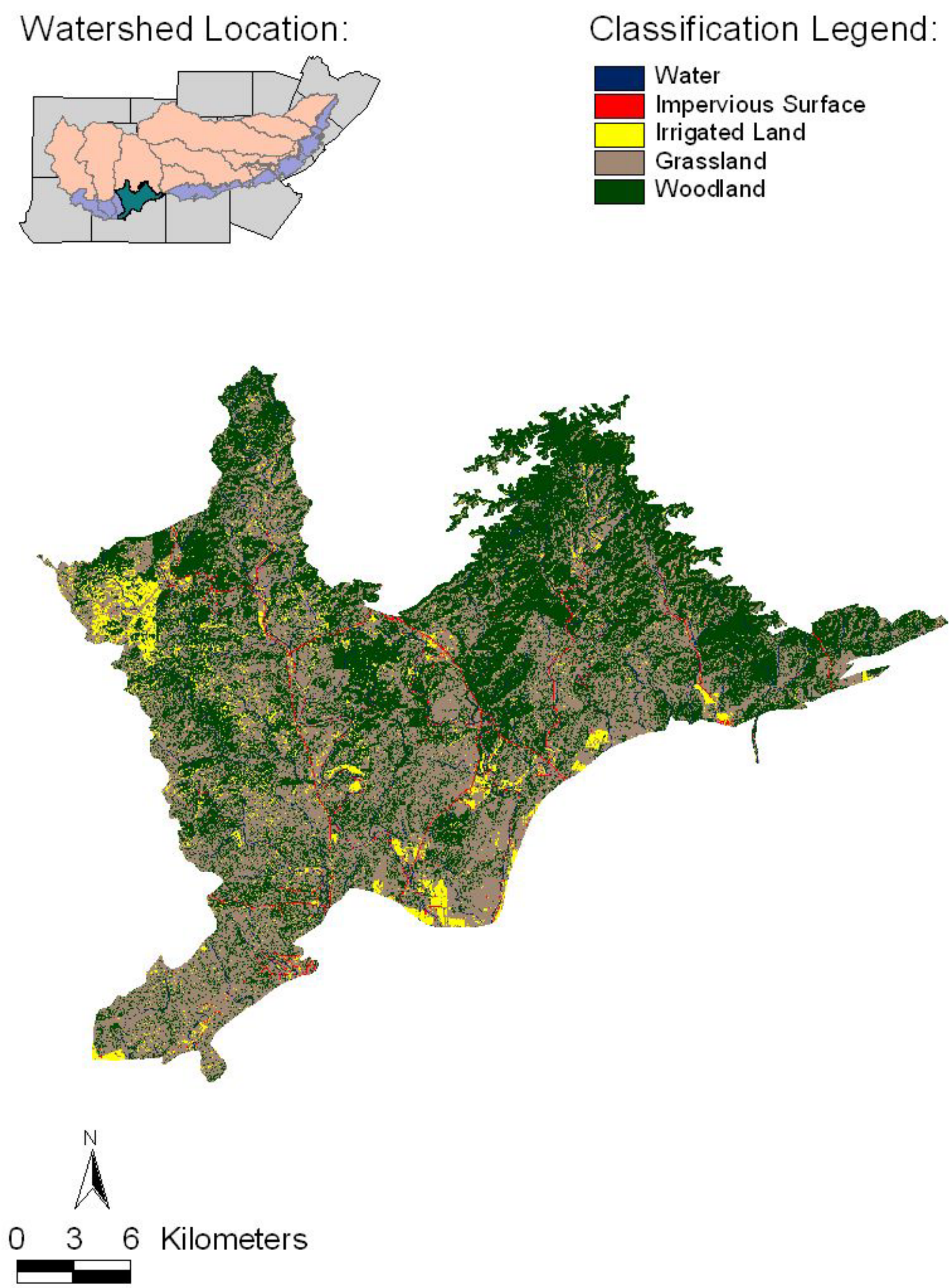

Figure 60. Land cover classification of the Upper Frio watershed overlay of the Edwards Aquifer recharge zone for 1993.

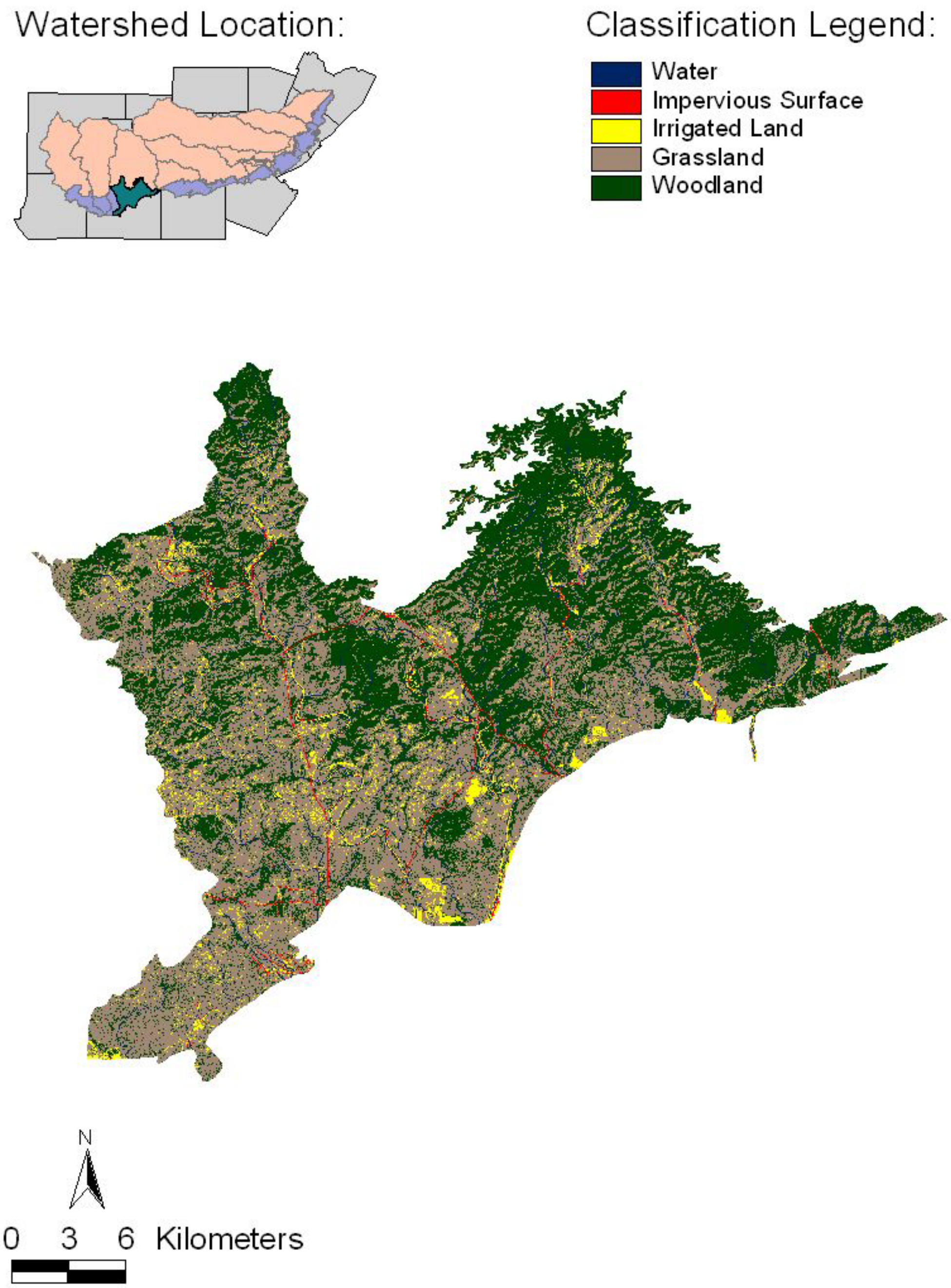

Figure 61. Land cover classification of the Upper Frio watershed overlay of the Edwards Aquifer recharge zone for 2000.

classification results for the Upper Frio recharge zone. Like the watershed contributing zone, the watershed recharge zone is not integrated into any urban areas. The results for the Upper Frio recharge zone showed that the area covered by water increased by 3.66%. The increase in water coverage may have been caused by increased water levels in the larger rivers of the watershed recharge zone. The area covered by impervious surfaces increased by 5.56%, which could be considered negligible given the area involved. Irrigated land had the largest decrease at 11.52%. Given the presence of agriculture seen in the imagery, this decrease was reasonable within the classification results. The area of the watershed recharge zone covered by grassland experienced the largest increase (11.31%) and the area covered by woodland had the second largest reduction (9.13%). An increase in mixed grassland and woodland could have contributed to a misclassification of woodland as grassland. With the exception of water and impervious surfaces, the results found for the Upper Frio recharge zone did not reflect the same trends of the Edwards Aquifer recharge zone.

The Nueces Headwaters watershed area that overlays the Edwards Aquifer contributing zone equals 1,957.94-km^2 (Figures 62 through 64). Table 28 presents the

Table 28. Land cover classification results for the Nueces Headwaters contributing zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	40.43	40.43	42.55	5.26
Impervious Surface	17.79	17.79	18.67	4.92
Irrigated Land	19.37	8.72	9.65	-50.18
Grassland	814.71	653.89	548.89	-32.63
Woodland	1,065.64	1,237.11	1,338.17	25.57

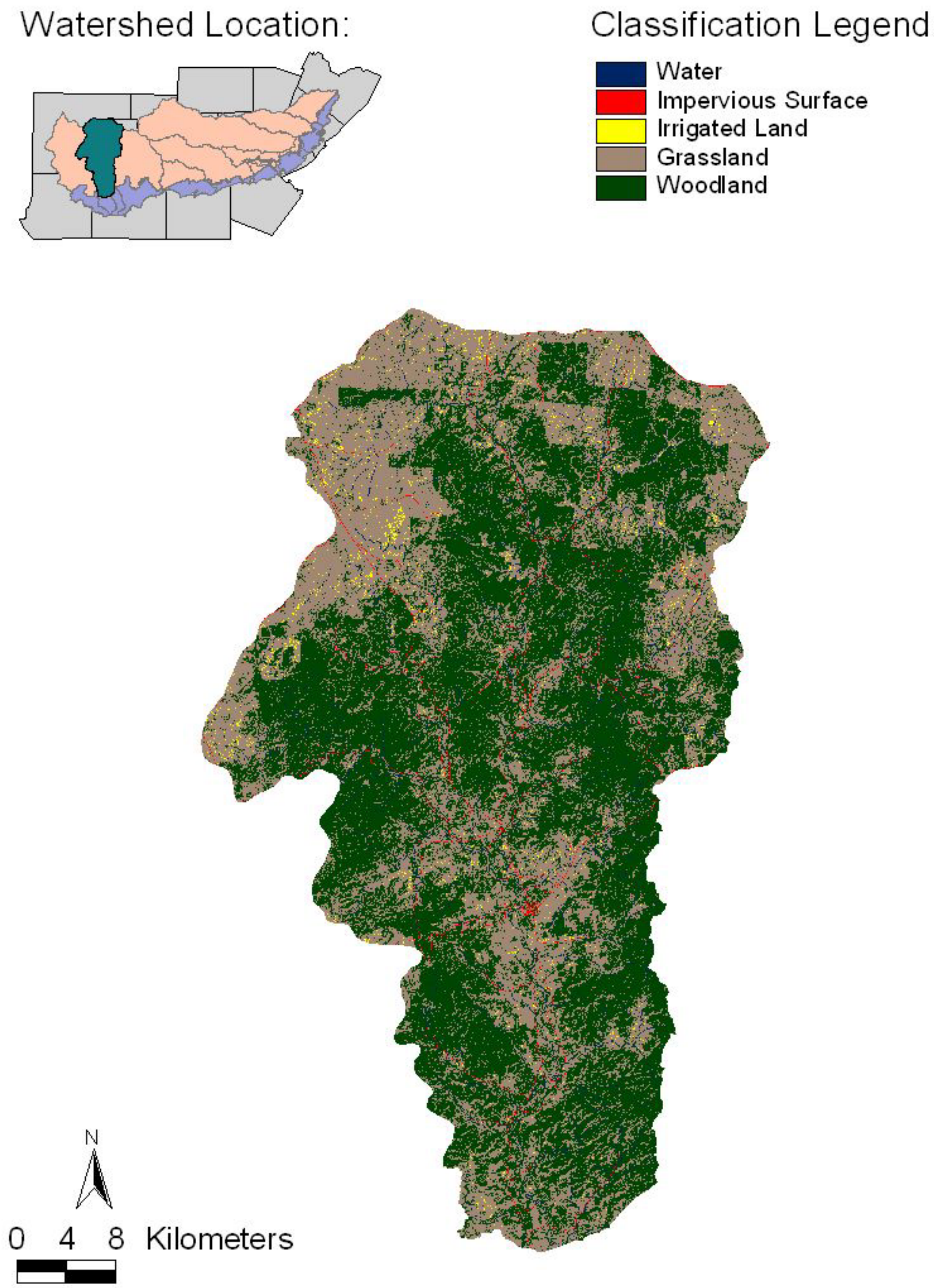

Figure 62. Land cover classification of the Nueces Headwaters watershed overlay of the Edwards Aquifer contributing zone for 1986.

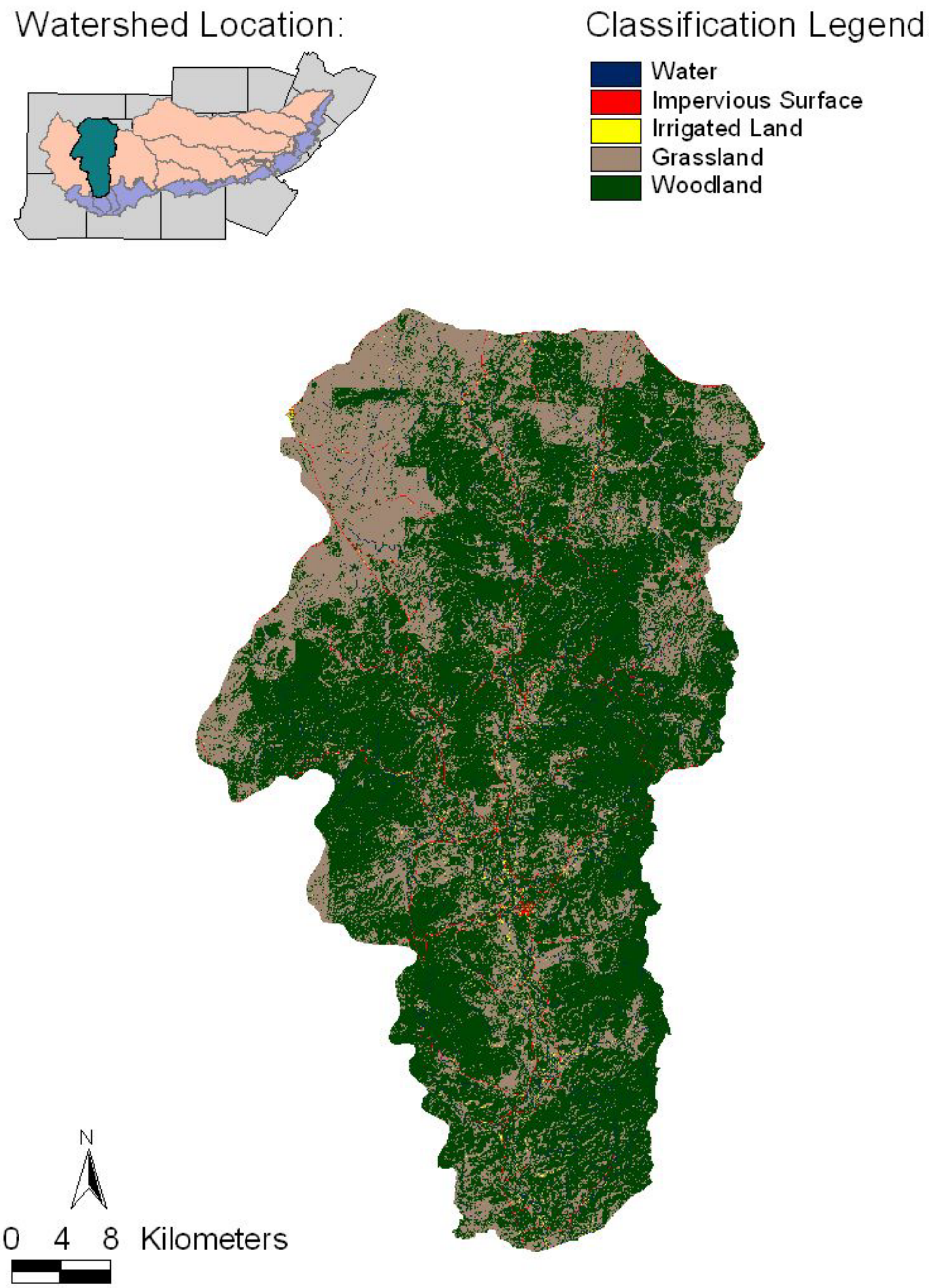

Figure 63. Land cover classification of the Nueces Headwaters watershed overlay of the Edwards Aquifer contributing zone for 1993.

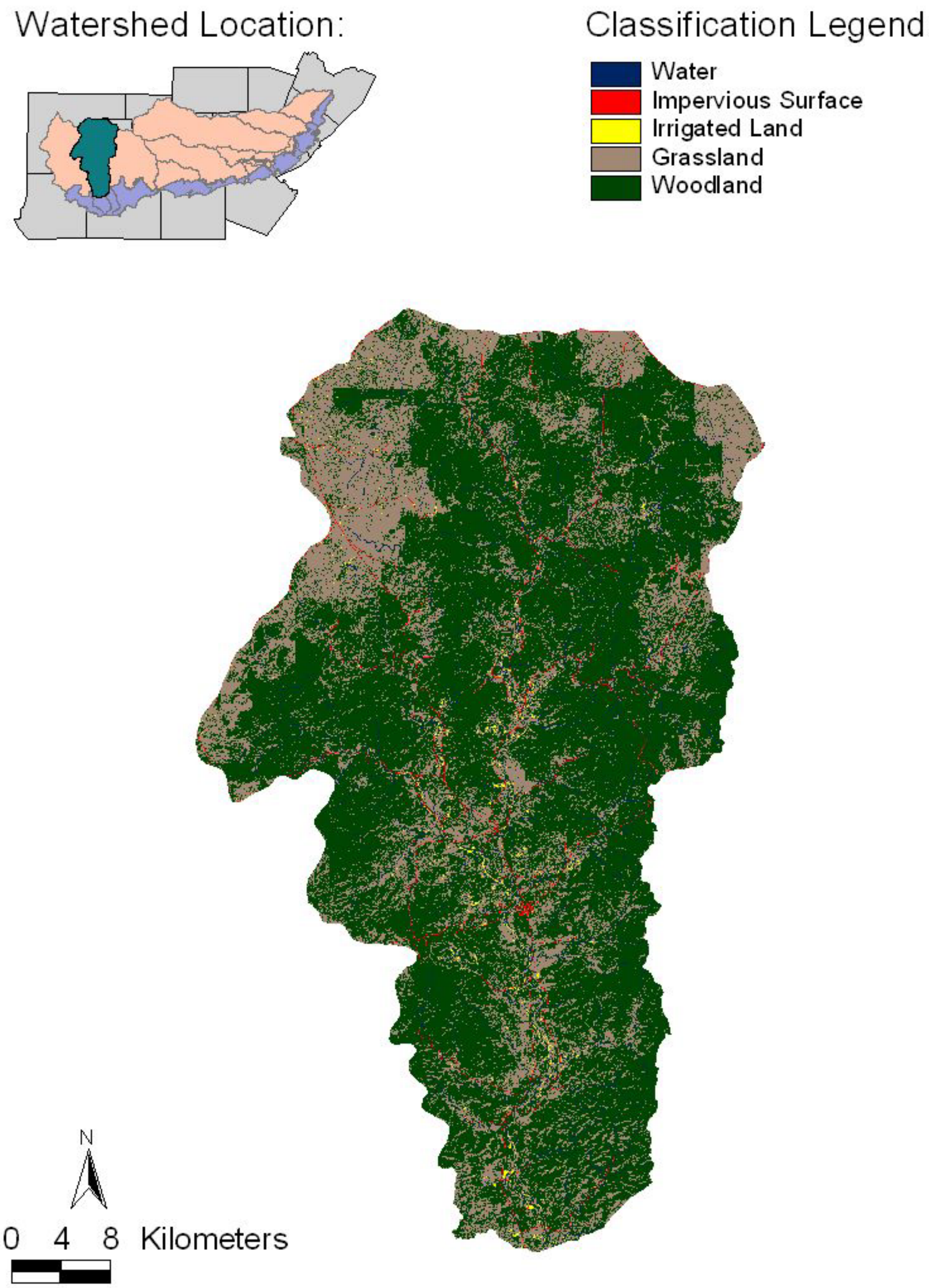

Figure 64. Land cover classification of the Nueces Headwaters watershed overlay of the Edwards Aquifer contributing zone for 2000.

land cover classification results for the Nueces Headwaters contributing zone. Within the results for the Nueces Headwaters contributing zone, the area covered by water increased by 5.26%. The increase in water coverage may have been caused by increased water levels in the larger rivers present. The area of impervious surfaces increased by 4.92%. Transportation structures were the primary impervious surface likely to be present. This could be considered negligible due to the low level of urbanization within the watershed contributing zone. Misclassification of bare soil or low vegetation cover could have resulted in higher levels of impervious surfaces for the later images. Irrigated land was found to decrease by 50.18%. Agriculture did not have a strong presence within the Nueces Headwaters watershed. The area covered by grassland had the lowest decrease (32.63%) while the area covered by woodland had the largest increase (25.57%). The results found for the Nueces Headwaters contributing zone had the identical land cover change trends of the Edwards Aquifer contributing zone.

The Nueces Headwaters watershed area that overlays the Edwards Aquifer recharge zone equals 192.57-km^2 (Figures 65 through 66). Table 29 presents the land cover classification results for the Nueces Headwaters recharge zone. As with the watershed

Table 29. Land cover classification results for the Nueces Headwaters recharge zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	4.45	4.45	4.70	5.64
Impervious Surface	1.56	1.56	1.63	4.54
Irrigated Land	1.00	1.12	2.52	152.13
Grassland	122.52	70.70	68.74	-43.90
Woodland	63.04	114.74	114.98	82.38

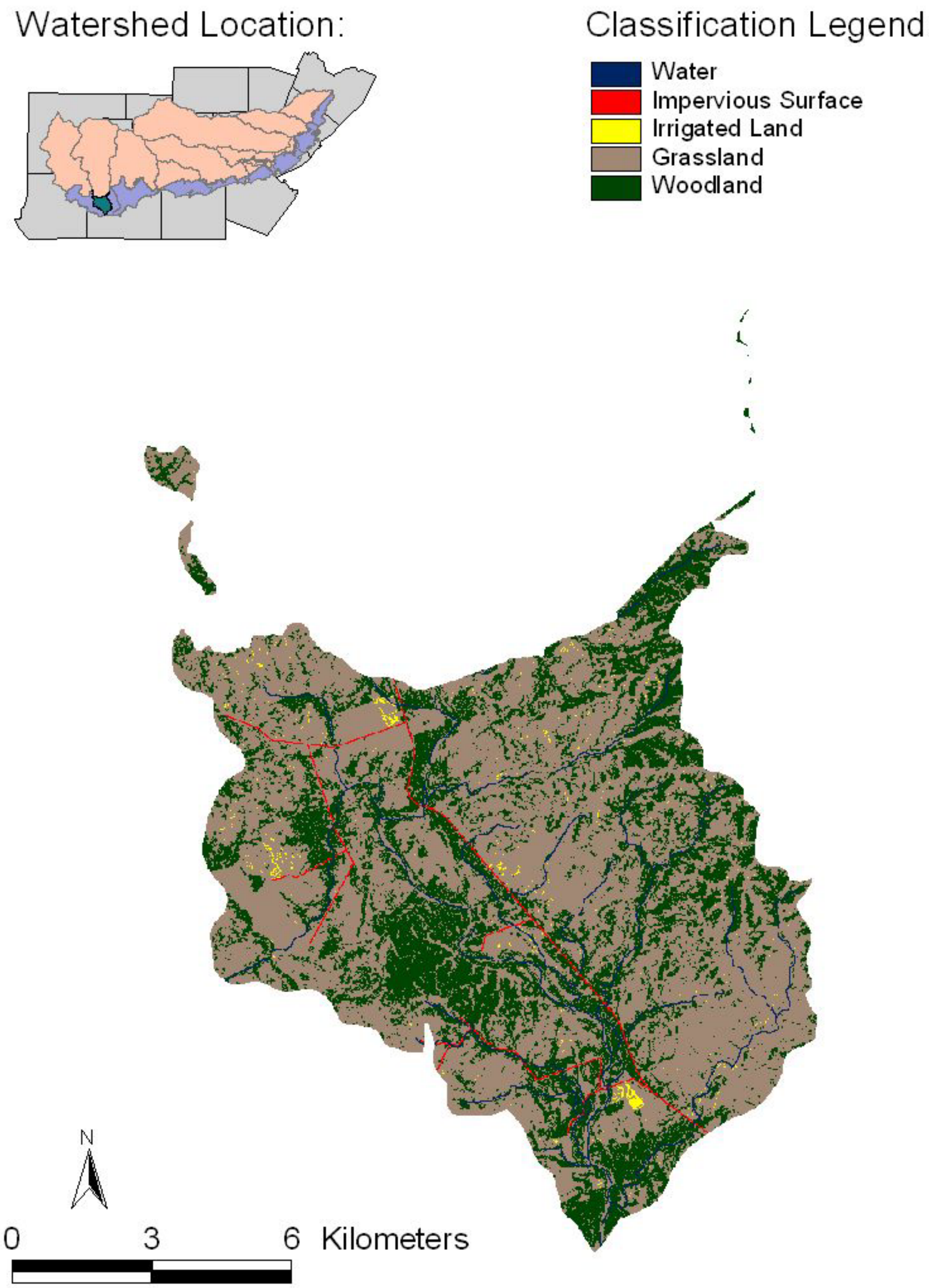

Figure 65. Land cover classification of the Nueces Headwaters watershed overlay of the Edwards Aquifer recharge zone for 1986.

Figure 66. Land cover classification of the Nueces Headwaters watershed overlay of the Edwards Aquifer recharge zone for 1993.

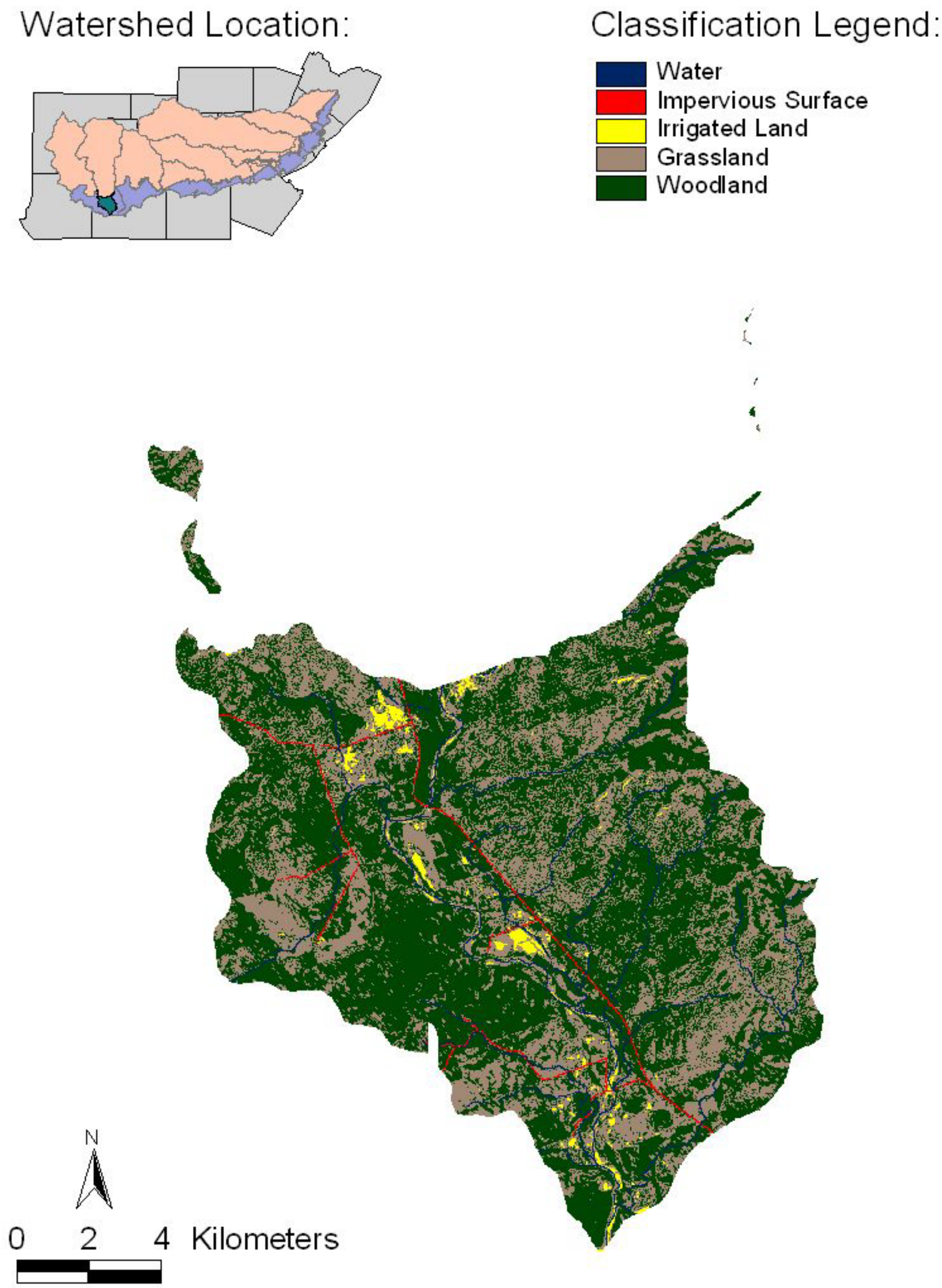

Figure 67. Land cover classification of the Nueces Headwaters watershed overlay of the Edwards Aquifer recharge zone for 2000.

contributing zone, the watershed recharge zone is not integrated into any urban areas. The results for the Nueces Headwaters recharge zone showed that the area covered by water increased by 5.64%. The increase in water coverage may have been caused by increased water levels in the larger rivers present. The area covered by impervious surfaces increased by 4.54%, which could be considered negligible given the area involved. Irrigated land had the largest increase at 152.13%, but the actual area represented a small component of the watershed recharge zone. The area of the watershed recharge zone covered by grassland experienced the only decrease (43.90%) and the area covered by woodland had the largest increase (82.38%). With the exception of water, the results found for the Nueces Headwaters recharge zone generally reflected the same trends of the Edwards Aquifer recharge zone.

The Upper Nueces watershed area that overlays the Edwards Aquifer recharge zone equals 168.50-km^2 (Figures 68 through 70). Table 30 presents the land cover classification results for the Upper Nueces recharge zone. There is no contributing zone for the Upper Nueces watershed. The results for the Upper Nueces recharge zone showed that the area covered by water increased by 5.44%. The increase in water

Table 30. Land cover classification results for the Upper Nueces recharge zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	4.24	4.35	4.48	5.44
Impervious Surface	0.79	0.79	0.92	16.28
Irrigated Land	3.84	4.27	6.74	75.40
Grassland	90.93	96.76	104.84	15.30
Woodland	68.69	62.33	51.52	-25.00

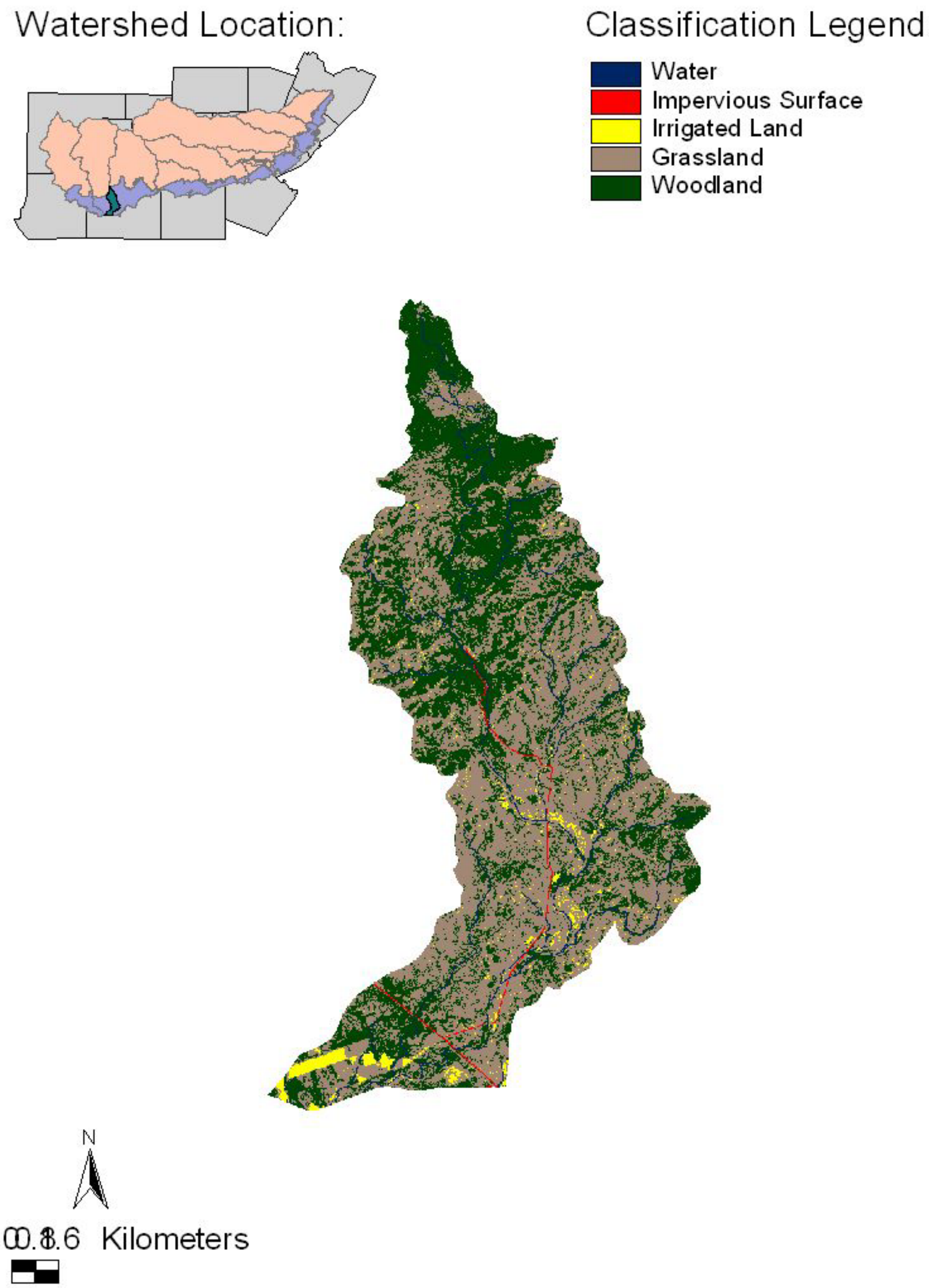

Figure 68. Land cover classification of the Upper Nueces watershed overlay of the Edwards Aquifer recharge zone for 1986.

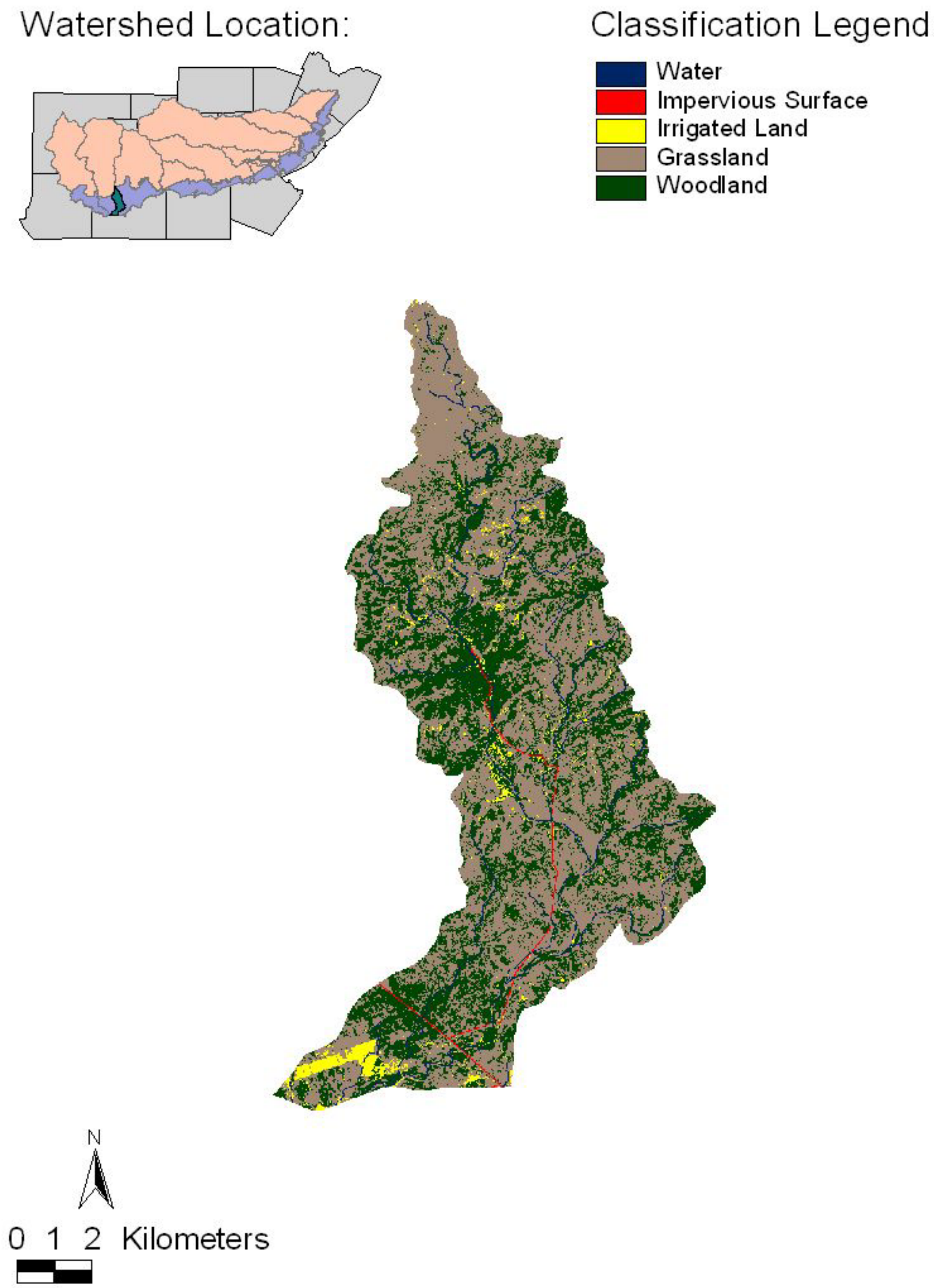

Figure 69. Land cover classification of the Upper Nueces watershed overlay of the Edwards Aquifer recharge zone for 1993.

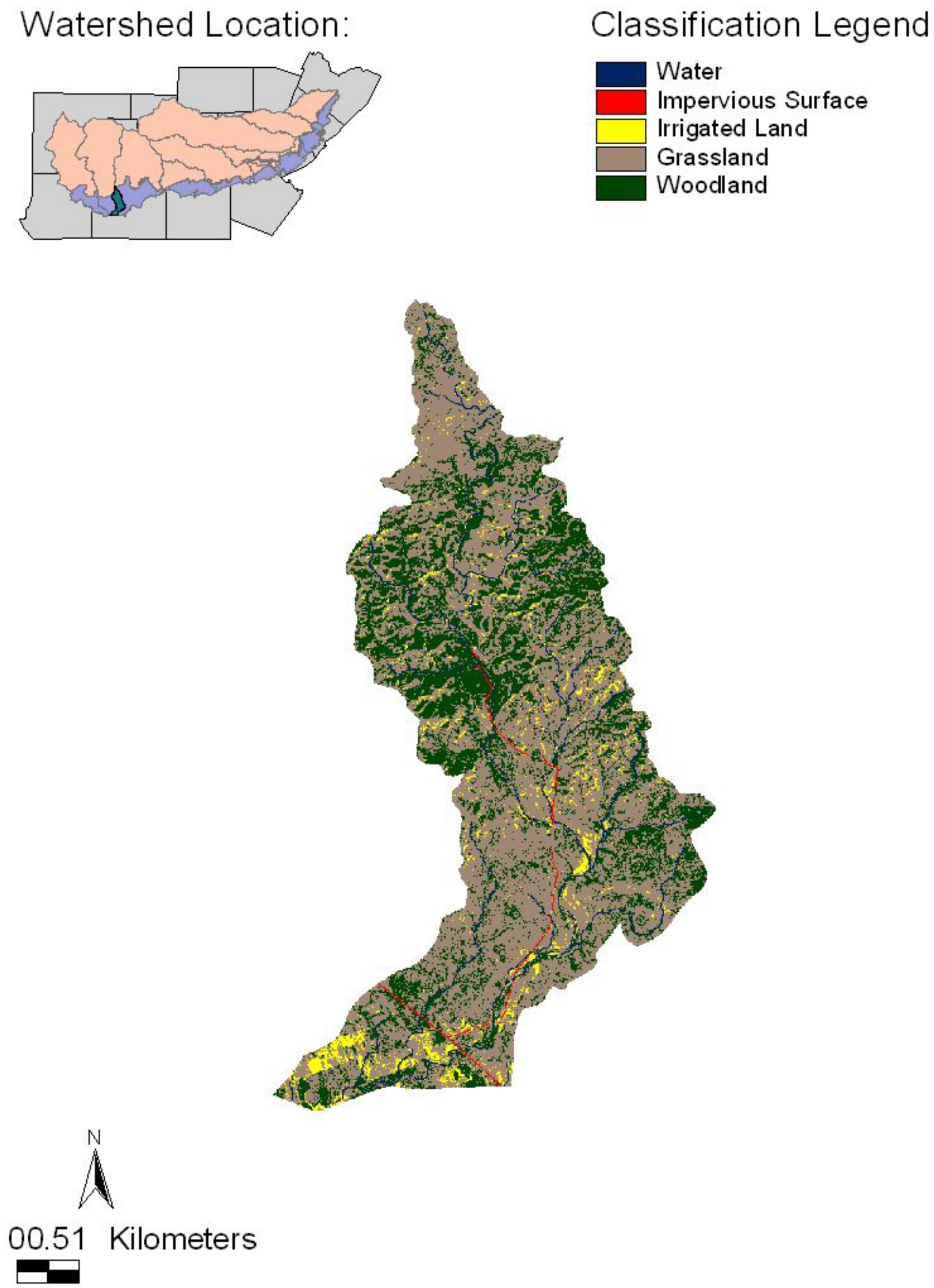

Figure 70. Land cover classification of the Upper Nueces watershed overlay of the Edwards Aquifer recharge zone for 2000.

coverage may have been caused by increased water levels in the larger rivers present. The area covered by impervious surfaces increased by 16.28%, which could be considered negligible given the area involved. Irrigated land was found to have the largest increase at 75.40%, but the actual area represents a small component of the watershed recharge zone. The area of the watershed recharge zone covered by grassland also experienced an increase (15.40%) and the area covered by woodland had the only decrease (25.00%). An increase in mixed grassland and woodland could have contributed to a misclassification of woodland as grassland. With the exception of impervious surface and irrigated land, the results found for the Upper Nueces recharge zone generally did not reflect the same trends of the Edwards Aquifer recharge zone.

The West Nueces watershed area that overlays the Edwards Aquifer contributing zone equals 1,869.26-km^2 (Figures 71 through 73). Table 31 presents the land cover classification results for the West Nueces contributing zone. Within the results for the West Nueces contributing zone, the area covered by water increased by 1.79%. The increase in water coverage may have been caused by increased water levels in the larger rivers of the watershed contributing zone. The area of impervious surfaces increased by

Table 31. Land cover classification results for the West Nueces contributing zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	30.76	29.67	31.31	1.79
Impervious Surface	11.56	27.42	27.03	133.90
Irrigated Land	17.15	25.88	21.66	26.25
Grassland	1,049.25	969.68	811.01	-22.71
Woodland	760.54	816.60	978.24	28.63

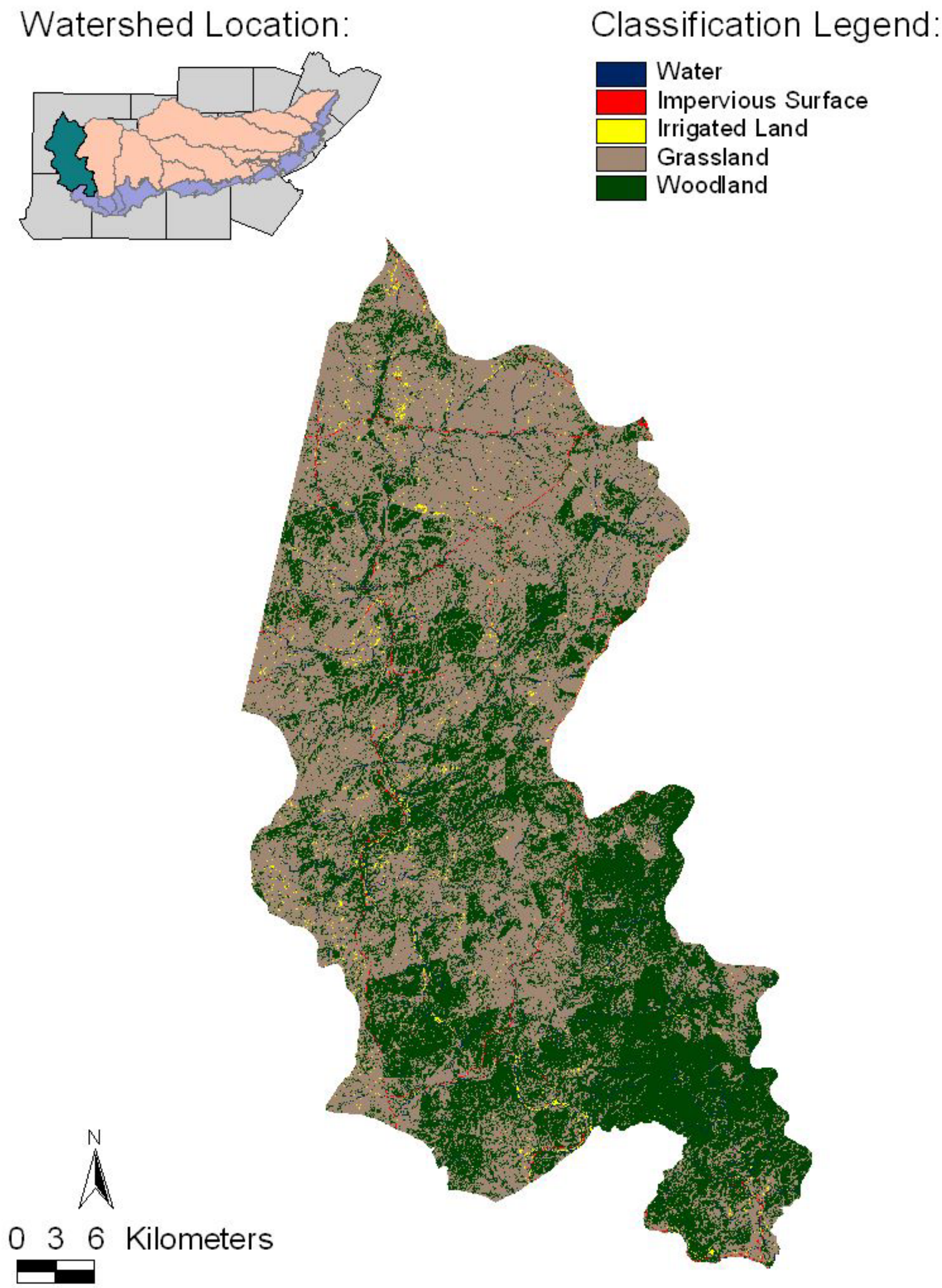

Figure 71. Land cover classification of the West Nueces watershed overlay of the Edwards Aquifer contributing zone for 1986.

