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A TECHNIQUE TO IDENTIFY POTENTIAL ELK HABITAT IN THE WHITE MOUNTAINS OF ARIZONA

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A TECHNIQUE TO IDENTIFY POTENTIAL ELK HABITAT IN THE WHITE MOUNTAINS OF ARIZONA

by

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ABSTRACT

A species-habitat approach to habitat analysis and evaluation is developed for identifying potential habitat of wildlife species. Rocky Mountain elk and the White Mountains of Arizona are utilized in a case study to illustrate the technique. The technique was modeled after USFWS Habitat Evaluation Procedures and is an alternative method to developing Habitat Suitability Index models. A mapping system is employed in the technique designed to evaluate a land area for habitat suitability of a particular wildlife species.

Elk summer range habitat components are forage, water, hiding cover, thermal cover and road impacts. Habitat variables are identified that define optimal and suboptimal conditions of the habitat variables. These variables are mapped and overlayed producing a habitat component composite map. A km^2 grid is overlayed providing a geographic definition for rating. Each grid cell is evaluated for each habitat component area and assigned a high, moderate or zero suitability rating.

CHAPTER 1

INTRODUCTION

A habitat based approach in natural resource planning is an effective means to incorporate wildlife use considerations with other land use demands. Wildlife habitat is defined by Gysel and Lyon (1980) as the sum of all environmental factors required by a species to survive and reproduce in a particular area. Understanding a wildlife species habitat requirements allows planners to evaluate land resource capabilities to support those species. Once land capabilities are identified project impact assessments, future condition predictions and land use allocations can be made. Wildlife habitat analysis and evaluation techniques allow wildlife to be included in this land use planning process.

The U.S. Fish and Wildlife Service (USFWS) has developed the Habitat Evaluation Procedures (HEP) program to better incorporate wildlife in the natural resource planning process. HEP is applied as a standardized system to improve communication between agencies and professions and to provide a framework focusing species-habitat research (Schamberger and Krohn 1982). In HEP baseline resources are inventoried, evaluated for representative species habitat quality and quantified for the basis of project impact predictions (USFWS 1980a). These predictions have been used as the basis for mitigation and compensation for habitat losses by project development. The key element linking baseline resource inventory and species habitat requirements is the Habitat Suitability Index (HSI) model developed for each evaluation species. HSI models provide the means to evaluate resource conditions for species habitat suitability.

The principles and procedures in HEP were used as a basis for developing this technique. This study is the development of an alternative technique to evaluate a land resource for species habitat suitability. Differences and similarities between this technique and HEP will be discussed further in Chapters 3 and 4.

The purpose of this study is to develop an habitat analysis technique to locate potential habitat based on identified species requirements, translate those requirements to a geographic format and locate the habitat requirements on a land base through a mapping overlay system. For illustration purposes the technique will be applied to Rocky Mountain elk (*Cervus elaphus nelsoni*) in the White Mountains of Arizona.

This study is part of an on-going elk habitat analysis and utilization research project for the White Mountain Apache Indian Tribe. The project is designed in three portions: habitat mapping, elk observations and habitat utilization. The model developed in this study to predict potential elk habitat is an extension of the habitat mapping linking the habitat utilization portion of the project. The elk observations and utilization data will be used later to verify this mapping technique.

CHAPTER 2

STUDY AREA

The study area is located in the northeast corner of Fort Apache Indian Reservation (FAIR) in east-central Arizona (Figure 1). The two case study areas used in this project are each 50 km^2.

Topography and Soils

The Mogollon Rim divides both study areas producing two dominant topographic regions. The northern two-thirds of the area is gently downsloping to the west with a series of protruding mountains. The southern third, below the Mogollon Rim, has steeper slopes and is dissected by river canyons. Elevations vary on the case study areas between 1982m (6500') and 2805m (9200')(Figures 2 and 3).

Soils are comprised of two associations, Gordo and Sponseller-Ess. The Gordo association is deep, well-drained, medium moderately fine textured soils formed from weathered material from basalt, cinders and ash. The Sponseller-Ess association is deep, well-drained medium and moderately fine textured soils formed from basic igneous rock (Mitchell 1981).

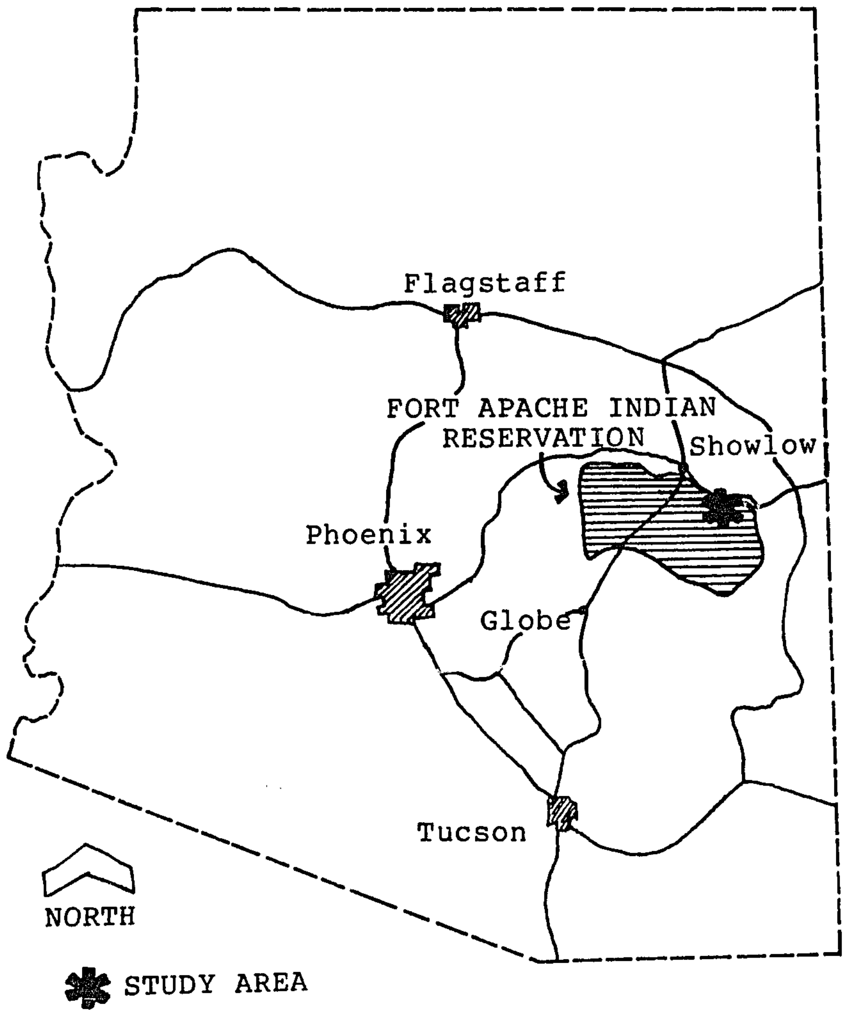


Figure 1. The Fort Apache Indian Reservation (FAIR) study area in Arizona (BIA 1977).

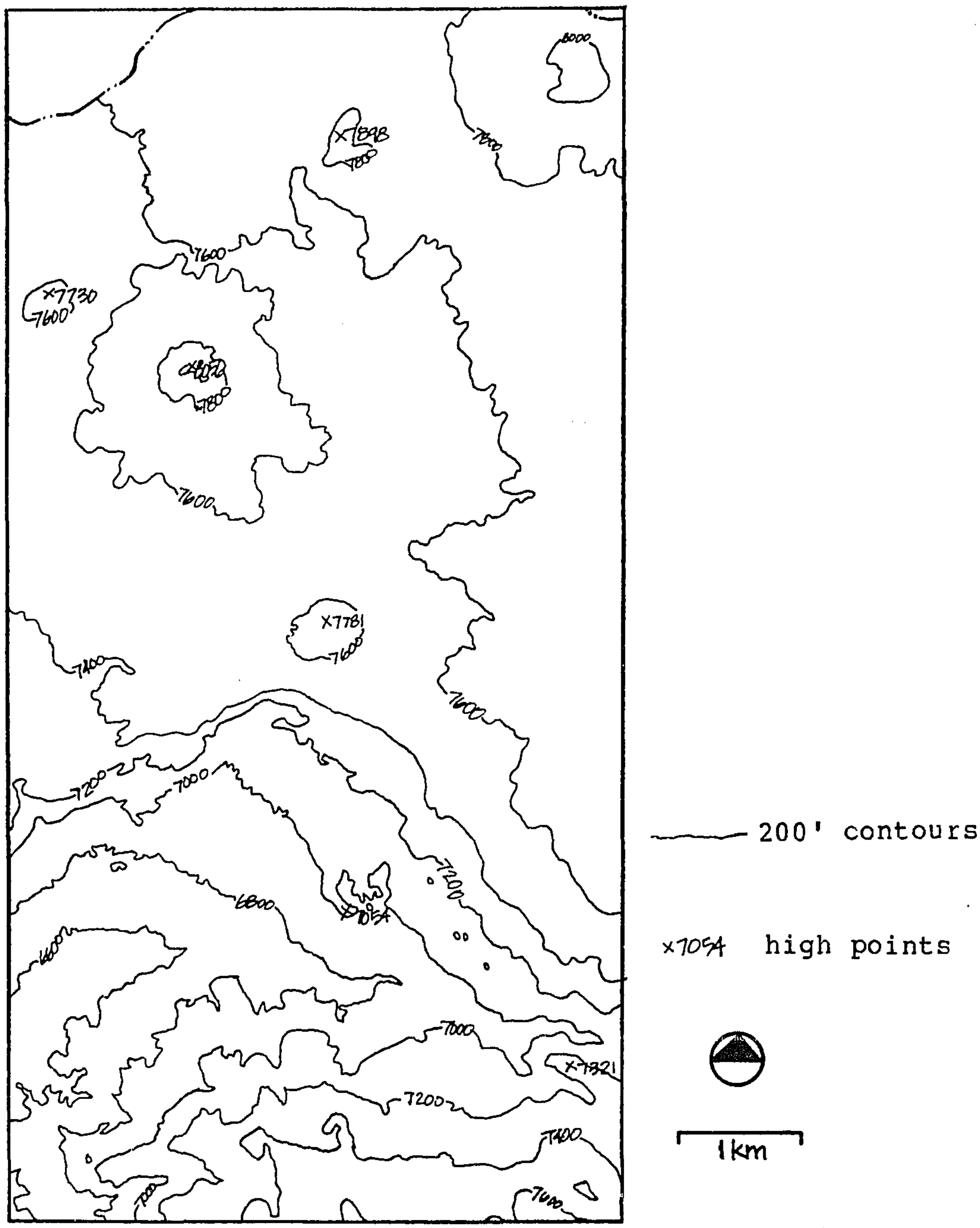


Figure 2. Topography--McNary.

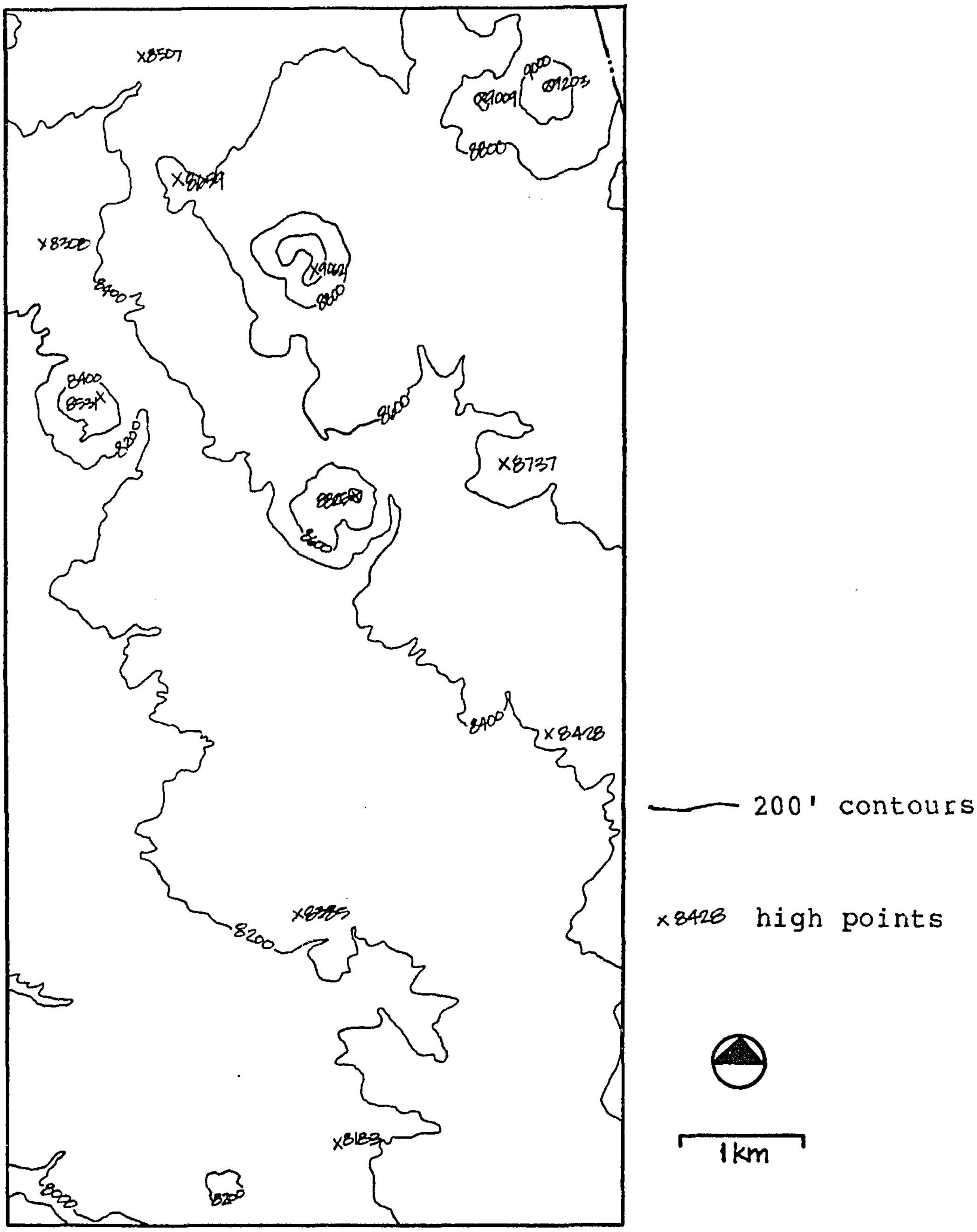


Figure 3. Topogragphy--Horseshoe Cienega.

Climate

The mountainous topography and high elevation of the area have an influence on the climatic conditions. The following climatic data are averages of measurements taken at McNary, elevation 2232m (7320'), from 1900 to 1957 (BIA 1977). The area receives annual precipitation of 62.7cm (24.7") including 240cm (94.6") snowfall. Average January minimum and maximum temperatures are -8.7 C (16.4 F) and 6.7 C (44.0'F), respectively. Average July minimum and maximum temperatures 8.9 C are 26.9 C (48.1'F) and (80.5'F),respectively. The average growing season is 110 days (BIA 1977).

Vegetation

Brown and Lowe (1980) identify three biotic communities present in the area--Rocky Mountain subalpine conifer forest, Rocky Mountain montane conifer forest, and subalpine grassland. The following community descriptions were taken from Brown (1982). Rocky Mountain subalpine conifer forest is a cold wet forest at elevations ranging from 2450-2600m to timberline at 3500-3800m. Engelmann spruce (*Picea engelmanni*) is the prevalent spruce species commonly found with corkbark fir (*Abies lasiocarpa* var. *arizonica*). Aspen (*Populus tremuloides*) communities are common in mixed aged stands below 2900m elevations. Blue spruce (*Picea pungens*) is sometimes present in association with Engelmann spruce or aspen particularly in canyons and along margins of small mountain parks. At lower elevations, below 2600m, the spruce-fir association will mix with Douglas-fir (Pseudotsuga menziesii), white fir (Abies concolor) and ponderosa pine (Pinus ponderosa).

The Rocky Mountain montane conifer forest is located on drier sites predominantly between 2300m and 2650m. Two major communities are included--ponderosa pine forest and mixed conifer forest. The ponderosa pine forest is generally at lower elevations with ponderosa pine the dominant species. Southwestern white pine (Pinus strobiformus) is a common associate at lower elevations with Douglas-fir, white fir and aspen at higher elevations. Gambel's oak (Quercus gambelii) and New Mexican locust (Robinia neomexicana) may dominate lower and rockier sites. The mixed conifer forest is located at higher elevations, in canyons and on north-facing slopes with Douglas-fir, white fir, limber pine (Pinus flexilis) and aspen being dominant species. This forest generally forms a discontinuous belt between the warmer drier pine forest below and the colder wetter spruce fir forests above. Aspen subclimax communities are common throughout ponderosa pine and mixed conifer forests.

The best development of subalpine grassland is between 2500 to 2600m and 3500m elevations. Grasslands are located in "valleys, slopes and ridges on usually flat or undulating terrain adjacent to and within subalpine forests"

(Brown 1982). Grassland size varies from a few acres of forest opening to thousands of acres creating extensive meadow areas. Festuca, Agropyron, Stipa, Poa, Muhlenbergia are dominant perennial bunchgrasses on well-drained sites. In wetter "cienega" areas, bunchgrasses are replaced by sedges (Carex, Cyperus) and rushes (Juncus).

Wildlife

Many wildlife species can be found in any of the three biotic communities depending upon the micro-site conditions. The following species are listed as characteristic species in particular vegetative communities but their distribution is not limited to those communities. Brown (1982) and BIA (1977) were used as sources for the species lists.

Species common to Rocky Mountain subalpine conifer forest include: red squirrel (Tamiasciurus hudsonicus), red-backed mouse (Clethrionomys gapperi), least chipmunk (Eutamias minimus), blue grouse (Dendrogapus obscurus), gray jay (Perisoreus canadensis), golden-crowned kinglet (Regulus satrapa), red-breasted nuthatch (Sitta canadensis), Clark's nutcracker (Nucifraga columbiana), and Cassin's finch (Carpodacus cassinii).

Species common to the Rocky Mountain montane conifer forest include: elk, mule deer (Odocoileus hemionus), tassel-eared squirrel (Sciurus aberti), golden-mantled ground squirrel (Citellus lateralis), Nuttall's cottontail

(*Sylvilagus nuttalli*), deer mouse (*Peromyscus maniculatus*), porcupine (*Erithizon dorsatum*), wild turkey (*Meleagris gallopavo*), band-tail pigeon (*Columba fasciata*), stellar jay (*Cyanocitta stelleri*), short-horned lizard (*Phrynosoma douglassi*), and tiger salamander (*Ambystoma tigrinum*).

Species common to subalpine grassland community are: elk, mule deer, montane vole (*Microtus montanus*), long-tailed vole (*M. longicaudus*) gray-colloared chipmunk (*Eutamias cinereicollis*), pocket gopher (*Thomomys talpoides*), and blue grouse.

FAIR has a big game resource allowing regulated hunting for elk, mule deer, white-tail deer (*O. virginianus*), mountain lion (*Felis concolor*), black bear (*Ursus americana*), and wild turkey.

CHAPTER 3

PROCEDURES

Habitat Suitability Index (HSI) models are developed to provide a standardized means for evaluating habitat quality for particular species of interest (USFWS 1981). HSI models for terrestrial species are comprised of those habitat variables which provide a measure of species food, cover and water requirements. These habitat variables are combined to form an index which provides a comparison of how well a particular land area being evaluated compares to optimum habitat for the species in question. The elk habitat suitability model developed in this study follows the general outline for developing HSI models as described in USFWS Standards for the development of habitat suitability index models 103 ESM (1981). There are five phases in HSI model construction (Figure 4). The specific process developed in this technique is an alternative method to Phase III Structure the model. The differences will be discussed further in Chapter 4.

Set Model Objectives

Model objectives are important for guiding the development of the model to fit the particular needs of the

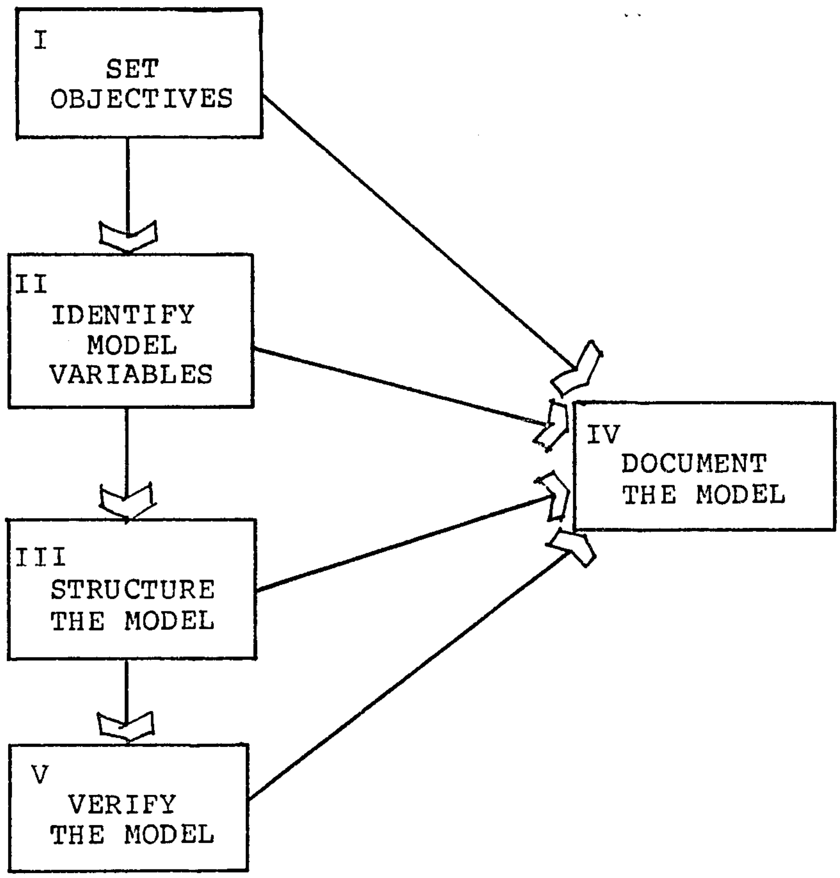


Figure 4. Habitat Suitability Index model construction process (USFWS 1981).

study. These include: defining model outputs, delineating seasonal and geographic area of concern, and describing model assumptions. These objectives are particularly important for far-ranging species such as elk which utilize a wide variety of habitat types throughout a year. For the purpose of this study, the model is applied to a relatively small geographic area and is developed on the basis of summer habitat requirements of elk alone.

The model outputs objective is defined to provide a level of realism to attain while developing the model. The acceptance level defines the degree the model outputs actually represent true environmental conditions. USFWS (1981) describes several levels of acceptance for model outputs. For the purpose of this study, the acceptance levels are consolidated to three: one, model outputs seem reasonable to the author; two, apply the model methodology to another set of sample data to compare resulting outputs; and three, compare model outputs to actual population data in the study area to further define the level of realism in the model. A certain level of acceptance is atteined already by using the case study approach of applying the method to a real data set as with elk in the White Mountains. In this study levels one and two will be attained in this document, while level three will be attained in the near future. Level one of acceptance will be attained by evaluating the final suitability ratings for limiting factors and comparing the results to similar studies in the Blue Mountains of Oregon and Washington (Thomas et al 1979, Leckenby and Adams 1981). Acceptance level two will be attained by applying the suitability rating procedure to elk habitat utilization data from a study by DelGiudice (1982) on an adjacent land area. Currently an elk habitat utilization project is being conducted on the Fort Apache Indian Reservation. The results will be compared to these model outputs to attain the third level of acceptance.

