MARTIN MARIETTA

ES/ER/TM-152

(ESD--4394)

ENVIRONMENTAL RESTORATION PROGRAM

Terrestrial Habitat Mapping of the Oak Ridge Reservation: Phase 1

This document has been approved for release to the public by:

David B. Gilliland 5/24/95

Asst. Technical Information Officer Date
Oak Ridge K-25 Site

ENERGY SYSTEMS ER

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

UCN-17560 (6 7-91)

ES/ER/TM-152

Terrestrial Mapping of the Oak Ridge Reservation: Phase 1

R. A. Washington-Allen
T. L. Ashwood
S. W. Christensen

H. Offerman
University of Maryland
College Park, Maryland 20743
Under Subcontract ORX00033

P. Scarbrough-Luther
University of Tennessee
Knoxville, TN 37996
Under Subcontract 11B-99732-C T-18

Environmental Restoration Division
P.O. Box 2003
Oak Ridge, Tennessee 37831-7298

Date Issued—June 1995

Prepared by
Environmental Sciences Division
Oak Ridge National Laboratory
ESD Publication 4394

Prepared for the
U.S. Department of Energy
Office of Environmental Management
under budget and reporting code EU 20 10 30 1

LOCKHEED MARTIN ENERGY SYSTEMS, INC.
managing the
Environmental Management Activities at
Oak Ridge K-25 Site Paducah Gaseous Diffusion Plant
Oak Ridge Y-12 Plant Portsmouth Gaseous Diffusion Plant
Oak Ridge National Laboratory
under contract DE-AC05-84OR21400
for the
U.S. DEPARTMENT OF ENERGY

PREFACE

This report, Terrestrial Habitat Mapping of the Oak Ridge Reservation: Phase 1, ES/ER/TM-152, was prepared as a technical report documenting work performed under the Oak Ridge Reservation Ecological Monitoring and Assessment Program. This work was performed under work breakdown structure 1.4.12.2.3.4 (activity data sheet 8304, "Technical Integration"). Publication of this document meets an activity data sheet milestone of June 30, 1995. This document provides the Environmental Restoration Program with information on current land use/land cover distribution on the Oak Ridge Reservation, including specific land use/land cover maps of each operable unit. These results will be used in support of the ecological risk assessment for the entire Reservation and in support of ecological risk assessments for individual operable units.

CONTENTS

FIGURES

TABLES

ACRONYMS

ASCII	American Standard Code for Information Interchange
BMIP	Base Mapping and Imagery Project
CAD	Computing Applications Division
CC	cubic convolution
COORD_SYS	coordinate system
CR	Chestnut Ridge
DOE	U.S. Department of Energy
ERWM	Environmental Restoration and Waste Management
GIS	geographic information system
GISST	Geographic Information System Spatial Technologies
GPS	Global Positioning System
GRS	Geodetic Reference System
IR	infrared
KHAT	estimated value of Cohen's Kappa statistic
LL	lower left
LR	lower right
Energy Systems	Lockheed Martin Energy Systems
NAD	North American Datum
NCOLS	number of columns
NROWS	number of rows
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OU	operable unit
SDTS	Spatial Data Transfer Standard
SPCS	State Plane Coordinate System
TM	Landsat 5 Thematic Mapper
TSP	Tennessee State Plane
TVA	Tennessee Valley Authority
UEFPC	Upper East Fork Poplar Creek
UL	upper left
UR	upper right
USGS	U.S. Geological Survey
WRS	World Reference System

ACKNOWLEDGMENTS

We would like to thank Deborah Awl of the Environmental Sciences Division, who provided the 1959 forest compartment map data; Dan Levine, Contaminant Behavior and Transport Group of the Environmental Chemistry Section, for his Global Positioning System training (sorry about the antenna); Linda Mann of the Environmental Assessment and Compliance Group; Pat Parr and Robin Graham of the Natural Resource Analysis Group for their expert opinions, which aided in the interpretation of aerial photographs; Mike Miller, Peter Pace, and Mark Tuttle at Computer Applications Division for the Geographic Information System Spatial Technologies server digital imagery and their input and valuable ideas, which aided greatly in bringing this project to completion; and Brenda Thompson, Hydrology Group of the Earth and Engineering Sciences Section, for her production of the operable units locator map.

EXECUTIVE SUMMARY

This report presents the results of the first phase in development of a habitat map of the terrestrial ecosystem on the Oak Ridge Reservation (ORR). During this phase, a satellite image of the ORR was classified into land use/land cover types, the classified image was incorporated into a geographic information system map of the ORR, and the accuracy of the map was assessed.

The U.S. Department of Energy is in the process of remediating historical contamination on the ORR. Two key components of the environmental restoration program are ecological risk assessment and monitoring to ensure that cleanup goals are met. In 1994, a strategy was developed for implementation of ecological risk assessment on the ORR and a specific program was initiated to implement this strategy for the terrestrial biota of the entire ORR. This program, called the ORR Ecological Monitoring and Assessment Program, consists of three primary tasks: (1) development of a habitat map and habitat models for key species of interest, (2) preparation of an ecological risk assessment for the entire ORR, and (3) collection of data needed to support the ecological risk assessment and to provide a baseline against which to assess the effects of remedial actions.

A habitat map is a critical foundation for evaluation of the potential impact of historical (or ongoing) contamination on terrestrial biota of the ORR. The abundance and distribution of wildlife species and plant communities of concern are intrinsically linked to the abundance and distribution of habitat on which those species and communities rely. Thus, the impact of spatially discrete patches of contamination on those biota is directly proportional to the degree of overlap between habitat and contamination.

For virtually all species of wildlife, vegetation type is a basic attribute of habitat. The degree of detail required in description of the vegetation will vary with the species being considered, but, as a first step, a broad scale vegetation cover map of the ORR is essential. Once the broad vegetation types are mapped, specific habitat requirements for individual species can be measured in the field and overlaid on the map.

Landsat 5 Thematic Mapper satellite imagery was used to create the land use/land cover map. A Thematic Mapper image consists of seven images of the same point on the earth produced by seven separate sensors, each of which detects a unique part of the electromagnetic spectrum. Separately and in various combinations, these spectral images can be correlated with vegetation type or other land cover type. The image selected for this map was from April 13, 1994, and covers 189,000 ha.

A supervised classification methodology was used to identify each pixel in the image as one of nine categories: evergreen plantation, water, urban land, evergreen forest, barren land, deciduous forest, mixed forest, pasture land, and transitional areas. Areas covered by clouds or cloud shadows and areas misclassified as clouds were converted to land use/land cover categories by using other available information, including aerial photos and a previous (1975) vegetation map of the ORR. Deciduous forest and mixed forest each account for ~31% of the land on the ORR. At the time of the image, evergreen plantation and evergreen forest together accounted for another 8% of the ORR. Thus, in April, 1994, ~70% of the ORR was covered by some type of forest.

The accuracy of the supervised classification was assessed by comparing the classified image with aerial photos generated as part of the Base Mapping and Imagery Project of the Environmental Restoration and Waste Management Program. More than 1,450 points were compared between the image and the aerial photos. The overall accuracy of the classified image was 66%. This is the proportion of pixels assigned to the correct classification. Accuracy was highest (i.e., user's accuracy >75%) in the water, evergreen plantation, barren land, deciduous forest, and urban land categories, and lowest in the transitional areas and evergreen forest categories.

A separate land use/land cover map has been generated for each of the operable units and waste area groupings defined as part of the Environmental Restoration Program. When combined with information from the ongoing habitat modeling effort, these individual maps will lead to an assessment of how much of each wildlife species' habitat is potentially contaminated.

Two further actions are recommended for future work on the land use/land cover map. First, some relatively simple steps will be taken to improve the accuracy of the classification. Second, the 1994 map will be compared with an earlier 1984 map. The purpose of the comparison is to assess the degree of change that has occurred in land cover during the past 10 years so a decision can be made as to how frequently the land use map should be updated. Both of these activities will begin in 1995 and be completed in 1996.

1. INTRODUCTION

The U.S. Department of Energy (DOE) is in the process of remediating historical contamination on the Oak Ridge Reservation (ORR). This environmental restoration program is governed by a Federal Facilities Agreement between DOE, Region IV of the U.S. Environmental Protection Agency, and the State of Tennessee (represented by the Tennessee Department of Environment and Conservation). Two key components of the environmental restoration program are ecological risk assessment and monitoring to ensure that cleanup goals are met. In 1994, the Federal Facilities Agreement parties agreed on a strategy for implementation of ecological risk assessment on the ORR (Suter et al. 1994) and on a specific program to implement this strategy for the terrestrial biota of the entire ORR (Ashwood et al. 1994). This program, called the ORR Ecological Monitoring and Assessment Program, consists of three primary tasks: (1) development of a habitat map and habitat models for key species of interest, (2) preparation of an ecological risk assessment for the entire ORR, and (3) collection of data needed to support the ecological risk assessment and provide a baseline against which to assess the effects of remedial actions.

A habitat map is a critical foundation for evaluation of the potential impact of historical (or ongoing) contamination on terrestrial biota of the ORR. The abundance and distribution of wildlife species and plant communities of concern are intrinsically linked to the abundance and distribution of habitat on which those species and communities rely. Thus, the impact of spatially discrete patches of contamination on those biota is correlated with the degree of overlap between habitat and contamination. Spatially discrete patches of contamination on the ORR are called operable units (OUs) and waste area groupings (WAGs), and are represented on the locator map in Fig. 1.

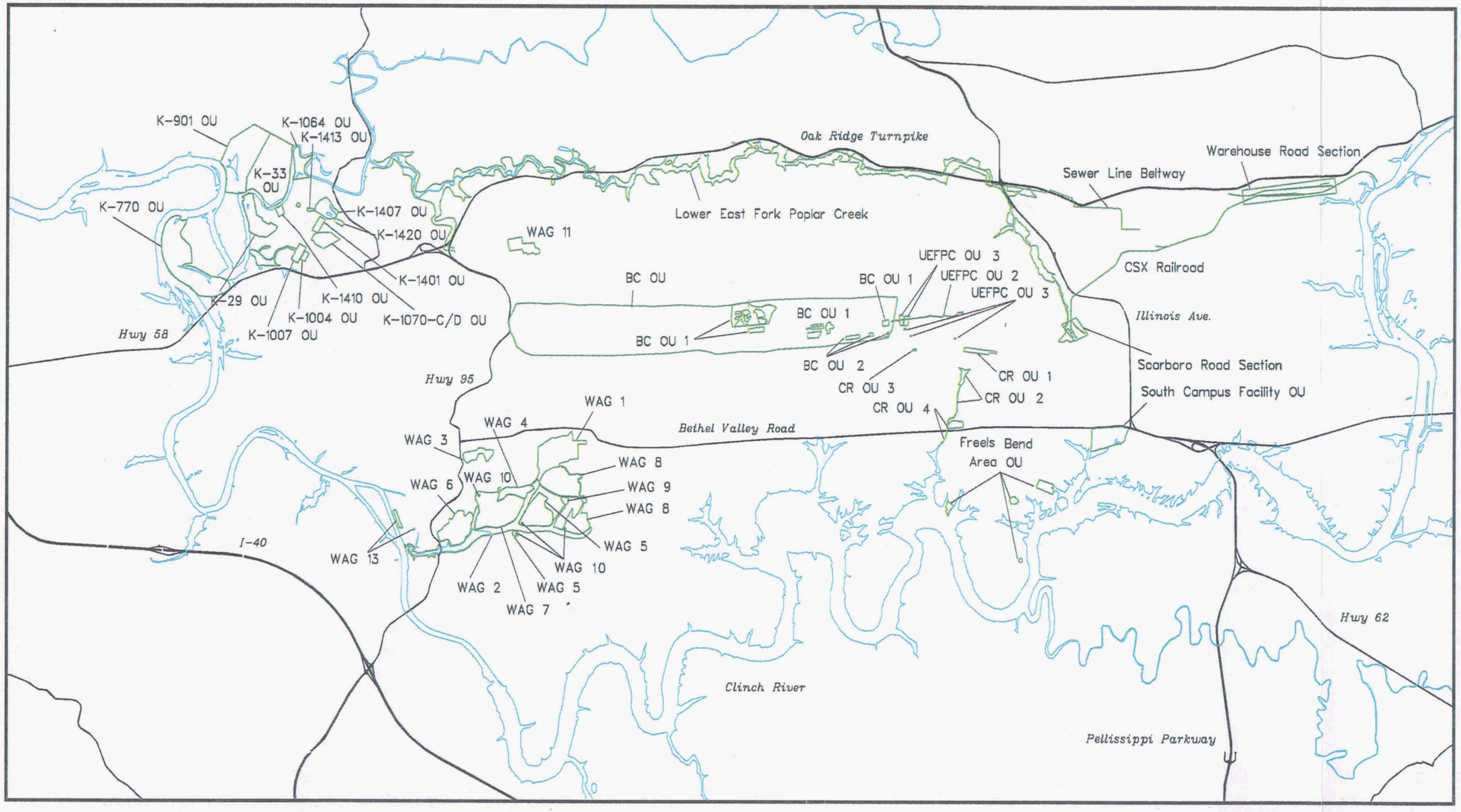
To be useful, a habitat map must include attributes of habitat that are most important in defining the spatial distribution and abundance of a species. For virtually all species of wildlife, vegetation type is a basic attribute of habitat. Therefore, the habitat map must start with a vegetation map. The degree of detail required in description of the vegetation will, of course, vary with the species being considered, but, as a first step, a broad-scale vegetation cover map of the ORR is essential.

After the broad vegetation types are mapped, specific habitat requirements (e.g., overstory species composition) for individual species can be measured in the field and overlaid on the map. These requirements will be defined as part of the habitat modeling effort that is proceeding in parallel with the habitat mapping task (Ashwood et al. 1994).

Earlier researchers developed a land use/land cover map of the ORR using a 1984 satellite image (Chatfield and Graham unpubl. data). Their work was primarily aimed at demonstrating the effectiveness of this technique in supporting landscape-level ecological analysis. For this project, a more-up-to-date image of the ORR was needed and a different type of spatial analysis was required.

This report presents the results of the first phase of development of a habitat map—development of a land use/land cover map of the ORR. Activities during this first phase consisted of acquisition of a recent satellite image of the ORR, incorporation of that image into a geographic information system (GIS), classification of the image into land use/land cover types

(including broad vegetative cover types), assessment of the accuracy of the classified image, and preparation of land use/land cover maps for areas of the ORR for which remedial actions may be considered. The rest of this report describes these steps and their results. In the final section of the report, we present recommendations for further work to enhance the utility of this land use/land cover map.



Scale 1:90,000

Miles
0
1
5

Kilometers
0
2
10

Roads

Operable Unit (OU) and Waste Area Grouping (WAG) boundaries

Water

GUIDE TO CODES

BC – Bear Creek
CR – Chestnut Ridge
K – K-25 Plant
OU – Operable unit
UEFPC – Upper East Fork Poplar Creek
WAG – Waste Area Grouping

Fig. 1. The ORR's OUs, WAGs, and surrounding areas. The ORR has a combined total of 12 WAGs and 25 OUs.

2. METHODS

Converting a satellite image from a picture of a section of the earth to a thematic map can be accomplished in a number of varying ways. These variations mostly reflect the specific purpose of a project, its logistical vagaries, and related time and budget constraints. Figure 2 illustrates the methodology that was used to take the April 13, 1994, Landsat 5 Thematic Mapper (TM) satellite image of the ORR and produce a classified image of the ORR, its OUs, and WAGs. Our schema is adapted from an overview of image processing methodology suggested by Campbell (1987).

2.1 DATA ACQUISITION

The land use/land cover map for the ORR was developed using remotely sensed data. Available options for acquisition of remotely sensed data include aerial photography, aerial sensors, and satellite-borne sensors. Satellite systems offer several advantages over other data-acquisition options. Digital data gathered by satellite sensors are easily processed, analyzed, and stored; areas are sampled on a regular basis for change detection (every 16 days); and the stability of satellite platforms reduces distortion in the final image as compared with airborne platforms (ERDAS 1994).

Landsat 5 TM satellite imagery was used to create a land use/land cover map for the ORR. A TM image consists of seven images of the same point on the earth that are spatially matched together in a sandwich layer. Each image is produced by seven separate sensors (radiometers), each of which detects a unique part of the electromagnetic spectrum (herein called bands) reflected from the earth's surface. The bands detected by the sensors include the visible (red, green, and blue), infrared (IR, 3 types: a near-IR and two mid-IRs), and a thermal wavelength. Each sensor detects the reflected surface radiation as a continuous analog signal that is sampled into discrete values of radiance. The radiance values are then transformed to 8-bit digital numbers (brightness value) with a range of 0–255, or 256 values. The instant-field-of-view, the area detected by the satellite's sensors, is on average 30 × 30 m that form the individual picture elements (pixels) that compose an individual image layer. A full TM scene is usually a rectangular grid of pixels of ~180 × 180 km in area. The bands detected by the TM sensors, singularly and in combinations of mathematical transforms, can be correlated with, and therefore can be used to discriminate physical and chemical characteristics of surface features (e.g., vegetation abundance, vegetation type, soil moisture, snow and cloud differentiation, and rock type discrimination) and can serve as indexes of their presence (e.g., Tucker 1979).

The image used to create the land use/land cover map was purchased from EOSAT Corporation. It was taken from satellite path 19/row 35 on April 13, 1994, at ~9 a.m. Eastern Standard Time (Fig. 3). A spring image was selected to maximize the physiological differences between evergreen and deciduous vegetation types; the April 13th date was chosen for its low (<10%) cloud cover. Appendix B contains the characteristics of the Landsat TM image.

The image area used is nearly 189,000 ha in size, consists of 1,460 rows by 1,427 columns of pixels, and has an approximate center point of 35:49:40 West longitude and 84:17:22 North latitude.

ORNL-DWG 95M-1106

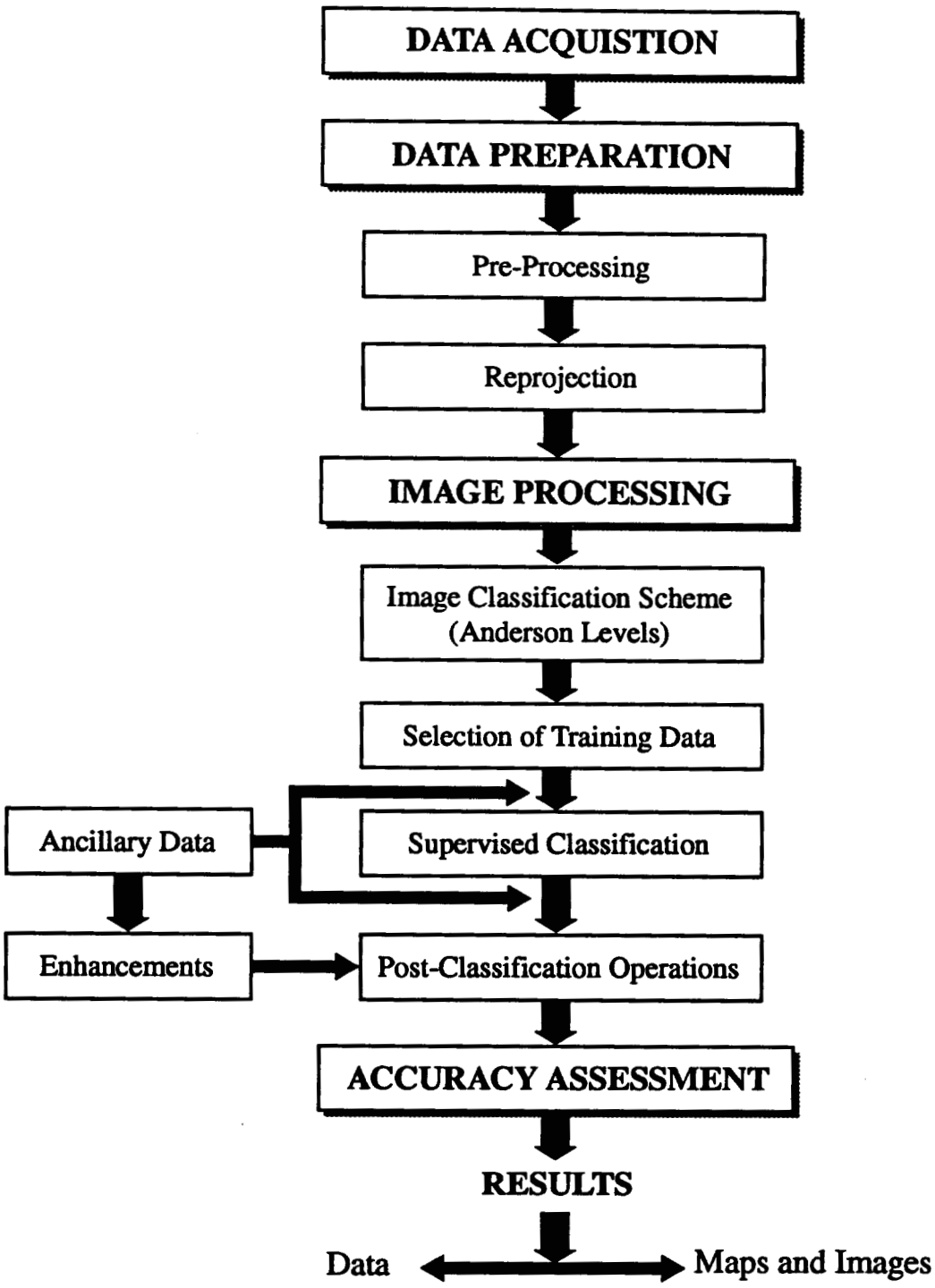


Fig. 2. A flow diagram of the methodology followed in the classification of an April 13, 1994, Landsat 5 TM satellite image of the ORR. The schema was adapted from Campbell (1987).

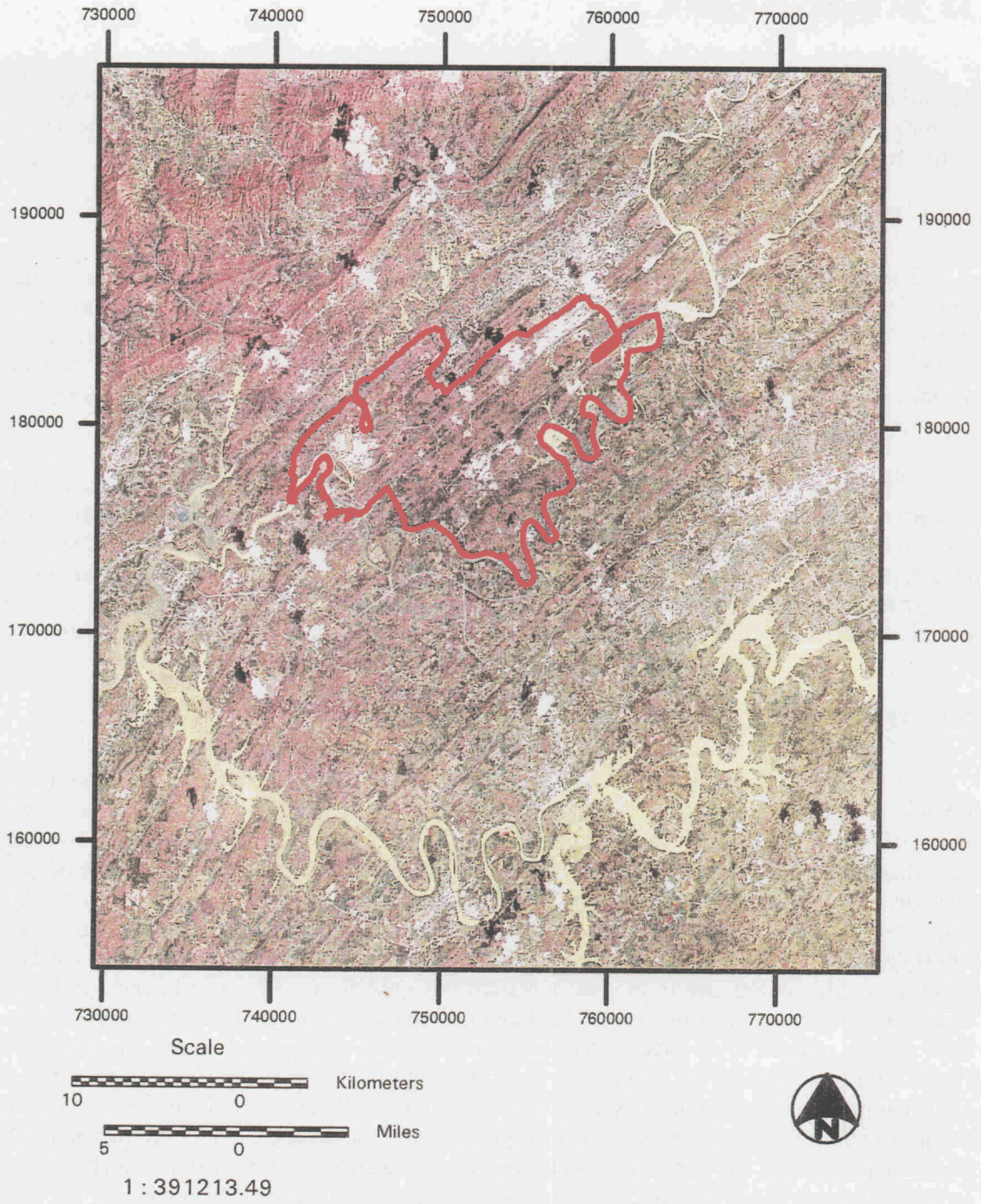


Fig. 3. An April 13, 1994, Landsat 5 TM true-color composite image of the ORR (bordered in red) and surrounding areas before classification. The image was provided by EOSAT Corporation. The image projection is Tennessee State Plane (TSP) meters, Zone 5301, and North American Datum (NAD) 83.

2.2 DATA PREPARATION

Data preparation and processing took place at Oak Ridge National Laboratory's (ORNL) Environmental Sciences Division GIS Laboratory. A Sun Microsystems, Inc., SPARC 10™ running UNIX™ as its operating system, ERDAS, Inc., Imagine 8.1™ and ARC/INFO™ GIS software were used to process the digital image.

2.2.1 Preprocessing

The 100 × 100 km image was georeferenced (spatially linked to a spherical representation/projection of the earth's surface) to United States Geological Survey (USGS) ground control points and terrain corrected using a USGS 1:24,000 digital elevation model by EOSAT, Inc. However, a logistical problem was created when the image received was in the wrong projection: Universal Transverse Mercator Zone 17. Therefore, preprocessing by reprojecting the imagery was required.

The image was reprojected using a cubic convolution (CC) resampling algorithm to Universal Transverse Mercator Zone 16. The image was then further resampled using a CC to the standard ORR map projection (i.e., TSP, Zone 5301, NAD 1983) with 25 × 25-m pixels. The CC is a resampling technique used for geometric correction of images (geometrically fitting an image in one geometric orientation to a different orientation that allows it to conform to an alternative projection) and is recommended for giving the best fit between projections (Jensen 1986).

2.3 IMAGE PROCESSING

After the data have been prepared, the next step is processing the image. According to Jensen (1986), image processing refers to the variety of operations that can be applied to image data. In this section, we will introduce concepts relevant to the process of image classification. Image classification is a process of pattern recognition. The patterns recognized are groups of similar spectral signatures associated with surface features. If a single pixel is looked at within the image grid, that pixel is one of seven pixels in the image sandwich layer; a spectral signature is a plot of brightness values of each of the seven pixels as a function of each of the seven TM bands. The seven connected points within the plot represent the amount of reflectance in each of the seven bands and is the spectral signature of the point on the earth represented by the pixel. In theory, each unique object on the face of the earth has a unique spectral signature (Campbell 1987). Pixels having similar spectral signatures are assumed to be the same type of object on the earth; and such pixels can be grouped or classified accordingly. Classification is the process of taking groups of similar spectral signatures and assigning them to discrete categories (Romesburg 1990). In image processing, two types of classifications are recognized: supervised, in which the analyst is directly involved in the pattern recognition process; or unsupervised, in which the analyst specifies statistical parameters to be used by a computer-automated pattern recognition algorithm.