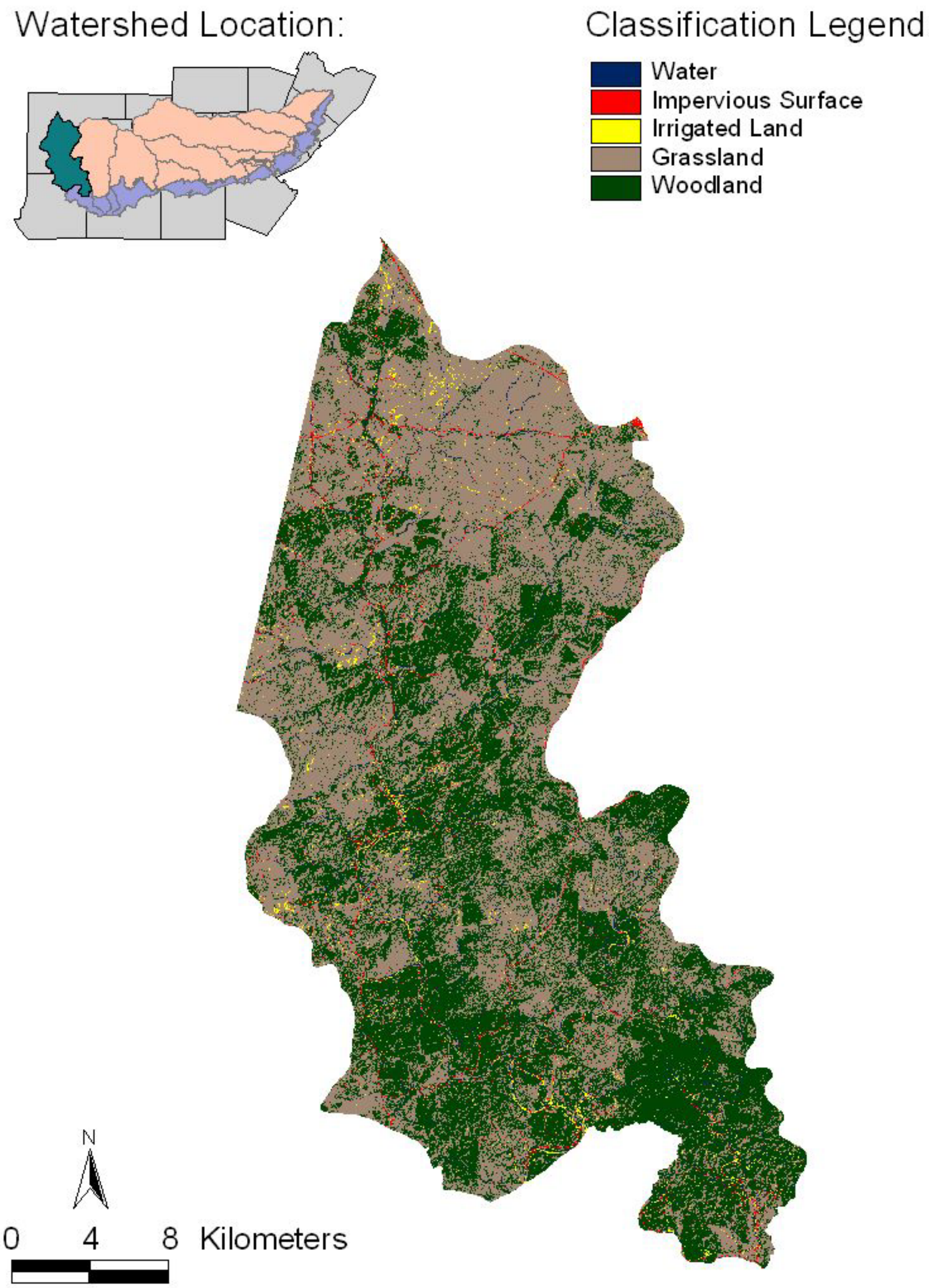

Figure 72. Land cover classification of the West Nueces watershed overlay of the Edwards Aquifer contributing zone for 1993.

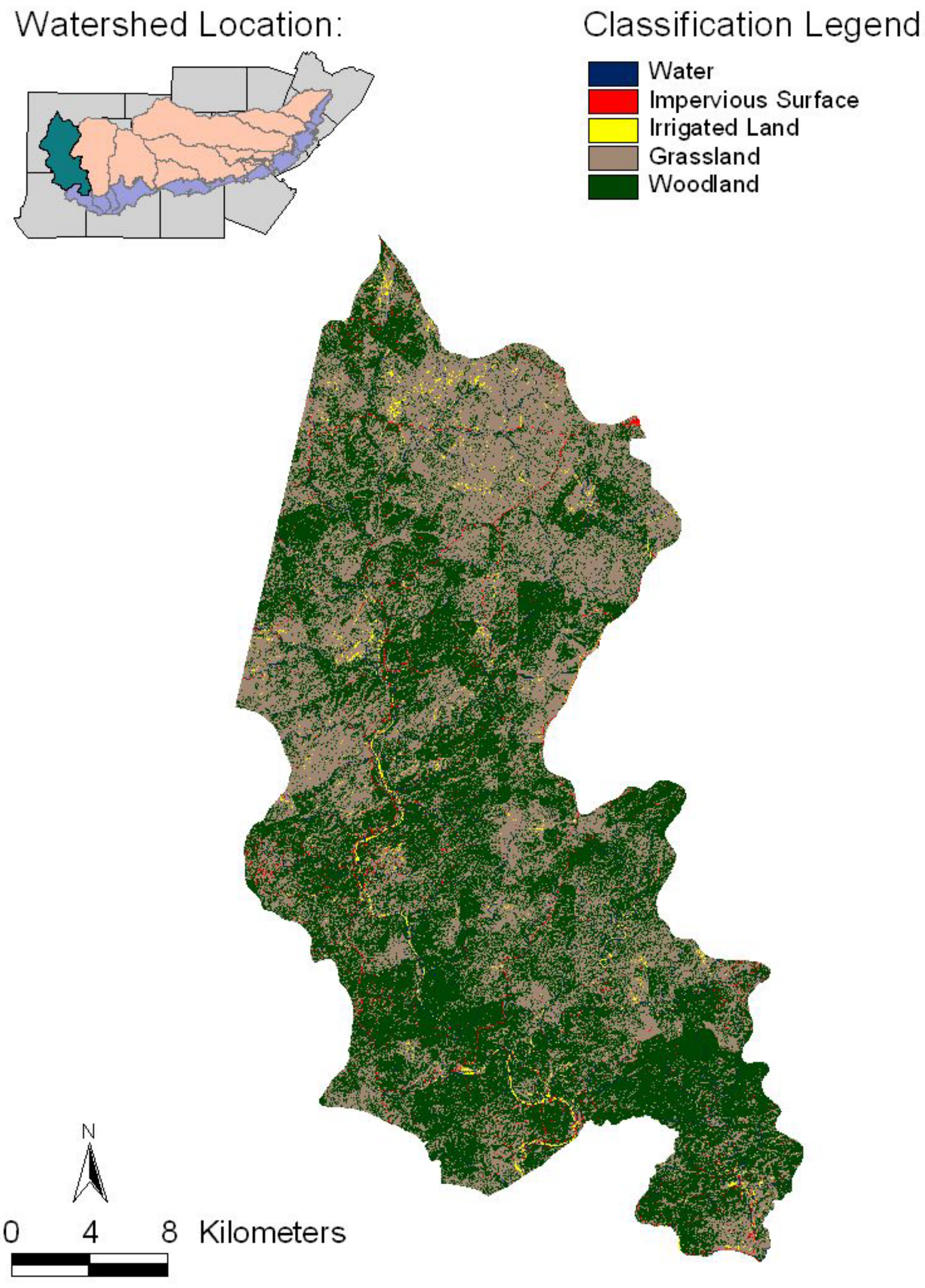

Figure 73. Land cover classification of the West Nueces watershed overlay of the Edwards Aquifer contributing zone for 2000.

133.90%. Transportation structures were the primary impervious surface likely to be present and given the greater amount of grassland, misclassification of low ground cover as impervious surface could have led to this increase. Irrigated land was found to increase by 26.25%. Agriculture did not have a strong presence within the West Nueces watershed. The area covered by grassland had the only decrease (22.71%) while the area covered by woodland had the second largest increase (28.63%). With the exception of water, the results found for the West Nueces Headwaters contributing zone had the same general land cover change trends of the Edwards Aquifer contributing zone.

The West Nueces watershed area that overlays the Edwards Aquifer recharge zone equals 381.85-km^2 (Figures 74 through 76). Table 32 presents the land cover classification results for the West Nueces recharge zone. As with the watershed contributing zone, the watershed recharge zone is not integrated into any urban areas. The results for the West Nueces recharge zone showed that the area covered by water increased by 0.40%. The increase in water coverage may have been caused by increased water levels in the larger rivers of the watershed recharge zone, but was not considered significant. The area covered by impervious surfaces increased by 108.67%.

Table 32. Land cover classification results for the West Nueces recharge zone area from 1986 through 2000.

Land Cover Classification	1986 Area (km^2)	1993 Area (km^2)	2000 Area (km^2)	Net Change (%)
Water	8.22	7.92	8.26	0.40
Impervious Surface	3.50	7.69	7.30	108.67
Irrigated Land	6.74	8.87	11.01	63.41
Grassland	175.25	159.51	165.39	-5.93
Woodland	188.14	197.86	189.90	0.93

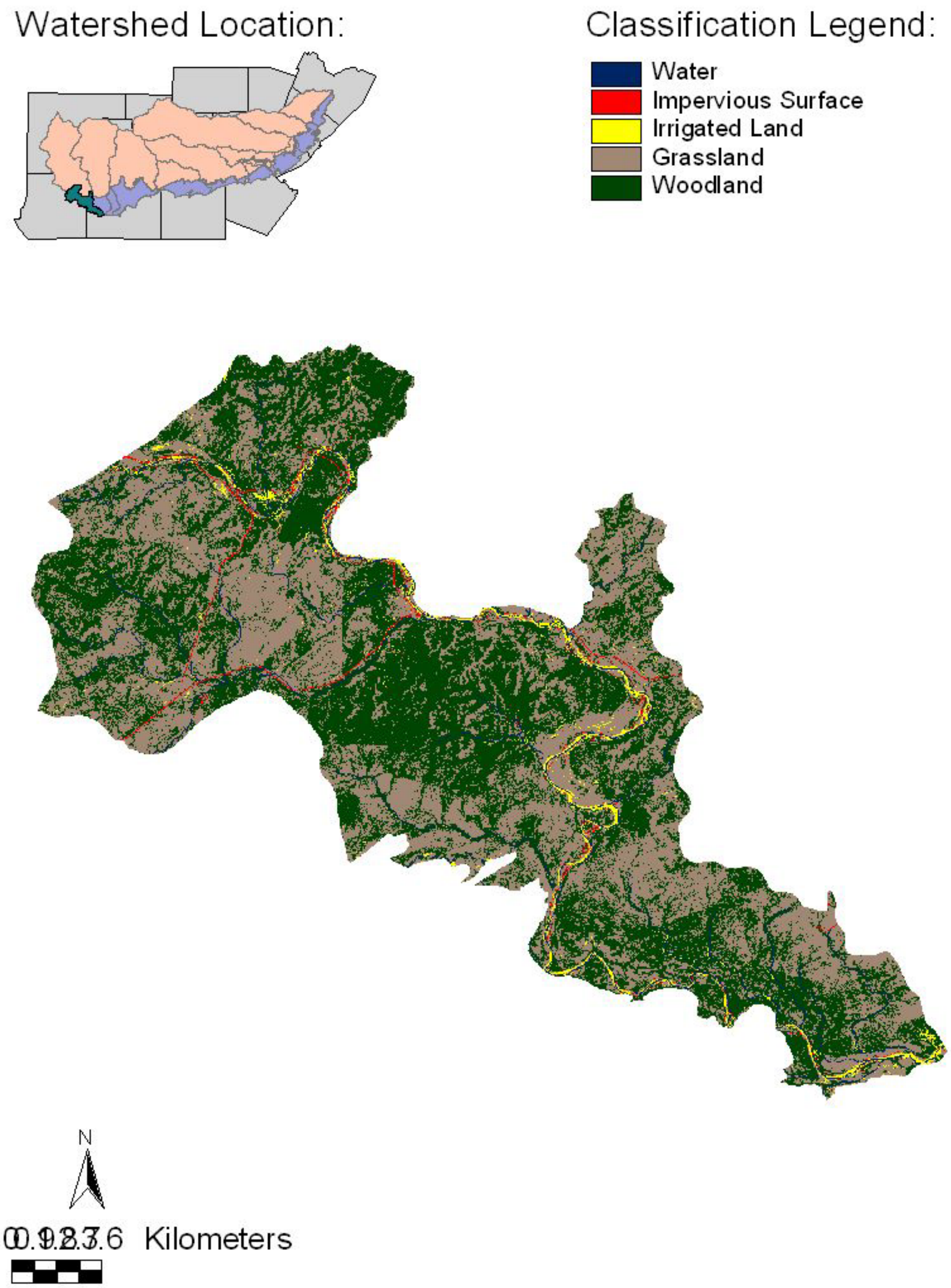

Figure 74. Land cover classification of the West Nueces watershed overlay of the Edwards Aquifer recharge zone for 1986.

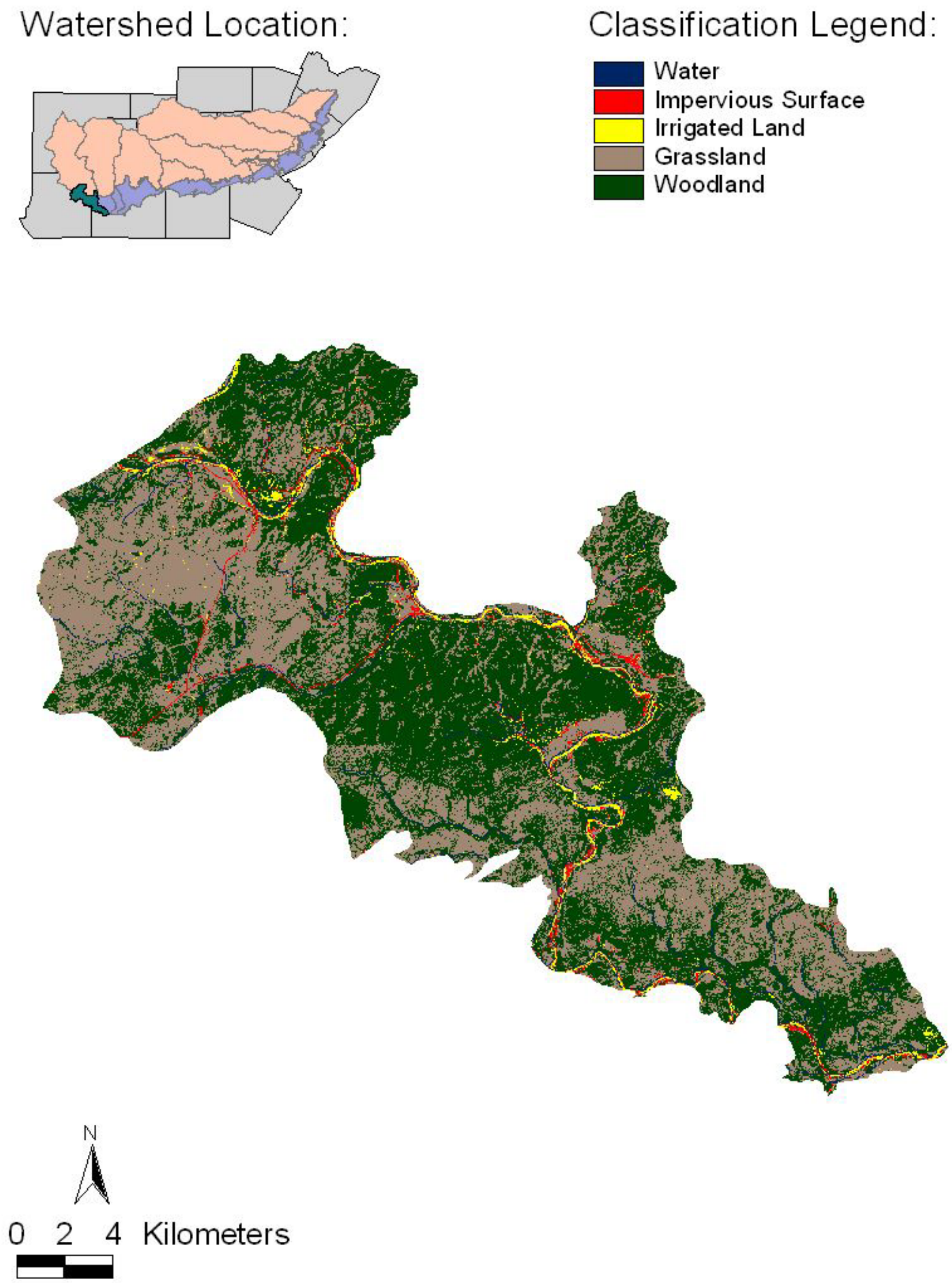

Figure 75. Land cover classification of the West Nueces watershed overlay of the Edwards Aquifer recharge zone for 1993.

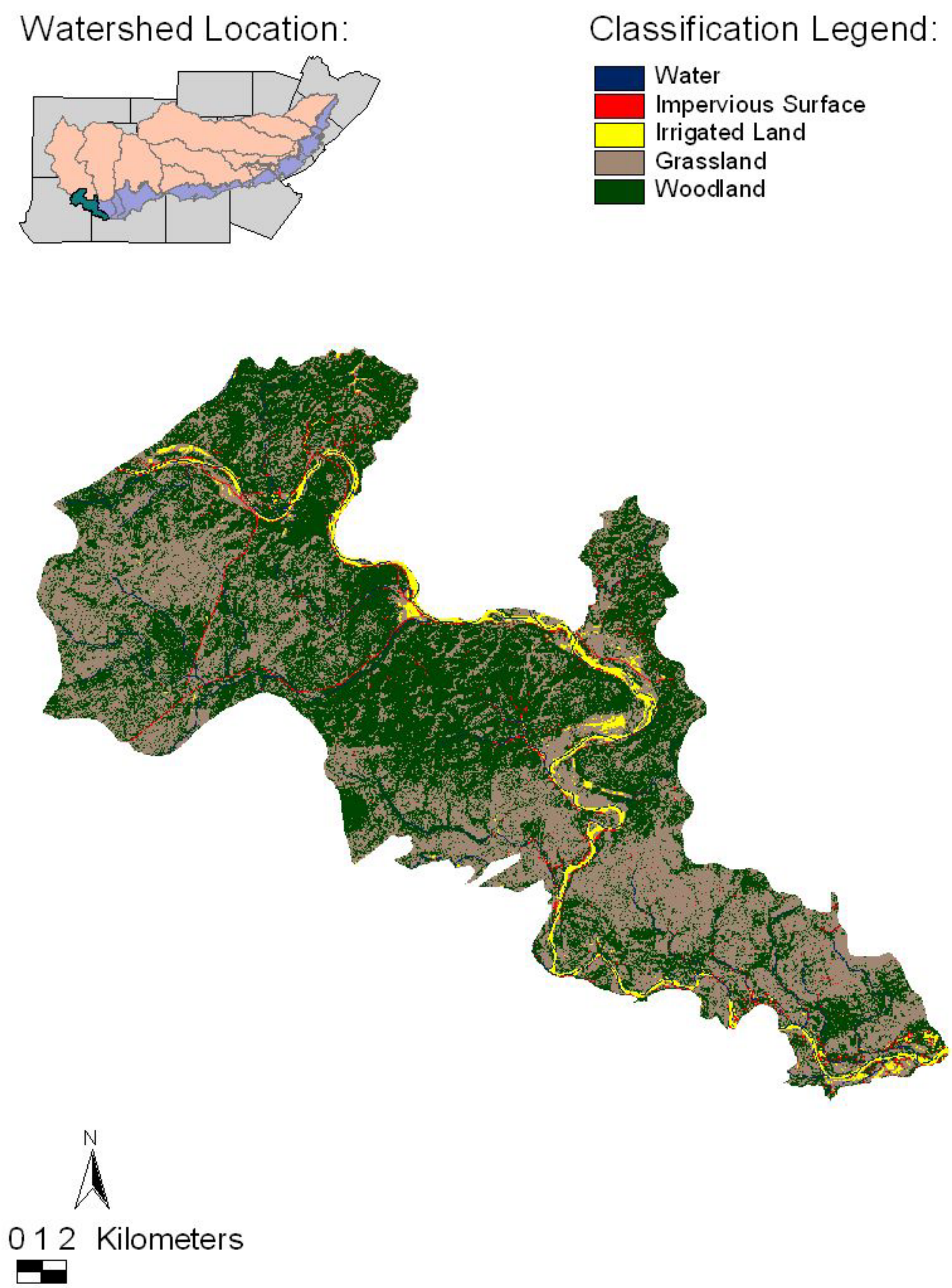

Figure 76. Land cover classification of the West Nueces watershed overlay of the Edwards Aquifer recharge zone for 2000.

Transportation structures were the primary impervious surface likely to be present and given the greater amount of grassland, misclassification of low ground cover as impervious surface could have led to this increase. Irrigated land was found to have the second largest increase at 63.41%, but the actual area represents a relatively small component of the watershed recharge zone. The area of the watershed recharge zone covered by grassland experienced the only decrease (5.93%) and the area covered by woodland had a small increase (0.93%). The results found for the West Nueces recharge zone generally reflected the same trends of the Edwards Aquifer recharge zone with the exception of the area classified as water.

Accuracy Assessment

Tables 33 through 35 present the land cover classification accuracy assessment values for the Edwards Aquifer contributing and recharge zone data products. As can be inferred from the tables, the 1986 accuracy was 76.6%, the 1993 accuracy was 77.2%, and the 2000 accuracy was found to be 76.0%. In all three assessments, water, impervious surfaces, and woodland had a user accuracy of 89% or greater. These three values represent an exceptionally high degree of accuracy. On the other hand, grassland and especially irrigated land had much lower accuracies. From the tables it can be seen that the primary misclassification for irrigated land was grassland and woodland. The spectral values within the satellite imagery were perhaps not dissimilar enough for the classification procedure to discern between irrigated land, such as cropland, and grassland. However, the overall accuracy for each time period exceeded the acceptable level of 70%.

Table 33. Land cover classification accuracy assessment values for the Edwards Aquifer contributing and recharge zone for 1986.

Land Cover Classification	Water	Impervious Surface	Irrigated Land	Grassland	Woodland
Water	97	1	0	1	1
Impervious	0	91	1	4	4
Irrigated Land	0	6	33	48	13
Grassland	0	2	5	72	21
Woodland	0	1	0	9	90

Table 34. Land cover classification accuracy assessment values for the Edwards Aquifer contributing and recharge zone for 1993.

Land Cover Classification	Water	Impervious Surface	Irrigated Land	Grassland	Woodland
Water	98	0	0	1	1
Impervious	1	91	0	4	4
Irrigated Land	1	0	30	38	31
Grassland	0	2	6	76	16
Woodland	0	0	0	9	91

Table 35. Land cover classification accuracy assessment values for the Edwards Aquifer contributing and recharge zone for 2000.

Land Cover Classification	Water	Impervious Surface	Irrigated Land	Grassland	Woodland
Water	96	1	0	2	1
Impervious	0	89	1	5	5
Irrigated Land	0	5	26	45	24
Grassland	0	1	3	79	17
Woodland	0	1	0	9	90

Summary

Within the final numeric results, a few general trends were observed across all of the Edwards Aquifer contributing and recharge zone watershed areas. The percentage of water covering each watershed area remained relatively constant over the observation periods, with obvious fluctuations being present in areas with reservoir systems. As expected from the population data, impervious surfaces within the Edwards Aquifer contributing and recharge zones experienced either no significant change or increased growth. Two anomalous impervious surface changes were observed. Both the Medina watershed recharge and Cibolo watershed contributing zones experienced net decreases (<3%) in impervious surface area. This is possibly because of misclassified bare soil or low vegetation cover. The watershed areas experiencing the most change in impervious surface coverage over time were the Austin-Travis Lakes and Upper San Antonio watershed recharge zones. These watershed areas are adjacent to the cities of Austin and San Antonio, respectively. Both findings should be considered significant from a hydrologic perspective due to their location in the recharge zone location. Irrigated lands were present in much greater area towards the western portion of the Edwards Aquifer, west of San Antonio. However, no clear pattern of change as a function of spatial location was observed when the watershed contributing and recharge zones were combined. A net decrease was observed in the contributing zone and a net increase was observed in the recharge zone. This could also be hydrologically important if it causes increased water demand in the recharge zone. Grassland experienced a general decline in every watershed zone except the Upper Frio watershed contributing and recharge zones, and the Upper Nueces watershed recharge zone, where there were net increases. Likewise, woodland increased in each watershed with the exception of the Upper San Antonio watershed recharge zone, the Upper Frio watershed contributing and recharge zones, and the Upper Nueces watershed recharge zone. These observations are the likely result of woody plant encroachment within the Edwards Aquifer contributing and recharge zones. The extent to which the encroachment has occurred is not absolutely quantifiable. More often than not, increases in the presence of mixed grassland and woodland cover presence probably led to an increased classification of woodland. Therefore the areas classified as woodland should be considered as mixed woodland and grassland, with woodland being the dominant land cover. Very few homogeneous coverage areas were observed, with the obvious exception of agricultural and some grassland areas. Water demand by vegetation in both zones could have increased given the observed increase in woodland.

CHAPTER IV

SSURGO 2.x SOIL DATABASE PRE-PROCESSOR

In addition to land cover, soils play an integral role in maintaining ecosystem sustainability. Among the many influences of soil properties, different ecohydrologic process controls may be exhibited at the land surface. Soil properties such as bulk density and saturated hydraulic conductivity affect processes such as infiltration and nutrient transport. To better understand the influence of soil properties and other ecological parameters, modeling software packages have been created to simulate different hydrologic and environmental conditions. The Soil and Water Assessment Tool (SWAT), developed by the Texas A&M University Blackland Research Center (BRC), is a physically-based modeling tool for predicting the impact of land management practices on water, sediment, and agricultural chemical yields. The subsequent implementation of a geographical information system (GIS) interface for SWAT (ArcView SWAT) now allows researchers to extract parameter information from various digital spatial data sets to be used for watershed modeling efforts (Di Luzio et al., 2002).

A modified version of the State Soil and Geographic (STATSGO) database currently serves as the default soils input data set for the ArcView SWAT model (BRC, 2001). Produced by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) at a spatial scale of 1:250,000, the STATSGO database was originally intended only for multistate, river basin, and state level modeling. Consequently, the magnitude of this scale does not represent an adequate spatial resolution for modeling at the county level or below (USDA-NRCS, 1991). The Soil Survey Geographic (SSURGO) database, also developed by the USDA-NRCS, provides the highest level of detail available for soils data on a countywide basis. Typical spatial scales are 1:15,840, 1:20,000, or 1:24,000; therefore, the SSURGO database may be used for state, township, and landowner level modeling (USDA-NRCS, 1995). Figure 77 illustrates the difference in spatial resolution between the STATSGO and SSURGO databases for a section of the Sabinal River watershed near Uvalde, Texas.

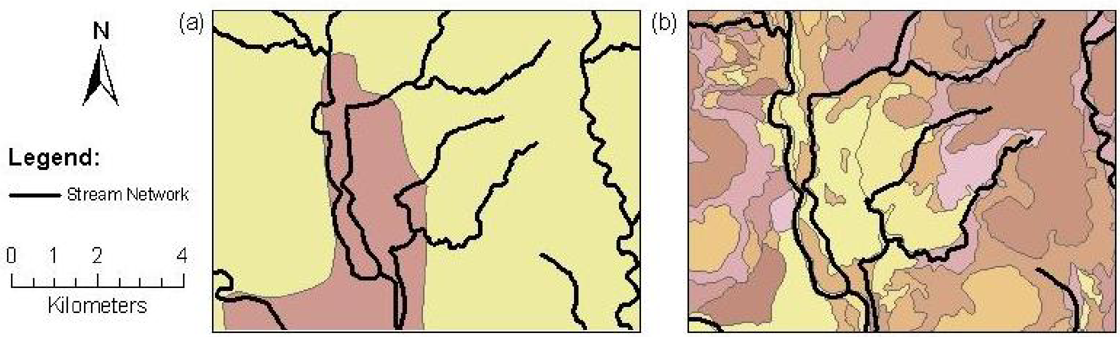

Figure 77. Comparison of soils data for an arbitrary section of the Upper Sabinal River watershed: (a) STATSGO database, (b) SSURGO 2.x database.

GIS-based versions of the SSURGO database are publicly available for download from the USDA-NRCS website (USDA-NRCS, 2004). Unfortunately, in standard format, the necessary tabular component of the SSURGO database is incompatible for direct use by the ArcView SWAT model due to data structure differences. The SSURGO database does, however, contain all of the parameter values necessary to produce an input soils data set that can be used by the ArcView SWAT model. A method was developed by the BRC and USDA-NRCS to convert a SSURGO 1.0

database file into the modified STATSGO format (Wang and Buland, 2002). While this procedure accomplishes the given task, it contains two major limitations. First, the BRC-NRCS method completely relies on the third-party commercial software package, Microsoft Access, to facilitate the conversion. Second, the method is very time consuming with users having to complete 27 steps simply to convert the tabular component of a SSURGO 1.0 database file. An additional problem exists in that the USDA has begun to upgrade the existing SSURGO 1.0 database with an improved SSURGO 2.x version, the format of which is structurally different from the earlier version. Therefore, the current BRC-NRCS method cannot be used to process the emerging SSURGO database information.

Modeling at the county level and below with higher resolution is essential for understanding ecological processes at smaller spatial scales. Pesticide transport modeling within a riparian buffer zone presents an obvious case where higher resolution at a smaller spatial scale would be beneficial. Use of the SSURGO 2.x database may provide prediction advantages compared with those derived from the STATSGO database. Therefore, a new method is needed to convert the SSURGO 2.x database into a seamless format that can be used by the ArcView SWAT model.

Design Objectives

The focus of this chapter is the design and implementation of a SSURGO database pre-processor to evaluate soil data set resolution influence on the hydrologic output parameters of the ArcView SWAT model. Hydrologic output parameters include: total watershed outflow, water yield, soil water content, evapotranspiration, surface runoff, percolation, and groundwater contribution. The software extension allows users to readily integrate SSURGO 2.x database files within the ArcView SWAT model, which may improve modeling efforts through enhanced resolution of the soil input data. This work is completed in three phases:

1) Identification of variables and relationships within the SSURGO 2.x database that correspond to the required soil input parameters of the ArcView SWAT model.

2) Design of methods to extract and associate the identified SSURGO database values into a cohesive input data set that can be used by the ArcView SWAT model.

3) Implementation of the methodologies in the form of an Avenue script extension for use within the ArcView SWAT model.

Description of SSURGO

SSURGO database files are arranged orthophotoquads or 7.5-minute quadrangle units that are distributed on a countywide basis. Occasionally, a grouping of counties is distributed as one combined database file. Each county or grouping of counties that make up a particular SSURGO database file consists of two principal data components. The first is a GIS-based, vector format usually available as either a shapefile or coverage. This principal data component allows a user to view the distribution of soils in a graphical format. Associated with each shapefile or coverage is a unique attributes table. The attributes table provides a list of the different polygons that represent the continuous coverage of soils contained in the corresponding shapefile or coverage. Each of the polygons denotes a different soil type, which may appear one or more times. Different soil types are uniquely defined in the attributes table by a numerical code, referred to as the map unit key (mukey). The mukey value field in the attributes table provides a many-to-one relationship from the graphical data component to the second principal data component, which is the tabular data source. Contained within the tabular data sources are the parameter values for the soil properties corresponding to each soil type in the shapefile or coverage.

The SSURGO 2.x database is an upgrade to the SSURGO 1.0 database with regard to information accuracy and data management. The tabular data source for a SSURGO 2.x database file is comprised of 61 different ASCII text files, each containing a relationship to the others. Metadata giving a complete listing of the text file names and their respective value fields are available on the USDA-NRCS SSURGO website (USDA-NRCS, 2004). To obtain the 131 soils input parameters required for the ArcView SWAT model (Table 36), it is not necessary to query the complete set of tabular data source text files. The required parameters are located in the map unit, component, and horizon text files. The map unit text file contains the set of possible soil types that appear in a SSURGO shapefile or coverage. Component properties, such as percent composition and hydrologic soil group, associated with each map unit value, are contained within the component text file. The horizon text file lists the different soil horizon properties for each component. Some horizon properties include bulk density and percent organic matter.

All of the tabular data source text files contain a specific value field, called a primary key, which has entries that uniquely identify each text file record. The primary key value fields also define a relationship between each of the text files. Soil type polygons

Table 36. ArcView SWAT and corresponding SSURGO 2.x database variables.

ArcView SWAT Variable	Variable Description and Units	SSURGO 2.x Variable
Muid	Mapping unit identifier	Mukey[b,c]
Seqn	Sequence number	Calculation
Snam	Soil name	Concatinated Mukey[b,c]
S5id	Soil interpretation record	Not required for model
Cmppct	Soil component percent	Comppct_r[c]
Nlayers	Number of soil layers	Calculation
Hydgrp	Soil hydraulic group	Hydgrp[c]
Sol_zmx	Maximum rooting depth of soil profile [mm]	Not required for model
Anion_excl	Fraction of porosity from which anions are excluded	Not required for model
Sol_crk	Potential or maximum crack volume of soil profile as fraction of total volume	Not required for model
Texture	Texture of the soil layer	Not required for model
Sol_z[a]	Depth from soil surface to bottom of layer [mm]	Hzdepb_r[d]; Unit calculation
Sol_bd[a]	Bulk density [mg/m^3 or g/cm^3]	Dbovendry_r[d]
Sol_awc[a]	Available water capacity of soil layer [mm H_2O/mm soil]	Awc_r[d]
Sol_k[a]	Saturated hydraulic conductivity [mm/hr]	Ksat_r[d]
Sol_cbn[a]	Organic carbon content [% of soil weight]	[Om_r[d]/1.72][e]
Clay[a]	Clay content [% of soil weight]	Claytotal_r[d]
Silt[a]	Silt content [% of soil weight]	Silttotal_r[d]
Sand[a]	Sand content [% of soil weight]	Sandtotal_r[d]
Rock[a]	Rock fragment content [% of total weight]	1 – Sieveno10_r[d]
Sol_alb[a]	Soil albedo	[0.6/exp(0.4*Om_r[d]/1.72)][f]
Usle_k[a]	USLE soil erodibility K-factor [0.013 metric ton-m^2-hr/m^3-metric ton-cm]	Kffact[d]
Sol_ec[a]	Electrical conductivity [dS/m]	Ec_r[d]

(a) Can have a value for up to 10 different soil layers.
(b) Parameter located in the map unit text file.
(c) Parameter located in the component text file.
(d) Parameter located in the horizon text file.
(e) Determined from p.383 Brady and Weil (1996).
(f) Determined from Baumer (1990).

in the shapefile or coverage are related through a corresponding mukey value in the attributes table to a unique mukey record in the map unit text file. The mukey value field is the primary key of map unit text file. Within the component text file, the value field, component key (cokey), serves as the primary key. There is a one-to-many relationship between the mukey value field in the map unit text file and the mukey value field in the component text file. The primary key of the horizon text file is referred to as the horizon key (chkey). A one-to-many relationship exists between the cokey value field in the component text file and the cokey value field in the horizon text file. Thus, a single record in the shapefile or coverage attributes table may cascade into an association of multiple horizon records. This would be intuitive since a soil polygon may have more than one soil component, each containing multiple horizons. Using these fundamental relationships, a basic tabular data source processing methodology to extract the required parameters from a SSURGO 2.x database file was developed.

The primary difficulty with the SSURGO 2.x tabular data source is the structural format. All of the 61 ASCII text files are delimited using the pipe "|" character. The ArcView program only allows a user to import a text file that is delimited by tabs or commas. An additional problem is the presence of quotation quantifiers within the tabular source data. Quantifiers are used to denote data that should be interpreted in character format. An algorithm was developed to import the three pipe delimited text files into table documents within the ArcView program. Once the text files were imported as table documents, the records in the map unit table were joined to the matching records in the component table through the mukey value field. The newly appended records in the component table were then joined to matching records in the horizon table using the cokey value field. Calculation fields were added to correct any unit inconsistencies between the SSURGO 2.x database values and the corresponding soil input parameters required by the ArcView SWAT model. Other necessary value fields were appended that required a calculation based on values in the joined tabular data sources (Table 36). After the calculations were complete, the records in the final table are reformatted to match the formatting requirements of the 'usersoil.dbf' file, which is used as the soil input file by the ArcView SWAT model.

With the basic methodology established to extract the required soil parameter values from the SSURGO 2.x database, a collection of Avenue scripts were written to complete the individual processing tasks. Avenue is the object-oriented programming language native to the ArcView program. The Avenue scripts were then compiled into an extension file for ease of use within the ArcView program graphical user interface (GUI). When loaded in the ArcView program, the extension appears as 'SSURGO SWAT' in the toolbar menu.

Case Study: The Upper Sabinal River Watershed

After successful development of the SSURGO 2.x database pre-processor extension, an ArcView SWAT model case study for the Upper Sabinal River watershed near Uvalde, Texas was created. The purpose of the case study was to examine the hydrologic output parameters of the ArcView SWAT model for basic differences that may have occurred by using the SSURGO 2.x database information versus the STATSGO database information. The Upper Sabinal River Watershed was selected for data availability and the low amount of evolving urbanization (impervious surfaces) present during the modeling period.

Watershed and Sub-Basin Delineation

The automatic watershed delineation tool, available within the ArcView SWAT model interface, was used to delineate the Upper Sabinal River watershed. A 1:24,000 digital elevation model (DEM) file was obtained for processing from the Texas Natural Resource Information Service (TNRIS). The DEM file is a subset of the United States Geological Survey (USGS) National Elevation Dataset (NED). The projection chosen for the project, based on the projection of the DEM, was Universal Transverse Mercator (UTM) Zone 14 with the North American Datum of 1983 (NAD83). To improve the results of the delineation procedure, a USGS National Hydrography Dataset (NHD) file for the Upper Frio watershed was used to 'burn in' the actual locations of the streams located within the watershed boundary. A mask of the Upper Frio watershed, identified by the 8-digit hydrologic unit code (HUC) 12110106, was used as the watershed focus area. DEM sinks were filled during the delineation process. After the DEM file had been processed, the stream definition threshold area was set to 10-km^2. The threshold area specifies the minimum size for a sub-basin delineated within the watershed boundary (Di Luzio et al., 2002). Development of a stream network derived from the processed DEM and the sub-basin constraints was the next step in the procedure. An additional watershed outlet was added to represent USGS gauging station number 08198000. This USGS gauging station is located at the approximate natural outlet of the Upper Sabinal River watershed and was therefore defined as the primary watershed outlet. Based on the input topographic and hydrographic data specifications, 29 sub-basins were defined for the delineated Upper Sabinal River watershed. Figure 78 illustrates the delineated sub-basins of the Upper Sabinal River watershed. Table 37 presents the corresponding areas of the delineated sub-basins. Two identical copies of the model were created, one for the STATSGO data (the STATSGO model) and one for the SSURGO data (the SSURGO model).

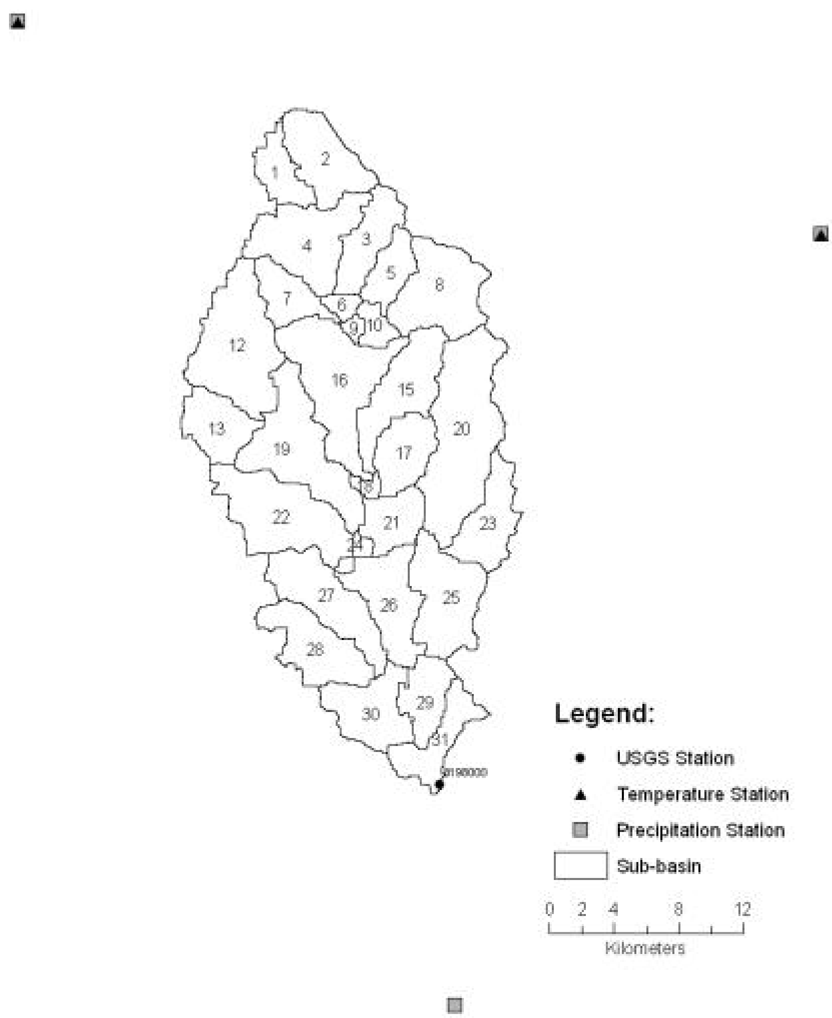

Figure 78. Delineated sub-basins of the Upper Sabinal River watershed.

Table 37. Sub-basin areas of the Upper Sabinal River watershed.

Sub-basin Number	Area (km^2)
1	10.45
2	20.57
3	27.20
4	15.19
5	10.18
6	26.60
7	11.86
8	2.89
9	1.65
10	4.93
11	36.17
12	14.99
13	22.47
14	36.55
15	1.98
16	14.78
17	32.88
18	31.81
19	46.16
20	17.12
21	2.66
22	12.22
23	21.73
24	25.63
25	24.01
26	21.11
27	19.48
28	12.78
29	14.38

Land Use and Soil Definition

Land use information was extracted from the 1992 USGS National Land Cover Data (NLCD) collection (USGS, 2003). The NLCD was chosen for its spatial resolution, accuracy, and period in time that it characterizes. Derived from Landsat Thematic Mapper (TM) satellite imagery, the spatial resolution of the NLCD is 30-m, which is identical to the spatial resolution of the DEM. The regional user's accuracy for the two largest land use classification percentages of the total watershed area, evergreen forest (woodland) (65% of total) and rangeland (25% of total), have been determined as 57% and 53%, respectively (Wickham et al., 2004). User's accuracy denotes the probability that using the derived thematic map will result in actually finding the specified classification (Congalton and Green, 1998). The NLCD characterizes land use across the United States from the early 1990's. The time period of characterization places the data set at the midpoint of the simulation period, which will be addressed in the model simulation section that follows. It was necessary to convert the NLCD file from a geo-tiff image to ArcView grid format, and re-project the data from its standard Albers Conical Equal Area projection with NAD83 datum to the project projection. When integrated into both the STATSGO and SSURGO models, the NLCD was reclassified and overlain onto the Upper Sabinal River watershed. Table 38 presents the results of the reclassification and the percentage distribution of the land use classes within each sub-basin of the Upper Sabinal River Watershed.

A STATSGO shapefile was obtained from the United States Environmental Protection Agency (U. S. EPA) Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) 3.0 data set for the Upper Frio Watershed (U. S. EPA, 2004). The modified STATSGO tabular data source was included with the installation of the ArcView SWAT model interface, but is also available from the BRC SWAT website (BRC, 2004). When the STATSGO data set was defined as the soil layer of the

Table 38. Percentages of land cover classification within each sub-basin of the Upper Sabinal River watershed.

Sub-basin	Residential-High Density	Range-Brush	Pasture	Range-Grasses	Water	Wetlands-Mixed	Commercial	Bermuda Grass	Forest-Deciduous	Forest-Evergreen	Forest-Mixed	Agriculture Land-Close Grown	Residential-Low Density	Industry	Agriculture Land-Row Crops	Orchard
1	0.00	14.33	0.26	12.20	0.00	0.00	0.00	0.00	7.39	65.75	0.00	0.00	0.00	0.07	0.00	0.00
2	0.00	12.87	0.27	9.18	0.00	0.00	0.00	0.00	5.31	72.29	0.00	0.00	0.00	0.08	0.00	0.00
3	0.00	7.94	2.64	5.71	0.07	0.00	0.00	0.00	5.61	76.42	0.00	0.94	0.00	0.68	0.00	0.00
4	0.00	11.06	1.10	4.26	0.04	0.01	0.00	0.00	2.21	80.02	0.00	0.50	0.16	0.64	0.00	0.00
5	0.00	4.09	0.01	1.89	0.00	0.00	0.00	0.00	3.14	90.42	0.00	0.05	0.00	0.35	0.05	0.00
6	0.00	6.54	0.06	4.04	0.00	0.00	0.00	0.00	4.21	84.53	0.00	0.06	0.01	0.53	0.02	0.00
7	0.00	5.84	4.06	6.78	0.19	0.00	0.00	0.00	1.10	79.98	0.00	0.37	0.00	1.68	0.00	0.00
8	0.00	9.10	2.99	4.58	0.93	0.00	0.00	0.00	2.99	77.84	0.00	0.50	0.00	1.06	0.00	0.00
9	0.00	16.99	30.57	11.87	2.14	0.00	0.00	0.00	1.21	35.24	0.00	0.33	0.00	1.65	0.00	0.00
10	0.00	14.56	1.39	10.79	0.00	0.00	0.00	0.00	1.79	70.63	0.00	0.50	0.00	0.35	0.00	0.00
11	0.00	6.65	0.55	6.98	0.00	0.00	0.11	0.00	1.68	83.77	0.00	0.00	0.00	0.20	0.05	0.00
12	0.00	13.86	0.10	7.56	0.00	0.00	0.00	0.00	1.12	76.88	0.00	0.00	0.00	0.48	0.00	0.00
13	0.00	16.44	1.83	10.98	0.10	0.00	0.00	0.00	1.87	59.86	0.00	6.90	0.00	0.29	1.73	0.00
14	0.00	24.47	2.91	18.35	0.12	0.00	0.00	0.00	1.38	48.54	0.00	2.73	0.00	0.89	0.61	0.00
15	0.00	16.98	0.00	5.90	0.05	0.00	0.00	0.00	3.00	27.88	0.00	38.56	0.00	0.05	7.58	0.00
16	0.00	20.78	1.49	8.22	0.02	0.01	0.00	0.00	1.11	61.10	0.00	4.93	0.00	0.76	1.57	0.00
17	0.00	32.58	2.93	14.39	0.01	0.00	0.02	0.00	1.28	41.37	0.00	5.11	0.00	0.43	1.87	0.00
18	0.00	21.86	3.90	10.36	0.07	0.00	0.15	0.00	1.09	57.29	0.00	3.36	0.00	1.53	0.39	0.00
19	0.00	16.97	2.06	14.48	0.03	0.00	0.07	0.00	4.59	60.21	0.00	0.47	0.00	0.99	0.11	0.00
20	0.00	11.46	0.63	3.33	0.00	0.00	0.37	0.00	4.49	79.05	0.00	0.03	0.00	0.63	0.01	0.01
21	0.00	23.68	0.21	5.26	0.35	0.00	0.00	0.00	3.01	38.37	0.00	25.03	0.00	3.46	0.62	0.00
22	0.00	20.43	0.18	6.28	0.04	0.00	0.00	0.00	1.74	41.12	0.03	27.07	0.00	0.46	2.66	0.00
23	0.04	22.81	0.31	5.81	0.23	0.05	0.09	0.39	2.16	41.74	0.00	22.66	0.90	0.60	2.19	0.00
24	0.00	12.25	2.10	5.51	0.35	0.02	0.44	0.00	1.45	65.27	0.02	10.15	0.00	1.52	0.92	0.00
25	0.00	14.98	0.77	13.99	0.13	0.01	0.07	0.00	0.71	60.26	0.00	7.46	0.00	1.35	0.28	0.00
26	0.00	13.70	0.61	6.53	0.00	0.00	0.11	0.00	0.15	75.15	0.00	2.36	0.00	1.24	0.08	0.07
27	0.00	23.50	1.10	12.37	0.30	0.03	0.00	0.00	0.45	43.82	0.00	17.89	0.00	0.37	0.16	0.01
28	0.00	7.48	1.91	1.46	0.52	0.18	0.00	0.00	0.59	73.10	0.04	13.51	0.00	0.20	1.00	0.00
29	0.00	2.72	0.33	0.74	0.65	0.08	0.00	0.01	0.01	87.17	0.00	7.63	0.01	0.61	0.04	0.00

STATSGO model, the ‘stmuid’ option was selected as specified by the ArcView SWAT model interface manual. It should be noted that the ‘stmuid’ option only extracts the dominant soil group present in each STATSGO polygon (Di Luzio et al., 2002). The soil layer was then reclassified and overlain onto the watershed area of the STATSGO model. For the SSURGO model, SSURGO 2.x database files for Bandera, Real, and Uvalde Counties were downloaded from the USDA-NRCS SSURGO website (USDA-NRCS, 2004). The shapefiles for each county were combined using the merge function of the ArcView geoprocessing tool. The final merged product was re-projected from Geographic coordinates with the North American Datum of 1927 (NAD27), to the project projection. Each county tabular data source was processed by the SSURGO SWAT extension according to the procedure defined in the SSURGO SWAT Installation and Instruction Guide (Peschel, 2004). After processing, the three tabular data sources were combined into one table document, which was renamed as ‘usersoil.dbf,’ and was placed in the appropriate ArcView SWAT file directory (Di Luzio et al., 2002). Table 39 presents the percentage distribution of the hydrologic soil groups and percentage weighted saturated hydraulic conductivity within each sub-basin for the two models of the Upper Sabinal River Watershed.