HSI model geographic applicability is dependent on the species habitat use pattern. The species must utilize resources in the same ways for the HSI model to be applicable. Rocky mountain elk are widely distributed across the western United States (Bryant and Maser 1982). Skovlin (1982) describes a variety of habitat types utilized by elk depending upon the geographic location. DelGiudice and Rodiek (in preparation) found elk more sensitive to potable water locations in Arizona's White mountains than in habitats further north (Marcum 1976, Leckenby and Adams 1981). Therefore, the geographic area of applicability for this elk model has been designated only to the White Mountains of Arizona.

The seasonal applicability is limited to summer range for several reasons. One, the study area is located at high elevation (1982m to 2805m) so elk cannot get into the area until late spring because of high snow levels (J. Caid, pers. comm.). Second, DelGiudice (1982) completed an elk habitat analysis study during the spring and summer seasons on a study area adjacent to the north providing habitat utilization information applicable to the development of this model. Third, Skovlin (1982) describes summer habitat use patterns as being mainly foraging building up winter fat stores while spring and fall habitat use patterns are quite different. Lastly, model applicability is determined by seasonal use pattern similar to geographic applicability. Each time the use or activity in an area changes a new model must be developed.

Model assumptions are important to recognize when developing or using suitability models. The first assumption in developing this model is that potential elk habitat can be predicted based on known habitat requirements and existing resource conditions. A related assumption is taken in accepting known habitat requirements to be accurate. Current wildlife literature is used as a source for habitat requirements determined by elk observation studies. The underlying assumption is habitats frequented by elk contain optimal habitat components. The next assumption includes habitat components that can be incorporated in the model and those that cannot. Water, forage and cover components will be included (Thomas et al 1979). Other habitat variables such as weather conditions cannot be incorporated (Skovlin 1982). The last assumption is that land areas may exist with the appropriate habitat variables, but do not currently support an elk population. Suitable areas identified as possessing elk habitat components are assumed to have the capability to support a population even though none may currently exist in the area.

Identify Model Variables

Habitat components define the species requirements in the suitability model. Habitat variables are the "building blocks" that define how each component can be measured and included in the model (USFWS 1981). There are many considerations in choosing habitat variables. A few are time and money available, and intended use of the model. USFWS (1981) suggests variables can be any measurable physical, chemical or biological characteristics. Current literature and expert opinion are sources for defining habitat variables. USFWS (1981) outlines three criteria to use in selecting variables: one, the variable is related to the capacity of habitat to support species; two, there is at least a basic understanding of the relationship of the varible to the habitat; and three, the variable is practical to measure within existing constraints on the model application. Tree diagrams are used by USFWS (1981) to organize habitat variables and components (Figure 5).

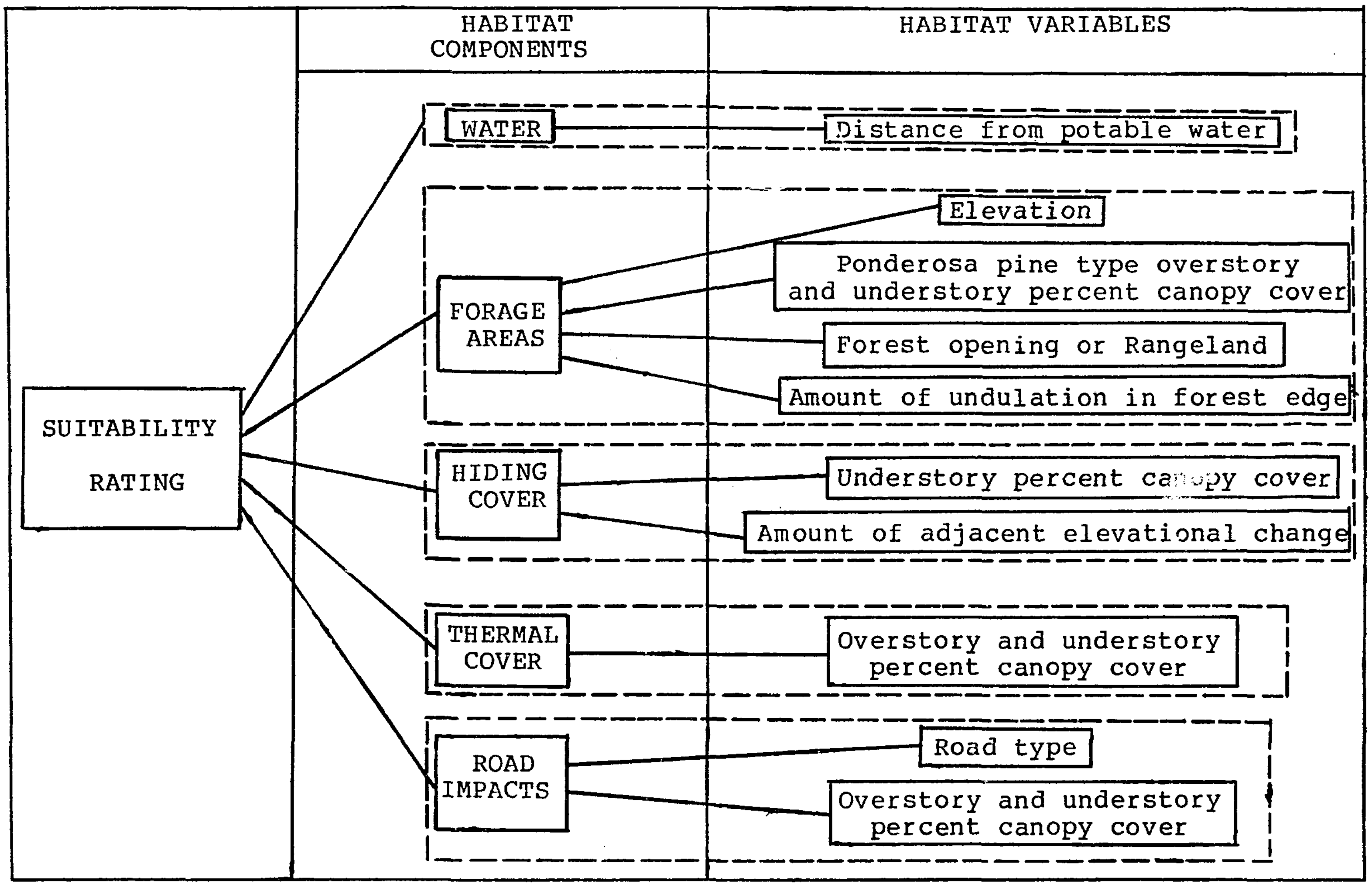


Figure 5. Habitat variable tree-diagram.

Thomas et al (1979) defines optimum elk habitat as "the amount and arrangement of cover and forage areas that result in the maximum possible proper use of the maximum possible area by the animals". Forage areas, hiding cover, thermal cover and water are the four components of optimal elk habitat (Thomas et al 1979). Road impacts are included in this model as a component since habitat effectiveness can be greatly reduced by roads (Perry and Overly 1976).

Habitat variables are the measurable features defining each habitat component. Variables used in this elk model must be mappable to be included in this mapping system technique. Sources for the identified variables must be maps, aerial photos or some other form easily transferred to a geographic format. Further definition of the habitat variables is needed in this technique (Figure 6). Literature sources used to identify the habitat variables are also used to define optimal and suboptimal conditions of the variable. These variable optimal and suboptimal conditions are transferred to make the habitat component maps.

Water has been identified as a very important habitat component in the White Mountains by DelGiudice (1982). DelGiudice and Rodiek (in preparation) observed 265 elk during early spring and late spring-summer 1981 finding "elk using habitat within 402m of potable water significantly ($P<0.0001$) more than other areas". During

HABITAT COMPONENTS	HABITAT VARIABLES	OPTIMAL CONDITIONS	SUBOPTIMAL CONDITIONS
WATER	Distance	<402m of water	areas between 402m and 804m of water
FORAGE AREAS	Elevation	>2287m (7500')	<2287m (7500')
	Ponderosa pine type overstory and understory canopy cover	11-29% overstory and 0-29% understory	30-69% overstory and 0-29% understory
	Forest opening and Rangeland	0-10% canopy cover	
	Amount of undulation in forest edge	greater amount of edge	lesser amount of edge
HIDING COVER	Understory percent canopy cover	30-100% understory	30-100% understory
	Amount of adjacent elevational change	adjacent slope change	
THERMAL COVER	Overstory and understory percent canopy cover	30-100% overstory and 0-29% understory	
ROAD IMPACTS	Road type		
	Overstory and understory percent canopy cover		

Figure 6. Habitat variables optimal and suboptimal conditions.

late spring-summer elk were found in 402m proximity of water 66.45% of the time and within 804m the majority of the remainder of time.

Forage areas contain grass and sedge species of high quality in sufficient quantity for elk. Suitable forage species can be found anywhere in a forest ecosystem, but are most predominant in forest meadows and open pondersoa pine forests (McConnell and Smith 1970). Forest openings or rangeland are defined by 0 to 10 percent forest canopy cover. Open ponderosa pine forests are defined by low to moderate overstory forest percent canopy cover and low understory percent canopy cover. DelGiudice (1982) identified six high use meadows located above 2287m (7500') elevation, on his adjacent study area. Reynolds (1966a) found a preference for elk use within 183m (600') of an edge in Arizona ponderosa pine forest. Optimal forage areas within 183m of forest edge can be enhanced with a greater amount of undulation in the meadow-forest edge (Thomas et al 1979).

Thomas et al (1979) defines optimal hiding cover as areas with "vegetation capable of hiding 90% of a standing adult elk from view of a human at a distance equal to or less than 61m (200')". Understory is the dominant variable with adjacent elevational change enhancing the quality of the hiding cover. Time and budget constraints did not allow for any field measurements of hiding cover in this study.

Therefore, understory percent canopy cover and adjacent slope change are used as habitat variables in this model.

Thermal cover refers to areas with vegetation and topographic features in appropriate combination such that elk can utilize the area as a thermal-neutral zone (Thomas et al 1979). Elk use the physical environment to balance the ambient air temperature with their body temperatures thereby reducing energy lost through the physiological response of cooling the body (Moen 1973). During the summer season elk are building up energy and fat stores for the winter season, thereby any energy required to cool the body during the summer is lost. Closed overstory forest canopies are most effective in reducing solar radiation infiltration to the forest floor (Thomas et al 1979). An open understory canopy allows air movement under the forest canopy creating even cooler microclimates (Edgerton and McConnell 1976). Thomas et al (1979) state that thermal cover is often limiting in the Blue Mountains of Oregon. For this reason the optimal category has a broad definition and no suboptimal category.

Road impacts on adjacent elk habitat are dependent on the road type (e.g. main, secondary or primitive roads) and the forest canopy cover along the road (Perry and Overly 1976). Traffic levels are assumed to be correlated with quality of road, so heaviest use is on main roads and lightest use is on primitive roads. Road impacts are heaviest in open vegetation where elk would be in sight of passing motorists and lightest in closed forests providing hiding cover. Perry and Overly (1976) identify distances from roads by vegetation type and the reduction in habitat used by elk (Figure 7).

Structure the Model

Structuring the HSI model in HEP is organizing the habitat variables to develop a quality measure of the land area. A representative land area is chosen and evaluated resulting in an HSI rating. Then the rating for that area is expanded to all similar areas (USFWS 1981). The mapping system in this technique applies the identified habitat variables to the entire land area locating all areas with the appropriate variables. The entire study area is then rated for habitat suitability producing potential use areas.

The habitat variables and optimal and suboptimal conditions outlined in Figure 6 provide a list of data required to complete the mapping system. A list of baseline resource maps is made from data requirements identified. For this study baseline resource maps include: vegetation, canopy cover--overstory and understory, topography, surface water and roads (Appendix A).

Habitat component maps are made following the habitat variables optimal and suboptimal conditions using baseline resource maps as sources of information. Decision-models are included for illustration of the procedures

ROAD TYPE	VEGETATION DENSITY TYPES					
	Meadow		Open Forest		Closed Forest	
	impact distance	use reduction	impact distance	use reduction	impact distance	use reduction
Main	<.8km	95%	<.8km	46%	<.2km	36%
Secondary	<.8km	44%	<.8km	67%	No Impact	
Primitive	<.2km	57%	<.2km	36%	No Impact	

Figure 7. Road impacts (Perry and Overly 1976).

followed in developing each habitat component map. Each map for both case study areas is included following the procedure decision-models.

Water proximity map contains areas within 402m of a water feature as optimal and areas between 402m and 804m as suboptimal suitability (Figure 8). The 402m and 804m distances are figured to scale and outlined around surface water features (Figures 9 and 10).

Forage areas are more complicated than water proximity and is completed in several steps (Figure 11). First, all areas in rangeland or ponderosa pine vegetation type with 11-69% overstory and 0-29% understory canopy cover are delineated. This map is overlayed on the topography map to determine those areas above or below 2287m elevation. Amount of edge is used as a second differentiation between optimal and suboptimal forage areas. All those areas with a different vegetation type or higher canopy cover percentages are excluded and left blank on the final habitat component map (Figures 12 and 13).

The hiding cover map is based on two variables--understory canopy cover and adjacent slope change (Figure 14). Areas with 30-100% understory canopy cover are delineated first, overlaying the preliminary map on topography producing optimal and suboptimal categories (Figures 15 and 16). Adjacent slope change is defined as a change in topographic features producing a different slope.

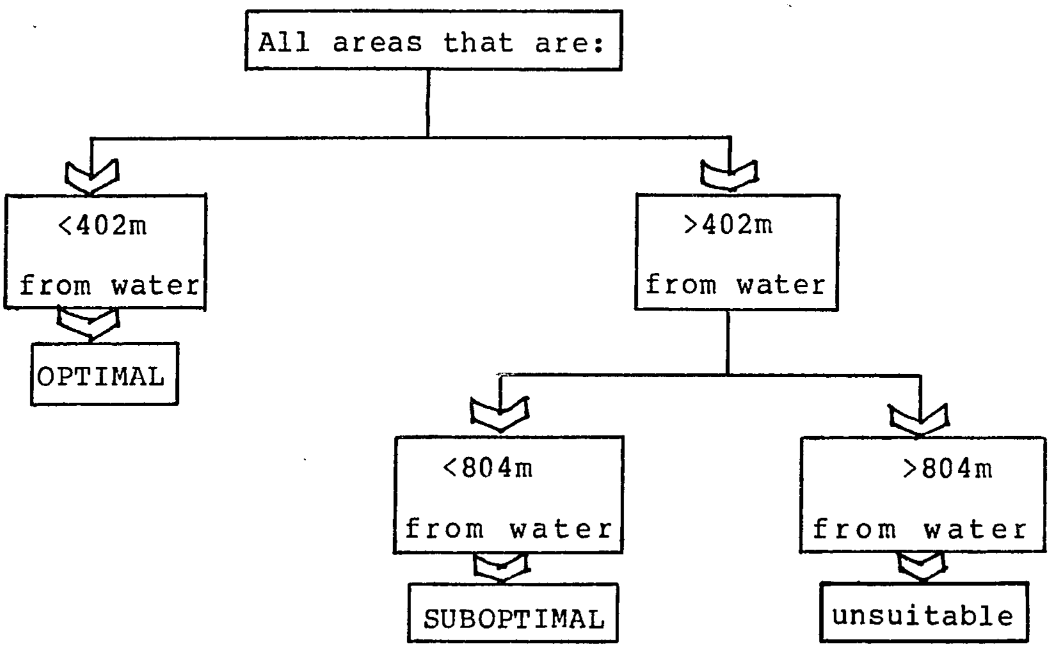


Figure 8. Water proximity decision-model.

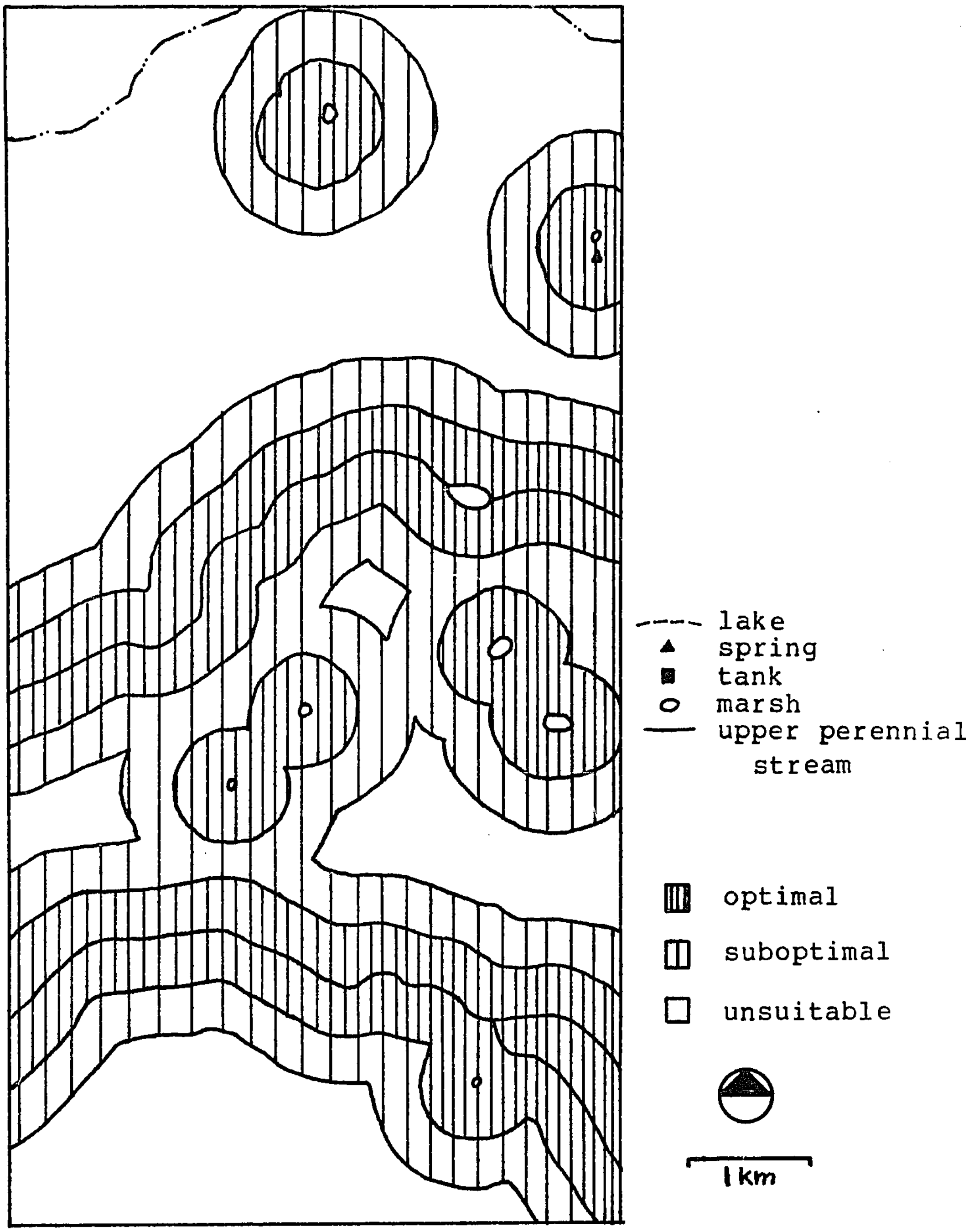


Figure 9. Water proximity habitat component map--McNary.

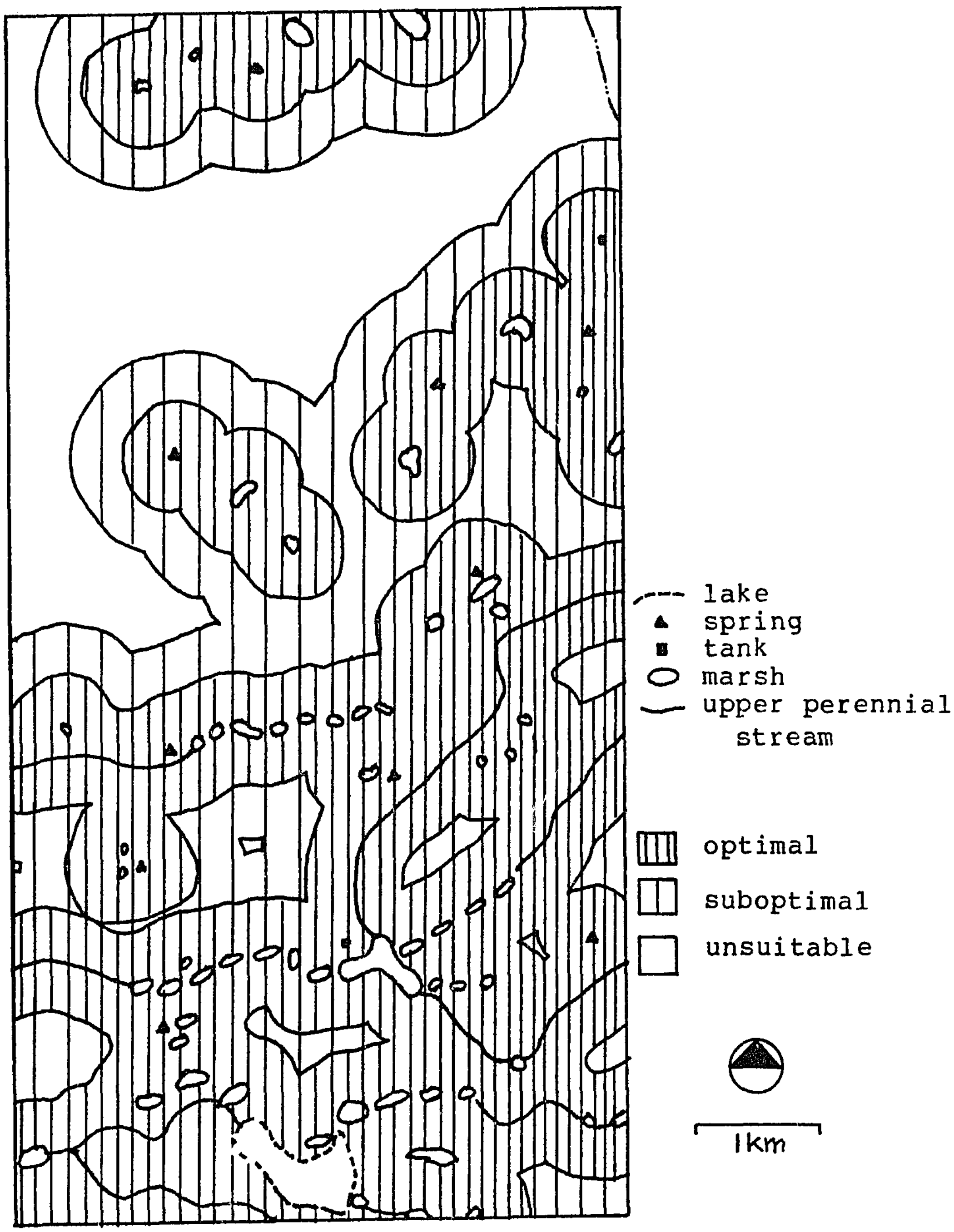


Figure 10. Water proximity habitat component map--Horseshoe Cienga.