Supervised classifications are dependant on (1) the analyst's knowledge or the availability of ground-truthed information on the area of interest and (2) the degree of accuracy and precision required by the project (Campbell 1987). Unsupervised procedures are usually conducted when data are not available about surface features of a site of interest. However, with the advent of artificial intelligence, ancillary data, data other than the satellite imagery that aids in its classification (e.g., aerial photography, digital elevation models, and related site chemical and

physical characteristics), and sophisticated multivariate statistical analyses, the line has blurred between the two methods, and current approaches are more likely to be hybrids of the two (Jensen 1986). The computer-automated pattern recognition algorithm that is usually used in both cases is a multivariate cluster analysis program (Romesburg 1989).

2.3.1 Image Classification Scheme

The USGS classification scheme of Anderson et al. (1976) for remotely sensed data was used in previous work by Chatfield and Graham (unpublished data) to assign land use/land cover classes. They identified nine spectrally distinct classes on the ORR. For this project, a modified version of their classification scheme was used that combined Anderson level-I and -II categories, in which all forest land classes are Anderson level II and all other classes were Anderson level I (Table 1). The categories in Table 1 were then used to select training sites for image classification.

Table 1. The Anderson level land use/land cover classes used in the classification of the April 13, 1994, classified image[a]

Land use/land cover	Description
Evergreen plantation	Areas of pine trees that are row planted, are of uniform age, and are generally younger than 35 years (in 1994)
Water	Lakes, rivers, sewage ponds, ponds, and streams
Urban land	Mixture of administrative buildings, laboratories, heavy commercial and industrial buildings, lawns and clumped shade trees
Evergreen forest land	Areas dominated by mature pine forest type with trees generally older than 35 years (in 1994) and having an uneven canopy
Barren land	Cropped fields, plowed or bare ground areas, or areas where vegetation has been removed, such as construction sites or quarries
Deciduous forest land	Areas of hardwood forest types dominated by oaks and hickories
Mixed forest land	Areas of a mixture of hardwoods and pine trees
Pasture land	Fields with pasture grasses, grassland, row crops and/or shrubland cover
Transitional areas	Secondary early successional sites, usually grassland to grassland shrub mix; generally mowed along powerline corridors

[a]The classes were adapted from Chatfield and Graham (unpublished data).

2.3.1.1 Selection of training data

Training sites are analyst-selected spectral signatures that train or guide a classification algorithm in selection of areas within an image that are similar to the selected spectral signature. Such a classification is termed a supervised classification. Training sites are recognizable areas on an image or on the ground having distinct spectral properties that are used by a statistical pattern recognition algorithm to distinguish similar sites within an image (Jensen 1986). A

combination of field surveys of 15 ground locations and information obtained from April 3 aerial photographs at 1:6,000 scale was used to identify 128 training sites, each of which was assigned to its known land use/land cover class (Table 1). Nine known land use/land cover categories exist; however, two additional classes were statistically generated that accounted for cloud and cloud shadow cover (Table 2).

Table 2. Comparison between the ORR image subset and the entire Landsat 5 TM satellite image

	Subset image	Whole image
Class name	Pixel no./Frequency (%)	Pixel no./Frequency (%)
Evergreen plantation	492/1.60	17,559/0.60
Water	148/0.50	171,632/6.00
Cloud	12/0.04	79,162/3.00
Cloud shadow	38/0.12	25,503/0.80
Urban land	4,340/14.00	483,573/16.10
Evergreen forest land	1,889/6.12	115,812/4.00
Barren land	132/0.43	5,589/0.20
Deciduous forest land	9,632/31.20	615,467/20.50
Mixed forest land	9,786/31.70	504,888/16.80
Transitional land	4,079/13.20	579,555/19.30
Total no. of pixels	30,844	3,002,889
Columns x rows	213 x 213	1753 x 1713

2.3.2 Supervised Classification

The spectral signatures of the training sites were then input to a maximum-likelihood clustering algorithm, which uses them to distinguish similar sites. The process of using training sites distinguishes a supervised classification from an unsupervised classification in which the clustering algorithm would have to first identify its own set of similar spectral signatures before proceeding to group them with similar image signatures. The classification was performed using a maximum-likelihood clustering algorithm, which is a statistical decision criterion used to assist in the classification of overlapping signatures where pixels are assigned to the class in which they have the highest probability of being a member (see Jensen 1986 pp. 212–214 for an excellent discussion of the mathematics of this algorithm). This algorithm is a parametric classification method because it assumes that the image's brightness values are normally distributed.

2.3.3 Postclassification

After classification, additional work was required to increase the accuracy of the output data. The April 13, 1994, TM image had a substantial number of clouds which, together with their shadows, obscured landscape features. Therefore, the resulting classified image had two additional classes called clouds and cloud shadow. Additionally, we discovered that the shoreline transition

between water bodies and land cover/land use features tended to be misclassified as clouds. Therefore, ancillary data, such as concurrent aerial photography, was used to reclassify cloud and cloud shadow pixels to the class they obscured.

2.3.3.1 Ancillary data

Ancillary data were needed for removal of clouds and cloud shadow, as well as pixels that had been misclassified as either category. We originally planned to use the Environmental Restoration and Waste Management Program/Tennessee Valley Authority Base Mapping and Imagery Project's (ERWM/TVA BMIP) orthophotos of the ORR to supply the needed information in the areas obscured by clouds and cloud shadow (Ashwood et al. 1994). The orthophotos were made during aerial surveys conducted one week after the Landsat 5 TM satellite overpass. The entire set of orthophotos will eventually be converted to digital format. However, only six digital images, covering only the ORNL site area (~1,928 ha), were available in the time frame required for this report. These limited data were used in conjunction with two other sets of aerial photos of sections of the reservation. Both sets of aerial photos were from EG&G Company. One set was dated May 26–27, 1988, at scales of 1:7,960–1:20,000, and the other set was dated April 3, 1992, at a scale of 1:11,900. Other ancillary data included (a) a 1:24,000 forest type and condition map created from 1959 aerial photos of the reservation, and (b) a 1:63,360 vegetation map of the reservation prepared by Robert L. Burgess in 1975.

2.3.3.2 Enhancements

The entire ancillary data set was used to correctly classify pixels that had been misclassified as clouds and to remove clouds and cloud shadow from the classified image (Fig. 3). The misclassified cloud pixels tended to occur along shorelines and thus were a transitional area between water and forest or grassland that could be reclassified for the whole scene. However, data were insufficient to remove cloud and cloud shadow cover outside the reservation. Also, although the majority of pixels misclassified as clouds have been removed from within the image, 163 and 48 misclassified pixels of clouds and cloud shadow, respectively, are still scattered throughout the image.

2.4 ACCURACY ASSESSMENT

Following enhancements, the accuracy assessment was performed. An accuracy assessment is the process of determining the accuracy of the information in a map that will be used by different investigators (Campbell 1987). This process is carried out by either qualitatively comparing the correspondence of a classified image of unknown quality to a standard that is assumed to be correct or by statistically measuring the correspondence of samples at similar locations within the image and the standard. We chose to statistically measure the agreement between the classified image and a standard.

2.4.1 Development of the Standard for Comparison

The original plan for conducting the accuracy assessment was to use the ERWM/TVA BMIP's orthophotos of the ORR as the standard to be used for comparison with the classified

image. However, as stated previously, this was not possible for most of the image. Two alternatives were considered: (1) a ground survey of sampling points, and (2) a comparison of the ORNL orthophoto imagery to a similar area on the Landsat TM image.

2.4.1.1 Pilot project to determine the feasibility of a ground survey to develop the reference

A pilot project was implemented to test the feasibility of a ground survey of sampling points. A minimum of 50 samples is recommended per class; more samples are required for classes in which confusion is expected (Congalton 1991). The classified image had a precision level of 9 Anderson level-II classes after removal of obscuring clouds and cloud shadow. Therefore, a minimum of 450 samples were required.

A survey of ground points was undertaken to determine the cost of obtaining land use/land cover data for points with known locations determined by using two Ashtech Global Positioning Systems (GPS). The Ashtech receivers communicate with GPS satellites and use triangulation from known satellite positions to locate the map coordinate position of the receiver on the ground. One receiver's antenna is set up at a known coordinate location on the roof of Building 1505 at ORNL and is operated simultaneously with the unit in the field. This procedure is followed because the position signals from GPS satellites are randomly scrambled by the U.S. military. The degree of scrambling can be determined from the fixed receiver, and this correction is applied to the data from the field receiver.

Two different survey teams went to the field at separate times. Team I consisted of Tom Ashwood and Robert Washington-Allen, who collected 30 GPS points on October 6-7 and 17-18, 1994. Data collected was a site description of the land use/land cover encountered and the latitude and longitude of the site. The Ashtech GPS unit has a data logger, and collected data were downloaded to a computer at the Environmental Sciences Division. Team II consisted of the Threatened and Endangered Survey team within the Environmental Sciences Division's Natural Resource Group and Robert Washington-Allen. The intent of Team II was to both acquire the ground position survey points and develop a spatial database of the study sites used for biological surveys. The team collected 18 points on October 24–26, and October 31, 1994. The coordinate data from both surveys were then input into the ARC/INFO ® GIS software package and a spatial coverage generated in TSP map projection.

A number of difficulties were encountered during these surveys, including errors in operating the units and equipment malfunction. Consequently, only 48 data points from four of the seven dates were useful. Each survey period took a minimum of 3 hours. The entire Landsat image covers ~190,000 ha, which includes the ORR and surrounding areas. These points were gathered from widespread areas around the reservation. Clearly to gather 450 points a minimum of two weeks would be required. Given time and budget constraints, a more practical alternative, utilizing the ORNL orthophotos, was devised.

2.4.1.2 Development of the reference from the X-10 subset of the image

Six digital orthophoto images and their metadata files (Appendix C) were acquired from the GIS Spatial Technologies (GISST) server and placed in a mosaic (a single image) using ERDAS, Inc., Imagine 8.1™ software. The same coordinate area was subset from the main classified Landsat image. Clouds and cloud shadows were removed from the ORNL satellite image and the statistics were generated for the new subsetted image and compared with that of the entire image

(Table 2). The distribution of percentages for each class between images was comparable. Consequently, it was assumed that an accuracy assessment of the ORNL classified image subset compared with the ORNL orthophoto would be a feasible means of assessing the accuracy of the entire image.

2.4.2 Random Sampling of the Standard

The ORNL digital orthophoto is the reference or standard image used for determination of the accuracy of classification of the ORNL Landsat 5 TM image. Pixel size in the reference photo is 0.5 m as compared with the satellite image's 25 m. Therefore, individual trees could be identified to the species level, and individual cultural features could easily be discerned.

The ERDAS, Inc., Imagine 8.1™ software's Classification module was used to perform the accuracy assessment, beginning with the process of randomly sampling the classified image. One-thousand seven hundred and fifty points were randomly positioned within the classified image. The module then generated the class values in a table over which each random point was located. Because the six-image mosaic is not a perfect quadrangle (square), some of the random points intersected the image's background, which had a value of 0; consequently, 1,479 points were assessed. These same 1,479 random points were also displayed within the reference image and the actual class value was entered in the table in the reference column. After the entire table was filled, the module generated an error matrix from which the accuracy statistics were calculated (Table 3).

2.4.3 Error Matrix

The error matrix (Table 3) is a contingency table, which compares the classified pixels to the reference pixels in a $c \times c$ matrix (c = the number of categories, in this case, eight). The error matrix was created in several steps. First, the reference pixels, which were designated a specific category by ground truthing, were spatially matched to the same pixel in the image resulting from the classification process. Next, an accuracy table, which is simply a list of the values of corresponding reference and classified pixels, was created. As the final step, the error matrix was produced from the accuracy table.

By reading along the major diagonal of the table from upper left (UL) to lower right (LR), one can see the number of pixels that were correctly classified for each category. The way the pixels known to be of each specific category were classified is listed in the column for that category. Using evergreen plantation (category one) as an example, 25 pixels were correctly classified as evergreen plantation. Reading down the column, it can be seen that none were classified as water, urban land, or barren land. The producer's errors in classification of evergreen plantation pixels are seen to be 19 pixels that were classified as evergreen forest land, 4 as deciduous forest land, 15 as mixed forest land and 1 as a transitional area. The user's errors in classification refers to other kinds of pixels that were incorrectly assigned to the evergreen plantation category. These are found by reading across the first row (rather than reading down the first column). They are two pixels of evergreen forest and one each of deciduous forest land and mixed forest land.

A smaller number of reference pixels were used for barren land and water because these two categories tend to have distinct reflectance characteristics and are seldom misclassified. These classes also show the expected highest accuracy in the error matrix. The areas that show a higher

Table 3. Error matrix for each land use/land cover category within the April 13, 1994, classified Landsat 5 TM image of the ORR's ORNL[a]

	Reference data								
Classified data	Evergreen plantation	Water	Urban land	Evergreen forest land	Barren land	Deciduous forest land	Mixed forest land	Transitional areas	Classified total (no. of pixels)
Evergreen plantation	25	0	0	2	0	1	1	0	29
Water	0	5	0	0	0	0	0	0	5
Urban land	0	1	166	23	0	7	11	8	217
Evergreen forest land	19	0	3	44	0	1	16	1	84
Barren land	0	0	0	0	6	1	0	0	7
Deciduous forest land	4	1	9	35	0	343	42	13	447
Mixed forest land	15	0	2	87	0	49	333	10	496
Transitional areas	1	0	17	28	1	44	41	62	194
Reference total (no. of pixels)	64	7	197	219	7	446	444	94	1479

[a]Rows are the classified totals and columns are the number of classes in the reference data. The pasture land class is not included because it does not occur within the ORNL area.

incidence of incorrect classification are areas that have a less distinct spectral reflectance from each other and therefore have a higher tendency to be misclassified. These classes, evergreen forest and evergreen plantation, showed a particularly high proportion of misclassification (i.e., relatively lower accuracy).

The error matrix helps answer the questions posed by Hay (1979):

- What proportion of the classification decision is correct?
- What proportion of assignments to a given category is correct?
- What proportion of a given category is correctly classified?
- Are errors randomly distributed?

2.4.4 Calculation of Accuracy Assessment Statistics

Accuracy statistics of the entire image are unknown and cannot be calculated. However, they can be ***estimated*** by calculations from the error matrix that was obtained from the independent accuracy assessment data set. To the extent that the independent accuracy assessment data set is representative of the entire image, accuracy statistics calculated from the assessment data set (via the error matrix) should be good estimates of the accuracy of the entire classified image. The error matrix, developed from this independent data set, therefore can be used to develop a number of statistics useful for assessing the accuracy of the classified image (Congalton 1991).

- The ***overall accuracy*** is a single statistic representing the proportion of all of the reference pixels that are correctly classified.
- Cohen's ***Kappa*** statistic (Cohen 1960; Titus et al. 1984; Congalton 1991) also expresses the proportion of reference pixels correctly classified by the procedure, but in this case after adjusting for (removing) the effect of correct classification by chance.
- ***Producer's accuracy*** can be calculated for each of the eight land use/land cover categories. Each of these expresses the proportion of reference pixels actually in that category that were classified as being in that category. This statistic informs the producer of the classification of how well the category can be classified.
- ***User's accuracy*** can also be calculated for each of the eight categories. This expresses the proportion of pixels classified in a particular category that actually belong in that category. A user who wanted to know the probability of actually finding deciduous forest if he or she went to a field location indicated by the map as being deciduous forest would be more interested in this statistic.

The calculation of each of these is described in the following sections.

2.4.4.1 Overall accuracy

The overall accuracy of a classified image is the fraction of pixels assigned to the correct category. It addresses the first question in Sect. 2.4.3, "What proportion of the classification decision is correct?" This estimate is calculated from the error matrix. The pixels tabulated along the major diagonal of the matrix [from upper right (UR) to lower left (LL)] are the pixels that

were correctly classified. Those tabulated anywhere else in the matrix represent misclassifications. The overall accuracy (fraction correctly classified) can therefore be calculated by dividing the sum of the major diagonal (970 pixels) by the total number of pixels (1,479) in the error matrix. The overall percent accuracy of the reference data set is 970/1,479, or 66%; this is an estimate of the accuracy of the entire image.

2.4.4.2 Kappa statistic

Cohen's Kappa statistic (Cohen 1960; Titus et al. 1984; Congalton 1991), like overall accuracy, expresses the proportion of reference pixels correctly classified by the procedure, but in this case after adjusting for (removing) the effect of correct classification by chance. Like the overall accuracy calculated above, Kappa addresses the first question in Sect. 2.4.3, "What proportion of the classification decision is correct?" Kappa is a discrete multivariate statistic, estimated from the error matrix as

$$KHAT = (P_0 - P_C)/(1 - P_C)$$

where KHAT denotes kappa, P_0 is the proportion of pixels correctly classified, and P_C is the proportion of observations expected to be classified correctly by chance alone. P_C is calculated from the error matrix by using the row and column proportions (i.e., P_C is the sum of row times column proportions summed over all categories). Further information about this calculation can be found in Titus et al. (1984); Campbell (1987); and Congalton (1991). Kappa has its maximum value of 1 when all observations are correctly classified. Some advantages of the kappa statistic are that confidence limits can be calculated for it, and it can form the basis of statistical tests. These tests can, for example, evaluate the significance of differences among classifications performed using different methods, or by different analysts (Congalton 1991).

The value of KHAT calculated from the error matrix was 0.55. This is interpreted as meaning that the classification has achieved an accuracy that is 55% better than would be expected from a random assignment of pixels to classes.

2.4.4.3 Producer's accuracy

Producer's accuracy is so named because it is a statistic that informs the producer of the classification how well each category can be classified. It can be calculated column by column from the error matrix (Table 3); with eight categories there are eight values of producer's accuracy (Table 4). Each of these expresses the proportion of reference pixels actually in that category that were classified as being in that category.

Although Table 3 contains enough information to calculate these statistics, Table 4 summarizes key information from Table 3 to support easy calculation of producer's and user's accuracies. The first three columns of data in Table 4 are (a) the major diagonal (pixels correctly classified) from Table 3, (b) the column (reference pixel) totals from Table 3, and (c) the row (classified pixel) totals from Table 3. Producer's accuracy, the probability of a reference pixel in a particular category being correctly classified, is calculated as the total number of correctly classified pixels in the category, divided by the total number of reference pixels in the category. It is thus the ratio of column (a) to column (b) for the category's row in Table 4. Column (d) in Table 4 shows the results of these calculations for each category.

Table 4. Accuracy totals for each land use/land cover category within the April 13, 1994, classified Landsat 5 TM image of the ORR's ORNL

Land use/land cover class	(a) Number of pixels correctly classified	(b) Reference totals (no. of pixels)[a]	(c) Classified totals (no. of pixels)[b]	(d) Producer's accuracy (%) (a/b)	(e) Users accuracy (%) (a/c)
Evergreen plantation	25	64	29	39	86
Water	5	7	5	71	100
Urban land	166	197	217	84	76
Evergreen forest land	44	219	84	20	52
Barren land	6	7	7	85	85
Deciduous forest land	343	446	447	76	76
Mixed forest land	333	444	496	75	67
Transitional areas	62	94	194	66	32

[a]The reference totals are the number of sample pixels of that class counted in the reference data (the digital orthophoto).
[b]The classified totals are the total number of sample pixels that were classified in that category.

Using urban land as an example, of the 197 pixels in the reference data set that were actually urban land, 166, or 84%, were classified as urban. This category therefore has a producer's accuracy of 84%. Table 4 shows this value, as well as producer's accuracy calculations for the other seven categories.

2.4.4.4 User's accuracy

The user's accuracy percentage, or reliability, is calculated as the total number of correctly classified pixels for each class divided by the total number of pixels classified into that class. It is a measure of the probability that a pixel is correctly classified. Continuing our example of urban land in Table 4, of the 217 pixels that were classified as urban land, 166 were actually urban land, for a user's accuracy of 76% for urban land. This means that a user visiting an area within the image that was classified as urban land would expect to have a 76% chance of actually finding urban land at that location (Table 4).

It should be noted that the term "user's accuracy" may be misleading, in that many users will be less interested in this statistic than in other statistics or aspects of the classification. A user wanting to visit areas of the landscape while knowing in advance what category of land to expect would be most interested in this "user's accuracy" statistic. However, a risk assessor, representing another kind of user, might well be less interested in the "user's accuracy" than in the degree to which the classified totals match the reference (actual) totals. A statistic representing this match could be calculated for this particular kind of user. Other users might have still other specialized interests.

3. RESULTS

3.1 IMAGE SUBSET

ARC/INFO vector coverages for the ORR boundary, OU boundaries, primary and secondary roads, and open water features were available in digital format through the Oak Ridge Environmental Information System. The map layer projections (TSP, Zone 5301, NAD 1983) were the same as the resampled image projection. The polygons of the ORR and the OUs were used to subset the ORR from the final version of the classified image (Fig. 4) and to generate area statistics for each land use and land cover within the reservation (Table 5). The same procedure was followed for each individual OU dispersed throughout the reservation.

3.2 THE OAK RIDGE RESERVATION'S LAND USE/LAND COVER STATISTICS

Table 5 indicates that the reservation is some 14,172 ha in size and that the most prevalent land cover on the reservation is deciduous forest land (~4,029 ha). However, these areas must be considered an approximation, as they are based on a two-dimensional estimate and do not account for the ridge and valley geomorphic structure of the reservation (i.e., the given measure is an underestimate). Forest land dominates the landscape (~8,203 ha). Transitional areas, including mostly mowed strips for powerlines or cleared areas along major and minor roadways and around urban areas, are the most evident anthropogenic feature on the ORR. The vegetation composition of the transitional areas is primarily a grassland/shrubland mix. Urban land, which, in addition to plant buildings, includes lawn grass and small open ponds/sewage systems, comprised some 1,437 ha (or ~10% of the ORR) of land. Barren land is the smallest category (~3% of the ORR).

3.3 THE OPERABLE UNITS' LAND USE/LAND COVER STATISTICS

The area statistics for each land use/land cover class within an OU are listed in Appendix A in conjunction with maps of each OU. There are ~36 OUs comprising ~1,100 ha (or 8% of the ORR).

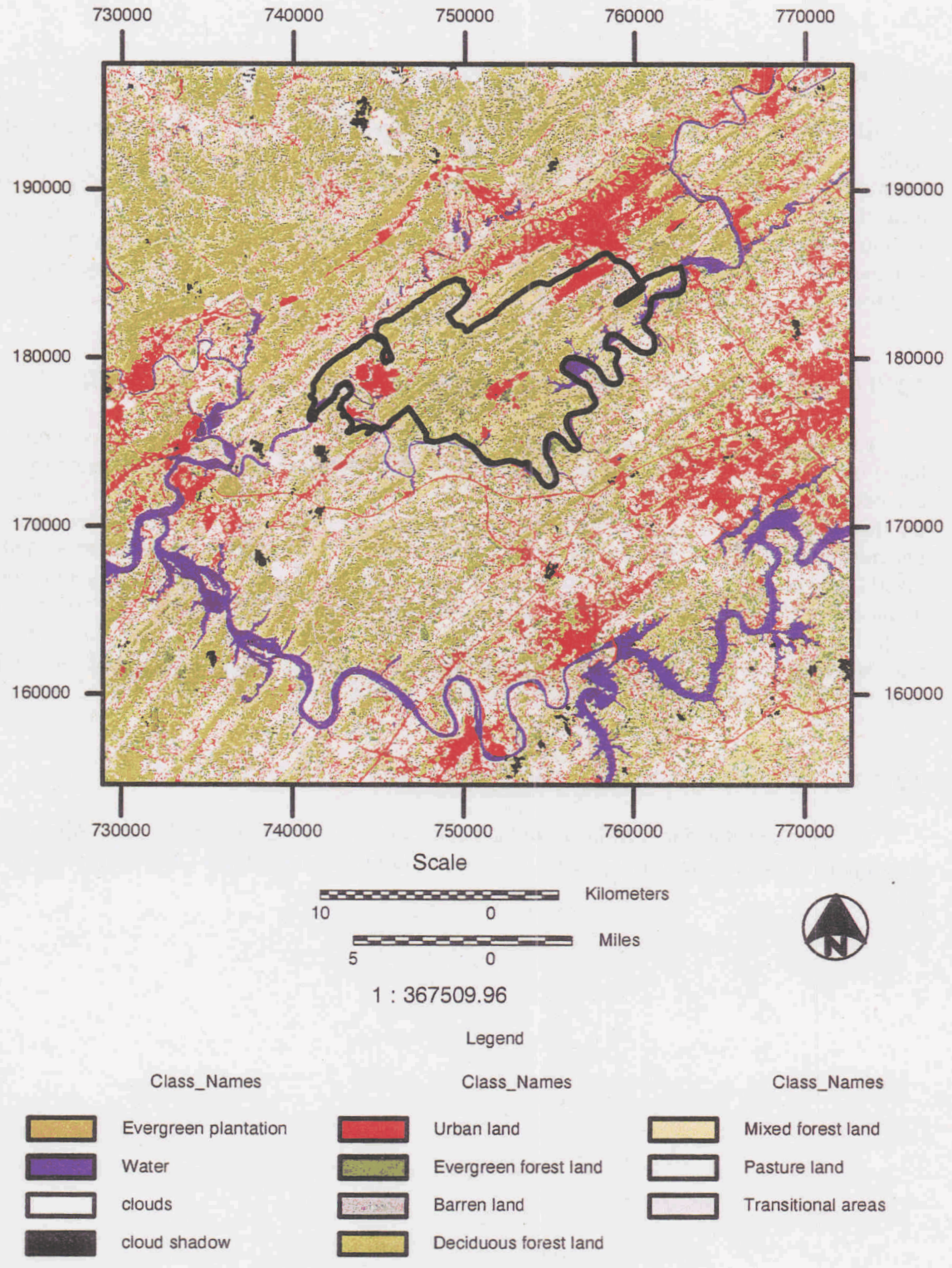


Fig. 4. The April 13, 1994, classified Landsat 5 TM image of the ORR. The image projection is TSP meters, Zone 5301, and NAD 83.

Table 5. Land use/land cover area statistics for DOE's ORR[a]

Land use/land cover	Area (Ha)
Evergreen plantation	323.50
Water	939.31
Urban land	1,437.50
Evergreen forest land	704.87
Barren land	47.00
Deciduous forest land	4,028.62
Mixed forest land	3,469.19
Agricultural land	312.44
Transitional areas	2,896.19
Total area	14,171.81

[a]These statistics do not include the 10 ha and 3 ha misclassified as clouds and cloud shadow, respectively.

4. DISCUSSION

A number of factors may explain why the accuracy measure obtained for the classified image (66%) was not higher. Error was introduced into the classification procedure because the image was georeferenced by EOSAT to a map projection and subsequently twice reprojected. The CC resampling procedure was used in all three cases (see Jensen 1986 or Campbell 1987 for a lucid explanation of the mathematics of this procedure). Therefore, the image was resampled at least three times. Essentially, we have a subsample of a subsample of a subsample. Jensen (1986) has noted that though the CC geometric correction procedure provides the best fit for data resampling, it greatly obscures the original radiometric values of the image. Consequently, the reliability of future quantitative analysis with the data (e.g., applying discrete models such as vegetation indexes) is reduced, though analyses that describe landscape pattern may still be applicable (Ashwood et al. 1994).

Second, beyond the spectral information provided by the satellite imagery, we were, at this stage, unable to use other ancillary data to make the classification procedure more efficient and avoid confusion between classes (e.g., a vegetation index, elevation, slope, aspect, or soil texture data). Multivariate classification procedures have been shown to be greatly enhanced by additional discriminating data (Kent and Coker 1992). Ancillary data that were used to correct the cloud cover and cloud shadow areas, particularly the 1959 forest compartment map, were probably an additional source of error due to natural and anthropogenic changes and map classification accuracy that occurred in the 35 years since its preparation.

Third, there was inadequate time at this stage to undertake a comparison of the chosen algorithm with other classification algorithms available in the ERDAS, Inc., software, such as the nonparametric methods and other parametric methods (e.g., the minimum distance classifier).