Hydrologic Resource Unit Distribution

Land use and soil type may be defined for each watershed sub-basin as either dominant or in multiple hydrologic response units (HRUs). The dominant option assigns the land use and soil type present in the highest percentage within each watershed sub-basin. HRUs are sub-components of watershed sub-basins that consist of unique land

Table 39. Percentages of hydrologic soil group and weighted hydraulic conductivity within each sub-basin for the STATSGO and SSURGO models of the Upper Sabinal River watershed.

Sub-basin	STATSGO					SSURGO				
	Hydrologic Soil Group (%)				Weighted Hydraulic Conductivity (mm/hr)	Hydrologic Soil Group (%)				Weighted Hydraulic Conductivity (mm/hr)
	A	B	C	D		A	B	C	D	
1	0.00	0.00	0.00	100.00	3.22	0.73	0.00	1.74	97.53	16.73
2	0.00	0.00	0.00	100.00	3.12	0.64	0.00	0.00	99.36	13.37
3	0.00	0.00	0.00	100.00	2.30	6.07	0.23	0.00	87.48	29.35
4	0.00	0.00	0.00	100.00	2.30	0.26	0.16	0.00	99.59	10.62
5	0.00	0.00	0.00	100.00	2.30	0.00	0.18	0.69	99.12	10.04
6	0.00	0.00	0.00	100.00	2.32	0.00	0.33	0.00	99.68	10.00
7	0.00	0.00	0.00	100.00	2.30	1.08	0.49	0.00	98.43	13.45
8	0.00	0.00	0.00	100.00	2.30	0.00	15.77	0.00	84.24	24.08
9	0.00	0.00	0.00	100.00	2.30	0.00	33.32	0.00	39.64	29.64
10	0.00	0.00	0.00	100.00	2.30	2.09	4.17	2.42	69.56	16.60
11	0.00	0.00	0.00	100.00	2.30	1.98	0.26	13.24	84.55	15.45
12	0.00	0.00	0.00	100.00	2.30	1.17	0.21	16.78	81.86	14.88
13	0.00	20.84	0.00	79.16	1.91	0.01	18.63	3.89	77.48	14.39
14	0.00	7.85	0.00	92.15	2.15	4.67	12.93	9.46	72.92	29.71
15	0.00	98.91	0.00	1.09	0.44	13.44	71.58	0.00	14.98	70.16
16	0.00	19.08	0.00	80.92	1.94	0.10	11.31	27.00	61.59	19.66
17	0.00	18.39	0.00	81.61	2.15	5.24	20.34	23.90	50.52	36.79
18	0.00	6.33	0.00	93.67	2.59	0.03	8.30	18.79	72.90	18.02
19	0.00	2.51	0.00	97.49	2.25	0.00	5.16	10.66	84.19	12.91
20	0.00	1.17	0.00	98.84	2.41	0.00	0.12	20.29	79.58	17.64
21	0.00	29.78	0.00	70.23	7.43	5.99	26.07	48.57	19.36	43.70
22	0.00	73.04	0.00	26.96	0.93	4.40	41.61	12.69	41.31	37.26
23	0.00	60.83	0.00	39.17	4.80	3.21	36.20	31.81	28.78	27.45
24	0.00	7.16	0.00	92.84	7.60	1.85	8.75	39.85	49.54	26.03
25	0.00	0.36	0.00	99.64	7.61	0.00	8.70	27.49	63.82	23.30
26	0.00	0.00	0.00	100.00	5.14	0.00	5.67	20.37	73.96	24.67
27	0.00	12.89	0.00	87.11	6.90	0.23	12.07	14.92	72.77	21.22
28	0.00	45.74	0.00	54.26	5.44	5.51	18.97	46.43	38.08	40.79
29	0.00	0.00	0.00	100.00	30.86	2.82	18.42	27.76	60.01	36.77

use and soil type combinations defined by the user. The HRU distribution threshold is used to eliminate low percentage land uses or soil types, but can also be used to maximize the level of spatial distribution (Di Luzio et al., 2002). In the STATSGO and SSURGO models, the multiple HRU option was selected and a threshold level of zero was specified for both the land use and soil type layers. For the STATSGO model, a total of 491 HRUs were created within the entire watershed area, while in the SSURGO model, 2,397 HRUs were created. The larger number of HRUs associated with the SSURGO model is to be expected given the higher resolution of the soil data set.

Weather Station Inputs

User-defined climate input parameters for the ArcView SWAT model consist of precipitation, temperature, solar radiation, wind speed, and relative humidity. If historic records are not available, the ArcView SWAT model can simulate the climate input parameter values. Daily precipitation, maximum temperature, and minimum temperature records were electronically requested from the National Oceanic and Atmospheric Administration (NOAA) for all stations in Bandera, Real, and Uvalde Counties (NOAA, 2004). Three National Weather Service (NWS) cooperative stations closest to the area of study were identified to have historic daily precipitation records for the period of simulation: Medina (COOP ID: 415742; Latitude: 29°49′N, Longitude: 99°15′N), Prade Ranch (COOP ID: 417232; Latitude: 29°55′N, Longitude: 99°46′N), and Sabinal (COOP ID: 417873; Latitude: 29°22′N, Longitude: 99°29′N). Historic daily maximum and minimum temperature records were only available from the Prade Ranch and Sabinal weather stations. The precipitation and temperature time series were processed to meet the required ArcView SWAT format and any missing values were marked for simulation (Di Luzio et al., 2002). Specifically, solar radiation, wind speed, and relative humidity records were not available for the Upper Sabinal River watershed area and were marked for simulation in both models. The Hondo weather station (Latitude: 29°33′N, Longitude: 99°15′N), contained within the ArcView SWAT model U.S. weather station database, was used to generate missing and non-available climate inputs for both models. Although the missing and non-available climate inputs were generated in each model independently, the ArcView SWAT model generation procedure utilizes a preset seed value; therefore the climate inputs for the STATSGO and SSURGO models are identical (J. Arnold, personal communication, 2004).

Simulation Information

The time period of simulation selected was from January 1, 1990 through December 31, 1994. Daily rainfall with the curve number runoff method used on a daily time step for routing was selected. The rainfall distribution chosen was skewed normal. Potential evapotranspiration was determined using the Priestly-Taylor method. The variable storage method was used for routing. Crack flow, channel dimensions, stream water quality, and lake water quality were not active during the simulation. Before simulation, the input parameters were checked to determine if the values fell within the adequate range for model calculation. The simulation was executed independently for both the STATSGO and the SSURGO models. Output data were generated at a daily frequency.

Results and Discussion

In this section, we present a comparison of the hydrologic output parameters resulting from two ArcView SWAT models of the Upper Sabinal River Watershed. Monthly average area-weighted precipitation, actual watershed outflow, and the two simulated watershed outflows are shown in Figure 79. For basic comparison purposes, neither of the two models were calibrated to the observed USGS outflow time series, which results in an outflow magnitude differential. Using the non-parametric Spearman rank method, analysis revealed that the STATSGO and SSURGO models had a daily mean watershed outflow by month correlation coefficient value of 0.97, indicating a strong positive linear relationship between the two times series. Compared with the USGS outflow, the STATSGO model outflow had a correlation coefficient value of 0.27, while the SSURGO model outflow had a correlation coefficient value of 0.37. These lower values suggest a weak linear relationship between the observed and simulated outflows and may be improved with model calibration. With regard to area-weighted precipitation, the STATSGO, SSURGO, and USGS outflow time series had correlation coefficient values of 0.55, 0.64, and 0.43, respectively. The precipitation-outflow relationships of the two simulated models are within reasonable expectation for typical rainfall-runoff correlation coefficient values. USGS outflow was more weakly related to the area-weighted precipitation records used in the models, and is most likely explained by the spatial variability present within regional precipitation patterns. The non-parametric Wilcoxon matched-pairs signed-ranks test revealed that the daily mean

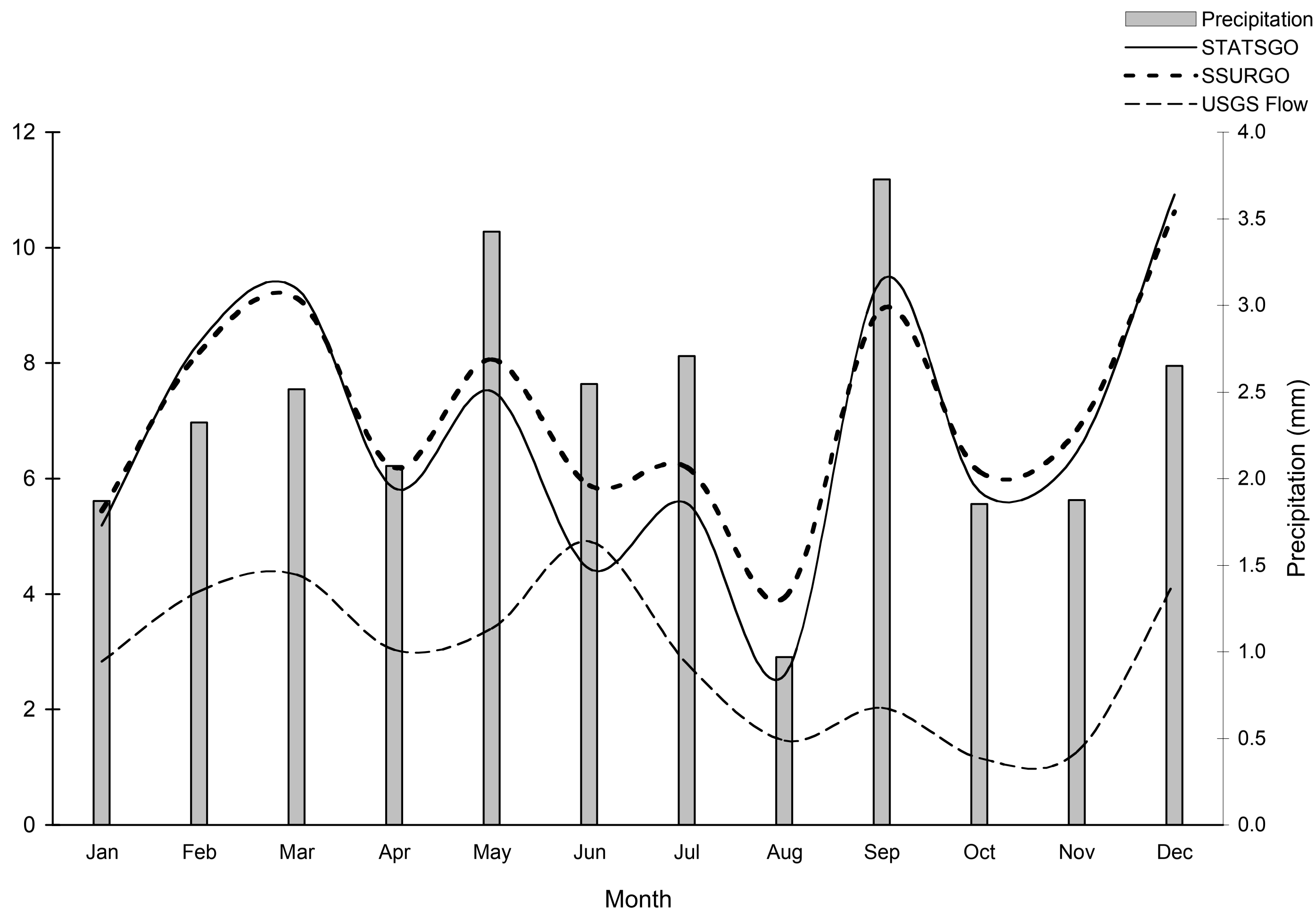

Figure 79. Precipitation, STATSGO model outflow, SSSURGO model outflow, and USGS outflow series.

watershed outflow by month for the two models did not change at a 5% level of significance.

Water yield is defined as the net amount of water that leaves a sub-basin and contributes to the streamflow in a reach during the specified simulation time step. The ArcView SWAT model water balance parameters involved in the determination of water yield are: surface runoff, lateral flow, groundwater return flow, transmission losses, and pond abstractions (Neitsch et al., 2002). Table 40 presents the daily mean water yield (in millimeters) by month within each sub-basin for the two models of the Upper Sabinal River Watershed. At the 5% level of significance, inequities between the two models for daily mean water yield were found in sub-basins 1-7, 13, 15, 22-25, and 28. SSURGO model daily mean water yield values were consistently higher each month within the listed sub-basins, with the exception of sub-basins 24 and 25. The hydrologic output parameters that comprise water yield will now be examined individually.

Soil water content is the amount of water present throughout the entire soil profile at the end of the simulation time period. The ArcView SWAT model uses the following expression to calculate the final soil water content within a sub-basin:

$$SW_t = SW_0 + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - w_{seep} - Q_{gw}) \quad (1)$$

where t is the time in days, SW_0 is the initial soil water content on day i, R_{day} is the precipitation on day i, Q_{surf} is the surface runoff on day i, E_a is the evapotranspiration on day i, w_{seep} is the amount of water leaving the bottom of the soil profile on day i, and Q_{gw} is the groundwater return flow on day i (Neitsch et al., 2002). Table 41 presents daily

Table 40. Sub-basin daily average water yield results by month (in millimeters of H_2O) for the STATSGO (STAT) and SSURGO (SSUR) models of the Upper Sabinal River watershed.

Sub-basin	January		February		March		April		May		June		July		August		September		October		November		December	
	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR
1	0.65	0.76	1.21	1.28	1.53	1.60	0.94	1.04	1.25	1.48	0.61	1.05	0.70	1.07	0.59	1.06	2.24	2.48	1.02	1.35	0.73	1.06	1.38	1.47
2	0.65	0.77	1.22	1.33	1.54	1.64	0.95	1.07	1.25	1.51	0.61	1.15	0.71	1.19	0.60	1.19	2.24	2.63	1.03	1.45	0.74	1.12	1.39	1.49
3	0.70	0.77	1.33	1.28	1.57	1.58	0.98	1.04	1.30	1.51	0.66	1.12	0.86	1.13	0.67	1.12	2.45	2.49	1.11	1.37	0.81	1.06	1.45	1.44
4	0.70	0.78	1.32	1.31	1.58	1.63	0.98	1.06	1.29	1.51	0.66	1.16	0.83	1.17	0.68	1.19	2.42	2.60	1.14	1.45	0.83	1.11	1.44	1.48
5	1.36	1.34	1.84	1.88	2.18	2.14	1.25	1.43	1.74	1.87	1.20	1.55	1.10	1.46	0.39	0.81	1.64	1.64	1.11	1.28	1.83	1.97	3.27	3.31
6	1.35	1.35	1.84	1.89	2.18	2.15	1.25	1.44	1.76	1.91	1.21	1.57	1.10	1.48	0.38	0.82	1.65	1.67	1.10	1.30	1.83	2.00	3.27	3.33
7	0.70	0.76	1.32	1.24	1.58	1.56	0.99	1.02	1.30	1.48	0.67	1.08	0.85	1.07	0.68	1.07	2.43	2.41	1.15	1.33	0.82	1.03	1.44	1.43
8	0.70	0.75	1.32	1.24	1.55	1.51	0.98	1.02	1.30	1.46	0.65	1.07	0.86	1.08	0.67	1.01	2.44	2.37	1.12	1.29	0.81	0.98	1.45	1.36
9	0.65	0.67	1.29	1.09	1.50	1.30	0.91	0.90	1.34	1.33	0.70	0.92	0.94	0.96	0.67	0.77	2.47	2.07	1.14	1.09	0.78	0.78	1.42	1.20
10	1.32	1.24	1.85	1.77	2.19	2.05	1.29	1.35	1.82	1.79	1.27	1.44	1.09	1.13	0.41	0.59	1.65	1.37	1.12	1.00	1.81	1.68	3.25	3.11
11	0.70	0.76	1.31	1.16	1.59	1.49	0.99	0.98	1.29	1.42	0.66	0.96	0.82	0.91	0.68	0.93	2.41	2.15	1.14	1.23	0.84	1.02	1.44	1.41
12	0.71	0.75	1.33	1.16	1.56	1.48	0.98	0.97	1.30	1.43	0.65	0.92	0.86	0.88	0.67	0.88	2.49	2.16	1.14	1.18	0.83	0.97	1.47	1.40
13	1.17	1.23	1.71	1.76	2.06	2.03	1.22	1.33	1.66	1.77	1.23	1.46	0.93	1.11	0.36	0.57	1.41	1.35	0.94	0.97	1.57	1.62	3.08	3.05
14	0.66	0.69	1.26	1.14	1.50	1.41	0.92	0.94	1.27	1.35	0.66	0.91	0.83	0.91	0.65	0.82	2.37	2.19	1.13	1.17	0.78	0.84	1.41	1.27
15	0.72	1.22	1.23	1.66	1.58	1.86	0.93	1.27	1.07	1.51	1.08	1.36	0.31	0.71	0.11	0.28	0.71	0.93	0.33	0.59	0.75	1.07	2.53	2.44
16	1.18	1.24	1.72	1.77	2.07	2.04	1.23	1.35	1.67	1.77	1.24	1.45	0.94	1.07	0.37	0.56	1.42	1.32	0.95	0.94	1.58	1.59	3.09	3.03
17	0.63	0.65	1.19	1.03	1.44	1.33	0.87	0.88	1.21	1.25	0.62	0.74	0.76	0.68	0.60	0.58	2.27	1.88	1.07	1.00	0.73	0.69	1.36	1.17
18	0.80	0.75	1.21	1.12	1.05	0.99	0.80	0.76	0.84	0.88	0.51	0.64	1.07	0.98	0.28	0.37	0.72	0.55	0.86	0.71	0.99	0.86	1.15	1.01
19	1.29	1.27	1.82	1.80	2.16	2.08	1.28	1.37	1.84	1.88	1.27	1.51	1.09	1.24	0.40	0.65	1.63	1.47	1.08	1.07	1.76	1.75	3.21	3.16
20	1.28	1.26	1.83	1.80	2.17	2.09	1.29	1.37	1.74	1.75	1.24	1.40	1.07	1.16	0.43	0.62	1.56	1.42	1.08	1.05	1.77	1.71	3.22	3.13
21	0.58	0.64	0.97	0.96	0.85	0.85	0.61	0.63	0.69	0.66	0.35	0.38	0.81	0.69	0.13	0.18	0.40	0.32	0.49	0.42	0.65	0.56	0.92	0.81
22	0.44	0.68	0.82	1.02	0.70	0.92	0.50	0.68	0.56	0.78	0.33	0.59	0.53	0.87	0.13	0.29	0.30	0.45	0.36	0.58	0.47	0.68	0.61	0.84
23	0.42	0.58	0.80	0.91	0.68	0.80	0.48	0.58	0.53	0.59	0.27	0.36	0.54	0.63	0.08	0.16	0.23	0.26	0.30	0.36	0.43	0.50	0.64	0.74
24	0.68	0.70	1.07	1.03	0.95	0.92	0.69	0.68	0.70	0.68	0.37	0.40	0.93	0.79	0.19	0.25	0.51	0.39	0.63	0.52	0.78	0.69	1.04	0.93
25	0.73	0.73	1.13	1.08	1.00	0.95	0.72	0.72	0.78	0.75	0.41	0.47	1.00	0.87	0.21	0.28	0.57	0.46	0.71	0.61	0.86	0.75	1.13	0.99
26	0.80	0.79	1.20	1.16	1.06	1.03	0.77	0.79	0.80	0.82	0.45	0.53	1.05	0.96	0.26	0.33	0.68	0.58	0.82	0.73	0.96	0.87	1.17	1.06
27	0.71	0.74	1.11	1.11	0.99	0.99	0.72	0.72	0.81	0.78	0.45	0.54	0.96	0.91	0.22	0.30	0.58	0.52	0.71	0.69	0.84	0.81	1.07	1.02
28	0.47	0.70	0.85	1.03	0.73	0.93	0.51	0.69	0.49	0.65	0.24	0.40	0.60	0.72	0.11	0.27	0.28	0.40	0.37	0.52	0.51	0.67	0.73	0.88
29	0.76	0.78	1.16	1.13	1.04	1.04	0.74	0.77	0.71	0.73	0.40	0.49	1.00	0.85	0.24	0.35	0.60	0.55	0.74	0.71	0.90	0.83	1.14	0.98

Table 41. Sub-basin daily average soil water content results by month (in millimeters of H_2O) for the STATSGO (STAT) and SSURGO (SSUR) models of the Upper Sabinal River watershed.

Sub-basin	January		February		March		April		May		June		July		August		September		October		November		December	
	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR
1	40.13	24.42	42.77	24.41	39.00	22.04	34.33	18.58	23.52	12.78	14.38	7.36	10.89	5.50	11.10	6.53	27.31	16.37	32.09	18.60	41.55	24.74	41.69	24.23
2	38.84	17.64	41.23	16.74	37.66	14.82	33.41	12.40	21.66	7.35	13.15	4.25	10.35	3.36	9.64	3.47	25.71	10.66	30.59	11.71	39.86	16.96	40.22	16.54
3	27.22	28.09	27.96	28.92	24.29	28.55	20.98	26.32	11.02	19.97	7.90	12.22	6.74	7.60	4.57	7.29	17.97	16.34	20.36	19.59	27.53	26.64	27.18	27.38
4	27.37	22.30	28.05	22.16	24.51	21.32	21.26	19.32	11.03	14.39	7.89	9.60	6.71	5.48	4.60	5.39	18.33	13.27	20.90	15.23	27.88	21.12	27.43	21.29
5	28.39	28.25	28.22	28.30	26.68	28.67	20.85	25.49	12.33	20.17	7.31	11.65	5.27	6.55	2.30	4.43	21.17	14.97	23.24	18.17	29.23	25.94	28.45	27.88
6	28.58	25.33	28.41	25.04	26.87	25.13	21.09	21.91	12.86	17.24	7.48	10.20	5.38	5.71	2.50	3.98	21.18	13.83	23.25	16.33	29.37	23.29	28.61	24.80
7	27.29	33.00	27.99	34.50	24.46	34.43	21.24	32.10	10.97	26.03	7.85	17.13	6.67	9.07	4.49	8.78	18.15	19.28	20.83	23.62	27.79	31.54	27.35	32.57
8	27.13	39.27	27.84	42.42	24.28	43.95	21.04	42.02	11.01	33.00	7.89	18.01	6.73	10.71	4.58	10.32	18.06	21.81	20.59	28.10	27.57	36.99	27.16	39.05
9	26.13	66.98	26.85	73.64	22.05	76.51	18.11	73.44	12.77	66.30	8.61	45.12	7.18	24.09	5.71	23.03	18.58	39.42	21.07	52.22	27.40	65.54	25.80	69.19
10	28.38	62.05	28.19	64.56	26.66	67.60	21.21	64.89	13.81	57.25	7.78	36.41	5.54	21.97	3.02	14.49	21.36	33.42	23.29	44.70	29.19	59.93	28.41	64.67
11	27.43	39.53	28.11	41.67	24.64	41.53	21.46	38.93	10.86	30.81	7.82	20.67	6.64	11.17	4.43	10.15	18.29	23.81	20.95	29.34	27.94	38.46	27.53	39.76
12	27.36	41.88	28.01	44.48	24.36	43.93	21.03	40.84	11.15	32.15	7.87	20.67	6.67	11.64	4.79	11.15	18.66	25.85	21.25	31.84	28.06	41.26	27.44	42.48
13	82.20	74.32	84.96	76.93	85.07	80.59	81.20	78.24	76.77	71.75	61.71	49.89	50.43	35.44	41.55	28.27	63.11	47.48	70.40	59.24	83.36	75.22	86.85	79.64
14	43.23	61.56	45.30	66.92	42.52	68.94	39.18	66.13	33.15	58.32	25.33	38.97	18.79	21.87	16.64	23.73	32.21	40.34	36.57	49.79	44.47	61.49	44.19	64.14
15	283.30	154.85	296.33	160.82	302.18	169.54	303.93	168.75	307.86	159.70	259.89	121.38	222.24	103.85	191.07	91.14	223.04	119.66	247.64	140.20	285.46	165.12	304.40	171.80
16	77.27	71.24	80.00	73.41	80.13	76.87	76.21	74.29	71.64	66.06	56.84	42.85	45.39	30.61	36.46	24.59	58.00	44.54	65.17	56.57	77.85	73.00	81.31	76.59
17	69.66	87.13	73.36	95.23	72.05	98.37	68.75	94.36	65.03	85.69	54.62	60.97	41.76	36.07	39.59	39.91	57.48	61.89	63.42	74.45	73.20	89.17	73.96	93.00
18	39.98	63.02	43.36	68.96	41.22	70.72	39.33	71.09	30.37	63.02	19.26	37.46	15.17	21.44	9.79	14.21	29.21	33.89	31.39	44.38	36.89	56.08	39.37	63.35
19	34.10	51.39	34.46	53.07	33.22	55.23	28.14	52.35	21.57	46.27	13.62	28.89	9.60	16.99	5.72	11.84	24.05	27.95	26.74	36.62	34.02	49.72	34.13	53.29
20	31.57	49.57	31.68	51.29	30.33	53.15	24.77	49.62	16.99	40.77	10.43	23.04	7.33	14.24	3.74	9.05	22.59	26.69	25.12	35.29	31.92	48.12	31.60	51.36
21	112.66	102.04	123.69	112.10	124.65	117.09	122.68	117.22	106.82	97.46	79.92	62.58	71.59	54.46	63.19	47.39	86.28	72.38	97.33	86.48	108.45	99.71	117.57	108.85
22	181.76	109.45	197.91	117.54	200.23	122.40	202.31	124.40	191.69	112.76	152.30	82.51	125.73	68.54	111.69	61.72	134.63	80.97	149.36	92.42	167.49	105.75	185.08	115.85
23	166.92	115.44	183.48	126.64	186.03	132.06	187.17	133.48	172.66	115.54	131.49	77.34	106.95	62.10	92.57	52.07	118.00	78.24	135.23	93.96	152.88	109.17	169.68	120.98
24	57.60	70.49	64.86	79.02	64.97	81.84	61.96	80.16	45.50	59.59	26.42	32.92	20.39	26.22	12.86	18.87	35.52	44.07	43.05	55.73	51.28	66.16	57.31	73.08
25	44.63	67.12	50.18	75.06	49.86	77.71	46.34	76.23	31.79	59.62	15.76	34.36	12.60	25.15	7.43	18.69	29.53	42.25	34.90	52.56	41.34	62.45	45.23	68.93
26	33.60	48.76	37.12	54.72	36.18	56.35	32.66	53.86	20.66	36.76	10.22	17.86	7.48	12.63	3.67	7.42	23.74	29.03	25.45	36.45	30.61	44.30	33.31	48.98
27	68.52	74.04	74.67	80.42	74.45	82.07	71.89	80.91	61.00	69.62	44.03	49.16	39.54	41.23	34.28	35.33	54.43	56.07	59.02	62.93	66.32	71.40	71.27	77.24
28	130.44	79.75	145.41	88.14	147.49	91.31	147.53	90.34	127.27	68.64	90.24	42.23	72.23	36.97	58.21	29.24	83.60	53.33	99.57	65.23	115.45	76.38	130.15	83.70
29	40.22	56.91	45.01	62.66	44.50	64.54	40.62	63.05	22.70	44.51	10.82	24.21	10.14	20.24	4.64	14.54	26.20	35.54	31.02	43.22	37.13	52.50	40.57	58.45

mean soil water content (in millimeters) by month within each sub-basin for the two models of the Upper Sabinal River Watershed. Daily mean soil water content inequities for the two models were found in sub-basins 1-2, 4, and 7-29 at the 5% level of significance. The SSURGO model produced consistently higher soil water content in sub-basins 7-12, 14, 17-20, 24-27, and 29. Since the soil water content parameter is composed of water yield parameters itself, further investigation into evapotranspiration, surface runoff, percolation, and groundwater return flow is necessary.

Collective actual evaporation is determined for each sub-basin through a series of calculation steps involving soil and land cover information. Table 42 presents the daily mean evaporation (in millimeters) by month within each sub-basin for the two models of the Upper Sabinal River Watershed. At the 5% level of significance, an inequity in the mean daily evapotranspiration for the two models was found in sub-basins 1-8, 11-16, 19, 22-23, and 28. In each sub-basin of the Upper Sabinal River Watershed, the SSURGO model resulted in lower evapotranspiration values than the STATSGO model. It should be noted that the SWAT theoretical documentation indicates the Priestly-Taylor method, which was used in this study for input parameter simplification purposes, typically underestimates potential evapotranspiration in semi-arid regions (Neitsch et al., 2002).

The curve number method of surface runoff determination used in this study is primarily based on land cover and hydrologic soil group. Antecedent moisture conditions also influence the curve number magnitudes. Table 43 presents the daily

Table 42. Sub-basin daily average evapotranspiration results by month (in millimeters of H_2O) for the STATSGO (STAT) and SSURGO (SSUR) models of the Upper Sabinal River watershed.

Sub-basin	January		February		March		April		May		June		July		August		September		October		November		December	
	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR
1	0.60	0.54	0.85	0.71	1.08	0.90	1.31	1.07	2.65	1.90	2.51	1.88	1.90	1.40	1.23	0.93	1.04	0.90	0.61	0.49	0.67	0.59	0.46	0.40
2	0.59	0.53	0.83	0.68	1.06	0.84	1.29	0.97	2.69	1.72	2.45	1.63	1.91	1.27	1.25	0.88	1.02	0.87	0.61	0.46	0.66	0.57	0.45	0.39
3	0.58	0.52	0.81	0.68	1.02	0.86	1.22	1.02	2.48	1.92	2.17	1.85	1.84	1.41	1.16	0.96	1.01	0.88	0.60	0.48	0.65	0.58	0.44	0.39
4	0.58	0.52	0.80	0.66	1.01	0.83	1.21	0.97	2.49	1.74	2.17	1.73	1.85	1.33	1.16	0.89	0.97	0.85	0.59	0.46	0.64	0.56	0.43	0.38
5	0.61	0.56	0.85	0.72	1.11	0.93	1.56	1.18	2.67	2.17	1.96	1.91	1.60	1.22	0.65	0.61	1.28	1.08	0.78	0.61	0.71	0.61	0.49	0.44
6	0.62	0.56	0.86	0.72	1.11	0.93	1.54	1.15	2.65	2.09	1.96	1.85	1.60	1.18	0.65	0.60	1.29	1.09	0.78	0.61	0.71	0.61	0.50	0.45
7	0.58	0.52	0.80	0.70	1.01	0.88	1.21	1.06	2.48	1.96	2.16	2.03	1.85	1.52	1.17	1.01	0.97	0.87	0.59	0.49	0.64	0.57	0.43	0.39
8	0.59	0.53	0.82	0.70	1.04	0.90	1.24	1.08	2.50	2.23	2.20	2.12	1.88	1.55	1.20	1.10	1.01	0.89	0.62	0.51	0.66	0.58	0.45	0.40
9	0.64	0.59	0.92	0.84	1.16	1.09	1.32	1.30	2.35	2.41	2.20	2.78	1.88	2.06	1.21	1.33	1.06	0.93	0.63	0.54	0.71	0.63	0.51	0.47
10	0.62	0.58	0.86	0.78	1.11	1.02	1.49	1.32	2.55	2.57	1.95	2.48	1.58	1.83	0.65	0.73	1.27	1.12	0.78	0.69	0.72	0.66	0.50	0.47
11	0.58	0.52	0.79	0.72	1.01	0.92	1.21	1.14	2.50	2.24	2.18	2.26	1.86	1.75	1.17	1.10	0.96	0.86	0.59	0.53	0.64	0.58	0.43	0.39
12	0.58	0.53	0.80	0.75	1.02	0.95	1.22	1.18	2.47	2.32	2.18	2.33	1.85	1.77	1.14	1.11	0.95	0.87	0.58	0.54	0.64	0.59	0.43	0.41
13	0.62	0.58	0.89	0.80	1.17	1.06	1.55	1.33	2.77	2.56	2.39	2.52	2.01	1.86	0.81	0.75	1.31	1.15	0.83	0.72	0.74	0.68	0.51	0.48
14	0.59	0.55	0.85	0.78	1.09	1.01	1.27	1.21	2.47	2.34	2.36	2.64	1.99	1.85	1.14	1.11	0.95	0.87	0.56	0.51	0.64	0.59	0.46	0.43
15	0.63	0.60	1.01	0.89	1.35	1.22	1.79	1.60	3.76	3.30	3.82	3.06	3.45	2.48	1.39	0.98	1.46	1.29	1.00	0.89	0.82	0.75	0.55	0.53
16	0.62	0.59	0.89	0.81	1.16	1.06	1.54	1.35	2.74	2.63	2.39	2.52	2.00	1.83	0.80	0.75	1.29	1.16	0.82	0.72	0.74	0.68	0.51	0.48
17	0.59	0.57	0.86	0.84	1.12	1.11	1.32	1.37	2.51	2.64	2.56	3.19	2.21	2.21	1.15	1.21	0.96	0.92	0.56	0.55	0.63	0.61	0.46	0.45
18	0.56	0.52	0.85	0.80	1.13	1.07	1.46	1.39	2.60	2.65	1.93	2.45	1.50	1.71	0.38	0.50	1.13	1.02	0.57	0.52	0.56	0.51	0.44	0.40
19	0.62	0.58	0.87	0.77	1.13	1.02	1.47	1.26	2.55	2.35	2.03	2.31	1.65	1.63	0.68	0.68	1.30	1.13	0.80	0.69	0.73	0.66	0.51	0.47
20	0.62	0.58	0.86	0.78	1.12	1.02	1.53	1.36	2.64	2.62	2.01	2.31	1.64	1.66	0.67	0.71	1.29	1.15	0.79	0.70	0.72	0.66	0.50	0.47
21	0.58	0.56	0.94	0.88	1.24	1.19	1.80	1.80	3.29	3.56	2.38	2.60	1.89	1.83	0.62	0.67	1.28	1.19	0.76	0.74	0.63	0.60	0.47	0.45
22	0.56	0.53	0.90	0.81	1.20	1.08	1.80	1.57	3.46	2.97	3.02	2.44	2.49	1.81	0.81	0.62	1.23	1.13	0.72	0.64	0.60	0.56	0.44	0.42
23	0.58	0.55	0.94	0.89	1.25	1.20	1.87	1.80	3.65	3.59	3.07	2.86	2.49	2.07	0.80	0.71	1.25	1.16	0.76	0.74	0.63	0.60	0.46	0.45
24	0.58	0.55	0.90	0.86	1.18	1.15	1.80	1.80	3.08	3.40	2.20	2.39	1.71	1.74	0.50	0.54	1.23	1.14	0.70	0.69	0.61	0.58	0.45	0.43
25	0.58	0.54	0.89	0.83	1.16	1.09	1.74	1.69	2.84	3.09	2.10	2.39	1.53	1.70	0.43	0.49	1.22	1.10	0.68	0.65	0.60	0.56	0.45	0.42
26	0.57	0.53	0.84	0.79	1.09	1.04	1.71	1.67	2.59	2.91	1.96	2.11	1.43	1.52	0.37	0.42	1.19	1.07	0.63	0.60	0.57	0.54	0.43	0.41
27	0.58	0.54	0.89	0.82	1.15	1.09	1.68	1.63	2.73	2.76	2.12	2.24	1.58	1.66	0.51	0.55	1.24	1.11	0.69	0.66	0.60	0.57	0.45	0.43
28	0.58	0.55	0.92	0.85	1.23	1.13	1.94	1.81	3.83	3.51	2.86	2.34	2.31	1.76	0.77	0.58	1.23	1.15	0.73	0.67	0.62	0.57	0.45	0.43
29	0.56	0.53	0.86	0.79	1.12	1.04	1.80	1.73	3.01	3.14	1.91	2.14	1.54	1.58	0.42	0.51	1.20	1.08	0.66	0.60	0.58	0.54	0.43	0.41

Table 43. Sub-basin daily average surface runoff results by month (in millimeters of H_2O) for the STATSGO (STAT) and SSURGO (SSUR) models of the Upper Sabinal River watershed.

Sub-basin	January		February		March		April		May		June		July		August		September		October		November		December	
	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR
1	0.14	0.10	0.54	0.43	0.82	0.69	0.39	0.24	0.73	0.59	0.16	0.08	0.42	0.27	0.23	0.20	1.82	1.61	0.48	0.35	0.17	0.12	0.87	0.75
2	0.14	0.10	0.54	0.46	0.82	0.70	0.39	0.24	0.72	0.57	0.15	0.07	0.42	0.27	0.22	0.21	1.80	1.66	0.48	0.37	0.16	0.12	0.86	0.75
3	0.15	0.09	0.60	0.40	0.85	0.64	0.42	0.22	0.75	0.54	0.19	0.08	0.49	0.24	0.26	0.19	1.88	1.49	0.52	0.32	0.18	0.10	0.87	0.69
4	0.14	0.09	0.59	0.44	0.84	0.69	0.41	0.24	0.73	0.56	0.18	0.08	0.47	0.24	0.25	0.20	1.87	1.61	0.52	0.36	0.18	0.11	0.86	0.73
5	0.46	0.34	0.77	0.61	1.14	0.89	0.40	0.23	0.95	0.67	0.57	0.33	0.49	0.33	0.00	0.01	1.16	0.93	0.52	0.26	1.02	0.83	2.40	2.23
6	0.47	0.36	0.79	0.63	1.16	0.90	0.41	0.24	0.99	0.70	0.59	0.35	0.50	0.35	0.01	0.01	1.18	0.96	0.53	0.28	1.03	0.85	2.41	2.25
7	0.15	0.09	0.60	0.40	0.85	0.66	0.43	0.24	0.76	0.59	0.20	0.10	0.50	0.25	0.26	0.19	1.89	1.53	0.54	0.34	0.19	0.10	0.87	0.71
8	0.15	0.08	0.59	0.37	0.84	0.60	0.42	0.22	0.74	0.51	0.19	0.08	0.48	0.21	0.25	0.17	1.87	1.38	0.52	0.32	0.18	0.09	0.86	0.63
9	0.19	0.10	0.69	0.38	0.89	0.57	0.47	0.26	0.91	0.60	0.30	0.16	0.64	0.32	0.31	0.17	2.03	1.37	0.63	0.38	0.24	0.10	0.93	0.62
10	0.50	0.37	0.82	0.64	1.20	0.96	0.45	0.32	1.08	0.82	0.65	0.48	0.51	0.29	0.01	0.01	1.25	0.86	0.57	0.27	1.07	0.83	2.44	2.25
11	0.14	0.06	0.58	0.28	0.84	0.55	0.41	0.15	0.72	0.49	0.17	0.05	0.46	0.19	0.24	0.15	1.86	1.32	0.51	0.24	0.19	0.07	0.86	0.64
12	0.15	0.07	0.59	0.29	0.84	0.56	0.42	0.17	0.74	0.52	0.18	0.06	0.47	0.21	0.25	0.15	1.89	1.35	0.53	0.27	0.18	0.07	0.87	0.66
13	0.46	0.36	0.78	0.62	1.13	0.94	0.42	0.32	0.99	0.83	0.67	0.51	0.43	0.28	0.01	0.01	1.10	0.87	0.49	0.27	0.97	0.82	2.41	2.21
14	0.17	0.10	0.61	0.40	0.84	0.65	0.42	0.28	0.81	0.64	0.23	0.14	0.54	0.29	0.28	0.19	1.93	1.53	0.57	0.41	0.21	0.11	0.89	0.68
15	0.35	0.24	0.64	0.43	0.89	0.75	0.31	0.30	0.62	0.73	0.77	0.64	0.09	0.20	0.01	0.01	0.66	0.72	0.25	0.26	0.62	0.63	2.29	1.77
16	0.46	0.34	0.78	0.60	1.13	0.93	0.42	0.33	1.00	0.81	0.67	0.50	0.43	0.27	0.01	0.01	1.11	0.86	0.50	0.27	0.97	0.80	2.41	2.19
17	0.15	0.08	0.56	0.33	0.79	0.61	0.38	0.29	0.77	0.64	0.22	0.15	0.49	0.26	0.26	0.16	1.87	1.41	0.55	0.40	0.18	0.09	0.87	0.64
18	0.37	0.29	0.61	0.45	0.48	0.33	0.32	0.18	0.36	0.28	0.16	0.10	0.81	0.60	0.01	0.01	0.46	0.21	0.53	0.29	0.60	0.41	0.75	0.58
19	0.51	0.38	0.83	0.66	1.21	0.97	0.47	0.32	1.13	0.86	0.67	0.49	0.54	0.32	0.01	0.01	1.24	0.92	0.56	0.29	1.07	0.85	2.45	2.26
20	0.48	0.35	0.79	0.62	1.16	0.94	0.42	0.30	1.01	0.75	0.61	0.42	0.50	0.30	0.01	0.01	1.18	0.89	0.53	0.29	1.03	0.83	2.42	2.22
21	0.32	0.23	0.58	0.37	0.47	0.30	0.30	0.19	0.45	0.30	0.19	0.12	0.70	0.54	0.03	0.02	0.32	0.21	0.39	0.27	0.50	0.34	0.72	0.52
22	0.24	0.25	0.48	0.37	0.30	0.29	0.15	0.16	0.28	0.29	0.13	0.12	0.41	0.53	0.02	0.02	0.21	0.21	0.24	0.26	0.33	0.35	0.45	0.49
23	0.24	0.20	0.50	0.33	0.33	0.25	0.18	0.14	0.32	0.22	0.13	0.08	0.46	0.48	0.01	0.01	0.19	0.16	0.24	0.21	0.34	0.29	0.52	0.47
24	0.34	0.24	0.58	0.40	0.49	0.32	0.31	0.17	0.38	0.23	0.16	0.08	0.78	0.57	0.01	0.01	0.36	0.21	0.44	0.27	0.54	0.37	0.75	0.56
25	0.36	0.27	0.60	0.44	0.52	0.35	0.33	0.19	0.43	0.25	0.17	0.08	0.82	0.61	0.01	0.01	0.39	0.23	0.48	0.31	0.58	0.40	0.80	0.60
26	0.36	0.28	0.58	0.44	0.50	0.37	0.29	0.18	0.35	0.21	0.15	0.07	0.80	0.61	0.01	0.00	0.42	0.26	0.49	0.34	0.59	0.43	0.76	0.60
27	0.36	0.29	0.60	0.47	0.50	0.37	0.32	0.18	0.46	0.26	0.19	0.10	0.78	0.62	0.02	0.01	0.41	0.27	0.48	0.35	0.57	0.44	0.77	0.62
28	0.23	0.21	0.48	0.34	0.34	0.28	0.17	0.13	0.22	0.16	0.09	0.06	0.49	0.48	0.01	0.01	0.19	0.18	0.26	0.25	0.36	0.34	0.53	0.48
29	0.34	0.26	0.56	0.41	0.48	0.34	0.26	0.14	0.28	0.16	0.12	0.06	0.77	0.54	0.01	0.01	0.36	0.25	0.45	0.32	0.55	0.40	0.75	0.53

mean surface runoff (in millimeters) by month within each sub-basin for the two models of the Upper Sabinal River Watershed. An inequity in daily mean surface runoff for the two models at the 5% level of significance was found in all of the watershed sub-basins, with the exception of sub-basins 15 and 22. The SSURGO model produced lower surface in each of the sub-basins except sub-basin 22. The most likely explanation for the lower levels of surface runoff is the much higher presence of soils with hydrologic groups A, B. and C within the SSURGO model.

Percolation is the amount of water per sub-basin that moves past the root zone during the specified time step and is calculated for each soil layer in the soil profile (Neitsch et al., 2002). Table 44 presents the daily mean percolation (in millimeters) by month within each sub-basin for the two models of the Upper Sabinal River Watershed. At the 5% level of significance, there were no sub-basins where the daily mean percolation for the two models was found to be equivalent. The SSURGO model produced larger daily mean percolation values for all of the sub-basins, which is likely attributed to the presence of more soils with higher infiltration characteristics.

The groundwater return flow is the contribution to streamflow that returns to the reach from the shallow aquifer during the specified time step (Neitsch et al., 2002). Table 45 presents the daily mean groundwater return flow (in millimeters) by month within each sub-basin for the two models of the Upper Sabinal River Watershed. The daily mean groundwater return flow for the two models was found to be unequal in all of the sub-basins at the 5% level of significance. Daily mean groundwater return values were greater in each sub-basin with the SSURGO model. The higher saturated hydraulic

Table 44. Sub-basin daily average amount of water percolating out of the root zone by month (in millimeters of H_2O) for the STATSGO (STAT) and SSURGO (SSUR) models of the Upper Sabinal River watershed.