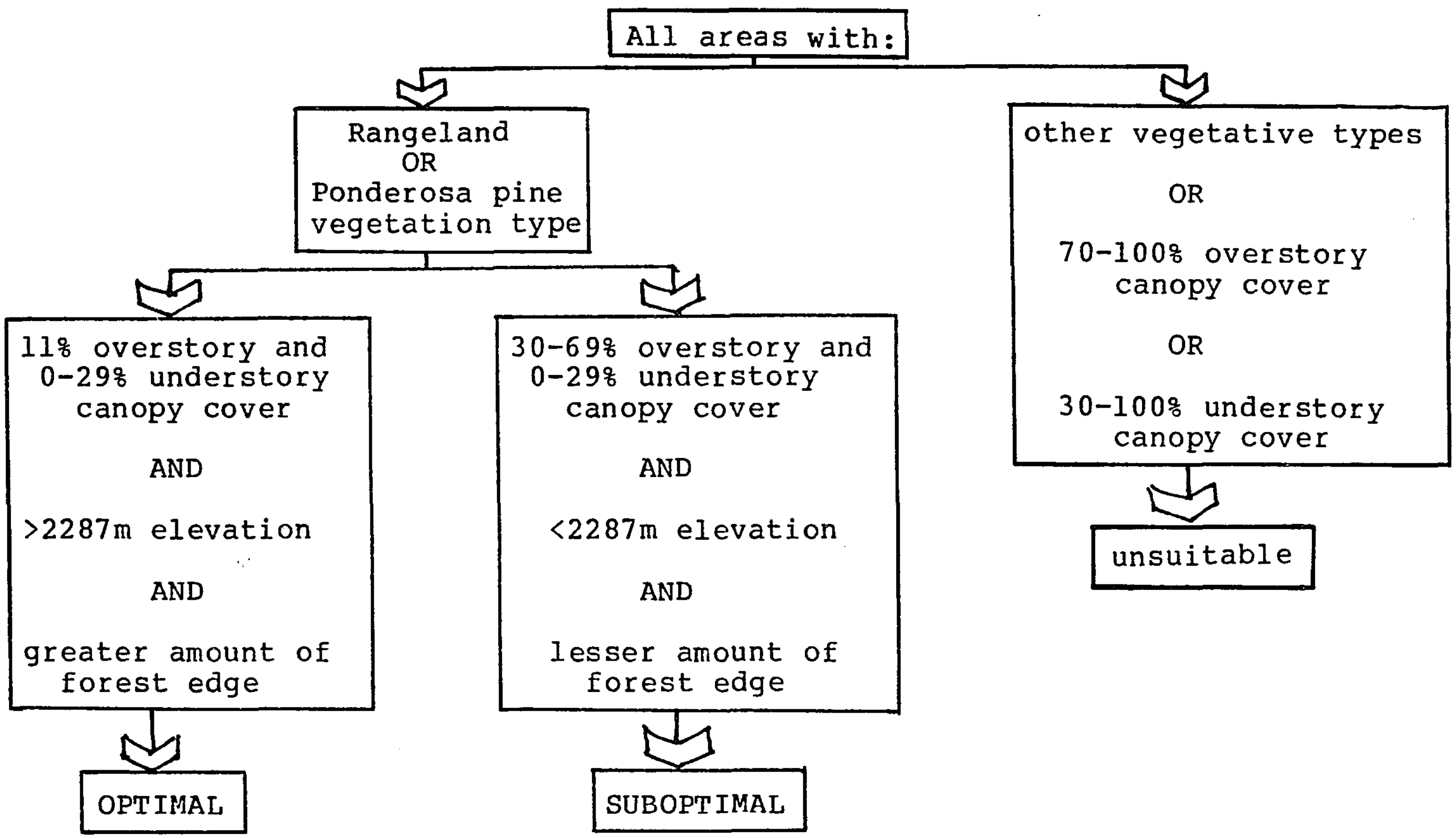


Figure 11. Forage areas decision-model.

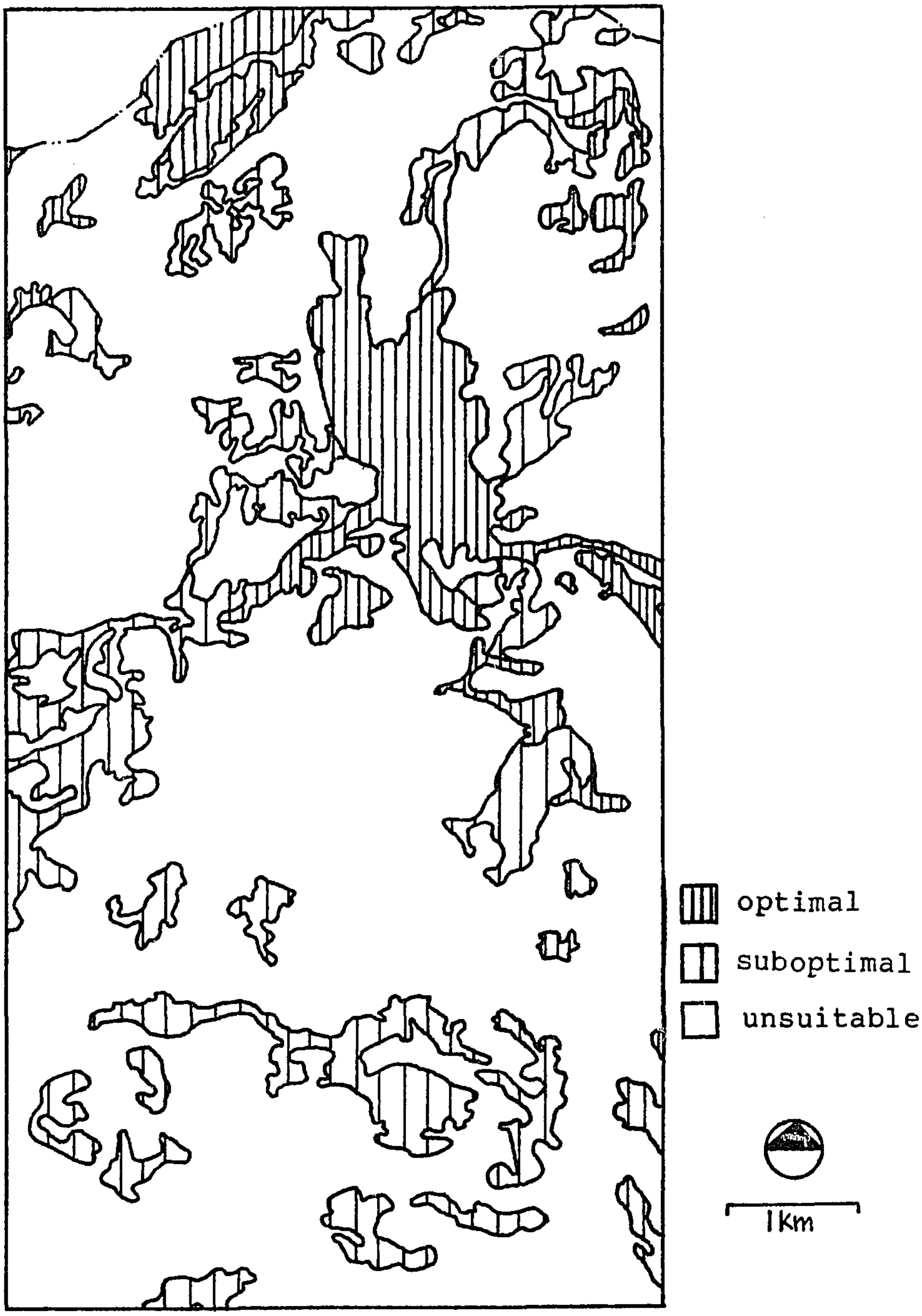


Figure 12. Forage area habitat component map--McNary.

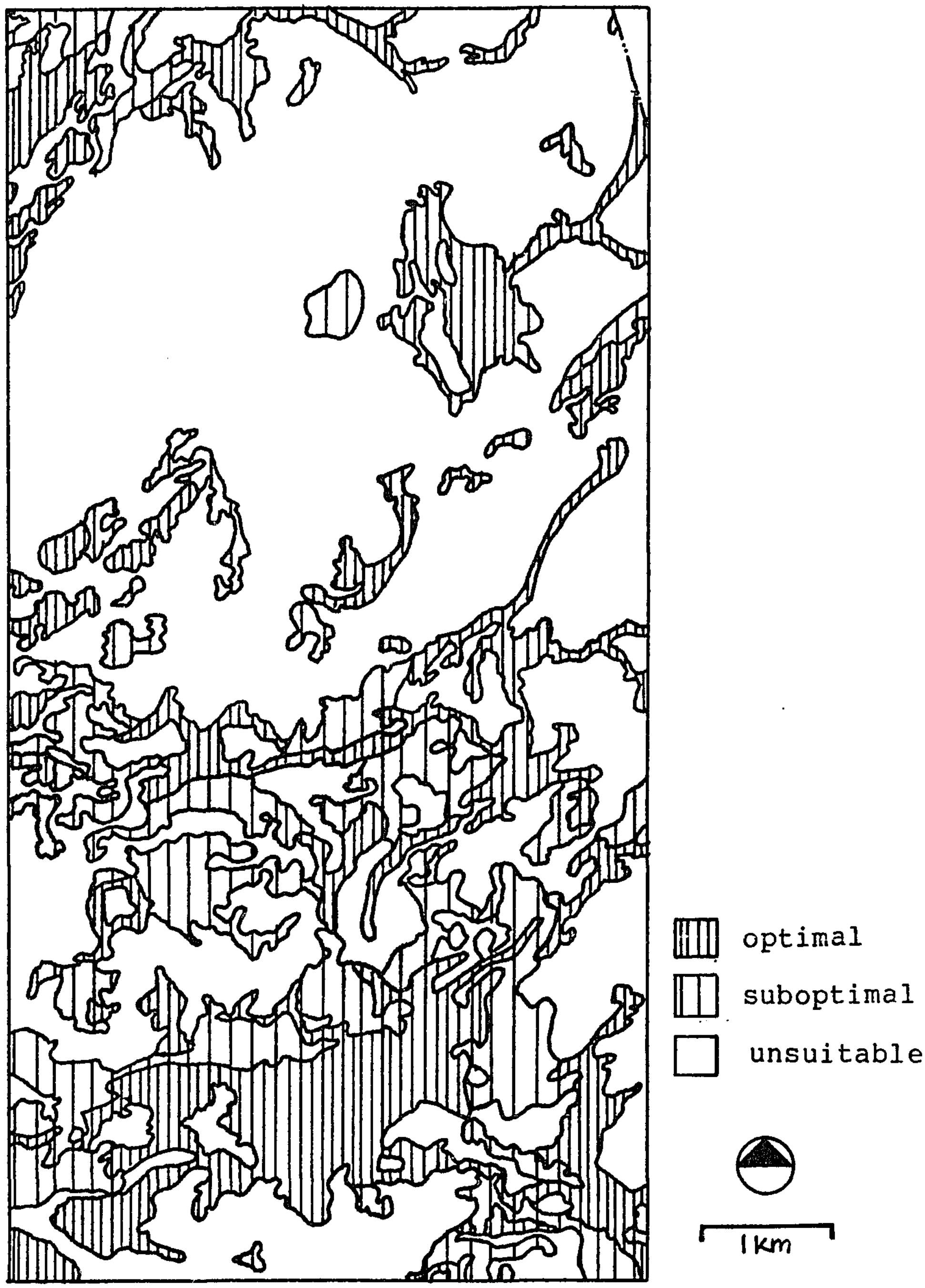


Figure 13. Forage area habitat component map--
Horseshoe Cienega.

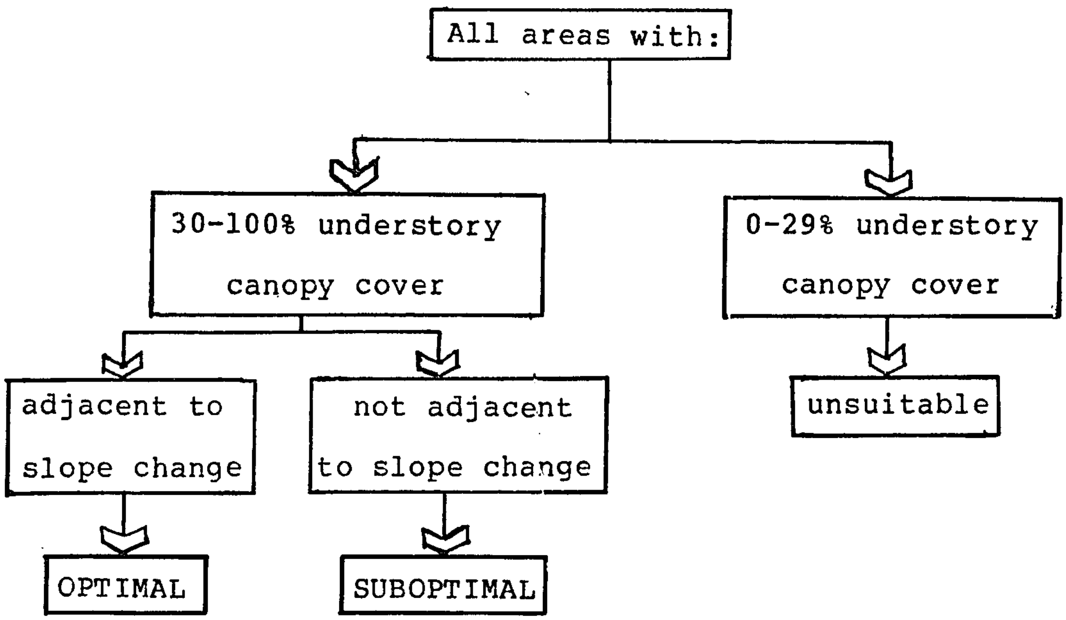


Figure 14. Hiding cover decision-model.

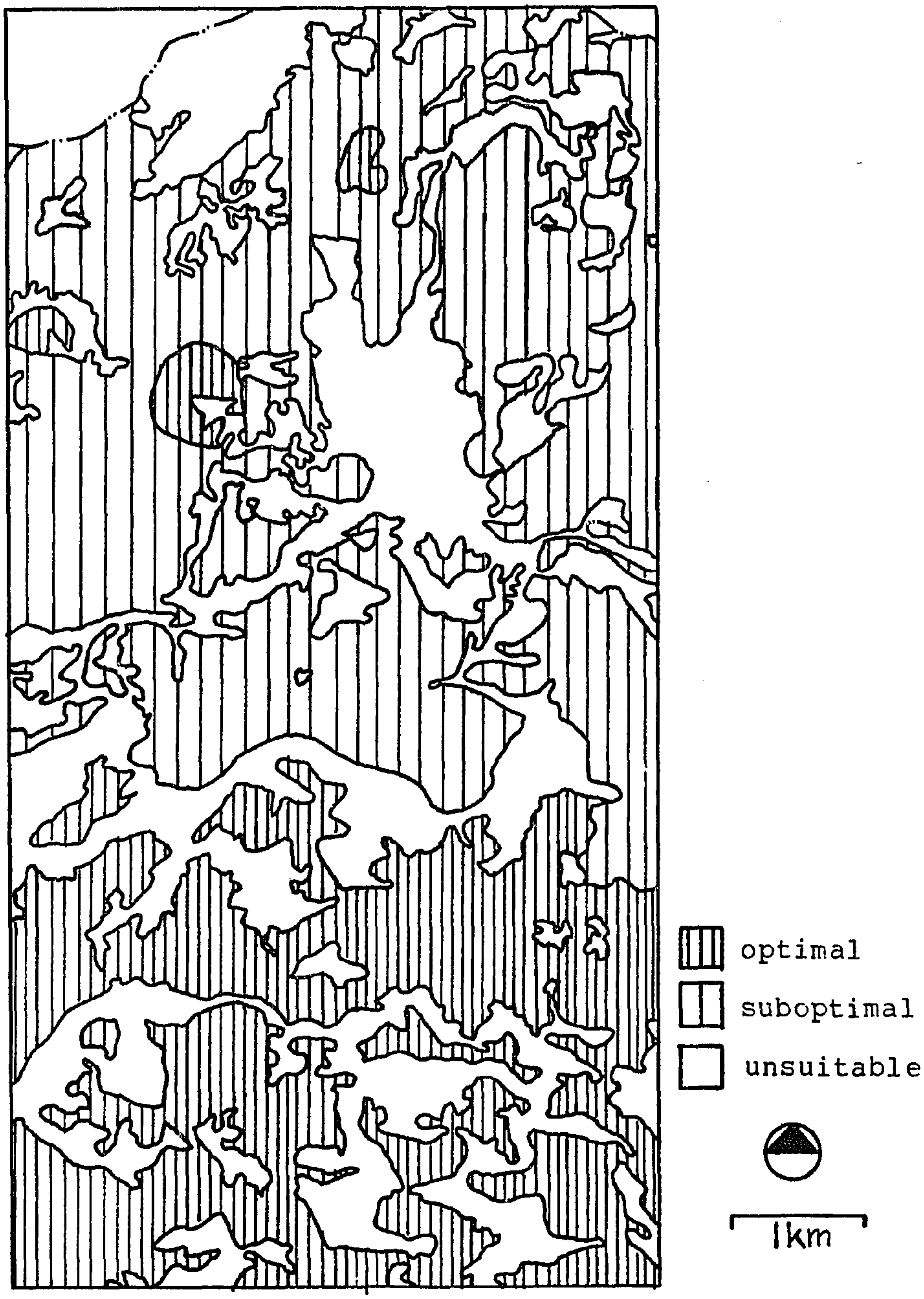


Figure 15. Hiding cover habitat component map--McNary.

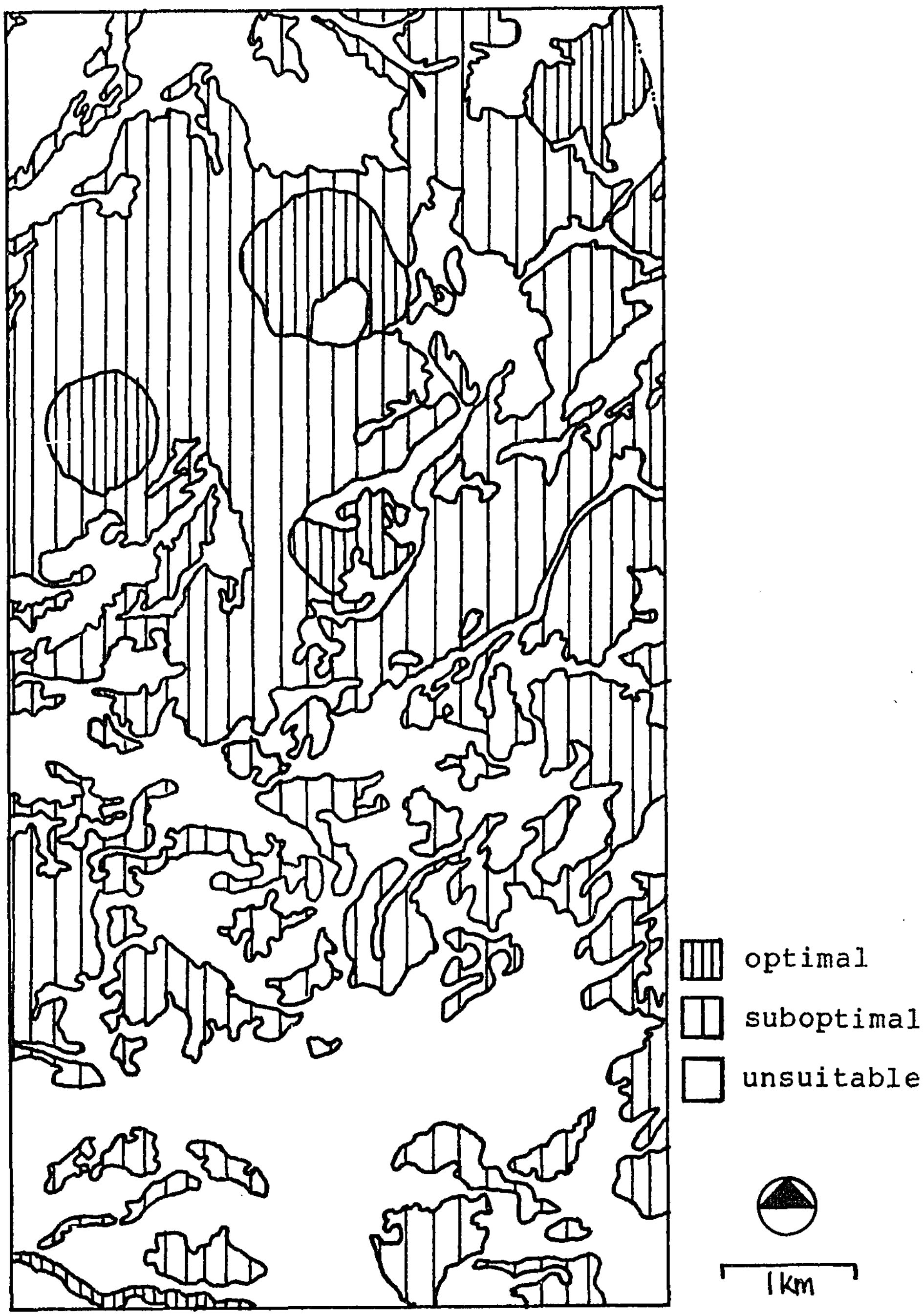


Figure 16. Hiding cover habitat component map--
Horseshoe Cienega.

The Mogollon Rim in the south and protruding mountain peaks to the north constitute adjacent slope change on these two case study areas.

Thermal cover is defined by a particular combination of overstory and understory canopy cover percentages (Figure 17). A dense overstory and open understory is represented by 30-100% overstory and 0-29% understory canopy covers (Figures 18 and 19).

Road impact areas are delineated by overlaying roads and canopy cover baseline resource maps. Each of the three road types is evaluated separately (Figure 20). Distance along roads impacted is dependent on density of roadside vegetation (Figures 21 and 22). For example, a main road passing through a meadow impacts up to 0.8km to either side unless denser vegetation is within that 0.8km distance. If that occurs, the resulting impact is decreased. Most impact areas on the two case studies were reduced due to the small meadows and adjacent dense vegetation.

All five habitat component maps are overlayed producing the habitat component composite map. The actual overlaying is done in two-steps creating a critical elk habitat map as an intermediate product (Figure 23). Forage areas and water proximity maps are combined for the critical elk habitat components map. Water proximity is used as the most important component thereby defining the geographic area that will be evaluated (Figures 24 and 25). All areas

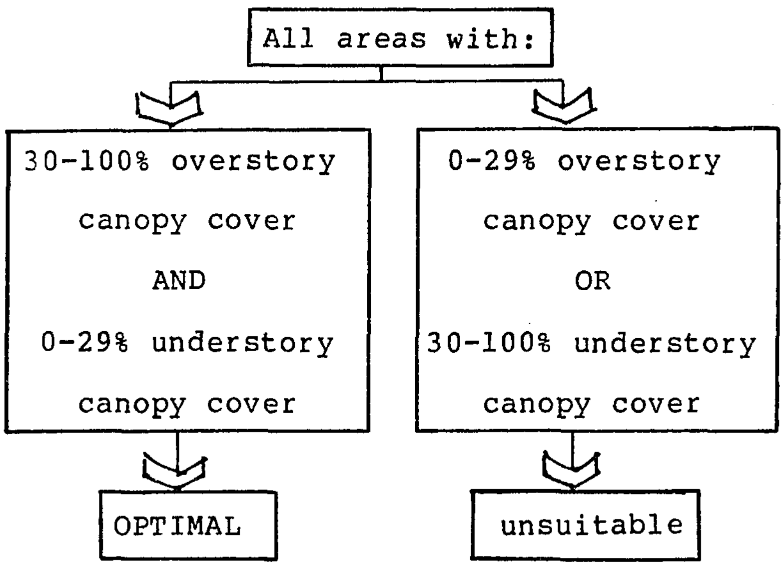


Figure 17. Thermal cover decision-model.