In addition, the number of sample pixels for three of the land use/land cover categories [barren land (7), evergreen plantation (29), and water (5); Table 3] were fewer than the recommended 50-pixel assignment for an error analysis. This was partially a function of the assumption of a random distribution of a population in a random sampling scheme that tends to underestimate members of a population that are rare and clumped (Bonham 1989). Barren land and water tended to have highly clumped distributions and to be rare relative to the other categories classified. The confusion in the evergreen plantation is underestimated because of its low sample size (Table 3). We would expect a high confusion of evergreen plantation with evergreen forest land and moderate confusion with mixed forest land because of (1) the similarities in their canopy's spectral reflectance and (2) the topographic constraints presented by the ridge and valley physiographic region, which encompasses the ORR, leads to increased shadowing within forest classes—an additional source of classification error. It is probable that an additional 75 or more sampling points are required for an estimate of the confusion of the evergreen plantation class.

Finally, the pasture land category at some 312 ha is misleading, as very little of the reservation is actually agricultural land (Table 5). It should be viewed as potential pasture land or as a remnant of the Reservation's historical land use. The pasture land category exemplifies the potential confusion between land use and land cover categories, because both the transitional and pasture land categories are essentially a grassland/shrubland vegetation cover type. Additionally, grassland occurs more accurately as lawns within the urban land area, particularly around each of the buildings on the reservation (Fig. 4 and individual OUs in Appendix A). These sites

provide services to a number of species, including deer, various invertebrates, geese, various other birds, and ubiquitous squirrels and groundhogs. However, data resolution was not fine enough to account for these lawns, as was evident in the various OUs that included urban land.

Fortunately, classification accuracy increases with clumping in an Anderson level classification scheme (though precision decreases), and the data are amenable to this. Alternatively, the classified image should be viewed as a dynamic evolutionary template that is undergoing adaptive change. Already the Computing Application Division's (CAD) GIS and Computer Modeling Group have begun a land classification of the digital orthophotos, and, depending on the schema used, the finer spatial resolution of the orthophotos would aid in Anderson level-III classifications. In addition, the joint DOE and Department of Defense Strategic Environmental Research and Development Program Strategy for Natural Resources Management on Department of Defense/DOE Lands project is examining finer classification of the ORR TM satellite data to detect the presence of rare habitat on the reservation (e.g., cedar barrens).

4.1 RECOMMENDATIONS

Near the end of this project, EOSAT delivered the requested TM image in the correct projection. However, this image was also a CC resample. If possible, a nearest neighbor resample should be acquired and the classification redone using an intelligent classification schema in combination with decision rules and ancillary data, such as digital elevation models.

Upon the completion of the ERWM/TVA BMI project, digital orthophotos will be available that could facilitate vegetation/animal species mapping at an Anderson level-III resolution. Further collaboration between ESD's ecologists and CAD's GIS and Computer Modeling group could produce a widely applicable land use/land cover classification schema. The complete orthophoto of the ORR would allow a re-estimation of the entire classified TM image's accuracy statistics as well as provide a more extensive area for correction of misclassifications and removal of clouds and cloud shadow.

A qualitative comparison of the landscape pattern of the ORR to the landscape surrounding it suggests that the ORR is largely a contiguous forested landscape surrounded by a fragmented mosaic of urban and agricultural land uses (Fig. 4). A number of empirical and theoretical studies have determined that fragmentation of landscapes has implications for species extinction and changes in biodiversity (e.g., Diamond and May 1977). A change detection between the raw and classified 1984 (Chatfield and Graham unpublished data) and 1994 Landsat 5 TM images (both) would assess the magnitude of changes in land use and land cover, quantify their impact on landscape pattern, determine their effect on species' habitats and biodiversity, and facilitate the management of the ORR landscape and its incorporated ecosystems. As recommended by Ashwood et al. (1994), landscape metrics should be used to measure the magnitude of spatio-temporal changes in landscape pattern, both among areas within the ORR, and between areas outside the reservation's immediate vicinity compared with the areas within. The latter case would provide a test of the observation that the ORR and other DOE facilities are unique areas for biodiversity compared with the highly urbanized areas that usually surround them (Patricia Parr pers. comm. August 1994).

5. REFERENCES

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 Adat.* U. S. Geological Survey Professional Paper 964.

Ashwood, T. L., B. E. Sample, G. W. Suter II, H. Offerman, M. G. Turner, J. M. Loar, and L. W. Barnthouse. 1994. *Work Plan for the Oak Ridge Reservation Ecological Monitoring and Assessment Program.* DOE/OR/01-1298&D1, Oak Ridge National Laboratory, Tennessee.

Bonham, C. D. 1989. *Measurements of Terrestrial Vegetation.* John Wiley & Sons, New York.

Campbell, J. B. 1987. *Introduction to Remote Sensing.* Guilford Press, New York.

Chatfield, T. A. and R. L. Graham. (Unpublished Report) *A Land Use/Land Cover Map of the Oak Ridge Reservation and Surrounding Areas.* Environmental Sciences Division Publication, Oak Ridge National Laboratory, Tennessee.

Cohen, J. 1960. "A Coefficient of Agreement for Nominal Scales." *Educ. Psychol. Measur.* 20, pp. 37–46.

Congalton, R. G. 1991. "A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data," *Remote Sensing of Environment* 37(**1**), pp. 35–46.

Diamond, J. M. and R. M. May. 1977. "Island Biogeography and the Design of Nature Reserves" in *Ecology of Biological Invasions of North America and Hawaii,* H. A. Mooney and J. A. Drake, eds. Springer-Verlag, New York.

ERDAS. 1991. *ERDAS Field Guide.* Second Edition, ERDAS, Inc., Atlanta.

ERDAS. 1994. *ERDAS Field Guide.* Third Edition, ERDAS, Inc., Atlanta.

Hay, A. 1979. "Sampling Designs to Test Land Use Map Accuracy," *Photogrammetric Engineering and Remote Sensing* 45, pp. 529–533.

Jensen, J. R. 1986. *Introductory Digital Image Processing.* Prentice-Hall, Englewood Cliffs, New Jersey.

Kent, M. and P. Coker. 1992. *Vegetation Description and Analysis.* CRC Press, Boca Raton, Florida, and Belhaven Press, London.

Parr, P. 1994. Natural Resource Analysis Group, personal communication to R. A. Washington-Allen, August.

Romesburg, C. 1990. *Cluster Analysis for Researchers.* Robert E. Krieger Publishing Company, Inc., Malabar, Florida.

Suter II, G. W., B. E. Sample, D. S. Jones, and T. L. Ashwood. 1994. *Approach and Strategy for Performing Ecological Risk Assessments for the Department of Energy's Oak Ridge Reservation: 1994 Revision.* ES/ER/TM-33/R1, Oak Ridge National Laboratory, Tennessee.

Titus, K., J. A. Mosher, and B. K. Williams. 1984. "Chance-corrected Classification for Use in Discriminant Analysis: Ecological Applications," *Am. Midl. Nat.* 111, pp. 1–7.

Tucker, C. J. 1979. "Red and Photographic Infrared Linear Combinations for Monitoring Vegetation," *Remote Sensing of Environment* 8, pp. 127–150.

Appendix A

MAPS AND AREAL STATISTICS OF LAND USE/LAND COVER FOR 37 OPERABLE UNITS ON THE OAK RIDGE RESERVATION

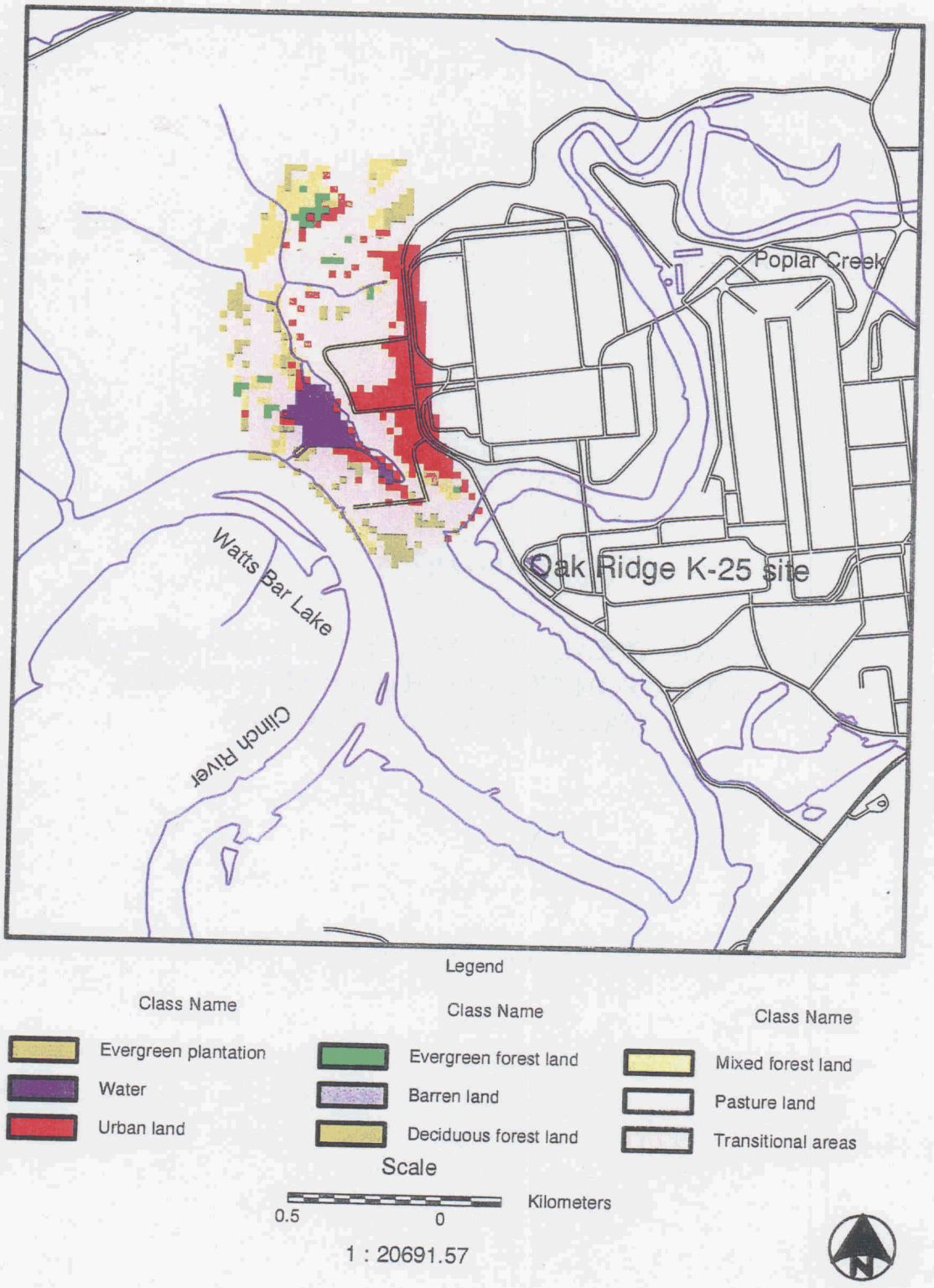


Fig. A.1. An April 13, 1994, classified Landsat 5 TM image of the Area 10 OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.1. Area 10 OU

Land use/land cover		Area (Ha)
Evergreen plantation		0.31
Water		3.56
Urban land		15.94
Evergreen forest land		1.75
Barren land		0.00
Deciduous forest land		6.87
Mixed forest land		7.62
Pasture land		3.19
Transitional areas		38.31
	Total	77.55

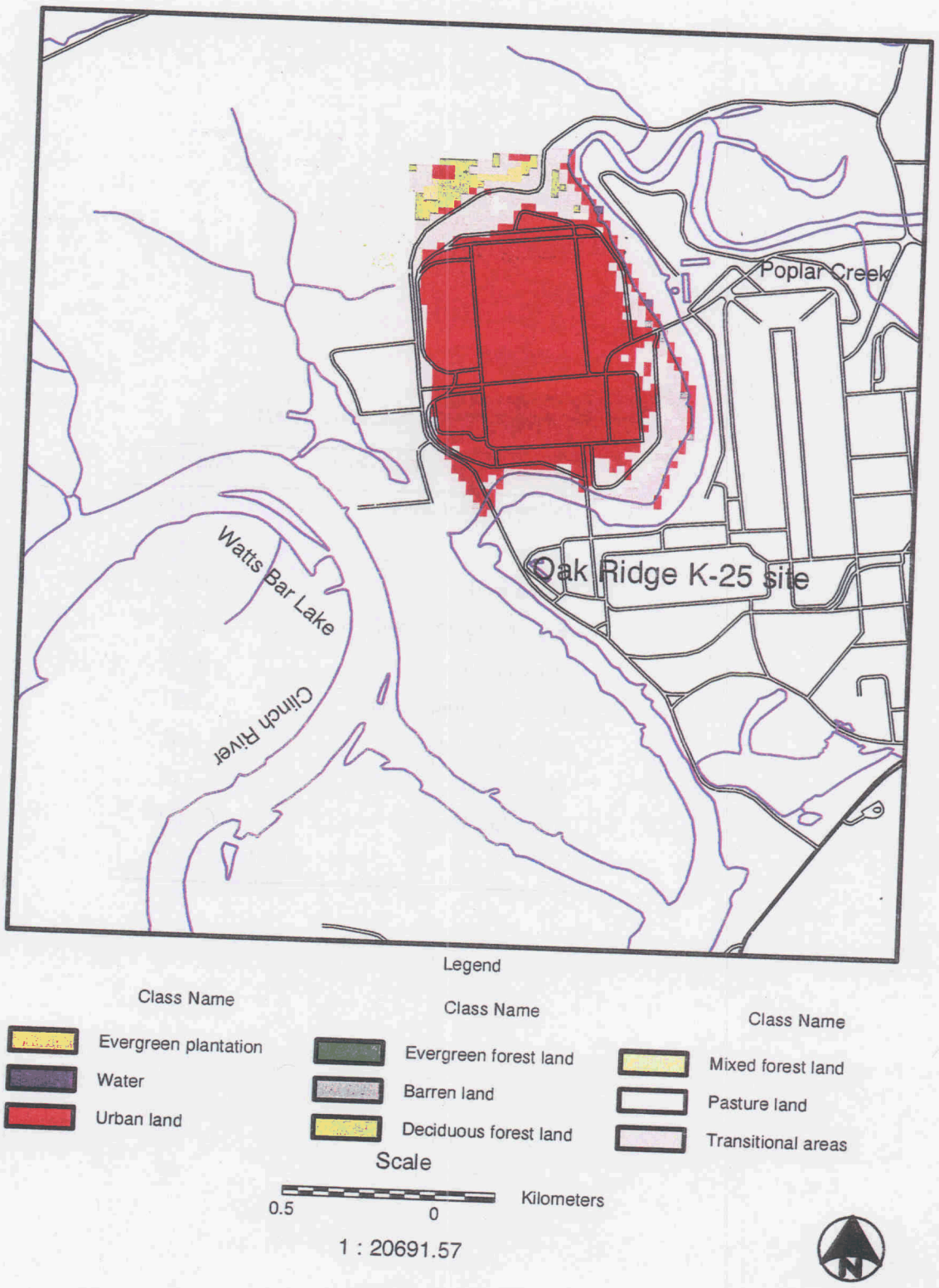


Fig. A.2. An April 13, 1994, classified Landsat 5 TM image of the K-33 OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.2. K-33 OU

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.12
Urban land	65.00
Evergreen forest land	0.00
Barren land	0.37
Deciduous forest land	2.94
Mixed forest land	0.87
Pasture land	5.06
Transitional areas	13.94
Total	88.30

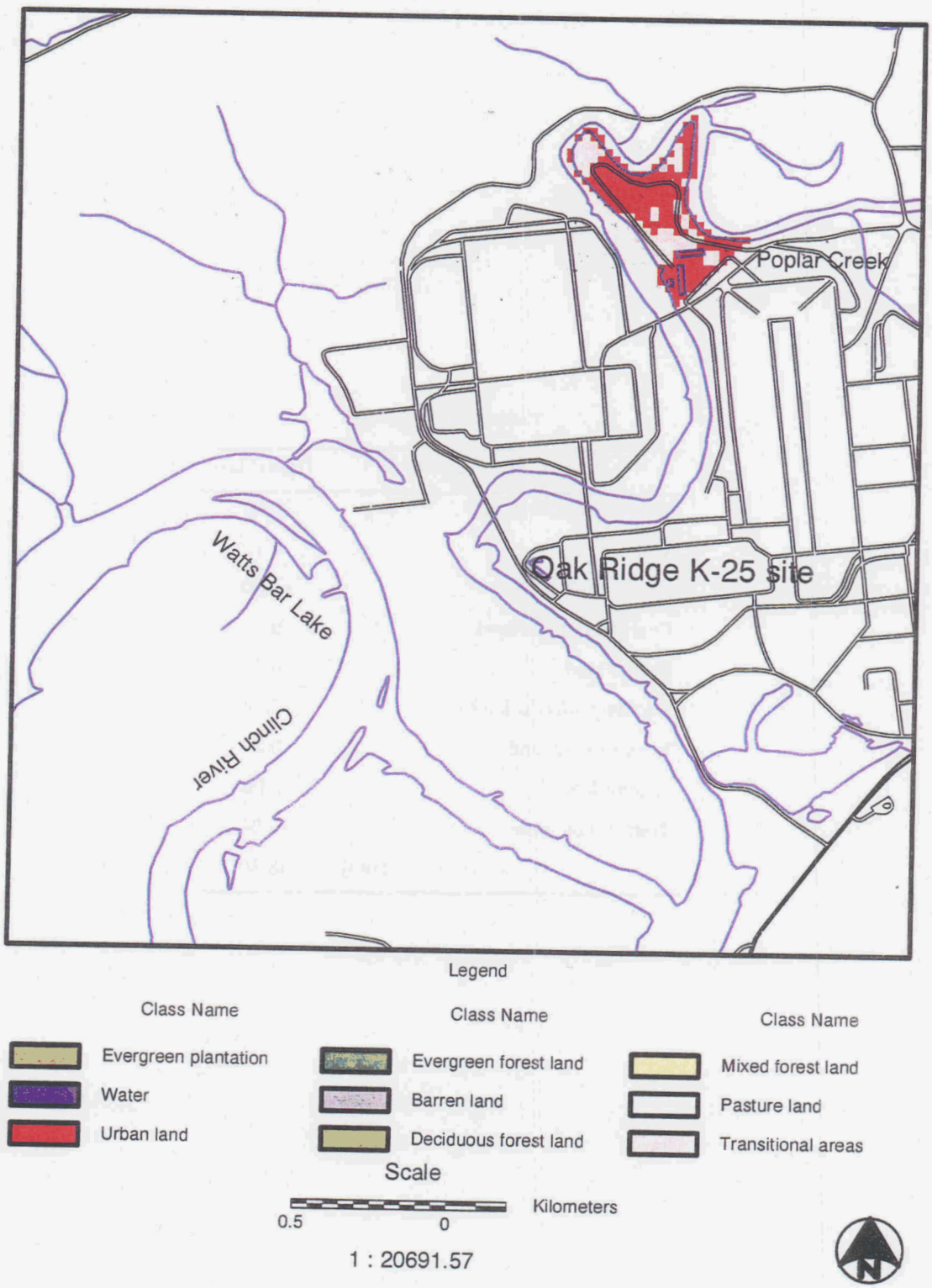


Fig. A.3. An April 13, 1994, classified Landsat 5 TM image of the K-1064 OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.3. K-1064 OU

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	11.06
Evergreen forest land	0.00
Barren land	0.06
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.19
Transitional areas	3.56
Total	14.87

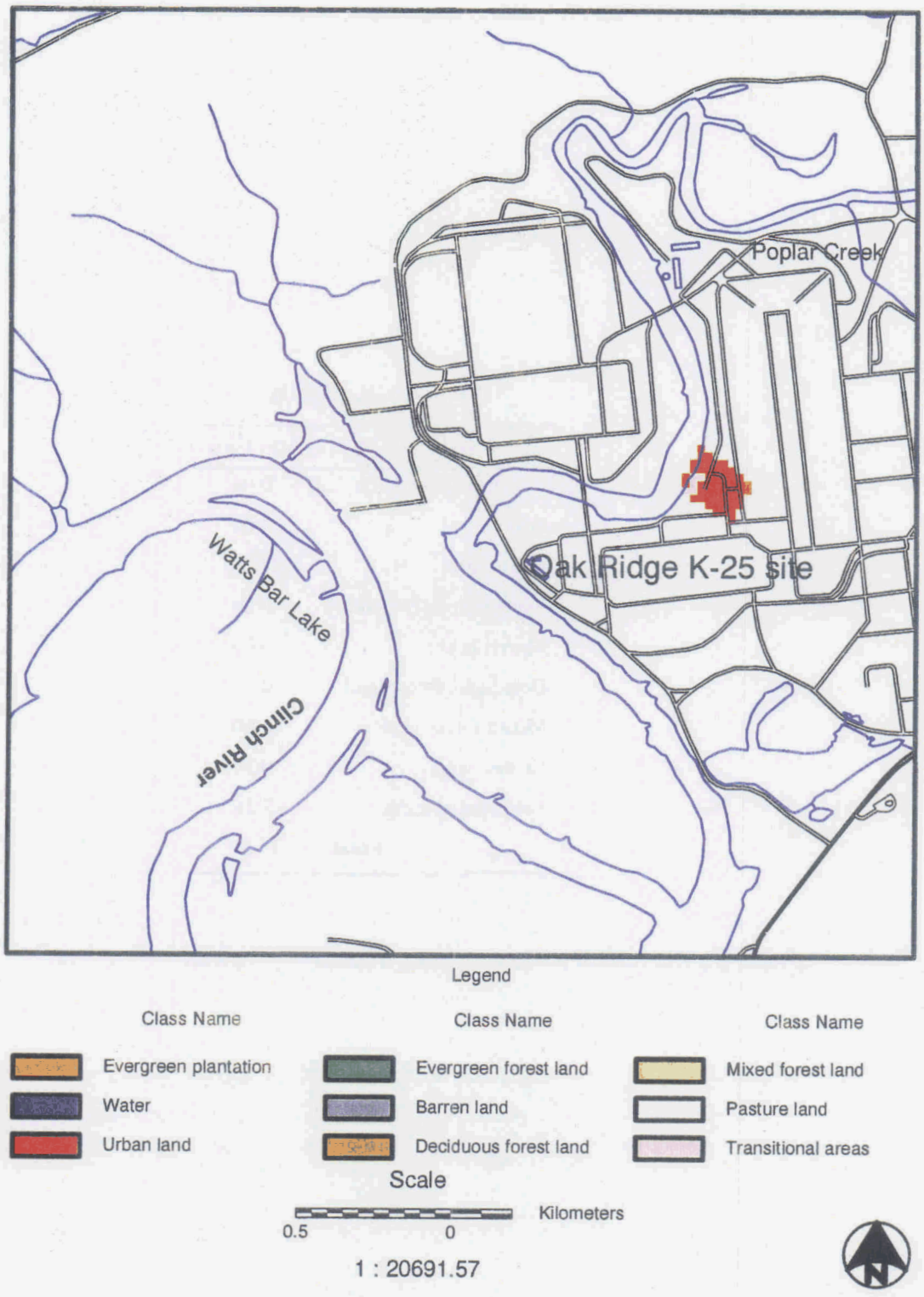


Fig. A.4. An April 13, 1994, classified Landsat 5 TM image of the K-1410 OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.4. K-1410 OU

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	3.19
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.00
Transitional areas	0.31
Total	3.50

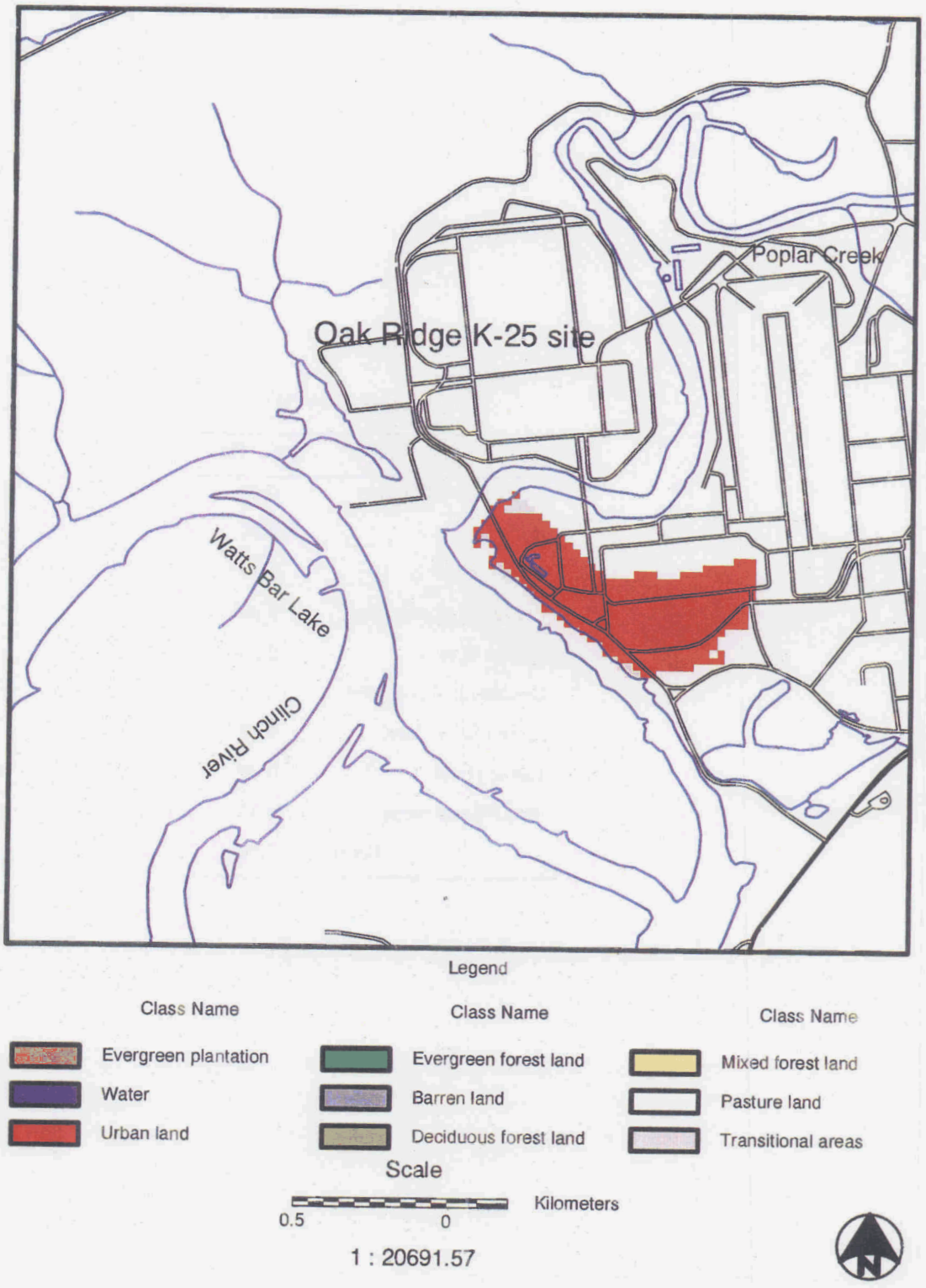


Fig. A.5. An April 13, 1994, classified Landsat 5 TM image of the K-29 OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.5. K-29 OU

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	25.62
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.62
Transitional areas	0.88
Total	27.12