Sub-basin	January		February		March		April		May		June		July		August		September		October		November		December	
	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR
1	0.61	0.76	0.82	1.13	0.58	0.83	0.49	0.89	0.51	1.11	0.21	0.76	0.54	1.24	0.20	0.45	0.97	1.68	0.47	0.81	0.50	0.65	0.79	1.00
2	0.63	0.79	0.84	1.18	0.59	0.86	0.50	0.97	0.52	1.26	0.21	0.92	0.55	1.43	0.20	0.52	0.99	1.79	0.48	0.86	0.51	0.68	0.80	1.02
3	0.58	0.71	0.77	1.08	0.52	0.79	0.45	0.87	0.50	1.10	0.22	0.77	0.59	1.24	0.20	0.45	0.97	1.63	0.45	0.78	0.48	0.59	0.73	0.95
4	0.62	0.77	0.83	1.16	0.56	0.83	0.49	0.95	0.54	1.23	0.24	0.90	0.64	1.41	0.22	0.51	1.06	1.76	0.49	0.84	0.53	0.66	0.79	1.01
5	1.13	1.39	0.84	1.25	0.90	1.36	0.41	0.84	0.78	1.52	0.58	1.40	0.49	0.76	0.00	0.08	0.83	1.58	0.60	1.05	0.91	1.15	0.98	1.26
6	1.12	1.40	0.83	1.25	0.89	1.36	0.40	0.85	0.77	1.53	0.58	1.42	0.48	0.77	0.00	0.08	0.81	1.59	0.59	1.06	0.90	1.16	0.97	1.25
7	0.61	0.72	0.81	1.10	0.55	0.79	0.48	0.87	0.53	1.07	0.24	0.74	0.63	1.22	0.21	0.44	1.03	1.62	0.48	0.78	0.52	0.60	0.77	0.96
8	0.58	0.64	0.76	0.96	0.52	0.71	0.45	0.79	0.50	1.01	0.22	0.69	0.59	1.08	0.20	0.39	0.97	1.44	0.45	0.69	0.48	0.52	0.73	0.89
9	0.52	0.54	0.68	0.76	0.44	0.60	0.36	0.61	0.45	0.83	0.22	0.53	0.53	0.75	0.19	0.29	0.89	1.12	0.42	0.54	0.47	0.40	0.67	0.82
10	1.19	1.27	0.87	1.10	0.93	1.16	0.43	0.68	0.84	1.23	0.62	1.05	0.51	0.56	0.01	0.06	0.86	1.16	0.62	0.77	0.94	0.96	1.02	1.18
11	0.63	0.72	0.84	1.15	0.57	0.84	0.50	0.85	0.55	0.96	0.25	0.56	0.65	1.06	0.22	0.37	1.07	1.63	0.50	0.79	0.54	0.59	0.80	1.00
12	0.58	0.65	0.76	1.01	0.52	0.75	0.45	0.73	0.50	0.80	0.22	0.43	0.59	0.88	0.20	0.30	0.98	1.41	0.46	0.69	0.50	0.52	0.73	0.91
13	1.13	1.29	0.90	1.11	0.88	1.16	0.44	0.64	0.76	1.27	0.57	1.05	0.44	0.53	0.01	0.06	0.72	1.13	0.54	0.74	0.83	0.95	0.95	1.25
14	0.60	0.63	0.76	0.89	0.51	0.66	0.42	0.69	0.49	0.91	0.24	0.57	0.57	0.86	0.21	0.33	0.97	1.27	0.47	0.62	0.53	0.49	0.73	0.91
15	0.75	1.29	0.87	1.09	0.55	1.07	0.44	0.39	0.27	1.05	0.26	0.62	0.10	0.21	0.01	0.04	0.08	0.59	0.17	0.36	0.31	0.85	0.54	1.68
16	1.15	1.32	0.90	1.13	0.89	1.16	0.45	0.64	0.78	1.27	0.58	1.01	0.45	0.52	0.01	0.06	0.74	1.10	0.55	0.71	0.85	0.97	0.97	1.31
17	0.59	0.58	0.74	0.79	0.49	0.58	0.40	0.54	0.46	0.68	0.22	0.34	0.51	0.52	0.20	0.22	0.89	1.05	0.47	0.51	0.52	0.42	0.69	0.89
18	0.55	0.60	0.64	0.77	0.44	0.53	0.34	0.49	0.44	0.57	0.14	0.26	0.51	0.58	0.00	0.04	0.46	0.55	0.42	0.47	0.36	0.40	0.61	0.68
19	1.15	1.29	0.84	1.13	0.88	1.19	0.41	0.71	0.81	1.32	0.59	1.15	0.49	0.61	0.01	0.07	0.80	1.25	0.57	0.82	0.89	0.98	0.98	1.20
20	1.24	1.34	0.92	1.15	0.98	1.24	0.45	0.69	0.87	1.28	0.65	1.10	0.53	0.61	0.00	0.05	0.90	1.23	0.65	0.83	0.99	1.03	1.07	1.27
21	0.39	0.49	0.46	0.69	0.30	0.40	0.17	0.27	0.23	0.34	0.06	0.09	0.19	0.27	0.00	0.00	0.15	0.21	0.17	0.24	0.21	0.29	0.42	0.78
22	0.39	0.59	0.52	0.79	0.36	0.47	0.21	0.40	0.24	0.59	0.10	0.27	0.19	0.43	0.00	0.04	0.19	0.47	0.19	0.35	0.17	0.35	0.31	0.73
23	0.33	0.50	0.45	0.70	0.29	0.41	0.16	0.27	0.17	0.36	0.06	0.11	0.11	0.24	0.00	0.00	0.08	0.22	0.11	0.25	0.14	0.27	0.29	0.71
24	0.44	0.52	0.54	0.70	0.36	0.51	0.21	0.33	0.30	0.36	0.08	0.11	0.34	0.41	0.00	0.01	0.29	0.32	0.28	0.36	0.27	0.36	0.53	0.78
25	0.46	0.52	0.54	0.66	0.36	0.50	0.22	0.35	0.33	0.42	0.09	0.14	0.38	0.42	0.00	0.01	0.32	0.37	0.30	0.36	0.29	0.35	0.55	0.71
26	0.53	0.55	0.62	0.70	0.44	0.55	0.27	0.38	0.40	0.46	0.12	0.15	0.49	0.52	0.00	0.02	0.44	0.46	0.40	0.42	0.33	0.40	0.61	0.73
27	0.49	0.57	0.56	0.72	0.37	0.53	0.24	0.39	0.36	0.53	0.11	0.20	0.37	0.47	0.00	0.02	0.34	0.47	0.31	0.42	0.28	0.39	0.54	0.71
28	0.33	0.55	0.49	0.76	0.34	0.53	0.18	0.35	0.19	0.37	0.05	0.12	0.19	0.45	0.00	0.01	0.15	0.35	0.17	0.36	0.19	0.38	0.36	0.83
29	0.52	0.63	0.61	0.82	0.44	0.61	0.27	0.42	0.37	0.48	0.11	0.17	0.45	0.59	0.01	0.02	0.40	0.52	0.37	0.46	0.34	0.43	0.62	0.82

Table 45. Sub-basin daily average groundwater discharge in the reach by month (in millimeters of H_2O) for the STATSGO (STAT) and SSURGO (SSUR) models of the Upper Sabinal River watershed.

Sub-basin	January		February		March		April		May		June		July		August		September		October		November		December	
	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR	STAT	SSUR
1	0.48	0.64	0.63	0.82	0.68	0.89	0.53	0.77	0.49	0.86	0.43	0.93	0.25	0.76	0.35	0.83	0.37	0.83	0.52	0.97	0.54	0.92	0.48	0.70
2	0.49	0.66	0.64	0.85	0.69	0.92	0.54	0.81	0.50	0.92	0.44	1.05	0.26	0.90	0.36	0.96	0.38	0.95	0.54	1.06	0.55	0.98	0.49	0.73
3	0.45	0.61	0.59	0.78	0.63	0.84	0.48	0.73	0.45	0.83	0.41	0.93	0.26	0.77	0.37	0.83	0.40	0.83	0.53	0.95	0.53	0.88	0.46	0.66
4	0.49	0.65	0.64	0.84	0.68	0.91	0.52	0.79	0.49	0.90	0.45	1.03	0.28	0.88	0.40	0.94	0.43	0.93	0.58	1.05	0.58	0.96	0.51	0.72
5	0.68	0.92	0.90	1.18	0.87	1.17	0.75	1.12	0.61	1.10	0.53	1.13	0.47	1.03	0.37	0.75	0.30	0.63	0.47	0.94	0.62	1.05	0.69	1.00
6	0.68	0.92	0.89	1.18	0.86	1.17	0.75	1.12	0.61	1.10	0.53	1.14	0.47	1.04	0.37	0.76	0.30	0.64	0.46	0.94	0.61	1.06	0.68	1.01
7	0.48	0.62	0.63	0.79	0.67	0.85	0.51	0.74	0.48	0.83	0.44	0.91	0.28	0.75	0.39	0.81	0.42	0.81	0.57	0.94	0.56	0.88	0.50	0.67
8	0.45	0.57	0.59	0.72	0.62	0.76	0.48	0.67	0.45	0.75	0.41	0.84	0.26	0.69	0.37	0.73	0.39	0.73	0.53	0.84	0.53	0.78	0.46	0.59
9	0.41	0.51	0.54	0.62	0.56	0.63	0.41	0.55	0.38	0.60	0.36	0.67	0.24	0.53	0.34	0.52	0.36	0.52	0.48	0.64	0.49	0.61	0.43	0.48
10	0.71	0.82	0.95	1.07	0.91	1.04	0.78	0.98	0.64	0.91	0.57	0.91	0.51	0.79	0.40	0.56	0.32	0.46	0.49	0.69	0.65	0.79	0.72	0.81
11	0.49	0.64	0.65	0.80	0.69	0.86	0.52	0.76	0.50	0.83	0.46	0.82	0.29	0.62	0.41	0.70	0.44	0.73	0.59	0.91	0.59	0.87	0.51	0.70
12	0.45	0.57	0.59	0.72	0.62	0.77	0.48	0.67	0.45	0.72	0.41	0.68	0.26	0.49	0.37	0.58	0.40	0.60	0.53	0.77	0.54	0.75	0.47	0.61
13	0.66	0.85	0.90	1.11	0.89	1.06	0.78	0.98	0.63	0.91	0.54	0.92	0.47	0.79	0.35	0.54	0.27	0.45	0.42	0.67	0.56	0.77	0.64	0.80
14	0.47	0.57	0.61	0.70	0.64	0.73	0.48	0.63	0.43	0.67	0.41	0.74	0.27	0.58	0.36	0.60	0.39	0.60	0.53	0.73	0.55	0.70	0.49	0.55
15	0.37	0.97	0.59	1.22	0.69	1.10	0.62	0.96	0.46	0.76	0.31	0.71	0.22	0.50	0.10	0.27	0.05	0.20	0.08	0.32	0.13	0.43	0.24	0.66
16	0.67	0.87	0.91	1.13	0.90	1.08	0.79	0.99	0.64	0.91	0.56	0.91	0.48	0.77	0.36	0.52	0.28	0.43	0.43	0.65	0.57	0.75	0.65	0.81
17	0.46	0.53	0.60	0.65	0.62	0.66	0.47	0.55	0.42	0.55	0.38	0.54	0.25	0.37	0.33	0.38	0.36	0.40	0.50	0.56	0.52	0.57	0.47	0.48
18	0.36	0.41	0.53	0.60	0.52	0.60	0.44	0.52	0.41	0.52	0.32	0.47	0.20	0.31	0.27	0.32	0.20	0.27	0.29	0.37	0.34	0.39	0.34	0.38
19	0.68	0.84	0.91	1.09	0.88	1.06	0.76	1.00	0.62	0.95	0.55	0.97	0.49	0.86	0.38	0.60	0.30	0.50	0.46	0.74	0.60	0.84	0.68	0.85
20	0.75	0.87	0.99	1.14	0.96	1.11	0.84	1.03	0.68	0.95	0.60	0.94	0.53	0.82	0.42	0.59	0.33	0.49	0.52	0.73	0.68	0.84	0.75	0.87
21	0.24	0.40	0.37	0.57	0.37	0.53	0.30	0.42	0.23	0.35	0.16	0.24	0.09	0.13	0.11	0.15	0.07	0.09	0.10	0.13	0.14	0.20	0.18	0.26
22	0.20	0.41	0.33	0.62	0.39	0.60	0.35	0.50	0.27	0.46	0.19	0.44	0.12	0.32	0.11	0.26	0.08	0.22	0.12	0.30	0.15	0.31	0.16	0.33
23	0.18	0.37	0.30	0.56	0.34	0.53	0.29	0.43	0.21	0.36	0.13	0.26	0.08	0.14	0.07	0.14	0.04	0.09	0.06	0.14	0.09	0.20	0.12	0.25
24	0.30	0.42	0.44	0.58	0.43	0.56	0.36	0.48	0.29	0.40	0.20	0.28	0.13	0.17	0.18	0.22	0.13	0.15	0.17	0.21	0.22	0.28	0.24	0.33
25	0.31	0.39	0.46	0.55	0.44	0.53	0.36	0.47	0.30	0.41	0.22	0.32	0.14	0.19	0.19	0.23	0.14	0.17	0.20	0.24	0.24	0.29	0.26	0.32
26	0.35	0.41	0.52	0.58	0.50	0.56	0.43	0.51	0.37	0.45	0.28	0.35	0.18	0.22	0.25	0.27	0.20	0.21	0.27	0.30	0.32	0.34	0.32	0.36
27	0.31	0.41	0.46	0.59	0.45	0.58	0.38	0.50	0.32	0.46	0.25	0.40	0.15	0.24	0.20	0.26	0.15	0.21	0.21	0.30	0.25	0.34	0.26	0.36
28	0.21	0.45	0.32	0.63	0.37	0.60	0.32	0.51	0.24	0.43	0.14	0.29	0.08	0.18	0.10	0.23	0.07	0.17	0.09	0.23	0.13	0.29	0.16	0.35
29	0.35	0.47	0.51	0.66	0.50	0.65	0.43	0.58	0.36	0.50	0.26	0.38	0.17	0.25	0.23	0.31	0.18	0.25	0.25	0.34	0.29	0.38	0.31	0.40

conductivity values associated with the SSURGO database would have contributed to higher groundwater return flow values.

Summary

This paper presents the design and implementation of a SSURGO 2.x database pre-processor extension for the ArcView SWAT model. The extension allows for the integration of SSURGO 2.x database files into new or currently existing ArcView SWAT models. A case study for the Upper Sabinal River Watershed was developed to illustrate the basic effects that SSURGO database information may have on hydrologic modeling. Results indicated that the SSURGO model produced a greater daily mean water yield each month for the Upper Sabinal River Watershed. Evapotranspiration and surface runoff were found to be consistently lower across the watershed using the SSURGO database information. The higher water yield values are attributed to the higher percolation and resulting groundwater return flow values. Significantly larger saturated hydraulic conductivity values associated with the SSURGO soils data are the likely reason for the increased water yield. A further systematic analysis is needed to assess additional factors, such as the effects of sub-basin size, the spatial correlation between soil type and land cover, and other uncertainties associated with the SSURGO database information within the ArcView SWAT model.

CHAPTER V

IDENTIFYING URBANIZING WATERSHEDS

A complete characterization of the term 'urbanization' often cannot be fully realized through land cover analysis alone. Other factors, such as population and land use, implicitly contribute towards and modify underlying numerical values that may be assigned to urbanizing areas. For example, consider the land cover classification of a rooftop within a satellite image. Performed correctly, this landscape element will be classified as an impervious surface. However, this categorization says nothing about the human-related attributes of the impervious surface itself. The impervious surface could be a single-family dwelling or a multi-story apartment building containing ten families. The impacts on certain ecological parameters, such as water demand, would likely be greater if the impervious surface were associated with the multi-story apartment versus the single-family unit. It is therefore necessary to integrate additional information to better refine the numerical values assigned to identify urbanizing watersheds.

Background

Several studies using only remotely-sensed satellite imagery have attempted to provide various relative indices of urbanization. Kayayama et al. (2001) proposed that an urban index could be defined using a difference ratio of Landsat Thematic Mapper (TM) satellite imagery. The Kayayama index is calculated using the following expression

$$TMI = \frac{B7 - B4}{B7 + B4} \tag{6}$$

where TMI is the urban index value, B7 is the TM thermal image band, and B4 is the TM infrared image band. This index makes no distinction between land cover classes and also does not include ancillary data sources. The Kayayama index could be used when impervious surfaces have already been identified and masked, to provide a relative degree of imperviousness based simply on passive reflectance, or when other ancillary data is not available. Another similar index by Zha et al. (2003), called the normalized differential built-up index (NDBI), uses the same type of TM difference ratio, but uses the TM mid-infrared image band 5 instead of the TM thermal image band 7. This method is again successful at identifying built-up and urban areas relative to other land cover within the image, but no other context is provided. A more specific method of identifying urban extent is using the percentage of impervious surfaces within a watershed. DeWalle et al. (2000) and Gillies et al. (2003) used impervious surface area to characterize urbanization for understanding potential effects on climate change and water quality issues, respectively. In both cases, the percentage of impervious surface area was shown to be a good predictor of urban growth and impact. Other studies have focused on population and other traditional socioeconomic parameters, such as household income, to calculate an index of urbanization (Alig et al., 2004). A hybrid method incorporating remote sensing and population information was developed by Qiu et al. (2003). The researchers used classified Landsat imagery with U.S. Census population and Topologically Integrated Geographic Encoding and Referencing (TIGER) road information to characterize urbanization within the Dallas-Fort Worth metropolitan area of Texas. Given the data available for this project, a combined method using existing urban area identification techniques was developed.

Methods

The procedure developed for identifying urbanizing watersheds within the Edwards Aquifer contributing and recharge zones involves two parameters: the percentage of impervious surfaces, and population density. Impervious surfaces present the greatest human-related influence within the watershed. From a strictly hydrologic perspective, impervious surfaces result in higher surface runoff volume and reduced infiltration. At the same time, wildlife habitats are essentially removed and carbon sequestration is mitigated. From the results of Chapter 3, a historic record of the extent of impervious surfaces within the Edwards Aquifer contributing and recharge zones was available. Tables 46 and 47 present the percentages of impervious surface area for each watershed contributing and recharge zone of the Edwards Aquifer, respectively. An advantage to using the percentage of impervious surface area for each watershed contributing and

Table 46. Percentage of impervious surface area in the Edwards Aquifer watershed contributing zones from 1986 through 2000.

Watershed Name	1986 (%)	1993 (%)	2000 (%)
Austin-Travis Lakes	7	7	8
San Marcos	4	4	6
Upper San Antonio	9	11	14
Middle Guadalupe	6	6	8
Cibolo	5	5	5
Upper Guadalupe	4	4	4
Medina	4	4	5
Hondo	1	1	1
Upper Frio	2	2	2
Nueces Headwaters	1	1	1
West Nueces	1	1	1

Table 47. Percentage of impervious surface area in the Edwards Aquifer watershed recharge zones from 1986 through 2000.

Watershed Name	1986 (%)	1993 (%)	2000 (%)
Austin-Travis Lakes	11	12	16
San Marcos	3	3	4
Upper San Antonio	17	20	33
Middle Guadalupe	5	5	8
Cibolo	2	2	3
Medina	6	6	6
Hondo	1	1	1
Upper Frio	1	1	1
Nueces Headwaters	1	1	1
Upper Nueces	0	0	1
West Nueces	1	2	2

recharge zones is that the set of possible values is fixed within the range of 0 through 100. Population is often used to characterize the demands and impacts on different ecological parameters. Population as a value by itself is not an extensive property; therefore population density was used as the measure of interest. U.S. Census data values were obtained for each state boundary that overlays the Edwards aquifer contributing and recharge zones (U.S. Census Bureau, 1980; 1990; 2000). The corresponding county area was used to divide each county population value for 1986, 1993, and 2000. ArcView GIS was used to determine the area of intersection for each watershed contributing and recharge zone with each county. The individual areas were converted to fractions of each watershed contributing and recharge zone, and were then used as population density weighting factors. Since two of the observation points do not correspond to the census dates, an interpolation procedure was needed. There are several numerical methods in existence to interpolate intermediate points within a data set. The spline procedure was used in the Matlab program to interpolate the population density values for 1986 and 1993. The spline procedure gives a smoother approximation than standard linear interpolation. The final result was a weighted population density value for each watershed contributing and recharge zone at each of the observation points. Tables 48 and 49 present the population density values for the watershed contributing and recharge zones.

Table 48. Population density values for the Edwards Aquifer watershed contributing zones from 1986 through 2000.

Watershed Name	1986 (persons/km^2)	1993 (persons/km^2)	2000 (persons/km^2)
Austin-Travis Lakes	83.21	107.36	137.60
San Marcos	16.14	21.69	28.61
Upper San Antonio	340.17	383.58	428.64
Middle Guadalupe	29.94	39.51	52.64
Cibolo	88.88	102.88	119.09
Upper Guadalupe	12.50	15.53	19.43
Medina	47.44	54.42	62.31
Hondo	5.39	6.86	9.18
Upper Frio	3.09	3.59	4.41
Nueces Headwaters	1.70	1.79	1.97
West Nueces	0.60	0.64	0.64

Table 49. Population density values for the Edwards Aquifer watershed recharge zones from 1986 through 2000.

Watershed Name	1986 (persons/km^2)	1993 (persons/km^2)	2000 (persons/km^2)
Austin-Travis Lakes	100.26	128.68	164.54
San Marcos	31.61	42.78	56.19
Upper San Antonio	340.17	383.58	428.64
Middle Guadalupe	29.92	39.51	52.64
Cibolo	194.30	221.80	251.84
Medina	170.01	192.03	215.43
Hondo	7.15	8.69	11.34
Upper Frio	5.64	5.93	6.42
Nueces Headwaters	5.64	5.93	6.42
Upper Nueces	5.64	5.93	6.42
West Nueces	2.63	2.81	3.01

After both input parameters are developed, they are combined through the following expression for each observation point

$$UI = (ISA)(PD) \tag{7}$$

where UI is the normalized urban index between 0 and 100 in persons per square kilometer for the watershed area of interest, ISA is the fractional percentage of impervious surface area, and PD is the corresponding population density. This calculation was carried out for each Edwards Aquifer watershed contributing and recharge zone to identify areas relative to each other that may be experiencing urbanization. It essentially provides the effective population density value for each watershed zone in the region.

Results and Discussion

Graphical results of the calculations at each observation point are presented in Figures 80 through 82. The actual numerical results of the urbanizing watershed identification procedure are given in Tables 50 and 51. As can be seen in Figure 80, the darker areas indicate greater effective population density and thus, urbanization in 1986 can generally be found in the upper northeast portion of the aquifer. The San Antonio-Austin Interstate 35 corridor is clearly defined within the 1986 results. The watershed areas of greatest urbanization in 1986 are the Upper San Antonio watershed contributing and recharge zones. Following these two zones are the Austin-Travis Lakes watershed contributing and recharge zones, the Cibolo watershed contributing zone, and the Medina watershed recharge zone. Watersheds least urbanized are the Hondo watershed contributing zone and all of the watershed zones westward. The 1993 results (Figure 81)

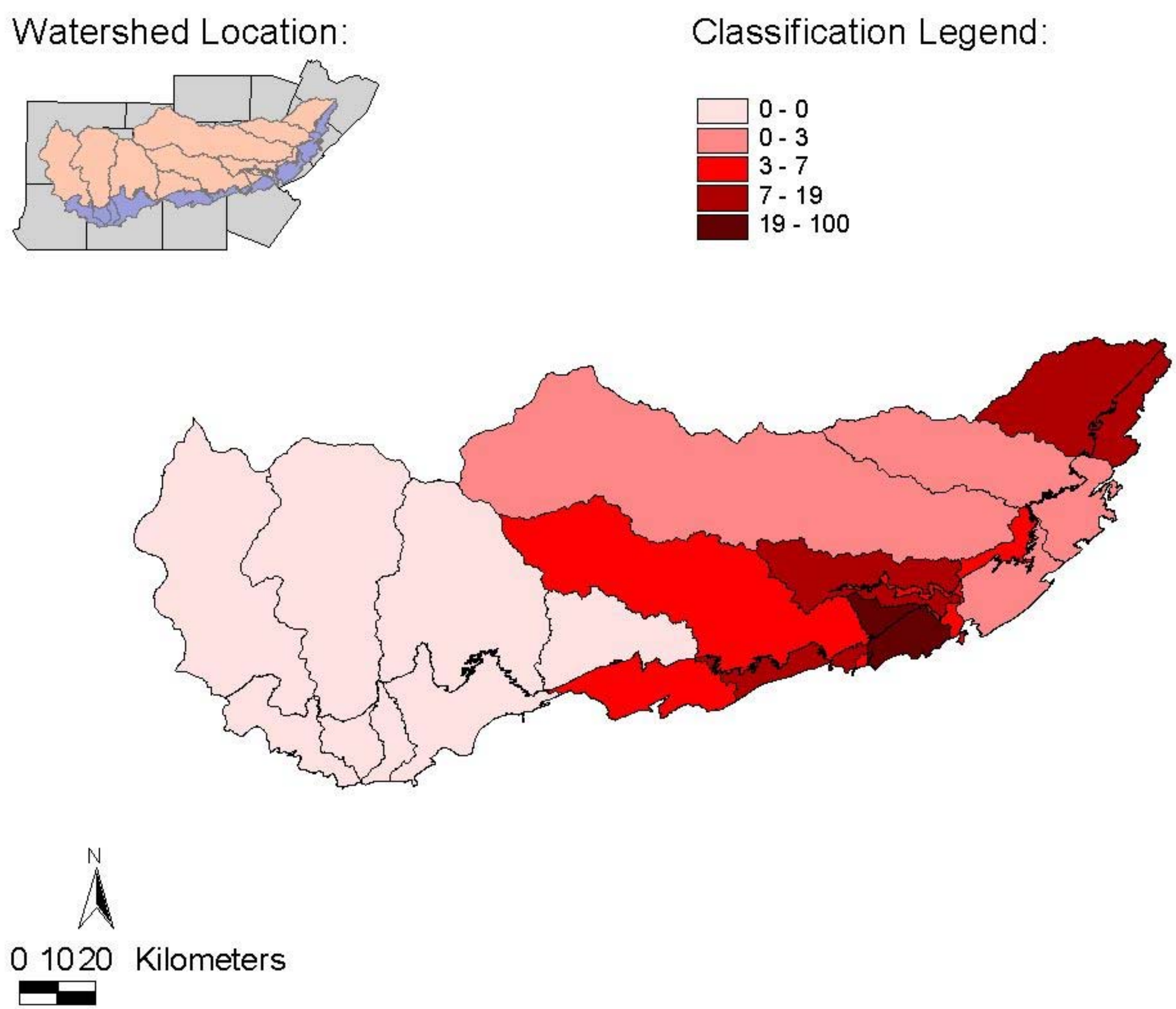

Figure 80. 1986 urban index for the Edwards Aquifer region.

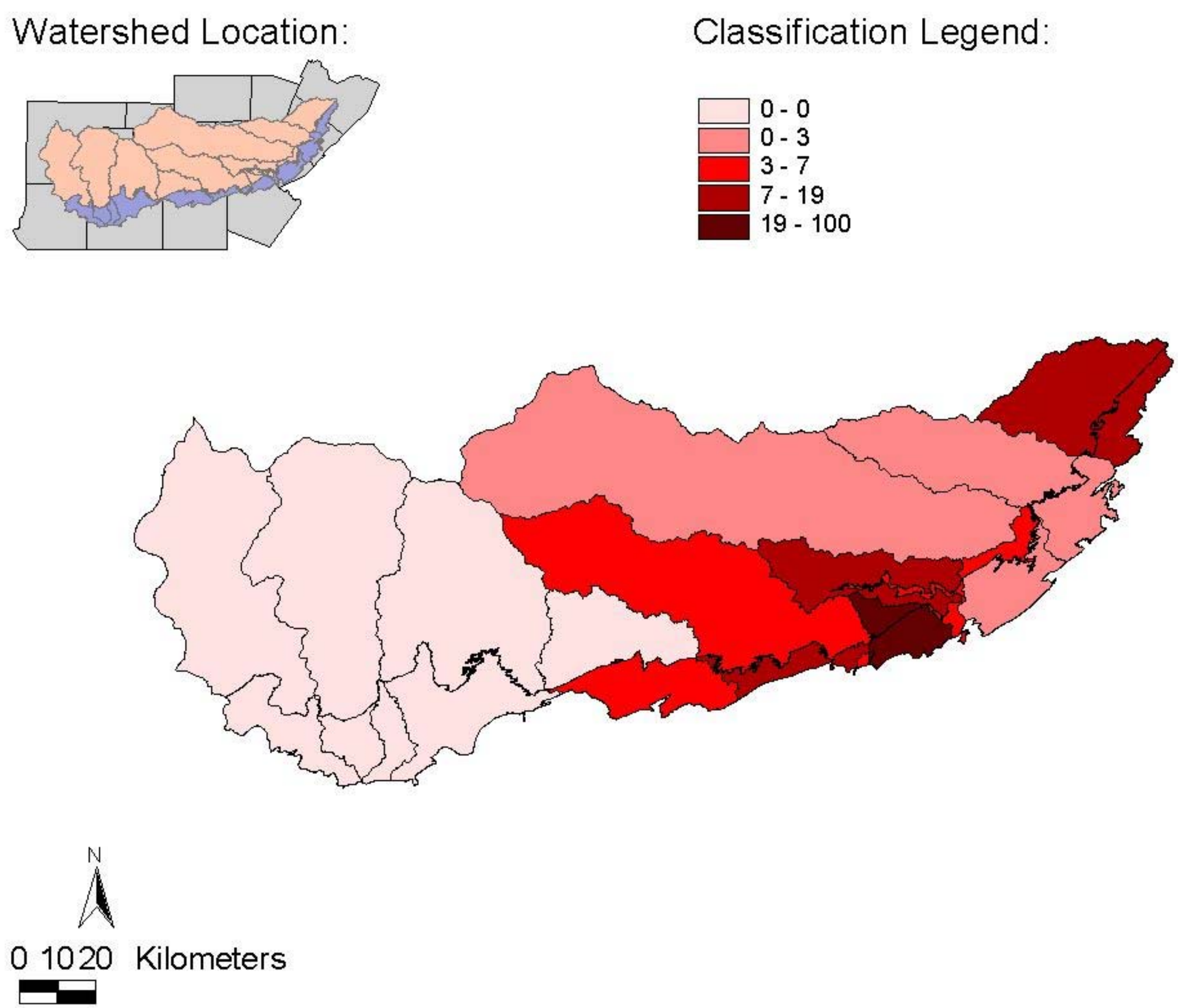

Figure 81. 1993 urban index for the Edwards Aquifer region.

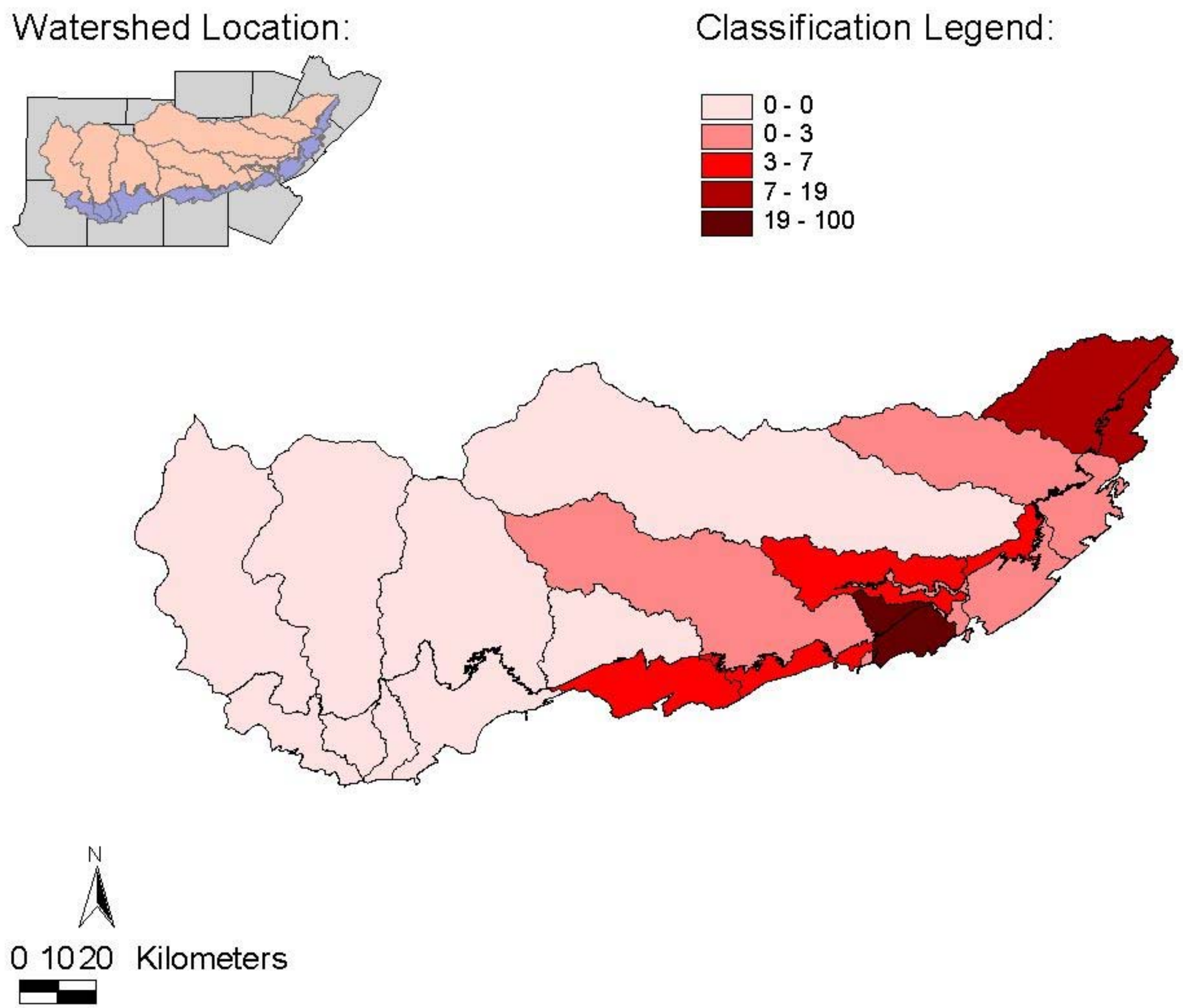

Figure 82. 2000 urban index for the Edwards Aquifer region.

Table 50. Normalized urbanizing watershed index for the Edwards Aquifer watershed contributing zones from 1986 through 2000.

Watershed Name	1986	1993	2000
Austin-Travis Lakes	19.03	17.81	18.34
San Marcos	2.11	2.06	2.86
Upper San Antonio	100.00	100.00	100.00
Middle Guadalupe	5.87	5.62	7.02
Cibolo	14.52	12.19	9.92
Upper Guadalupe	1.63	1.47	1.30
Medina	6.20	5.16	5.19
Hondo	0.18	0.16	0.15
Upper Frio	0.20	0.17	0.15
Nueces Headwaters	0.06	0.02	0.03
West Nueces	0.02	0.02	0.01

Table 51. Normalized urbanizing watershed index for the Edwards Aquifer watershed recharge zones from 1986 through 2000.

Watershed Name	1986	1993	2000
Austin-Travis Lakes	19.07	20.13	18.61
San Marcos	1.64	1.67	1.59
Upper San Antonio	100.00	100.00	100.00
Middle Guadalupe	2.59	2.58	2.98
Cibolo	6.72	5.78	5.34
Medina	17.64	15.02	9.14
Hondo	7.15	8.69	11.34
Upper Frio	0.10	0.08	0.05
Nueces Headwaters	0.10	0.08	0.05
Upper Nueces	0.00	0.00	0.05
West Nueces	0.05	0.07	0.04

indicate the exact same graphical findings as the 1986 urbanization index. Numerically, the values are approximately the same, though no predictable patterns are present in the data (Tables 50 and 51). The 2000 urbanization index results (Figure 82) show the Upper San Antonio and Austin-Travis Lakes watershed contributing and recharge zones as the highest relative concentration areas of urbanization. The likely reason for this graphical shift is that much larger populations developed within these two watershed contributing and recharge zones, such that the relative index values become skewed.

Summary

Quantifying urbanization using impervious surface area and population density to provide a relative impact indicator for current and future watershed studies was the focus of this chapter. The results showed that the Upper San Antonio and Austin-Travis Lakes watershed contributing and recharge zones should be of primary concern to investigators who monitor ecological parameters, such as wildlife habitat, carbon sequestration and water availability. The types of ecological parameters most affected through change by impervious surfaces and population increases can be pared down to those present within the watershed areas identified though this procedure.

CHAPTER VI

CONCLUSIONS

The purpose of this project was to characterize the land cover in a semi-arid region, specifically, the Edwards Aquifer contributing and recharge zones of Texas. Currently available land cover data sets were evaluated and deemed not sufficient for temporal land cover analyses. Remotely-sensed Landsat satellite imagery data from 1986 through 2000 were obtained, and land cover was classified, for the Edwards Aquifer contributing and recharge zones. Urbanization between 1986 and 2000, through the growth of impervious surface area, increased in the contributing zone by almost 20%, with an approximate 50% increase identified within the recharge zone. Likewise, grassland was found to decrease by 18% in the contributing zone and by 20% in the recharge zone. This information, coupled with the increase of forestland by 16% in the contributing zone and 10% in the recharge zone, would indicate that mixed land cover development through woody plant encroachment was observed to have taken place between 1986 and 2000. Further studies would be required to indicate the mixed cover compositions and extent of individual vegetation species. The final land cover products provide a historical land cover record for the Edwards Aquifer contributing and recharge zones between 1986 and 2000, with a greater overall accuracy than any publicly available land cover data set.

Soils represent a fundamental abiotic parameter in defining the characteristics of an ecosystem. They serve as a necessary compliment to land cover data when modeling is considered. The United States Department of Agriculture (USDA) Natural Resources

Conservation Service (NRCS) produces the most detailed digital spatial soil data sets that are publicly available. The Soil Survey Geographic (SSURGO) database contains basic attributes for the continuous coverage of soils across the United States. In its standard format, the SSURGO database is incompatible for use within the ArcView Soil and Water Assessment Tool (SWAT). A modified version of the State Soil and Geographic (STATSGO) database is the template soils data set used by ArcView SWAT. This project defined the design methodology and development of a SSURGO database pre-processor extension for the ArcView SWAT model. A case study for the Upper Sabinal River watershed near Uvalde, Texas was performed. Results indicated that hydrologic output parameter differences did occur when using the STATSGO and SSURGO database information in the ArcView SWAT model under identical modeling conditions. Further studies are necessary to determine the extent of soil data set resolution influence within the output parameters of the ArcView SWAT model.

A numerically indexed identification method for urbanizing areas within the Edwards Aquifer contributing and recharge zones was developed. Results indicated that the Upper San Antonio watershed contributing and recharge zones that intersect with the northern portion of the city of San Antonio possessed the highest levels of urbanization relative to the entire region. The Austin-Travis Lakes watershed contributing and recharge zones were almost at the same levels of urbanization. Watersheds to the west of the Hondo watershed ranked consistently as the least urbanized. This method presents investigators with a technique to prioritize ecological parameter studies within a large region, such as the Edwards Aquifer contributing and recharge zones.

While the results of this project provide some advances in the quantitative understanding of landscape elements within the Edwards Aquifer contributing and recharge zones, several adjacent research questions are identified. Among these adjacent research questions, the following three should be considered and pursued:

1) To what extent is it possible to identify specific woody plant species within the results of this project using ancillary ecological signals, such as precipitation and streamflow? Correlating growth patterns identified within remotely-sensed satellite imagery with ecological signals may allow for further discernment of individual species within areas classified as forestland.

2) How sensitive are the individual hydrologic output parameters of the ArcView SWAT model to changes in soil data set resolution? Certain hydrologic output parameters, such as groundwater flow, may be much more sensitive to the use of SSURGO database information versus STATSGO database information.

3) To what extent can the effective population density for a watershed be used to estimate future urbanization within the Edwards Aquifer contributing and recharge zones? Since effective population takes into account the percentage of impervious surfaces within a watershed, it may be a viable parameter for urban growth prediction.

Addressing the results of this project and providing solutions to the proposed research questions will allow investigators to further understand the ecological parameters within the Edwards Aquifer contributing and recharge zones. Additional studies may aid policy development and promote the design of improved sustainable systems involving human development within the region.

REFERENCES

Abuelgasim, A. A., W. D. Ross, S. Gopal and C. E. Woodcock. 2002. Mapping forest post-fire canopy consumption in several overstory types using multi-temporal Landsat TM and ETM data. *Remote Sensing of Environment* 82(2-3): 481-496.

Afinowicz, J. D., C. L. Munster and B. P. Wilcox. 2003. Verification of a methodology for targeting brush control to maximize water yield through hydrologic modeling. ASAE Paper No. 032121. Las Vegas, Nevada: American Society of Agricultural Engineers.

Alig, R. J., J. D. Kline and M. Lichtenstein. 2004. Urbanization on the US landscape: looking ahead in the 21st century. *Landscape and Urban Planning* 69(2-3): 219-234.

Anderson, J. R., E. E. Hardy, J. T. Roach and R. E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. Geological Survey Professional Paper No. 964. Washington D.C.: United States Geological Survey.

Arrington, D. R., J. R. Conner, W. Dugas, S. Hejl, D. Magness, R. Muttiah, K. Olenick, W. Rosenthal, R. Srinivasan, K. O. Winemiller, M. Zinn, N. Wilkins, C. Amonett, S. Bednarz, T. Dybala, R. Griffith and H. Jarboe. 2002. Ecosystem and wildlife implications of brush: management systems designed to improve water yield, TR-201. College Station, Texas: Texas Water Resources Institute.

Badhwar, G. D., K. E. Henderson, D. E. Pitts, W. R. Johnson, M. L. Sestak, T. Woolford and J. Carnes. 1984. Comparison of simulated thematic mapper data and multispectral scanner data. *Remote Sensing of Environment* 14(1-3): 247-255.

Barrett, M. E. and R. J. Charbeneau. 1997. A parsimonious model for simulating flow in a karst aquifer. *Journal of Hydrology* 196(1-4): 47-65.

Baumer, O. W. 1990. Prediction of Soil Hydraulic Properties. In: WEPP Files for Indiana. Lincoln, Nebraska: SCS National Soil Survey Laboratory.

Brady, N. C. and R. R. Weil. 1996. *The Nature and Properties of Soils*. Upper Saddle River, New Jersey: Prentice Hall, Inc.

BRC. 2001. United States soils database download. Available at: www.brc.tamus.edu/swat/swatsoils.html. Accessed 31 August 2004.

Carpenter, G. A., S. Gopal, S. Macomber, S. Martens, C. E. Woodcock and J. Franklin. 1999. A neural network method for efficient vegetation mapping. *Remote Sensing of Environment* 70(2): 208-223.

Clapham, Jr., W. B. 2003. Continuum-based classification of remotely sensed imagery to describe urban sprawl on a watershed scale. *Remote Sensing of Environment* 86(3): 322-340.

Congalton, R. G. and K. Green. 1998. *Assessing the Accuracy of Remotely Sensed Data: Principles and Practices*. Boca Raton, Florida: Lewis Publishers, Inc.

Cummins, K. L. 2000. The temporal mapping of riparian vegetation at Leon Creek in Bexar County, Texas from 1987 to 1999. M.S. Thesis. College Station: Texas A&M University, Department of Rangeland Ecology and Management.

Di Luzio, M. R., R. Srinivasan, J. G. Arnold and S. L. Neitsch. 2002. Soil and Water Assessment Tool, ArcView GIS Interface Manual: Version 2000, TR-192. College Station, Texas: Texas Water Resources Institute.

Dugas, W. A., R. A. Hicks and P. Wright. 1998. Effect of removal of Juniperus ashei on evapotranspiration and runoff in the Seco Creek watershed. *Water Resources Research* 34(6): 1499-1506.

Esquilin, R. 2002. Edwards Aquifer bibliography through 2002. San Antonio, Texas: The Edwards Aquifer Authority. Available at: www.edwardsaquifer.org. Accessed 31 August 2004.

Ferrill, D. A. and A. P. Morris. 2003. Dilation normal faults. *Journal of Structural Geology* 25(2): 183-196.

Forman, R. T. T. and M. Godron. 1986. *Landscape Ecology*. New York: John Wiley & Sons, Inc.

Gutierrez, M., E. Johnson and K. Mickus. 2004. Watershed assessment along a segment of the Rio Conchos in northern Mexico using satellite images. *Journal of Arid Environments* 56(3): 395-412.

Hall O. and G. J. Hay. 2003. A multiscale object-specific approach to digital change detection. *International Journal of Applied Earth Observation and Geoinformation* 4(4): 311-327.

Harris, H. G. 2000. Changes in ecosystem services and runoff due to land use change in the watersheds of San Antonio, Texas. M.S. Thesis. College Station: Texas A&M University, Department of Agricultural Engineering.

Helmschrot, J. and Flugel, W-.A. 2002. Land use characterization and change detection analysis for hydrological model parameterization of large scale afforested areas using remote sensing. *Physics and Chemistry of the Earth, Parts A/B/C* 27(9-10):711-718.

Holland, A. F., D. M. Sanger, C. P. Gawle, S. B. Lerberg, M. S. Santiago, G. H. M. Riekerk, L. E. Zimmerman, and G. I. Scott. 2004. Linkages between tidal ecosystems and the landscape and demographic attributes of their watersheds. *Journal of Experimental Marine Biology and Ecology* 298(2): 151-178.

Jensen, J. R. 1996. Introductory *Digital Image Processing: A Remote Sensing Perspective, Second Edition*. Upper Saddle River, New Jersey: Prentice Hall, Inc.

Khorzad, K. 2003. Edwards Aquifer evaluation: Kinney County, Texas. *Journal of the American Water Resources Association* 39(5): 1093-1107.

Kreuter, U. P., H. G. Harris, M. D. Matlock and R. E. Lacey. 2001. Change in ecosystem service values in the San Antonio area, Texas. *Ecological Economics* 39(3): 333-346.

Lillesand, T. and R. Kiefer. 1994. *Remote Sensing and Image Interpretation*. New York: John Wiley & Sons, Inc.

Loáiciga, H. A., D. R. Maidment and J. B. Valdes. 2000. Climate-change impacts in a regional karst aquifer, Texas, USA. *Journal of Hydrology* 227(1-4): 173-194.

McMahan, C. A., R. G. Frye and K. L. Brown. 1984. The vegetation types of Texas – including cropland. Bulletin 7000-120. Austin, Texas: Texas Parks and Wildlife Department.

Miller, J. D. and S. R. Yool. 2002. Mapping forest post-fire canopy consumption in several overstory types using multi-temporal Landsat TM and ETM data. *Remote Sensing of Environment* 82(2-3): 481-496.

Musgrove, M. L. and J. L. Banner. 2004. Controls on the spatial and temporal variability of vadose dripwater geochemistry: Edwards Aquifer, central Texas. *Geochemica et Cosmochimica Acta* 68(5): 1007-1020.

NASA. 2004. NASA Landsat 7 Page. Available at: landsat.gsfc.nasa.gov/. Accessed 31 August 2004.

NOAA. 2004. National Climatic Data Center Daily Precipitation Records. Available at: lwf.ncdc.noaa.gov/oa/climate/climatedata.html. Accessed 31 August 2004.

Neitsch, S. L., J. G. Arnold, J. R. Kiniry, R. Srinivasan and J. R. Williams. 2002. Soil and Water Assessment Tool User's Manual: Version 2000, TR-193. College Station, Texas: Texas Water Resources Institute.

Oetter, D. R., W. B. Cohen, M. Berterretche, T. K. Maiersperger and R. E. Kennedy. 2001. Land cover mapping in an agricultural setting using multiseasonal thematic mapper data. *Remote Sensing of Environment* 72(2): 139-155.

Oetting, G. C., J. L. Banner and J. M. Sharp, Jr. 1996. Regional controls on the geochemical evolution of saline groundwaters in the Edwards Aquifer, central Texas. *Journal of Hydrology* 181(1-4): 251-283.

Otterstrom, S. M. 2001. Trends in national and regional population concentration in the United States from 1790 to 1990: from the frontier to the urban transformation. *The Social Science Journal* 38(3): 393-407.

Pax-Lenney, M., C. E. Woodcock, S. A. Macomber, S. Gopal and C. Song. 2001. Forest mapping with a generalized classifier and Landsat TM data. *Remote Sensing of Environment* 77(3): 241-250.

Peschel, J. M. 2004. SSURGO SWAT Installation and Instruction Guide. Available at: lcluc.tamu.edu/ssurgo/instructions.pdf. Accessed 31 August 2004.

Peterson, D. L., K. P. Price and E. A. Martinko. 2002.Discriminating between cool season and warm season grassland cover types in northeastern Kansas. *International Journal of Remote Sensing* 23(23): 5015-5030.

Price, K. P., X. Guo and J. M. Stiles. 2002. Optimal Landsat TM band combinations and vegetation indices for discrimination of six grassland types in eastern Kansas. *International Journal of Remote Sensing* 23(23): 5031-5042.

Puente, C. 1976. Statistical analysis of water-level, springflow, and streamflow data for the Edwards Aquifer in south-central Texas, Open-File Report 76-393. San Antonio, Texas: United States Geological Survey.

Rosenthal, W., W. Dugas, S. Bednarz, T. Dybala and R. Muttiah. 2002. Simulation of brush removal within eight watersheds in Texas. ASAE Paper No. 022168. Chicago, Illinois: American Society of Agricultural Engineers.

Scanlon, B. R., R. E. Mace, M. E. Barrett and B. Smith. 2003. Can we simulate regional groundwater flow in a karst system using equivalent porous media models? Case study, Barton Springs, Edwards Aquifer, USA. *Journal of Hydrology* 276(1-4): 137-158.

Schowengerdt, R. A. 1997. *Remote Sensing: Models and Methods for Image Processing, Second Edition*. New York: Academic Press, Inc.

Sleavin, W. J., D. L. Civco, S. Prisloe and L. Giannotti. 2000. Measuring impervious surfaces for non-point source pollution modeling. In *Proceedings of the ASPRS Annual Conference*. Washington D.C.: ASPRS.

Stefanov, W. L., M. S. Ramsey and P. R. Christensen. 2001. Monitoring urban land cover change: an expert system approach to land cover classification of semiarid to arid urban centers. *Remote Sensing of Environment* 77(2): 173-185.

Tapiador, F. J. and J. L. Casanova. 2003. Land use mapping methodology using remote sensing for the regional planning directives in Segovia, Spain. *Landscape and Urban Planning* 62(2): 103-115.

Tong, S. T. Y. and W. Chen. 2002. Modeling the relationship between land use and surface water quality. *Journal of Environmental Management* 66(4): 377-393.

TCEQ. 2001. Metadata: Edwards Aquifer land use / land cover. Available at: www.tnrcc.state.tx.us/gis/metadata/edw_lulc_met.html. Accessed 31 August 2004.

Thurow, A. P., J. R. Conner, T. L. Thurow and M. D. Garriga. 2001. A preliminary analysis of Texas ranchers' willingness to participate in a brush control cost-sharing program to improve off-site water yields. *Ecological Economics* 37(1): 139-152.

TNRIS. 2004a. Texas Natural Resources Information System. Available at: www.tnris.org/. Accessed 31 August 2004.

TNRIS. 2004b. Texas Department of Transportation Urban Maps. Available at: www.tnris.org/DigitalData/TxDOT/txdot.htm. Accessed 31 August 2004.

TNRIS. 2004c. Digital Orthophoto Quarter Quadrangles (DOQQ). Available at: www.tnris.org/DigitalData//doqs.htm. Accessed 31 August 2004.

TPWD. 1998. Federal Geographic Data Committee Metadata for VEGPY. Available at: www.tpwd.state.tx.us/gis/downloads/vegpy.htm. Accessed 31 August 2004.