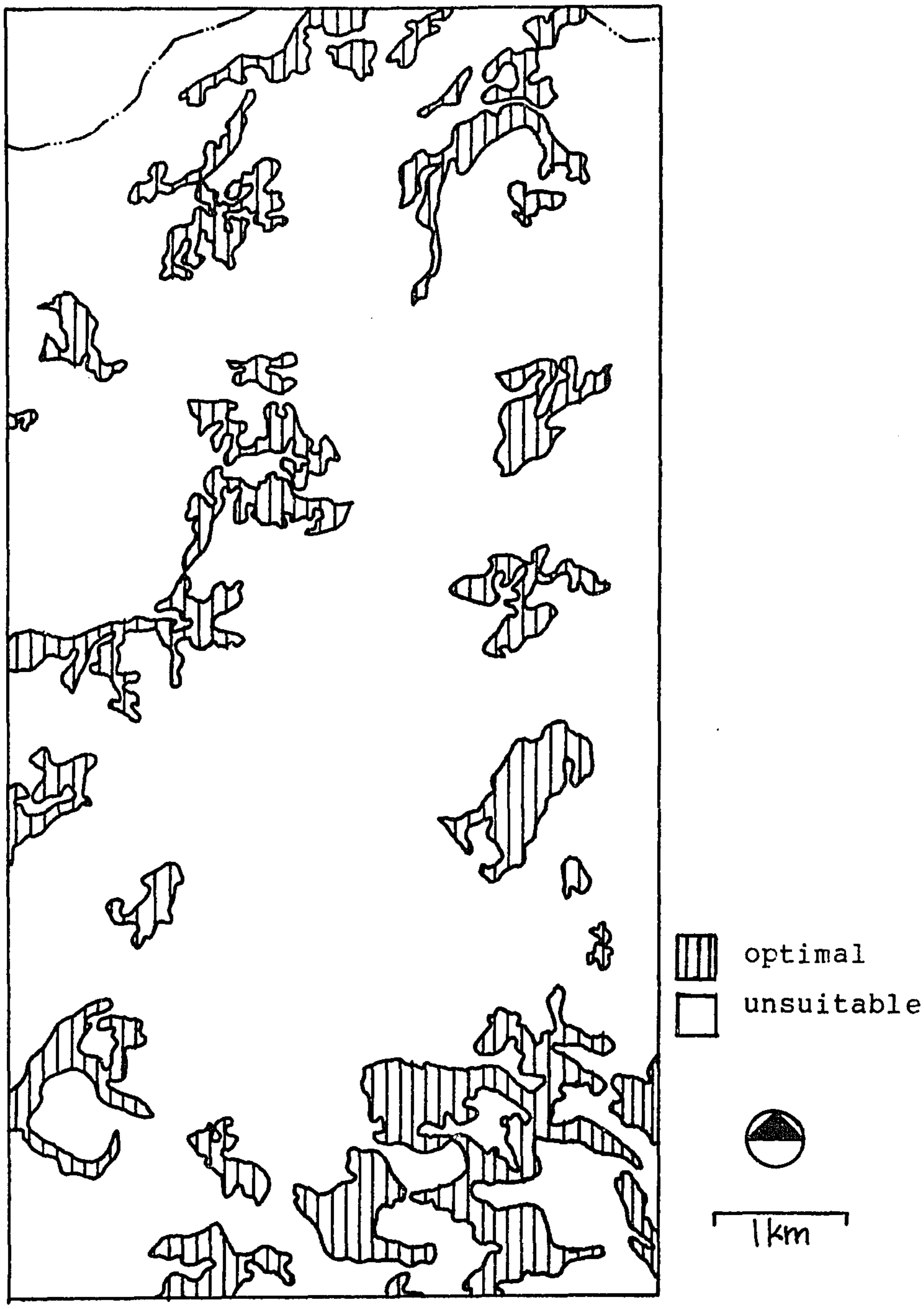


Figure 18. Thermal cover habitat component map--McNary.

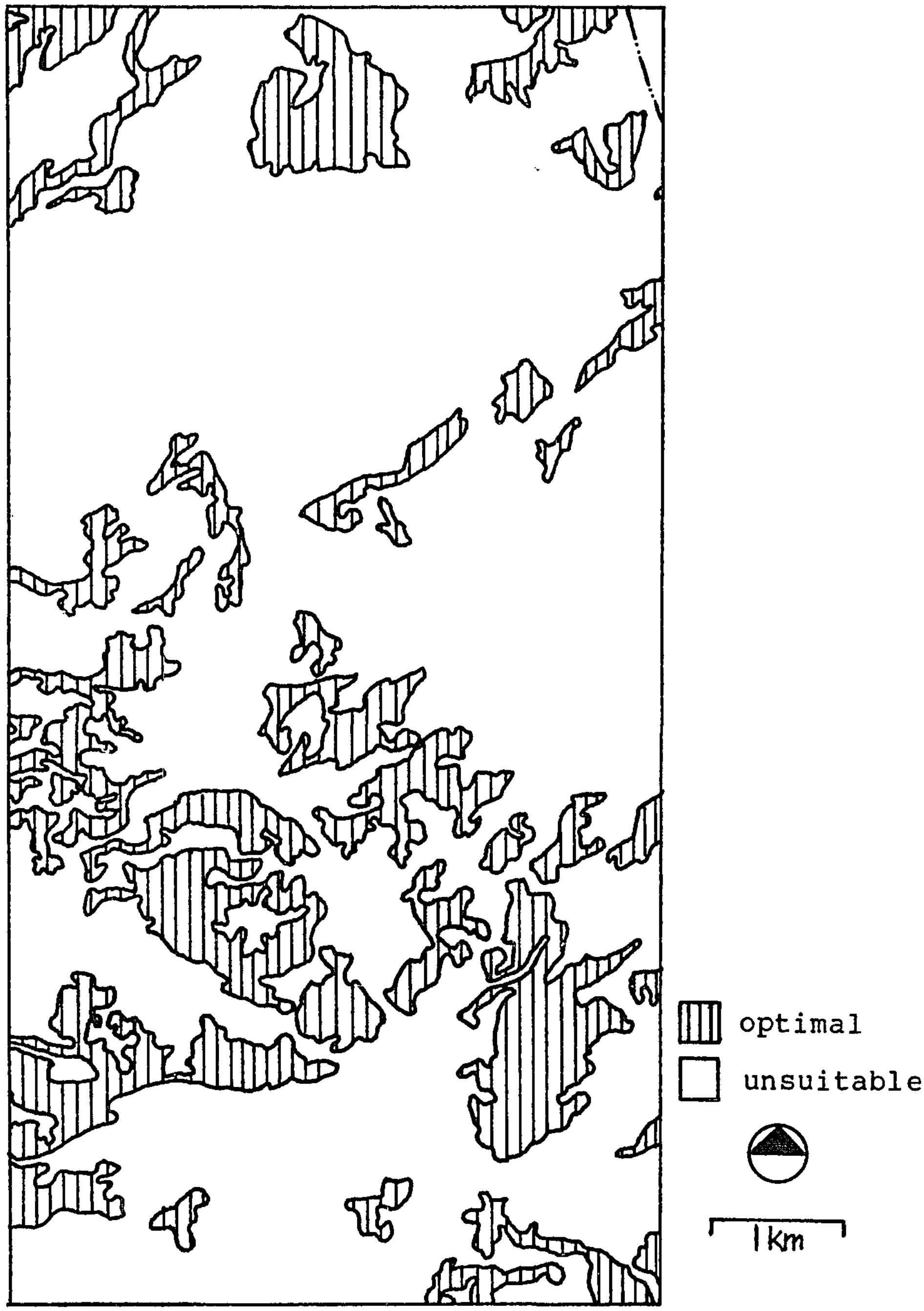


Figure 19. Thermal cover habitat component map--
Horseshoe Cienega.

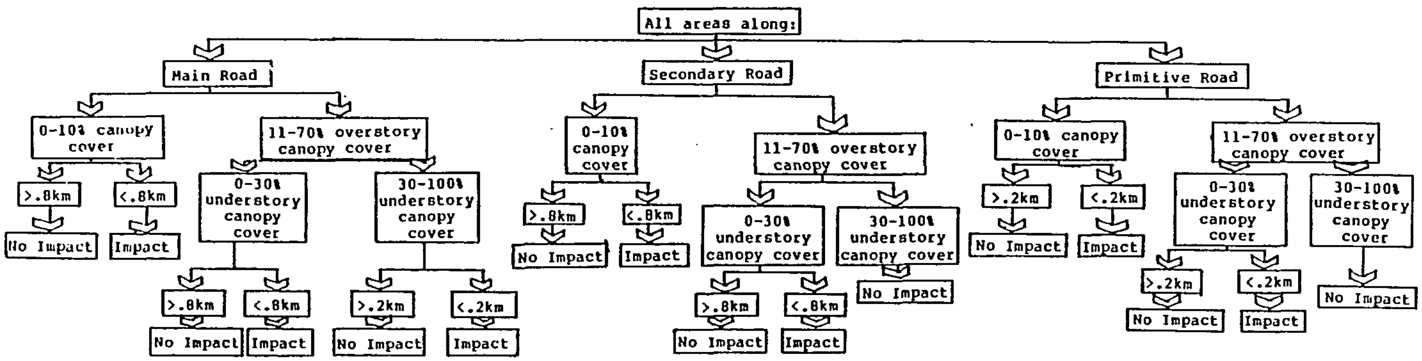


Figure 20. Road impact decision-model.

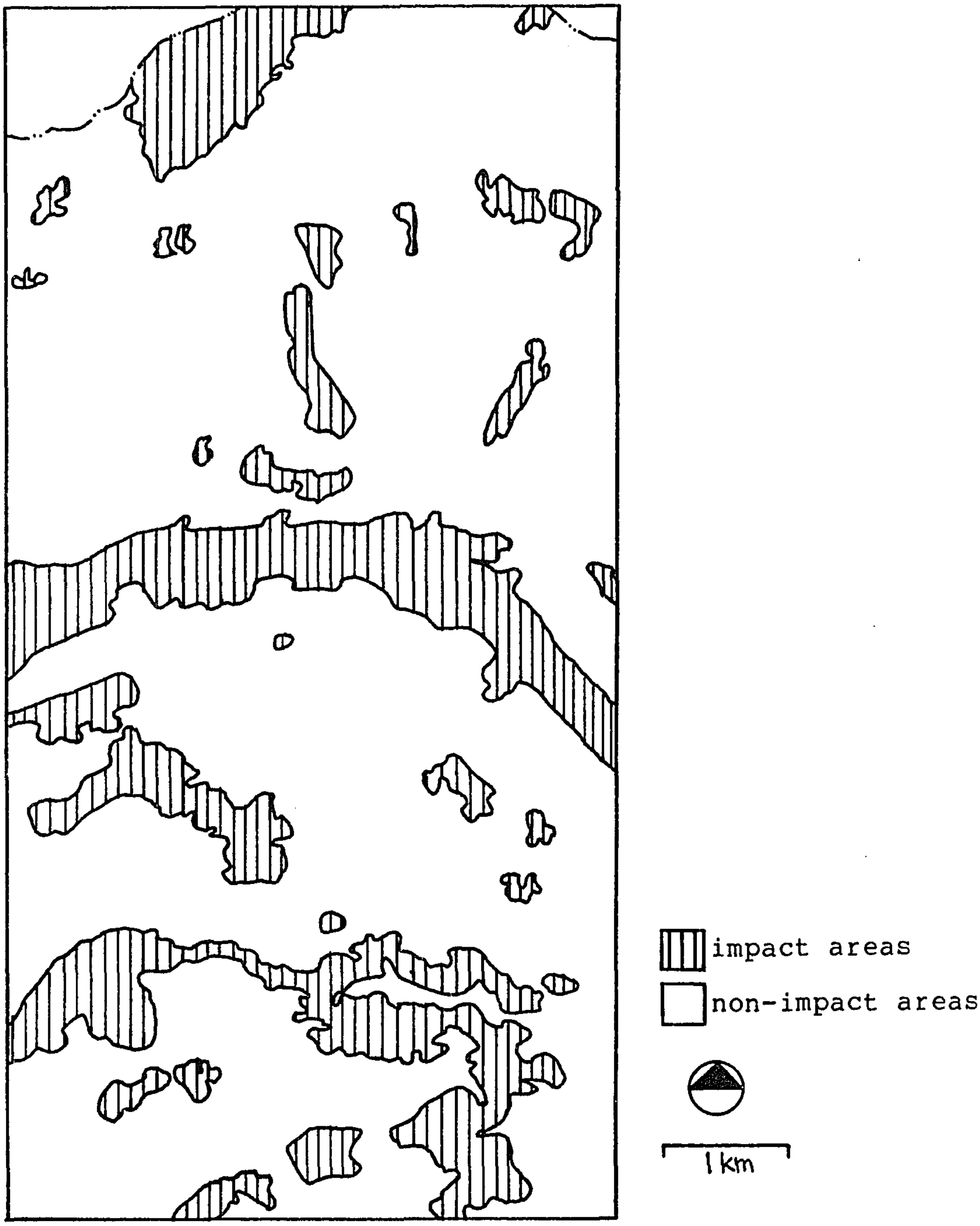


Figure 21. Road impacts habitat component map--McNary.

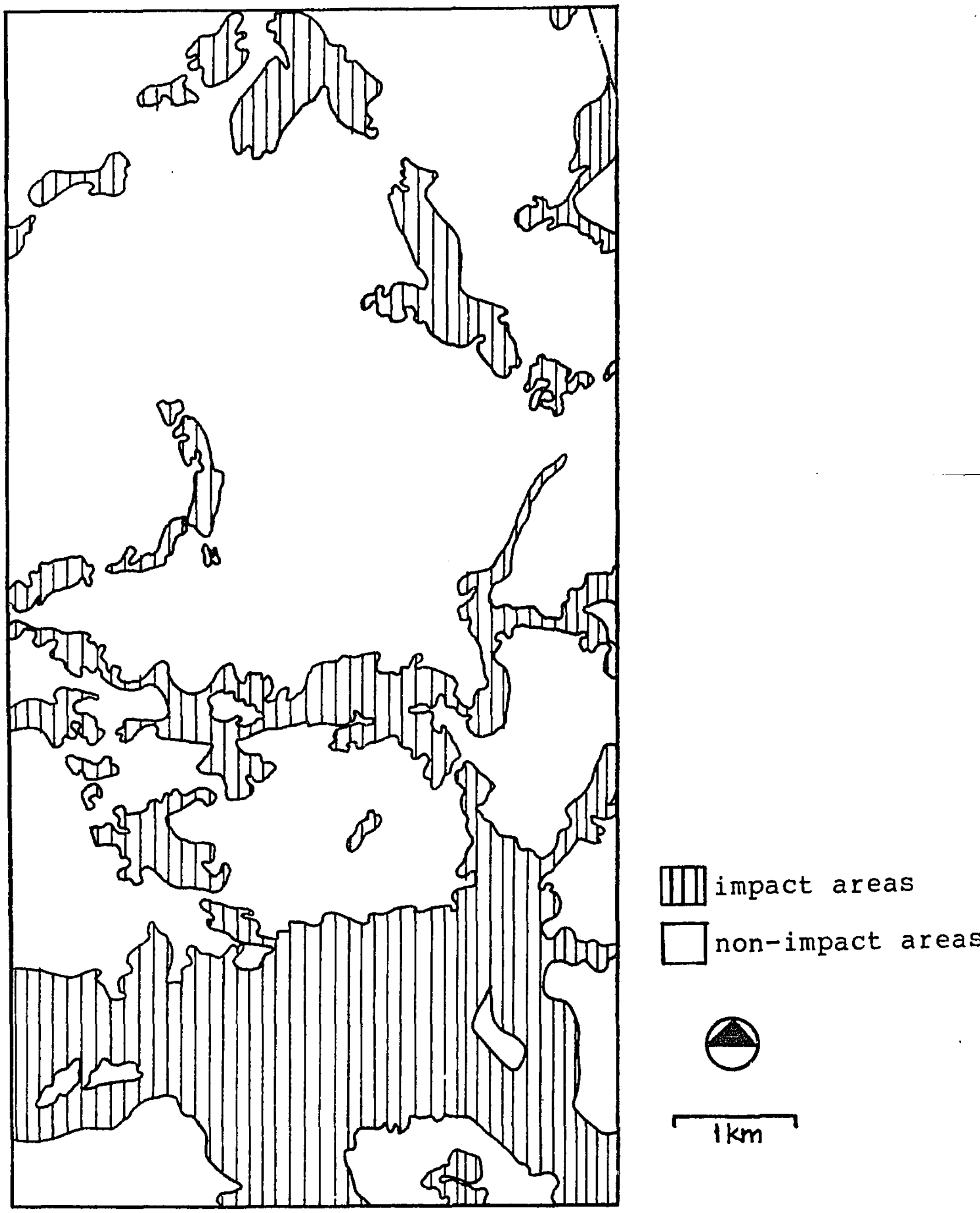


Figure 22. Road impacts habitat component map--
Horseshoe Cienega.

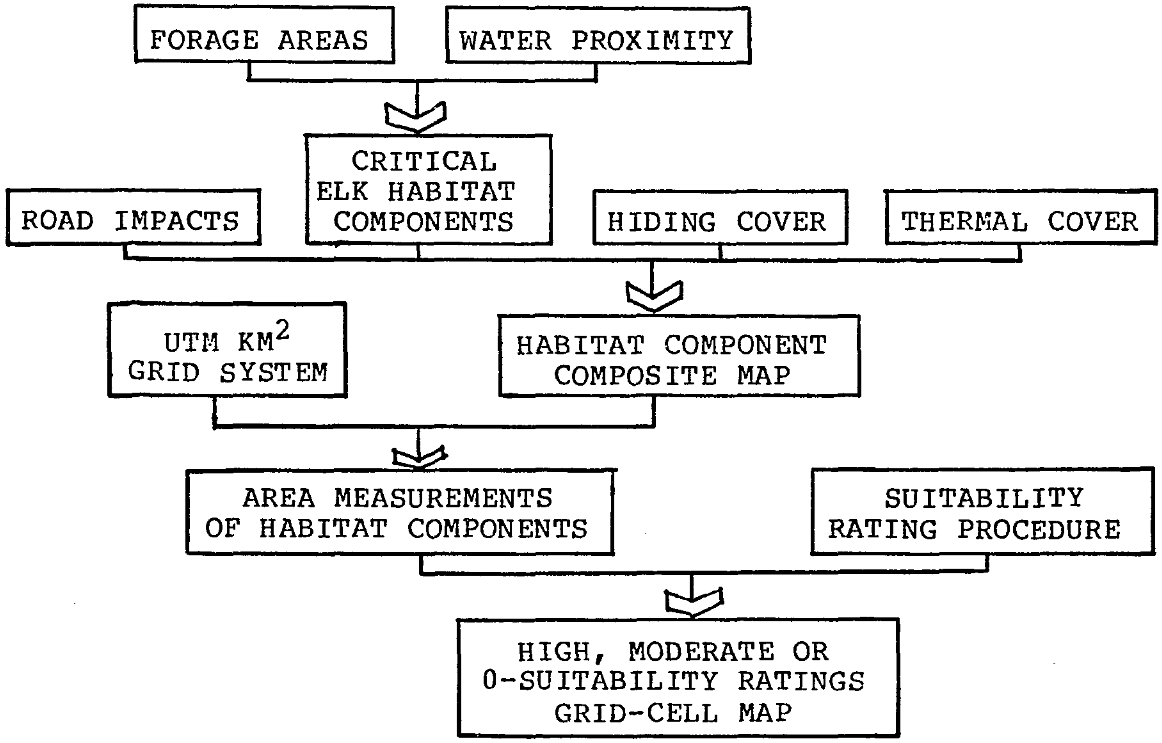
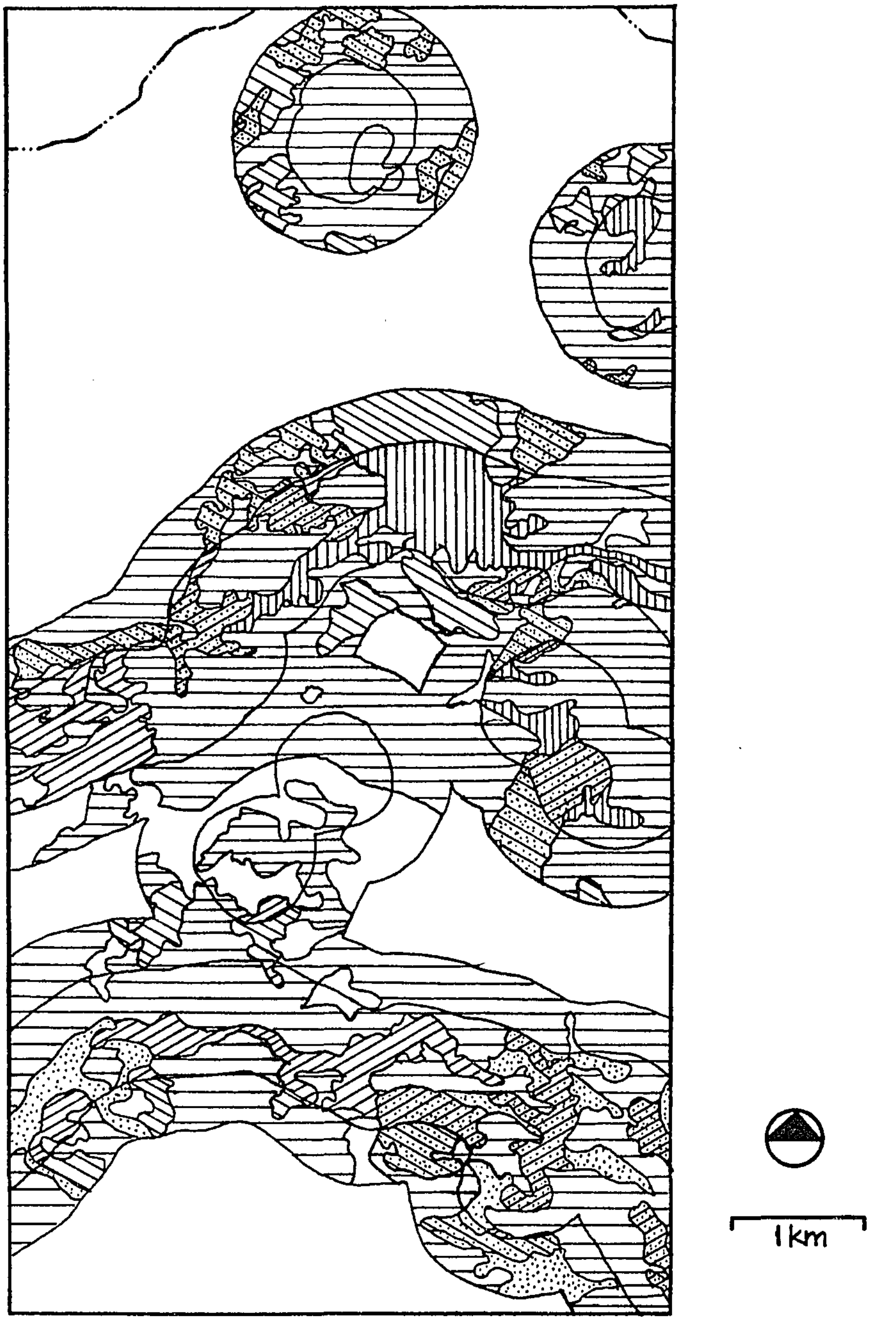
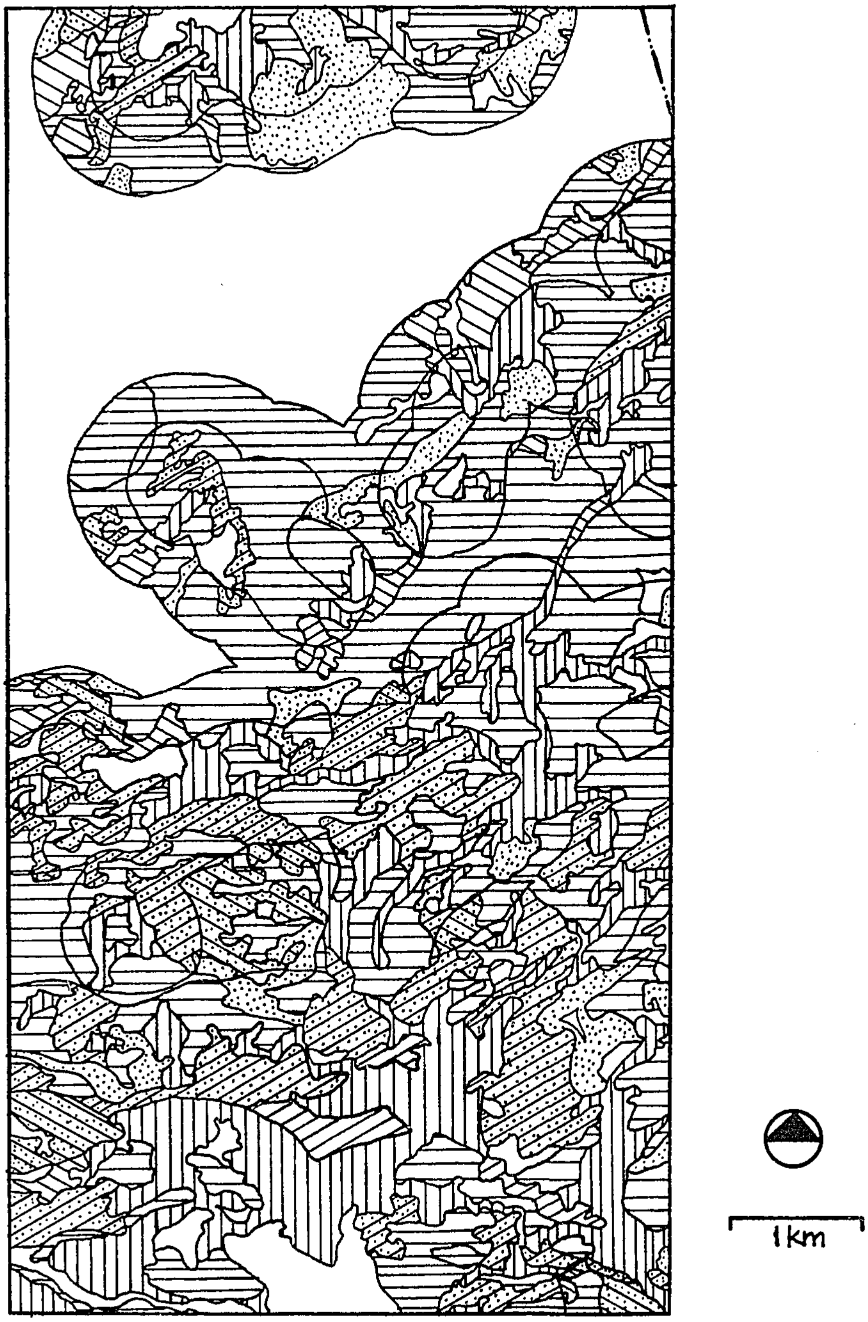