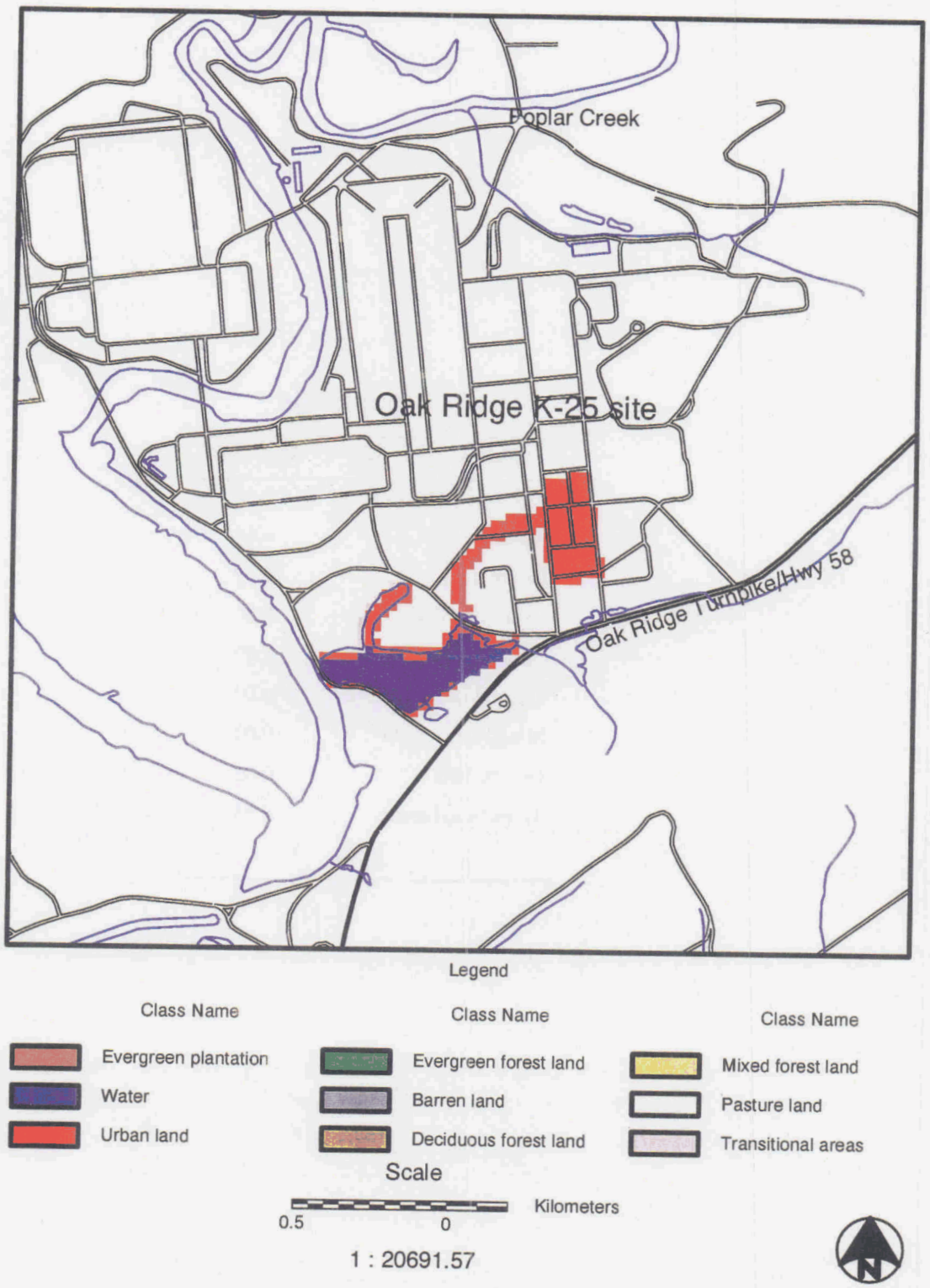


Fig. A.6. An April 13, 1994, classified Landsat 5 TM image of the K-1007 OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.6. K-1007 OU

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	7.62
Urban land	13.75
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.19
Transitional areas	0.75
Total	22.31

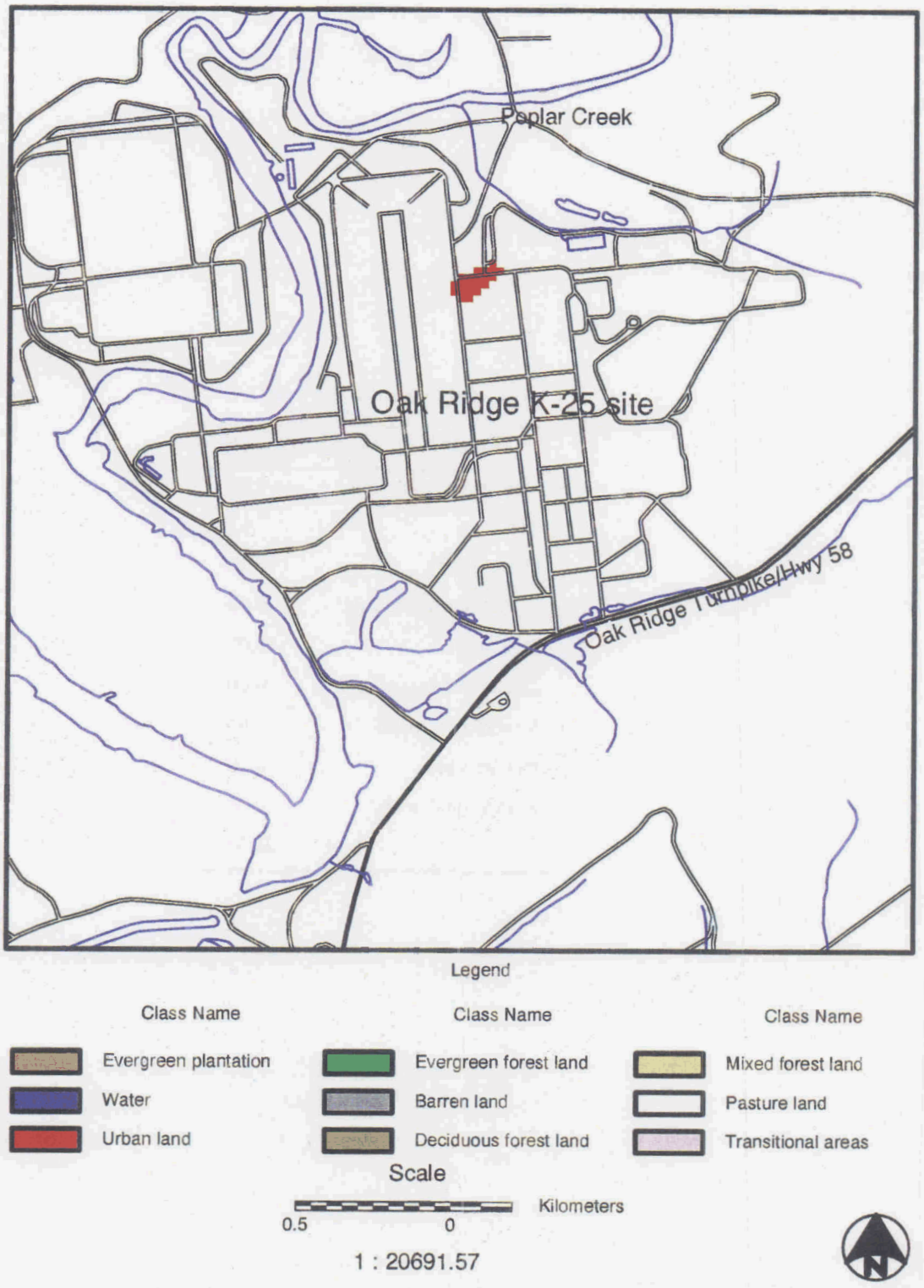


Fig. A.7. An April 13, 1994, classified Landsat 5 TM image of the K-1413 OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.7. K-1413 OU

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	1.31
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.00
Transitional areas	0.00
Total	1.31

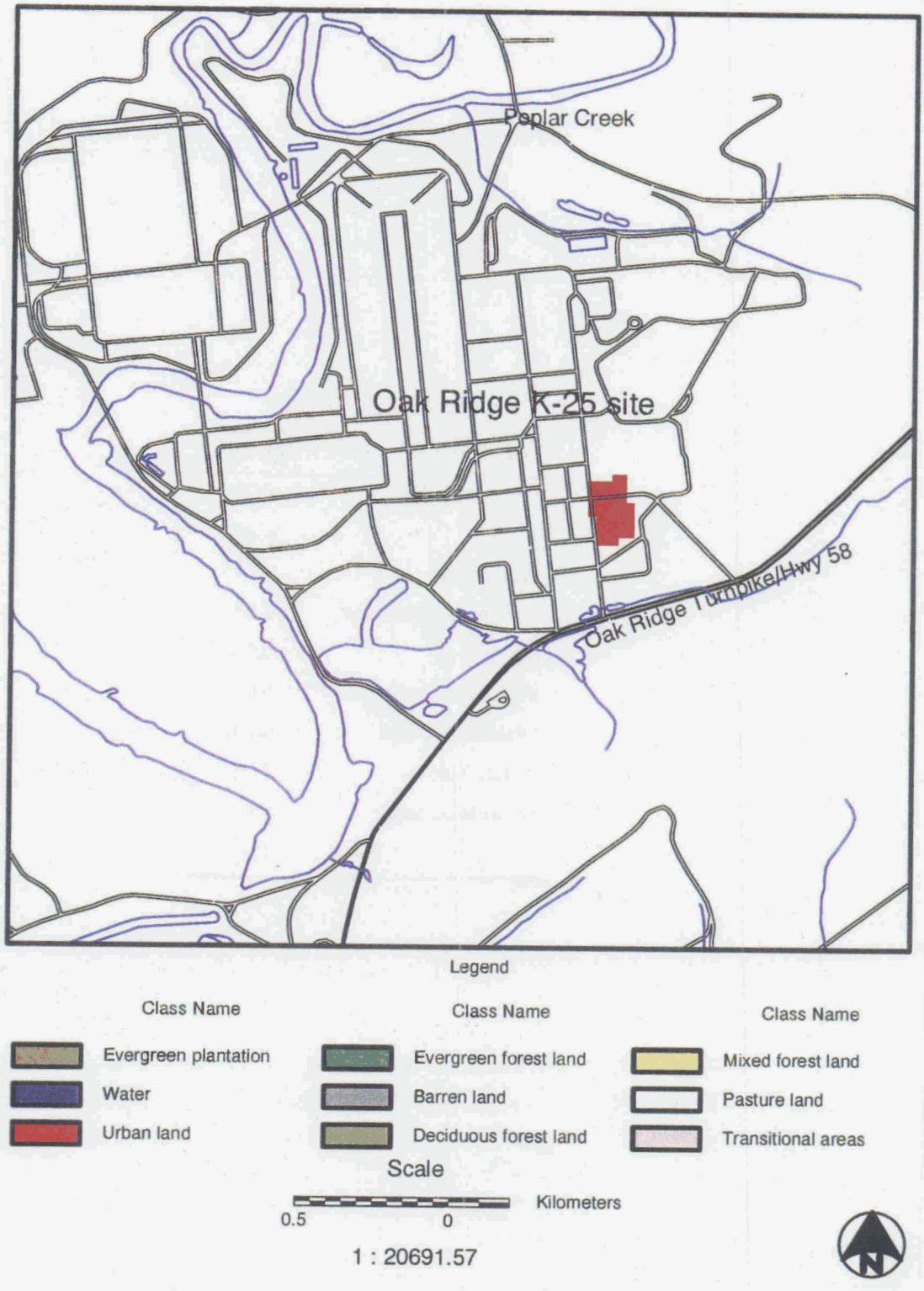


Fig. A.8. An April 13, 1994, classified Landsat 5 TM image of the K-1004 OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.8. K-1004 OU

Land Use/Land Cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	2.94
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.00
Transitional areas	0.00
Total	2.94

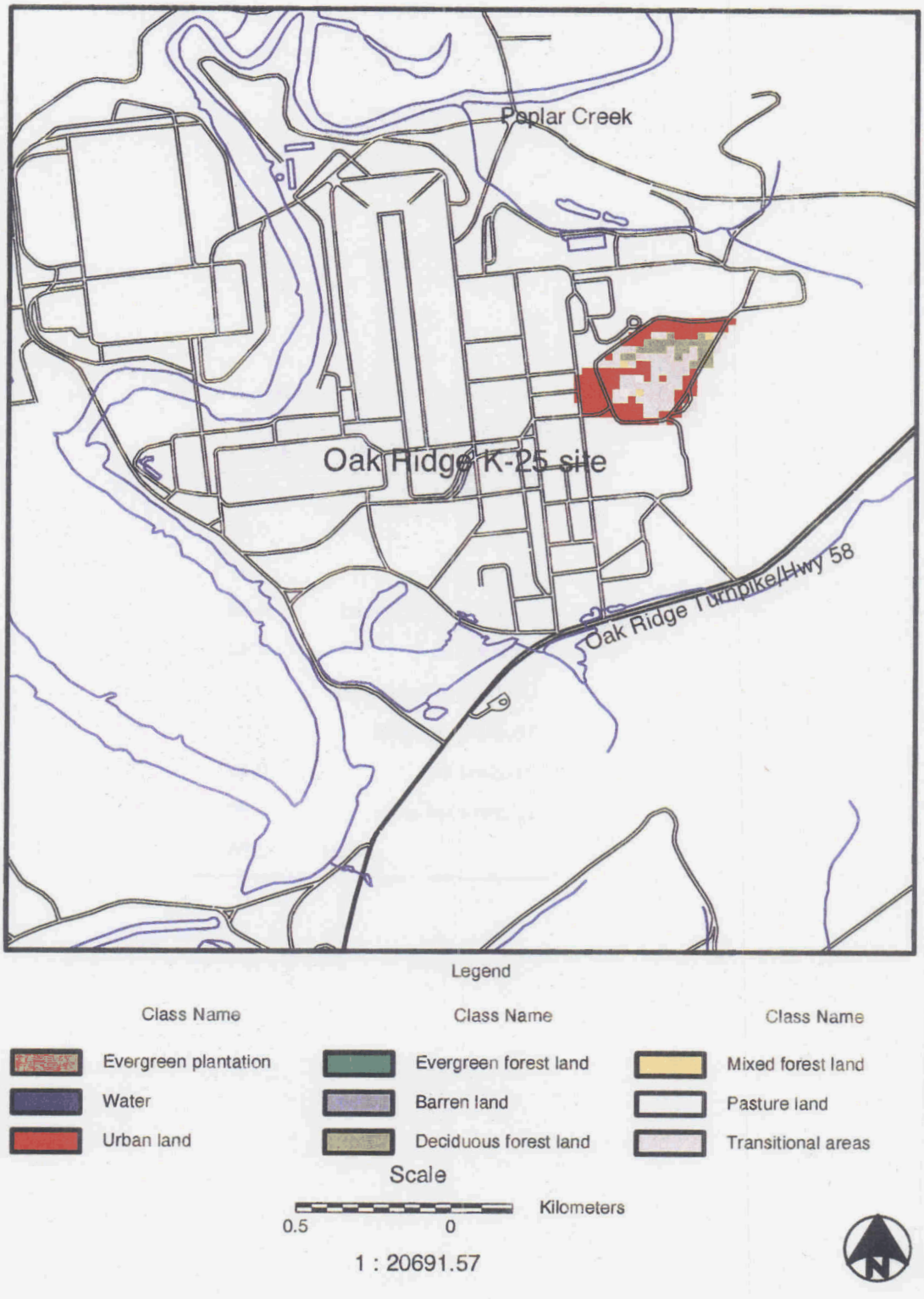


Fig. A.9. An April 13, 1994, classified Landsat 5 TM image of the K-1070-C/D OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.9. K-1070-C/D OU

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	6.56
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	1.69
Mixed forest land	0.19
Pasture land	0.25
Transitional areas	4.37
Total	13.06

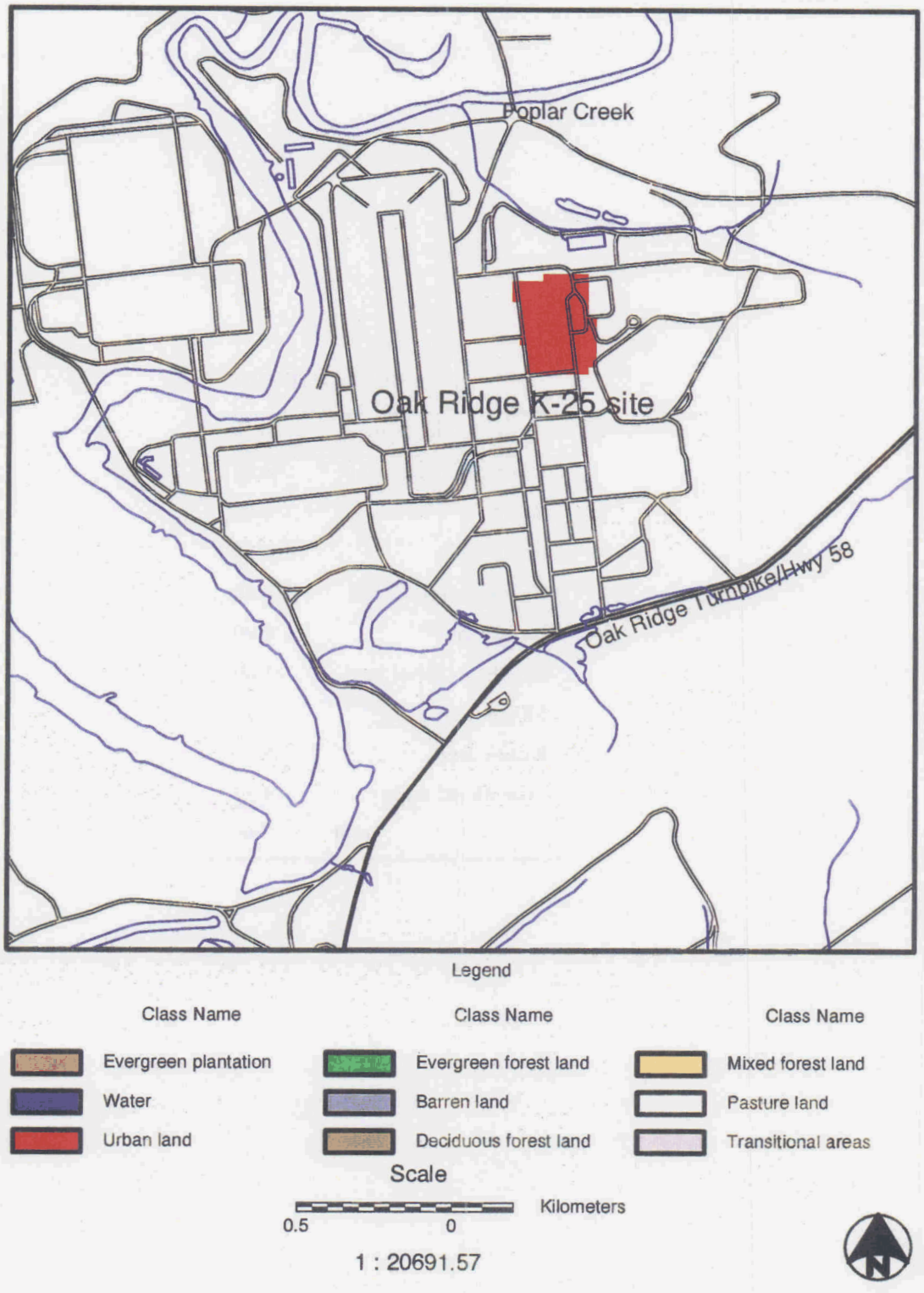


Fig. A.10. An April 13, 1994, classified Landsat 5 TM image of the K-1401 OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.10. K-1401 OU

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	8.06
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.00
Transitional areas	0.00
Total	8.06

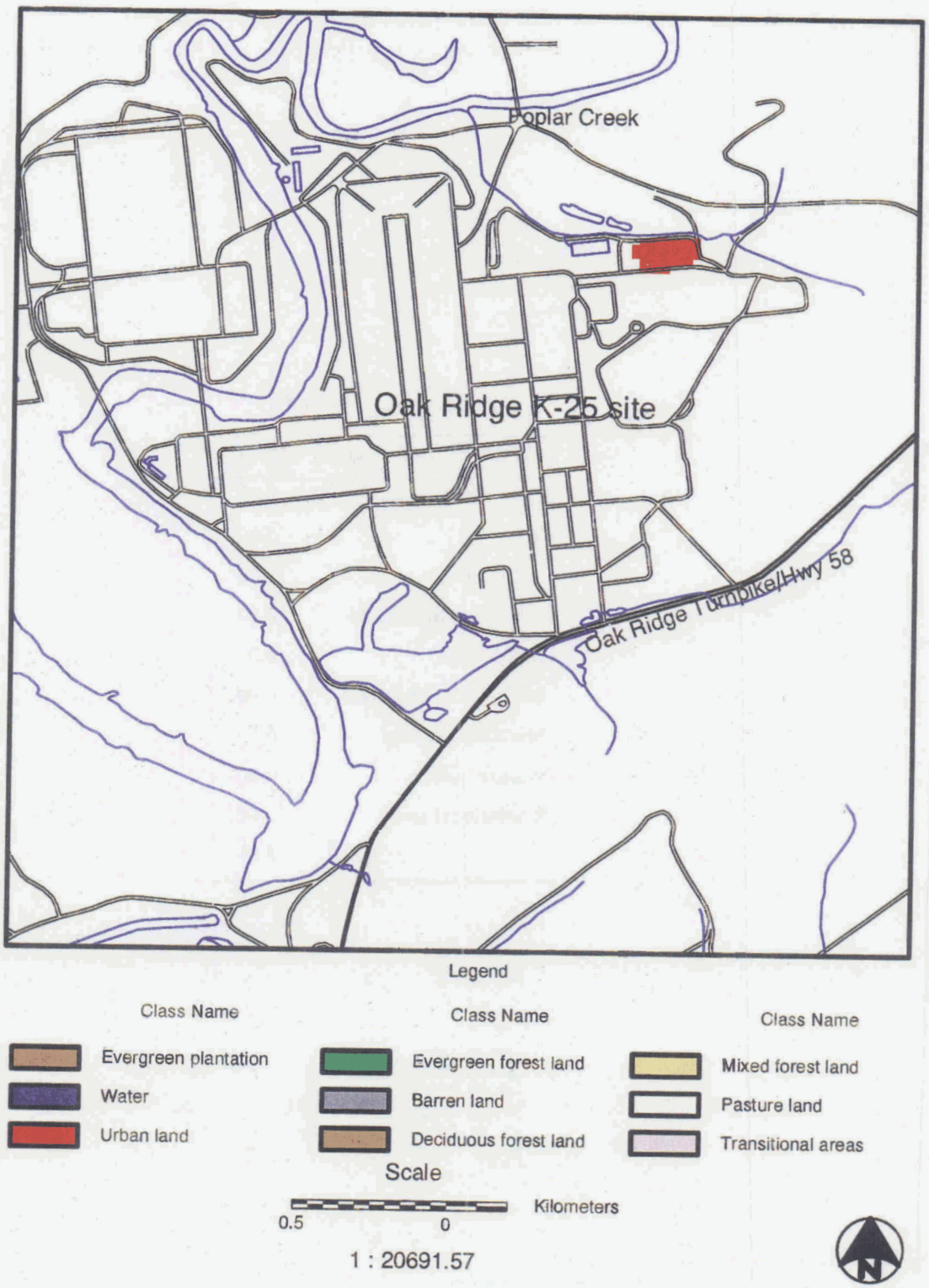


Fig. A.11. An April 13, 1994, classified Landsat 5 TM image of the K-1420 OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.11. K-1420 OU

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	2.31
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.00
Transitional areas	0.00
Total	2.31

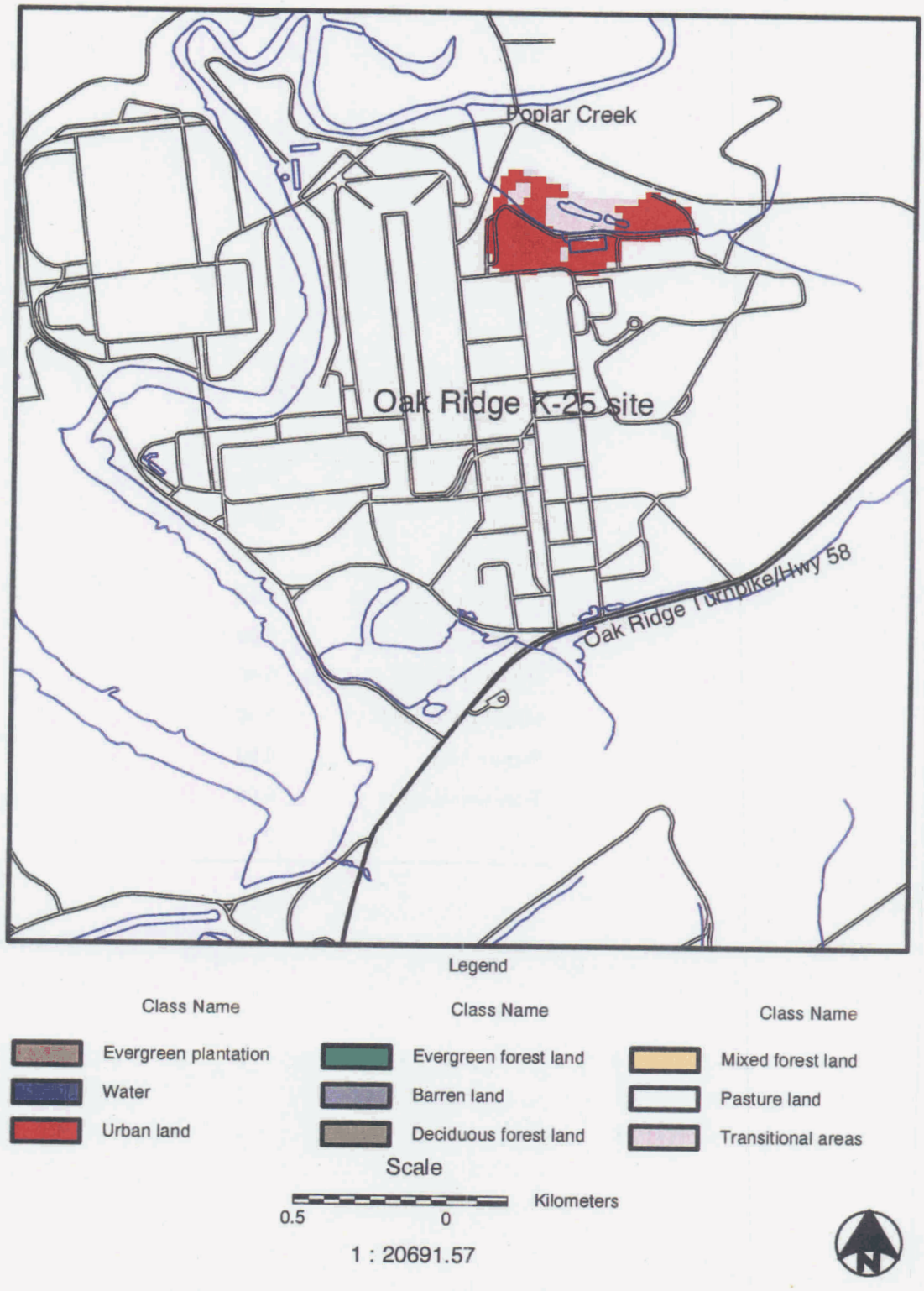


Fig. A.12. An April 13, 1994, classified Landsat 5 TM image of the K-1407 OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.12. K-1407 OU

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	12.31
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.00
Transitional areas	4.19
Total	16.50