USDA-NRCS. 1991. State Soil Geographic (STATSGO) Database: Data Use Information. Miscellaneous Publication Number 1492. Washington D.C.: United States Department of Agriculture Natural Resources Conservation Service.

USDA-NRCS. 1995. Soil Survey Geographic (SSURGO) Database: Data Use Information. Miscellaneous Publication Number 1527. Washington D.C.: United States Department of Agriculture Natural Resources Conservation Service.

USDA-NRCS. 2004. National Soil Survey Geographic (SSURGO) Database. Available at: www.ncgc.nrcs.usda.gov/branch/ssb/products/ssurgo/data/tx.html. Accessed 31 August 2004.

USGS. 1990. USGeoData 1:250,000 and 1:100,0000 scale land use and land cover and associated maps digital data. Geological Survey Circular No. 895. Reston, Virginia: United States Geological Survey.

USGS. 2003. National Land Cover Data set product description. Available at: landcover.usgs.gov/prodescription.asp. Accessed 31 August 2004.

USGS. 2004a. Landsat 7 Project Website. Available at: landsat7.usgs.gov/index.php. Accessed 31 August 2004.

USGS. 2004b. USGS Global Visualization Viewer. Available at: glovis.usgs.gov/. Accessed 31 August 2004.

USGS. 2004c. 1:250,000-scale Hydrologic Units of the United States. Available at: water.usgs.gov/GIS/metadata/usgswrd/XML/huc250k.xml. Accessed 31 August 2004.

USGS. 2004d. National Hydrography Dataset Home Page. Available at: nhd.usgs.gov/. Accessed 31 August 2004.

U. S. Census Bureau. 1980 U. S. Census Database, 1980: Data Table Description File. Available at: www.nationalatlas.gov/census1980m.html. Accessed 31 August 2004.

U. S. Census Bureau. 1990. U. S. Census Database, 1990: Data Table Description File. Available at: www.nationalatlas.gov/census1990m.html. Accessed 31 August 2004.

U. S. Census Bureau. 2000. U. S. Census Database, 2000: Data Table Description File. Available at: www.nationalatlas.gov/census2000m.html. Accessed 31 August 2004.

U. S. EPA. 2004. Better Assessment Science Integrating Point and Non-Point Sources 3.0: Upper Frio Watershed HUC 12110106. Available at: www.epa.gov/ost/ftp/basins/gis_data/huc/12110106/. Accessed 31 August 2004.

Wang, E. and D. Buland, 2002. Creation of Johnson County SWAT SSURGO Soil Input Dataset: Using the AvSwat Model with SSURGO Data in Johnson County, Iowa. Available at: waterhome.tamu.edu/NRCSdata/SWAT_SSURGO/. Accessed 31 August 2004.

Wickham, J. D., S. V. Stehman, J. H. Smith and L. Yang. 2004. Thematic accuracy of the 1992 land-cover data for the western United States. *Remote Sensing of Environment* 91(3-4): 452-468.

Wilcox, B. P. 2002. Shrub control and streamflow on rangelands: a process based viewpoint. *Journal of Range Management* 55(4): 318-326.

Wu, C. and A. T. Murray. 2003. Estimating impervious surface distribution by spectral mixture analysis. *Remote Sensing of Environment* 84(4): 493-505.

Wu, X. B., E. J. Redeker and T. L. Thurow. 2001. Vegetation and water yield dynamics in an Edwards plateau watershed. *Journal of Range Management* 54(2): 98-105.

Veni, G. 1999. A geomorphological strategy for conduction environmental impact assessments in karst areas. *Geomorphology* 31(1-4): 151-180.

Zhang, J. and G. M. Foody. 1998. A fuzzy classification of sub-urban land cover from remotely sensed imagery. *International Journal of Remote Sensing* 19(14): 2721-2738.

Zhang, J. and G. M. Foody. 2001. Fully-fuzzy supervised classification of sub-urban land cover from remotely sensed imagery: statistical and neural network approaches. *International Journal of Remote Sensing* 22(4): 615-628.

APPENDIX A

Table A-1 presents the locations of the ground control points used to adjust the Landsat images.

Table A-1. Spatial locations of the ground control points used to readjust Landsat images.

Watershed	X-coordinate [m]	Y-coordinate [m]
Austin-Travis Lakes	567823.17	3390233.35
Austin-Travis Lakes	610725.14	3339688.39
Austin-Travis Lakes	629831.40	3362452.50
Austin-Travis Lakes	596489.34	3341022.11
Austin-Travis Lakes	594513.30	3370855.14
San Marcos	629673.46	3280890.18
San Marcos	609102.57	3307913.06
San Marcos	541070.91	3330691.99
San Marcos	638949.46	3298678.53
San Marcos	609263.05	3322439.23
Upper San Antonio	559142.82	3256455.66
Upper San Antonio	554639.94	3281532.68
Upper San Antonio	542239.58	3274499.31
Upper San Antonio	547421.94	3251963.94
Upper San Antonio	550691.61	3243775.76
Middle Guadalupe	593296.53	3286190.13
Middle Guadalupe	577619.21	3282495.77
Middle Guadalupe	605434.65	3270872.35
Middle Guadalupe	669009.89	3285598.84
Middle Guadalupe	665674.61	3297363.76
Middle Guadalupe	651093.12	3252703.22
Middle Guadalupe	649308.04	3230319.31
Middle Guadalupe	610992.55	3262305.11
Middle Guadalupe	624308.12	3239382.92
Middle Guadalupe	605450.07	3270894.35
Cibolo	582169.53	3277308.59
Cibolo	585996.22	3266949.73
Cibolo	538183.97	3293409.77
Cibolo	547109.92	3286563.42
Cibolo	556132.69	3296525.87
Cibolo	596509.68	3236131.57

Table A-1 (Continued)

Watershed	X-coordinate [m]	Y-coordinate [m]
Cibolo	568509.68	3236131.57
Cibolo	568598.10	3259788.09
Cibolo	596294.67	3258059.38
Cibolo	603774.14	3214332.45
Cibolo	588490.23	3253867.87
Upper Guadalupe	569736.10	3312232.08
Upper Guadalupe	542220.80	3313420.91
Upper Guadalupe	509280.07	3316598.25
Upper Guadalupe	541259.56	3299701.24
Upper Guadalupe	527169.38	3313252.58
Upper Guadalupe	463926.71	3338684.83
Upper Guadalupe	508126.15	3317088.63
Upper Guadalupe	475493.54	3319927.64
Upper Guadalupe	433264.36	3326506.70
Upper Guadalupe	527163.42	3313245.44
Medina	510630.88	3286933.01
Medina	487333.59	3294824.77
Medina	502218.30	3265903.29
Medina	522657.83	3259624.88
Medina	445086.89	3304349.18
Medina	510640.51	3286951.07
Medina	533956.41	3252094.45
Medina	540451.04	3233989.73
Medina	538861.52	3273605.98
Medina	502411.26	3268506.25
Hondo	460474.93	3269516.18
Hondo	498978.47	3257605.69
Hondo	485586.37	3280822.30
Hondo	475451.10	3273515.35
Hondo	487067.79	3265361.75
Hondo	488227.73	3219455.96
Hondo	477826.29	3207149.28
Hondo	482463.73	3247666.71
Hondo	497459.53	3258472.87
Hondo	479067.21	3232621.88
Upper Frio	450264.82	3277004.35

Table A-1 (Continued)

Watershed	X-coordinate [m]	Y-coordinate [m]
Upper Frio	424812.36	3287394.47
Upper Frio	429334.04	3275322.04
Upper Frio	442964.85	3305708.28
Upper Frio	426546.99	3312665.83
Upper Frio	429830.00	3217214.69
Upper Frio	488839.94	3196875.06
Upper Frio	458363.55	3238018.77
Upper Frio	453864.79	3259096.74
Upper Frio	465739.95	3201889.48
Nueces Headwaters	386486.14	3318923.16
Nueces Headwaters	390802.04	3314543.69
Nueces Headwaters	394008.01	3280346.13
Nueces Headwaters	412944.05	3293087.72
Nueces Headwaters	395313.71	3293047.17
Nueces Headwaters	407744.71	3245624.75
Nueces Headwaters	401083.11	3258836.67
Nueces Headwaters	400054.50	3282411.87
Nueces Headwaters	407240.87	3273368.02
Nueces Headwaters	393043.07	3270346.62
West Nueces	378324.20	3319739.96
West Nueces	381730.94	3305651.99
West Nueces	355653.22	3304828.64
West Nueces	379038.20	3290879.32
West Nueces	372475.58	3303153.01
West Nueces	363921.24	3269992.76
West Nueces	378782.13	3290131.80
West Nueces	377464.74	3254312.27
West Nueces	392316.92	3257352.81
West Nueces	373214.99	3275112.17
Upper Nueces	439810.83	3134654.55
Upper Nueces	439774.64	3126149.68
Upper Nueces	420768.14	3195010.16
Upper Nueces	433527.79	3157764.49
Upper Nueces	460898.07	3156403.21

APPENDIX B

Tables B-1, B-2, and B-3 present the 1986, 1993, and 2000 accuracy assessment results for the Edwards Aquifer contributing and recharge zone land cover classifications performed in this study.

Table B-1. Accuracy assessment results for the 1986 Edwards Aquifer contributing and recharge zone data set.

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
358647.10	3318560.38	Water	Water
360271.60	3307103.38	Water	Water
382644.10	3286070.38	Water	Water
372555.10	3282906.88	Water	Water
381789.10	3282450.88	Water	Water
371757.10	3282165.88	Water	Water
367909.60	3279116.38	Water	Water
387831.10	3267345.88	Water	Water
373609.60	3255005.38	Water	Water
389085.10	3252554.38	Water	Water
557662.60	3281880.88	Water	Water
478632.10	3335147.38	Water	Water
476437.60	3331727.38	Water	Water
472191.10	3331385.38	Water	Water
485187.10	3329589.88	Water	Water
496273.60	3327281.38	Water	Water
447795.10	3326283.88	Water	Water
457314.10	3321609.88	Water	Water
523747.60	3320726.38	Water	Water
489348.10	3318930.88	Water	Water
566497.60	3314342.38	Water	Water
545179.60	3313401.88	Water	Water
538054.60	3312347.38	Water	Water
486241.60	3311093.38	Water	Water
505792.60	3310665.88	Water	Water
520413.10	3308499.88	Water	Water
573708.10	3307986.88	Water	Water
486099.10	3307359.88	Water	Water
498582.10	3307359.88	Water	Water
574534.60	3307046.38	Water	Water
571029.10	3306675.88	Water	Water
480940.60	3306647.38	Water	Water
567238.60	3306162.88	Water	Water
575389.60	3303540.88	Water	Water
577014.10	3302856.88	Water	Water
516594.10	3302799.88	Water	Water

Table B-1 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
576729.10	3302571.88	Water	Water
556722.10	3302372.38	Water	Grassland
439330.60	3306590.38	Water	Water
430780.60	3306248.38	Water	Water
443805.10	3305649.88	Water	Water
422572.60	3304538.38	Water	Water
432348.10	3304167.88	Water	Water
417756.10	3289632.88	Water	Water
443605.60	3282393.88	Water	Water
446797.60	3279144.88	Water	Water
443947.60	3275354.38	Water	Water
418525.60	3273957.88	Water	Water
413167.60	3268685.38	Water	Water
426078.10	3266604.88	Water	Water
438760.60	3256743.88	Water	Water
425793.10	3255461.38	Water	Water
561937.60	3331584.88	Water	Water
546205.60	3328934.38	Water	Water
554385.10	3328421.38	Water	Water
552418.60	3324146.38	Water	Water
594199.60	3317448.88	Water	Water
413053.60	3320184.88	Water	Water
407211.10	3319529.38	Water	Water
400000.60	3312318.88	Water	Water
407325.10	3309297.88	Water	Water
403791.10	3290972.38	Water	Water
390168.10	3284360.38	Water	Water
398005.60	3281766.88	Water	Water
402622.60	3274071.88	Water	Water
397635.10	3268970.38	Water	Water
410773.60	3265179.88	Water	Water
581773.60	3292938.88	Water	Water
570345.10	3287580.88	Water	Water
472533.10	3302258.38	Water	Water
463527.10	3299892.88	Water	Water
493537.60	3295133.38	Water	Water
496444.60	3294563.38	Water	Water
455946.10	3293223.88	Water	Water
501289.60	3292767.88	Water	Water
509668.60	3281168.38	Water	Water
501802.60	3276152.38	Water	Water
502087.60	3275582.38	Water	Water
470680.60	3284958.88	Water	Water
458254.60	3283847.38	Water	Water
470880.10	3283733.38	Water	Water
482907.10	3277406.38	Water	Water

Table B-1 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
475554.10	3257655.88	Water	Water
525628.60	3296472.88	Water	Impervious Surface
550765.60	3295959.88	Water	Water
534207.10	3295133.38	Water	Water
562678.60	3293081.38	Water	Water
524773.60	3291513.88	Water	Woodland
547773.10	3290373.88	Water	Water
555981.10	3289575.88	Water	Water
561510.10	3288492.88	Water	Water
605599.60	3352845.88	Water	Water
613180.60	3351734.38	Water	Water
611926.60	3346062.88	Water	Water
607566.10	3341388.88	Water	Water
609219.10	3340733.38	Water	Water
599643.10	3338111.38	Water	Water
581887.60	3335660.38	Water	Water
588157.60	3335004.88	Water	Water
601723.60	3329646.88	Water	Water
359758.60	3319928.38	Impervious Surface	Impervious Surface
379252.60	3262899.88	Impervious Surface	Impervious Surface
381390.10	3262187.38	Impervious Surface	Impervious Surface
378597.10	3257883.88	Impervious Surface	Impervious Surface
394956.10	3242664.88	Impervious Surface	Grassland
538482.10	3282023.38	Impervious Surface	Impervious Surface
554413.60	3279372.88	Impervious Surface	Impervious Surface
559743.10	3278346.88	Impervious Surface	Impervious Surface
547573.60	3275667.88	Impervious Surface	Impervious Surface
540277.60	3275610.88	Impervious Surface	Impervious Surface
541531.60	3275553.88	Impervious Surface	Impervious Surface
549568.60	3275097.88	Impervious Surface	Impervious Surface
549340.60	3274584.88	Impervious Surface	Impervious Surface
545863.60	3273444.88	Impervious Surface	Impervious Surface
547317.10	3272988.88	Impervious Surface	Impervious Surface
467916.10	3346005.88	Impervious Surface	Woodland
468714.10	3339678.88	Impervious Surface	Impervious Surface
468885.10	3338510.38	Impervious Surface	Impervious Surface
478860.10	3328934.38	Impervious Surface	Impervious Surface
474898.60	3327138.88	Impervious Surface	Impervious Surface
478318.60	3327138.88	Impervious Surface	Impervious Surface
488037.10	3324260.38	Impervious Surface	Impervious Surface
483363.10	3317990.38	Impervious Surface	Impervious Surface
552960.10	3315938.38	Impervious Surface	Impervious Surface
512661.10	3313401.88	Impervious Surface	Grassland
496416.10	3311349.88	Impervious Surface	Impervious Surface
561567.10	3310722.88	Impervious Surface	Impervious Surface
575589.10	3309383.38	Impervious Surface	Impervious Surface

Table B-1 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
508927.60	3308841.88	Impervious Surface	Impervious Surface
524973.10	3307787.38	Impervious Surface	Impervious Surface
528906.10	3306704.38	Impervious Surface	Irrigated Land
575104.60	3305991.88	Impervious Surface	Impervious Surface
536145.10	3304424.38	Impervious Surface	Impervious Surface
518104.60	3303284.38	Impervious Surface	Woodland
571200.10	3302543.38	Impervious Surface	Impervious Surface
543412.60	3300519.88	Impervious Surface	Impervious Surface
560227.60	3300462.88	Impervious Surface	Impervious Surface
529675.60	3299864.38	Impervious Surface	Impervious Surface
543469.60	3299664.88	Impervious Surface	Impervious Surface
537370.60	3299180.38	Impervious Surface	Impervious Surface
418183.60	3311577.88	Impervious Surface	Impervious Surface
450730.60	3282536.38	Impervious Surface	Impervious Surface
448735.60	3276693.88	Impervious Surface	Impervious Surface
447709.60	3269939.38	Impervious Surface	Impervious Surface
434742.10	3254121.88	Impervious Surface	Impervious Surface
427075.60	3248136.88	Impervious Surface	Impervious Surface
545692.60	3335432.38	Impervious Surface	Impervious Surface
563676.10	3334577.38	Impervious Surface	Impervious Surface
566725.60	3332354.38	Impervious Surface	Impervious Surface
550167.10	3331641.88	Impervious Surface	Impervious Surface
533010.10	3331328.38	Impervious Surface	Impervious Surface
559771.60	3327053.38	Impervious Surface	Impervious Surface
575760.10	3321410.38	Impervious Surface	Impervious Surface
586419.10	3321153.88	Impervious Surface	Impervious Surface
569205.10	3318560.38	Impervious Surface	Impervious Surface
559857.10	3316764.88	Impervious Surface	Impervious Surface
587958.10	3316536.88	Impervious Surface	Impervious Surface
588841.60	3315710.38	Impervious Surface	Impervious Surface
575503.60	3312090.88	Impervious Surface	Impervious Surface
585592.60	3308499.88	Impervious Surface	Impervious Surface
600640.60	3305735.38	Impervious Surface	Impervious Surface
577641.10	3305678.38	Impervious Surface	Impervious Surface
578923.60	3301916.38	Impervious Surface	Impervious Surface
576472.60	3301659.88	Impervious Surface	Impervious Surface
584367.10	3295190.38	Impervious Surface	Impervious Surface
583255.60	3288207.88	Impervious Surface	Impervious Surface
488151.10	3301146.88	Impervious Surface	Impervious Surface
481567.60	3292682.38	Impervious Surface	Impervious Surface
471649.60	3289518.88	Impervious Surface	Grassland
499636.60	3288293.38	Impervious Surface	Impervious Surface
492511.60	3288065.38	Impervious Surface	Impervious Surface
494877.10	3287780.38	Impervious Surface	Impervious Surface
532696.60	3285870.88	Impervious Surface	Impervious Surface
528079.60	3285785.38	Impervious Surface	Impervious Surface

Table B-1 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
496159.60	3284018.38	Impervious Surface	Impervious Surface
515454.10	3283134.88	Impervious Surface	Impervious Surface
502030.60	3281253.88	Impervious Surface	Impervious Surface
500377.60	3279144.88	Impervious Surface	Impervious Surface
510124.60	3275724.88	Impervious Surface	Woodland
538311.10	3270908.38	Impervious Surface	Impervious Surface
532012.60	3270879.88	Impervious Surface	Impervious Surface
504481.60	3269169.88	Impervious Surface	Impervious Surface
508015.60	3266576.38	Impervious Surface	Impervious Surface
479458.60	3276722.38	Impervious Surface	Impervious Surface
516337.60	3300633.88	Impervious Surface	Impervious Surface
529419.10	3292682.38	Impervious Surface	Impervious Surface
548115.10	3289062.88	Impervious Surface	Impervious Surface
613893.10	3351164.38	Impervious Surface	Impervious Surface
614064.10	3348285.88	Impervious Surface	Impervious Surface
608535.10	3345236.38	Impervious Surface	Impervious Surface
614776.60	3345150.88	Impervious Surface	Impervious Surface
611784.10	3343554.88	Impervious Surface	Impervious Surface
608307.10	3343355.38	Impervious Surface	Impervious Surface
613152.10	3342927.88	Impervious Surface	Impervious Surface
612211.60	3342272.38	Impervious Surface	Impervious Surface
611499.10	3341987.38	Impervious Surface	Impervious Surface
597021.10	3341445.88	Impervious Surface	Grassland
610729.60	3339137.38	Impervious Surface	Woodland
579265.60	3333266.38	Impervious Surface	Impervious Surface
597249.10	3332525.38	Impervious Surface	Impervious Surface
367995.10	3301802.38	Irrigated Land	Woodland
384411.10	3266832.88	Irrigated Land	Woodland
549796.60	3285927.88	Irrigated Land	Irrigated Land
541873.60	3279401.38	Irrigated Land	Grassland
461389.60	3337940.38	Irrigated Land	Grassland
458910.10	3327566.38	Irrigated Land	Woodland
480940.60	3327309.88	Irrigated Land	Irrigated Land
470253.10	3326939.38	Irrigated Land	Woodland
486156.10	3325172.38	Irrigated Land	Grassland
488920.60	3320042.38	Irrigated Land	Woodland
503256.10	3319016.38	Irrigated Land	Woodland
505507.60	3315339.88	Irrigated Land	Irrigated Land
508215.10	3315197.38	Irrigated Land	Impervious Surface
520755.10	3313686.88	Irrigated Land	Irrigated Land
488977.60	3309896.38	Irrigated Land	Grassland
501318.10	3309525.88	Irrigated Land	Grassland
483334.60	3308556.88	Irrigated Land	Grassland
486754.60	3307245.88	Irrigated Land	Grassland
512290.60	3306761.38	Irrigated Land	Grassland
490773.10	3304908.88	Irrigated Land	Grassland

Table B-1 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
547089.10	3301574.38	Irrigated Land	Impervious Surface
555895.60	3300291.88	Irrigated Land	Irrigated Land
432946.60	3315396.88	Irrigated Land	Grassland
430866.10	3311007.88	Irrigated Land	Grassland
429954.10	3310095.88	Irrigated Land	Irrigated Land
434115.10	3309012.88	Irrigated Land	Grassland
439245.10	3304937.38	Irrigated Land	Irrigated Land
420406.60	3295902.88	Irrigated Land	Impervious Surface
422259.10	3294734.38	Irrigated Land	Grassland
424795.60	3293879.38	Irrigated Land	Grassland
426021.10	3291627.88	Irrigated Land	Grassland
429640.60	3291371.38	Irrigated Land	Grassland
426676.60	3290573.38	Irrigated Land	Irrigated Land
446940.10	3289946.38	Irrigated Land	Grassland
453637.60	3288350.38	Irrigated Land	Irrigated Land
453295.60	3286013.38	Irrigated Land	Grassland
447709.60	3284531.38	Irrigated Land	Irrigated Land
429526.60	3284217.88	Irrigated Land	Grassland
428614.60	3279458.38	Irrigated Land	Impervious Surface
424966.60	3279230.38	Irrigated Land	Grassland
427446.10	3279144.88	Irrigated Land	Irrigated Land
428130.10	3278802.88	Irrigated Land	Irrigated Land
453381.10	3276323.38	Irrigated Land	Woodland
446569.60	3274242.88	Irrigated Land	Irrigated Land
427389.10	3273558.88	Irrigated Land	Impervious Surface
436423.60	3273387.88	Irrigated Land	Grassland
449875.60	3270053.38	Irrigated Land	Irrigated Land
425365.60	3269796.88	Irrigated Land	Grassland
423798.10	3267659.38	Irrigated Land	Grassland
449932.60	3267174.88	Irrigated Land	Irrigated Land
449562.10	3266633.38	Irrigated Land	Irrigated Land
444403.60	3265920.88	Irrigated Land	Grassland
424539.10	3265607.38	Irrigated Land	Grassland
441069.10	3259821.88	Irrigated Land	Grassland
423684.10	3257655.88	Irrigated Land	Grassland
426762.10	3255461.38	Irrigated Land	Irrigated Land
419551.60	3253580.38	Irrigated Land	Grassland
435939.10	3249219.88	Irrigated Land	Irrigated Land
436765.60	3248906.38	Irrigated Land	Irrigated Land
420492.10	3244289.38	Irrigated Land	Grassland
416958.10	3241638.88	Irrigated Land	Irrigated Land
565699.60	3327908.38	Irrigated Land	Irrigated Land
582885.10	3321296.38	Irrigated Land	Woodland
557406.10	3320640.88	Irrigated Land	Irrigated Land
587673.10	3318617.38	Irrigated Land	Woodland
579721.60	3315453.88	Irrigated Land	Irrigated Land

Table B-1 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
385066.60	3322806.88	Irrigated Land	Irrigated Land
400143.10	3310181.38	Irrigated Land	Grassland
415077.10	3307388.38	Irrigated Land	Grassland
384781.60	3307245.88	Irrigated Land	Grassland
377200.60	3298125.88	Irrigated Land	Grassland
398404.60	3250758.88	Irrigated Land	Grassland
486640.60	3300776.38	Irrigated Land	Grassland
500947.60	3300434.38	Irrigated Land	Grassland
494734.60	3299408.38	Irrigated Land	Impervious Surface
472134.10	3297470.38	Irrigated Land	Grassland
495988.60	3297014.38	Irrigated Land	Irrigated Land
495133.60	3296501.38	Irrigated Land	Irrigated Land
493167.10	3296130.88	Irrigated Land	Irrigated Land
505051.60	3294791.38	Irrigated Land	Grassland
489604.60	3294591.88	Irrigated Land	Irrigated Land
490744.60	3292083.88	Irrigated Land	Irrigated Land
481168.60	3288093.88	Irrigated Land	Woodland
511435.60	3287922.88	Irrigated Land	Grassland
496273.60	3277007.38	Irrigated Land	Grassland
506248.60	3274869.88	Irrigated Land	Grassland
458026.60	3280455.88	Irrigated Land	Grassland
495190.60	3271107.88	Irrigated Land	Grassland
500748.10	3267744.88	Irrigated Land	Grassland
499123.60	3263526.88	Irrigated Land	Woodland
521097.10	3299693.38	Irrigated Land	Irrigated Land
520213.60	3298581.88	Irrigated Land	Grassland
544410.10	3298040.38	Irrigated Land	Grassland
537171.10	3297812.38	Irrigated Land	Irrigated Land
551848.60	3297413.38	Irrigated Land	Grassland
560170.60	3297014.38	Irrigated Land	Woodland
540676.60	3296900.38	Irrigated Land	Woodland
543868.60	3292169.38	Irrigated Land	Irrigated Land
531414.10	3289889.38	Irrigated Land	Irrigated Land
523063.60	3288891.88	Irrigated Land	Grassland
364632.10	3333095.38	Grassland	Grassland
364774.60	3329618.38	Grassland	Grassland
364518.10	3329504.38	Grassland	Grassland
366712.60	3325628.38	Grassland	Grassland
375547.60	3317220.88	Grassland	Grassland
385009.60	3312632.38	Grassland	Grassland
377371.60	3311891.38	Grassland	Grassland
374578.60	3311834.38	Grassland	Grassland
358362.10	3309497.38	Grassland	Grassland
368109.10	3307815.88	Grassland	Woodland
378825.10	3302600.38	Grassland	Grassland
360642.10	3301488.88	Grassland	Grassland

Table B-1 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
373495.60	3300804.88	Grassland	Grassland
372355.60	3299579.38	Grassland	Woodland
370731.10	3288321.88	Grassland	Woodland
359445.10	3287352.88	Grassland	Grassland
385152.10	3285728.38	Grassland	Grassland
390367.60	3276978.88	Grassland	Grassland
375120.10	3272618.38	Grassland	Grassland
386719.60	3262643.38	Grassland	Woodland
381048.10	3255432.88	Grassland	Grassland
555040.60	3278004.88	Grassland	Grassland
458026.60	3341274.88	Grassland	Grassland
467317.60	3336429.88	Grassland	Grassland
479544.10	3333636.88	Grassland	Woodland
529077.10	3326483.38	Grassland	Grassland
448251.10	3322293.88	Grassland	Grassland
501318.10	3318930.88	Grassland	Woodland
438789.10	3317847.88	Grassland	Grassland
531756.10	3317391.88	Grassland	Grassland
515482.60	3316821.88	Grassland	Grassland
514485.10	3316736.38	Grassland	Irrigated Land
494877.10	3316536.88	Grassland	Grassland
528108.10	3316479.88	Grassland	Grassland
507901.60	3314313.88	Grassland	Irrigated Land
449790.10	3312233.38	Grassland	Grassland
449020.60	3311634.88	Grassland	Grassland
502201.60	3311093.38	Grassland	Irrigated Land
476124.10	3310694.38	Grassland	Grassland
512518.60	3310608.88	Grassland	Grassland
536686.60	3310238.38	Grassland	Woodland
557520.10	3299750.38	Grassland	Grassland
563733.10	3298809.88	Grassland	Woodland
425992.60	3316422.88	Grassland	Grassland
443748.10	3293337.88	Grassland	Grassland
428386.60	3282279.88	Grassland	Irrigated Land
420492.10	3279942.88	Grassland	Woodland
424881.10	3279914.38	Grassland	Grassland
416587.60	3275582.38	Grassland	Woodland
430552.60	3270851.38	Grassland	Grassland
426078.10	3269312.38	Grassland	Grassland
440698.60	3267858.88	Grassland	Woodland
427303.60	3260334.88	Grassland	Grassland
421974.10	3259736.38	Grassland	Grassland
435739.60	3250074.88	Grassland	Grassland
559942.60	3333237.88	Grassland	Woodland
544011.10	3329247.88	Grassland	Grassland
565015.60	3324801.88	Grassland	Woodland

Table B-1 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
600042.10	3323348.38	Grassland	Grassland
581773.60	3320669.38	Grassland	Grassland
558631.60	3316736.38	Grassland	Grassland
411457.60	3324830.38	Grassland	Grassland
400000.60	3324032.38	Grassland	Grassland
393588.10	3317876.38	Grassland	Grassland
389854.60	3315168.88	Grassland	Grassland
395440.60	3313430.38	Grassland	Grassland
402651.10	3308300.38	Grassland	Grassland
390367.60	3306590.38	Grassland	Grassland
406356.10	3291485.38	Grassland	Woodland
406384.60	3286013.38	Grassland	Grassland
395868.10	3285101.38	Grassland	Grassland
397549.60	3283505.38	Grassland	Grassland
399345.10	3283220.38	Grassland	Grassland
404019.10	3274299.88	Grassland	Woodland
397293.10	3254663.38	Grassland	Grassland
406185.10	3251385.88	Grassland	Grassland
405529.60	3245229.88	Grassland	Grassland
569062.60	3296672.38	Grassland	Woodland
446170.60	3308072.38	Grassland	Grassland
477948.10	3307559.38	Grassland	Grassland
499551.10	3298752.88	Grassland	Grassland
504909.10	3297783.88	Grassland	Grassland
463270.60	3292596.88	Grassland	Woodland
498867.10	3285500.38	Grassland	Woodland
527139.10	3283505.38	Grassland	Grassland
491884.60	3283476.88	Grassland	Irrigated Land
482023.60	3283277.38	Grassland	Impervious Surface
495732.10	3279030.88	Grassland	Grassland
501574.60	3266433.88	Grassland	Woodland
477634.60	3280968.88	Grassland	Grassland
478489.60	3276950.38	Grassland	Grassland
460306.60	3265464.88	Grassland	Grassland
552048.10	3295218.88	Grassland	Woodland
603091.60	3340704.88	Grassland	Impervious Surface
585279.10	3338880.88	Grassland	Grassland
577555.60	3336173.38	Grassland	Grassland
596508.10	3336030.88	Grassland	Grassland
604887.10	3332040.88	Grassland	Grassland
584766.10	3328877.38	Grassland	Woodland
596251.60	3328107.88	Grassland	Grassland
362038.60	3317505.88	Woodland	Woodland
367197.10	3316565.38	Woodland	Woodland
358561.60	3313572.88	Woodland	Woodland
356395.60	3305136.88	Woodland	Woodland

Table B-1 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
369762.10	3286554.88	Woodland	Woodland
378226.60	3273302.38	Woodland	Woodland
369505.60	3267089.38	Woodland	Woodland
385978.60	3266775.88	Woodland	Woodland
371415.10	3266690.38	Woodland	Woodland
392448.10	3265578.88	Woodland	Woodland
375946.60	3257285.38	Woodland	Woodland
384981.10	3255090.88	Woodland	Woodland
373524.10	3254549.38	Woodland	Woodland
393445.60	3246968.38	Woodland	Grassland
547972.60	3282422.38	Woodland	Woodland
548314.60	3280968.88	Woodland	Grassland
412284.10	3253466.38	Woodland	Woodland
413595.10	3240185.38	Woodland	Grassland
457770.10	3340704.88	Woodland	Grassland
473131.60	3329048.38	Woodland	Woodland
496074.10	3327765.88	Woodland	Woodland
460705.60	3327480.88	Woodland	Woodland
492939.10	3324944.38	Woodland	Woodland
463812.10	3322379.38	Woodland	Woodland
527452.60	3322094.38	Woodland	Grassland
472561.60	3317078.38	Woodland	Woodland
456231.10	3315710.38	Woodland	Woodland
457086.10	3313658.38	Woodland	Woodland
500377.60	3310608.88	Woodland	Woodland
499522.60	3309725.38	Woodland	Woodland
484959.10	3307673.38	Woodland	Woodland
524289.10	3306761.38	Woodland	Woodland
534577.60	3305678.38	Woodland	Woodland
513345.10	3304794.88	Woodland	Woodland
526597.60	3304053.88	Woodland	Woodland
487923.10	3302999.38	Woodland	Woodland
425536.60	3313601.38	Woodland	Woodland
441553.60	3309326.38	Woodland	Woodland
432348.10	3301374.88	Woodland	Woodland
423256.60	3300348.88	Woodland	Woodland
429697.60	3297926.38	Woodland	Woodland
414022.60	3285785.38	Woodland	Woodland
437164.60	3281823.88	Woodland	Woodland
427218.10	3279372.88	Woodland	Woodland
435796.60	3274071.88	Woodland	Grassland
426676.60	3269454.88	Woodland	Woodland
416445.10	3265407.88	Woodland	Woodland
423057.10	3253437.88	Woodland	Woodland
434656.60	3250274.38	Woodland	Woodland
551734.60	3335403.88	Woodland	Woodland

Table B-1 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
571171.60	3329361.88	Woodland	Woodland
593316.10	3319386.88	Woodland	Woodland
562792.60	3319187.38	Woodland	Grassland
588471.10	3302258.38	Woodland	Woodland
406698.10	3323234.38	Woodland	Woodland
401026.60	3319557.88	Woodland	Woodland
406669.60	3316194.88	Woodland	Woodland
398404.60	3314228.38	Woodland	Woodland
408237.10	3303968.38	Woodland	Woodland
389598.10	3300719.38	Woodland	Woodland
382273.60	3298923.88	Woodland	Woodland
380820.10	3297413.38	Woodland	Woodland
392989.60	3296928.88	Woodland	Woodland
386862.10	3283733.38	Woodland	Woodland
410175.10	3268428.88	Woodland	Woodland
411030.10	3265635.88	Woodland	Woodland
409462.60	3243804.88	Woodland	Grassland
579636.10	3294962.38	Woodland	Woodland
570630.10	3291086.38	Woodland	Woodland
580434.10	3290744.38	Woodland	Impervious Surface
574648.60	3287951.38	Woodland	Woodland
465522.10	3306618.88	Woodland	Woodland
489633.10	3303027.88	Woodland	Woodland
491884.60	3302742.88	Woodland	Woodland
455034.10	3299778.88	Woodland	Woodland
454407.10	3298382.38	Woodland	Woodland
476893.60	3298182.88	Woodland	Woodland
471165.10	3293166.88	Woodland	Woodland
461275.60	3291627.88	Woodland	Woodland
483420.10	3285186.88	Woodland	Woodland
490288.60	3283163.38	Woodland	Woodland
501090.10	3282536.38	Woodland	Woodland
534036.10	3275895.88	Woodland	Woodland
467403.10	3288407.38	Woodland	Woodland
467916.10	3278546.38	Woodland	Woodland
482878.60	3276921.88	Woodland	Woodland
461731.60	3275354.38	Woodland	Woodland
489975.10	3272618.38	Woodland	Woodland
459708.10	3270965.38	Woodland	Woodland
454806.10	3270936.88	Woodland	Woodland
465066.10	3268599.88	Woodland	Woodland
486355.60	3267488.38	Woodland	Woodland
474300.10	3261959.38	Woodland	Woodland
497898.10	3260106.88	Woodland	Woodland
517563.10	3302429.38	Woodland	Woodland
559002.10	3294107.38	Woodland	Woodland

Table B-1 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
518731.60	3290373.88	Woodland	Grassland
556437.10	3288150.88	Woodland	Woodland
613636.60	3348741.88	Woodland	Woodland
596593.60	3343241.38	Woodland	Woodland

Table B-2. Accuracy assessment results for the 1993 Edwards Aquifer contributing and recharge zone data set.

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
368365.60	3325314.88	Water	Water
359217.10	3314399.38	Water	Water
364945.60	3300035.38	Water	Water
368793.10	3291285.88	Water	Water
384240.10	3284987.38	Water	Water
389712.10	3278204.38	Water	Water
388686.10	3277406.38	Water	Water
391336.60	3275354.38	Water	Water
459337.60	3332097.88	Water	Water
482166.10	3328421.38	Water	Water
482251.60	3326996.38	Water	Water
454777.60	3325770.88	Water	Water
493224.10	3322949.38	Water	Water
533950.60	3321780.88	Water	Water
500548.60	3320241.88	Water	Water
464439.10	3318845.38	Water	Water
492255.10	3317904.88	Water	Water
477406.60	3316907.38	Water	Water
497584.60	3316850.38	Water	Water
449533.60	3315710.38	Water	Water
456259.60	3314883.88	Water	Water
517392.10	3314085.88	Water	Water
506505.10	3313059.88	Water	Water
498382.60	3312290.38	Water	Water
549654.10	3312119.38	Water	Water
494535.10	3309753.88	Water	Water
574050.10	3308784.88	Water	Water
572910.10	3308585.38	Water	Water
566953.60	3306932.38	Water	Water
573879.10	3306134.38	Water	Water
489576.10	3306048.88	Water	Water
571884.10	3305022.88	Water	Water
549169.60	3304737.88	Water	Water
572824.60	3304367.38	Water	Water
560569.60	3304082.38	Water	Water

Table B-2 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
577270.60	3303854.38	Water	Water
568806.10	3302258.38	Water	Water
525571.60	3302172.88	Water	Water
548770.60	3300662.38	Water	Water
550366.60	3299493.88	Water	Water
423000.10	3311948.38	Water	Water
433060.60	3308756.38	Water	Water
435625.60	3306390.88	Water	Water
424510.60	3280455.88	Water	Water
452697.10	3278888.38	Water	Water
421062.10	3273074.38	Water	Water
413196.10	3268656.88	Water	Water
442095.10	3262728.88	Water	Water
420093.10	3255632.38	Water	Water
425907.10	3253380.88	Water	Water
561738.10	3321581.38	Water	Water
577099.60	3315111.88	Water	Water
596080.60	3311777.38	Water	Water
397635.10	3324488.38	Water	Water
399829.60	3324402.88	Water	Water
414906.10	3316907.38	Water	Water
407439.10	3314313.88	Water	Water
386349.10	3298809.88	Water	Water
414478.60	3295275.88	Water	Water
401254.60	3289632.88	Water	Water
395668.60	3282963.88	Water	Water
410175.10	3278318.38	Water	Water
411115.60	3267431.38	Water	Water
408949.60	3242636.38	Water	Water
583768.60	3296444.38	Water	Water
471849.10	3307017.88	Water	Water
470994.10	3303854.38	Water	Water
453210.10	3297299.38	Water	Water
461247.10	3294363.88	Water	Water
501802.60	3292824.88	Water	Water
513145.60	3289604.38	Water	Water
515397.10	3288321.88	Water	Water
514086.10	3287352.88	Water	Water
521610.10	3281054.38	Water	Water
500890.60	3280826.38	Water	Water
503769.10	3279600.88	Water	Water
502315.60	3275781.88	Water	Water
497242.60	3274613.38	Water	Water
508614.10	3271734.88	Water	Water
506391.10	3269768.38	Water	Water
462957.10	3285471.88	Water	Grassland

Table B-2 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
476922.10	3284246.38	Water	Water
462928.60	3281937.88	Water	Water
476950.60	3281453.38	Water	Water
486013.60	3280911.88	Water	Water
461019.10	3276237.88	Water	Water
460905.10	3267260.38	Water	Water
494905.60	3267032.38	Water	Water
499123.60	3265379.38	Water	Water
479002.60	3263498.38	Water	Water
503712.10	3261075.88	Water	Water
517420.60	3294278.38	Water	Woodland
544866.10	3292340.38	Water	Water
523063.60	3288008.38	Water	Water
557662.60	3284046.88	Water	Water
578781.10	3338852.38	Water	Water
594114.10	3335831.38	Water	Water
584595.10	3332781.88	Water	Water
595938.10	3329504.38	Water	Water
598788.10	3328250.38	Water	Water
382986.10	3320669.38	Impervious Surface	Impervious Surface
364432.60	3297926.38	Impervious Surface	Impervious Surface
369961.60	3271449.88	Impervious Surface	Impervious Surface
375747.10	3266063.38	Impervious Surface	Impervious Surface
386776.60	3257399.38	Impervious Surface	Impervious Surface
392932.60	3247452.88	Impervious Surface	Grassland
542244.10	3286469.38	Impervious Surface	Impervious Surface
556750.60	3282194.38	Impervious Surface	Woodland
548485.60	3277149.88	Impervious Surface	Impervious Surface
541332.10	3276978.88	Impervious Surface	Impervious Surface
540619.60	3275040.88	Impervious Surface	Impervious Surface
545977.60	3274670.38	Impervious Surface	Impervious Surface
542073.10	3273444.88	Impervious Surface	Impervious Surface
541474.60	3272475.88	Impervious Surface	Impervious Surface
541816.60	3272019.88	Impervious Surface	Impervious Surface
540220.60	3271136.38	Impervious Surface	Impervious Surface
541788.10	3270480.88	Impervious Surface	Grassland
459622.60	3344067.88	Impervious Surface	Impervious Surface
469455.10	3339479.38	Impervious Surface	Impervious Surface
461589.10	3336401.38	Impervious Surface	Water
515454.10	3327537.88	Impervious Surface	Impervious Surface
514257.10	3327366.88	Impervious Surface	Impervious Surface
515938.60	3326454.88	Impervious Surface	Grassland
487923.10	3326226.88	Impervious Surface	Impervious Surface
516252.10	3323975.38	Impervious Surface	Impervious Surface
458568.10	3322949.38	Impervious Surface	Impervious Surface
484531.60	3322122.88	Impervious Surface	Impervious Surface

Table B-2 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
489006.10	3322094.38	Impervious Surface	Impervious Surface
488407.60	3320754.88	Impervious Surface	Impervious Surface
488065.60	3319842.88	Impervious Surface	Impervious Surface
479202.10	3319215.88	Impervious Surface	Impervious Surface
489633.10	3318446.38	Impervious Surface	Impervious Surface
508015.60	3316251.88	Impervious Surface	Impervious Surface
563220.10	3312347.38	Impervious Surface	Impervious Surface
570886.60	3312233.38	Impervious Surface	Impervious Surface
559059.10	3311492.38	Impervious Surface	Impervious Surface
537969.10	3308157.88	Impervious Surface	Impervious Surface
536202.10	3308129.38	Impervious Surface	Impervious Surface
571570.60	3304253.38	Impervious Surface	Impervious Surface
552931.60	3302400.88	Impervious Surface	Impervious Surface
572568.10	3302400.88	Impervious Surface	Impervious Surface
572767.60	3302144.38	Impervious Surface	Impervious Surface
419751.10	3315795.88	Impervious Surface	Impervious Surface
443748.10	3305478.88	Impervious Surface	Impervious Surface
434457.10	3299493.88	Impervious Surface	Impervious Surface
435055.60	3278403.88	Impervious Surface	Impervious Surface
452611.60	3277862.38	Impervious Surface	Impervious Surface
436281.10	3271763.38	Impervious Surface	Impervious Surface
427702.60	3259736.38	Impervious Surface	Impervious Surface
576472.60	3323576.38	Impervious Surface	Impervious Surface
588043.60	3323006.38	Impervious Surface	Impervious Surface
572169.10	3320156.38	Impervious Surface	Impervious Surface
571143.10	3315938.38	Impervious Surface	Impervious Surface
388657.60	3326198.38	Impervious Surface	Impervious Surface
404332.60	3284702.38	Impervious Surface	Impervious Surface
587046.10	3295959.88	Impervious Surface	Impervious Surface
582885.10	3295190.38	Impervious Surface	Woodland
583825.60	3292910.38	Impervious Surface	Impervious Surface
576786.10	3292368.88	Impervious Surface	Impervious Surface
582201.10	3286184.38	Impervious Surface	Impervious Surface
580576.60	3285414.88	Impervious Surface	Impervious Surface
578809.60	3283704.88	Impervious Surface	Impervious Surface
571228.60	3279173.38	Impervious Surface	Impervious Surface
497755.60	3302001.88	Impervious Surface	Impervious Surface
483391.60	3297698.38	Impervious Surface	Impervious Surface
483220.60	3296615.38	Impervious Surface	Impervious Surface
494592.10	3287666.38	Impervious Surface	Impervious Surface
495504.10	3286982.38	Impervious Surface	Impervious Surface
484645.60	3286440.88	Impervious Surface	Impervious Surface
513117.10	3286440.88	Impervious Surface	Impervious Surface
482308.60	3285101.38	Impervious Surface	Woodland
497071.60	3283590.88	Impervious Surface	Impervious Surface
534150.10	3281994.88	Impervious Surface	Impervious Surface

Table B-2 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
504424.60	3281510.38	Impervious Surface	Impervious Surface
508614.10	3281111.38	Impervious Surface	Grassland
502116.10	3278204.38	Impervious Surface	Impervious Surface
503113.60	3278004.88	Impervious Surface	Impervious Surface
537741.10	3274926.88	Impervious Surface	Impervious Surface
537285.10	3273359.38	Impervious Surface	Impervious Surface
534748.60	3270167.38	Impervious Surface	Impervious Surface
501831.10	3263469.88	Impervious Surface	Impervious Surface
539508.10	3298838.38	Impervious Surface	Impervious Surface
557092.60	3296529.88	Impervious Surface	Impervious Surface
525571.60	3296045.38	Impervious Surface	Impervious Surface
526084.60	3293822.38	Impervious Surface	Impervious Surface
529362.10	3291855.88	Impervious Surface	Impervious Surface
590665.60	3349995.88	Impervious Surface	Impervious Surface
616999.60	3349653.88	Impervious Surface	Impervious Surface
604231.60	3346290.88	Impervious Surface	Impervious Surface
605941.60	3346034.38	Impervious Surface	Woodland
587530.60	3344666.38	Impervious Surface	Impervious Surface
580947.10	3343953.88	Impervious Surface	Impervious Surface
599016.10	3343298.38	Impervious Surface	Impervious Surface
611385.10	3342158.38	Impervious Surface	Impervious Surface
586476.10	3340134.88	Impervious Surface	Impervious Surface
593259.10	3334833.88	Impervious Surface	Impervious Surface
590095.60	3331527.88	Impervious Surface	Impervious Surface
602236.60	3329361.88	Impervious Surface	Impervious Surface
589468.60	3328278.88	Impervious Surface	Impervious Surface
540933.25	3283210.28	Impervious Surface	Impervious Surface
371073.10	3320184.88	Irrigated Land	Grassland
358647.10	3291570.88	Irrigated Land	Woodland
387546.10	3267744.88	Irrigated Land	Woodland
390453.10	3263412.88	Irrigated Land	Woodland
393730.60	3262529.38	Irrigated Land	Grassland
389256.10	3261360.88	Irrigated Land	Woodland
387660.10	3259793.38	Irrigated Land	Woodland
393816.10	3249789.88	Irrigated Land	Irrigated Land
394671.10	3242721.88	Irrigated Land	Irrigated Land
417670.60	3252611.38	Irrigated Land	Woodland
417528.10	3250815.88	Irrigated Land	Woodland
411172.60	3240555.88	Irrigated Land	Irrigated Land
458539.60	3340904.38	Irrigated Land	Woodland
447966.10	3334149.88	Irrigated Land	Irrigated Land
452355.10	3330045.88	Irrigated Land	Woodland
454549.60	3328079.38	Irrigated Land	Woodland
487866.10	3325143.88	Irrigated Land	Irrigated Land
509611.60	3322407.88	Irrigated Land	Grassland
531072.10	3322236.88	Irrigated Land	Irrigated Land