Figure 23. Mapping overlay combination method.



optimal water and forage 1
optimal water and suboptimal forage 2
suboptimal water and optimal or suboptimal forage 3
hiding cover
thermal cover

Figure 24. Habitat component composite map--McNary.



optimal water and forage 1
optimal water and suboptimal forage 2
suboptimal water and optimal or suboptimal forage 3
hiding cover
thermal cover

Figure 25. Habitat component composite map--
Horseshoe Cienega.

farther than 804m from a water feature are excluded from the final composite map. Thermal cover, hiding cover and road impacts are added to the critical habitat map resulting in the final habitat component composite map.

A km^2 grid system is used for the evaluation area for suitability ratings. The Universal Trans Mercator (UTM) grid is overlayed on the habitat component composite map. Each km2 grid cell containing any habitat component is numbered (Figures 26 and 27). Every polygon is measured and recorded by UTM grid cell for each habitat component (Tables 1 and 2).

Suitability ratings are based on Thomas et al (1979) optimal mix of habitat components translated to use in the Southwest U.S. by Rodiek and DelGiudice (in press). Thomas et al (1979) suggest 60% forage, 20% hiding cover and 20% thermal cover for the optimal mix of elk habitat in Oregon's Blue Mountains. Rodiek and DelGiudice (in press) translated that to 50% forage and 50% cover for optimal mix of elk habitat in the White Mountains. Higher summer temperatures increases the need for thermal cover on summer ranges. Figure 28 shows the general rating criteria for high and moderate suitability.

The actual suitability rating method (Figure 29) considers the area measurements, the habitat component composite map showing polygon configuration and the rating criteria. The rating procedure is developed into a list of

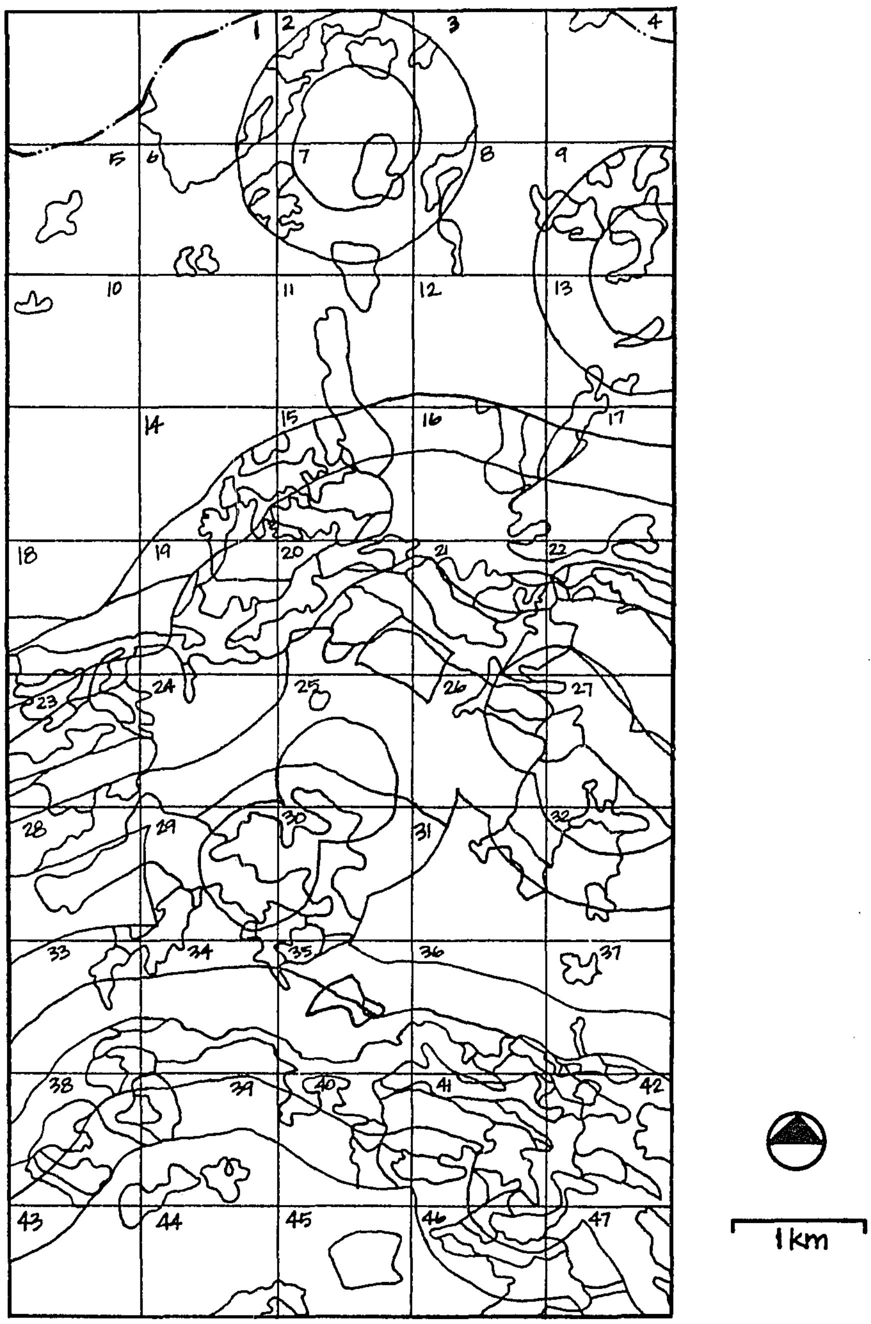


Figure 26. UTM-grid system--McNary.

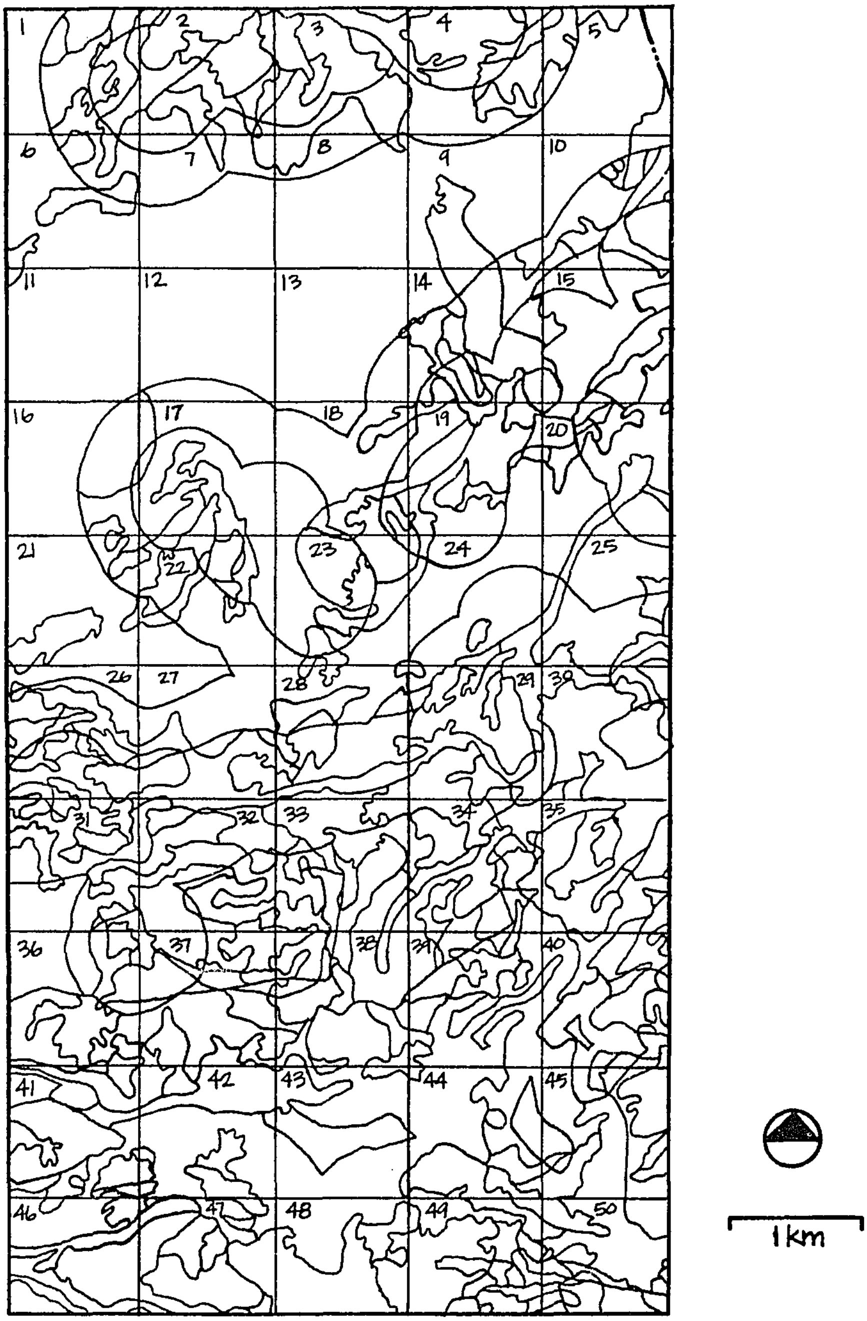


Figure 27. UTM-grid system--Horseshoe Cienega.

Table 1. Area measurements (in hectares) by grid-cell--McNary.

CELL #	ROAD IMPACT	THERMAL COVER	HIDING COVER		WATER PROXIMITY		FORAGE AREAS			SUITABILITY RATING
			S	O	S	O	1	2	3	
1	73	3.5	0.5	-	12.3	-	11.8	-	-	0
2	20.8	20.3	61	1.3	52	41	27.3	1	-	0
3	-	2.3	26	-	24	1	5.7	-	-	0
4	2.5	-	-	-	-	-	-	-	-	0
5	4.8	-	-	-	-	-	-	-	-	0
6	3.3	7	6.8	-	16	-	7	-	-	0
7	6	3.3	64	10	35	23	14.3	-	-	0
8	5.3	8.3	-	-	22	0.3	8.3	-	-	0
9	18.3	2.3	47	-	47	30	14	-	12	0
10	2	-	-	-	-	-	-	-	-	0
11	18	-	-	-	2.3	-	2.5	-	-	0
12	-	-	0.8	-	4.3	-	3.5	-	-	0
13	7.5	1.8	66	-	48	25	3	-	2.8	0
14	2	12.5	-	-	37	10	12.5	2	-	0
15	33	21	25	-	39	53	28.8	13.8	15.8	H
16	0.5	8	16.5	-	33	60	28	47	0.5	0
17	8	5.8	64	-	39	36	6.8	-	-	0
18	44	10.8	29	-	44	-	12.3	1.5	-	0
19	59	23	65	-	27	72	4.8	22.3	2.3	M
20	42	-	43	-	44	42	14	-	17	0
21	69	22	35	-	49	38	26.5	9	16	M
22	14	7	57	-	55	45	4.3	2	17	0
23	47	2	28	5	16	84	4	48	-	0
24	1.3	2	-	-	35	56	-	5.8	-	0

Table 1--continued

CELL #	ROAD IMPACT	THERMAL COVER	WATER PROXIMITY		HIDING COVER		FORAGE AREAS			SUITABILITY RATING
			S	O	S	O	1	2	3	
25	1.3	-	44	49	42	3	-	-	-	0
26	3.3	6	58	29	70	-	3	2.3	5.3	0
27	49	18	19	81	70	-	-	18	10	M
28	20	-	38	2	-	11	-	-	-	0
29	39	-	50	42	-	20	11	3	-	0
30	12	-	45	33	-	30	2.8	1.3	-	0
31	13	14	27	-	13	-	14	-	-	0
32	2.8	-	43	28	28	21	4.3	2.5	5.3	0
33	17	8.5	39	53	-	71	0.8	3	-	0
34	16	2	22	78	-	69	3.8	13.3	-	0
35	18.8	-	34	62	-	57	0.5	14.8	-	0
36	19.8	6.3	37	34	-	50	-	11.8	-	0
37	5.3	-	36	8	-	-	-	1	-	0
38	42	26	38	48	-	25	6.5	9.8	-	0
39	19.8	0.8	7	37	-	32	5.5	1.3	-	0
40	21	11	33	42	-	38	10	17	-	0
41	43	49	24	76	-	40	13	30	-	M
42	28	45	1	99	-	40	-	29	-	M
43	2	-	-	-	-	16	-	-	-	0
44	12	-	-	-	-	-	-	-	-	0
45	21	-	-	-	-	-	-	-	-	0
46	44	29	37	13	-	19	8.3	4	-	0
47	13	21	52	36	-	60	1	8.8	-	0

Table 2. Area measurements (in hectares) by grid-cell--
Horseshoe Cienega.

CELL #	ROAD IMPACT	THERMAL COVER	HIDING COVER		WATER PROXIMITY		FORAGE AREAS			SUITABILITY RATING
			S	O	S	O	1	2	3	
1	--	20	-	17	30	20	28	5.3	2.5	M
2	25	12	-	19	10	90	3	7.5	30	0
3	52	59	-	17	27	73	-	-	13	0
4	0.5	15	54	1	46	45	7.3	-	5.3	0
5	7.8	7.3	-	2.3	13	-	1	-	-	0
6	19	5	9	-	20	1	5.8	-	-	0
7	2	2	-	7.8	36	1.8	1.3	-	-	0
8	5	17	.75	-	18	-	-	-	-	0
9	4.5	-	4	-	5.3	-	1.5	-	-	0
10	6	4.3	29	-	45	23	11.8	-	5.8	0
11	.75	-	-	.75	-	.75	-	-	-	0
12	.75	-	11.3	.5	11.8	-	.5	-	-	0
13	-	-	12	-	12	-	-	-	-	0
14	44	4	12	-	41	36	27	-	24	0
15	4.3	16.5	58	-	7	93	-	10	16.8	0
16	-	2.5	15	27	40	2.5	2.5	-	-	0
17	11.3	15	66	5.3	31	69	-	15	4	0
18	-	13.3	73	7	62	31	-	-	1.3	0
19	-	18	59	-	19	79	1.3	-	14	0
20	15	6.5	69	-	36	64	3.8	-	15.3	0
21	17.3	3.8	2.3	-	11	-	6	-	-	0
22	12.8	8	50	-	50	28	7	4.3	1.8	0
23	-	6.3	47	26	42	58	8.3	3.8	10.8	0
24	6	1.3	80	-	30	66	1.5	-	10	0
25	13.3	1.5	66	-	36	60	1.8	-	8.8	0

Table 2--continued

CELL #	ROAD IMPACT	THERMAL COVER	HIDING COVER		WATER PROXIMITY		FORAGE AREAS			SUITABILITY RATING
			S	O	S	O	1	2	3	
26	26.8	27.3	23	-	44	41	17.8	16.8	2.3	M
27	28	1.5	46	-	42	41	5.5	4.8	1.8	O
28	42	39	40	-	39	61	4.5	21	12	M
29	41	20	32	-	-	100	-	19	31.8	M
30	18	-	68	-	17	83	2.3	-	18.5	O
31	12.5	26.5	23	17	20	80	1.3	27	3.5	M
32	34	58	20.8	-	29	71	15.5	39	9.8	H
33	9	11.8	39	-	31	69	9.3	17.5	19	O
34	25.3	34	27	-	10	90	3	22	18	M
35	20	23	36	-	6	94	-	23	22	M
36	1	15	58	-	19	80	-	13.5	12.3	O
37	39	28	38	-	21	79	7.3	13	11.5	M
38	39	38	28	-	12	88	2	34	16	H
39	58	31	23	-	5	95	4	32	26	M
40	53	35	24	-	12	88	-	15	14	M
41	90	46	8	-	37	63	29	17	8	O
42	97	26	6	-	-	100	-	21	50	O
43	100	10	1	-	-	100	-	31	58	O
44	94	21	16	-	6	94	-	30	41	O
45	48	32	30	-	5	95	-	19	26	M
46	30	27	7	7	-	100	-	27	41	O
47	28	10	25	8	-	100	-	-	26	O
48	84	10	7	-	-	100	-	9	28	O
49	38	18.8	45	-	4	94	-	22.5	22.3	M
50	67	23.8	27.3	-	24	76	15	10.8	38	O

	SUITABILITY RATING	
HABITAT COMPONENT	HIGH	MODERATE
Water Proximity	optimal	optimal suboptimal
Forage Areas	optimal	optimal suboptimal
Hiding Cover	optimal suboptimal	optimal suboptimal
Thermal Cover	optimal	optimal

Figure 28. Suitability rating criteria.

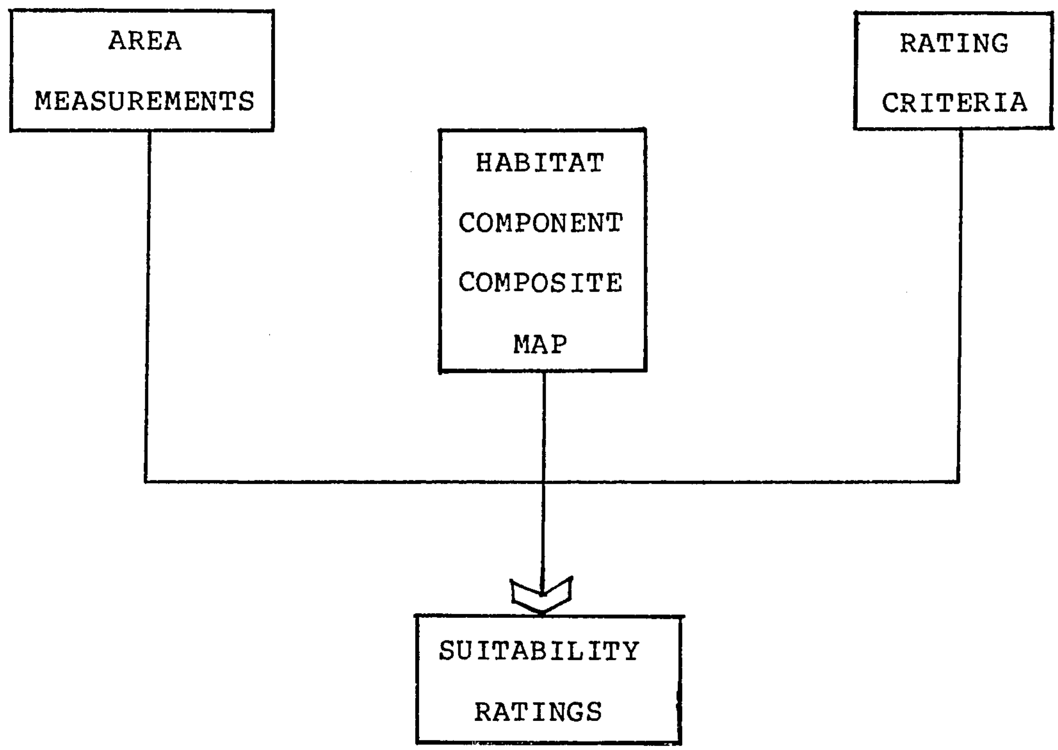


Figure 29. Suitability rating method.

questions in an "if-go to statement" format (Figure 30). Optimal mix percentages for each habitat component are included in the series of questions refering to the percent area measurements. Beginning with question 1 FORAGE AREAS, each question is checked and answered in sequential order. A simplified graphic presentation of the rating procedure is illustrated in Figure 31.

This rating procedure is completed for each km^2 grid cell. The final suitability ratings for the 2 case study areas are included in Tables 1 and 2. When working through the procedure, if any component is rated MODERATE that cell automatically is reduced to a MODERATE or ZERO rating. Similarly, if any cell has a ZERO rating for one component the entire cell is rated ZERO. Grid cell ratings can be transferred to final suitability rating maps when completed (Figures 32 and 33).