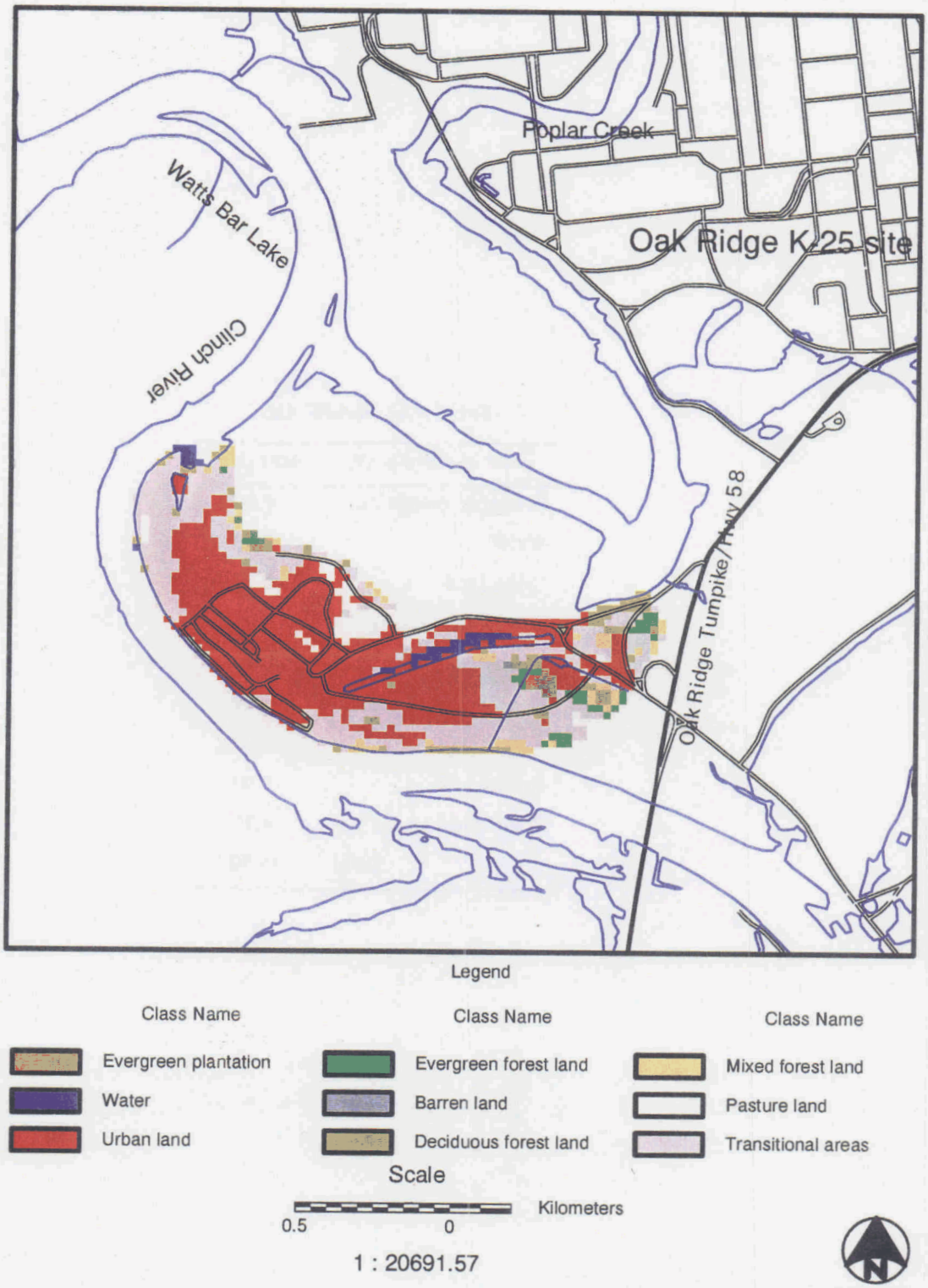


Fig. A.13. An April 13, 1994, classified Landsat 5 TM image of the K-770 OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.13. K-770 OU

Land use/land cover	Area (Ha)
Evergreen plantation	1.06
Water	2.00
Urban land	43.81
Evergreen forest land	2.37
Barren land	0.06
Deciduous forest land	4.37
Mixed forest land	3.12
Pasture land	4.19
Transitional areas	28.00
Total	88.98

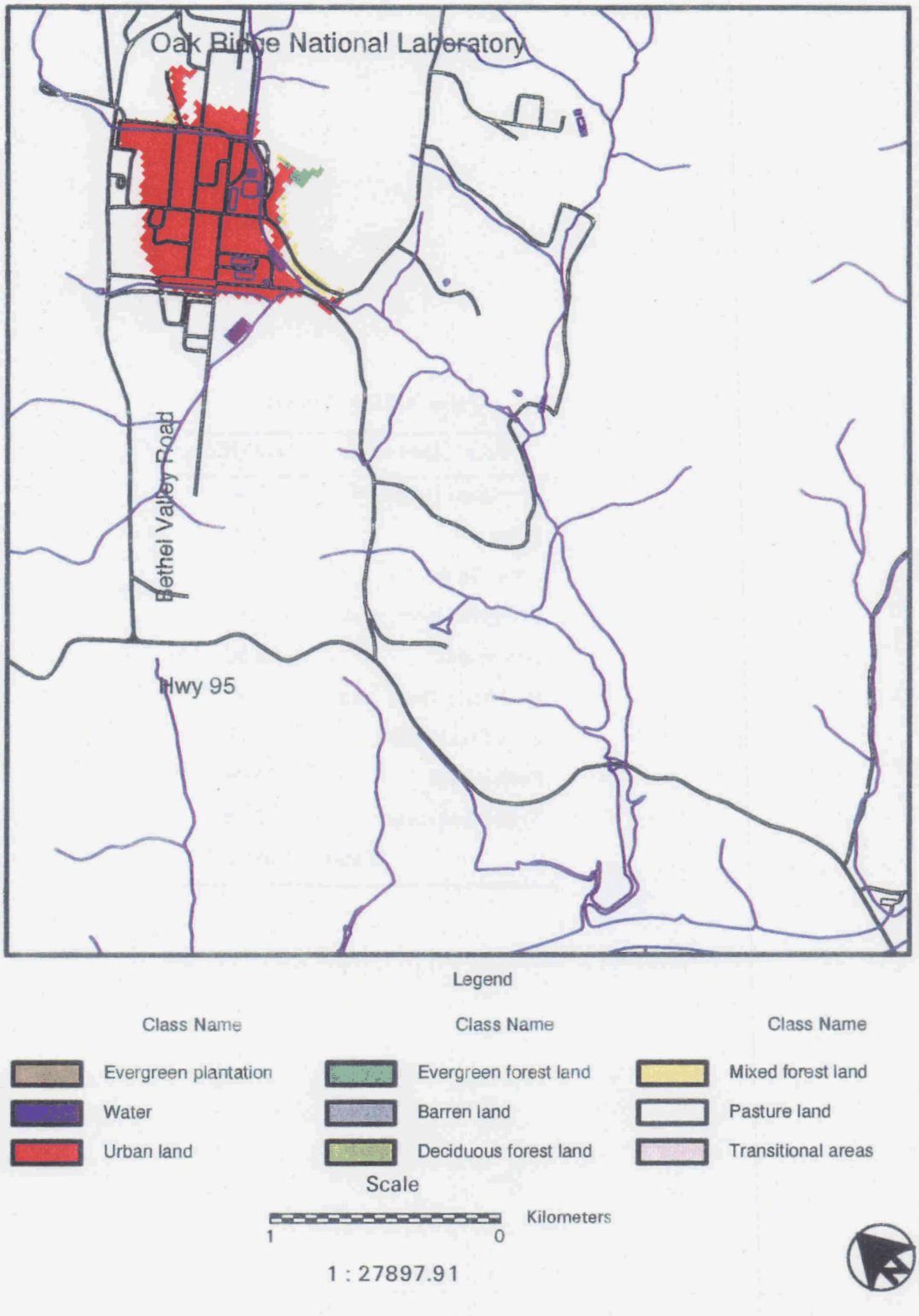


Fig. A.14. An April 13, 1994, classified Landsat 5 TM image of WAG 1. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.14. WAG 1

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	48.18
Evergreen forest land	0.81
Barren land	0.00
Deciduous forest land	1.25
Mixed forest land	0.81
Pasture land	0.94
Transitional areas	0.00
Total	51.99

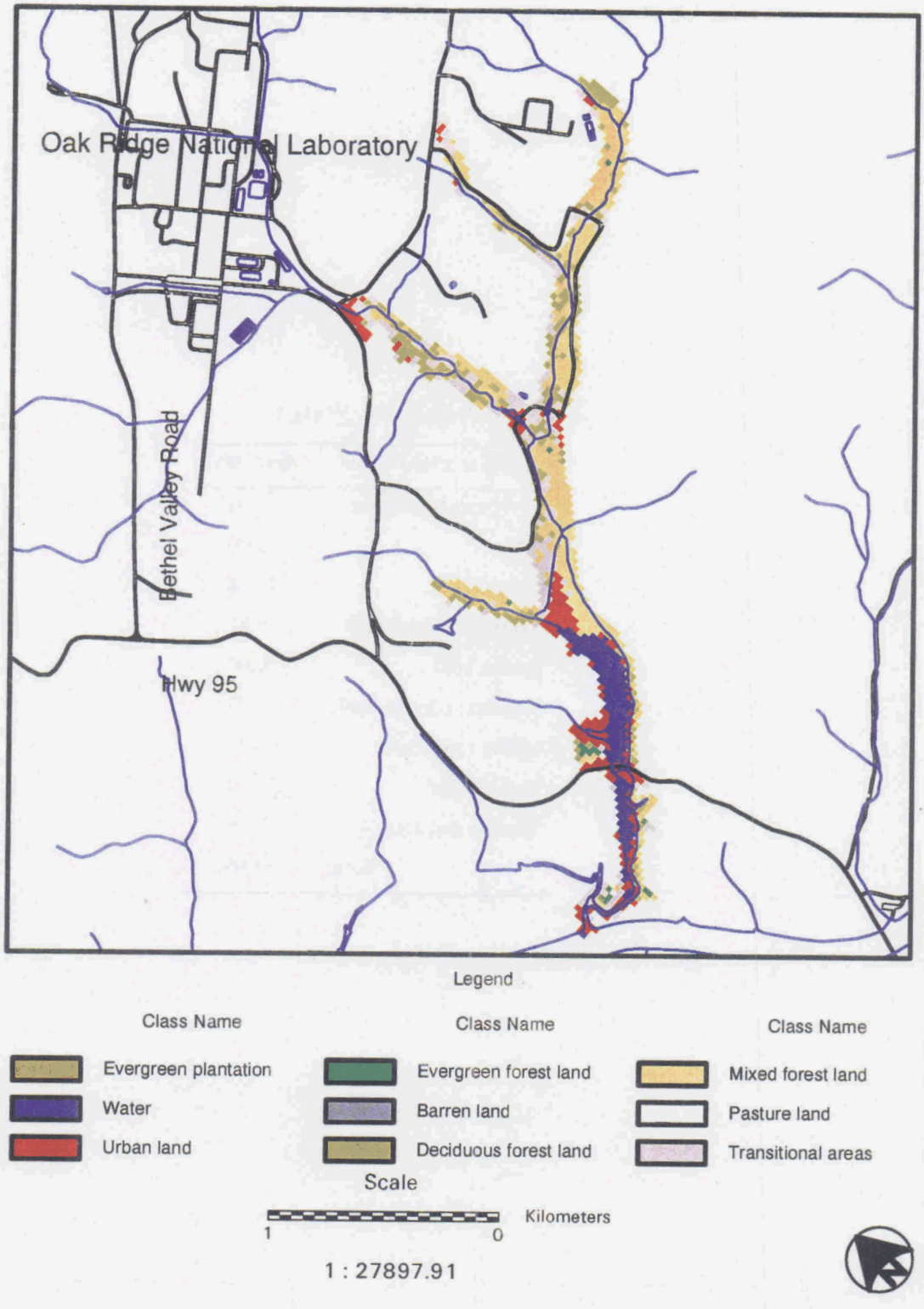


Fig. A.15. An April 13, 1994, classified Landsat 5 TM image of WAG 2. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.15. WAG 2

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	9.00
Urban land	13.00
Evergreen forest land	1.00
Barren land	0.00
Deciduous forest land	15.75
Mixed forest land	29.00
Pasture land	0.06
Transitional areas	14.81
Total	82.62

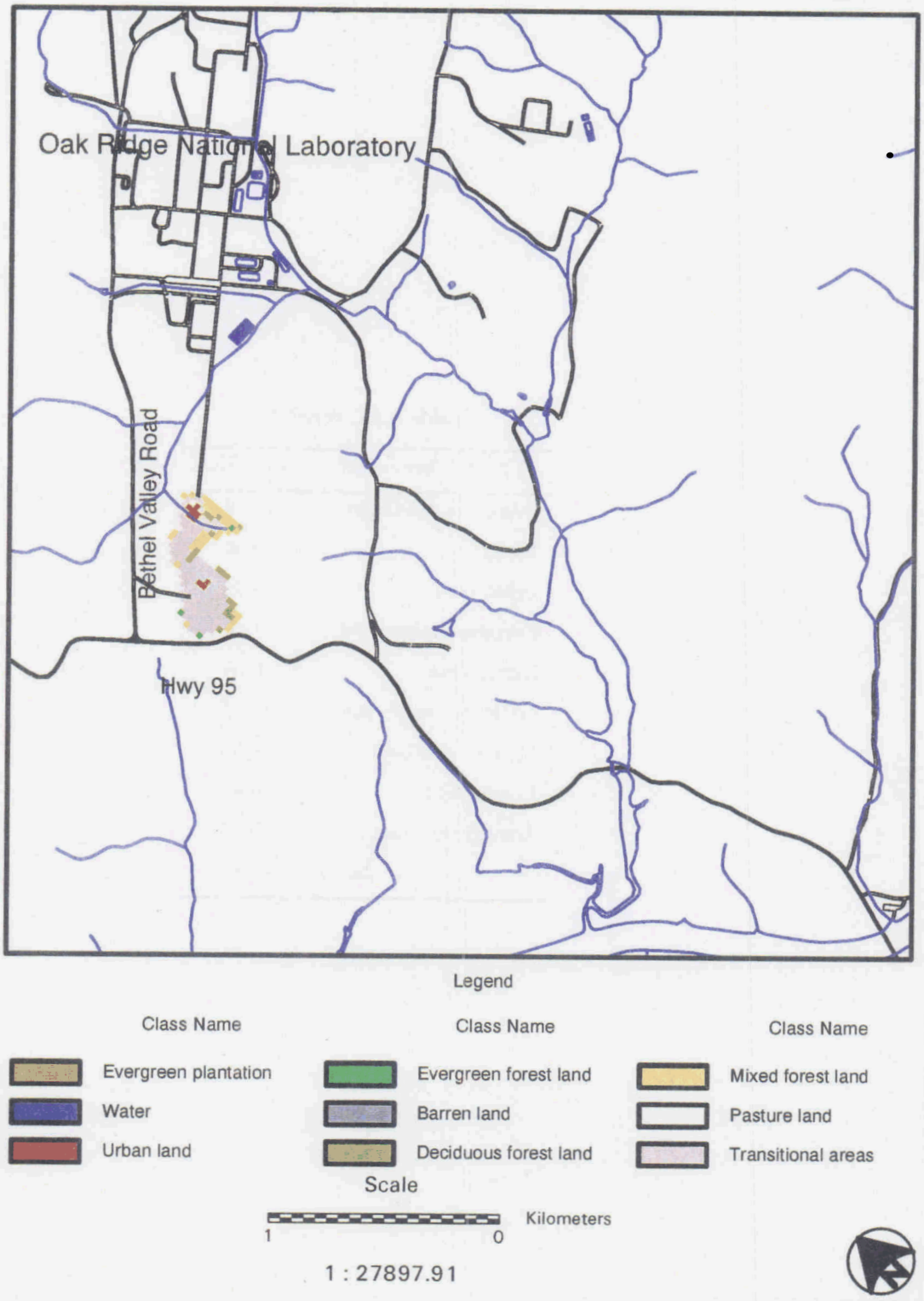


Fig. A.16. An April 13, 1994, classified Landsat 5 TM image of WAG 3. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.16. WAG 3

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	0.56
Evergreen forest land	0.19
Barren land	0.00
Deciduous forest land	1.06
Mixed forest land	2.19
Pasture land	0.06
Transitional areas	8.12
Total	12.18

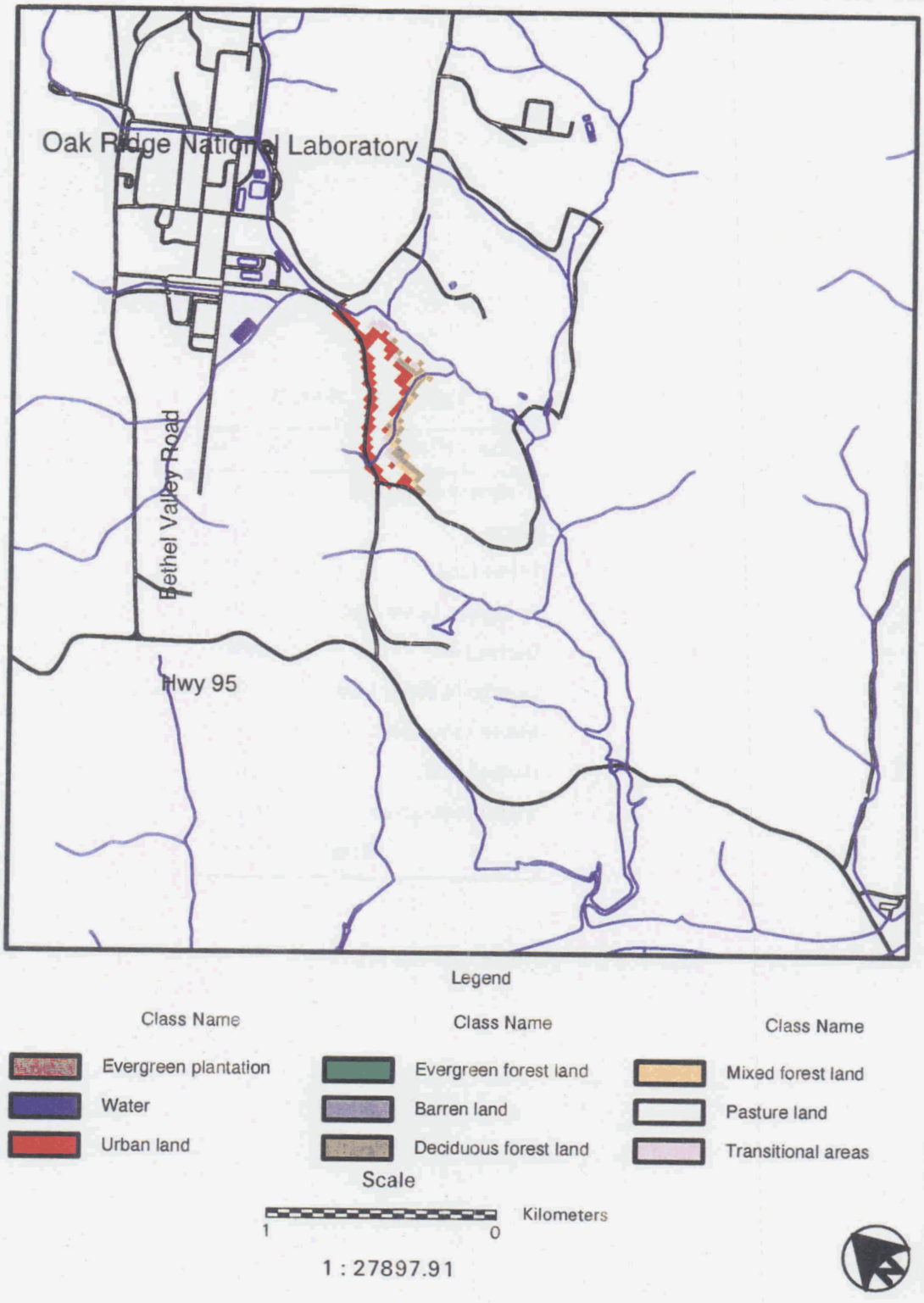


Fig. A.17. An April 13, 1994, classified Landsat 5 TM image of WAG 4. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.17. WAG 4

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	6.37
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	2.19
Mixed forest land	1.19
Pasture land	4.50
Transitional areas	1.06
Total	15.31

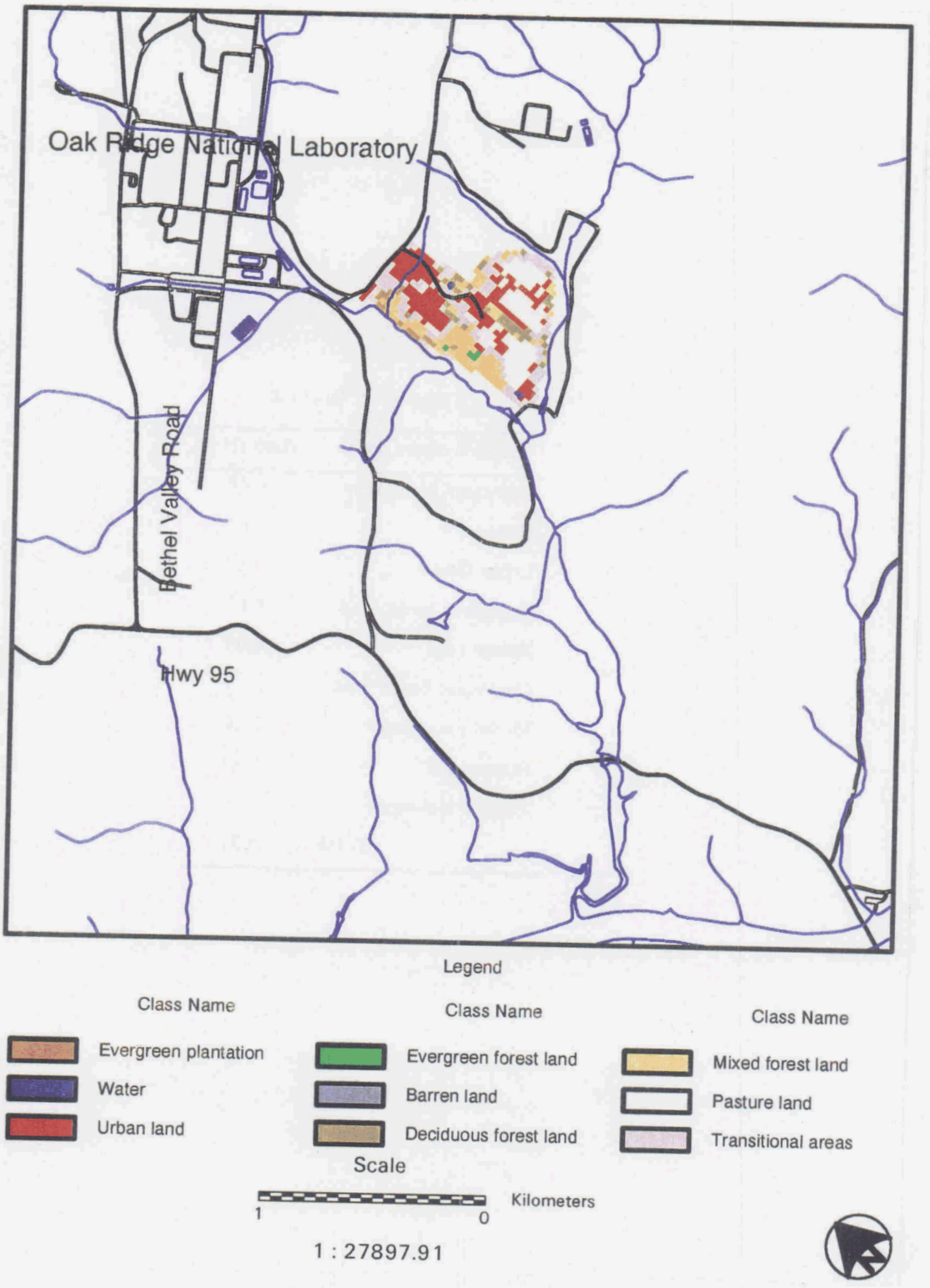


Fig. A.18. An April 13, 1994, classified Landsat 5 TM image of WAG 5. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.18. WAG 5

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	10.19
Evergreen forest land	0.25
Barren land	0.00
Deciduous forest land	3.56
Mixed forest land	6.44
Pasture land	7.69
Transitional areas	9.06
Total	37.19

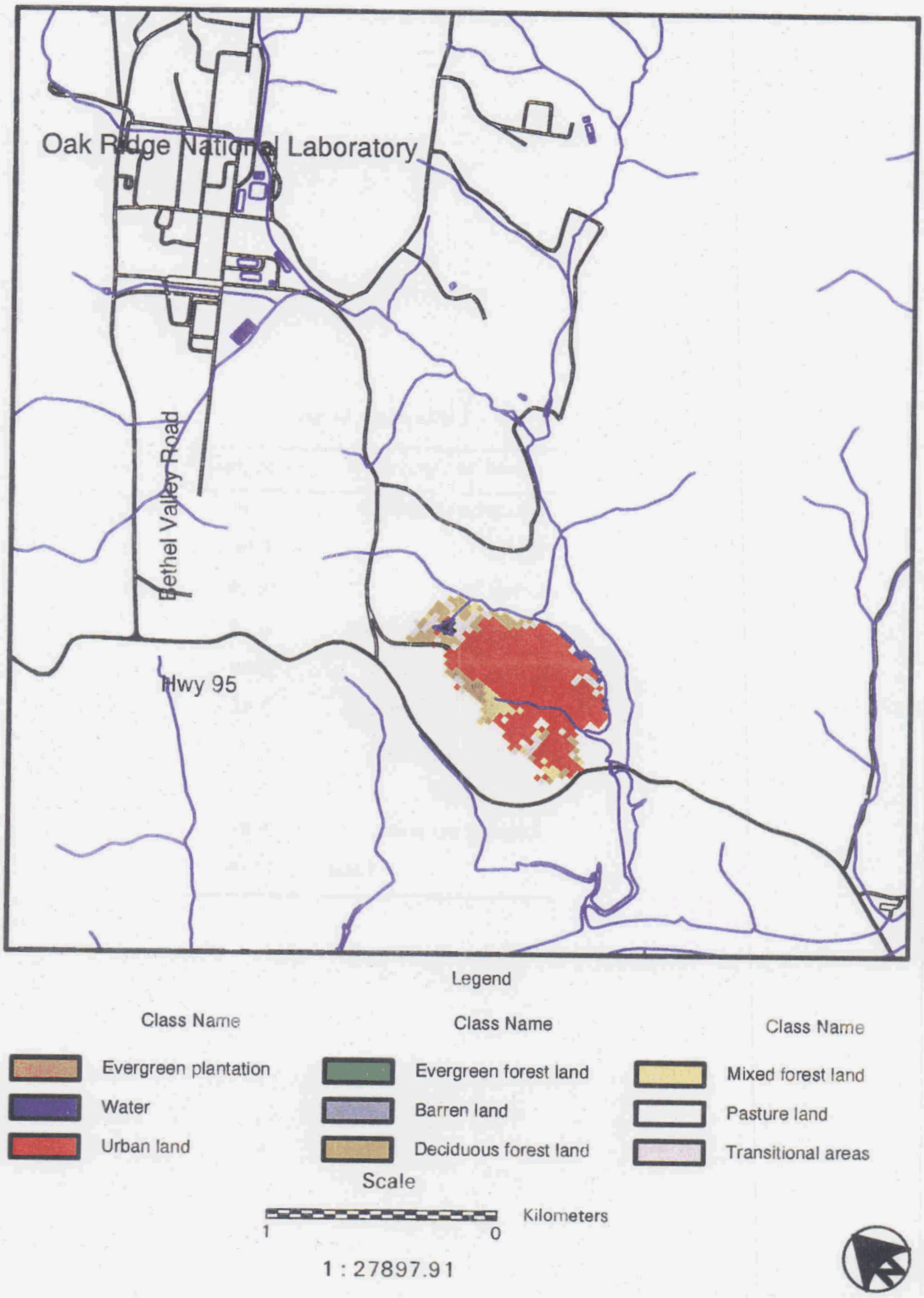


Fig. A.19. An April 13, 1994, classified Landsat 5 TM image of WAG 6. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.19. WAG 6

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.75
Urban land	25.50
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	5.06
Mixed forest land	2.06
Pasture land	0.50
Transitional areas	2.94
Total	36.81