Table B-2 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
491770.60	3317505.88	Irrigated Land	Irrigated Land
515140.60	3317220.88	Irrigated Land	Irrigated Land
483306.10	3316080.88	Irrigated Land	Irrigated Land
507274.60	3315938.38	Irrigated Land	Irrigated Land
509611.60	3315738.88	Irrigated Land	Grassland
527538.10	3313487.38	Irrigated Land	Irrigated Land
482052.10	3313401.88	Irrigated Land	Woodland
509041.60	3312318.88	Irrigated Land	Woodland
497214.10	3310808.38	Irrigated Land	Grassland
515910.10	3309639.88	Irrigated Land	Grassland
552390.10	3308898.88	Irrigated Land	Grassland
527196.10	3302372.38	Irrigated Land	Grassland
427959.10	3317705.38	Irrigated Land	Grassland
427788.10	3316280.38	Irrigated Land	Grassland
422344.60	3315653.38	Irrigated Land	Grassland
424539.10	3313430.38	Irrigated Land	Woodland
421831.60	3313373.38	Irrigated Land	Woodland
421375.60	3313002.88	Irrigated Land	Grassland
429127.60	3309497.38	Irrigated Land	Irrigated Land
433089.10	3309354.88	Irrigated Land	Grassland
428443.60	3302999.38	Irrigated Land	Woodland
440641.60	3296843.38	Irrigated Land	Woodland
418953.10	3294905.38	Irrigated Land	Woodland
443491.60	3291114.88	Irrigated Land	Woodland
413680.60	3289433.38	Irrigated Land	Grassland
453637.60	3289119.88	Irrigated Land	Grassland
413167.60	3287922.88	Irrigated Land	Grassland
447310.60	3287580.88	Irrigated Land	Grassland
427389.10	3287295.88	Irrigated Land	Irrigated Land
439957.60	3284018.38	Irrigated Land	Woodland
428899.60	3282450.88	Irrigated Land	Woodland
429783.10	3277434.88	Irrigated Land	Irrigated Land
438304.60	3276266.38	Irrigated Land	Woodland
449077.60	3271364.38	Irrigated Land	Grassland
447681.10	3269996.38	Irrigated Land	Irrigated Land
447795.10	3257741.38	Irrigated Land	Irrigated Land
428671.60	3256772.38	Irrigated Land	Woodland
419751.10	3254862.88	Irrigated Land	Grassland
427588.60	3254321.38	Irrigated Land	Grassland
422316.10	3248592.88	Irrigated Land	Grassland
433089.10	3248592.88	Irrigated Land	Irrigated Land
540505.60	3331556.38	Irrigated Land	Irrigated Land
539280.10	3325913.38	Irrigated Land	Grassland
561937.60	3324174.88	Irrigated Land	Irrigated Land
546690.10	3319785.88	Irrigated Land	Grassland
594969.10	3300035.38	Irrigated Land	Grassland

Table B-2 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
394471.60	3307730.38	Irrigated Land	Grassland
400770.10	3299436.88	Irrigated Land	Grassland
399886.60	3296244.88	Irrigated Land	Grassland
387232.60	3294705.88	Irrigated Land	Irrigated Land
403392.10	3285386.38	Irrigated Land	Irrigated Land
401682.10	3276921.88	Irrigated Land	Grassland
579237.10	3289974.88	Irrigated Land	Grassland
580263.10	3284844.88	Irrigated Land	Grassland
469284.10	3312347.38	Irrigated Land	Woodland
465094.60	3304994.38	Irrigated Land	Woodland
460848.10	3303512.38	Irrigated Land	Grassland
503398.60	3299094.88	Irrigated Land	Woodland
468144.10	3298724.38	Irrigated Land	Woodland
478404.10	3298353.88	Irrigated Land	Irrigated Land
458083.60	3297669.88	Irrigated Land	Woodland
496245.10	3295988.38	Irrigated Land	Grassland
477948.10	3295874.38	Irrigated Land	Irrigated Land
500890.60	3293736.88	Irrigated Land	Woodland
496017.10	3287808.88	Irrigated Land	Irrigated Land
477862.60	3286326.88	Irrigated Land	Woodland
459309.10	3285129.88	Irrigated Land	Woodland
491656.60	3280455.88	Irrigated Land	Grassland
493993.60	3278489.38	Irrigated Land	Woodland
458112.10	3264552.88	Irrigated Land	Irrigated Land
488008.60	3259365.88	Irrigated Land	Irrigated Land
520270.60	3294363.88	Irrigated Land	Water
544296.10	3293736.88	Irrigated Land	Irrigated Land
530245.60	3292425.88	Irrigated Land	Irrigated Land
530815.60	3291228.88	Irrigated Land	Grassland
531756.10	3290544.88	Irrigated Land	Irrigated Land
520185.10	3290402.38	Irrigated Land	Grassland
526113.10	3289689.88	Irrigated Land	Grassland
524916.10	3288464.38	Irrigated Land	Irrigated Land
561111.10	3280569.88	Irrigated Land	Grassland
603547.60	3329903.38	Irrigated Land	Grassland
373780.60	3326483.38	Grassland	Grassland
369021.10	3324630.88	Grassland	Grassland
378055.60	3322892.38	Grassland	Woodland
368736.10	3321353.38	Grassland	Grassland
362437.60	3320013.88	Grassland	Grassland
381931.60	3318845.38	Grassland	Grassland
362637.10	3314085.88	Grassland	Grassland
378255.10	3310409.38	Grassland	Grassland
379423.60	3309753.88	Grassland	Woodland
372954.10	3309440.38	Grassland	Grassland
356025.10	3303170.38	Grassland	Grassland

Table B-2 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
361554.10	3302885.38	Grassland	Grassland
376716.10	3298154.38	Grassland	Grassland
359416.60	3289119.88	Grassland	Grassland
353859.10	3287295.88	Grassland	Grassland
359074.60	3281909.38	Grassland	Grassland
363634.60	3269340.88	Grassland	Grassland
370959.10	3267659.38	Grassland	Grassland
372954.10	3265436.38	Grassland	Woodland
388344.10	3255945.88	Grassland	Woodland
398547.10	3246797.38	Grassland	Grassland
420093.10	3246996.88	Grassland	Grassland
455575.60	3338453.38	Grassland	Grassland
468058.60	3336771.88	Grassland	Grassland
459993.10	3335859.88	Grassland	Woodland
460050.10	3333351.88	Grassland	Woodland
446427.10	3331328.38	Grassland	Grassland
465379.60	3330615.88	Grassland	Grassland
505593.10	3327908.38	Grassland	Woodland
435027.10	3323006.38	Grassland	Grassland
476979.10	3322236.88	Grassland	Grassland
506163.10	3320555.38	Grassland	Grassland
455917.60	3318389.38	Grassland	Grassland
536572.60	3317505.88	Grassland	Grassland
543241.60	3315197.38	Grassland	Woodland
446227.60	3313800.88	Grassland	Woodland
529390.60	3311378.38	Grassland	Grassland
528136.60	3309867.88	Grassland	Grassland
547146.10	3308100.88	Grassland	Grassland
527880.10	3302172.88	Grassland	Grassland
506277.10	3301916.38	Grassland	Grassland
536458.60	3300519.88	Grassland	Grassland
555268.60	3299009.38	Grassland	Grassland
436936.60	3312546.88	Grassland	Grassland
422914.60	3309440.38	Grassland	Grassland
428130.10	3307473.88	Grassland	Grassland
422259.10	3305364.88	Grassland	Grassland
443890.60	3295817.38	Grassland	Grassland
429241.60	3293451.88	Grassland	Grassland
426306.10	3289946.38	Grassland	Grassland
434827.60	3285842.38	Grassland	Grassland
450103.60	3284417.38	Grassland	Grassland
413823.10	3266633.38	Grassland	Grassland
435853.60	3263469.88	Grassland	Grassland
421831.60	3260078.38	Grassland	Grassland
444090.10	3259280.38	Grassland	Grassland
435768.10	3255347.38	Grassland	Grassland

Table B-2 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
435340.60	3251243.38	Grassland	Grassland
540534.10	3331185.88	Grassland	Irrigated Land
554128.60	3330216.88	Grassland	Irrigated Land
564132.10	3328649.38	Grassland	Irrigated Land
563505.10	3324972.88	Grassland	Irrigated Land
567181.60	3324545.38	Grassland	Grassland
571912.60	3321638.38	Grassland	Grassland
560740.60	3316850.38	Grassland	Grassland
391707.10	3326112.88	Grassland	Grassland
410346.10	3325856.38	Grassland	Grassland
388515.10	3321837.88	Grassland	Grassland
387916.60	3309639.88	Grassland	Grassland
390054.10	3308613.88	Grassland	Grassland
381418.60	3301403.38	Grassland	Grassland
414934.60	3300177.88	Grassland	Grassland
402622.60	3289917.88	Grassland	Grassland
386121.10	3284018.38	Grassland	Grassland
396865.60	3271193.38	Grassland	Grassland
408294.10	3269540.38	Grassland	Grassland
402394.60	3264780.88	Grassland	Grassland
406926.10	3245799.88	Grassland	Grassland
408009.10	3245315.38	Grassland	Grassland
477121.60	3306675.88	Grassland	Grassland
455632.60	3303797.38	Grassland	Grassland
488863.60	3301830.88	Grassland	Impervious Surface
482223.10	3301146.88	Grassland	Woodland
450474.10	3299978.38	Grassland	Grassland
457998.10	3298296.88	Grassland	Woodland
491599.60	3293280.88	Grassland	Irrigated Land
493338.10	3286212.88	Grassland	Irrigated Land
495646.60	3286127.38	Grassland	Impervious Surface
491799.10	3284075.38	Grassland	Grassland
467032.60	3264581.38	Grassland	Woodland
523092.10	3301403.38	Grassland	Grassland
596935.60	3354299.38	Grassland	Woodland
597448.60	3349283.38	Grassland	Grassland
585934.60	3341844.88	Grassland	Grassland
577213.60	3339821.38	Grassland	Grassland
572283.10	3336344.38	Grassland	Woodland
598788.10	3333323.38	Grassland	Grassland
596679.10	3333152.38	Grassland	Woodland
586077.10	3331955.38	Grassland	Grassland
601552.60	3331556.38	Grassland	Woodland
366370.60	3327081.88	Woodland	Woodland
374350.60	3319985.38	Woodland	Woodland
377599.60	3313430.38	Woodland	Woodland

Table B-2 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
365971.60	3311435.38	Woodland	Woodland
359815.60	3292625.38	Woodland	Woodland
382815.10	3286839.88	Woodland	Woodland
370417.60	3281823.88	Woodland	Woodland
381447.10	3281282.38	Woodland	Woodland
366399.10	3276009.88	Woodland	Woodland
366627.10	3275810.38	Woodland	Woodland
381618.10	3270879.88	Woodland	Woodland
381504.10	3265692.88	Woodland	Woodland
375661.60	3257285.38	Woodland	Woodland
392134.60	3255432.88	Woodland	Woodland
396352.60	3251357.38	Woodland	Woodland
399402.10	3245571.88	Woodland	Woodland
455718.10	3325001.38	Woodland	Woodland
521296.60	3323576.38	Woodland	Woodland
479316.10	3323547.88	Woodland	Woodland
519045.10	3322122.88	Woodland	Grassland
492027.10	3317277.88	Woodland	Grassland
504538.60	3317220.88	Woodland	Woodland
514713.10	3316023.88	Woodland	Woodland
527737.60	3314969.38	Woodland	Woodland
472276.60	3314541.88	Woodland	Grassland
545293.60	3312233.38	Woodland	Woodland
563448.10	3311463.88	Woodland	Woodland
554556.10	3303654.88	Woodland	Woodland
544894.60	3302771.38	Woodland	Woodland
443377.60	3291627.88	Woodland	Woodland
431179.60	3284360.38	Woodland	Woodland
450360.10	3283448.38	Woodland	Woodland
438304.60	3282735.88	Woodland	Woodland
435540.10	3275325.88	Woodland	Woodland
431350.60	3274242.88	Woodland	Woodland
451044.10	3273615.88	Woodland	Woodland
427218.10	3272333.38	Woodland	Woodland
433117.60	3268457.38	Woodland	Woodland
421176.10	3267260.38	Woodland	Woodland
435625.60	3266490.88	Woodland	Woodland
440841.10	3259365.88	Woodland	Woodland
549454.60	3335574.88	Woodland	Woodland
559116.10	3330216.88	Woodland	Woodland
540477.10	3329418.88	Woodland	Grassland
557434.60	3328535.38	Woodland	Grassland
552333.10	3328050.88	Woodland	Woodland
570915.10	3323519.38	Woodland	Grassland
548970.10	3323006.38	Woodland	Woodland
551022.10	3321182.38	Woodland	Woodland

Table B-2 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
594570.10	3320640.88	Woodland	Woodland
589012.60	3315539.38	Woodland	Woodland
414592.60	3315225.88	Woodland	Woodland
397948.60	3311463.88	Woodland	Woodland
415875.10	3300605.38	Woodland	Woodland
394842.10	3297185.38	Woodland	Woodland
408465.10	3295247.38	Woodland	Woodland
407467.60	3294221.38	Woodland	Woodland
406099.60	3283191.88	Woodland	Woodland
407382.10	3274898.38	Woodland	Woodland
395041.60	3272846.38	Woodland	Woodland
407667.10	3266576.38	Woodland	Woodland
402109.60	3264780.88	Woodland	Woodland
579921.10	3309326.38	Woodland	Woodland
581431.60	3308300.38	Woodland	Woodland
576444.10	3293964.88	Woodland	Woodland
584652.10	3293907.88	Woodland	Woodland
575845.60	3289034.38	Woodland	Woodland
564873.10	3285870.88	Woodland	Woodland
565785.10	3282935.38	Woodland	Woodland
464040.10	3308670.88	Woodland	Woodland
481396.60	3303312.88	Woodland	Woodland
449847.10	3303141.88	Woodland	Woodland
463669.60	3300890.38	Woodland	Woodland
486213.10	3298866.88	Woodland	Woodland
490887.10	3298268.38	Woodland	Woodland
515226.10	3291143.38	Woodland	Woodland
490260.10	3287723.38	Woodland	Woodland
525942.10	3284588.38	Woodland	Woodland
488293.60	3283476.88	Woodland	Woodland
515853.10	3274983.88	Woodland	Woodland
525685.60	3273416.38	Woodland	Woodland
522607.60	3272390.38	Woodland	Woodland
463498.60	3287637.88	Woodland	Grassland
462216.10	3286526.38	Woodland	Woodland
484332.10	3276522.88	Woodland	Grassland
482194.60	3275582.38	Woodland	Woodland
493680.10	3273302.38	Woodland	Woodland
465864.10	3272390.38	Woodland	Woodland
468087.10	3268371.88	Woodland	Woodland
464980.60	3266718.88	Woodland	Woodland
491343.10	3266205.88	Woodland	Woodland
499864.60	3263184.88	Woodland	Woodland
534777.10	3296016.88	Woodland	Woodland
542215.60	3293480.38	Woodland	Woodland
555525.10	3284502.88	Woodland	Woodland

Table B-2 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
588556.60	3350223.88	Woodland	Grassland
587502.10	3345350.38	Woodland	Woodland
608934.10	3343041.88	Woodland	Woodland
572226.10	3335802.88	Woodland	Woodland
589841.03	3345146.22	Woodland	Woodland

Table B-3. Accuracy assessment results for the 2000 Edwards Aquifer contributing and recharge zone data set.

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
376580.35	3301375.63	Water	Water
358370.35	3298945.63	Water	Water
373100.35	3298165.63	Water	Water
378650.35	3275605.63	Water	Water
372410.35	3272635.63	Water	Water
389570.35	3264535.63	Water	Water
373130.35	3263245.63	Water	Water
375440.35	3262825.63	Water	Water
387740.35	3257185.63	Water	Water
377720.35	3315445.63	Water	Water
368630.35	3274195.63	Water	Water
387320.35	3268945.63	Water	Water
381110.35	3262285.63	Water	Water
360290.35	3323365.63	Water	Water
367100.35	3315265.63	Water	Water
376460.35	3301435.63	Water	Water
377570.35	3290515.63	Water	Water
353690.35	3288415.63	Water	Water
378230.35	3281395.63	Water	Water
360860.35	3281215.63	Water	Water
384650.35	3276565.63	Water	Impervious Surface
378170.35	3264355.63	Water	Grassland
377810.35	3261325.63	Water	Woodland
395630.35	3256705.63	Water	Water
376010.35	3255115.63	Water	Water
386150.35	3254395.63	Water	Water
395930.35	3253015.63	Water	Water
393230.35	3252475.63	Water	Water
394940.35	3242755.63	Water	Water
360350.35	3327565.63	Water	Water
364310.35	3303415.63	Water	Water
370610.35	3299845.63	Water	Water
355310.35	3290365.63	Water	Water
368510.35	3280465.63	Water	Water

Table B-3 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
370100.35	3273925.63	Water	Water
378080.35	3273505.63	Water	Water
376430.35	3270985.63	Water	Water
386270.35	3268705.63	Water	Water
381350.35	3267355.63	Water	Water
376460.35	3265615.63	Water	Water
379250.35	3257665.63	Water	Water
393680.35	3255145.63	Water	Water
379220.35	3314965.63	Water	Water
377120.35	3290065.63	Water	Water
366110.35	3281725.63	Water	Water
381110.35	3280525.63	Water	Water
366440.35	3276445.63	Water	Water
382160.35	3262975.63	Water	Water
385040.35	3262315.63	Water	Water
384890.35	3260785.63	Water	Water
395540.35	3254185.63	Water	Water
393920.35	3250525.63	Water	Water
392420.35	3246895.63	Water	Water
552980.35	3282925.63	Water	Water
547070.35	3282115.63	Water	Water
560240.35	3279085.63	Water	Water
546740.35	3278785.63	Water	Water
552710.35	3278545.63	Water	Water
546170.35	3276535.63	Water	Water
547040.35	3275575.63	Water	Water
552470.35	3274465.63	Water	Water
550640.35	3273805.63	Water	Water
540410.35	3272785.63	Water	Water
541700.35	3271225.63	Water	Water
540530.35	3270715.63	Water	Water
555860.35	3278995.63	Water	Water
417560.35	3248275.63	Water	Water
415220.35	3251755.63	Water	Water
412370.35	3241315.63	Water	Water
474530.35	3331255.63	Water	Water
479180.35	3328705.63	Water	Grassland
478460.35	3326275.63	Water	Water
516620.35	3324595.63	Water	Water
522980.35	3323635.63	Water	Water
524420.35	3321055.63	Water	Water
472460.35	3317965.63	Water	Water
466880.35	3316705.63	Water	Water
451520.35	3314095.63	Water	Water
490880.35	3313465.63	Water	Water
537500.35	3311965.63	Water	Water

Table B-3 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
557360.35	3311365.63	Water	Water
549410.35	3310585.63	Water	Water
482330.35	3309925.63	Water	Water
520250.35	3308755.63	Water	Water
567860.35	3308305.63	Water	Water
569840.35	3308215.63	Water	Water
574460.35	3307375.63	Water	Water
572690.35	3305425.63	Water	Water
560210.35	3304435.63	Water	Water
526760.35	3303895.63	Water	Water
575300.35	3303505.63	Water	Water
485030.35	3333325.63	Water	Water
481010.35	3330775.63	Water	Water
475130.35	3326725.63	Water	Water
473450.35	3326665.63	Water	Water
467300.35	3325195.63	Water	Water
486980.35	3325195.63	Water	Water
486500.35	3320305.63	Water	Water
521780.35	3319855.63	Water	Water
479480.35	3317245.63	Water	Water
473150.35	3316855.63	Impervious Surface	Impervious Surface
489200.35	3314125.63	Impervious Surface	Impervious Surface
563720.35	3312445.63	Impervious Surface	Impervious Surface
570830.35	3312295.63	Impervious Surface	Irrigated Land
558710.35	3310675.63	Impervious Surface	Impervious Surface
494660.35	3309745.63	Impervious Surface	Impervious Surface
566450.35	3307525.63	Impervious Surface	Impervious Surface
573830.35	3303415.63	Impervious Surface	Impervious Surface
568640.35	3302425.63	Impervious Surface	Impervious Surface
562820.35	3302185.63	Impervious Surface	Impervious Surface
464930.35	3346465.63	Impervious Surface	Impervious Surface
463340.35	3346195.63	Impervious Surface	Impervious Surface
458150.35	3345265.63	Impervious Surface	Impervious Surface
467390.35	3342565.63	Impervious Surface	Impervious Surface
460010.35	3340915.63	Impervious Surface	Impervious Surface
510920.35	3332125.63	Impervious Surface	Impervious Surface
450860.35	3330355.63	Impervious Surface	Impervious Surface
472910.35	3330325.63	Impervious Surface	Impervious Surface
498110.35	3327595.63	Impervious Surface	Impervious Surface
509540.35	3326065.63	Impervious Surface	Impervious Surface
449090.35	3325975.63	Impervious Surface	Grassland
530480.35	3324865.63	Impervious Surface	Impervious Surface
511820.35	3324655.63	Impervious Surface	Impervious Surface
527000.35	3322315.63	Impervious Surface	Impervious Surface
497060.35	3320305.63	Impervious Surface	Impervious Surface
507170.35	3320065.63	Impervious Surface	Impervious Surface

Table B-3 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
499460.35	3319825.63	Impervious Surface	Impervious Surface
552050.35	3317305.63	Impervious Surface	Impervious Surface
467300.35	3317275.63	Impervious Surface	Impervious Surface
522020.35	3316675.63	Impervious Surface	Impervious Surface
470960.35	3314755.63	Impervious Surface	Impervious Surface
446390.35	3314695.63	Impervious Surface	Woodland
449570.35	3314245.63	Impervious Surface	Impervious Surface
449060.35	3313105.63	Impervious Surface	Impervious Surface
528380.35	3312715.63	Impervious Surface	Impervious Surface
451250.35	3312355.63	Impervious Surface	Impervious Surface
485990.35	3312265.63	Impervious Surface	Impervious Surface
529640.35	3311635.63	Impervious Surface	Impervious Surface
498890.35	3311245.63	Impervious Surface	Impervious Surface
490070.35	3305485.63	Impervious Surface	Impervious Surface
544190.35	3303265.63	Impervious Surface	Impervious Surface
531920.35	3301075.63	Impervious Surface	Impervious Surface
479000.35	3333535.63	Impervious Surface	Grassland
497510.35	3328615.63	Impervious Surface	Impervious Surface
445190.35	3326755.63	Impervious Surface	Grassland
454640.35	3323215.63	Impervious Surface	Impervious Surface
443780.35	3313555.63	Impervious Surface	Impervious Surface
528470.35	3313225.63	Impervious Surface	Impervious Surface
532910.35	3309685.63	Impervious Surface	Impervious Surface
563150.35	3308995.63	Impervious Surface	Impervious Surface
520970.35	3307045.63	Impervious Surface	Impervious Surface
496160.35	3307015.63	Impervious Surface	Impervious Surface
525290.35	3305815.63	Impervious Surface	Impervious Surface
491930.35	3303655.63	Impervious Surface	Impervious Surface
487730.35	3326935.63	Impervious Surface	Impervious Surface
473630.35	3326815.63	Impervious Surface	Impervious Surface
489080.35	3326485.63	Impervious Surface	Impervious Surface
513950.35	3324595.63	Impervious Surface	Impervious Surface
530930.35	3321565.63	Impervious Surface	Impervious Surface
542420.35	3319975.63	Impervious Surface	Impervious Surface
508940.35	3318265.63	Impervious Surface	Impervious Surface
490880.35	3318025.63	Impervious Surface	Impervious Surface
484520.35	3315625.63	Impervious Surface	Woodland
504200.35	3312505.63	Impervious Surface	Impervious Surface
555020.35	3311605.63	Impervious Surface	Impervious Surface
491000.35	3310465.63	Impervious Surface	Impervious Surface
568130.35	3310105.63	Impervious Surface	Impervious Surface
505340.35	3307945.63	Impervious Surface	Impervious Surface
571490.35	3307855.63	Impervious Surface	Impervious Surface
527180.35	3306475.63	Impervious Surface	Impervious Surface
508220.35	3306325.63	Impervious Surface	Impervious Surface
505430.35	3306295.63	Impervious Surface	Impervious Surface

Table B-3 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
551990.35	3304885.63	Impervious Surface	Impervious Surface
552200.35	3303415.63	Impervious Surface	Woodland
518300.35	3303235.63	Impervious Surface	Impervious Surface
576140.35	3302485.63	Impervious Surface	Impervious Surface
563060.35	3298915.63	Impervious Surface	Woodland
423200.35	3296815.63	Impervious Surface	Impervious Surface
420500.35	3290035.63	Impervious Surface	Impervious Surface
422930.35	3283405.63	Impervious Surface	Impervious Surface
435350.35	3283165.63	Impervious Surface	Impervious Surface
443600.35	3282685.63	Impervious Surface	Grassland
417200.35	3275635.63	Impervious Surface	Impervious Surface
420170.35	3272575.63	Impervious Surface	Impervious Surface
425000.35	3271885.63	Impervious Surface	Impervious Surface
414170.35	3270925.63	Impervious Surface	Impervious Surface
427640.35	3269365.63	Impervious Surface	Impervious Surface
450920.35	3265585.63	Impervious Surface	Woodland
451850.35	3259975.63	Impervious Surface	Impervious Surface
449810.35	3256135.63	Impervious Surface	Impervious Surface
418970.35	3312985.63	Impervious Surface	Impervious Surface
432290.35	3309835.63	Impervious Surface	Impervious Surface
423110.35	3293335.63	Impervious Surface	Impervious Surface
449630.35	3291775.63	Impervious Surface	Impervious Surface
431120.35	3286495.63	Impervious Surface	Impervious Surface
426920.35	3281035.63	Impervious Surface	Impervious Surface
453980.35	3279055.63	Impervious Surface	Grassland
422660.35	3314095.63	Impervious Surface	Impervious Surface
421940.35	3301735.63	Impervious Surface	Impervious Surface
433400.35	3296875.63	Impervious Surface	Impervious Surface
419810.35	3296575.63	Irrigated Land	Grassland
450890.35	3290395.63	Irrigated Land	Grassland
446750.35	3288925.63	Irrigated Land	Irrigated Land
453590.35	3286405.63	Irrigated Land	Irrigated Land
446750.35	3285445.63	Irrigated Land	Woodland
452300.35	3283975.63	Irrigated Land	Irrigated Land
444650.35	3278065.63	Irrigated Land	Irrigated Land
438170.35	3275125.63	Irrigated Land	Woodland
439010.35	3274705.63	Irrigated Land	Grassland
423080.35	3267655.63	Irrigated Land	Irrigated Land
422870.35	3267505.63	Irrigated Land	Irrigated Land
449060.35	3266185.63	Irrigated Land	Grassland
417110.35	3263605.63	Irrigated Land	Irrigated Land
442250.35	3262705.63	Irrigated Land	Grassland
454910.35	3262645.63	Irrigated Land	Grassland
439670.35	3255745.63	Irrigated Land	Grassland
432980.35	3251485.63	Irrigated Land	Grassland
430520.35	3250195.63	Irrigated Land	Grassland

Table B-3 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
424880.35	3246235.63	Irrigated Land	Irrigated Land
426350.35	3310705.63	Irrigated Land	Irrigated Land
419960.35	3298765.63	Irrigated Land	Irrigated Land
417830.35	3293665.63	Irrigated Land	Grassland
454220.35	3288055.63	Irrigated Land	Irrigated Land
454820.35	3286405.63	Irrigated Land	Grassland
432590.35	3278215.63	Irrigated Land	Grassland
425120.35	3277645.63	Irrigated Land	Grassland
453110.35	3271765.63	Irrigated Land	Grassland
418160.35	3268255.63	Irrigated Land	Grassland
438530.35	3267745.63	Irrigated Land	Grassland
416030.35	3265915.63	Irrigated Land	Impervious Surface
441890.35	3264805.63	Irrigated Land	Woodland
441860.35	3260755.63	Irrigated Land	Grassland
451430.35	3260455.63	Irrigated Land	Grassland
421430.35	3258295.63	Irrigated Land	Woodland
445280.35	3257935.63	Irrigated Land	Impervious Surface
432710.35	3313765.63	Irrigated Land	Woodland
423380.35	3313345.63	Irrigated Land	Grassland
421040.35	3312025.63	Irrigated Land	Impervious Surface
438890.35	3310465.63	Irrigated Land	Grassland
431930.35	3309805.63	Irrigated Land	Grassland
425960.35	3309415.63	Irrigated Land	Woodland
420860.35	3309355.63	Irrigated Land	Woodland
421340.35	3309325.63	Irrigated Land	Grassland
428300.35	3308995.63	Irrigated Land	Grassland
418850.35	3308725.63	Irrigated Land	Woodland
421820.35	3307735.63	Irrigated Land	Grassland
424970.35	3306475.63	Irrigated Land	Grassland
432710.35	3304045.63	Irrigated Land	Woodland
427130.35	3303415.63	Irrigated Land	Woodland
431420.35	3303145.63	Irrigated Land	Grassland
434060.35	3302365.63	Irrigated Land	Woodland
439760.35	3301855.63	Irrigated Land	Woodland
443150.35	3301825.63	Irrigated Land	Grassland
423410.35	3301285.63	Irrigated Land	Irrigated Land
437660.35	3300595.63	Irrigated Land	Grassland
420650.35	3297595.63	Irrigated Land	Woodland
443750.35	3295465.63	Irrigated Land	Grassland
419240.35	3294475.63	Irrigated Land	Woodland
433400.35	3292075.63	Irrigated Land	Woodland
429410.35	3291775.63	Irrigated Land	Irrigated Land
415100.35	3290845.63	Irrigated Land	Irrigated Land
416300.35	3290455.63	Irrigated Land	Woodland
426020.35	3286285.63	Irrigated Land	Woodland
426080.35	3286135.63	Irrigated Land	Woodland

Table B-3 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
448820.35	3282175.63	Irrigated Land	Irrigated Land
425960.35	3279955.63	Irrigated Land	Irrigated Land
453530.35	3276505.63	Irrigated Land	Grassland
449180.35	3270535.63	Irrigated Land	Grassland
442850.35	3268615.63	Irrigated Land	Irrigated Land
431510.35	3263545.63	Irrigated Land	Grassland
434330.35	3261565.63	Irrigated Land	Woodland
432110.35	3259825.63	Irrigated Land	Irrigated Land
431300.35	3253075.63	Irrigated Land	Woodland
420410.35	3251155.63	Irrigated Land	Grassland
423500.35	3250645.63	Irrigated Land	Grassland
432950.35	3249025.63	Irrigated Land	Grassland
424520.35	3248935.63	Irrigated Land	Irrigated Land
420650.35	3241105.63	Irrigated Land	Grassland
416930.35	3240145.63	Irrigated Land	Irrigated Land
572480.35	3330175.63	Irrigated Land	Irrigated Land
553370.35	3329995.63	Irrigated Land	Grassland
553580.35	3321835.63	Irrigated Land	Irrigated Land
597650.35	3319645.63	Irrigated Land	Grassland
588260.35	3318505.63	Irrigated Land	Grassland
564860.35	3318115.63	Irrigated Land	Grassland
600170.35	3313375.63	Irrigated Land	Irrigated Land
549260.35	3333235.63	Irrigated Land	Grassland
557210.35	3333175.63	Irrigated Land	Grassland
562940.35	3328315.63	Irrigated Land	Woodland
567920.35	3327055.63	Irrigated Land	Impervious Surface
585080.35	3319105.63	Irrigated Land	Grassland
588860.35	3316825.63	Irrigated Land	Grassland
586790.35	3316555.63	Irrigated Land	Woodland
597200.35	3315475.63	Irrigated Land	Woodland
587780.35	3311515.63	Irrigated Land	Irrigated Land
599120.35	3308035.63	Irrigated Land	Woodland
549110.35	3334375.63	Irrigated Land	Grassland
545150.35	3326995.63	Irrigated Land	Irrigated Land
572630.35	3316015.63	Irrigated Land	Impervious Surface
555950.35	3332875.63	Irrigated Land	Irrigated Land
545390.35	3329275.63	Grassland	Grassland
559100.35	3326215.63	Grassland	Grassland
572090.35	3322765.63	Grassland	Grassland
551120.35	3321985.63	Grassland	Woodland
572330.35	3320245.63	Grassland	Grassland
590480.35	3310435.63	Grassland	Grassland
547070.35	3333085.63	Grassland	Grassland
556640.35	3330715.63	Grassland	Grassland
569210.35	3328915.63	Grassland	Grassland
567530.35	3327685.63	Grassland	Grassland

Table B-3 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
592190.35	3317035.63	Grassland	Woodland
592610.35	3314035.63	Grassland	Grassland
412670.35	3319945.63	Grassland	Woodland
400970.35	3319015.63	Grassland	Grassland
400070.35	3311935.63	Grassland	Grassland
410540.35	3296995.63	Grassland	Grassland
390410.35	3287215.63	Grassland	Woodland
391340.35	3285625.63	Grassland	Woodland
398420.35	3265735.63	Grassland	Grassland
409070.35	3263335.63	Grassland	Grassland
401240.35	3262405.63	Grassland	Grassland
405980.35	3248155.63	Grassland	Grassland
410990.35	3299335.63	Grassland	Grassland
412040.35	3293725.63	Grassland	Grassland
400550.35	3285055.63	Grassland	Grassland
408140.35	3324835.63	Grassland	Grassland
391040.35	3319045.63	Grassland	Grassland
386660.35	3318565.63	Grassland	Grassland
388130.35	3307975.63	Grassland	Grassland
394730.35	3306025.63	Grassland	Grassland
383870.35	3302155.63	Grassland	Woodland
393050.35	3300955.63	Grassland	Grassland
399620.35	3297385.63	Grassland	Grassland
400640.35	3280615.63	Grassland	Grassland
402680.35	3277075.63	Grassland	Woodland
397340.35	3276895.63	Grassland	Woodland
403220.35	3274525.63	Grassland	Grassland
406490.35	3268165.63	Grassland	Grassland
406100.35	3325975.63	Grassland	Grassland
410030.35	3318085.63	Grassland	Grassland
401750.35	3316585.63	Grassland	Grassland
410060.35	3300685.63	Grassland	Grassland
412520.35	3292615.63	Grassland	Grassland
402380.35	3287815.63	Grassland	Grassland
398240.35	3285085.63	Grassland	Impervious Surface
400220.35	3273175.63	Grassland	Grassland
406190.35	3270295.63	Grassland	Woodland
405650.35	3262825.63	Grassland	Woodland
397610.35	3257455.63	Grassland	Grassland
402950.35	3254215.63	Grassland	Grassland
413540.35	3246685.63	Grassland	Grassland
408140.35	3244705.63	Grassland	Grassland
389930.35	3295015.63	Grassland	Grassland
581840.35	3306025.63	Grassland	Grassland
583100.35	3302125.63	Grassland	Woodland
570710.35	3284695.63	Grassland	Woodland

Table B-3 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
583370.35	3304375.63	Grassland	Grassland
579530.35	3302215.63	Grassland	Grassland
563000.35	3293995.63	Grassland	Grassland
566780.35	3287605.63	Grassland	Grassland
566420.35	3287575.63	Grassland	Grassland
575480.35	3282505.63	Grassland	Grassland
570080.35	3278845.63	Grassland	Grassland
580700.35	3305185.63	Grassland	Grassland
582650.35	3294775.63	Grassland	Grassland
568190.35	3286735.63	Grassland	Grassland
577400.35	3285925.63	Grassland	Grassland
578990.35	3308095.63	Grassland	Grassland
573830.35	3298585.63	Grassland	Grassland
580430.35	3291175.63	Grassland	Grassland
564200.35	3284455.63	Grassland	Grassland
572270.35	3283255.63	Grassland	Grassland
446210.35	3307915.63	Grassland	Grassland
481040.35	3296395.63	Grassland	Grassland
483530.35	3293005.63	Grassland	Woodland
487940.35	3292285.63	Grassland	Grassland
503660.35	3288475.63	Grassland	Grassland
503300.35	3287455.63	Grassland	Grassland
501560.35	3276655.63	Grassland	Grassland
532550.35	3275425.63	Grassland	Grassland
502310.35	3274585.63	Grassland	Grassland
501800.35	3274285.63	Grassland	Irrigated Land
506750.35	3271345.63	Grassland	Grassland
506780.35	3270655.63	Grassland	Irrigated Land
506030.35	3270565.63	Grassland	Woodland
539180.35	3270355.63	Grassland	Woodland
506060.35	3269965.63	Grassland	Grassland
502070.35	3267175.63	Grassland	Grassland
489380.35	3298555.63	Grassland	Grassland
508370.35	3297565.63	Grassland	Grassland
463610.35	3295195.63	Grassland	Grassland
479360.35	3295165.63	Grassland	Woodland
506510.35	3293785.63	Grassland	Grassland
508340.35	3291025.63	Grassland	Grassland
498950.35	3289345.63	Grassland	Grassland
486410.35	3287305.63	Grassland	Grassland
535970.35	3282775.63	Grassland	Woodland
508190.35	3281515.63	Grassland	Grassland
537470.35	3281455.63	Grassland	Grassland
500840.35	3278575.63	Grassland	Irrigated Land
535340.35	3277765.63	Woodland	Grassland
532520.35	3270625.63	Woodland	Woodland

Table B-3 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
509900.35	3269365.63	Woodland	Woodland
449690.35	3305755.63	Woodland	Woodland
470480.35	3304105.63	Woodland	Woodland
494480.35	3294265.63	Woodland	Woodland
489950.35	3288715.63	Woodland	Woodland
472970.35	3310435.63	Woodland	Woodland
470540.35	3309355.63	Woodland	Woodland
470450.35	3302635.63	Woodland	Woodland
479660.35	3301915.63	Woodland	Woodland
465860.35	3301285.63	Woodland	Woodland
502160.35	3295825.63	Woodland	Woodland
472640.35	3294205.63	Woodland	Woodland
461630.35	3291985.63	Woodland	Woodland
460100.35	3291505.63	Woodland	Woodland
491510.35	3287605.63	Woodland	Woodland
484280.35	3282895.63	Woodland	Woodland
493580.35	3281785.63	Woodland	Woodland
511340.35	3279985.63	Woodland	Woodland
535340.35	3275965.63	Woodland	Woodland
520220.35	3275665.63	Woodland	Woodland
511610.35	3275485.63	Woodland	Woodland
507890.35	3272875.63	Woodland	Woodland
517940.35	3270175.63	Woodland	Woodland
500720.35	3269545.63	Woodland	Woodland
516800.35	3266875.63	Woodland	Woodland
496910.35	3282655.63	Woodland	Woodland
469280.35	3287935.63	Woodland	Woodland
476090.35	3285805.63	Woodland	Woodland
488090.35	3276115.63	Woodland	Woodland
472370.35	3272485.63	Woodland	Woodland
461390.35	3271105.63	Woodland	Woodland
471710.35	3268555.63	Woodland	Woodland
490550.35	3268435.63	Woodland	Woodland
466250.35	3266995.63	Woodland	Woodland
472580.35	3265585.63	Woodland	Woodland
474260.35	3264655.63	Woodland	Woodland
468470.35	3264445.63	Woodland	Woodland
503660.35	3264235.63	Woodland	Woodland
493430.35	3279085.63	Woodland	Woodland
496730.35	3259825.63	Woodland	Grassland
486560.35	3277435.63	Woodland	Grassland
488480.35	3277285.63	Woodland	Grassland
457220.35	3276265.63	Woodland	Grassland
471080.35	3273985.63	Woodland	Woodland
456890.35	3288025.63	Woodland	Woodland
486290.35	3272365.63	Woodland	Woodland

Table B-3 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
493730.35	3266815.63	Woodland	Woodland
486770.35	3266725.63	Woodland	Woodland
486230.35	3280285.63	Woodland	Woodland
474350.35	3277675.63	Woodland	Woodland
472040.35	3277615.63	Woodland	Grassland
467600.35	3270205.63	Woodland	Woodland
523790.35	3297385.63	Woodland	Woodland
517490.35	3297175.63	Woodland	Woodland
549140.35	3296815.63	Woodland	Woodland
556970.35	3296455.63	Woodland	Woodland
533000.35	3294265.63	Woodland	Grassland
525350.35	3294025.63	Woodland	Woodland
531380.35	3289045.63	Woodland	Woodland
519020.35	3300205.63	Woodland	Woodland
516710.35	3297445.63	Woodland	Woodland
518150.35	3302035.63	Woodland	Woodland
536750.35	3293635.63	Woodland	Grassland
521450.35	3290635.63	Woodland	Woodland
563360.35	3288685.63	Woodland	Woodland
559280.35	3286255.63	Woodland	Woodland
521630.35	3298675.63	Woodland	Woodland
544730.35	3293785.63	Woodland	Woodland
547790.35	3289195.63	Woodland	Woodland
615800.35	3352975.63	Woodland	Grassland
610400.35	3352135.63	Woodland	Woodland
604790.35	3348715.63	Woodland	Woodland
598460.35	3347275.63	Woodland	Woodland
604310.35	3346615.63	Woodland	Woodland
613010.35	3346045.63	Woodland	Woodland
591980.35	3329005.63	Woodland	Woodland
597680.35	3325615.63	Woodland	Woodland
608510.35	3353545.63	Woodland	Woodland
612770.35	3351565.63	Woodland	Woodland
603980.35	3351475.63	Woodland	Woodland
590000.35	3350335.63	Woodland	Woodland
586520.35	3349945.63	Woodland	Woodland
614390.35	3349255.63	Woodland	Woodland
616370.35	3348565.63	Woodland	Woodland
615680.35	3348055.63	Woodland	Woodland
593240.35	3346345.63	Woodland	Woodland
607280.35	3342565.63	Woodland	Woodland
581870.35	3341905.63	Woodland	Woodland
595850.35	3338485.63	Woodland	Woodland
599330.35	3336445.63	Woodland	Woodland
603620.35	3330115.63	Woodland	Woodland
590210.35	3338995.63	Woodland	Woodland

Table B-3 (Continued)

X-coordinate [m]	Y-coordinate [m]	Classified	Actual
592880.35	3338515.63	Woodland	Woodland
599570.35	3354775.63	Woodland	Woodland
612860.35	3353185.63	Woodland	Woodland
607040.35	3346645.63	Woodland	Impervious Surface
601730.35	3344845.63	Woodland	Woodland
573020.35	3337075.63	Woodland	Woodland

The following ArcView Avenue Script was used to randomly select points from a shapefile data set.

```
‘ Number of records to select
recnum = 100

theview = av.getactivedoc
thetheme = theview.getactivethemes.get(0)
thetable = thetheme.getftab
selbmp = thetable.getselection
selbmp.clearall
maxnum = selbmp.getsize - 1

reccount = 0
while (reccount < recnum)
  newrec = number.makerandom(0, maxnum)
  if (selbmp.get(newrec).not) then
    selbmp.set(newrec)
    reccount = reccount + 1
  end
end

theview.invalidate
```