Document the Model

Documentation takes place throughout the entire model development and is one of the most critical features of the HEP process. USFWS (1981) lists four reasons for the importance of documentation: one, the user understands the objectives and assumptions of the model; two, to inform the user about evaluation species and habitat use; three, the user understands the model outputs and results; and four, documentation is necessary for adaptation and updating of the model. Many resource decisions have been made in the

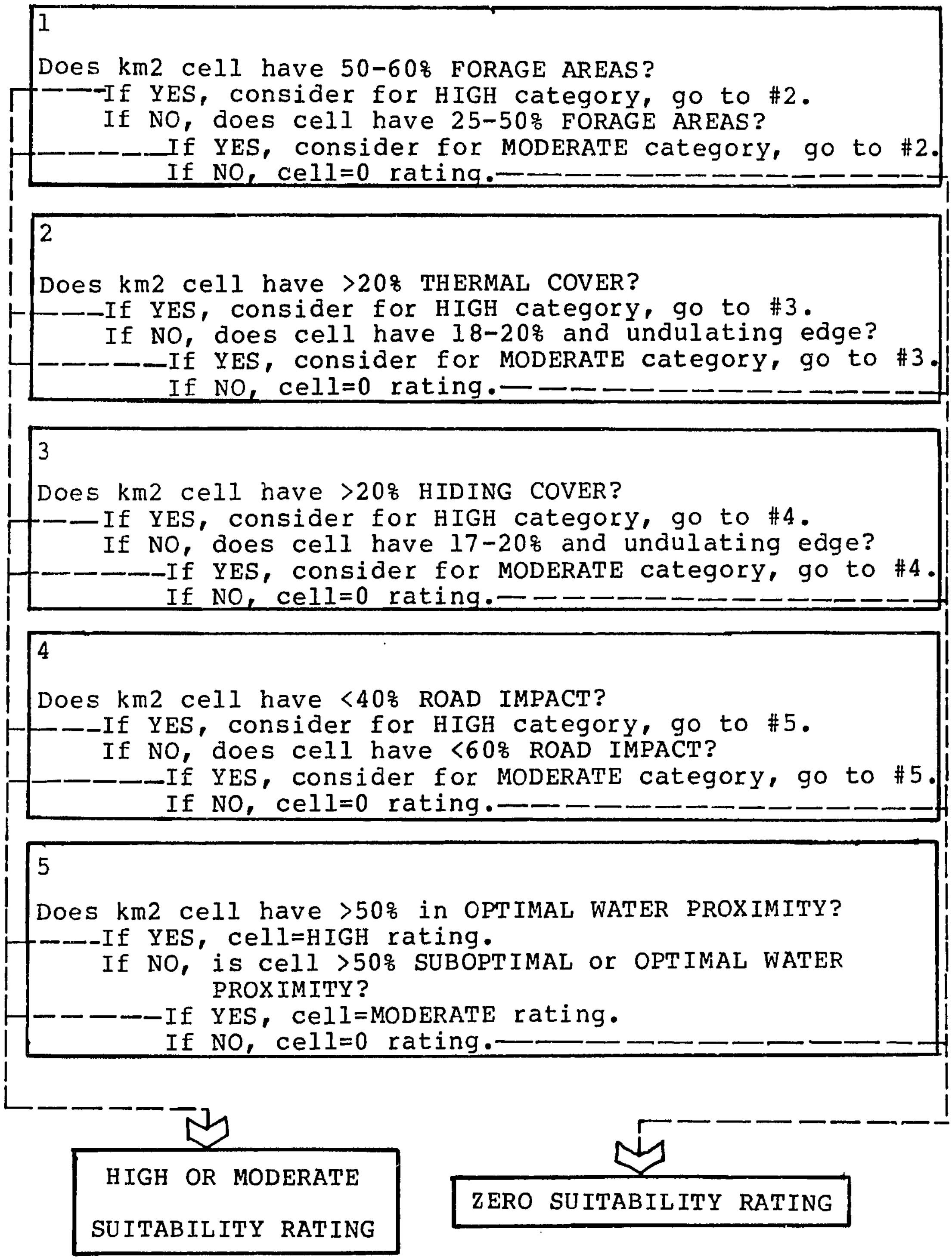


Figure 30. Suitability rating procedure.

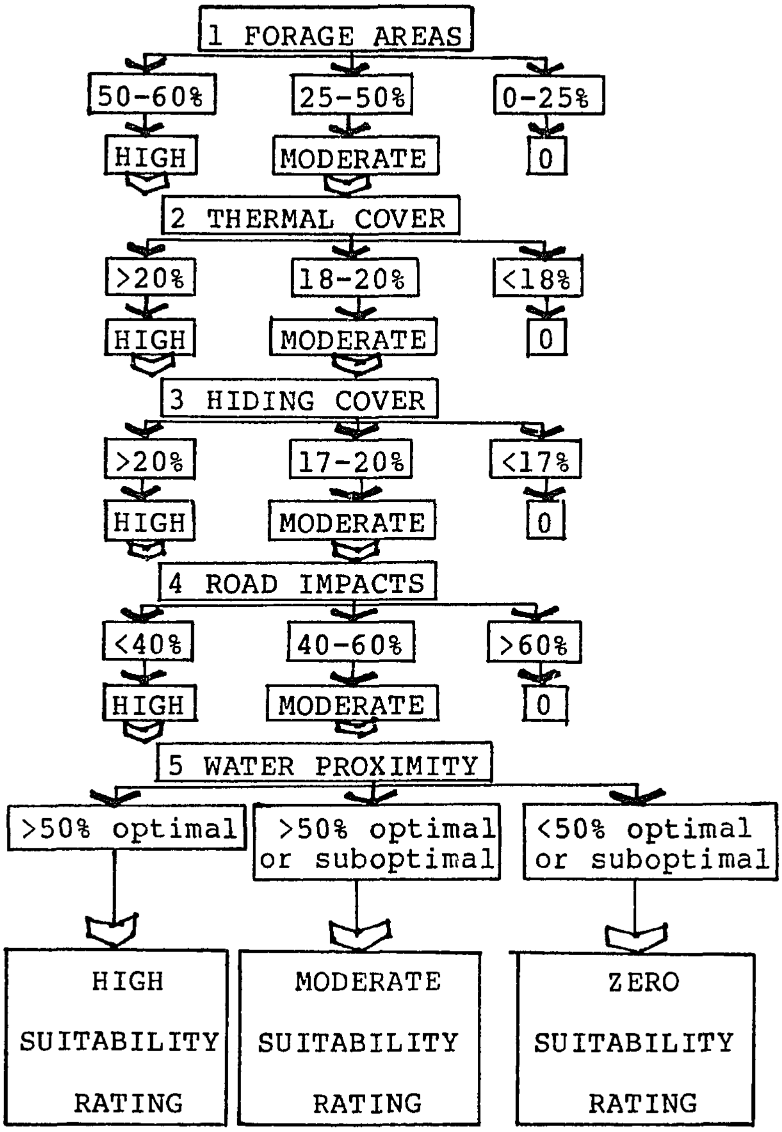


Figure 31. Simplified suitability rating procedure.

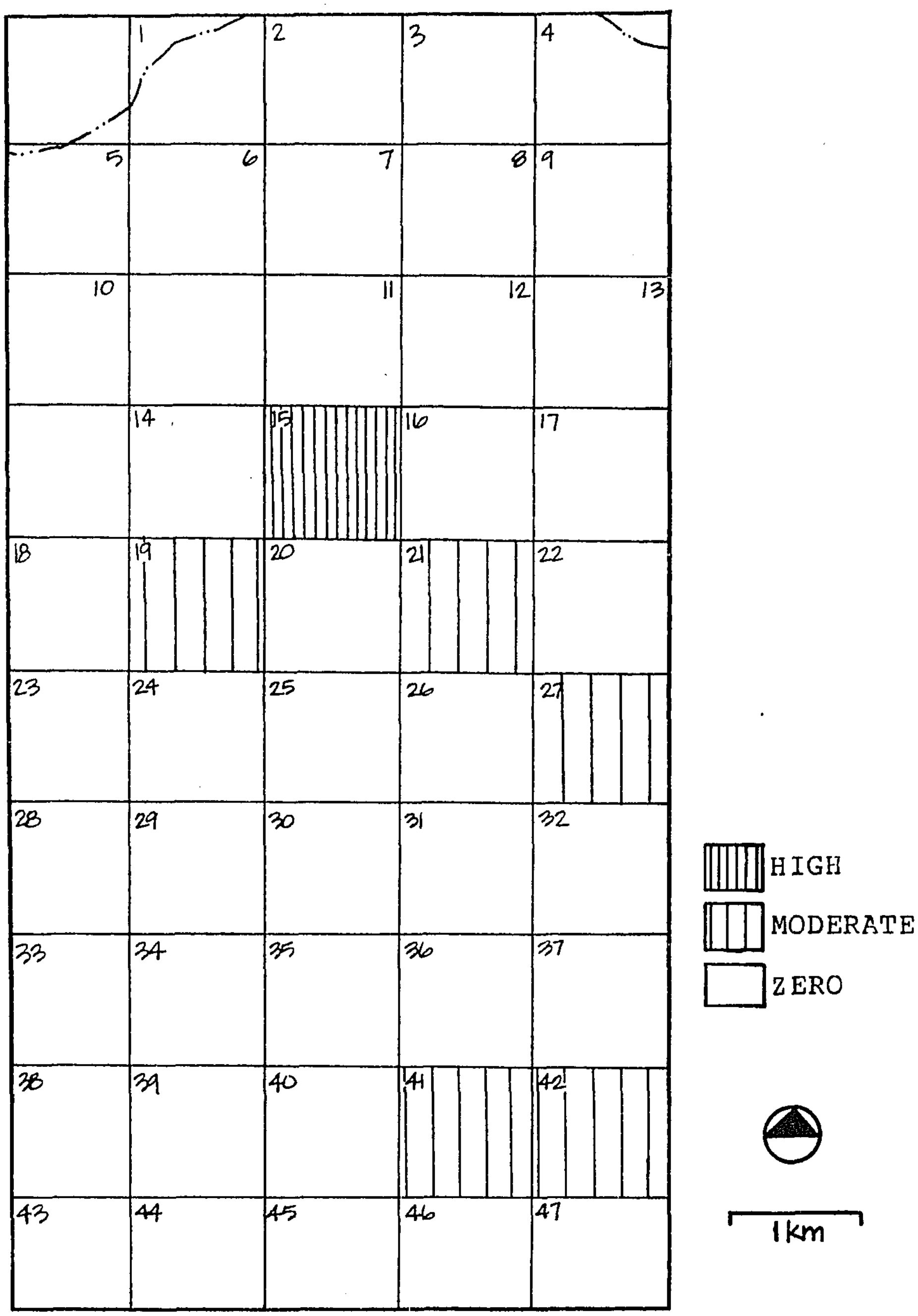


Figure 32. Final suitability ratings--McNary.

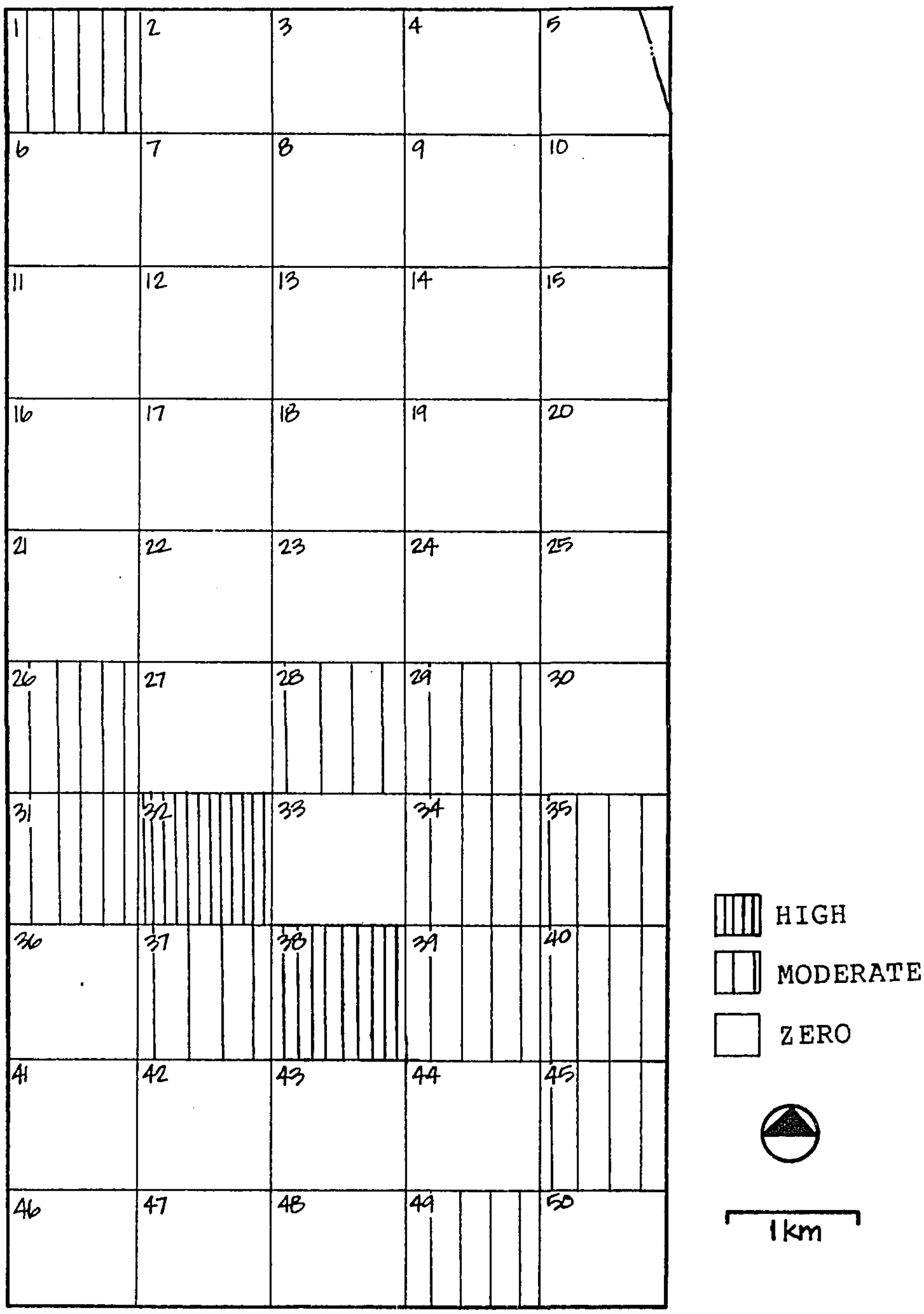


Figure 33. Final suitability ratings--Horseshoe Cienega.

past without documenting the basis for those decisions. HEP provides a documented structure to justify resource decisions. The first, third and fourth reasons are most important for this study which presents an actual technique and not necessarily elk habitat information. Documentation is used to communicate the technique to potential users. Documentation needs to be specific and detailed enough for a user to apply the model correctly on a different study area.

Verify the Model

Model verification is used as a final check of the model outputs as previously defined in the objectives (USFWS 1981). Farmer et al (1982) describes verification as an evaluation process to determine if the "behaves as the model builder intended and if this behavior conforms to currently accepted biological theory and operational feasibility". Models can be verified at several levels as described in the model outputs objective. One, the author reviews the documented model checking assumptions and procedures. The model can be applied to sample data such as DelGiudice's (1982) adjacent study area. Species authorities can review the model to evaluate the habitat information and assumptions used to define the habitat components and variables. The ultimate step in verification is model validation where the model is compared to real environmental conditions and evaluated for how well it matches (Farmer et al 1982). Model outputs can be compared to actual animal sightings as part of a long term habitat utilization project to make correlations between potential habitat use variables and actual use areas.

This model is verified to a particular acceptance level previously described in the model output objective. The habitat variables and mapping system has been applied to an adjacent area. An evaluation of the rating procedure and results of the verification process is discussed in Chapter 4.

CHAPTER 4

RESULTS AND DISCUSSION

Results

Mapping Technique Outputs

Each of six steps in the mapping system technique results in an output product (Figure 34). The initial species literature review results in identified habitat variables. Habitat variables are transferred to geographic format by the optimal and suboptimal conditions combined to produce the habitat component maps. Overlaying all the habitat component maps results in one composite map showing the spatial relationships between the habitat components. All resulting polygons in the composite map are measured producing quantification of habitat components by grid-cells. The final suitability ratings are completed for each UTM grid-cell and transferred to geographic format. The suitability rating map allows areas with high potential for elk use to be identified in a geographic format. Ratings for the 100km^2 area evaluated resulted in three km^2 having high suitability, 18 km^2 having moderate suitability and the remaining 79km^2 currently unsuitable for elk summer range.

STEPS IN COMPLETING MAPPING TECHNIQUE	OUTPUT PRODUCT
1 species literature review	habitat variable including optimal and suboptimal conditions
2 transfer habitat variables to geographic format	habitat component maps
3 overlay habitat component maps	habitat component composite maps
4 measure all polygons (in hectares) by grid-cell	area measurements of habitat components and percent of each grid-cell
5 complete suitability rating evaluation for each grid-cell	suitability ratings
6 transfer ratings to map	grid-cell map showing suitability ratings for potential habitat

Figure 34. Mapping system technique steps and products.

Elk Habitat Use Information

Another important result of developing a species suitability model is a summary of habitat information for the selected species in the particular geographic area. Documentation of current species habitat use knowledge allows future users to know what information was considered and where the model may be updated. The following discussion summarizes habitat studies utilized in developing this model for elk in the White Mountains. Elk habitat use studies completed and on-going in the Pacific Northwest have identified specific habitat components and variables (Marcum 1976, Perry and Overly 1976, Thomas et al 1979, Leckenby and Adams 1981, Skovlin 1982). Optimal habitat conditions have been identified including forest structure for hiding and thermal cover, proximity to potable water, road impacts and forage areas. Reynolds (1966a, 1966b) studied elk, deer and cattle use of forest edge areas in ponderosa pine and spruce-fir forests in Arizona developing proximity distances of openings for preferred use. DelGiudice (1982) observed elk using specific areas in Arizona's White Mountains and listed characteristics common to those specific high use areas. DelGiudice and Rodiek (in preparation) have identified water proximity criteria for elk habitat. Rodiek and DelGiudice (1982, in press) have used current elk habitat utilization knowledge from the Pacific Northwest and Arizona to develop forest management criteria for elk habitat improvement.

Thomas et al (1979) summarized and synthesized elk habitat utilization information in the Pacific Northwest in developing the habitat component optimal mix criteria to use in forest management. Rodiek and DelGiudice (1982, in press) transferred Thomas et al (1979) work altering the criteria to better describe elk habitat utilization in Arizona's White Mountains. Therefore, the work of Thomas et al (1979), Rodiek and DelGiudice (1982, in press) served as a basis for the habitat variables identified in this predictive habitat mapping technique.

Mapping System Technique

The mapping system technique developed in this study is an habitat analysis and evaluation technique related to the methods used in Thomas et al (1979) and USFWS Habitat Evaluation Procedures (1981). The technique is based on principles in both Thomas et al (1979) and USFWS (1981) habitat evaluation techniques transferred to a geographic format. The actual mapping and suitability rating methods are structured for application to any species or geographic area. The structure of the mapping technique including making the habitat component maps, overlaying and combining the maps, measuring the polygon areas and rating the grid cells are all dependent upon the information provided in the habitat variables. Habitat variables can be defined by careful study for any wildlife species in any geographic location. Rocky Mountain elk and Arizona's White Mountains were used only as a case study in developing and illustrating this mapping technique.

Discussion

Evaluation of Model Output Results

The acceptance level of the elk habitat suitability model is dependent on the level of verification as previously described in Chapter 3. Evaluating the habitat variables identified and the suitability ratings provides more information to ascertain the accuracy of the model to represent reality, thereby increasing the acceptance level for model applicability.

DelGiudice (1982) identified six high use forage areas for late spring-summer seasons. All six areas are micro- or macro-openings in moderate (30-80%) to dense (80-100%) forest canopy cover located above 2287m elevation. All six forage areas have a source of potable water on-site. Hiding cover was measured following Thomas et al (1979) criteria and found to be optimal on at least three sides of the openings. Road impact and thermal cover were more difficult to assess because no understory canopy cover information was available. Road accessability was rated easy on 67% of the sites and remote on the remaining 33%. But roads are defined as rut roads in the study, so according to Perry and Overly (1976) the roads would have little impact on habitat use particularly in denser forests. Thermal cover is rated high according to the overstory canopy cover, but is difficult to further assess with the lack of understory canopy cover information. All of the habitat variables identified through this technique are present in DelGiudice (1982) six high use areas. Analysis of available information suggests the six high use areas would be rated moderate to high suitability using the mapping technique developed in this study.

Suitability ratings lower than high for grid-cells (Tables 1 and 2) are each lacking a particular habirat component limiting its overall suitability. Analysis for limiting components in each cell is listed in Appendix B while the information is summarized in Table 3. Thermal cover is the most limiting habitat component in both the McNary and Horseshoe Cienega areas preventing cells from being considered suitable at all. Thomas et al (1979) identifies thermal cover to be the limiting factor in the Blue Mountains of Oregon and Washington elk habitat. Forage areas are second to thermal cover in limiting suitability in both case study areas. Less than 50% forage areas is the overwhelming limitation keeping moderate rated cells from the high suitability category in both areas. Road impacts are the next habitat component reducing the number of high ratings. The state highway passing through both of the areas drastically increases the amount of road impacts

Table 3. Limiting habitat components in suitability ratings--summary of grid-cell analysis.

GRID CELLS case study and suitability rating (total)	HABITAT COMPONENTS Forage Area #	Forage Area %	Thermal Cover #	Thermal Cover %	Hiding Cover #	Hiding Cover %	Water Proximity #	Water Proximity %	Road Impact #	Road Impact %
McNary zero-rating(40)	35	87.5	36	90.	18	45.	17	42.5	1	2.5
moderate-rating (6)	5	83.3	1	16.7	0	0	0	0	4	66.7
Horseshoe Cienega zero-rating(36)	25	69.4	28	77.8	18	50.	9	25.	6	16.7
moderate-rating (12)	11	91.2	0	0	1	8.3	0	0	5	41.7
Subtotal zero-rating(76)	60	78.9	64	84.2	36	47.4	26	34.2	7	9.2
moderate-rating (18)	16	88.9	1	5.6	1	5.6	0	0	5	41.7
TOTAL (96)	76	80.9	65	69.1	37	39.4	26	34.2	16	17.0

(Figures 22 and 23, Appendix A). Considering the total number of zero and moderate rated grid cells forage areas are the most limiting, followed by thermal cover, hiding cover, water proximity and road impact habitat components.

Mapping Technique Uses

The mapping system technique developed in this study can be used as a management and planning tool. Managers can use the technique to identify potential habitat and therefore potentially valuable wildlife resources in an area. Once potential habitat is identified, the information can serve as a basis for habitat improvement projects or population studies or as an initial step in completing a HEP study. The final habitat component-suitability rating analysis identifies limiting factors across the entire study area. This information is very important for managers trying to improve habitats available and population numbers. Potential use areas identified as valuable wildlife areas are critical information for managers working under multiple use management and competing resource uses.

The following discussion illustrates potential uses of habitat suitability information developed in the case studies completed for this project. Only three km^2 cells (3%) from a total of 100 km^2 were evaluated to be high suitability for elk habitat. At the same time 18 km^2 cells (18%) were evaluated to have a moderate suitability for elk habitat. In a multiple use land management scheme 3% of the land area is evaluated as valuable wildlife resource and could be allocated to elk habitat management. The areas rated moderate could actually be enhanced by timber management cutting openings in the forest creating more forage areas. Forest structure (overstory and understory percent canopy cover) is the key element in defining four of the five habitat components. Timber management has the most influence on forest structure, thereby influencing wildlife management (Thomas 1979).

Water proximity has been identified as the most critical habitat variable. Managers could evaluate locations containing the appropriate mix of other habitat variables and lacking water. Managers can improve existing conditions by providing water in such areas, creating suitable habitat for elk. Habitatmanipulation projects become more cost-effective when based on careful habitat analysis and evaluation.