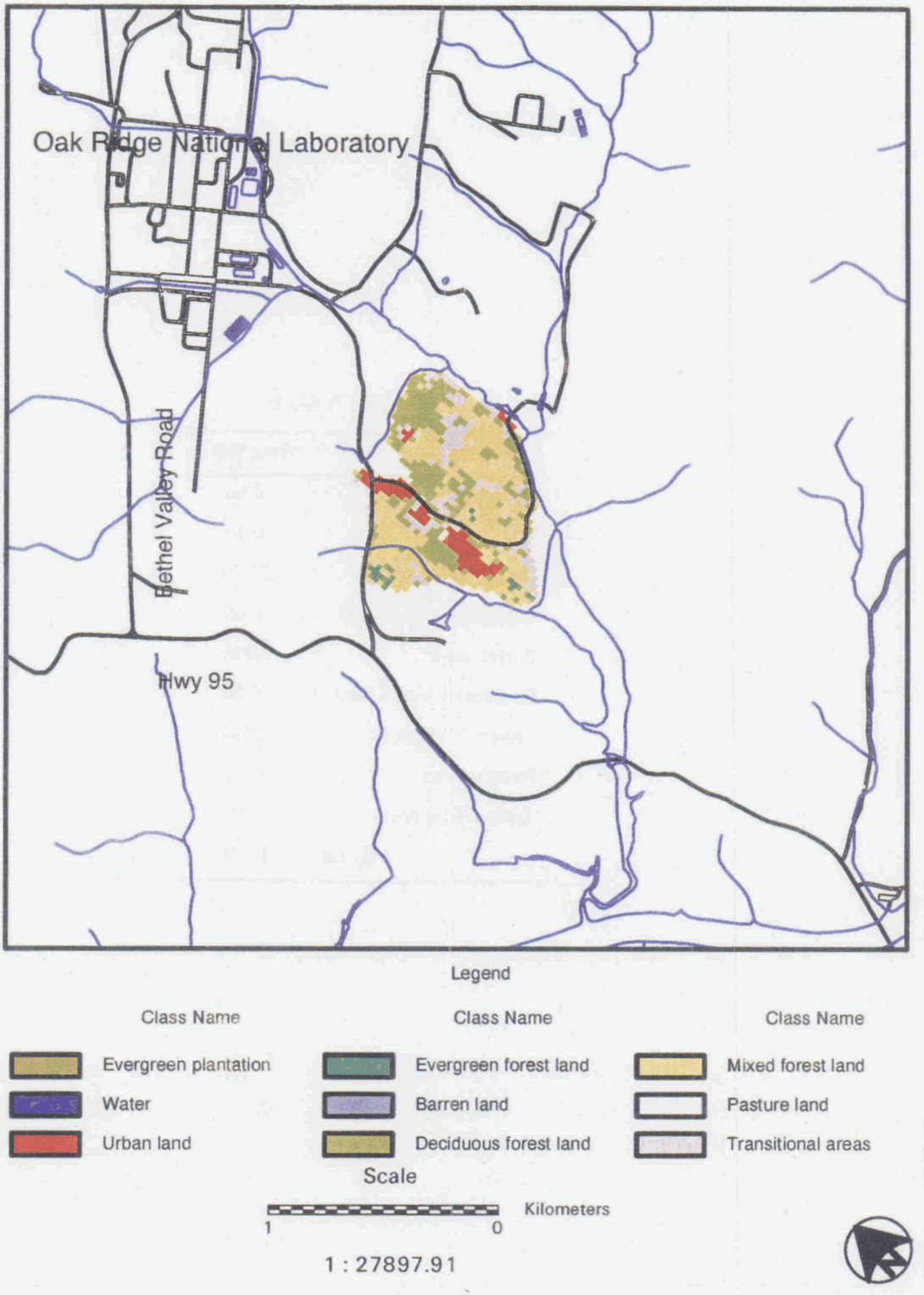


Fig. A.20. An April 13, 1994, classified Landsat 5 TM image of WAG 7. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.20. WAG 7

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	5.37
Evergreen forest land	1.44
Barren land	0.00
Deciduous forest land	17.25
Mixed forest land	25.31
Pasture land	0.12
Transitional areas	8.31
Total	57.80

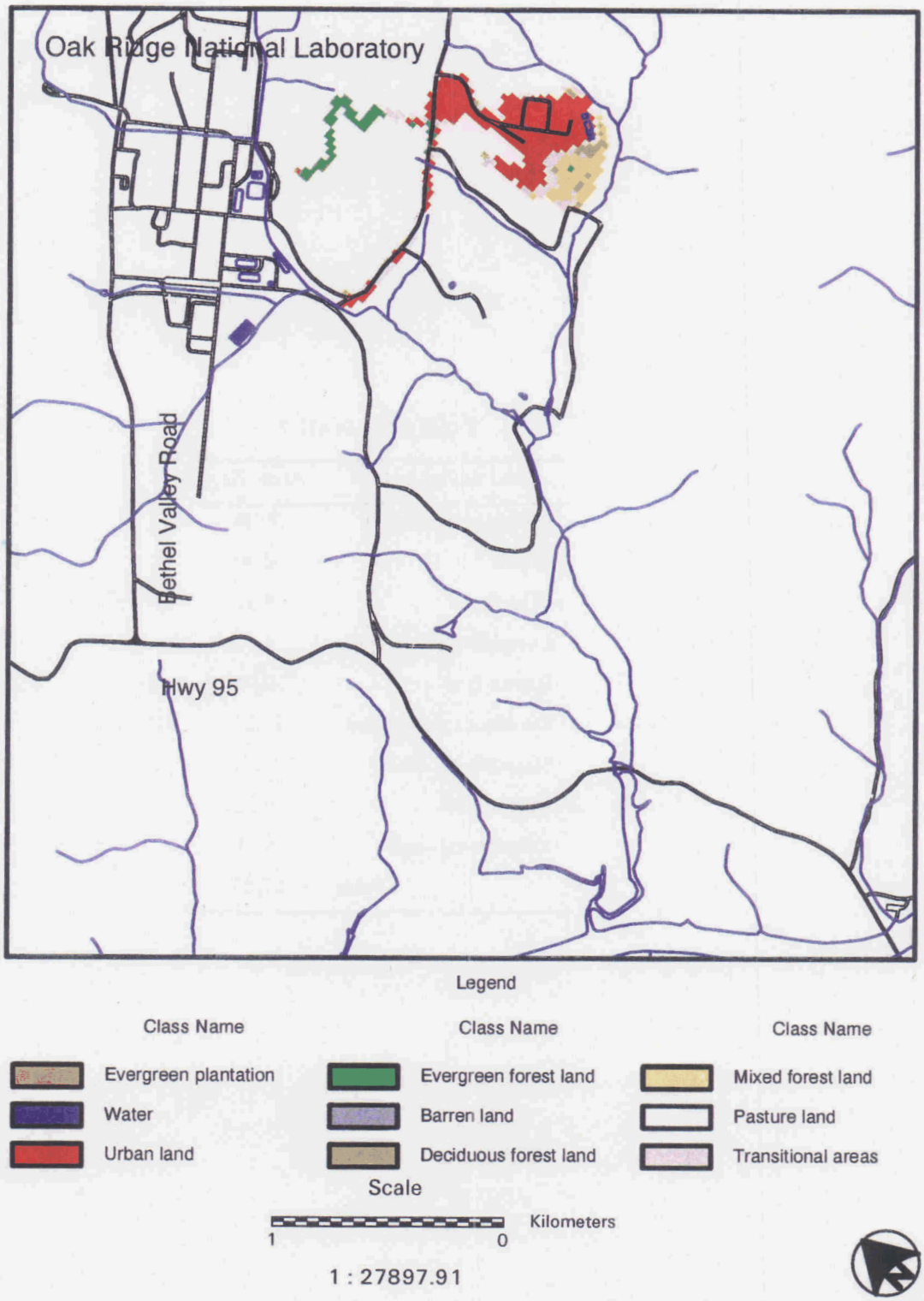


Fig. A.21. An April 13, 1994, classified Landsat 5 TM image of WAG 8. The map projection is TSP meters, Zone 5301, NAD 1983.

Table A.21. WAG 8

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	17.81
Evergreen forest land	3.44
Barren land	0.00
Deciduous forest land	1.44
Mixed forest land	3.75
Pasture land	0.00
Transitional areas	5.12
Total	31.56

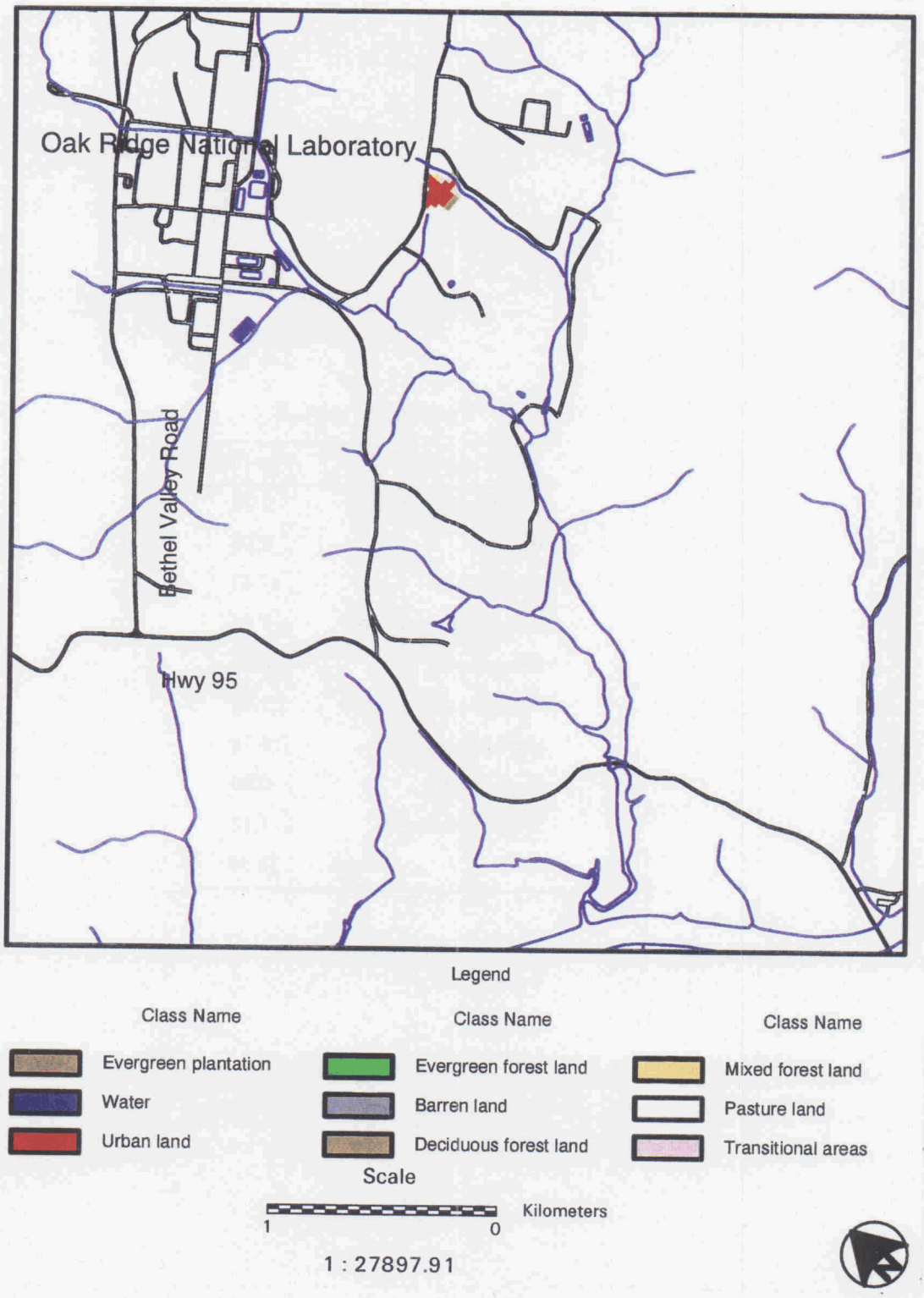


Fig. A.22. An April 13, 1994, classified Landsat 5 TM image of WAG 9. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.22. WAG 9

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	1.37
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.25
Mixed forest land	0.06
Pasture land	0.00
Transitional areas	0.31
Total	1.99

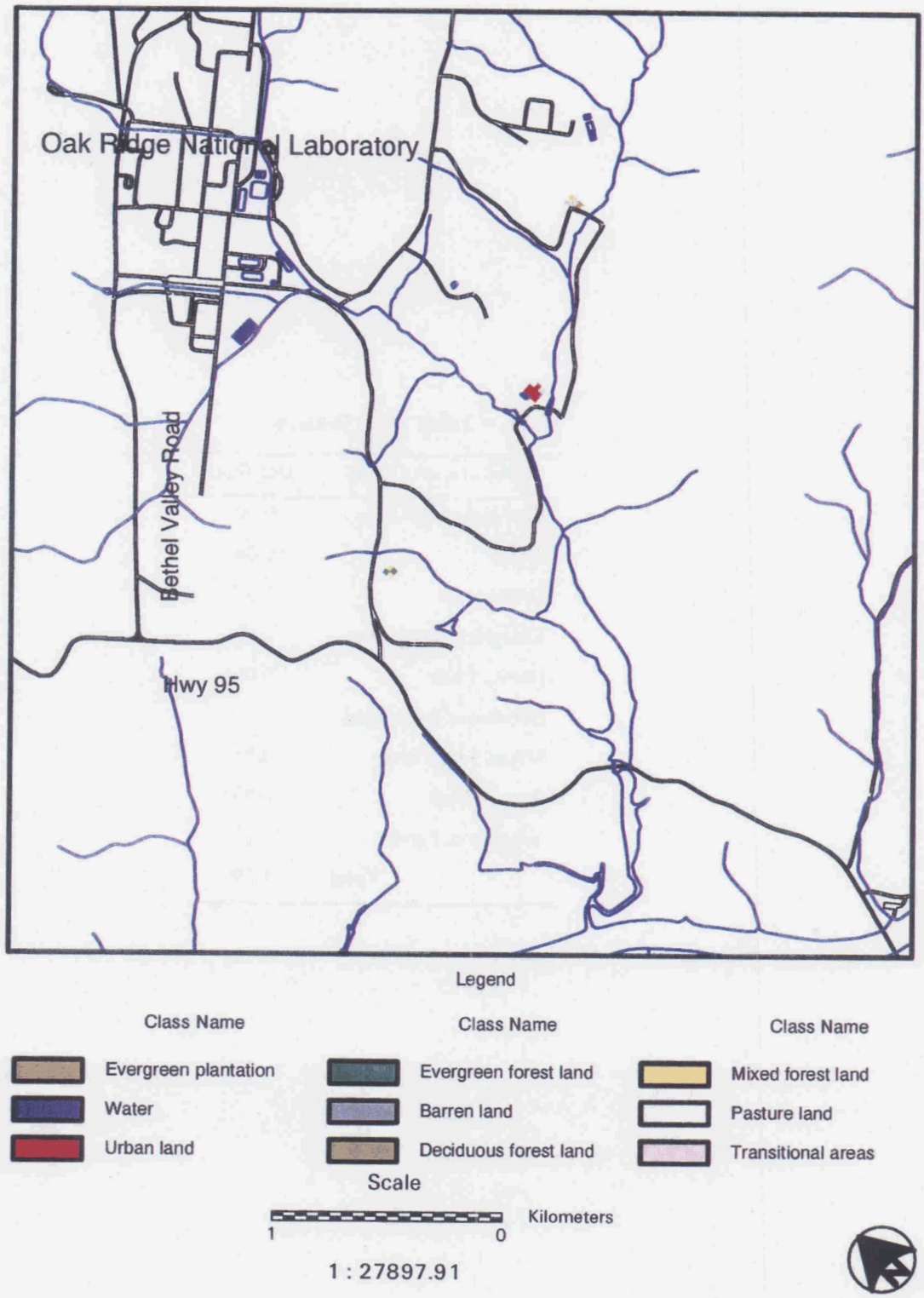


Fig. A.23. An April 13, 1994, classified Landsat 5 TM image of WAG 10. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.23. WAG 10

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	0.50
Evergreen forest land	0.12
Barren land	0.00
Deciduous forest land	0.06
Mixed forest land	0.19
Pasture land	0.00
Transitional areas	0.25
Total	1.12

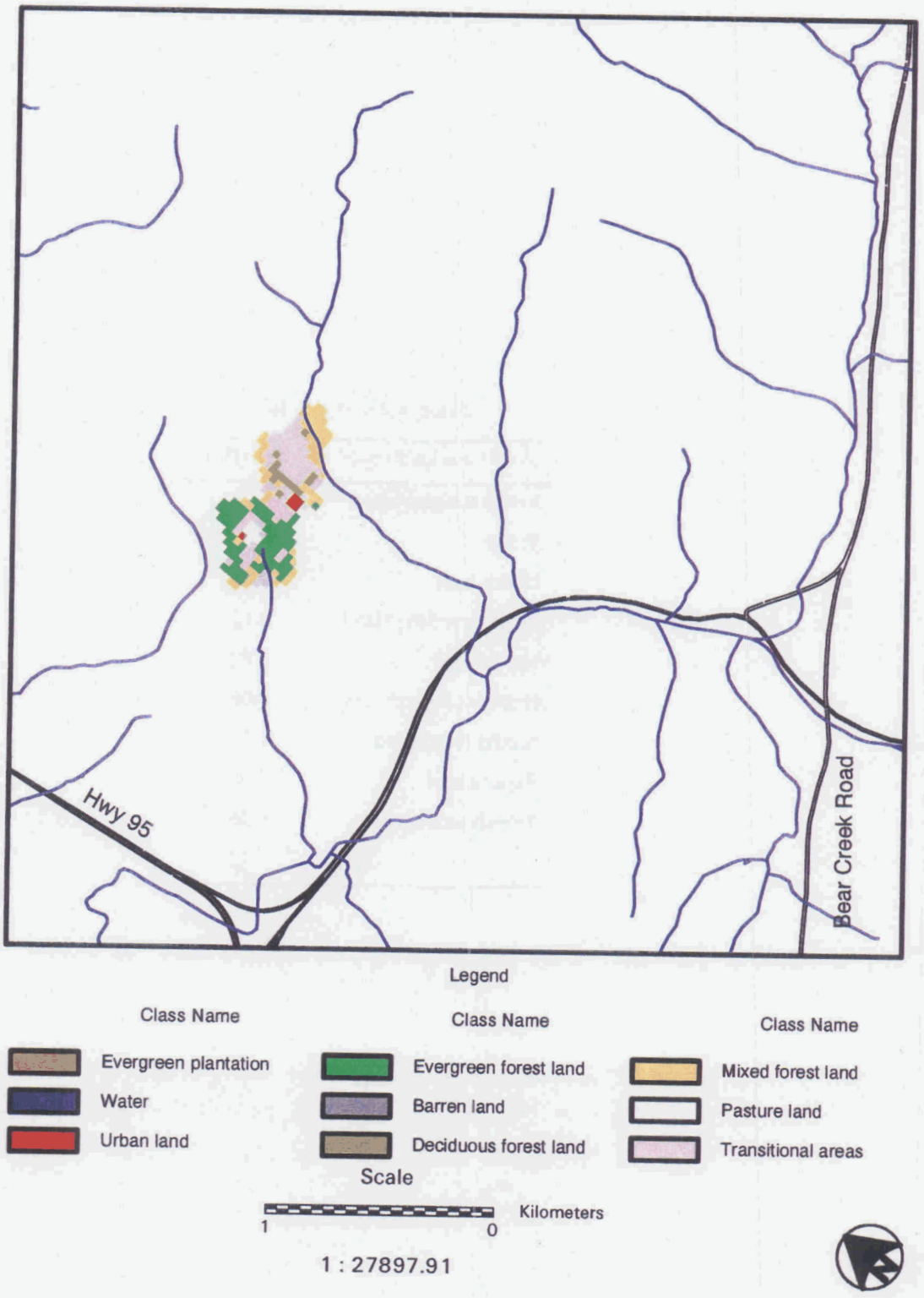


Fig. A.24. An April 13, 1994, classified Landsat 5 TM image of WAG 11. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.24. WAG 11

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	0.31
Evergreen forest land	4.56
Barren land	0.00
Deciduous forest land	0.81
Mixed forest land	3.81
Pasture land	0.37
Transitional areas	5.12
Total	14.98

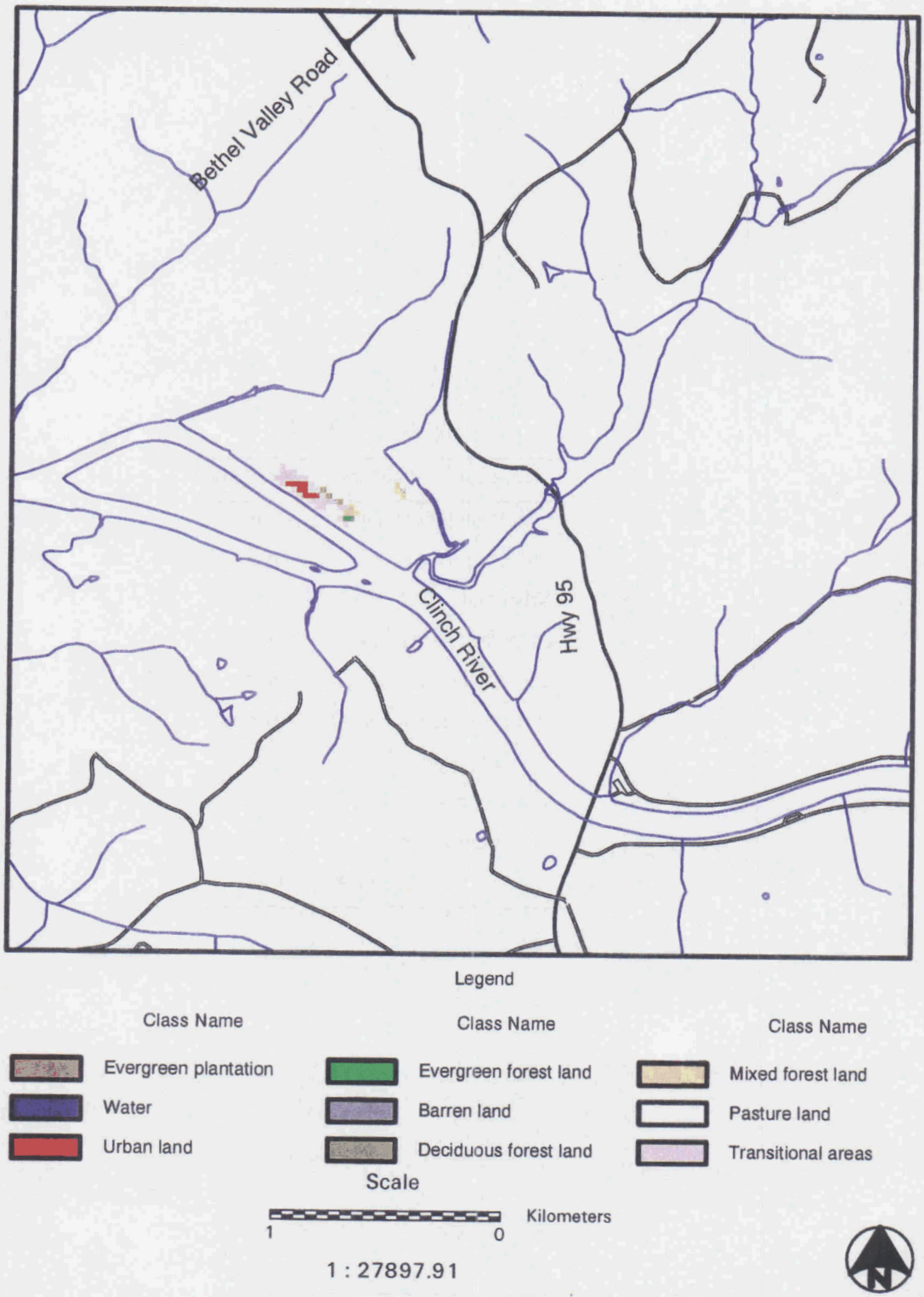


Fig. A.25. An April 13, 1994, classified Landsat 5 TM image of WAG 13. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.25. WAG 13

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	0.56
Evergreen forest land	0.12
Barren land	0.00
Deciduous forest land	0.18
Mixed forest land	0.44
Pasture land	0.37
Transitional areas	1.81
Total	3.48

Fig. A.26. An April 13, 1994, classified Landsat 5 TM image of the Bear Creek (BC) OU. The map projection is TSP meters, Zone 5301, and NAD 1993.