APPENDIX C

```
' This script was designed to produce SSURGO data sets for the ArcView SWAT Model
' Author: Joshua M. Peschel, E.I.T,
' Created: 6.1.2003 - Version 1.0
' Updates: 1.01 (11.24.03), 1.02 (12.08.03)
' Last Modified: 05.25.2004 - Version 2.0

' Versions 1.01 and 1.02:
' 1) Fixed sorting errors that appeared with certain data sets (errors prevented model
from running)

' Version 2.0:
' 1) Ability to process SSURGO 1.0 and 2.x data sets
' 2) Combine tables feature added


' Set working directory path
Path = av.GetProject.GetWorkDir.AsString
WorkDir = Path+"\"
WorkDir.AsFileName.SetCWD

'PathFileName = FileName.GetCWD
'msgBox.Info(PathFileName.AsString,"Working Directory")

' Check for the existance of temporary table documents and remove if present

' Temporary table names
mapunitTable = "mapunit"
chorizonTable = "chorizon"
compTable = "component"
compjoinTable = "compjoin"
chorizonjoinTable = "chorizonjoin"
tempTable1 = "temptable1"
tempTable2 = "temptable2"
usersoilsTable = "usersoils"
usersoilTable = "usersoil"

' Get temporary tables from project
mapunitTableDoc = av.getProject.findDoc(mapunitTable)
mapunitTableDocString = mapunitTableDoc.AsString
chorizonTableDoc = av.getProject.findDoc(chorizonTable)
chorizonTableDocString = chorizonTableDoc.AsString
compTableDoc = av.getProject.findDoc(compTable)
compTableDocString = compTableDoc.AsString
compjoinTableDoc = av.getProject.findDoc(compjoinTable)
```

```
compjoinTableDocString = compjoinTableDoc.AsString
chorizonjoinTableDoc = av.getProject.findDoc(chorizonjoinTable)
chorizonjoinTableDocString = chorizonjoinTableDoc.AsString
tempTable1Doc = av.getProject.findDoc(tempTable1)
tempTable1DocString = tempTable1Doc.AsString
tempTable2Doc = av.getProject.findDoc(tempTable2)
tempTable2DocString = tempTable2Doc.AsString
usersoilsTableDoc = av.getProject.findDoc(usersoilsTable)
usersoilsTableDocString = usersoilsTableDoc.AsString
usersoilTableDoc = av.getProject.findDoc(usersoilTable)
usersoilTableDocString = usersoilTableDoc.AsString

' Procedure to remove mapunit temporary table document
if (mapunitTableDocString = "mapunit") then

  av.getProject.removeDoc(mapunitTableDoc)
  mapunitTable = nil
  mapunitTableDoc = nil
  mapunitTableDocString = nil
  av.purgeObjects
'  MsgBox.Info("mapunit table deleted from the project","Message 0 : Table Document
Removed from Project")

'else

'  MsgBox.Warning("mapunit table document does not exist in the project","Error 0:
Table Document Existance Warning")

end

' Procedure to remove chorizon temporary table document
if (chorizonTableDocString = "chorizon") then

  av.getProject.removeDoc(chorizonTableDoc)
  chorizonTable = nil
  chorizonTableDoc = nil
  chorizonTableDocString = nil
  av.purgeObjects
'  MsgBox.Info("chorizon table deleted from the project","Message 0 : Table Document
Removed from Project")

'else
```

```
'  MsgBox.Warning("chorizon table document does not exist in the project","Error 0:
Table Document Existance Warning")

end

' Procedure to remove component temporary table document
if (compTableDocString = "component") then

  av.getProject.removeDoc(compTableDoc)
  compTable = nil
  compTableDoc = nil
  compTableDocString = nil
  av.purgeObjects
'  MsgBox.Info("component table deleted from the project","Message 0 : Table
Document Removed from Project")

'else

'  MsgBox.Warning("comp table document does not exist in the project","Error 0: Table
Document Existance Warning")

end

' Procedure to remove compjoin temporary table document
if (compjoinTableDocString = "compjoin") then

  av.getProject.removeDoc(compjoinTableDoc)
  compjoinTable = nil
  compjoinTableDoc = nil
  compjoinTableDocString = nil
  av.purgeObjects
'  MsgBox.Info("compjoin table deleted from the project","Message 0 : Table Document
Removed from Project")

'else

'  MsgBox.Warning("compjoin table document does not exist in the project","Error 0:
Table Document Existance Warning")

end

' Procedure to remove chorizonjoin temporary table document
if (chorizonjoinTableDocString = "chorizonjoin") then
```

```
  av.getProject.removeDoc(chorizonjoinTableDoc)
  chorizonjoinTable = nil
  chorizonjoinTableDoc = nil
  chorizonjoinTableDocString = nil
  av.purgeObjects
'  MsgBox.Info("chorizonjoin table deleted from the project","Message 0 : Table
Document Removed from Project")

'else

'  MsgBox.Warning("chorizonjoin table document does not exist in the project","Error 0:
Table Document Existance Warning")

end

' Procedure to remove temptable1 temporary table document
if (tempTable1DocString = "temptable1") then

  av.getProject.removeDoc(tempTable1Doc)
  tempTable1 = nil
  tempTable1Doc = nil
  tempTable1DocString = nil
  av.purgeObjects
'  MsgBox.Info("temptable1 table deleted from the project","Message 0 : Table
Document Removed from Project")

'else

'  MsgBox.Warning("temptable1 table document does not exist in the project","Error 0:
Table Document Existance Warning")

end

' Procedure to remove temptable2 temporary table document
if (tempTable2DocString = "temptable2") then

  av.getProject.removeDoc(tempTable2Doc)
  tempTable2 = nil
  tempTable2Doc = nil
  tempTable2DocString = nil
  av.purgeObjects
'  MsgBox.Info("temptable2 table deleted from the project","Message 0 : Table
Document Removed from Project")
```

```
'else

'  MsgBox.Warning("temptable2 table document does not exist in the project","Error 0:
Table Document Existance Warning")

end

' Procedure to remove usersoils temporary table document
if (usersoilsTableDocString = "usersoils") then

  av.getProject.removeDoc(usersoilsTableDoc)
  usersoilsTable = nil
  usersoilsTableDoc = nil
  usersoilsTableDocString = nil
  av.purgeObjects
'  MsgBox.Info("usersoils table deleted from the project","Message 0 : Table Document
Removed from Project")

'else

'  MsgBox.Warning("usersoils table document does not exist in the project","Error 0:
Table Document Existance Warning")

end

' Procedure to remove usersoil temporary table document
if (usersoilTableDocString = "usersoil") then

  av.getProject.removeDoc(usersoilTableDoc)
  usersoilTable = nil
  usersoilTableDoc = nil
  usersoilTableDocString = nil
  av.purgeObjects
'  MsgBox.Info("usersoil table deleted from the project","Message 0 : Table Document
Removed from Project")

'else

'  MsgBox.Warning("usersoil table document does not exist in the project","Error 0:
Table Document Existance Warning")

end
```

```
'-------------------------------------------------------------------
' Import pipe delimited SSURGO 2.x tabular data files into .dbf files
'-------------------------------------------------------------------

' Begin mapunit.txt import procedure
mapunitTextFileName = (WorkDir+"mapunit.txt").AsString.AsFileName

if (File.Exists(mapunitTextFileName)) then

  ' Create field names
  f1   = Field.Make("musym",#FIELD_VCHAR,10,0)
  f2   = Field.Make("muname",#FIELD_VCHAR,60,0)
  f3   = Field.Make("mukind",#FIELD_VCHAR,20,0)
  f4   = Field.Make("mustatus",#FIELD_VCHAR,20,0)
  f5   = Field.Make("muacres",#FIELD_DECIMAL,10,2)
  f6   = Field.Make("munitlfw_l",#FIELD_VCHAR,10,0)
  f7   = Field.Make("munitlfw_r",#FIELD_VCHAR,10,0)
  f8   = Field.Make("munitlfw_h",#FIELD_VCHAR,10,0)
  f9   = Field.Make("munitpfa_l",#FIELD_VCHAR,10,0)
  f10  = Field.Make("munitpfa_r",#FIELD_VCHAR,10,0)
  f11  = Field.Make("munitpfa_h",#FIELD_VCHAR,10,0)
  f12  = Field.Make("farmlndcl",#FIELD_VCHAR,30,0)
  f13  = Field.Make("muhelcl",#FIELD_VCHAR,30,0)
  f14  = Field.Make("muwathelcl",#FIELD_VCHAR,30,0)
  f15  = Field.Make("muwndhelcl",#FIELD_VCHAR,30,0)
  f16  = Field.Make("interpfocu",#FIELD_VCHAR,10,0)
  f17  = Field.Make("invesinten",#FIELD_VCHAR,10,0)
  f18  = Field.Make("iacornsr",#FIELD_VCHAR,10,0)
  f19  = Field.Make("nhiforsoig",#FIELD_VCHAR,10,0)
  f20  = Field.Make("nhspiagr",#FIELD_VCHAR,10,0)
  f21  = Field.Make("vtsepticsy",#FIELD_VCHAR,10,0)
  f22  = Field.Make("mucertstat",#FIELD_VCHAR,10,0)
  f23  = Field.Make("lkey",#FIELD_VCHAR,10,0)
  f24  = Field.Make("mukey",#FIELD_VCHAR,20,0)

  ' Create mapunit table
  mapunitTableName = (WorkDir+"mapunit.dbf").AsFileName
  mapunitVTab = VTab.MakeNew(mapunitTableName,dbase)
  mapunitTable = Table.Make(mapunitVTab)
  mapunitTable.SetName(("mapunit").AsString)

  ' Add fields to the component table
  mapunitVTab.AddFields(
   {f1,f2,f3,f4,f5,f6,f7,f8,f9,f10,
```

```
  f11,f12,f13,f14,f15,f16,f17,f18,f19,f20,
  f21,f22,f23,f24})

 ' Read mapunit.txt data into line file
  mapunitLineFile = LineFile.Make(mapunitTextFileName, #FILE_PERM_READ)
  mapunitLineFileSize = mapunitLineFile.GetSize

 ' Import procedure for mapunit.txt data
  mapunitVTab.SetEditable(True)
  mapunitFieldList = mapunitVTab.GetFields

  for each line in 1..mapunitLineFileSize
   mapunitPosition = mapunitLineFile.GetPos
   mapunitLine = mapunitLineFile.ReadELT

   ' Remove qualifier from data
    if (mapunitLine.Contains("""")) then
     mapunitLine = mapunitLine.Substitute("""", "")
    end

    mapunitLineLength = mapunitLine.Count
    if (mapunitPosition > -1) then
     newRecord = mapunitVTab.AddRecord

     ' Add data to fields
      for each recordfield in mapunitFieldList
       mapunitOffset = mapunitLine.IndexOf("|")
       mapunitValue = mapunitLine.Left(mapunitOffset)
       mapunitVTab.SetValue(recordfield,newRecord,mapunitValue)
       mapunitLine = mapunitLine.Right(mapunitLineLength-(mapunitOffset+1))
       mapunitLineLength = mapunitLine.Count
      end

    end
  end

  mapunitVTab.SetEditable(False)

else
 MsgBox.Warning("The mapunit.txt file does not exist in the home directory","Error 1:
File Existance Warning")
 Exit
end
```

```
' Begin comp.txt import procedure
componentTextFileName = (WorkDir+"comp.txt").AsString.AsFileName
if (File.Exists(componentTextFileName)) then

  ' Create field names
  f1   = Field.Make("comppct_l",#FIELD_DECIMAL,10,2)
  f2   = Field.Make("comppct_r",#FIELD_DECIMAL,10,2)
  f3   = Field.Make("comppct_h",#FIELD_DECIMAL,10,2)
  f4   = Field.Make("compname",#FIELD_VCHAR,20,0)
  f5   = Field.Make("compkind",#FIELD_VCHAR,20,0)
  f6   = Field.Make("majcompfla",#FIELD_VCHAR,3,0)
  f7   = Field.Make("otherph",#FIELD_VCHAR,20,0)
  f8   = Field.Make("localphase",#FIELD_VCHAR,20,0)
  f9   = Field.Make("slope_l",#FIELD_DECIMAL,10,2)
  f10  = Field.Make("slope_r",#FIELD_DECIMAL,10,2)
  f11  = Field.Make("slope_h",#FIELD_DECIMAL,10,2)
  f12  = Field.Make("sllnusle_l",#FIELD_DECIMAL,10,2)
  f13  = Field.Make("sllnusle_r",#FIELD_DECIMAL,10,2)
  f14  = Field.Make("sllnusle_h",#FIELD_DECIMAL,10,2)
  f15  = Field.Make("runoff",#FIELD_VCHAR,20,0)
  f16  = Field.Make("tfact",#FIELD_DECIMAL,10,2)
  f17  = Field.Make("wei",#FIELD_DECIMAL,10,2)
  f18  = Field.Make("weg",#FIELD_VCHAR,10,0)
  f19  = Field.Make("erocl",#FIELD_VCHAR,10,0)
  f20  = Field.Make("earthcovk1",#FIELD_VCHAR,20,0)
  f21  = Field.Make("earthcovk2",#FIELD_VCHAR,20,0)
  f22  = Field.Make("hydricon",#FIELD_VCHAR,20,0)
  f23  = Field.Make("hydricring",#FIELD_VCHAR,3,0)
  f24  = Field.Make("drainagecl",#FIELD_VCHAR,20,0)
  f25  = Field.Make("elev_l",#FIELD_DECIMAL,10,2)
  f26  = Field.Make("elev_r",#FIELD_DECIMAL,10,2)
  f27  = Field.Make("elev_h",#FIELD_DECIMAL,10,2)
  f28  = Field.Make("aspectcwie",#FIELD_DECIMAL,10,2)
  f29  = Field.Make("aspectrep",#FIELD_DECIMAL,10,2)
  f30  = Field.Make("aspctwise",#FIELD_DECIMAL,10,2)
  f31  = Field.Make("geomdesc",#FIELD_VCHAR,20,0)
  f32  = Field.Make("albedodr_l",#FIELD_DECIMAL,10,2)
  f33  = Field.Make("albedodr_r",#FIELD_DECIMAL,10,2)
  f34  = Field.Make("albedodr_h",#FIELD_DECIMAL,10,2)
  f35  = Field.Make("airtempa_l",#FIELD_DECIMAL,10,2)
  f36  = Field.Make("airtempa_r",#FIELD_DECIMAL,10,2)
  f37  = Field.Make("airtempa_h",#FIELD_DECIMAL,10,2)
  f38  = Field.Make("map_l",#FIELD_DECIMAL,10,2)
  f39  = Field.Make("map_r",#FIELD_DECIMAL,10,2)
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f40  = Field.Make("map_h",#FIELD_DECIMAL,10,2)
f41  = Field.Make("reannpre_l",#FIELD_DECIMAL,10,2)
f42  = Field.Make("reannpre_r",#FIELD_DECIMAL,10,2)
f43  = Field.Make("reannpre_h",#FIELD_DECIMAL,10,2)
f44  = Field.Make("ffd_l",#FIELD_DECIMAL,10,0)
f45  = Field.Make("ffd_r",#FIELD_DECIMAL,10,0)
f46  = Field.Make("ffd_h",#FIELD_DECIMAL,10,0)
f47  = Field.Make("nirrcapcl",#FIELD_VCHAR,10,0)
f48  = Field.Make("nirrcapsci",#FIELD_VCHAR,10,0)
f49  = Field.Make("nirrcapuni",#FIELD_VCHAR,10,0)
f50  = Field.Make("irrcapcl",#FIELD_VCHAR,10,0)
f51  = Field.Make("irrcapsci",#FIELD_VCHAR,10,0)
f52  = Field.Make("irrcapunit",#FIELD_VCHAR,10,0)
f53  = Field.Make("croprindex",#FIELD_VCHAR,10,0)
f54  = Field.Make("contrubgrp",#FIELD_VCHAR,10,0)
f55  = Field.Make("wndsuitgrp",#FIELD_VCHAR,10,0)
f56  = Field.Make("rsprod_l",#FIELD_DECIMAL,10,2)
f57  = Field.Make("rsprod_r",#FIELD_DECIMAL,10,2)
f58  = Field.Make("rsprod_h",#FIELD_DECIMAL,10,2)
f59  = Field.Make("forsuitgrp",#FIELD_VCHAR,10,0)
f60  = Field.Make("wlgrain",#FIELD_VCHAR,10,0)
f61  = Field.Make("wlgrass",#FIELD_VCHAR,10,0)
f62  = Field.Make("wlherbaceo",#FIELD_VCHAR,10,0)
f63  = Field.Make("wlshrub",#FIELD_VCHAR,10,0)
f64  = Field.Make("wlconifero",#FIELD_VCHAR,10,0)
f65  = Field.Make("wlhardwood",#FIELD_VCHAR,10,0)
f66  = Field.Make("wlwetplant",#FIELD_VCHAR,10,0)
f67  = Field.Make("wlshalloww",#FIELD_VCHAR,10,0)
f68  = Field.Make("wlrangelan",#FIELD_VCHAR,10,0)
f69  = Field.Make("wlopenland",#FIELD_VCHAR,10,0)
f70  = Field.Make("wlwoodland",#FIELD_VCHAR,10,0)
f71  = Field.Make("wlwetland",#FIELD_VCHAR,10,0)
f72  = Field.Make("soilslippo",#FIELD_VCHAR,10,0)
f73  = Field.Make("frostact",#FIELD_VCHAR,10,0)
f74  = Field.Make("init_l",#FIELD_DECIMAL,10,2)
f75  = Field.Make("init_r",#FIELD_DECIMAL,10,2)
f76  = Field.Make("init_h",#FIELD_DECIMAL,10,2)
f77  = Field.Make("totalsub_l",#FIELD_DECIMAL,10,2)
f78  = Field.Make("totalsub_r",#FIELD_DECIMAL,10,2)
f79  = Field.Make("totalsub_h",#FIELD_DECIMAL,10,2)
f80  = Field.Make("hydgrp",#FIELD_VCHAR,10,0)
f81  = Field.Make("corcon",#FIELD_VCHAR,10,0)
f82  = Field.Make("corsteel",#FIELD_VCHAR,10,0)
f83  = Field.Make("taxclname",#FIELD_VCHAR,60,0)
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f84  = Field.Make("taxorder",#FIELD_VCHAR,20,0)
f85  = Field.Make("taxsuborde",#FIELD_VCHAR,20,0)
f86  = Field.Make("taxgrtgrou",#FIELD_VCHAR,20,0)
f87  = Field.Make("taxsubgrp",#FIELD_VCHAR,30,0)
f88  = Field.Make("taxpartsiz",#FIELD_VCHAR,20,0)
f89  = Field.Make("taxpartsmo",#FIELD_VCHAR,10,0)
f90  = Field.Make("taxceactcl",#FIELD_VCHAR,10,0)
f91  = Field.Make("taxreactio",#FIELD_VCHAR,10,0)
f92  = Field.Make("taxtempcl",#FIELD_VCHAR,20,0)
f93  = Field.Make("taxmoistcl",#FIELD_VCHAR,10,0)
f94  = Field.Make("taxtempreg",#FIELD_VCHAR,20,0)
f95  = Field.Make("soiltaxedi",#FIELD_VCHAR,20,0)
f96  = Field.Make("castoriein",#FIELD_VCHAR,10,0)
f97  = Field.Make("flecolcomn",#FIELD_VCHAR,10,0)
f98  = Field.Make("flhe",#FIELD_VCHAR,3,0)
f99  = Field.Make("flphe",#FIELD_VCHAR,3,0)
f100 = Field.Make("flsoilleac",#FIELD_VCHAR,10,0)
f101 = Field.Make("flsoirunof",#FIELD_VCHAR,10,0)
f102 = Field.Make("fltemik2us",#FIELD_VCHAR,10,0)
f103 = Field.Make("fltriumph2",#FIELD_VCHAR,10,0)
f104 = Field.Make("indraingrp",#FIELD_VCHAR,10,0)
f105 = Field.Make("innitratel",#FIELD_VCHAR,10,0)
f106 = Field.Make("misoimgmtg",#FIELD_VCHAR,10,0)
f107 = Field.Make("vasoimgtgr",#FIELD_VCHAR,10,0)
f108 = Field.Make("mukey",#FIELD_VCHAR,20,0)
f109 = Field.Make("cokey",#FIELD_VCHAR,20,0)

' Create component table
componentTableName = (WorkDir+"component.dbf").AsFileName
componentVTab = VTab.MakeNew(componentTableName,dbase)
componentTable = Table.Make(componentVTab)
componentTable.SetName(("component").AsString)

' Add fields to the component table
componentVTab.AddFields(
 {f1,f2,f3,f4,f5,f6,f7,f8,f9,f10,
  f11,f12,f13,f14,f15,f16,f17,f18,f19,f20,
 f21,f22,f23,f24,f25,f26,f27,f28,f29,f30,
 f31,f32,f33,f34,f35,f36,f37,f38,f39,f40,
 f41,f42,f43,f44,f45,f46,f47,f48,f49,f50,
 f51,f52,f53,f54,f55,f56,f57,f58,f59,f60,
 f61,f62,f63,f64,f65,f66,f67,f68,f69,f70,
 f71,f72,f73,f74,f75,f76,f77,f78,f79,f80,
 f81,f82,f83,f84,f85,f86,f87,f88,f89,f90,
```

```
   f91,f92,f93,f94,f95,f96,f97,f98,f99,f100,
   f101,f102,f103,f104,f105,f106,f107,f108,f109})

  ' Read comp.txt data into line file
    componentLineFile = LineFile.Make(componentTextFileName,
#FILE_PERM_READ)
    componentLineFileSize = componentLineFile.GetSize

  ' Import procedure for comp.txt data
    componentVTab.SetEditable(True)
    componentFieldList = componentVTab.GetFields

    for each line in 1..componentLineFileSize
      componentPosition = componentLineFile.GetPos
      componentLine = componentLineFile.ReadELT

      ' Remove qualifier from data
        if (componentLine.Contains("""")) then
          componentLine = componentLine.Substitute("""", "")
        end

        componentLineLength = componentLine.Count
        if (componentPosition > -1) then
          newRecord = componentVTab.AddRecord

        ' Add data to fields
          for each recordfield in componentFieldList
            componentOffset = componentLine.IndexOf("|")
            componentValue = componentLine.Left(componentOffset)
            componentVTab.SetValue(recordfield,newRecord,componentValue)
            componentLine = componentLine.Right(componentLineLength-
(componentOffset+1))
            componentLineLength = componentLine.Count
          end

        end
    end

    componentVTab.SetEditable(False)

else
  MsgBox.Warning("The comp.txt file does not exist in the home directory","Error 1:
File Existance Warning")
  Exit
```

```
end

' Begin chorizon.txt import procedure
chorizonTextFileName = (WorkDir+"chorizon.txt").AsString.AsFileName
if (File.Exists(chorizonTextFileName)) then

  ' Create field names
  f1  = Field.Make("hzname",#FIELD_VCHAR,10,0)
  f2  = Field.Make("desgndisc",#FIELD_DECIMAL,10,0)
  f3  = Field.Make("desgn",#FIELD_VCHAR,12,0)
  f4  = Field.Make("desgnp",#FIELD_VCHAR,12,0)
  f5  = Field.Make("desgnvert",#FIELD_VCHAR,10,0)
  f6  = Field.Make("hzdept_l",#FIELD_DECIMAL,10,2)
  f7  = Field.Make("hzdept_r",#FIELD_DECIMAL,10,2)
  f8  = Field.Make("hzdept_h",#FIELD_DECIMAL,10,2)
  f9  = Field.Make("hzdepb_l",#FIELD_DECIMAL,10,2)
  f10  = Field.Make("hzdepb_r",#FIELD_DECIMAL,10,2)
  f11  = Field.Make("hzdepb_h",#FIELD_DECIMAL,10,2)
  f12  = Field.Make("hzthk_l",#FIELD_DECIMAL,10,2)
  f13  = Field.Make("hzthk_r",#FIELD_DECIMAL,10,2)
  f14  = Field.Make("hzthk_h",#FIELD_DECIMAL,10,2)
  f15  = Field.Make("frag10_l",#FIELD_DECIMAL,10,2)
  f16  = Field.Make("frag10_r",#FIELD_DECIMAL,10,2)
  f17  = Field.Make("frag10_h",#FIELD_DECIMAL,10,2)
  f18  = Field.Make("frag3_10_l",#FIELD_DECIMAL,10,2)
  f19  = Field.Make("frag3_10_r",#FIELD_DECIMAL,10,2)
  f20  = Field.Make("frag3_10_h",#FIELD_DECIMAL,10,2)
  f21  = Field.Make("sieve4_l",#FIELD_DECIMAL,10,2)
  f22  = Field.Make("sieve4_r",#FIELD_DECIMAL,10,2)
  f23  = Field.Make("sieve4_h",#FIELD_DECIMAL,10,2)
  f24  = Field.Make("sieve10_l",#FIELD_DECIMAL,10,2)
  f25  = Field.Make("sieve10_r",#FIELD_DECIMAL,10,2)
  f26  = Field.Make("sieve10_h",#FIELD_DECIMAL,10,2)
  f27  = Field.Make("sieve40_l",#FIELD_DECIMAL,10,2)
  f28  = Field.Make("sieve40_r",#FIELD_DECIMAL,10,2)
  f29  = Field.Make("sieve40_h",#FIELD_DECIMAL,10,2)
  f30  = Field.Make("sieve200_l",#FIELD_DECIMAL,10,2)
  f31  = Field.Make("sieve200_r",#FIELD_DECIMAL,10,2)
  f32  = Field.Make("sieve200_h",#FIELD_DECIMAL,10,2)
  f33  = Field.Make("sandtot_l",#FIELD_DECIMAL,10,2)
  f34  = Field.Make("sandtot_r",#FIELD_DECIMAL,10,2)
  f35  = Field.Make("sandtot_h",#FIELD_DECIMAL,10,2)
  f36  = Field.Make("sandvc_l",#FIELD_DECIMAL,10,2)
  f37  = Field.Make("sandvc_r",#FIELD_DECIMAL,10,2)
```

```
f38 = Field.Make("sandvc_h",#FIELD_DECIMAL,10,2)
f39 = Field.Make("sandco_l",#FIELD_DECIMAL,10,2)
f40 = Field.Make("sandco_r",#FIELD_DECIMAL,10,2)
f41 = Field.Make("sandco_h",#FIELD_DECIMAL,10,2)
f42 = Field.Make("sandmed_l",#FIELD_DECIMAL,10,2)
f43 = Field.Make("sandmed_r",#FIELD_DECIMAL,10,2)
f44 = Field.Make("sandmed_h",#FIELD_DECIMAL,10,2)
f45 = Field.Make("sandfine_l",#FIELD_DECIMAL,10,2)
f46 = Field.Make("sandfine_r",#FIELD_DECIMAL,10,2)
f47 = Field.Make("sandfine_h",#FIELD_DECIMAL,10,2)
f48 = Field.Make("sandvf_l",#FIELD_DECIMAL,10,2)
f49 = Field.Make("sandvf_r",#FIELD_DECIMAL,10,2)
f50 = Field.Make("sandvf_h",#FIELD_DECIMAL,10,2)
f51 = Field.Make("silttot_l",#FIELD_DECIMAL,10,2)
f52 = Field.Make("silttot_r",#FIELD_DECIMAL,10,2)
f53 = Field.Make("silttot_h",#FIELD_DECIMAL,10,2)
f54 = Field.Make("siltco_l",#FIELD_DECIMAL,10,2)
f55 = Field.Make("siltco_r",#FIELD_DECIMAL,10,2)
f56 = Field.Make("siltco_h",#FIELD_DECIMAL,10,2)
f57 = Field.Make("siltfine_l",#FIELD_DECIMAL,10,2)
f58 = Field.Make("siltfine_r",#FIELD_DECIMAL,10,2)
f59 = Field.Make("siltfine_h",#FIELD_DECIMAL,10,2)
f60 = Field.Make("claytot_l",#FIELD_DECIMAL,10,2)
f61 = Field.Make("claytot_r",#FIELD_DECIMAL,10,2)
f62 = Field.Make("claytot_h",#FIELD_DECIMAL,10,2)
f63 = Field.Make("claysizc_l",#FIELD_DECIMAL,10,2)
f64 = Field.Make("claysizc_r",#FIELD_DECIMAL,10,2)
f65 = Field.Make("claysizc_h",#FIELD_DECIMAL,10,2)
f66 = Field.Make("om_l",#FIELD_DECIMAL,10,2)
f67 = Field.Make("om_r",#FIELD_DECIMAL,10,2)
f68 = Field.Make("om_h",#FIELD_DECIMAL,10,2)
f69 = Field.Make("dbtenbar_l",#FIELD_DECIMAL,10,2)
f70 = Field.Make("dbtenbar_r",#FIELD_DECIMAL,10,2)
f71 = Field.Make("dbtenbar_h",#FIELD_DECIMAL,10,2)
f72 = Field.Make("dbthibar_l",#FIELD_DECIMAL,10,2)
f73 = Field.Make("dbthibar_r",#FIELD_DECIMAL,10,2)
f74 = Field.Make("dbthibar_h",#FIELD_DECIMAL,10,2)
f75 = Field.Make("dbfifbar_l",#FIELD_DECIMAL,10,2)
f76 = Field.Make("dbfifbar_r",#FIELD_DECIMAL,10,2)
f77 = Field.Make("dbfifbar_h",#FIELD_DECIMAL,10,2)
f78 = Field.Make("dbovdry_l",#FIELD_DECIMAL,10,2)
f79 = Field.Make("dbovdry_r",#FIELD_DECIMAL,10,2)
f80 = Field.Make("dbovdry_h",#FIELD_DECIMAL,10,2)
f81 = Field.Make("partden",#FIELD_DECIMAL,10,2)
```

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f82  = Field.Make("ksat_l",#FIELD_DECIMAL,10,2)
f83  = Field.Make("ksat_r",#FIELD_DECIMAL,10,2)
f84  = Field.Make("ksat_h",#FIELD_DECIMAL,10,2)
f85  = Field.Make("awc_l",#FIELD_DECIMAL,10,2)
f86  = Field.Make("awc_r",#FIELD_DECIMAL,10,2)
f87  = Field.Make("awc_h",#FIELD_DECIMAL,10,2)
f88  = Field.Make("wtenbar_l",#FIELD_DECIMAL,10,2)
f89  = Field.Make("wtenbar_r",#FIELD_DECIMAL,10,2)
f90  = Field.Make("wtenbar_h",#FIELD_DECIMAL,10,2)
f91  = Field.Make("wthirbar_l",#FIELD_DECIMAL,10,2)
f92  = Field.Make("wthirbar_r",#FIELD_DECIMAL,10,2)
f93  = Field.Make("wthirbar_h",#FIELD_DECIMAL,10,2)
f94  = Field.Make("wfifbar_l",#FIELD_DECIMAL,10,2)
f95  = Field.Make("wfifbar_r",#FIELD_DECIMAL,10,2)
f96  = Field.Make("wfifbar_h",#FIELD_DECIMAL,10,2)
f97  = Field.Make("wsatiate_l",#FIELD_DECIMAL,10,2)
f98  = Field.Make("wsatiate_r",#FIELD_DECIMAL,10,2)
f99  = Field.Make("wsatiate_h",#FIELD_DECIMAL,10,2)
f100 = Field.Make("lep_l",#FIELD_DECIMAL,10,2)
f101 = Field.Make("lep_r",#FIELD_DECIMAL,10,2)
f102 = Field.Make("lep_h",#FIELD_DECIMAL,10,2)
f103 = Field.Make("ll_l",#FIELD_DECIMAL,10,2)
f104 = Field.Make("ll_r",#FIELD_DECIMAL,10,2)
f105 = Field.Make("ll_h",#FIELD_DECIMAL,10,2)
f106 = Field.Make("pi_l",#FIELD_DECIMAL,10,2)
f107 = Field.Make("pi_r",#FIELD_DECIMAL,10,2)
f108 = Field.Make("pi_h",#FIELD_DECIMAL,10,2)
f109 = Field.Make("aashind_l",#FIELD_DECIMAL,10,2)
f110 = Field.Make("aashind_r",#FIELD_DECIMAL,10,2)
f111 = Field.Make("aashind_h",#FIELD_DECIMAL,10,2)
f112 = Field.Make("kwfact",#FIELD_DECIMAL,10,2)
f113 = Field.Make("kffact",#FIELD_DECIMAL,10,2)
f114 = Field.Make("caco3_l",#FIELD_DECIMAL,10,2)
f115 = Field.Make("caco3_r",#FIELD_DECIMAL,10,2)
f116 = Field.Make("caco3_h",#FIELD_DECIMAL,10,2)
f117 = Field.Make("gypsum_l",#FIELD_DECIMAL,10,2)
f118 = Field.Make("gypsum_r",#FIELD_DECIMAL,10,2)
f119 = Field.Make("gypsum_h",#FIELD_DECIMAL,10,2)
f120 = Field.Make("sar_l",#FIELD_DECIMAL,10,2)
f121 = Field.Make("sar_r",#FIELD_DECIMAL,10,2)
f122 = Field.Make("sar_h",#FIELD_DECIMAL,10,2)
f123 = Field.Make("ec_l",#FIELD_DECIMAL,10,2)
f124 = Field.Make("ec_r",#FIELD_DECIMAL,10,2)
f125 = Field.Make("ec_h",#FIELD_DECIMAL,10,2)
```

```
f126 = Field.Make("cec7_l",#FIELD_DECIMAL,10,2)
f127 = Field.Make("cec7_r",#FIELD_DECIMAL,10,2)
f128 = Field.Make("cec7_h",#FIELD_DECIMAL,10,2)
f129 = Field.Make("ecec_l",#FIELD_DECIMAL,10,2)
f130 = Field.Make("ecec_r",#FIELD_DECIMAL,10,2)
f131 = Field.Make("ecec_h",#FIELD_DECIMAL,10,2)
f132 = Field.Make("sumbases_l",#FIELD_DECIMAL,10,2)
f133 = Field.Make("sumbases_r",#FIELD_DECIMAL,10,2)
f134 = Field.Make("sumbases_h",#FIELD_DECIMAL,10,2)
f135 = Field.Make("ph1_1h2o_l",#FIELD_DECIMAL,10,2)
f136 = Field.Make("ph1_1h2o_r",#FIELD_DECIMAL,10,2)
f137 = Field.Make("ph1_1h2o_h",#FIELD_DECIMAL,10,2)
f138 = Field.Make("ph01mcl2_l",#FIELD_DECIMAL,10,2)
f139 = Field.Make("ph01mc12_r",#FIELD_DECIMAL,10,2)
f140 = Field.Make("ph01mc12_h",#FIELD_DECIMAL,10,2)
f141 = Field.Make("freeiron_l",#FIELD_DECIMAL,10,2)
f142 = Field.Make("freeiron_r",#FIELD_DECIMAL,10,2)
f143 = Field.Make("freeiron_h",#FIELD_DECIMAL,10,2)
f144 = Field.Make("feoxalat_l",#FIELD_DECIMAL,10,2)
f145 = Field.Make("feoxalat_r",#FIELD_DECIMAL,10,2)
f146 = Field.Make("feoxalat_h",#FIELD_DECIMAL,10,2)
f147 = Field.Make("extracid_l",#FIELD_DECIMAL,10,2)
f148 = Field.Make("extracid_r",#FIELD_DECIMAL,10,2)
f149 = Field.Make("extracid_h",#FIELD_DECIMAL,10,2)
f150 = Field.Make("extral_l",#FIELD_DECIMAL,10,2)
f151 = Field.Make("extral_r",#FIELD_DECIMAL,10,2)
f152 = Field.Make("extral_h",#FIELD_DECIMAL,10,2)
f153 = Field.Make("aloxalat_l",#FIELD_DECIMAL,10,2)
f154 = Field.Make("aloxalat_r",#FIELD_DECIMAL,10,2)
f155 = Field.Make("aloxalat_h",#FIELD_DECIMAL,10,2)
f156 = Field.Make("pbray1_l",#FIELD_DECIMAL,10,2)
f157 = Field.Make("pbray1_r",#FIELD_DECIMAL,10,2)
f158 = Field.Make("pbray1_h",#FIELD_DECIMAL,10,2)
f159 = Field.Make("poxalate_l",#FIELD_DECIMAL,10,2)
f160 = Field.Make("poxalate_r",#FIELD_DECIMAL,10,2)
f161 = Field.Make("poxalate_h",#FIELD_DECIMAL,10,2)
f162 = Field.Make("ph2osolu_l",#FIELD_DECIMAL,10,2)
f163 = Field.Make("ph2osolu_r",#FIELD_DECIMAL,10,2)
f164 = Field.Make("ph2osolu_h",#FIELD_DECIMAL,10,2)
f165 = Field.Make("ptotal_l",#FIELD_DECIMAL,10,2)
f166 = Field.Make("ptotal_r",#FIELD_DECIMAL,10,2)
f167 = Field.Make("ptotal_h",#FIELD_DECIMAL,10,2)
f168 = Field.Make("excavdifcl",#FIELD_DECIMAL,10,2)
f169 = Field.Make("excavdifms",#FIELD_DECIMAL,10,2)
```

```
f170 = Field.Make("cokey",#FIELD_VCHAR,20,0)
f171 = Field.Make("chkey",#FIELD_VCHAR,20,0)

' Create chorizon table
chorizonTableName = (WorkDir+"chorizon.dbf").AsFileName
chorizonVTab = VTab.MakeNew(chorizonTableName,dbase)
chorizonTable = Table.Make(chorizonVTab)
chorizonTable.SetName(("chorizon").AsString)

' Add fields to the chorizon table
chorizonVTab.AddFields(
 {f1,f2,f3,f4,f5,f6,f7,f8,f9,f10,
  f11,f12,f13,f14,f15,f16,f17,f18,f19,f20,
 f21,f22,f23,f24,f25,f26,f27,f28,f29,f30,
 f31,f32,f33,f34,f35,f36,f37,f38,f39,f40,
 f41,f42,f43,f44,f45,f46,f47,f48,f49,f50,
 f51,f52,f53,f54,f55,f56,f57,f58,f59,f60,
 f61,f62,f63,f64,f65,f66,f67,f68,f69,f70,
 f71,f72,f73,f74,f75,f76,f77,f78,f79,f80,
 f81,f82,f83,f84,f85,f86,f87,f88,f89,f90,
 f91,f92,f93,f94,f95,f96,f97,f98,f99,f100,
 f101,f102,f103,f104,f105,f106,f107,f108,f109,f110,
 f111,f112,f113,f114,f115,f116,f117,f118,f119,f120,
 f121,f122,f123,f124,f125,f126,f127,f128,f129,f130,
 f131,f132,f133,f134,f135,f136,f137,f138,f139,f140,
 f141,f142,f143,f144,f145,f146,f147,f148,f149,f150,
 f151,f152,f153,f154,f155,f156,f157,f158,f159,f160,
 f161,f162,f163,f164,f165,f166,f167,f168,f169,f170,
 f171})

' Read chorizon.txt data into line file
  chorizonLineFile = LineFile.Make(chorizonTextFileName, #FILE_PERM_READ)
  chorizonLineFileSize = chorizonLineFile.GetSize

' Import procedure for chorizon.txt data
  chorizonVTab.SetEditable(True)
  chorizonFieldList = chorizonVTab.GetFields

  for each line in 1..chorizonLineFileSize
    chorizonPosition = chorizonLineFile.GetPos
    chorizonLine = chorizonLineFile.ReadELT

    ' Remove qualifier from data
      if (chorizonLine.Contains("""")) then
```

```
      chorizonLine = chorizonLine.Substitute("""", "")
    end

    chorizonLineLength = chorizonLine.Count
    if (chorizonPosition > -1) then
      newRecord = chorizonVTab.AddRecord

      ' Add data to fields
        for each recordfield in chorizonFieldList
          chorizonOffset = chorizonLine.IndexOf("|")
          chorizonValue = chorizonLine.Left(chorizonOffset)
          chorizonVTab.SetValue(recordfield,newRecord,chorizonValue)
          chorizonLine = chorizonLine.Right(chorizonLineLength-(chorizonOffset+1))
          chorizonLineLength = chorizonLine.Count
        end

    end
  end

  chorizonVTab.SetEditable(False)

else
  MsgBox.Warning("The chorizon.txt file does not exist in the home directory","Error 1:
File Existance Warning")
  Exit
end

'------------------------------------------------------------------------
' Join mapunit table to components table and will join compjoin to chorizon
'------------------------------------------------------------------------

' Set up MapUnit table
SetMapUnitTable = av.GetProject.FindDoc("mapunit")
SetMapUnitVTab = SetMapUnitTable.GetVTab
SetMapUnitField = SetMapUnitVTab.FindField("mukey")

' Set up Component table
SetCompTable = av.GetProject.FindDoc("component")
SetCompVTab = SetCompTable.GetVtab
SetCompField = SetCompVTab.FindField("mukey")

' Perform mapunit to components join action
SetCompVTab.Join(SetCompField,SetMapUnitVTab,SetMapUnitField)
```

```
' Save a quick copy of joined table
CompJoinTable = av.GetProject.FindDoc("component")
CompJoinVTab = CompJoinTable.GetVTab
CompJoinVTab.Export("compjoin".asFileName,dbase,false)

' Remove join between mapunit and component tables
CompJoinVTab.UnJoinAll

' Add compjoin table to project
AddCompJoinVTab = VTab.Make("compjoin.dbf".AsFileName,false,false)
AddCompJoinTable = Table.Make(AddCompJoinVTab)
AddCompJoinTable.SetName("compjoin")
av.GetProject.AddDoc(AddCompJoinTable)

' Set up CompJoin table
SetCompJoinTable = av.GetProject.FindDoc("compjoin")
SetCompJoinVTab = SetCompJoinTable.GetVtab
SetCompJoinField = SetCompJoinVTab.FindField("cokey")

' Set up Horizon table
SetChorizonTable = av.GetProject.FindDoc("chorizon")
SetChorizonVTab = SetChorizonTable.GetVTab
SetChorizonField = SetChorizonVTab.FindField("cokey")

' Perform join between compjoin and chorizon
SetChorizonVTab.Join(SetChorizonField,SetCompJoinVTab,SetCompJoinField)

' Save a quick copy of joined table
ChorizonJoinTable = av.GetProject.FindDoc("chorizon")
ChorizonJoinVTab = ChorizonJoinTable.GetVTab
ChorizonJoinVTab.Export("chorizonjoin".asFileName,dbase,false)

' Remove join between compjoin and chorizontables
SetChorizonVTab.UnJoinAll

' Add chorizonjoin table to project
AddChorizonJoinVTab = VTab.Make("chorizonjoin.dbf".AsFileName,false,false)
AddChorizonJoinTable = Table.Make(AddChorizonJoinVTab)
AddChorizonJoinTable.SetName("chorizonjoin")
av.GetProject.AddDoc(AddChorizonJoinTable)

'-------------------------------------------------------------------------
' Add calculation fields to chorizonjoin.dbf
'-------------------------------------------------------------------------
```

```
' Find chorizonjoin table
ChorizonJoinTable = av.GetProject.FindDoc("chorizonjoin")
ChorizonJoinVTab = ChorizonJoinTable.GetVTab

' Create field names
f1 = Field.Make("hzdepth_rc",#FIELD_DECIMAL,10,2)
f2 = Field.Make("rock",#FIELD_DECIMAL,10,2)
f3 = Field.Make("k_calc",#FIELD_DECIMAL,10,2)
f4 = Field.Make("om_rc",#FIELD_DECIMAL,10,2)
f5 = Field.Make("sol_albc",#FIELD_DECIMAL,10,2)
f6 = Field.Make("textstring",#FIELD_VCHAR,1000,0)

ChorizonJoinFieldList = {f1,f2,f3,f4,f5,f6}
ChorizonJoinVTab.GetSelection.ClearAll
ChorizonJoinVTab.UpdateSelection
ChorizonJoinVTab.SetEditable(true)
ChorizonJoinVTab.AddFields(ChorizonJoinFieldList)
ChorizonJoinVTab.Calculate("[hzdepb_r]*10",f1)
ChorizonJoinVTab.Calculate("100 - [sieve10_r]",f2)
ChorizonJoinVTab.Calculate("[ksat_r]*3.6",f3)
ChorizonJoinVTab.Calculate("[om_r]/1.72",f4)
ChorizonJoinVTab.Calculate("0.6/exp(0.4*[om_rc])",f5)

' Concatenate fields into string for line file
bar = " ".Quote
dec = "d.dd".Quote
concat = " A".Quote
textstring =
"[mukey]+"+bar+"+[cokey]+"+concat+"+[mukey]+"+bar+"+[comppct_r].AsString+"+b
ar+"+[hydgrp]+"+bar+"+[desgnvert]+"+bar+"+[hzdepth_rc].SetFormat("+dec+").AsStri
ng+"+bar+"+[dbovdry_r].SetFormat("+dec+").AsString+"+bar+"+[awc_r].SetFormat("+
dec+").AsString+"+bar+"+[k_calc].SetFormat("+dec+").AsString+"+bar+"+[om_rc].Set
Format("+dec+").AsString+"+bar+"+[claytot_r].SetFormat("+dec+").AsString+"+bar+"
+[silttot_r].SetFormat("+dec+").AsString+"+bar+"+[sandtot_r].SetFormat("+dec+").AsS
tring+"+bar+"+[rock].SetFormat("+dec+").AsString+"+bar+"+[albedodr_r].SetFormat("
+dec+").AsString+"+bar+"+[kffact].SetFormat("+dec+").AsString+"+bar+"+[ec_r].SetF
ormat("+dec+").AsString"
ChorizonJoinVTab.Calculate(textstring,f6)
ChorizonJoinVTab.SetEditable(false)

'--------------------------------------------------------------------------
' Create usersoils.dbf file
'--------------------------------------------------------------------------
```

```
' Create field names
f1   = Field.Make("mukey",#FIELD_VCHAR,6,0)
f2  = Field.Make("cokey",#FIELD_VCHAR,20,0)
f3   = Field.Make("snam",#FIELD_VCHAR,30,0)
f4   = Field.Make("cmppct",#FIELD_DECIMAL,20,5)
f5   = Field.Make("hydgrp",#FIELD_VCHAR,1,0)
f6   = Field.Make("H1",#FIELD_DECIMAL,2,0)
f7   = Field.Make("sol_z1",#FIELD_DECIMAL,12,4)
f8   = Field.Make("sol_bd1",#FIELD_DECIMAL,12,4)
f9   = Field.Make("sol_awc1",#FIELD_DECIMAL,12,4)
f10  = Field.Make("sol_k1",#FIELD_DECIMAL,12,4)
f11  = Field.Make("sol_cbn1",#FIELD_DECIMAL,12,4)
f12  = Field.Make("clay1",#FIELD_DECIMAL,12,4)
f13  = Field.Make("silt1",#FIELD_DECIMAL,12,4)
f14  = Field.Make("sand1",#FIELD_DECIMAL,12,4)
f15  = Field.Make("rock1",#FIELD_DECIMAL,12,4)
f16  = Field.Make("sol_alb1",#FIELD_DECIMAL,12,4)
f17  = Field.Make("usle_k1",#FIELD_DECIMAL,12,4)
f18  = Field.Make("sol_ec1",#FIELD_DECIMAL,12,4)

f19  = Field.Make("skip2",#FIELD_VCHAR,1,0)
f20  = Field.Make("cmppct2",#FIELD_DECIMAL,20,5)
f21  = Field.Make("hydgrp2",#FIELD_VCHAR,1,0)
f22  = Field.Make("H2",#FIELD_DECIMAL,2,0)
f23  = Field.Make("sol_z2",#FIELD_DECIMAL,12,4)
f24  = Field.Make("sol_bd2",#FIELD_DECIMAL,12,4)
f25  = Field.Make("sol_awc2",#FIELD_DECIMAL,12,4)
f26  = Field.Make("sol_k2",#FIELD_DECIMAL,12,4)
f27  = Field.Make("sol_cbn2",#FIELD_DECIMAL,12,4)
f28  = Field.Make("clay2",#FIELD_DECIMAL,12,4)
f29  = Field.Make("silt2",#FIELD_DECIMAL,12,4)
f30  = Field.Make("sand2",#FIELD_DECIMAL,12,4)
f31  = Field.Make("rock2",#FIELD_DECIMAL,12,4)
f32  = Field.Make("sol_alb2",#FIELD_DECIMAL,12,4)
f33  = Field.Make("usle_k2",#FIELD_DECIMAL,12,4)
f34  = Field.Make("sol_ec2",#FIELD_DECIMAL,12,4)

f35  = Field.Make("skip3",#FIELD_VCHAR,1,0)
f36  = Field.Make("cmppct3",#FIELD_DECIMAL,20,5)
f37  = Field.Make("hydgrp3",#FIELD_VCHAR,1,0)
f38  = Field.Make("H3",#FIELD_DECIMAL,2,0)
f39  = Field.Make("sol_z3",#FIELD_DECIMAL,12,4)
f40  = Field.Make("sol_bd3",#FIELD_DECIMAL,12,4)
```

```
f41  = Field.Make("sol_awc3",#FIELD_DECIMAL,12,4)
f42  = Field.Make("sol_k3",#FIELD_DECIMAL,12,4)
f43  = Field.Make("sol_cbn3",#FIELD_DECIMAL,12,4)
f44  = Field.Make("clay3",#FIELD_DECIMAL,12,4)
f45  = Field.Make("silt3",#FIELD_DECIMAL,12,4)
f46  = Field.Make("sand3",#FIELD_DECIMAL,12,4)
f47  = Field.Make("rock3",#FIELD_DECIMAL,12,4)
f48  = Field.Make("sol_alb3",#FIELD_DECIMAL,12,4)
f49  = Field.Make("usle_k3",#FIELD_DECIMAL,12,4)
f50  = Field.Make("sol_ec3",#FIELD_DECIMAL,12,4)

f51  = Field.Make("skip4",#FIELD_VCHAR,1,0)
f52  = Field.Make("cmppct4",#FIELD_DECIMAL,20,5)
f53  = Field.Make("hydgrp4",#FIELD_VCHAR,1,0)
f54  = Field.Make("H4",#FIELD_DECIMAL,2,0)
f55  = Field.Make("sol_z4",#FIELD_DECIMAL,12,4)
f56  = Field.Make("sol_bd4",#FIELD_DECIMAL,12,4)
f57  = Field.Make("sol_awc4",#FIELD_DECIMAL,12,4)
f58  = Field.Make("sol_k4",#FIELD_DECIMAL,12,4)
f59  = Field.Make("sol_cbn4",#FIELD_DECIMAL,12,4)
f60  = Field.Make("clay4",#FIELD_DECIMAL,12,4)
f61  = Field.Make("silt4",#FIELD_DECIMAL,12,4)
f62  = Field.Make("sand4",#FIELD_DECIMAL,12,4)
f63  = Field.Make("rock4",#FIELD_DECIMAL,12,4)
f64  = Field.Make("sol_alb4",#FIELD_DECIMAL,12,4)
f65  = Field.Make("usle_k4",#FIELD_DECIMAL,12,4)
f66  = Field.Make("sol_ec4",#FIELD_DECIMAL,12,4)

f67  = Field.Make("skip5",#FIELD_VCHAR,1,0)
f68  = Field.Make("cmppct5",#FIELD_DECIMAL,20,5)
f69  = Field.Make("hydgrp5",#FIELD_VCHAR,1,0)
f70  = Field.Make("H5",#FIELD_DECIMAL,2,0)
f71  = Field.Make("sol_z5",#FIELD_DECIMAL,12,4)
f72  = Field.Make("sol_bd5",#FIELD_DECIMAL,12,4)
f73  = Field.Make("sol_awc5",#FIELD_DECIMAL,12,4)
f74  = Field.Make("sol_k5",#FIELD_DECIMAL,12,4)
f75  = Field.Make("sol_cbn5",#FIELD_DECIMAL,12,4)
f76  = Field.Make("clay5",#FIELD_DECIMAL,12,4)
f77  = Field.Make("silt5",#FIELD_DECIMAL,12,4)
f78  = Field.Make("sand5",#FIELD_DECIMAL,12,4)
f79  = Field.Make("rock5",#FIELD_DECIMAL,12,4)
f80  = Field.Make("sol_alb5",#FIELD_DECIMAL,12,4)
f81  = Field.Make("usle_k5",#FIELD_DECIMAL,12,4)
f82  = Field.Make("sol_ec5",#FIELD_DECIMAL,12,4)
```

```
f83  = Field.Make("skip6",#FIELD_VCHAR,1,0)
f84  = Field.Make("cmppct6",#FIELD_DECIMAL,20,5)
f85  = Field.Make("hydgrp6",#FIELD_VCHAR,1,0)
f86  = Field.Make("H6",#FIELD_DECIMAL,2,0)
f87  = Field.Make("sol_z6",#FIELD_DECIMAL,12,4)
f88  = Field.Make("sol_bd6",#FIELD_DECIMAL,12,4)
f89  = Field.Make("sol_awc6",#FIELD_DECIMAL,12,4)
f90  = Field.Make("sol_k6",#FIELD_DECIMAL,12,4)
f100 = Field.Make("sol_cbn6",#FIELD_DECIMAL,12,4)
f101 = Field.Make("clay6",#FIELD_DECIMAL,12,4)
f102 = Field.Make("silt6",#FIELD_DECIMAL,12,4)
f103 = Field.Make("sand6",#FIELD_DECIMAL,12,4)
f104 = Field.Make("rock6",#FIELD_DECIMAL,12,4)
f105 = Field.Make("sol_alb6",#FIELD_DECIMAL,12,4)
f106 = Field.Make("usle_k6",#FIELD_DECIMAL,12,4)
f107 = Field.Make("sol_ec6",#FIELD_DECIMAL,12,4)

f108 = Field.Make("skip7",#FIELD_VCHAR,1,0)
f109 = Field.Make("cmppct7",#FIELD_DECIMAL,20,5)
f110 = Field.Make("hydgrp7",#FIELD_VCHAR,1,0)
f111 = Field.Make("H7",#FIELD_DECIMAL,2,0)
f112 = Field.Make("sol_z7",#FIELD_DECIMAL,12,4)
f113 = Field.Make("sol_bd7",#FIELD_DECIMAL,12,4)
f114 = Field.Make("sol_awc7",#FIELD_DECIMAL,12,4)
f115 = Field.Make("sol_k7",#FIELD_DECIMAL,12,4)
f116 = Field.Make("sol_cbn7",#FIELD_DECIMAL,12,4)
f117 = Field.Make("clay7",#FIELD_DECIMAL,12,4)
f118 = Field.Make("silt7",#FIELD_DECIMAL,12,4)
f119 = Field.Make("sand7",#FIELD_DECIMAL,12,4)
f120 = Field.Make("rock7",#FIELD_DECIMAL,12,4)
f121 = Field.Make("sol_alb7",#FIELD_DECIMAL,12,4)
f122 = Field.Make("usle_k7",#FIELD_DECIMAL,12,4)
f123 = Field.Make("sol_ec7",#FIELD_DECIMAL,12,4)

f124 = Field.Make("skip8",#FIELD_VCHAR,1,0)
f125 = Field.Make("cmppct8",#FIELD_DECIMAL,20,5)
f126 = Field.Make("hydgrp8",#FIELD_VCHAR,1,0)
f127 = Field.Make("H8",#FIELD_DECIMAL,2,0)
f128 = Field.Make("sol_z8",#FIELD_DECIMAL,12,4)
f129 = Field.Make("sol_bd8",#FIELD_DECIMAL,12,4)
f130 = Field.Make("sol_awc8",#FIELD_DECIMAL,12,4)
f131 = Field.Make("sol_k8",#FIELD_DECIMAL,12,4)
f132 = Field.Make("sol_cbn8",#FIELD_DECIMAL,12,4)
```