The mapping technique can be used as a predictive planning tool similar to HEP (1980b). Future project impacts can be predicted and alterations made in the baseline resource maps used to map the habitat components. For example, the changes in forest structure and vegetation type (ponderosa pine to rangeland) made by timber cutting effecting elk habitat suitability can be predicted. Those changes can be made in the baseline resource maps thereby changing the resulting habitat component maps. Potential high use areas identified in this technique could be an important part of both wildlife management planning and multiple use natural resource planning.

Mapping Technique Advantages

Advantages of the mapping technique are many and range from the ease of application to the many number of resulting products. The habitat components and variables identified by current biological knowledge can easily be updated when improved information becomes available. Habitat variables, optimal and suboptimal conditions can be altered to better represent other geographic areas or seasons.

The mechanics of the mapping technique are designed to be flexible and easy to apply. The technique can be carried out by wildlife biologists or natural resource planners and technicians. Skills required to complete the technique are not specific to either wildlife biology or planning professions. Existing resource inventory information is utilized in the baseline maps so that no field work is required. If available resource inventory materials are limited or not as detailed as needed, fieldwork will be necessary. Computer application wouldbe particularly efficient in this case. The mapping technique can be easily applied on a computer by digitizing and applying map overlay and area measurement programs.

Entire land areas are analyzed for habitat suitability in this technique rather than representative area ratings applied to like areas as in HEP (USFWS 1981). Because of this characteristic, different areas can be rated and compared as long as the habitat use patterns are the same. Predicting future project impacts is also enhanced by evaluating an entire land area.

A variety of products result from the steps in this technique that can be used separately or together. Each product includes information that can be utilized in different phases of wildlife management. For example, each habitat component map could be valuable to a manager planning habitat improvement projects. Once habitat limitations are identified at the end of the technique, the habitat component maps can be consulted to identify locations for improvement projects. Management could become more efficient by concentrating efforts on the identified potential high use areas. Another example of product usefullness is the ability to quantify habitat components available for comparison to timber or recreation use area measurements in a multiple use land management plan.

Mapping Technique Limitations

Romesburg (1981) discusses the importance of using information and techniques such as these described in this study as planning tools only and realizing the limitations.

The logic of the technique may be sound, but the results are only as good as the information utilized in the technique. The highest quality information should be used, but current levels of wildlife biology knowledge is far from the truth or understanding the realities of nature. Planning utilizes the best information available to make decisions about future management. But in so doing, planners must realize this and include updating features in techniques. Models are used to simplify and describe complex environmental conditions. All habitat components or relationships are not included to allow the model to be workable. But enough components and relationships must be included for the model to be realistic and useful. If models become so complex by attempting to include all relationships as to become unwieldy, they defeat their purpose as a planning tool. Habitat suitability techniques are useful planning tools, but do not perfectly simulate true environmental reality.

More specific limitations include the techniques simplicity in data synthesis and suitability ratings. There is no statistical analysis. Computer application would allow for greater sophistication in defining habitat variables and evaluating for suitability ratings. The elk habitat suitability model developed in this study has a very narrow geographic applicability to Arizona's White Mountains.

Many assumptions are made throughout the technique, particularly in defining habitat variables optimal and suboptimal conditions and suitability rating procedures. These assumptions are based on currently available habitat use information, but are still assumptions. Final outputs are land suitability for elk summer range. Resulting locations are potential use areas, but not where elk are actually located. Actual population locations are not included in this technique.

Definition of suitability analysis units influences the final ratings. UTM grid-cells were used in this technique as an objective geographic definition. If the grid were shifted or a different shape cell were used the final ratings would be altered. The same general areas would probably be rated high, but the specific ratings would be different.

Suggested Improvements

Two improvements can be made in the elk habitat variables, optimal and suboptimal conditions. One, incorporate optimal sizes of cover and forage areas as defined by Thomas et al (1979) until further studies are completed in the White Mountains. Two, use Thomas et al (1979) and Lyon (1979) method of including road impacts rather than Perry and Overly (1976). The alternate method considers habitat effectiveness lost depending on the kilometers of roads by square kilometer rather than analyzing each road separately. Perry and Overly's (1976) technique was used in this study because road length measurements by grid-cell were not available.

All the mapping, overlaying and area measurement in this study were completed by hand. Alternative methods are much more efficient, particularly if evaluating a larger land area. Isaacson et al (1982) describes the use of large-scale aerial photography to interpret Landsat multispectral scanner data for elk habitat analysis. Various computer application can be accomplished and greatly improve the mapping and analysis technique.

CHAPTER 5

SUMMARY AND CONCLUSIONS

This study has developed an habitat analysis and evaluation technique utilizing a species-habitat approach designed to identify potential wildlife species habitat. The mapping overlay system technique is developed based on the USFWS Habitat Evaluation Procedures (USFWS 1980b) and an alternative method for structuring Habitat Suitability Index models (USFWS 1981). The procedures outlined by USFWS (1981) were incorporated in this technique. Major differences between HSI models and this mapping system technique are: the format of analysis information, the rating procedure and the application of the suitability ratings.

Two 50 km^2 areas in the White Mountains of Arizona were used as case studies with Rocky Mountain elk as an evaluation species. Forage areas, water, hiding cover, thermal cover and road impacts were identified as habitat components. Habitat variables were identified that physically define optimal and suboptimal environmental conditions of each habitat component. Habitat variables were mapped and overlayed to produce habitat component maps. All five habitat component maps were overlayed producing a composite map. A km^2 grid was overlayed to provide a geographic definition for the suitability rating procedure. Each polygon on the habitat component composite-grid map was measured using one-hectare and one-quarter hectare scale dot grids. Thomas et al (1979) habitat component optimal mix concept was used as the basis for the suitability rating procedure. The rating procedure was applied to each grid-cell evaluating the overall suitability based on habitat components present. Each cell was assigned a high, moderate or unsuitable suitability rating.

The technique can be used as both a management and planning tool. Land areas evaluated for wildlife habitat suitability can be the basis for land use allocation in multiple-use management plans. The technique will also identify limiting habitat components and areas of potentially valuable habitat. This information could be extremely useful in designing a habitat management program including habitat manipulation projects. The technique could easily have computer application and be utilized as a wildlife habitat resource inventory and evaluation program.

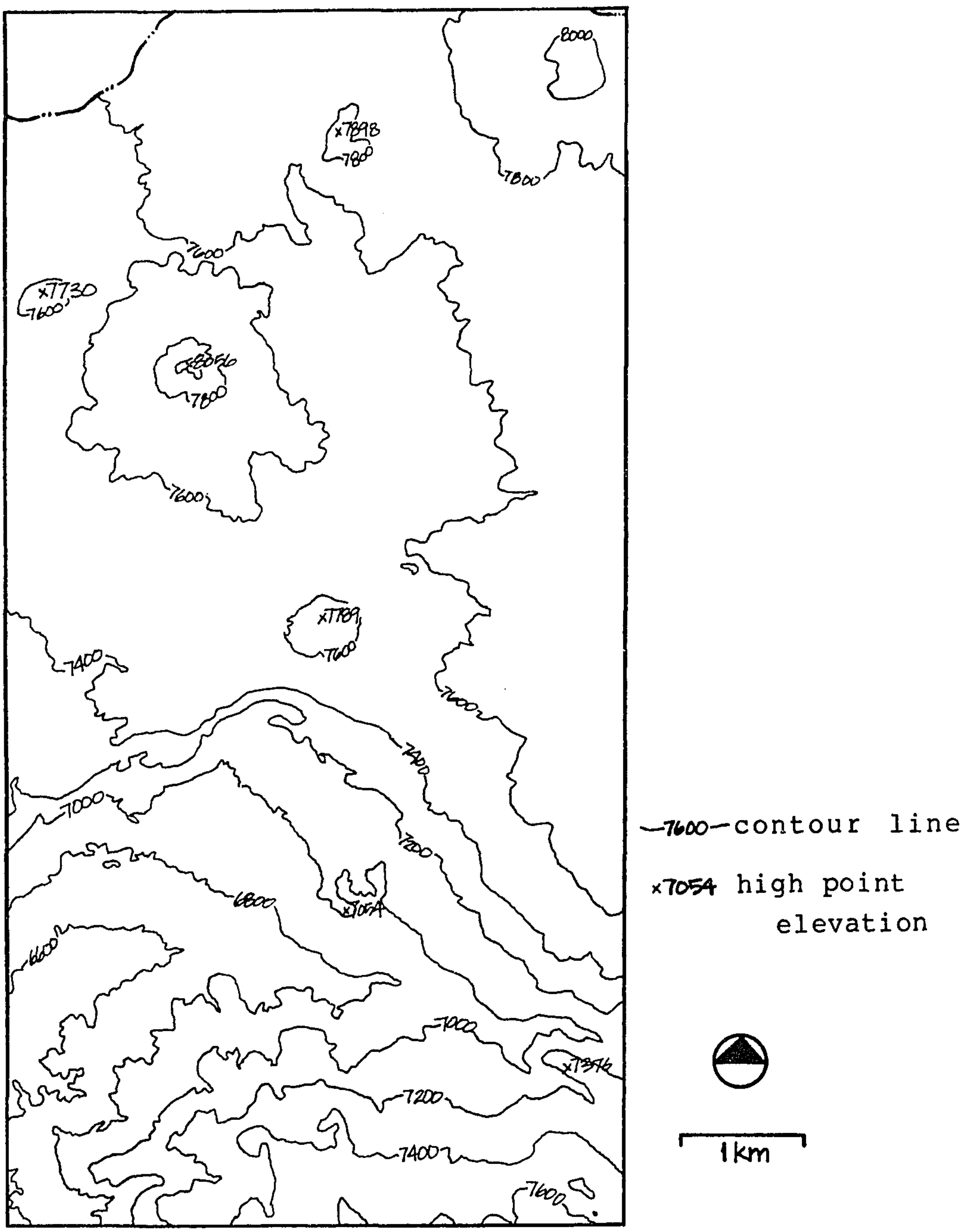
APPENDIX A.

BASELINE RESOURCE MAPS

APPENDIX A--Continued

TOPOGRAPHY

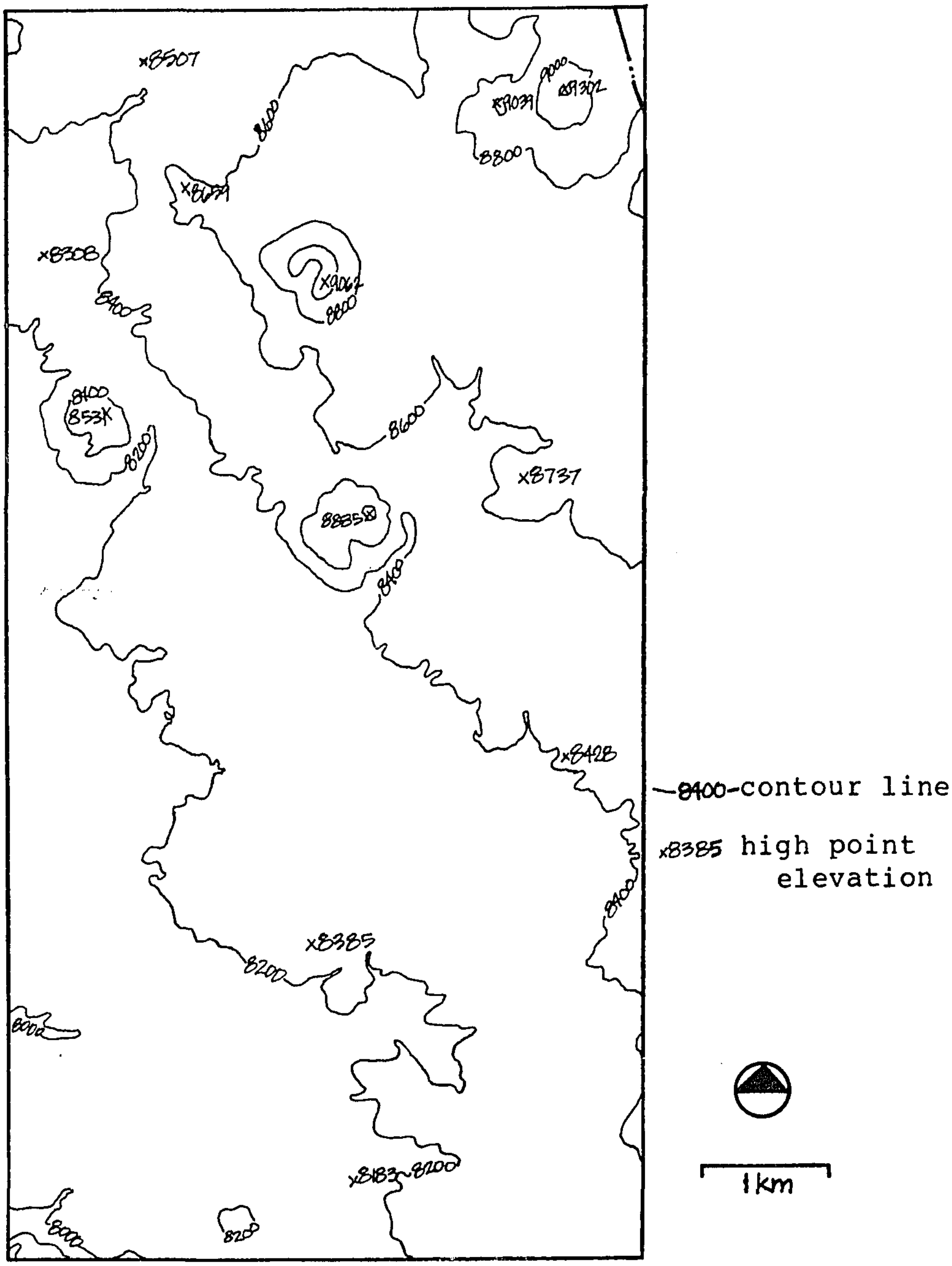
MC NARY



APPENDIX A--Continued

TOPOGRAPHY

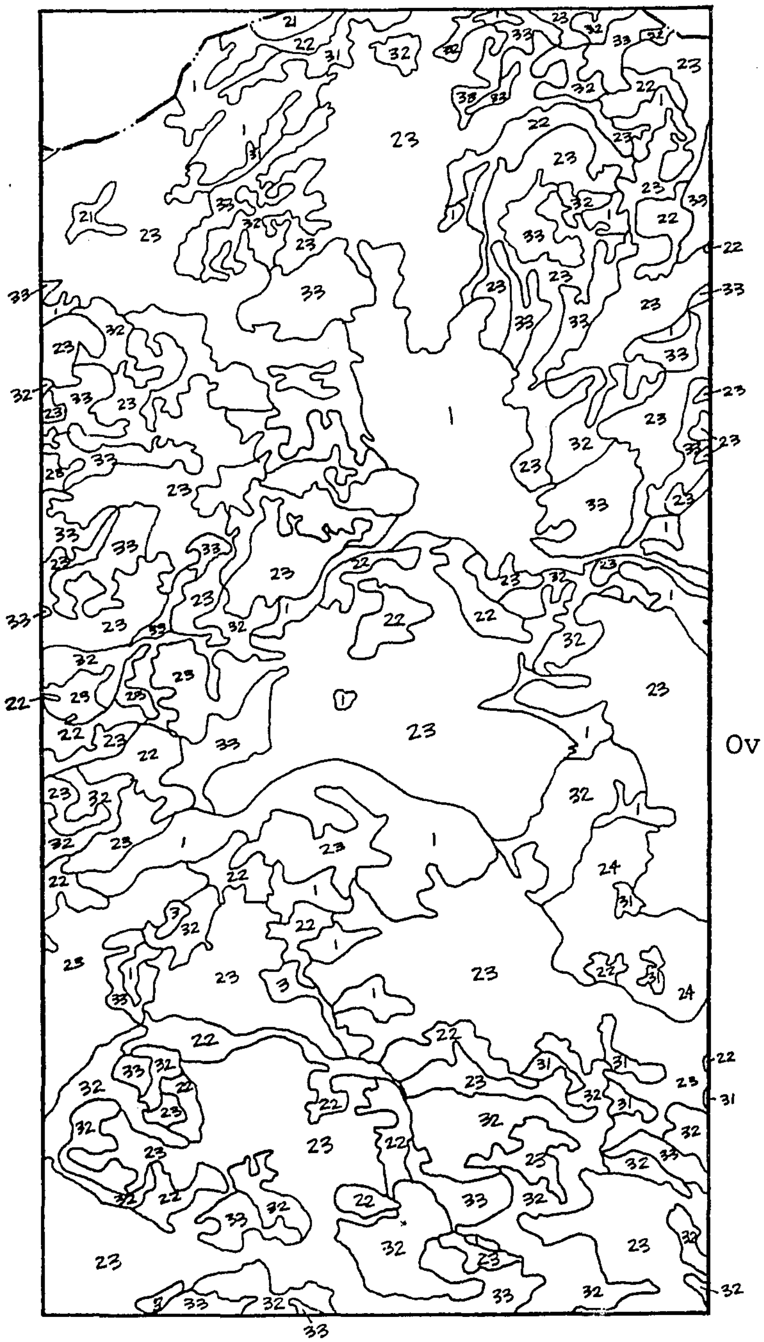
HORSESHOE CIENEGA



APPENDIX A--Continued

CANOPY COVER

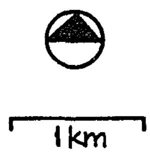
MC NARY



1 0-10%
2 11-29%
3 30-69%
4 70-100%

Overstory Understory

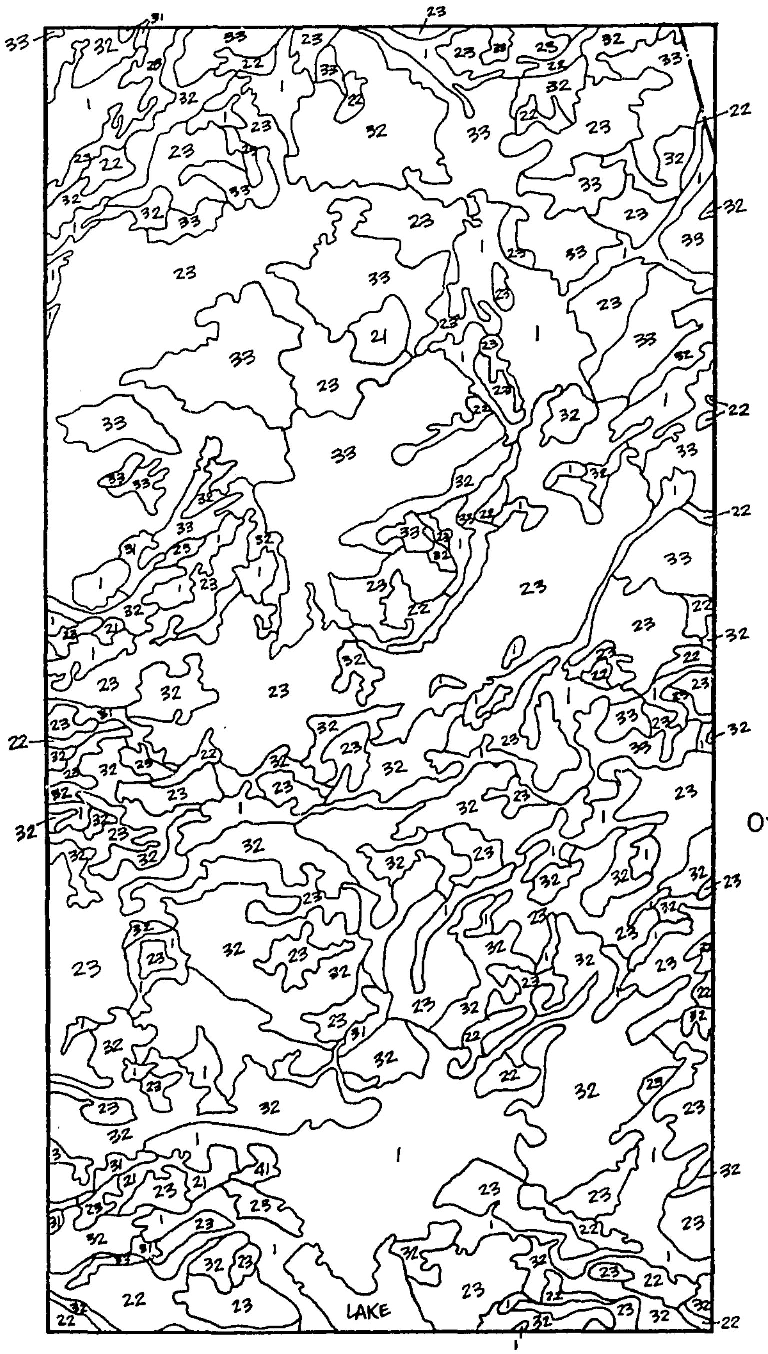
32



APPENDIX A--<u>Continued</u>

CANOPY COVER

HORSESHOE CIENEGA



1 0-10%
2 11-29%
3 30-69%
4 70-100%

Overstory Understory

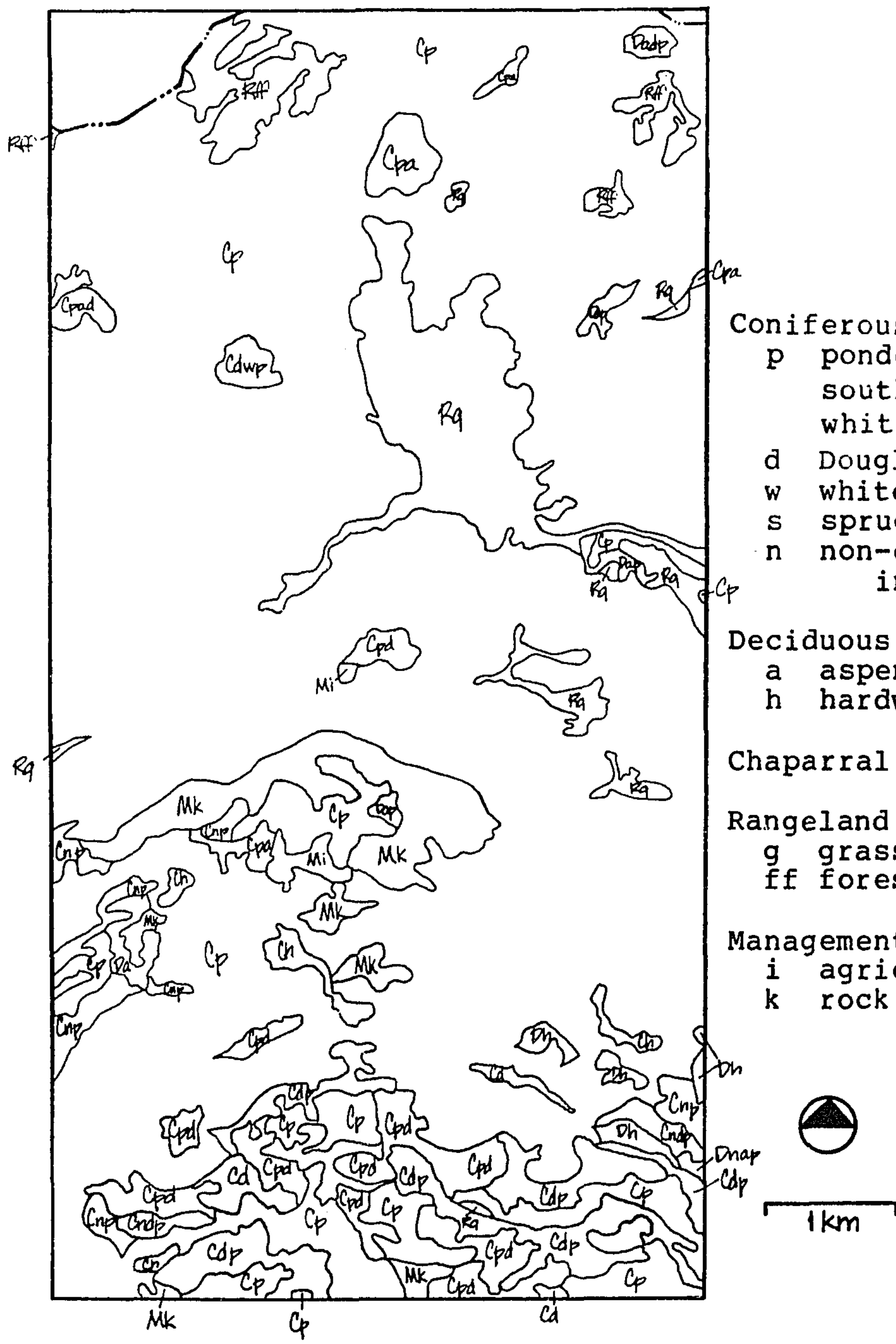
32

1km

APPENDIX A--Continued

VEGETATION

MC NARY



Coniferous Forest C
- p ponderosa and southwestern white pines
- d Douglas fir
- w white fir
- s spruce
- n non-commercial inoperable