Table A.26. BC OU

Land use/land cover	Area (Ha)
Evergreen plantation	20.94
Water	0.00
Urban land	85.37
Evergreen forest land	37.37
Barren land	0.44
Deciduous forest land	192.81
Mixed forest land	140.56
Pasture land	14.62
Transitional areas	246.06
Total	738.17

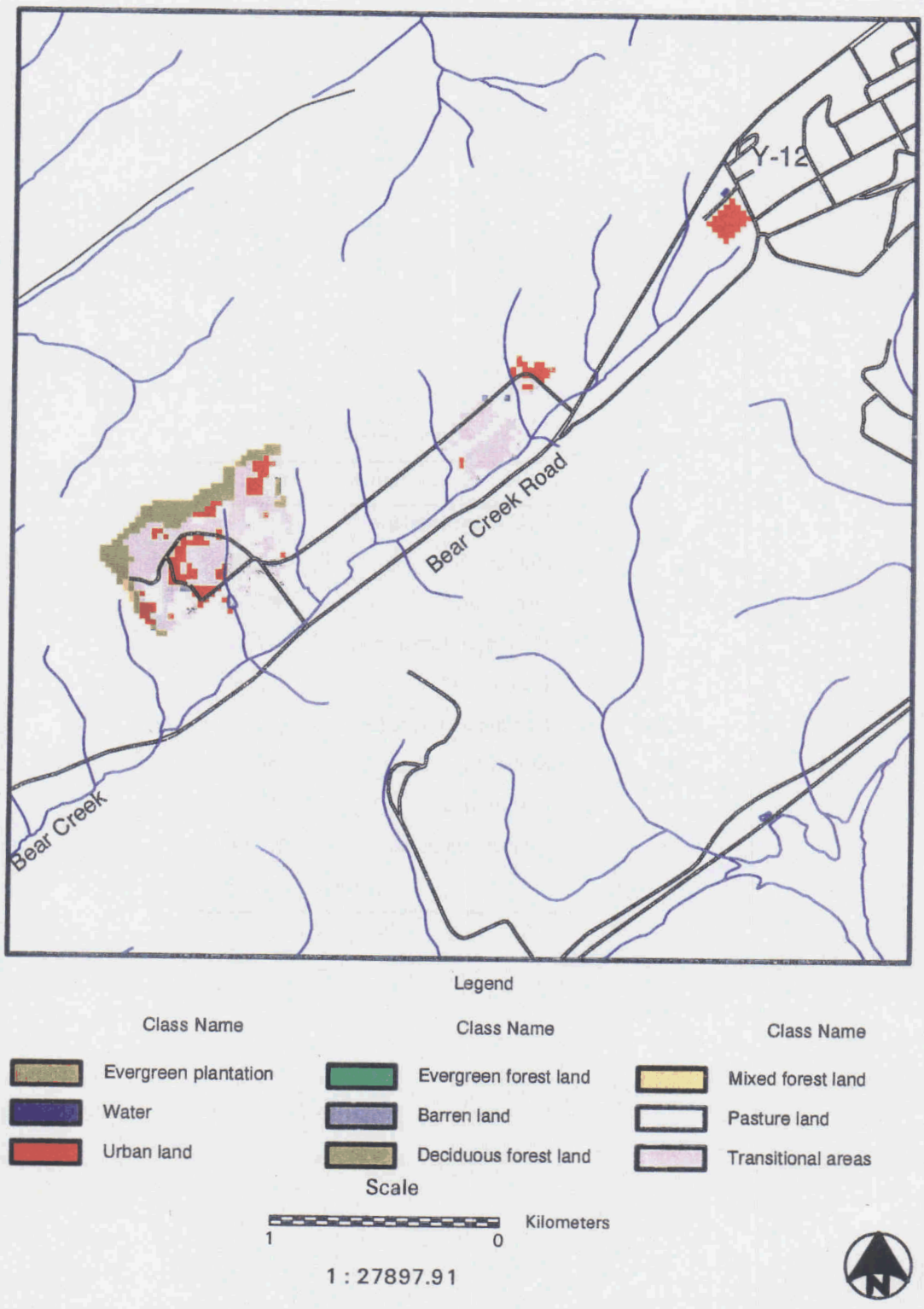


Fig. A.27. An April 13, 1994, classified Landsat 5 TM image of BC OU 1. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.27. BC OU 1

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	9.50
Evergreen forest land	0.00
Barren land	0.25
Deciduous forest land	8.19
Mixed forest land	0.25
Pasture land	9.19
Transitional areas	24.00
Total	51.38

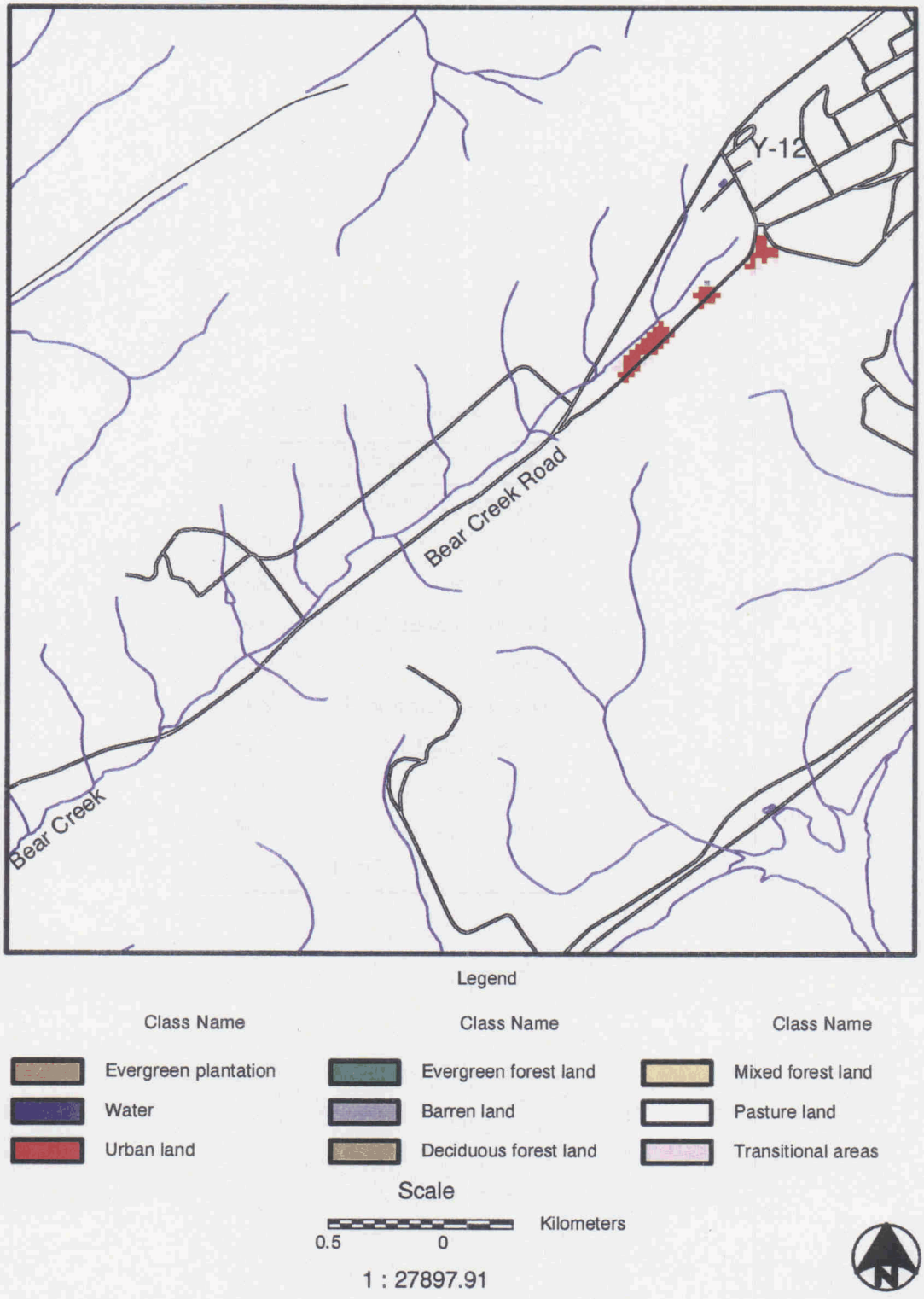


Fig. A.28. An April 13, 1994, classified Landsat 5 TM image of BC OU 2. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.28. BC OU 2

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	4.12
Evergreen forest land	0.00
Barren land	0.06
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.00
Transitional areas	0.62
Total	4.80

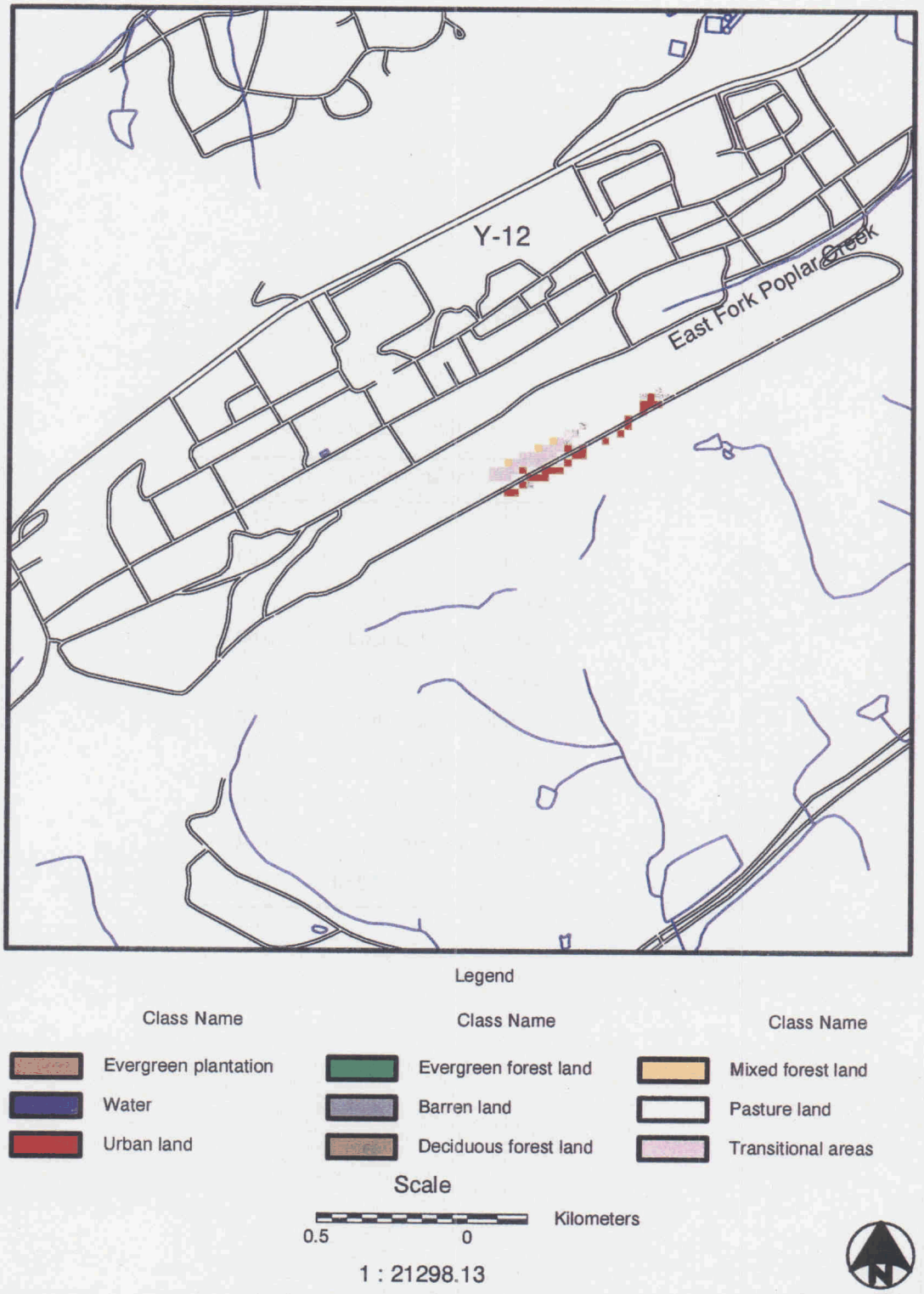


Fig. A.29. An April 13, 1994, classified Landsat 5 TM image of Chestnut Ridge (CR) OU 1. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.29. CR OU 1

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	1.50
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.00
Mixed forest land	0.19
Pasture land	2.50
Transitional areas	2.06
Total	6.25

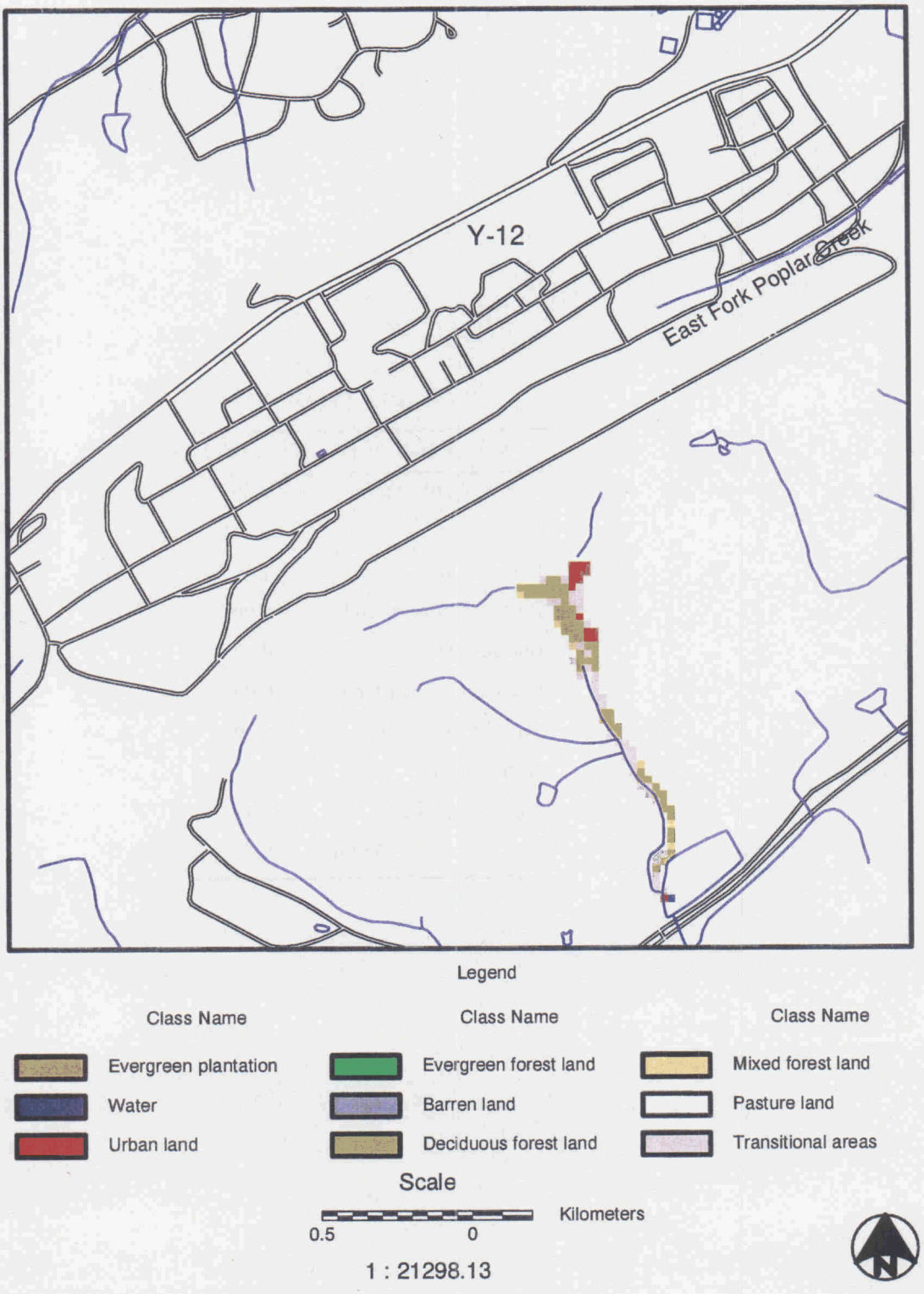


Fig. A.30. An April 13, 1994, classified Landsat 5 TM image of CR OU 2. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.30. CR OU 2

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.06
Urban land	0.94
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	3.81
Mixed forest land	0.38
Pasture land	0.00
Transitional areas	2.62
Total	7.81

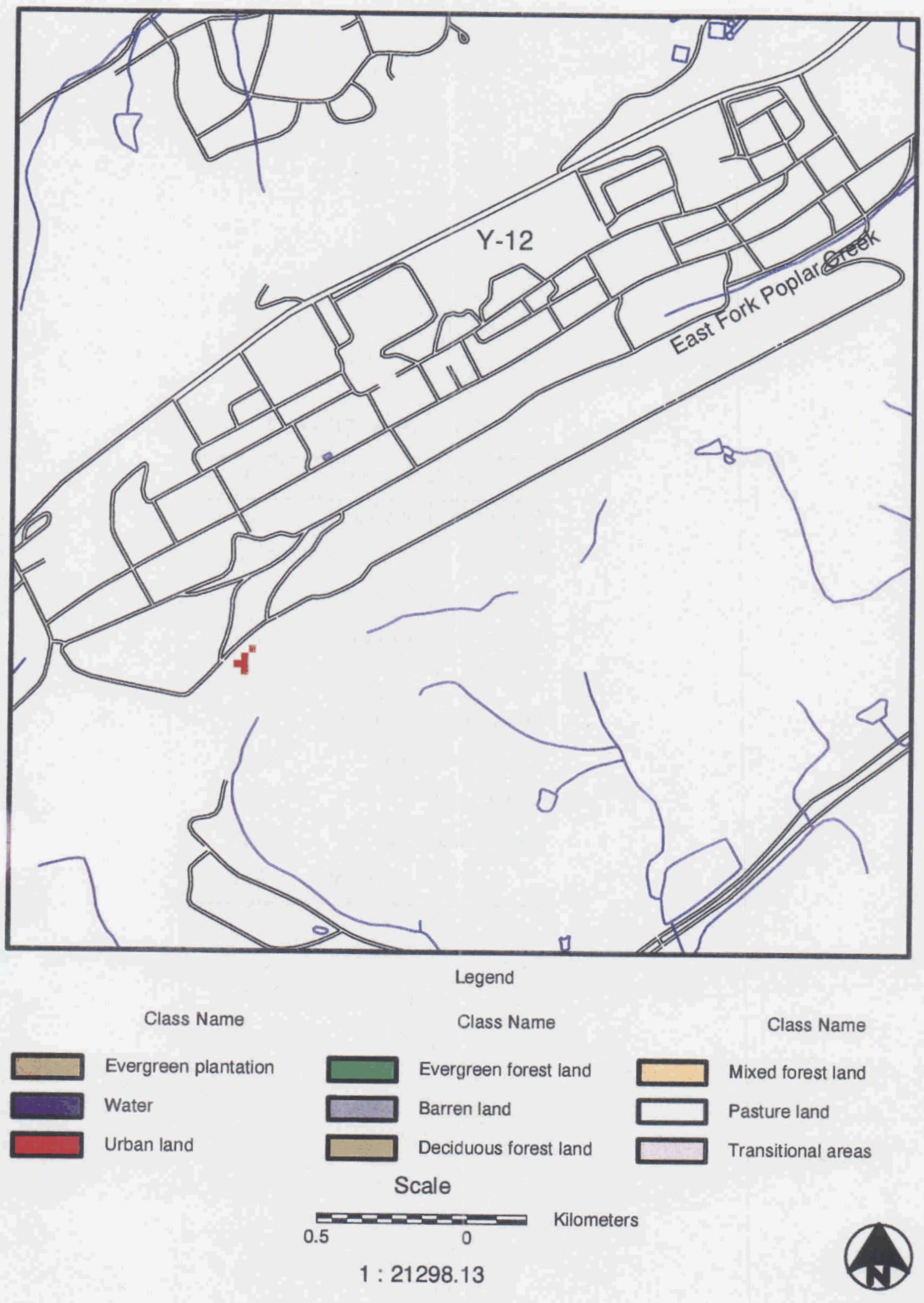


Fig. A.31. An April 13, 1994, classified Landsat 5 TM image of CR OU 3. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.31. CR OU 3

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	0.31
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.19
Transitional areas	0.00
Total	0.50

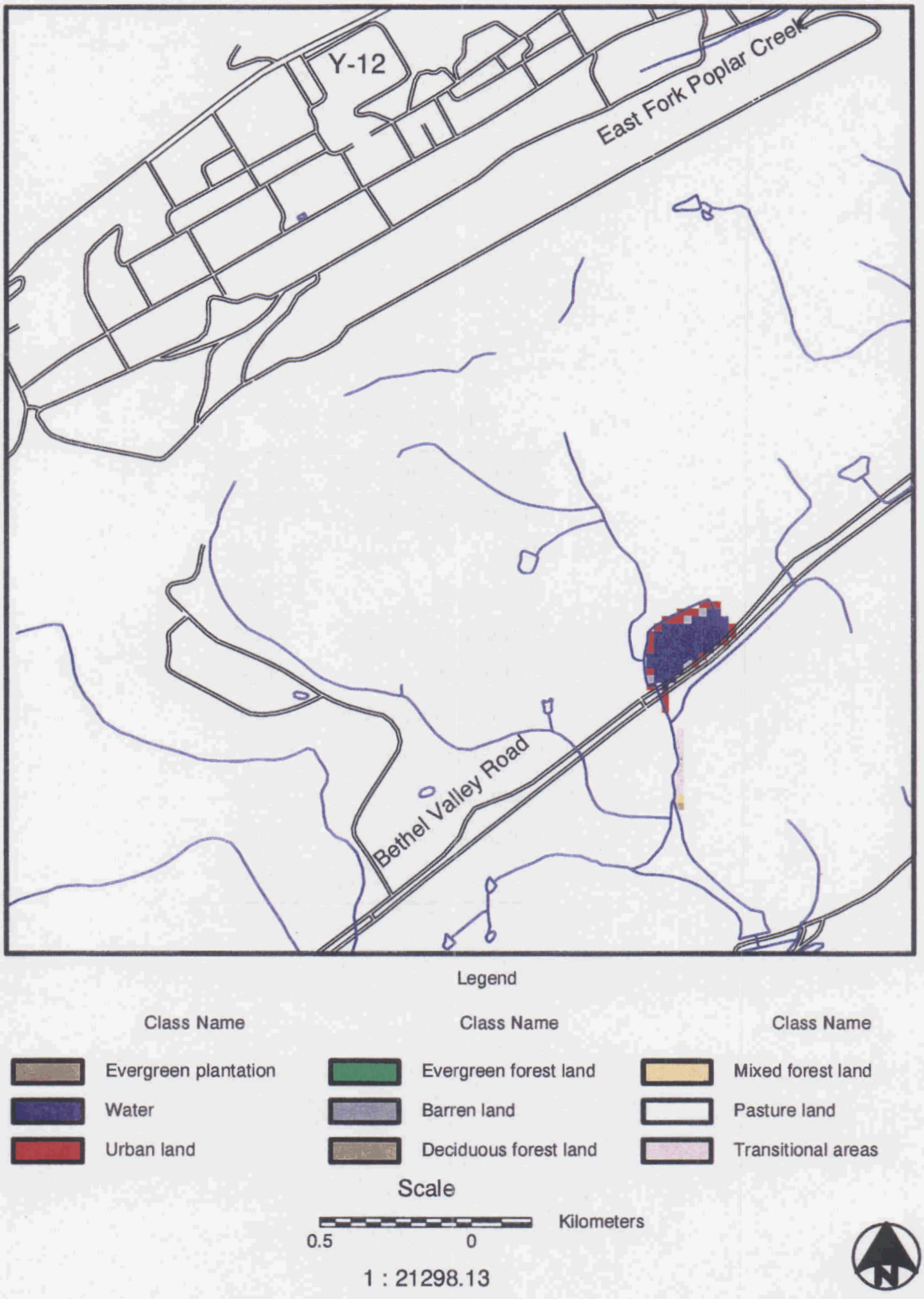


Fig. A.32. An April 13, 1994, classified Landsat 5 TM image of CR OU 4. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.32. CR OU 4

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	3.94
Urban land	1.44
Evergreen forest land	0.00
Barren land	0.31
Deciduous forest land	0.06
Mixed forest land	0.06
Pasture land	0.19
Transitional areas	0.56
Total	6.56

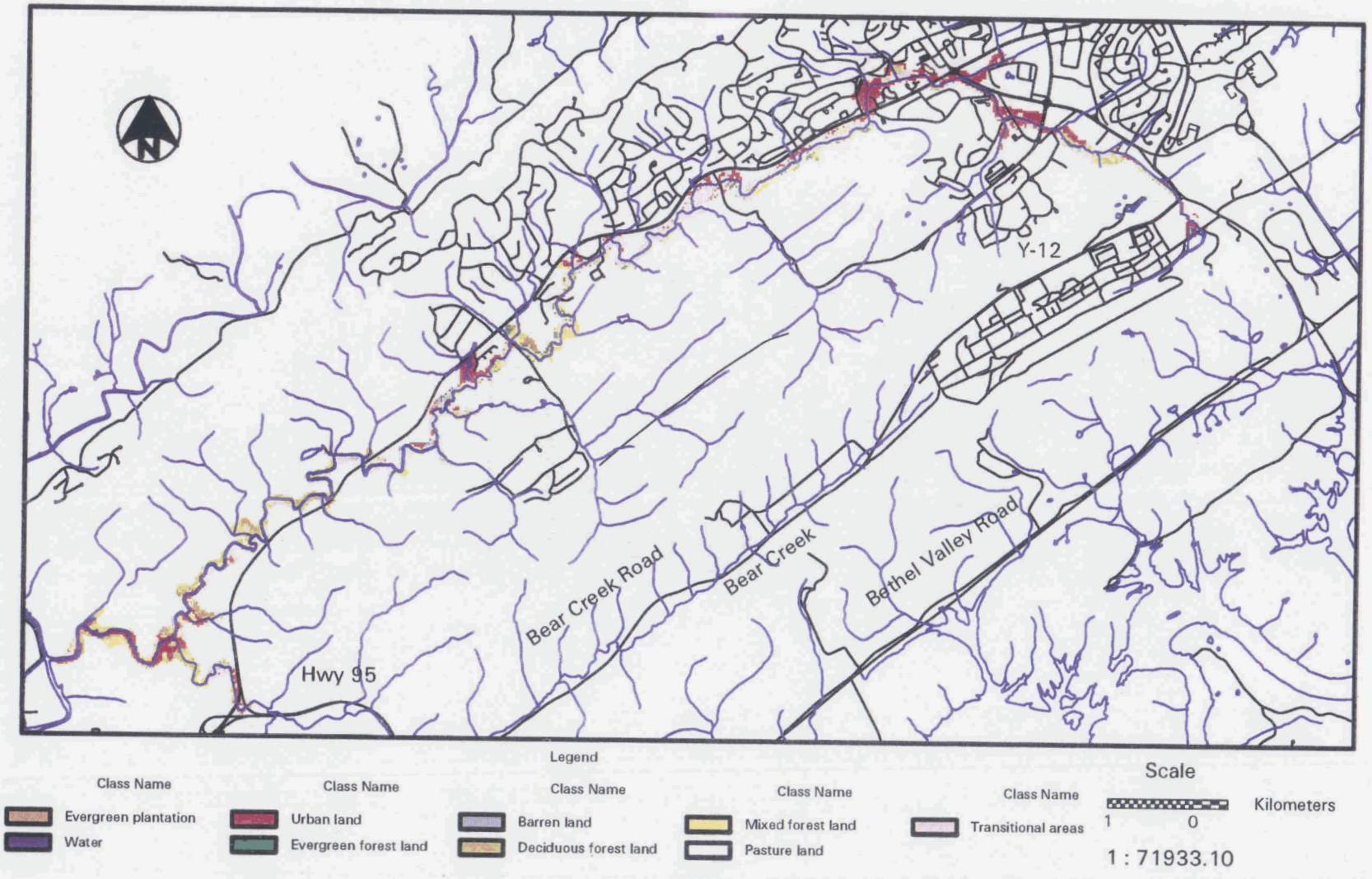


Fig. A.33. An April 13, 1994, classified Landsat 5 TM image of Lower East Fork Poplar Creek OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.33. Lower East Fork Poplar Creek OU

Land use/land cover	Area (Ha)
Evergreen plantation	2.62
Water	0.19
Urban land	99.81
Evergreen forest land	7.37
Barren land	2.00
Deciduous forest land	41.06
Mixed forest land	50.87
Pasture land	8.50
Transitional areas	133.87
Total	344.29

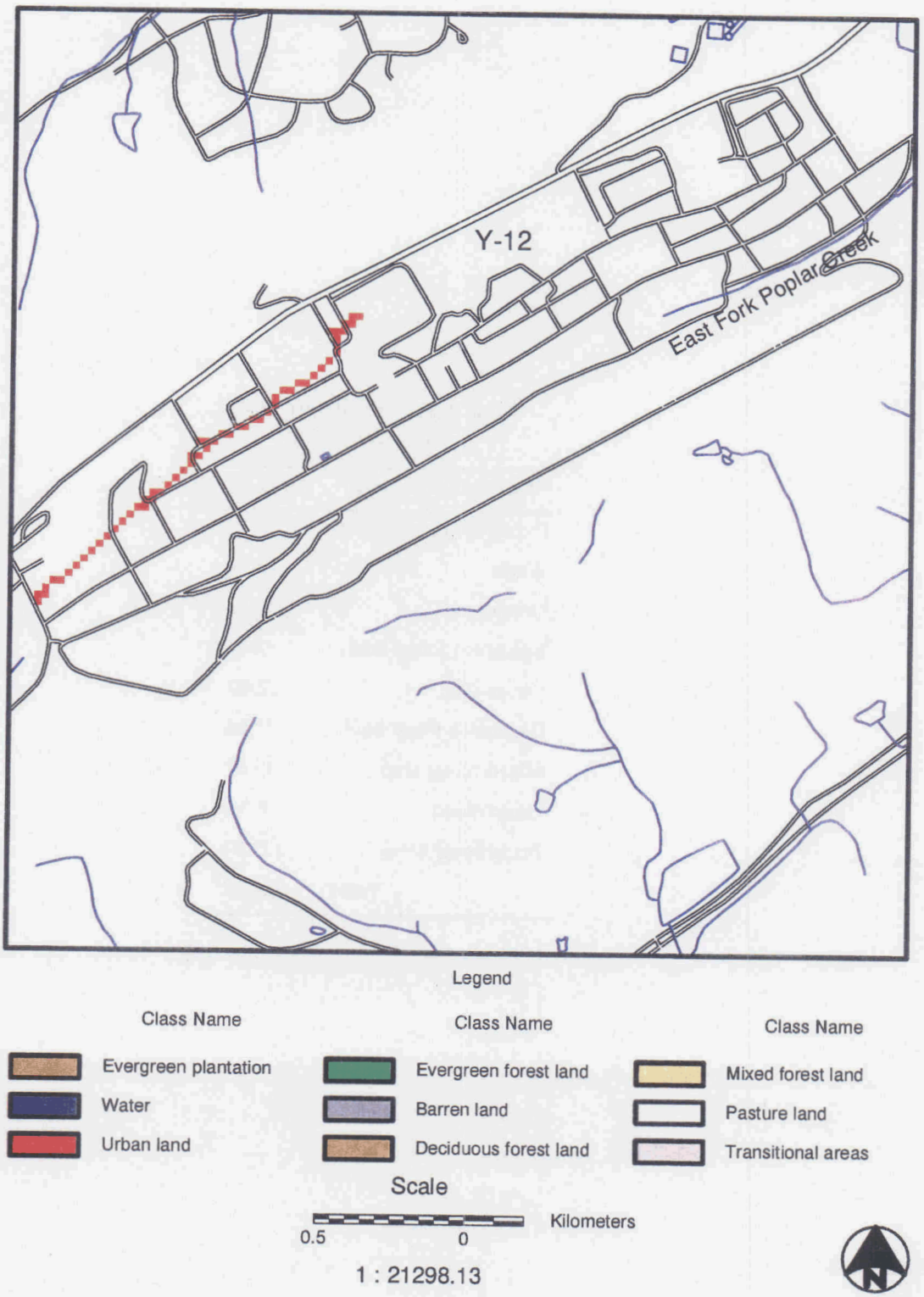


Fig. A.34. An April 13, 1994, classified Landsat 5 TM image of Upper East Fork Poplar Creek (UEFPC) OU 2. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table. A.34. UEFPC OU 2