```
f133 = Field.Make("clay8",#FIELD_DECIMAL,12,4)
f134 = Field.Make("silt8",#FIELD_DECIMAL,12,4)
f135 = Field.Make("sand8",#FIELD_DECIMAL,12,4)
f136 = Field.Make("rock8",#FIELD_DECIMAL,12,4)
f137 = Field.Make("sol_alb8",#FIELD_DECIMAL,12,4)
f138 = Field.Make("usle_k8",#FIELD_DECIMAL,12,4)
f139 = Field.Make("sol_ec8",#FIELD_DECIMAL,12,4)

f140 = Field.Make("skip9",#FIELD_VCHAR,1,0)
f141 = Field.Make("cmppct9",#FIELD_DECIMAL,20,5)
f142 = Field.Make("hydgrp9",#FIELD_VCHAR,1,0)
f143 = Field.Make("H9",#FIELD_DECIMAL,2,0)
f144 = Field.Make("sol_z9",#FIELD_DECIMAL,12,4)
f145 = Field.Make("sol_bd9",#FIELD_DECIMAL,12,4)
f146 = Field.Make("sol_awc9",#FIELD_DECIMAL,12,4)
f147 = Field.Make("sol_k9",#FIELD_DECIMAL,12,4)
f148 = Field.Make("sol_cbn9",#FIELD_DECIMAL,12,4)
f149 = Field.Make("clay9",#FIELD_DECIMAL,12,4)
f150 = Field.Make("silt9",#FIELD_DECIMAL,12,4)
f151 = Field.Make("sand9",#FIELD_DECIMAL,12,4)
f152 = Field.Make("rock9",#FIELD_DECIMAL,12,4)
f153 = Field.Make("sol_alb9",#FIELD_DECIMAL,12,4)
f154 = Field.Make("usle_k9",#FIELD_DECIMAL,12,4)
f155 = Field.Make("sol_ec9",#FIELD_DECIMAL,12,4)

f156 = Field.Make("skip10",#FIELD_VCHAR,1,0)
f157 = Field.Make("cmppct10",#FIELD_DECIMAL,20,5)
f158 = Field.Make("hydgrp10",#FIELD_VCHAR,1,0)
f159 = Field.Make("H10",#FIELD_DECIMAL,2,0)
f160 = Field.Make("sol_z10",#FIELD_DECIMAL,12,4)
f161 = Field.Make("sol_bd10",#FIELD_DECIMAL,12,4)
f162 = Field.Make("sol_awc10",#FIELD_DECIMAL,12,4)
f163 = Field.Make("sol_k10",#FIELD_DECIMAL,12,4)
f164 = Field.Make("sol_cbn10",#FIELD_DECIMAL,12,4)
f165 = Field.Make("clay10",#FIELD_DECIMAL,12,4)
f166 = Field.Make("silt10",#FIELD_DECIMAL,12,4)
f167 = Field.Make("sand10",#FIELD_DECIMAL,12,4)
f168 = Field.Make("rock10",#FIELD_DECIMAL,12,4)
f169 = Field.Make("sol_alb10",#FIELD_DECIMAL,12,4)
f170 = Field.Make("usle_k10",#FIELD_DECIMAL,12,4)
f171 = Field.Make("sol_ec10",#FIELD_DECIMAL,12,4)

' Create usersoils table
usersoilsTableName = ("usersoils.dbf").AsFileName
```

```
usersoilsVTab = VTab.MakeNew(usersoilsTableName,dbase)
usersoilsTable = Table.Make(usersoilsVTab)
usersoilsTable.SetName(("usersoils").AsString)

' Add fields to the usersoils table
usersoilsVTab.AddFields(
  {f1,f2,f3,f4,f5,f6,f7,f8,f9,f10,
   f11,f12,f13,f14,f15,f16,f17,f18,f19,f20,
   f21,f22,f23,f24,f25,f26,f27,f28,f29,f30,
   f31,f32,f33,f34,f35,f36,f37,f38,f39,f40,
   f41,f42,f43,f44,f45,f46,f47,f48,f49,f50,
   f51,f52,f53,f54,f55,f56,f57,f58,f59,f60,
   f61,f62,f63,f64,f65,f66,f67,f68,f69,f70,
   f71,f72,f73,f74,f75,f76,f77,f78,f79,f80,
   f81,f82,f83,f84,f85,f86,f87,f88,f89,f90,
   f91,f92,f93,f94,f95,f96,f97,f98,f99,f100,
   f101,f102,f103,f104,f105,f106,f107,f108,f109,f110,
   f111,f112,f113,f114,f115,f116,f117,f118,f119,f120,
   f121,f122,f123,f124,f125,f126,f127,f128,f129,f130,
   f131,f132,f133,f134,f135,f136,f137,f138,f139,f140,
   f141,f142,f143,f144,f145,f146,f147,f148,f149,f150,
   f151,f152,f153,f154,f155,f156,f157,f158,f159,f160,
   f161,f162,f163,f164,f165,f166,f167,f159,f160,f170,
   f171})

'-----------------------------------------------------------------------
' Arrange usersoils.dbf file into correct format
'-----------------------------------------------------------------------

' Find chorizon table
UsersoilsTable = av.FindDoc("chorizonjoin")
UsersoilsVTab = UsersoilsTable.GetVTab
UsersoilsField = UsersoilsVTab.FindField("textstring")

' Get records and sort
UsersoilsList = {}
for each record in UsersoilsVTab
  UsersoilsLine = UsersoilsVtab.ReturnValue(UsersoilsField,record)
  UsersoilsList.add(UsersoilsLine)
end
'UsersoilsList.Sort(true)

'----------------------------------------------------------------
'MsgBox.MultiListAsString(UsersoilsList,"Items in List","List Viewer")
```

```
'-----------------------------------------------------------------

UsersoilsOutputList = {}
UsersoilsLList = UsersoilsList.Get(0).AsList
SortFields = UsersoilsLList.Get(0)+" "+UsersoilsLList.Get(1)+"
"+UsersoilsLList.Get(2)
RecordExists = 0

' Create list of usersoils records
UsersoilsRemove = {}
for each record in (1..(UsersoilsList.Count-1))
  if(UsersoilsList.Get(record).Contains(SortFields)) then
    CreateLine = UsersoilsList.Get(record-1)+"
"+UsersoilsList.Get(record).substitute(SortFields,"")
    UsersoilsList.Set(record,CreateLine)
    RecordExists = RecordExists + 1
    UsersoilsList.RemoveOBJ(record-1)
    UsersoilsRemove.add(UsersoilsList.Get(record-1))
  else
    aNewLine = UsersoilsList.Get(record-1)
    UsersoilsLList = UsersoilsList.Get(record).AsList
    SortFields = UsersoilsLList.Get(0)+" "+UsersoilsLList.Get(1)+"
"+UsersoilsLList.Get(2)
    RecordExists = 0
  end
  UsersoilsOutputList.add(CreateLine)
end

'-----------------------------------------------------------------
'msgbox.listasstring(UsersoilsOutputList,"","Before")
'msgbox.listasstring(UsersoilsRemove,"","to remove")
'-----------------------------------------------------------------

for each record in UsersoilsRemove
  UsersoilsOutputList.RemoveObj(record)
end

UsersoilsOutputList.RemoveDuplicates

'-----------------------------------------------------------------
'msgbox.listasstring(UsersoilsOutputList,"","The final list")
'-----------------------------------------------------------------

' Create temptable file with usersoils
```

```
tempTableName = (WorkDir+"temptable1.dbf").AsFileName
tempVTab = VTab.MakeNew(tempTableName,dbase)
tempTable = Table.Make(tempVTab)
tempTable.SetName(("temptable1").AsString)

tempfield = Field.Make("textfield",#FIELD_CHAR,10000,0)
tempVTab.AddFields({tempfield})

tempVTab.SetEditable(True)
tempfield1 = tempVTab.FindField("textfield")

for each listline in 0..(UsersoilsOutputList.Count-1)

  newRecord = tempVTab.AddRecord
  tempRecord = UsersoilsOutputList.Get(listline).AsString
  tempVTab.SetValue(tempfield1,newRecord,tempRecord)

end

tempVTab.SetEditable(False)

' Save revised text version of tempTable
tempVTab.Export("chorizonjoinrevised".asFileName,dtext,false)

' Write procedure for usersoils table
UsersoilsTable = av.GetProject.FindDoc("usersoils")
UsersoilsVTab = UsersoilsTable.GetVTab
UsersoilsVTab.SetEditable(True)
UsersoilsFieldList = UsersoilsVTab.GetFields

'-----------------------------------------------------------------
'msgbox.listasstring(UsersoilsFieldList,"","Usersoils Field List")
'-----------------------------------------------------------------

' Begin procedure for writing records to usersoils table
UsersoilsTextFileName = (WorkDir+"chorizonjoinrevised.txt").AsString.AsFileName
if (File.Exists(UsersoilsTextFileName)) then

  ' Read mapunit.txt data into line file
    UsersoilsLineFile = LineFile.Make(UsersoilsTextFileName, #FILE_PERM_READ)
    UsersoilsLineFileSize = UsersoilsLineFile.GetSize

  ' Import procedure for chorizonjoinrevised.txt data
    UsersoilsFieldList = UsersoilsVTab.GetFields
```

```
    for each line in 1..UsersoilsLineFileSize
      UsersoilsPosition = UsersoilsLineFile.GetPos
      UsersoilsLine = UsersoilsLineFile.ReadELT
      UsersoilsLineLength = UsersoilsLine.Count

      if (UsersoilsPosition > 0) then
        newRecord = UsersoilsVTab.AddRecord

        ' Add data to fields
          for each recordfield in UsersoilsFieldList
            UsersoilsOffset = UsersoilsLine.IndexOf(" ")
            UsersoilsValue = UsersoilsLine.Left(UsersoilsOffset)
            UsersoilsVTab.SetValue(recordfield,newRecord,UsersoilsValue)
            UsersoilsLine = UsersoilsLine.Right(UsersoilsLineLength-(UsersoilsOffset+1))
            UsersoilsLineLength = UsersoilsLine.Count
          end

      end
end

UsersoilsVTab.SetEditable(False)

else
  MsgBox.Warning("The chorizonjoinrevised.txt file does not exist in the default
directory","Error 1: File Existance Warning")
  Exit
end

'UsersoilsTable.GetWin.Open

'------------------------------------------------------------------------
' Add necessary fields to usersoils.dbf
'------------------------------------------------------------------------

' Find usersoils table
UsersoilsTable = av.GetProject.FindDoc("usersoils")
UsersoilsVTab = UsersoilsTable.GetVTab

' Create field names
f1 = Field.Make("nlayers",#FIELD_DECIMAL,2,0)
f2 = Field.Make("seqn",#FIELD_DECIMAL,10,2)
f3 = Field.Make("s5id",#FIELD_CHAR,6,0)
f4 = Field.Make("sol_zmx",#FIELD_DECIMAL,5,2)
```

```
f5 = Field.Make("sol_crk",#FIELD_DECIMAL,5,2)
f6 = Field.Make("texture",#FIELD_CHAR,25,0)
f7 = Field.Make("anion_excl",#FIELD_DECIMAL,5,2)

UsersoilsFieldList = {f1,f2,f3,f4,f5,f6,f7}
UsersoilsVTab.SetEditable(True)
UsersoilsVTab.AddFields(UsersoilsFieldList)

' Determine the number of layers present in each record
'f1   = UsersoilsVTab.FindField("H1")
'f2   = UsersoilsVTab.FindField("H2")
'f3   = UsersoilsVTab.FindField("H3")
'f4   = UsersoilsVTab.FindField("H4")
'f5   = UsersoilsVTab.FindField("H5")
'f6   = UsersoilsVTab.FindField("H6")
'f7   = UsersoilsVTab.FindField("H7")
'f8   = UsersoilsVTab.FindField("H8")
'f9   = UsersoilsVTab.FindField("H9")
'f10  = UsersoilsVTab.FindField("H10")

' Determine the sequence number of each record
f1 = UsersoilsVTab.FindField("mukey")
f2 = UsersoilsVTab.FindField("seqn")

UsersoilsVTab.SetEditable(True)

for each record in UsersoilsVTab
  UsersoilsVTab.Calculate("1",f2)
end

MukeyList = {}
for each mukeyrec in UsersoilsVTab
  MukeyLine = UsersoilsVtab.ReturnValue(f1,mukeyrec)
  MukeyList.add(MukeyLine)
end

Mukeyval = 1
for each seqnrec in (1..(MukeyList.Count-1))
  if (MukeyList.Get(seqnrec) = MukeyList.Get(seqnrec-1)) then
    MukeyVal = MukeyVal + 1
    UsersoilsVTab.SetValue(f2,seqnrec,MukeyVal)
  else
    UsersoilsVTab.SetValue(f2,seqnrec,1)
    Mukeyval = 1
```

```
  end
end

' Determine the number of layers for each record
f0  = UsersoilsVTab.FindField("nlayers")
f1  = UsersoilsVTab.FindField("clay1")
f2  = UsersoilsVTab.FindField("clay2")
f3  = UsersoilsVTab.FindField("clay3")
f4  = UsersoilsVTab.FindField("clay4")
f5  = UsersoilsVTab.FindField("clay5")
f6  = UsersoilsVTab.FindField("clay6")
f7  = UsersoilsVTab.FindField("clay7")
f8  = UsersoilsVTab.FindField("clay8")
f9  = UsersoilsVTab.FindField("clay9")
f10 = UsersoilsVTab.FindField("clay10")

layer1List = {}
for each layer1rec in UsersoilsVTab
  layer1Line = UsersoilsVtab.ReturnValue(f1,layer1rec)
  layer1List.add(layer1Line)
end

layer2List = {}
for each layer2rec in UsersoilsVTab
  layer2Line = UsersoilsVtab.ReturnValue(f2,layer2rec)
  layer2List.add(layer2Line)
end

layer3List = {}
for each layer3rec in UsersoilsVTab
  layer3Line = UsersoilsVtab.ReturnValue(f3,layer3rec)
  layer3List.add(layer3Line)
end

layer4List = {}
for each layer4rec in UsersoilsVTab
  layer4Line = UsersoilsVtab.ReturnValue(f4,layer4rec)
  layer4List.add(layer4Line)
end

layer5List = {}
for each layer5rec in UsersoilsVTab
  layer5Line = UsersoilsVtab.ReturnValue(f5,layer5rec)
  layer5List.add(layer5Line)
```

```
end

layer6List = {}
for each layer6rec in UsersoilsVTab
  layer6Line = UsersoilsVtab.ReturnValue(f6,layer6rec)
  layer6List.add(layer6Line)
end

layer7List = {}
for each layer7rec in UsersoilsVTab
  layer7Line = UsersoilsVtab.ReturnValue(f7,layer7rec)
  layer7List.add(layer7Line)
end

layer8List = {}
for each layer8rec in UsersoilsVTab
  layer8Line = UsersoilsVtab.ReturnValue(f8,layer8rec)
  layer8List.add(layer8Line)
end

layer9List = {}
for each layer9rec in UsersoilsVTab
  layer9Line = UsersoilsVtab.ReturnValue(f9,layer9rec)
  layer9List.add(layer9Line)
end

layer10List = {}
for each layer10rec in UsersoilsVTab
  layer10Line = UsersoilsVtab.ReturnValue(f10,layer10rec)
  layer10List.add(layer10Line)
end

for each nlayerrec in (0..(layer1List.Count-1))
  if (layer1List.Get(nlayerrec) = 0) then
    UsersoilsVTab.SetValue(f0,nlayerrec,0)
  elseif (layer2List.Get(nlayerrec) = 0) then
    UsersoilsVTab.SetValue(f0,nlayerrec,1)
  elseif (layer3List.Get(nlayerrec) = 0) then
    UsersoilsVTab.SetValue(f0,nlayerrec,2)
  elseif (layer4List.Get(nlayerrec) = 0) then
    UsersoilsVTab.SetValue(f0,nlayerrec,3)
  elseif (layer5List.Get(nlayerrec) = 0) then
    UsersoilsVTab.SetValue(f0,nlayerrec,4)
  elseif (layer6List.Get(nlayerrec) = 0) then
```

```
    UsersoilsVTab.SetValue(f0,nlayerrec,5)
  elseif (layer7List.Get(nlayerrec) = 0) then
    UsersoilsVTab.SetValue(f0,nlayerrec,6)
  elseif (layer8List.Get(nlayerrec) = 0) then
    UsersoilsVTab.SetValue(f0,nlayerrec,7)
  elseif (layer9List.Get(nlayerrec) = 0) then
    UsersoilsVTab.SetValue(f0,nlayerrec,8)
  elseif (layer10List.Get(nlayerrec) = 0) then
    UsersoilsVTab.SetValue(f0,nlayerrec,9)
  else
    UsersoilsVTab.SetValue(f0,nlayerrec,10)
  end
end

'-------------------------------------------------------------------------
' Create usersoil.dbf and write final table
'-------------------------------------------------------------------------

' Find usersoils table
UsersoilsTable = av.GetProject.FindDoc("usersoils")
UsersoilsVTab = UsersoilsTable.GetVTab
f1 = Field.Make("textstring",#FIELD_VCHAR,5000,0)

' Concatenate fields into string for line file
bar = " ".Quote
dec = "d.dd".Quote
textstring="[mukey]+"+bar+"+[seqn].SetFormat("+dec+").AsString+"+bar+"+[snam]+"
+bar+"+[s5id]+"+bar+"+[cmppct].SetFormat("+dec+").AsString+"+bar+"+[nlayers].Set
Format("+dec+").AsString+"+bar+"+[hydgrp]+"+bar+"+[sol_zmx].SetFormat("+dec+").
AsString+"+bar+"+[anion_excl].SetFormat("+dec+").AsString+"+bar+"+[sol_crk].SetF
ormat("+dec+").AsString+"+bar+"+[texture]+"+bar+"+[sol_z1].SetFormat("+dec+").As
String+"+bar+"+[sol_bd1].SetFormat("+dec+").AsString+"+bar+"+[sol_awc1].SetForm
at("+dec+").AsString+"+bar+"+[sol_k1].SetFormat("+dec+").AsString+"+bar+"+[sol_c
bn1].SetFormat("+dec+").AsString+"+bar+"+[clay1].SetFormat("+dec+").AsString+"+b
ar+"+[silt1].SetFormat("+dec+").AsString+"+bar+"+[sand1].SetFormat("+dec+").AsStri
ng+"+bar+"+[rock1].SetFormat("+dec+").AsString+"+bar+"+[sol_alb1].SetFormat("+de
c+").AsString+"+bar+"+[usle_k1].SetFormat("+dec+").AsString+"+bar+"+[sol_ec1].Set
Format("+dec+").AsString+"+bar+"+[sol_z2].SetFormat("+dec+").AsString+"+bar+"+[s
ol_bd2].SetFormat("+dec+").AsString+"+bar+"+[sol_awc2].SetFormat("+dec+").AsStri
ng+"+bar+"+[sol_k2].SetFormat("+dec+").AsString+"+bar+"+[sol_cbn2].SetFormat("+
dec+").AsString+"+bar+"+[clay2].SetFormat("+dec+").AsString+"+bar+"+[silt2].SetFor
mat("+dec+").AsString+"+bar+"+[sand2].SetFormat("+dec+").AsString+"+bar+"+[rock
2].SetFormat("+dec+").AsString+"+bar+"+[sol_alb2].SetFormat("+dec+").AsString+"+
bar+"+[usle_k2].SetFormat("+dec+").AsString+"+bar+"+[sol_ec2].SetFormat("+dec+").
```

```
AsString+"+bar+"+[sol_z3].SetFormat("+dec+").AsString+"+bar+"+[sol_bd3].SetForm
at("+dec+").AsString+"+bar+"+[sol_awc3].SetFormat("+dec+").AsString+"+bar+"+[sol
_k3].SetFormat("+dec+").AsString+"+bar+"+[sol_cbn3].SetFormat("+dec+").AsString+
"+bar+"+[clay3].SetFormat("+dec+").AsString+"+bar+"+[silt3].SetFormat("+dec+").As
String+"+bar+"+[sand3].SetFormat("+dec+").AsString+"+bar+"+[rock3].SetFormat("+d
ec+").AsString+"+bar+"+[sol_alb3].SetFormat("+dec+").AsString+"+bar+"+[usle_k3].S
etFormat("+dec+").AsString+"+bar+"+[sol_ec3].SetFormat("+dec+").AsString+"+bar+"
+[sol_z4].SetFormat("+dec+").AsString+"+bar+"+[sol_bd4].SetFormat("+dec+").AsStri
ng+"+bar+"+[sol_awc4].SetFormat("+dec+").AsString+"+bar+"+[sol_k4].SetFormat("+
dec+").AsString+"+bar+"+[sol_cbn4].SetFormat("+dec+").AsString+"+bar+"+[clay4].S
etFormat("+dec+").AsString+"+bar+"+[silt4].SetFormat("+dec+").AsString+"+bar+"+[s
and4].SetFormat("+dec+").AsString+"+bar+"+[rock4].SetFormat("+dec+").AsString+"+
bar+"+[sol_alb4].SetFormat("+dec+").AsString+"+bar+"+[usle_k4].SetFormat("+dec+")
.AsString+"+bar+"+[sol_ec4].SetFormat("+dec+").AsString+"+bar+"+[sol_z5].SetForm
at("+dec+").AsString+"+bar+"+[sol_bd5].SetFormat("+dec+").AsString+"+bar+"+[sol_
awc5].SetFormat("+dec+").AsString+"+bar+"+[sol_k5].SetFormat("+dec+").AsString+"
+bar+"+[sol_cbn5].SetFormat("+dec+").AsString+"+bar+"+[clay5].SetFormat("+dec+")
.AsString+"+bar+"+[silt5].SetFormat("+dec+").AsString+"+bar+"+[sand5].SetFormat("
+dec+").AsString+"+bar+"+[rock5].SetFormat("+dec+").AsString+"+bar+"+[sol_alb5].
SetFormat("+dec+").AsString+"+bar+"+[usle_k5].SetFormat("+dec+").AsString+"+bar+
"+[sol_ec5].SetFormat("+dec+").AsString+"+bar+"+[sol_z6].SetFormat("+dec+").AsStr
ing+"+bar+"+[sol_bd6].SetFormat("+dec+").AsString+"+bar+"+[sol_awc6].SetFormat("
+dec+").AsString+"+bar+"+[sol_k6].SetFormat("+dec+").AsString+"+bar+"+[sol_cbn6]
.SetFormat("+dec+").AsString+"+bar+"+[clay6].SetFormat("+dec+").AsString+"+bar+"
+[silt6].SetFormat("+dec+").AsString+"+bar+"+[sand6].SetFormat("+dec+").AsString+
"+bar+"+[rock6].SetFormat("+dec+").AsString+"+bar+"+[sol_alb6].SetFormat("+dec+"
).AsString+"+bar+"+[usle_k6].SetFormat("+dec+").AsString+"+bar+"+[sol_ec6].SetFor
mat("+dec+").AsString+"+bar+"+[sol_z7].SetFormat("+dec+").AsString+"+bar+"+[sol_
bd7].SetFormat("+dec+").AsString+"+bar+"+[sol_awc7].SetFormat("+dec+").AsString+
"+bar+"+[sol_k7].SetFormat("+dec+").AsString+"+bar+"+[sol_cbn7].SetFormat("+dec+
").AsString+"+bar+"+[clay7].SetFormat("+dec+").AsString+"+bar+"+[silt7].SetFormat(
"+dec+").AsString+"+bar+"+[sand7].SetFormat("+dec+").AsString+"+bar+"+[rock7].Se
tFormat("+dec+").AsString+"+bar+"+[sol_alb7].SetFormat("+dec+").AsString+"+bar+"
+[usle_k7].SetFormat("+dec+").AsString+"+bar+"+[sol_ec7].SetFormat("+dec+").AsStr
ing+"+bar+"+[sol_z8].SetFormat("+dec+").AsString+"+bar+"+[sol_bd8].SetFormat("+d
ec+").AsString+"+bar+"+[sol_awc8].SetFormat("+dec+").AsString+"+bar+"+[sol_k8].S
etFormat("+dec+").AsString+"+bar+"+[sol_cbn8].SetFormat("+dec+").AsString+"+bar+
"+[clay8].SetFormat("+dec+").AsString+"+bar+"+[silt8].SetFormat("+dec+").AsString+
"+bar+"+[sand8].SetFormat("+dec+").AsString+"+bar+"+[rock8].SetFormat("+dec+").A
sString+"+bar+"+[sol_alb8].SetFormat("+dec+").AsString+"+bar+"+[usle_k8].SetForm
at("+dec+").AsString+"+bar+"+[sol_ec8].SetFormat("+dec+").AsString+"+bar+"+[sol_z
9].SetFormat("+dec+").AsString+"+bar+"+[sol_bd9].SetFormat("+dec+").AsString+"+b
ar+"+[sol_awc9].SetFormat("+dec+").AsString+"+bar+"+[sol_k9].SetFormat("+dec+").
AsString+"+bar+"+[sol_cbn9].SetFormat("+dec+").AsString+"+bar+"+[clay9].SetForm
```

```
at("+dec+").AsString+"+bar+"+[silt9].SetFormat("+dec+").AsString+"+bar+"+[sand9].S
etFormat("+dec+").AsString+"+bar+"+[rock9].SetFormat("+dec+").AsString+"+bar+"+[
sol_alb9].SetFormat("+dec+").AsString+"+bar+"+[usle_k9].SetFormat("+dec+").AsStri
ng+"+bar+"+[sol_ec9].SetFormat("+dec+").AsString"
'+bar+"+[sol_z10].SetFormat("+dec+").AsString+"+bar+"+[sol_bd10].SetFormat("+dec
+").AsString+"+bar+"+[sol_awc10].SetFormat("+dec+").AsString+"+bar+"+[sol_k10].S
etFormat("+dec+").AsString+"+bar+"+[sol_cbn10].SetFormat("+dec+").AsString+"+bar
+"+[clay10].SetFormat("+dec+").AsString+"+bar+"+[silt10].SetFormat("+dec+").AsStri
ng+"+bar+"+[sand10].SetFormat("+dec+").AsString+"+bar+"+[rock10].SetFormat("+de
c+").AsString+"+bar+"+[sol_alb10].SetFormat("+dec+").AsString+"+bar+"+[usle_k10].
SetFormat("+dec+").AsString+"+bar+"+[sol_ec10].SetFormat("+dec+").AsString"
UsersoilsVTab.SetEditable(True)
UsersoilsVTab.AddFields({f1})
UsersoilsVTab.Calculate(textstring,f1)
UsersoilsVTab.SetEditable(false)


' Create field names
f1   = Field.Make("mukey",#FIELD_CHAR,6,0)
f2   = Field.Make("seqn",#FIELD_DECIMAL,10,2)
f3   = Field.Make("snam",#FIELD_CHAR,30,0)
f4   = Field.Make("s5id",#FIELD_CHAR,6,0)
f5   = Field.Make("cmppct",#FIELD_DECIMAL,20,5)
f6   = Field.Make("nlayers",#FIELD_DECIMAL,2,0)
f7   = Field.Make("hydgrp",#FIELD_CHAR,1,0)
f8   = Field.Make("sol_zmx",#FIELD_DECIMAL,5,2)
f9   = Field.Make("anion_excl",#FIELD_DECIMAL,5,2)
f10  = Field.Make("sol_crk",#FIELD_DECIMAL,5,2)
f11  = Field.Make("texture",#FIELD_CHAR,25,0)
f12  = Field.Make("sol_z1",#FIELD_DECIMAL,12,4)
f13  = Field.Make("sol_bd1",#FIELD_DECIMAL,12,4)
f14  = Field.Make("sol_awc1",#FIELD_DECIMAL,12,4)
f15  = Field.Make("sol_k1",#FIELD_DECIMAL,12,4)
f16  = Field.Make("sol_cbn1",#FIELD_DECIMAL,12,4)
f17  = Field.Make("clay1",#FIELD_DECIMAL,12,4)
f18  = Field.Make("silt1",#FIELD_DECIMAL,12,4)
f19  = Field.Make("sand1",#FIELD_DECIMAL,12,4)
f20  = Field.Make("rock1",#FIELD_DECIMAL,12,4)
f21  = Field.Make("sol_alb1",#FIELD_DECIMAL,12,4)
f22  = Field.Make("usle_k1",#FIELD_DECIMAL,12,4)
f23  = Field.Make("sol_ec1",#FIELD_DECIMAL,12,4)
f24  = Field.Make("sol_z2",#FIELD_DECIMAL,12,4)
f25  = Field.Make("sol_bd2",#FIELD_DECIMAL,12,4)
f26  = Field.Make("sol_awc2",#FIELD_DECIMAL,12,4)
```

```
f27  = Field.Make("sol_k2",#FIELD_DECIMAL,12,4)
f28  = Field.Make("sol_cbn2",#FIELD_DECIMAL,12,4)
f29  = Field.Make("clay2",#FIELD_DECIMAL,12,4)
f30  = Field.Make("silt2",#FIELD_DECIMAL,12,4)
f31  = Field.Make("sand2",#FIELD_DECIMAL,12,4)
f32  = Field.Make("rock2",#FIELD_DECIMAL,12,4)
f33  = Field.Make("sol_alb2",#FIELD_DECIMAL,12,4)
f34  = Field.Make("usle_k2",#FIELD_DECIMAL,12,4)
f35  = Field.Make("sol_ec2",#FIELD_DECIMAL,12,4)
f36  = Field.Make("sol_z3",#FIELD_DECIMAL,12,4)
f37  = Field.Make("sol_bd3",#FIELD_DECIMAL,12,4)
f38  = Field.Make("sol_awc3",#FIELD_DECIMAL,12,4)
f39  = Field.Make("sol_k3",#FIELD_DECIMAL,12,4)
f40  = Field.Make("sol_cbn3",#FIELD_DECIMAL,12,4)
f41  = Field.Make("clay3",#FIELD_DECIMAL,12,4)
f42  = Field.Make("silt3",#FIELD_DECIMAL,12,4)
f43  = Field.Make("sand3",#FIELD_DECIMAL,12,4)
f44  = Field.Make("rock3",#FIELD_DECIMAL,12,4)
f45  = Field.Make("sol_alb3",#FIELD_DECIMAL,12,4)
f46  = Field.Make("usle_k3",#FIELD_DECIMAL,12,4)
f47  = Field.Make("sol_ec3",#FIELD_DECIMAL,12,4)
f48  = Field.Make("sol_z4",#FIELD_DECIMAL,12,4)
f49  = Field.Make("sol_bd4",#FIELD_DECIMAL,12,4)
f50  = Field.Make("sol_awc4",#FIELD_DECIMAL,12,4)
f51  = Field.Make("sol_k4",#FIELD_DECIMAL,12,4)
f52  = Field.Make("sol_cbn4",#FIELD_DECIMAL,12,4)
f53  = Field.Make("clay4",#FIELD_DECIMAL,12,4)
f54  = Field.Make("silt4",#FIELD_DECIMAL,12,4)
f55  = Field.Make("sand4",#FIELD_DECIMAL,12,4)
f56  = Field.Make("rock4",#FIELD_DECIMAL,12,4)
f57  = Field.Make("sol_alb4",#FIELD_DECIMAL,12,4)
f58  = Field.Make("usle_k4",#FIELD_DECIMAL,12,4)
f59  = Field.Make("sol_ec4",#FIELD_DECIMAL,12,4)
f60  = Field.Make("sol_z5",#FIELD_DECIMAL,12,4)
f61  = Field.Make("sol_bd5",#FIELD_DECIMAL,12,4)
f62  = Field.Make("sol_awc5",#FIELD_DECIMAL,12,4)
f63  = Field.Make("sol_k5",#FIELD_DECIMAL,12,4)
f64  = Field.Make("sol_cbn5",#FIELD_DECIMAL,12,4)
f65  = Field.Make("clay5",#FIELD_DECIMAL,12,4)
f66  = Field.Make("silt5",#FIELD_DECIMAL,12,4)
f67  = Field.Make("sand5",#FIELD_DECIMAL,12,4)
f68  = Field.Make("rock5",#FIELD_DECIMAL,12,4)
f69  = Field.Make("sol_alb5",#FIELD_DECIMAL,12,4)
f70  = Field.Make("usle_k5",#FIELD_DECIMAL,12,4)
```

```
f71  = Field.Make("sol_ec5",#FIELD_DECIMAL,12,4)
f72  = Field.Make("sol_z6",#FIELD_DECIMAL,12,4)
f73  = Field.Make("sol_bd6",#FIELD_DECIMAL,12,4)
f74  = Field.Make("sol_awc6",#FIELD_DECIMAL,12,4)
f75  = Field.Make("sol_k6",#FIELD_DECIMAL,12,4)
f76  = Field.Make("sol_cbn6",#FIELD_DECIMAL,12,4)
f77  = Field.Make("clay6",#FIELD_DECIMAL,12,4)
f78  = Field.Make("silt6",#FIELD_DECIMAL,12,4)
f79  = Field.Make("sand6",#FIELD_DECIMAL,12,4)
f80  = Field.Make("rock6",#FIELD_DECIMAL,12,4)
f81  = Field.Make("sol_alb6",#FIELD_DECIMAL,12,4)
f82  = Field.Make("usle_k6",#FIELD_DECIMAL,12,4)
f83  = Field.Make("sol_ec6",#FIELD_DECIMAL,12,4)
f84  = Field.Make("sol_z7",#FIELD_DECIMAL,12,4)
f85  = Field.Make("sol_bd7",#FIELD_DECIMAL,12,4)
f86  = Field.Make("sol_awc7",#FIELD_DECIMAL,12,4)
f87  = Field.Make("sol_k7",#FIELD_DECIMAL,12,4)
f88  = Field.Make("sol_cbn7",#FIELD_DECIMAL,12,4)
f89  = Field.Make("clay7",#FIELD_DECIMAL,12,4)
f90  = Field.Make("silt7",#FIELD_DECIMAL,12,4)
f91  = Field.Make("sand7",#FIELD_DECIMAL,12,4)
f92  = Field.Make("rock7",#FIELD_DECIMAL,12,4)
f93  = Field.Make("sol_alb7",#FIELD_DECIMAL,12,4)
f94  = Field.Make("usle_k7",#FIELD_DECIMAL,12,4)
f95  = Field.Make("sol_ec7",#FIELD_DECIMAL,12,4)
f96  = Field.Make("sol_z8",#FIELD_DECIMAL,12,4)
f97  = Field.Make("sol_bd8",#FIELD_DECIMAL,12,4)
f98  = Field.Make("sol_awc8",#FIELD_DECIMAL,12,4)
f99  = Field.Make("sol_k8",#FIELD_DECIMAL,12,4)
f100 = Field.Make("sol_cbn8",#FIELD_DECIMAL,12,4)
f101 = Field.Make("clay8",#FIELD_DECIMAL,12,4)
f102 = Field.Make("silt8",#FIELD_DECIMAL,12,4)
f103 = Field.Make("sand8",#FIELD_DECIMAL,12,4)
f104 = Field.Make("rock8",#FIELD_DECIMAL,12,4)
f105 = Field.Make("sol_alb8",#FIELD_DECIMAL,12,4)
f106 = Field.Make("usle_k8",#FIELD_DECIMAL,12,4)
f107 = Field.Make("sol_ec8",#FIELD_DECIMAL,12,4)
f108 = Field.Make("sol_z9",#FIELD_DECIMAL,12,4)
f109 = Field.Make("sol_bd9",#FIELD_DECIMAL,12,4)
f110 = Field.Make("sol_awc9",#FIELD_DECIMAL,12,4)
f111 = Field.Make("sol_k9",#FIELD_DECIMAL,12,4)
f112 = Field.Make("sol_cbn9",#FIELD_DECIMAL,12,4)
f113 = Field.Make("clay9",#FIELD_DECIMAL,12,4)
f114 = Field.Make("silt9",#FIELD_DECIMAL,12,4)
```

```
f115 = Field.Make("sand9",#FIELD_DECIMAL,12,4)
f116 = Field.Make("rock9",#FIELD_DECIMAL,12,4)
f117 = Field.Make("sol_alb9",#FIELD_DECIMAL,12,4)
f118 = Field.Make("usle_k9",#FIELD_DECIMAL,12,4)
f119 = Field.Make("sol_ec9",#FIELD_DECIMAL,12,4)
f120 = Field.Make("sol_z10",#FIELD_DECIMAL,12,4)
f121 = Field.Make("sol_bd10",#FIELD_DECIMAL,12,4)
f122 = Field.Make("sol_awc10",#FIELD_DECIMAL,12,4)
f123 = Field.Make("sol_k10",#FIELD_DECIMAL,12,4)
f124 = Field.Make("sol_cbn10",#FIELD_DECIMAL,12,4)
f125 = Field.Make("clay10",#FIELD_DECIMAL,12,4)
f126 = Field.Make("silt10",#FIELD_DECIMAL,12,4)
f127 = Field.Make("sand10",#FIELD_DECIMAL,12,4)
f128 = Field.Make("rock10",#FIELD_DECIMAL,12,4)
f129 = Field.Make("sol_alb10",#FIELD_DECIMAL,12,4)
f130 = Field.Make("usle_k10",#FIELD_DECIMAL,12,4)
f131 = Field.Make("sol_ec10",#FIELD_DECIMAL,12,4)

' Create usersoils table
usersoilTableName = (WorkDir+"usersoil.dbf").AsFileName
usersoilVTab = VTab.MakeNew(usersoilTableName,dbase)
usersoilTable = Table.Make(usersoilVTab)
usersoilTable.SetName(("usersoil").AsString)

' Add fields to the usersoil table
usersoilVTab.AddFields(
   {f1,f2,f3,f4,f5,f6,f7,f8,f9,f10,
   f11,f12,f13,f14,f15,f16,f17,f18,f19,f20,
   f21,f22,f23,f24,f25,f26,f27,f28,f29,f30,
   f31,f32,f33,f34,f35,f36,f37,f38,f39,f40,
   f41,f42,f43,f44,f45,f46,f47,f48,f49,f50,
   f51,f52,f53,f54,f55,f56,f57,f58,f59,f60,
   f61,f62,f63,f64,f65,f66,f67,f68,f69,f70,
   f71,f72,f73,f74,f75,f76,f77,f78,f79,f80,
   f81,f82,f83,f84,f85,f86,f87,f88,f89,f90,
   f91,f92,f93,f94,f95,f96,f97,f98,f99,f100,
   f101,f102,f103,f104,f105,f106,f107,f108,f109,f110,
   f111,f112,f113,f114,f115,f116,f117,f118,f119,f120,
   f121,f122,f123,f124,f125,f126,f127,f128,f129,f130,
   f131})

' Find usersoils table
UsersoilsTable = av.FindDoc("usersoils")
UsersoilsVTab = UsersoilsTable.GetVTab
```

```
UsersoilsField = UsersoilsVTab.FindField("textstring")

' Get records and sort
UsersoilsList = {}
for each record in UsersoilsVTab
  UsersoilsLine = UsersoilsVtab.ReturnValue(UsersoilsField,record)
  UsersoilsList.add(UsersoilsLine)
end
UsersoilsList.Sort(true)

'msgbox.listasstring(UsersoilsList,"","The final list")

' Create temptable2 file with usersoils
tempTableName = (WorkDir+"temptable2.dbf").AsFileName
tempVTab = VTab.MakeNew(tempTableName,dbase)
tempTable = Table.Make(tempVTab)
tempTable.SetName(("temptable2").AsString)

tempfield = Field.Make("textfield",#FIELD_VCHAR,10000,0)
tempVTab.AddFields({tempfield})

tempVTab.SetEditable(True)
tempfield1 = tempVTab.FindField("textfield")

for each listline in 0..(UsersoilsList.Count-1)

  newRecord = tempVTab.AddRecord
  tempRecord = UsersoilsList.Get(listline).AsString
  tempVTab.SetValue(tempfield1,newRecord,tempRecord)

end

tempVTab.SetEditable(False)

' Save revised text version of tempTable
tempVTab.Export("chorizonjoinrevised2".asFileName,dtext,false)

' Write procedure for usersoil table
UsersoilsTable = av.GetProject.FindDoc("usersoil")
UsersoilsVTab = UsersoilsTable.GetVTab
UsersoilsVTab.SetEditable(True)
UsersoilsFieldList = UsersoilsVTab.GetFields

' Begin procedure for writing records to usersoils table
```

```
UsersoilsTextFileName = (WorkDir+"chorizonjoinrevised2.txt").AsString.AsFileName
if (File.Exists(UsersoilsTextFileName)) then

  ' Read mapunit.txt data into line file
   UsersoilsLineFile = LineFile.Make(UsersoilsTextFileName, #FILE_PERM_READ)
   UsersoilsLineFileSize = UsersoilsLineFile.GetSize

  ' Import procedure for chorizonjoinrevised.txt data
   UsersoilsFieldList = UsersoilsVTab.GetFields

   for each line in 1..UsersoilsLineFileSize
    UsersoilsPosition = UsersoilsLineFile.GetPos
    UsersoilsLine = UsersoilsLineFile.ReadELT
    UsersoilsLineLength = UsersoilsLine.Count

    if (UsersoilsPosition > 0) then
     newRecord = UsersoilsVTab.AddRecord

     ' Add data to fields
      for each recordfield in UsersoilsFieldList
       UsersoilsOffset = UsersoilsLine.IndexOf(" ")
       UsersoilsValue = UsersoilsLine.Left(UsersoilsOffset)
       UsersoilsVTab.SetValue(recordfield,newRecord,UsersoilsValue)
       UsersoilsLine = UsersoilsLine.Right(UsersoilsLineLength-(UsersoilsOffset+1))
       UsersoilsLineLength = UsersoilsLine.Count
      end

    end
end

UsersoilsVTab.SetEditable(False)

else
  MsgBox.Warning("The chorizonjoinrevised2.txt file does not exist in the default
directory","Error 1: File Existance Warning")
  Exit
end

UsersoilsTable.GetWin.Open

' Check for the existance of temporary table documents and remove if present

' Temporary table names
mapunitTable = "mapunit"
```

```
chorizonTable = "chorizon"
compTable = "component"
compjoinTable = "compjoin"
chorizonjoinTable = "chorizonjoin"
tempTable1 = "temptable1"
tempTable2 = "temptable2"
usersoilsTable = "usersoils"

' Get temporary tables from project
mapunitTableDoc = av.getProject.findDoc(mapunitTable)
mapunitTableDocString = mapunitTableDoc.AsString
chorizonTableDoc = av.getProject.findDoc(chorizonTable)
chorizonTableDocString = chorizonTableDoc.AsString
compTableDoc = av.getProject.findDoc(compTable)
compTableDocString = compTableDoc.AsString
compjoinTableDoc = av.getProject.findDoc(compjoinTable)
compjoinTableDocString = compjoinTableDoc.AsString
chorizonjoinTableDoc = av.getProject.findDoc(chorizonjoinTable)
chorizonjoinTableDocString = chorizonjoinTableDoc.AsString
tempTable1Doc = av.getProject.findDoc(tempTable1)
tempTable1DocString = tempTable1Doc.AsString
tempTable2Doc = av.getProject.findDoc(tempTable2)
tempTable2DocString = tempTable2Doc.AsString
usersoilsTableDoc = av.getProject.findDoc(usersoilsTable)
usersoilsTableDocString = usersoilsTableDoc.AsString

' Procedure to remove mapunit temporary table document
if (mapunitTableDocString = "mapunit") then

  av.getProject.removeDoc(mapunitTableDoc)
  mapunitTable = nil
  mapunitTableDoc = nil
  mapunitTableDocString = nil
  av.purgeObjects
'  MsgBox.Info("mapunit table deleted from the project","Message 0 : Table Document
Removed from Project")

'else

'  MsgBox.Warning("mapunit table document does not exist in the project","Error 0:
Table Document Existance Warning")

end
```

```
' Procedure to remove chorizon temporary table document
if (chorizonTableDocString = "chorizon") then

  av.getProject.removeDoc(chorizonTableDoc)
  chorizonTable = nil
  chorizonTableDoc = nil
  chorizonTableDocString = nil
  av.purgeObjects
'  MsgBox.Info("chorizon table deleted from the project","Message 0 : Table Document
Removed from Project")

'else

'  MsgBox.Warning("chorizon table document does not exist in the project","Error 0:
Table Document Existance Warning")

end

' Procedure to remove component temporary table document
if (compTableDocString = "component") then

  av.getProject.removeDoc(compTableDoc)
  compTable = nil
  compTableDoc = nil
  compTableDocString = nil
  av.purgeObjects
'  MsgBox.Info("component table deleted from the project","Message 0 : Table
Document Removed from Project")

'else

'  MsgBox.Warning("comp table document does not exist in the project","Error 0: Table
Document Existance Warning")

end

' Procedure to remove compjoin temporary table document
if (compjoinTableDocString = "compjoin") then

  av.getProject.removeDoc(compjoinTableDoc)
  compjoinTable = nil
  compjoinTableDoc = nil
  compjoinTableDocString = nil
  av.purgeObjects
```

```
'  MsgBox.Info("compjoin table deleted from the project","Message 0 : Table Document
Removed from Project")

'else

'  MsgBox.Warning("compjoin table document does not exist in the project","Error 0:
Table Document Existance Warning")

end

' Procedure to remove chorizonjoin temporary table document
if (chorizonjoinTableDocString = "chorizonjoin") then

  av.getProject.removeDoc(chorizonjoinTableDoc)
  chorizonjoinTable = nil
  chorizonjoinTableDoc = nil
  chorizonjoinTableDocString = nil
  av.purgeObjects
'  MsgBox.Info("chorizonjoin table deleted from the project","Message 0 : Table
Document Removed from Project")

'else

'  MsgBox.Warning("chorizonjoin table document does not exist in the project","Error 0:
Table Document Existance Warning")

end

' Procedure to remove temptable1 temporary table document
if (tempTable1DocString = "temptable1") then

  av.getProject.removeDoc(tempTable1Doc)
  tempTable1 = nil
  tempTable1Doc = nil
  tempTable1DocString = nil
  av.purgeObjects
'  MsgBox.Info("temptable1 table deleted from the project","Message 0 : Table
Document Removed from Project")

'else

'  MsgBox.Warning("temptable1 table document does not exist in the project","Error 0:
Table Document Existance Warning")
```

```
end

' Procedure to remove temptable2 temporary table document
if (tempTable2DocString = "temptable2") then

  av.getProject.removeDoc(tempTable2Doc)
  tempTable2 = nil
  tempTable2Doc = nil
  tempTable2DocString = nil
  av.purgeObjects
'  MsgBox.Info("temptable2 table deleted from the project","Message 0 : Table
Document Removed from Project")

'else

'  MsgBox.Warning("temptable2 table document does not exist in the project","Error 0:
Table Document Existance Warning")

end

' Procedure to remove usersoils temporary table document
if (usersoilsTableDocString = "usersoils") then

  av.getProject.removeDoc(usersoilsTableDoc)
  usersoilsTable = nil
  usersoilsTableDoc = nil
  usersoilsTableDocString = nil
  av.purgeObjects
'  MsgBox.Info("usersoils table deleted from the project","Message 0 : Table Document
Removed from Project")

'else

'  MsgBox.Warning("usersoils table document does not exist in the project","Error 0:
Table Document Existance Warning")

end
```

VITA

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EDUCATION

M.S. in Biological & Agricultural Engineering (December 2004)
Thesis Title: Quantifying Land Cover in a Semi-Arid Region of Texas
Texas A&M University – College Station, Texas

B.S. in Biological System Engineering (May 2001)
Focus: Bioenvironmental Engineering
Texas A&M University – College Station, Texas

CERTIFICATION

Engineer-In-Training (E.I.T.), State of Texas No. ET-31853
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WORK EXPERIENCE

*Hydro*Scientia – College Station, Texas (2004 – present)
Founder and President

Biological & Agricultural Engineering Department – College Station, Texas (2001-04)
Research and Teaching Assistant (AGEN 370, AGEN 468, AGSM 470)

U.S. Naval Undersea Warfare Center – Newport, Rhode Island (Summer 2002)
Engineering Intern, Algorithm & Software Design Competency Group

LEADERSHIP & AWARDS

Texas A&M University Graduate Student Council, President (2003-04)
American Water Resources Association Student Chapter, President (2003-04, 2004-05)
Texas A&M University Montgomery Endowed Fellowship Prize
Texas Water Resources Institute W.G. Mills Fellowship
Biological & Agricultural Engineering Robert E. Stewart Graduate Excellence Award
Alpha Epsilon – Honor society for agricultural, food, and biological engineering

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