Deciduous Forest D
- a aspen
- h hardwood

Chaparral Ch

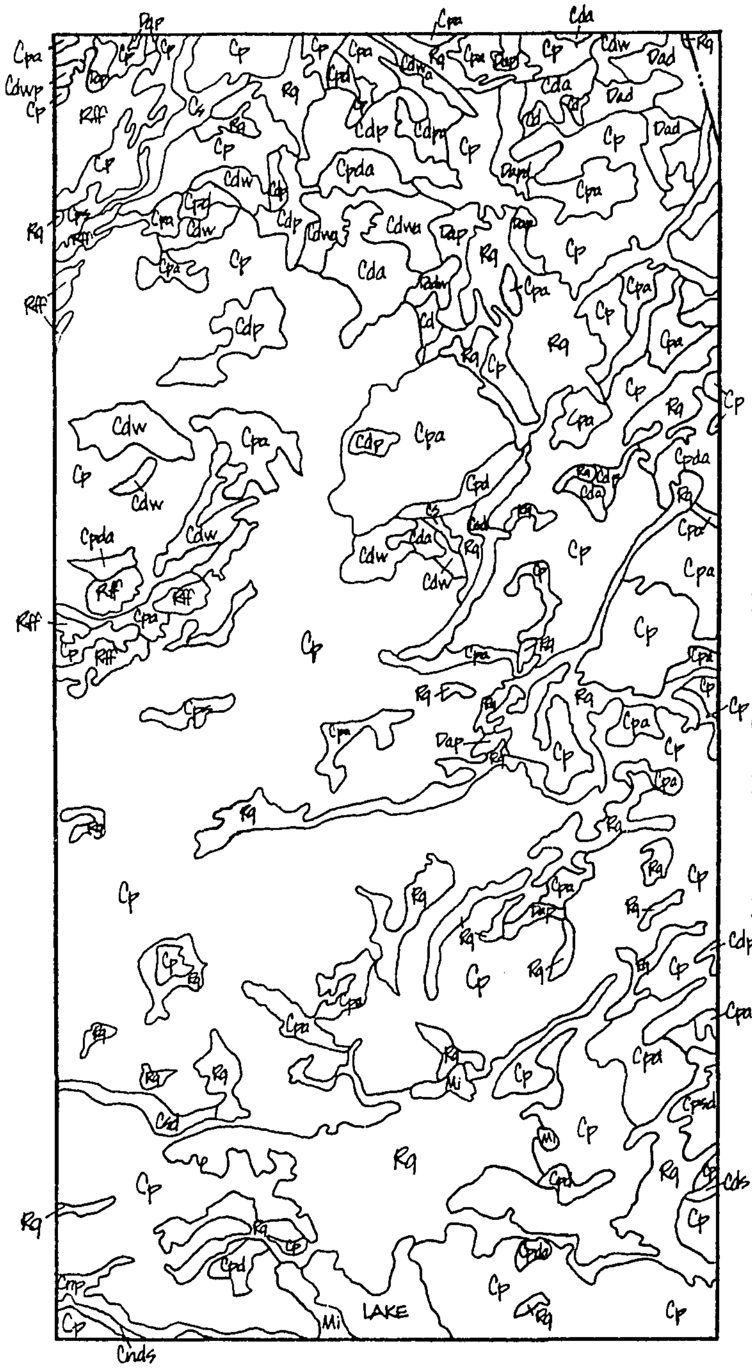
Rangeland R
- g grassland
- ff forest fire

Management Effected M
- i agriculture
- k rock

APPENDIX A--Continued

VEGETATION

HORSESHOE CIENEGA



Coniferous Forest
C
- p ponderosa and southwestern white pines
- d Douglas fir
- w white fir
- s spruce
- n non-commercial inoperable

Deciduous Forest D
- a aspen
- h hardwood

Chaparral Ch

Rangeland R
- g grassland
- ff forest fire

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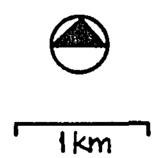
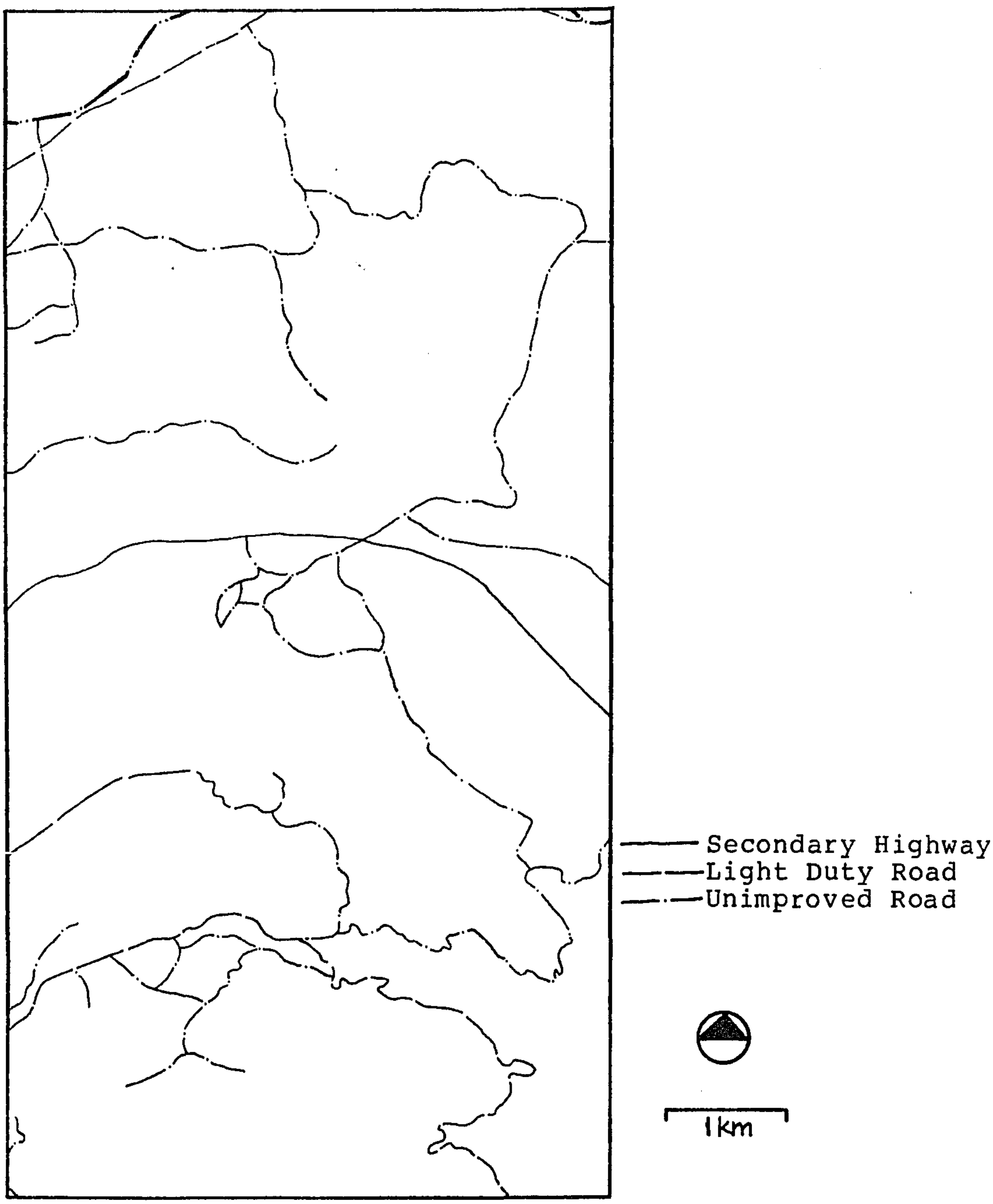
M
- i agriculture
- k rock



APPENDIX A--Continued

ROADS

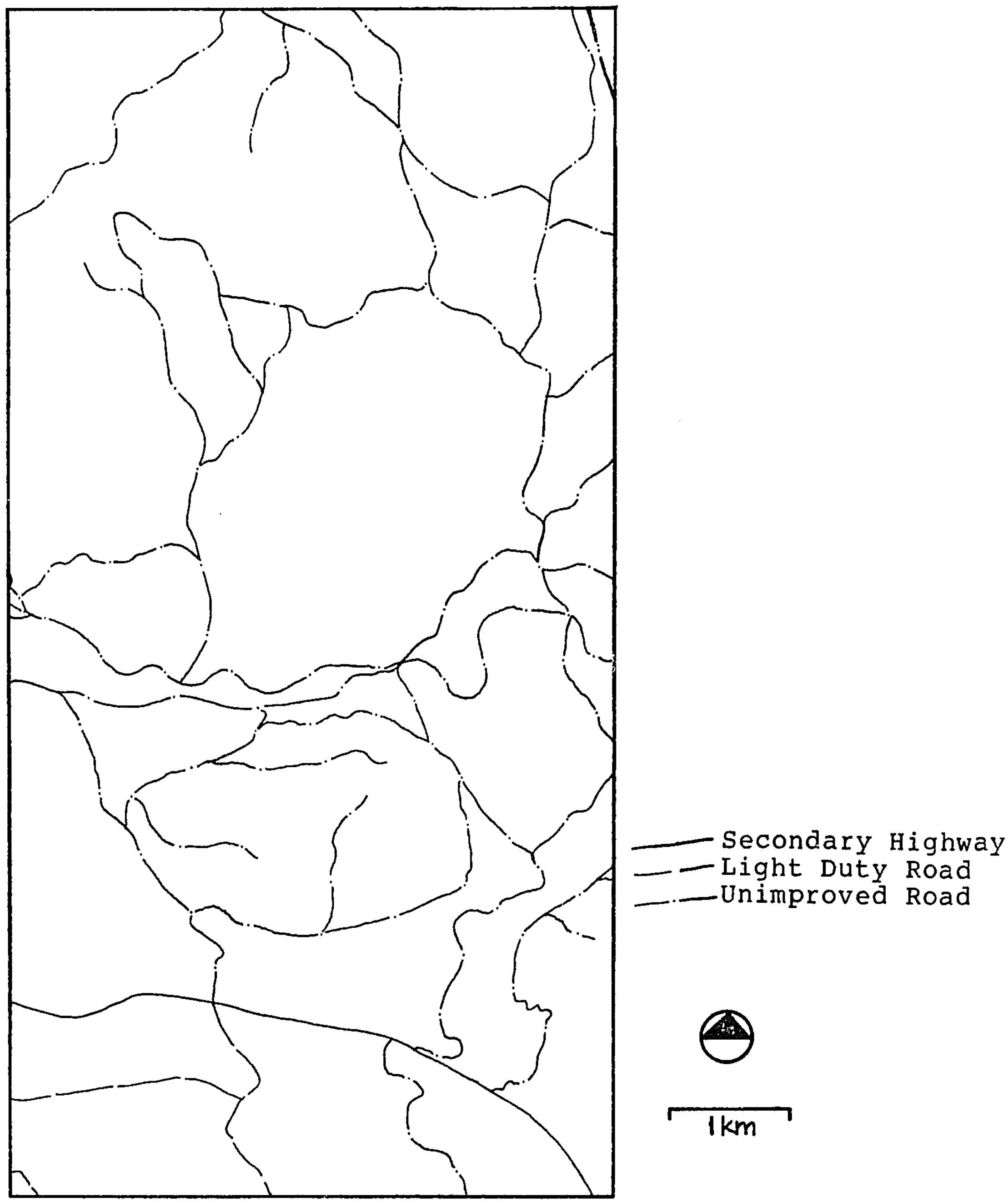
MC NARY



APPENDIX A--Continued

ROADS

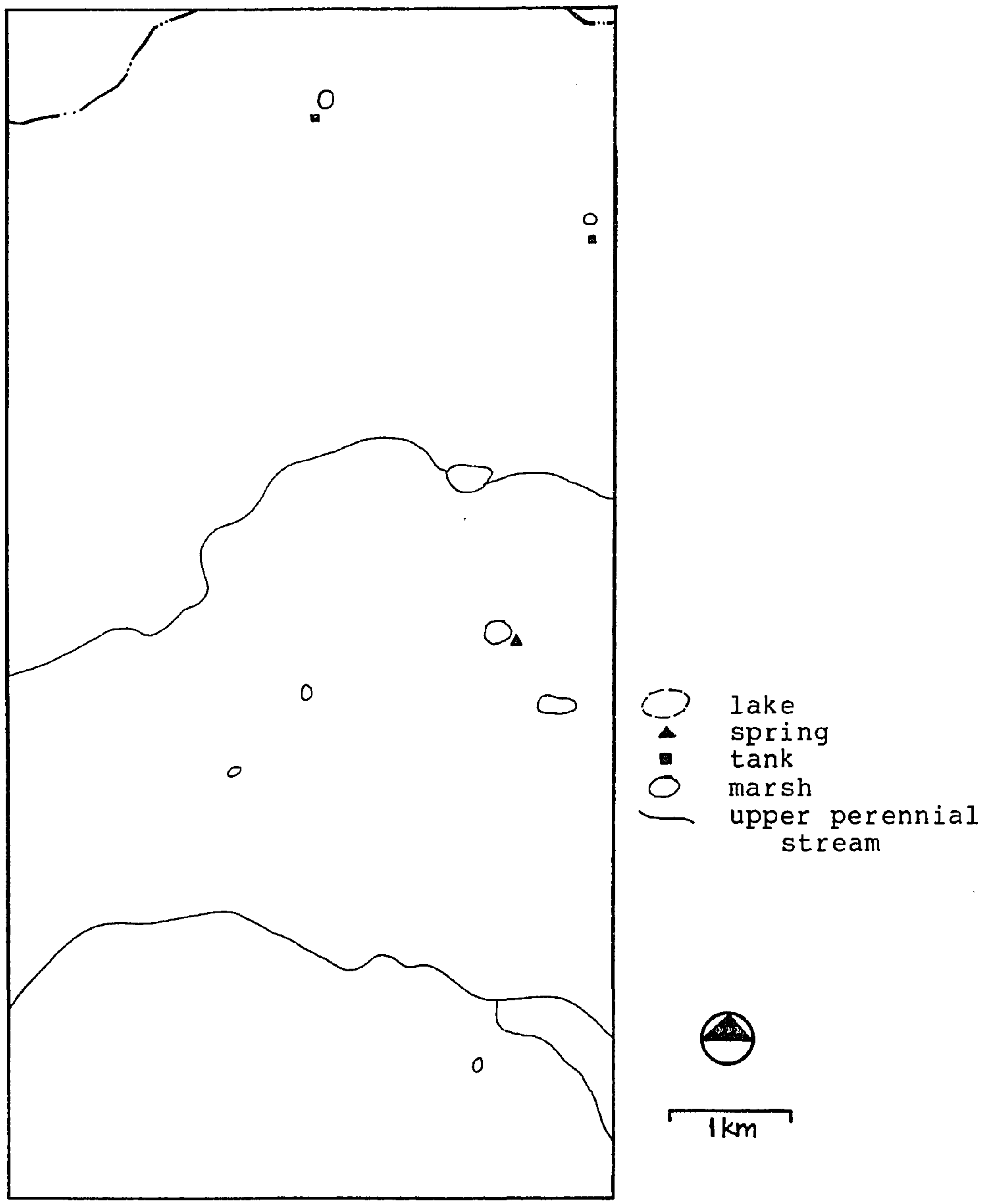
HORSESHOE CIENEGA



APPENDIX A--Continued

SURFACE WATER

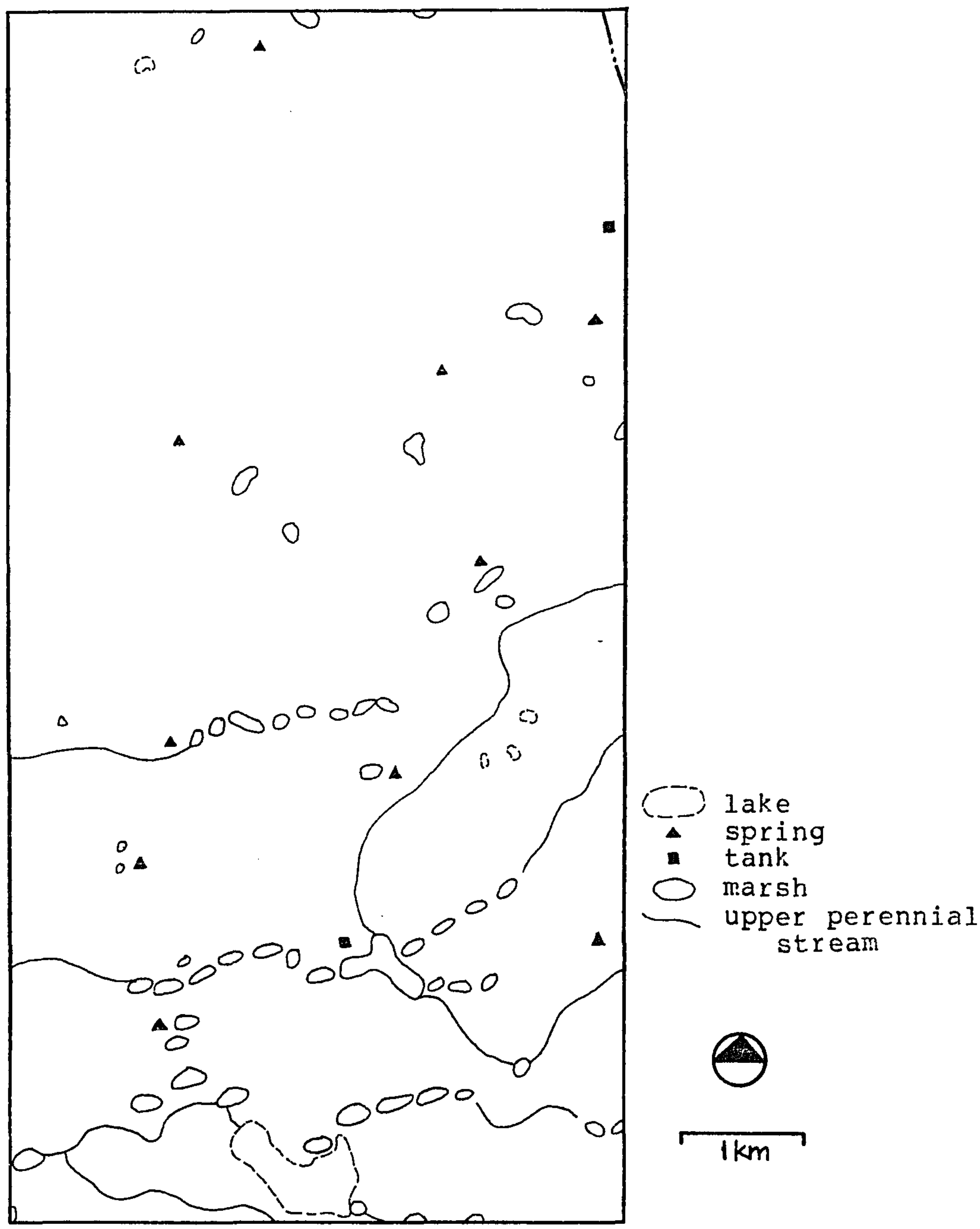
MC NARY



APPENDIX A--Continued

SURFACE WATER

HORSESHOE CIENEGA



APPENDIX B.

GRID-CELL RATING ANALYSIS--
LIMITING HABITAT COMPONENTS.

APPENDIX B--<u>Continued</u>

MC NARY

GRID CELL #	SUITABILITY RATING	FORAGE AREAS	THERMAL COVER	HIDING COVER	WATER PROXIMITY	ROAD IMPACT
1	0	X	X	X	X	X
2	M	X				
3	0	X	X		X	
4	0	X	X	X	X	
5	0	X	X	X	X	
6	0	X	X	X	X	
7	0	X	X			
8	0	X	X	X	X	
9	0		X			
10	0	X	X	X	X	
11	0	X	X	X	X	
12	0	X	X	X	X	
13	0	X	X			
14	0	X	X	X		
16	0		X	X		
17	0	X	X			
18	0	X	X			
19	M	X				X
20	0		X			
21	M					X
22	0	X	X			
23	0		X			
24	0	X	X	X		

APPENDIX B--<u>Continued</u>

MCNARY

GRID CELL#	SUITABILITY RATING	FORAGE AREAS	THERMAL COVER	HIDING COVER	WATER PROXIMITY	ROAD IMPACT
25	0	X		X		
26	0	X	X			
27	M	X	X			X
28	0	X	X	X	X	
29	0	X	X			
30	0	X	X			
31	0	X	X	X	X	
32	0	X	X			
33	0	X	X			
34	0	X	X			
35	0	X	X			
36	0	X	X			
37	0	X	X	X	X	
38	0	X				
39	0	X	X		X	
40	0		X			
41	M	X				X
42	M	X				
43	0	X	X	X	X	
44	0	X	X	X	X	
45	0	X	X	X	X	
46	0	X			X	
47	0	X				

APPENDIX B--<u>Continued</u>

HORSESHOE CIENEGA

GRID CELL#	SUITABILITY RATING	FORAGE AREAS	THERMAL COVER	HIDING COVER	WATER PROXIMITY	ROAD IMPACT
1	M	X		X		
2	0		X			
3	0	X		X		
4	0	X	X			
5	0	X	X	X	X	
6	0	X	X	X	X	
7	0	X	X	X	X	
8	0	X		X	X	
9	0	X	X	X	X	
10	0	X	X			
11	0	X	X	X	X	
12	0	X	X	X	X	
13	0	X	X	X	X	
14	0		X	X		
15	0		X			
16	0	X	X			
17	0	X	X			
18	0	X	X			
19	0	X				
20	0	X	X			
21	0	X	X	X	X	
22	0	X	X			
23	0		X			
24	0	X	X			

APPENDIX B--Continued

HORSESHOE CIENEGA

GRID CELL#	SUITABILITY RATING	FORAGE AREAS	THERMAL COVER	HIDING COVER	WATER PROXIMITY	ROAD IMPACT
25	0	X	X			
26	M	X				
27	0	X	X			
28	M	X				X
29	M	X				X
30	0	X	X			
31	M	X				
33	0		X			
34	M	X				
35	M	X				
36	0	X	X			
37	M	X				
39	M					X
40	M	X				X
41	0			X		X
42	0			X		X
43	0		X	X		X
44	0			X		X
45	M	X				X
46	0			X		
47	0	X	X	X		
48	0	X	X	X		X
49	M	X	X			
50	0					X

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