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	3.56
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.00
Transitional areas	0.00
Total	3.56

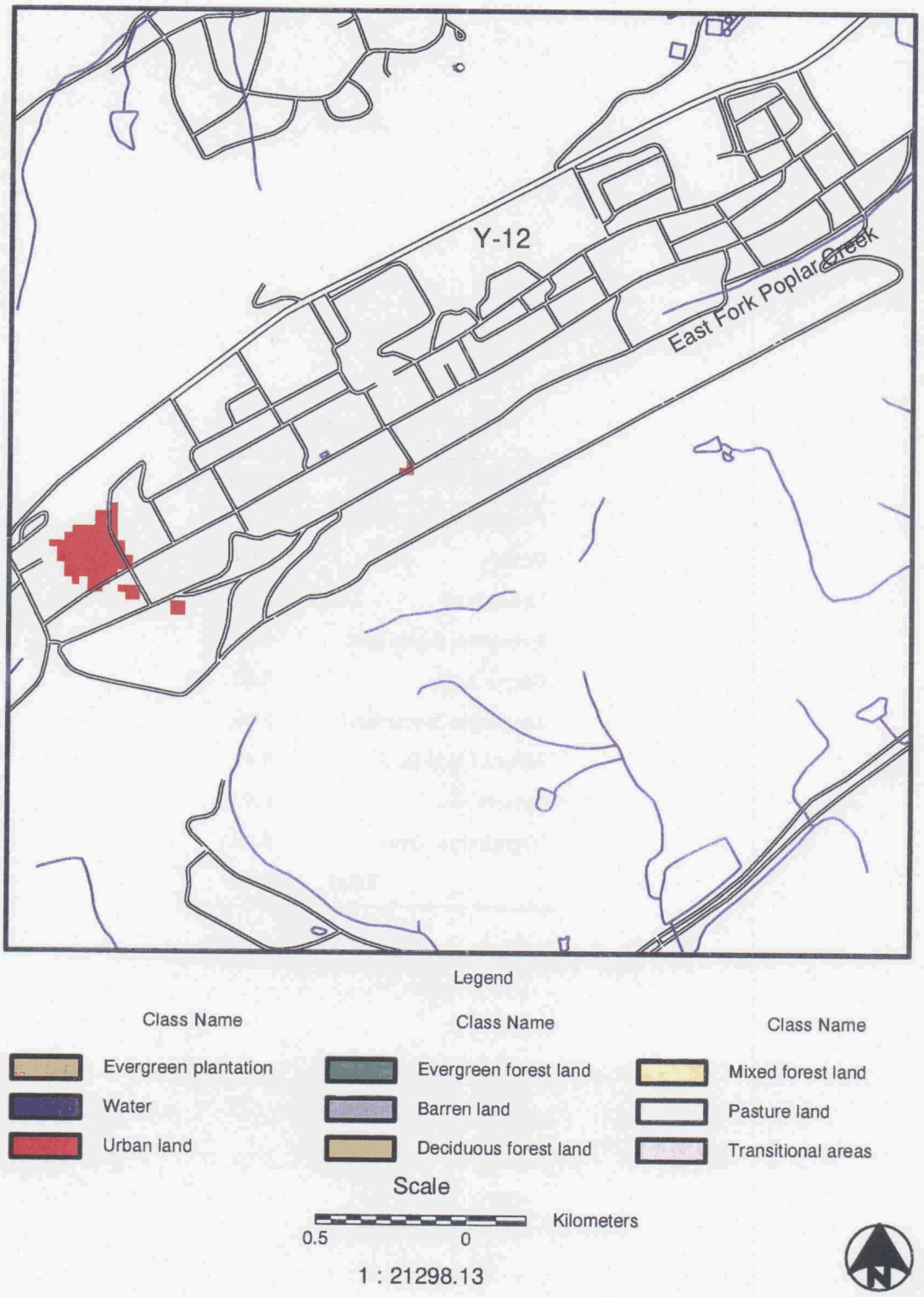


Fig. A.35. An April 13, 1994, classified Landsat 5 TM image of UEFPC OU 3. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.35. UEFPC OU 3

Land use/land cover	Area (Ha)
Evergreen plantation	0.00
Water	0.00
Urban land	5.19
Evergreen forest land	0.00
Barren land	0.00
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	0.00
Transitional areas	0.00
Total	5.19

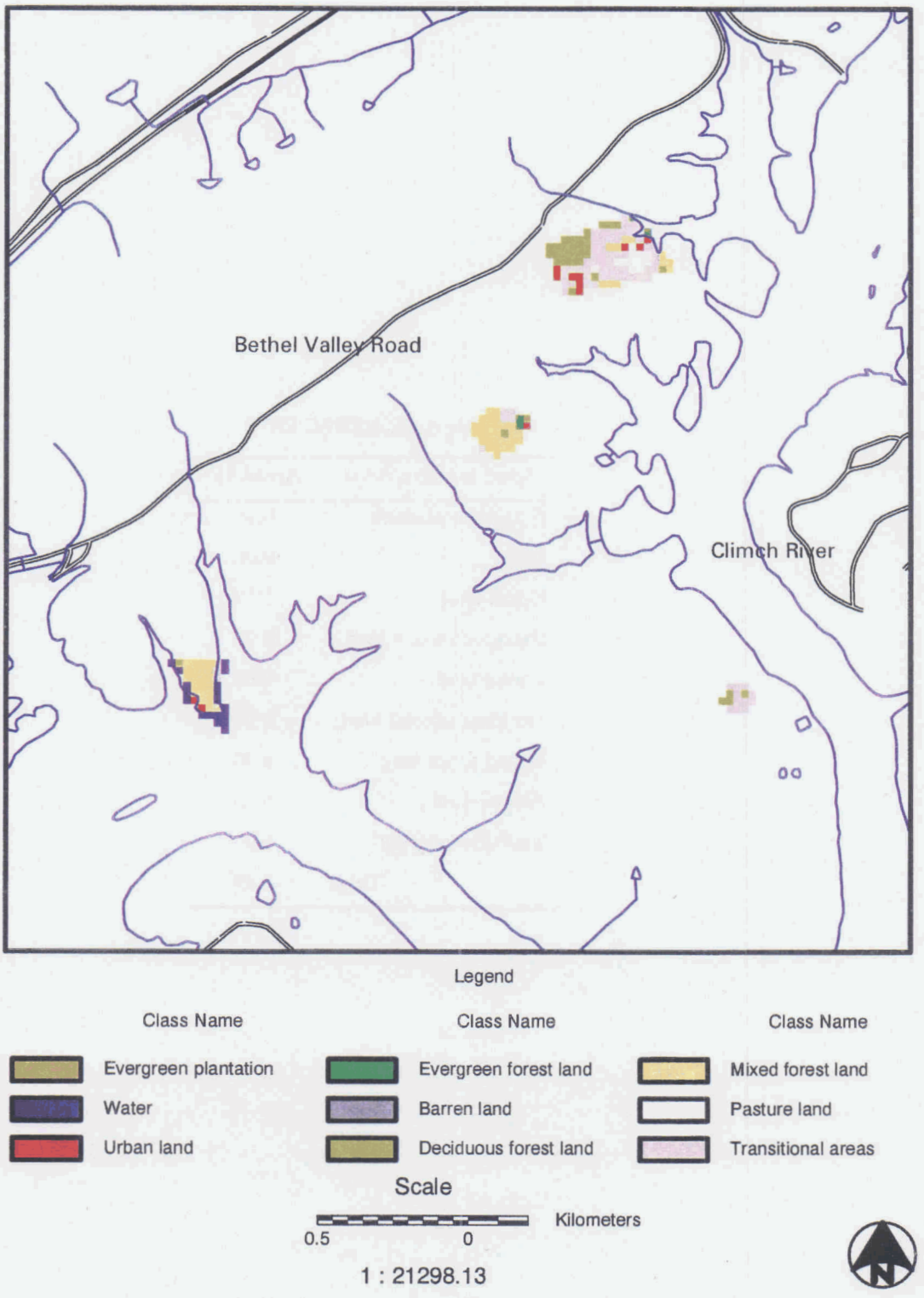


Fig. A.36. An April 13, 1994, classified Landsat 5 TM image of the Freels Bend area OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.36. Freels Bend area OU

Land use/land cover	Area (Ha)
Evergreen plantation	0.06
Water	1.12
Urban land	0.75
Evergreen forest land	0.25
Barren land	0.00
Deciduous forest land	2.06
Mixed forest land	3.88
Pasture land	0.81
Transitional areas	4.56
Total	13.49

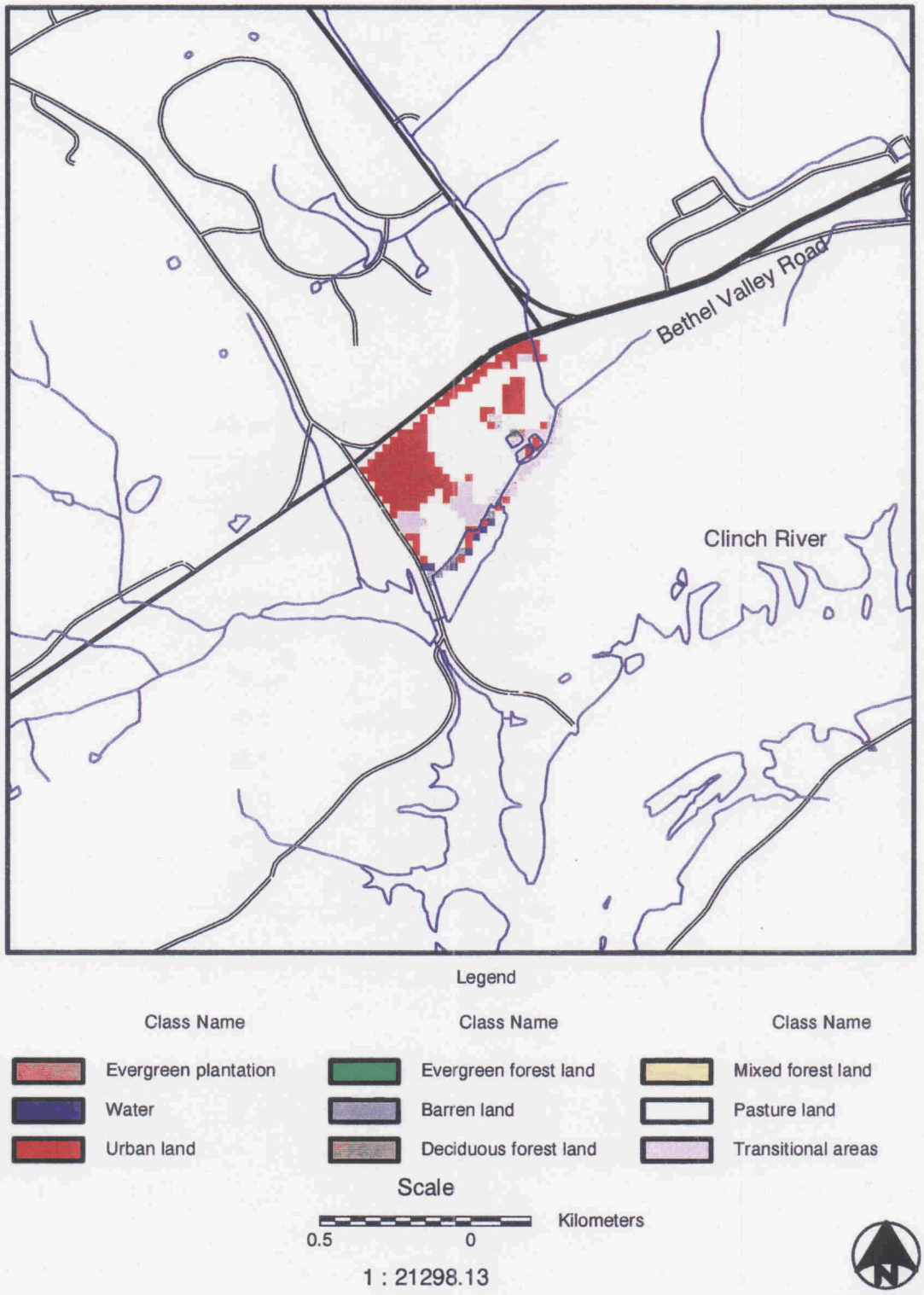


Fig. A.37. An April 13, 1994, classified Landsat 5 TM image of the South Campus Facility OU. The map projection is TSP meters, Zone 5301, and NAD 1983.

Table A.37. South Campus Facility OU

Land use/land cover	Area (Ha)
Evergreen plantation	0.06
Water	0.44
Urban land	9.81
Evergreen forest land	0.06
Barren land	0.44
Deciduous forest land	0.00
Mixed forest land	0.00
Pasture land	13.25
Transitional areas	4.50
Total	28.56

Appendix B

LANDSAT 5 THEMATIC MAPPER CHARACTERISTICS (HEADER FILE)

PRODUCT =94160002-01
WRS =019/03508
ACQUISITION DATE =19940413
SATELLITE =L5, INSTRUMENT =TM10
PRODUCT TYPE =MAP ORIENTED
PRODUCT SIZE =SUBSCENE
TYPE OF GEODETIC PROCESSING =TERRAIN
RESAMPLING =CC
RADIANCE GAINS/BIASES = 1.05548/-.00771 2.60376/-.01581 1.63223/-.01127 2.94161/-.02350 0.68439/-.00558 1.52431/0.12378 0.42472/-.00319
TAPE SPANNING FLAG=1/1 START LINE #= 1 LINES PER VOL= 4480
ORIENTATION = 0.00, PROJECTION =SPCS USGS PROJECTION # = 2 USGS MAP ZONE = 4100 USGS PROJECTION PARAMETERS = 0.637813700000000D+07 0.635675231414000D+07
0.000000000000000D+00 0.830000000000000D+02 0.000000000000000D+00
0.000000000000000D+00 0.000000000000000D+00 0.000000000000000D+00
0.000000000000000D+00 0.000000000000000D+00 0.000000000000000D+00
0.000000000000000D+00 0.000000000000000D+00 0.000000000000000D+00
0.000000000000000D+00
EARTH ELLIPSOID =GRS_1980
SEMI-MAJOR AXIS =6378137.000 SEMI-MINOR AXIS =6356752.314 PIXEL SIZE =25.00 PIXELS PER LINE= 4480 LINES PER IMAGE= 4480
Coordinates:
UL 0845406.9629W 362025.8059N 698575.000 223250.000 UR 0833917.8231W 361921.9045N 810550.000 223250.000 LR 0834104.0297W 351849.7203N 810550.000 111275.000 LL 0845456.7086W 351952.8283N 698575.000 111275.000
BANDS PRESENT =1234567, BLOCKING FACTOR = 1 RECORD LENGTH = 4480
SUN ELEVATION =51 SUN AZIMUTH =126
CENTER 0840012.5618W 355619.2243N 780130.539 179948.475 3263 1733
OFFSET=-135 REVB

Appendix C

ORTHOPHOTO METADATA

GISST RASTER METADATA

This American Standard Code for Information Interchange (ASCII) text file documents the metadata for a raster image stored in the GISST server. This server is maintained by Lockheed Martin Energy Systems (Energy Systems)/CAD of ORNL for use by the ORR Community. The numbers in parenthesis correspond to the July 8, 1994 version of the Spatial Data Transfer Standard (SDTS).

(-) DATABAS_ID:

(-) IMAGE_NAME: I4 Ortho CC'd

(-) THEME: Natural Color

(1.6.2.2) AREA: I4

(3.4.3) NCOLS: 3600

(3.4.2) NROWS: 3600

(-) PIXEL_SIZE: 0.5 m

(4.1.2.2.1) COORD_SYS: TSP

(1.5.1.1) WEST_BOUND: 748975

(1.5.1.2) EAST_BOUND: 750775

(1.5.1.3) NORTH_BOUND: 178025

(1.5.1.4) SOUTH_BOUND: 176225

(2.5.1.5) SOURCE: TVA Base Mapping and Imagery Project

(1.2.1) DESCRIPTION: orthoimage covers tile I4

(8.4) FILE_NAME: I4_CC.LAN

(6.4.2.1.7) FILE_SIZE: 38880128

(2.5.2.3) LAST_UPDATE: 07/28/94

(2.5.2.1) SUMMARY: ERDAS I4.LAN delivered by TVA 7/94. Color Corrected by Yang Cheng 8/10/94 to create I4_CC.LAN. Image was color corrected to minimize color discrepancy along flightpath edge with adjacent images with different exposure parameters. 24-bits.

GISST RASTER METADATA

This ASCII text file documents the metadata for a raster image stored in the GISST server. This server is maintained by Energy Systems/CAD of ORNL for use by the ORR Community. The numbers in parenthesis correspond to the July 8, 1994 version of the SDTS.

(-) DATABAS_ID:

(-) IMAGE_NAME: J3 Ortho CC'd

(-) THEME: Natural Color

(1.6.2.2) AREA: J3

(3.4.3) NCOLS: 3600

(3.4.2) NROWS: 3600

(-) PIXEL_SIZE: 0.5 m

(4.1.2.2.1) COORD_SYS: TSP

(1.5.1.1) WEST_BOUND: 748975

(1.5.1.2) EAST_BOUND: 750775

(1.5.1.3) NORTH_BOUND: 178025

(1.5.1.4) SOUTH_BOUND: 176225

(2.5.1.5) SOURCE: TVA Base Mapping and Imagery Project

(1.2.1) DESCRIPTION: orthoimage covers tile J3

(8.4) FILE_NAME: J3_CC.LAN

(6.4.2.1.7) FILE_SIZE: 38880128

(2.5.2.3) LAST_UPDATE: 07/28/94

(2.5.2.1) SUMMARY: ERDAS J3.LAN delivered by TVA 7/94. Color Corrected by Yang Cheng 8/10/94 to create J3_CC.LAN. Image was color corrected to minimize color discrepancy along flightpath edge with adjacent images with different exposure parameters. 24-bits.

GISST RASTER METADATA

This ASCII text file documents the metadata for a raster image stored in the GISST server. This server is maintained by Energy Systems/CAD of ORNL for use by the ORR Community. The numbers in parenthesis correspond to the July 8, 1994 version of the SDTS.

(-) DATABAS_ID:

(-) IMAGE_NAME: J4 Ortho CC'd

(-) THEME: Natural Color

(1.6.2.2) AREA: J4

(3.4.3) NCOLS: 3600

(3.4.2) NROWS: 3600

(-) PIXEL_SIZE: 0.5 m

(4.1.2.2.1) COORD_SYS: TSP

(1.5.1.1) WEST_BOUND: 748975

(1.5.1.2) EAST_BOUND: 750775

(1.5.1.3) NORTH_BOUND: 178025

(1.5.1.4) SOUTH_BOUND: 176225

(2.5.1.5) SOURCE: TVA Base Mapping and Imagery Project

(1.2.1) DESCRIPTION: orthoimage covers tile J4

(8.4) FILE_NAME: J4_CC.LAN

(6.4.2.1.7) FILE_SIZE: 38880128

(2.5.2.3) LAST_UPDATE: 07/28/94

(2.5.2.1) SUMMARY: ERDAS J4.LAN delivered by TVA 7/94. Color Corrected by Yang Cheng 8/10/94 to create J4_CC.LAN. Image was color corrected to minimize color discrepancy along flightpath edge with adjacent images with different exposure parameters. 24-bits.

GISST RASTER METADATA

This ASCII text file documents the metadata for a raster image stored in the GISST server. This server is maintained by Energy Systems/CAD of ORNL for use by the ORR Community. The numbers in parenthesis correspond to the July 8, 1994 version of the SDTS.

(-) DATABAS_ID:

(-) IMAGE_NAME: J5 Ortho CC'd

(-) THEME: Natural Color

(1.6.2.2) AREA: J5

(3.4.3) NCOLS: 3600

(3.4.2) NROWS: 3600

(-) PIXEL_SIZE: 0.5 m

(4.1.2.2.1) COORD_SYS: TSP

(1.5.1.1) WEST_BOUND: 748975

(1.5.1.2) EAST_BOUND: 750775

(1.5.1.3) NORTH_BOUND: 178025

(1.5.1.4) SOUTH_BOUND: 176225

(2.5.1.5) SOURCE: TVA Base Mapping and Imagery Project

(1.2.1) DESCRIPTION: orthoimage covers tile J5

(8.4) FILE_NAME: J5_CC.LAN

(6.4.2.1.7) FILE_SIZE: 38880128

(2.5.2.3) LAST_UPDATE: 07/28/94

(2.5.2.1) SUMMARY: ERDAS J5.LAN delivered by TVA 7/94. Color Corrected by Yang Cheng 8/10/94 to create J5_CC.LAN. Image was color corrected to minimize color discrepancy along flightpath edge with adjacent images with different exposure parameters. 24-bits.

GISST RASTER METADATA

This ASCII text file documents the metadata for a raster image stored in the GISST server. This server is maintained by Energy Systems/CAD of ORNL for use by the ORR Community. The numbers in parenthesis correspond to the July 8, 1994 version of the SDTS.

(-) DATABAS_ID:

(-) IMAGE_NAME: K4 Ortho CC'd

(-) THEME: Natural Color

(1.6.2.2) AREA: K4

(3.4.3) NCOLS: 3600

(3.4.2) NROWS: 3600

(-) PIXEL_SIZE: 0.5 m

(4.1.2.2.1) COORD_SYS: TSP

(1.5.1.1) WEST_BOUND: 748975

(1.5.1.2) EAST_BOUND: 750775

(1.5.1.3) NORTH_BOUND: 178025

(1.5.1.4) SOUTH_BOUND: 176225

(2.5.1.5) SOURCE: TVA Base Mapping and Imagery Project

(1.2.1) DESCRIPTION: orthoimage covers tile K4

(8.4) FILE_NAME: K4_CC.LAN

(6.4.2.1.7) FILE_SIZE: 38880128

(2.5.2.3) LAST_UPDATE: 07/28/94

(2.5.2.1) SUMMARY: ERDAS K4.LAN delivered by TVA 7/94. Color Corrected by Yang Cheng 8/10/94 to create K4_CC.LAN. Image was color corrected to minimize color discrepancy along flightpath edge with adjacent images with different exposure parameters. 24-bits.

GISST RASTER METADATA

This ASCII text file documents the metadata for a raster image stored in the GISST server. This server is maintained by Energy Systems/CAD of ORNL for use by the ORR Community. The numbers in parenthesis correspond to the July 8, 1994 version of the SDTS.

(-) DATABAS_ID:

(-) IMAGE_NAME: K5 Ortho CC'd

(-) THEME: Natural Color

(1.6.2.2) AREA: K5

(3.4.3) NCOLS: 3600

(3.4.2) NROWS: 3600

(-) PIXEL_SIZE: 0.5 m

(4.1.2.2.1) COORD_SYS: TSP

(1.5.1.1) WEST_BOUND: 748975

(1.5.1.2) EAST_BOUND: 750775

(1.5.1.3) NORTH_BOUND: 178025

(1.5.1.4) SOUTH_BOUND: 176225

(2.5.1.5) SOURCE: TVA Base Mapping and Imagery Project

(1.2.1) DESCRIPTION: orthoimage covers tile K5

(8.4) FILE_NAME: K5_CC.LAN

(6.4.2.1.7) FILE_SIZE: 38880128

(2.5.2.3) LAST_UPDATE: 07/28/94

(2.5.2.1) SUMMARY: ERDAS K5.LAN delivered by TVA 7/94. Color Corrected by Yang Cheng 8/10/94 to create K5_CC.LAN. Image was color corrected to minimize color discrepancy along flightpath edge with adjacent images with different exposure parameters. 24-bits.

DISTRIBUTION

1–2. T. Ashwood
3. L. D. Bates
4. B. A. Berven
5. H. L. Boston
6. E. Bright
7. J. S. Colley
8. R. B. Cook
9. D. G. Cope
10–12. S. Christensen
13. J. H. Cushman
14. V. H. Dale
15. R. Durfee
16. N. T. Edwards
17. D. E. Fowler
18. R. L. Graham
19. G. K. Jacobs
20. D. R. Hamrin
21. S. G. Hildebrand
22–26. R. Hinzeman
27. C. Hunsaker
28. P. Kanciruk
29. A. W. King
30. A. K. Lee
31. J. M. Loar
32. J. R. Lyons
32. L. Mann
33–35. D. M. Matteo
36. R. McCord
37. B. Moll
38–39. P. T. Owen
40. P. Pace
41–44. P. Parr
45. D. E. Reichle
46. B. Samples
47–51. P. Scarbrough-Luther
52. F. E. Sharples
53. R. C. Sleeman
54. G. Suter
55. M. Tuttle
56–65. R. A. Washington-Allen
66. K. With
67–69. K-25 Classification and Information Control Office
70–72. ER Central DMC
73. Central Research Library
74–88. ESD Library
89–91. ORNL Laboratory Records
92. K-25 Site Records
93. Y-12 Plant Records
94. ORNL Patent Section
95. ORNL Y-12 Technical Library

96. R. N. Farvolden, Professor, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario N2L 3G1 Canada
97. D. W. Freckman, Director, College of Natural Resources, 101 Natural Resources Building, Colorado State University, Fort Collins, CO 80523
98. G. Y. Jordy, Director, Office of Program Analysis, Office of Energy Research, ER-30, G-226, U.S. Department of Energy, Washington, DC 20545
99. B. E. Norton, Department of Rangeland Resources, The College of Natural Resources, Utah State University, Logan, UT 84322-5230
100–102. H. Offerman, Department of Geography, 1113 LeFrak Hall, University of Maryland, College Park, MD 20740
103. A. Patrinos, Director, Environmental Sciences Division, Office of Health and Environmental Research, ER-74, U.S. Department of Energy, Washington, DC 20585
104. R. D. Ramsey, Department of Geography and Earth Resources, The College of Natural Resources, Utah State University, Logan, UT 84322
105. A. Rasmussen, Department of Rangeland Resources, The College of Natural Resources, Utah State University, Logan, UT 84322-5230
106. D. Roberts, Department of Forest Resources, The College of Natural Resources, Utah State University, Logan, UT 84322

107. G. S. Sayler, Professor, 10515 Research Drive, Suite 100, The University of Tennessee, Knoxville, TN 37932-2567

108–110. M. Turner, Department of Zoology, University of Wisconsin, Bridge Hall 430 Lincoln Drive, Madison, WI 53706

111. N. E. West, Department of Rangeland Resources, The College of Natural Resources, Utah State University, Logan, UT 84322-5230

112. F. J. Wobber, Environmental Sciences Division, Office of Health and Environmental Research, ER-74, U.S. Department of Energy, Washington, DC 20585

113. Office of Assistant Manager for Energy Research and Development, U.S. Department of Energy Oak Ridge Operations, P.O. Box 2001, Oak Ridge, TN 37831-8600